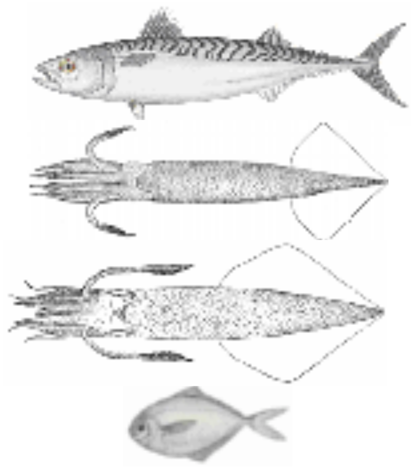
AMENDMENT 9 (DRAFT)
TO THE
ATLANTIC MACKEREL, SQUID, AND BUTTERFISH
FISHERY MANAGEMENT PLAN



VOLUME 2

APPENDICES

Appendix 1

Analytical Steps for Delineation of Butterfish GRAs

The following describes the analytical steps taken for delineation of the butterfish GRAs (by ten-minute square). The methods used by NEFSC staff to delineate seasonal small-mesh GRAs for butterfish discard reduction, by quarter-degree square, is described at the end of this document.

1. Estimate commercial small mesh fishing effort:

$$E_{Ci} = \frac{\sum Tows_i \times \overline{Towdur(hrs)}}{24hrs}$$

where,

E_{Ci} = Commercial small mesh effort (days fished) in the ith ten minute square,

$\Sigma Tows_i$ = Sum of NTows in the ith ten minute square Jan-Apr, 1996-2003 from the VTR data

$\overline{Towdur(hrs)}$ = Mean tow duration (constant) from the observer data for areas 622, 616, and 537 from Jan-Apr (see calculation of mean tow duration, page 4)

2. Estimate discard rate *for each ten minute square in areas 622, 616, and 537* using observer data:

$$R_i = \frac{\sum D_i}{E_{Oi}}$$

Where,

$\sum D_i$ = sum of observed butterfish discards from Jan-Apr, 1996-2003,

E_{Oi} = Observed effort in the ith ten minute square (days fished – tabulated directly from data)

3. Estimate total discards in each ten minute square:

$$E_{Ci} \cdot R_i$$

Note on calculating mean tow duration:

The vast majority (>90%) of small mesh landings from statistical areas 622, 616, and 537 from Jan-Apr are from large vessels (100+ ton classes).

VTR landings in lbs Jan-Apr 1996-2003 (mesh < 3.00 in)

	Stat Area					
tonclass	537	616	622	Grand Total	Pct of total	
0		80		80	0.0%	
20	34,310	100	495	34,905	0.1%	
40	10,055	249,756		259,811	0.8%	
60	367,251	182,010	88	549,349	1.6%	
80	413,067	733,992	81,229	1,228,288	3.7%	
100	657,850	379,292	992,684	2,029,826	6.0%	93.8%
120	670,144	1,447,928	1,925,277	4,043,349	12.1%	
140	554,276	720,316	3,643,315	4,917,907	14.7%	
160	589,604	1,172,731	1,165,535	2,927,870	8.7%	
180	5,700,275	8,411,471	1,937,504	16,049,250	47.8%	
200	8,022	223,944	1,278,540	1,510,506	4.5%	
Grand Total	9,004,854	13,521,620	11,024,667	33,551,141	100.0%	

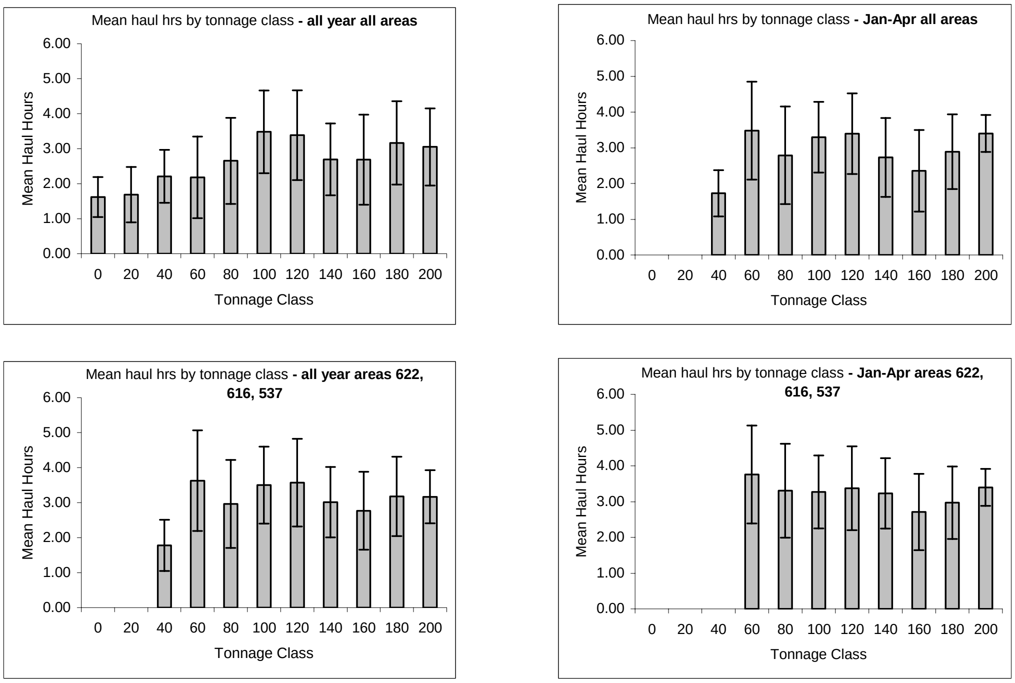
VTR landings in lbs Jan-Apr 1996-2003 (mesh < 3.75 in)

	Stat Area					
tonclass	537	616	622	Grand Total	Pct of total	
0		80		80	0.0%	
20	34,310	100	495	34,905	0.1%	
40	15,650	251,456		267,106	0.6%	
60	617,286	239,624	88	856,998	2.1%	
80	1,086,264	805,340	82,549	1,974,153	4.7%	
100	1,132,664	615,255	1,350,661	3,098,580	7.4%	92.5%
120	1,166,896	1,785,047	2,771,107	5,723,050	13.7%	
140	1,309,518	952,398	4,351,736	6,613,652	15.9%	
160	1,443,077	1,854,992	1,295,584	4,593,653	11.0%	
180	5,988,704	8,776,691	2,168,468	16,933,863	40.7%	
200	30,762	226,783	1,278,540	1,536,085	3.7%	
Grand Total	12,825,131	15,507,766	13,299,228	41,632,125	100.0%	

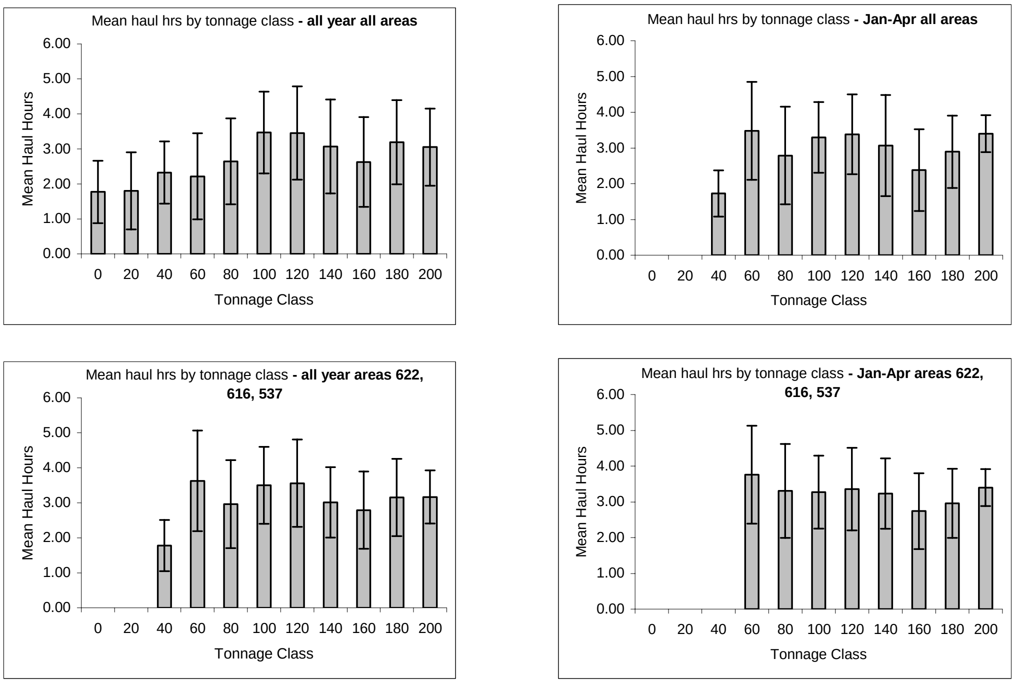
As such, the mean tow duration applied to trips reported in the VTR came only from those areas, times. This was not done, however, until after the relationship between vessel size (tonnage class) and tow duration was examined. This step was necessary because if a strong relationship existed, then vessel size would have to be considered in order to appropriately scale effort. The relationship between vessel size and tow duration was examined across years, not within years, since the numerator for the discard rate estimate is total butterfish discards from Jan-Apr across years.

Vessels were categorized into ton classes (20 gross tons each) and mean tow duration (hrs) was calculated by ton class. This was done separately for 3.75” and 3.00” observed tows. For either mesh size, a variety of decreasingly restrictive observer “universes” were examined. These data universes ranged from observed small mesh tows only in areas 622, 616, and 537 from Jan through Apr, to all areas over the entire year. A relationship between ton class and tow duration was discernable only in the least restrictive case (all areas, all year). This was also the only data universe in which observer coverage included the smallest ton classes. As noted above, these small vessels are relatively unimportant in terms of overall catch from statistical areas 622, 616, and 537 from Jan-Apr.

Mean tow duration by tonnage class for small mesh (<3.00 inch) trawl fishery



Mean tow duration by tonnage class for small mesh (<3.75 inch) trawl fishery



Following this exercise, a single mean tow duration was used for each mesh size regardless of vessel size:

- $\overline{Towdur(hrs)}$ for small mesh < 3.00 = 3.1002 hrs (CV = 0.359)
- $\overline{Towdur(hrs)}$ for small mesh < 3.75 = 3.0888 hrs (CV = 0.353)

Trawl gear size is also likely to be an important scaling factor in estimating effort, and tends to increase with increasing vessel size. Because gear size (width of trawl sweep in feet) is reported in the VTR data it can be used to scale effort directly, as opposed to using mean estimates. If used as an additional coefficient in estimating effort, the average effect would be greater scaling of effort for larger ton classes. Likewise, the variable "gearqty" in the VTR data could be used to account for tows in which multiple trawls were used. In summary, an alternative (unitless) expression of effort could be used that accounts for these other important variables: [mean tow duration]*[gearsize]*[gearqty]. This was not done in current analysis, but may merit further consideration.

Figures 1-4 were produced using the data generated in steps 1-3 above. The figures illustrate the distribution of fishing effort in either the <3.00 inch (Figures 1,2) or <3.75 inch (Figures 3,4) trawl fisheries from Jan-Apr, 1996-2003 as shaded ten minute squares. The cumulative percent of estimated butterfish discards for the same fisheries/areas/times is indicated by the expanding circles. In evaluating the broader effects and justification for reducing butterfish bycatch in a given ten minute square, four scenarios can be considered:

1) The co-occurrence of high levels of both fishery effort and butterfish discarding suggests that butterfish discarding is a function of fishing effort. As such, effort (mesh

size) restrictions are likely to be effective in these areas, but are also likely to negatively affect landings/revenue from the harvest of other species.

2) The co-occurrence of high fishery effort and low discarding is consistent with a clean small mesh fishery that occurs in areas of relatively low butterfish density. In this case, the implementation of mesh size restrictions is likely to have little benefit in reducing butterfish discards, but at relatively high cost to the fishery.

3) The co-occurrence of relatively low fishery effort and high discarding suggests that butterfish discarding is a function of relatively high butterfish density. As such, mesh size restrictions are likely to be effective in these areas at little cost to the fishery.

4) Finally, the co-occurrence of relatively low fishery effort and low discarding suggests that butterfish discarding is a function of fishing effort. In this case, effort restrictions are likely to have a small impact on the fishery, but are also likely to be somewhat ineffective.

Hypothetical butterfish GRAs that encompass approximately 50% of the estimated butterfish discards in Jan-Apr are indicated by the areas bounded by the solid lines in Figure 1 (<3.00 inch fishery) and Figure 3 (<3.75 inch fishery). GRAs that encompass approximately 95% of the estimated butterfish discards in Jan-Apr are indicated by the areas bounded by the dashed lines in Figure 2 (<3.00 inch fishery) and Figure 4 (<3.75 inch fishery). The two hypothetical GRAs were created with the additive effects of the existing southern scup GRA included and use the ten minute square grid as a template. In other words, the vertices of the GRAs intersect at coordinates that also correspond to ten minute square intersections. This was done in order to simplify as much as possible, the boundary definitions, which should alleviate enforceability concerns, to some degree.

Finally, the NEFSC winter and spring trawl catches of butterfish from 1996-2003 were examined in order to assess overlap of the hypothetical butterfish GRAs with the apparent distribution of the butterfish population. The results are given in Figures 5 and 6 show that the hypothetical butterfish GRAs overlap a minor portion (~10%) of the overall survey encounters with butterfish in the winter and spring. The distribution of the butterfish population appears to be widespread along the shelf break in the winter with movement onto the shelf in the spring.

Although the observer data indicate relatively high levels of discarding in the area northeast of the southern scup GRA from Jan-Apr, the survey data suggest that this is not a function of butterfish concentration in that area during that time of year, but rather a function of concentrated fishery effort. As such, the most effective approach to reducing butterfish discarding would likely to come from changes in fishing practices that would reduce butterfish removals on a year round basis.

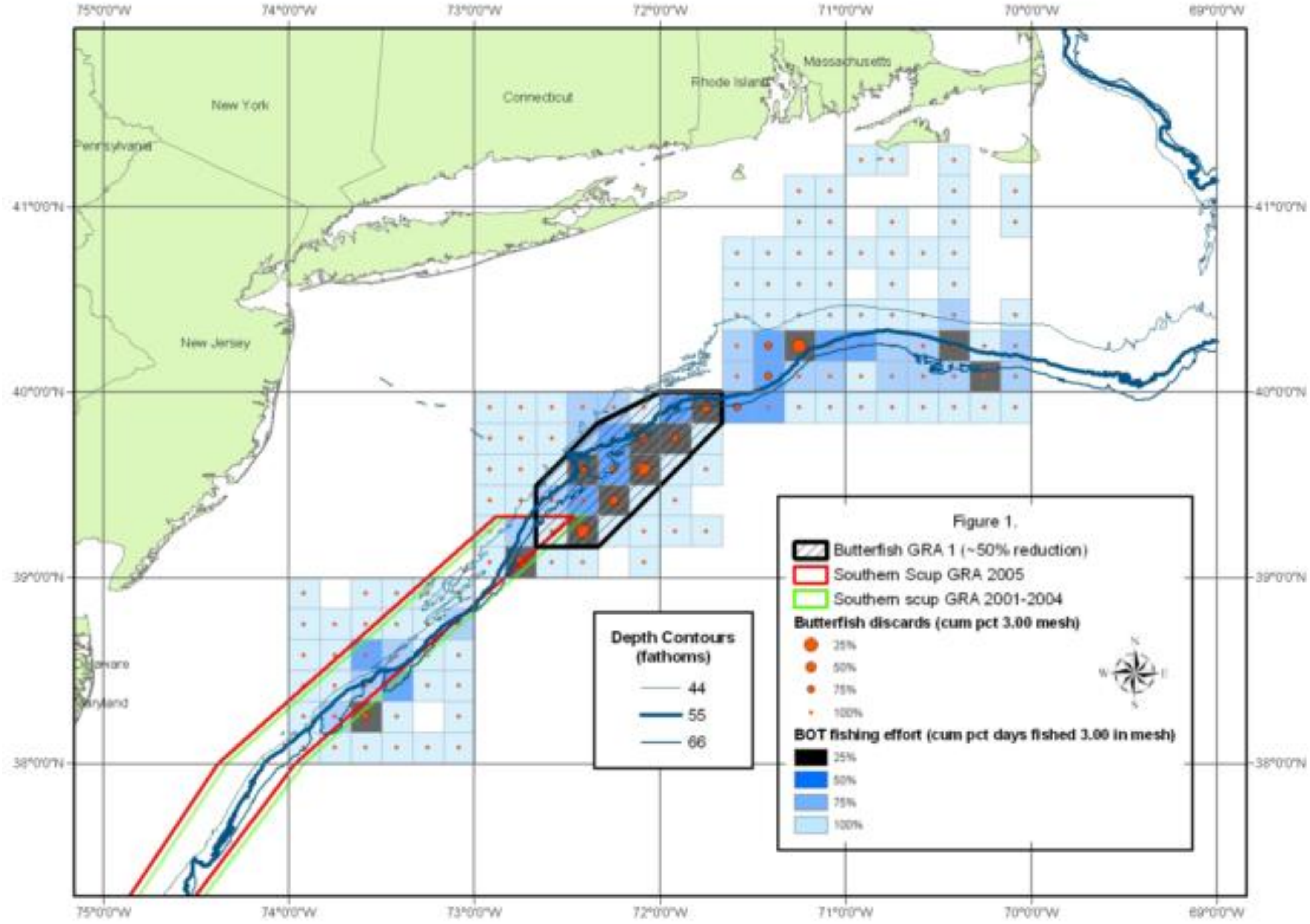
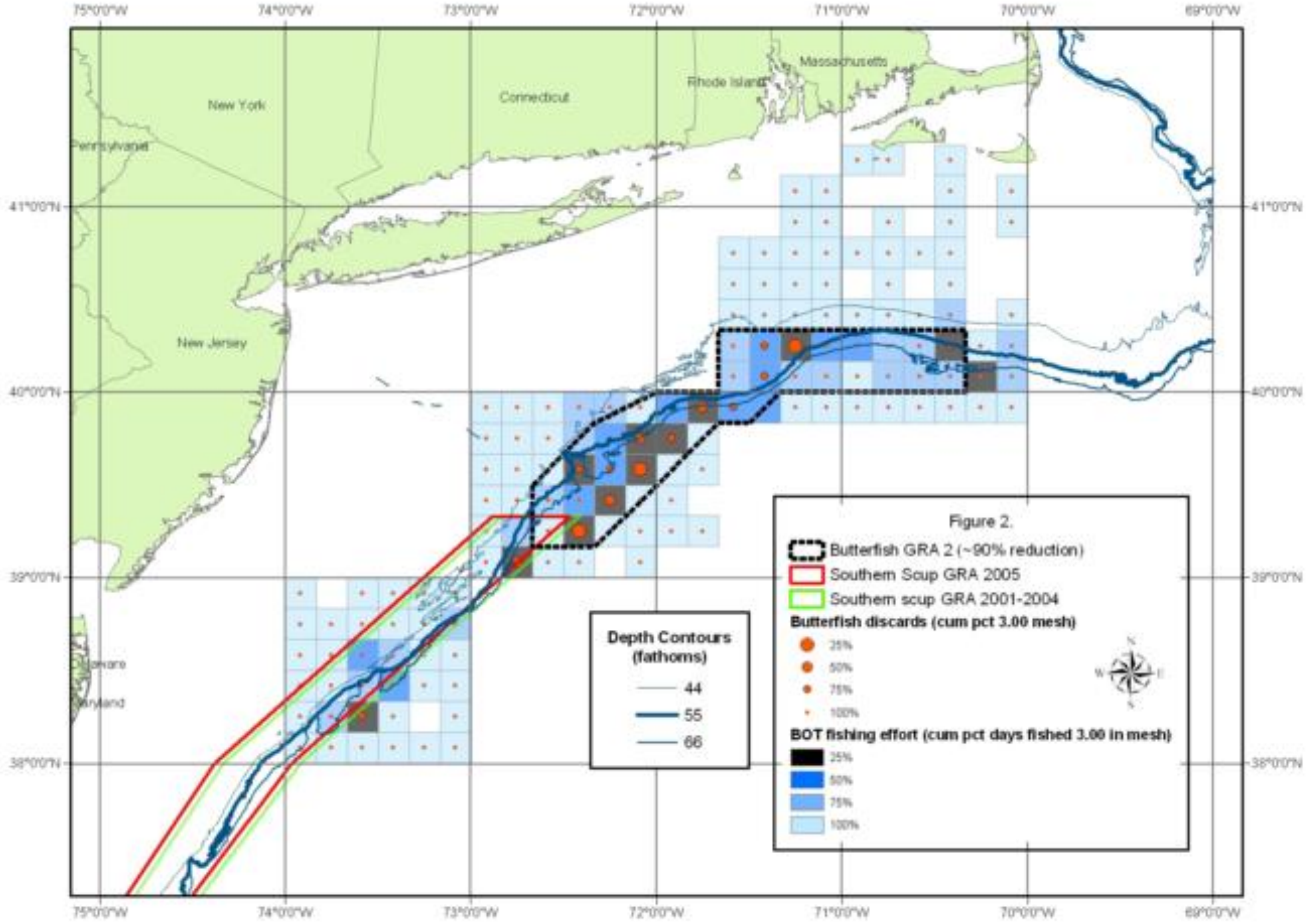


Figure 1.

75°0'0"W
74°0'0"W
73°0'0"W
72°0'0"W
71°0'0"W
70°0'0"W
69°0'0"W
41°0'0"N
40°0'0"N
39°0'0"N
38°0'0"N
New York
Connecticut
Rhode Island
Massachusetts
Pennsylvania
New Jersey
Delaware
Maryland
Depth Contours (fathoms)
44
55
66
Butterfish GRA 1 (~50% reduction)
Southern Scup GRA 2005
Southern scup GRA 2001-2004
Butterfish discards (cum pct 3.00 mesh)
25%
50%
75%
100%
BOT fishing effort (cum pct days fished 3.00 in mesh)
25%
50%
75%
100%
N
W
E
S



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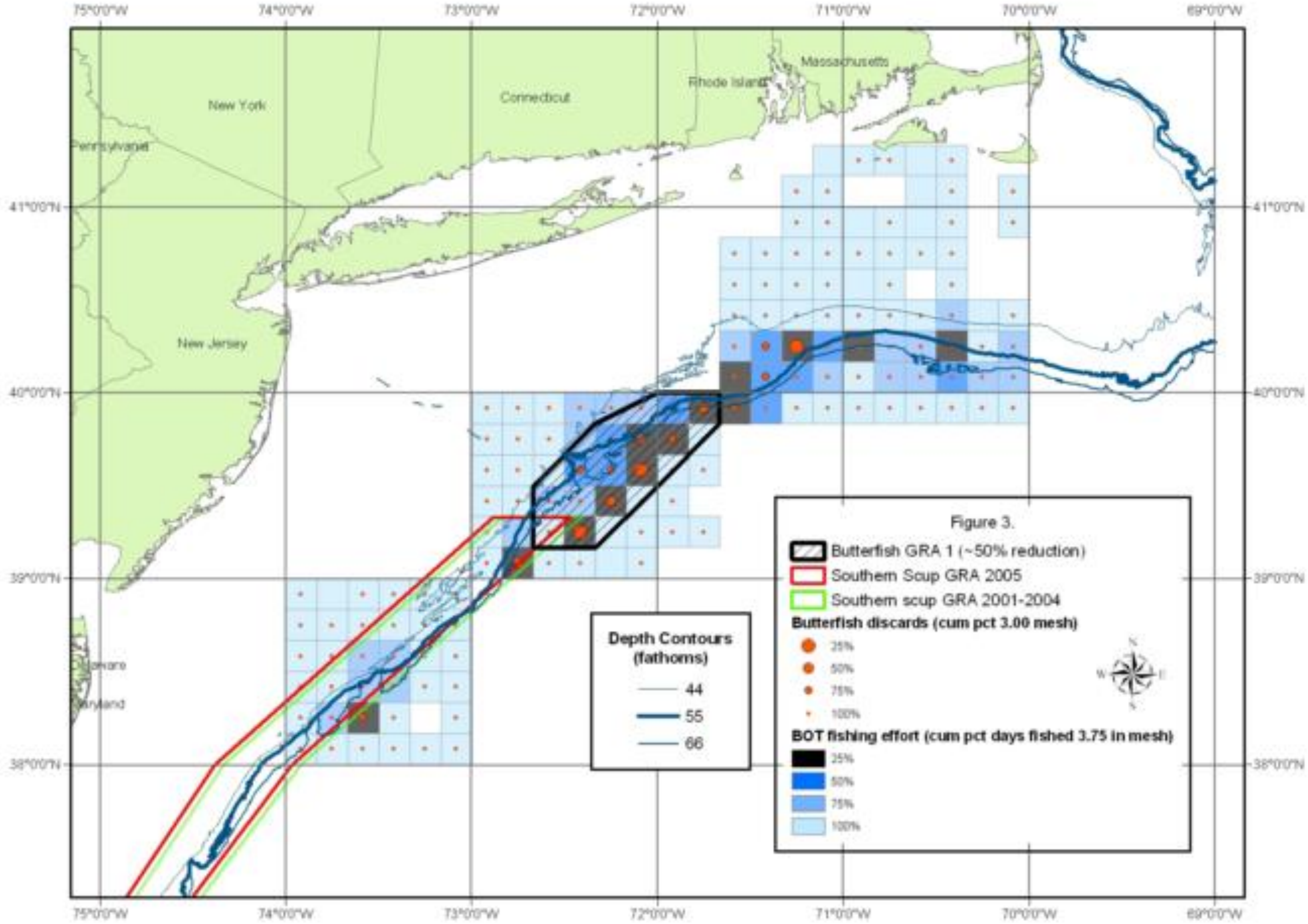
70°0'0"W
69°0'0"W
41°0'0"N
40°0'0"N
39°0'0"N
38°0'0"N
New York
Connecticut
Rhode Island
Massachusetts
Pennsylvania
New Jersey
Delaware
Maryland
Depth Contours (fathoms)
44
55
66
Figure 2.
Butterfish GRA 2 (~90% reduction)
Southern Scup GRA 2005
Southern scup GRA 2001-2004
Butterfish discards (cum pct 3.00 mesh)
25%
50%
75%
100%
BOT fishing effort (cum pct days fished 3.00 in mesh)
25%
50%
75%
100%
N
W
E
S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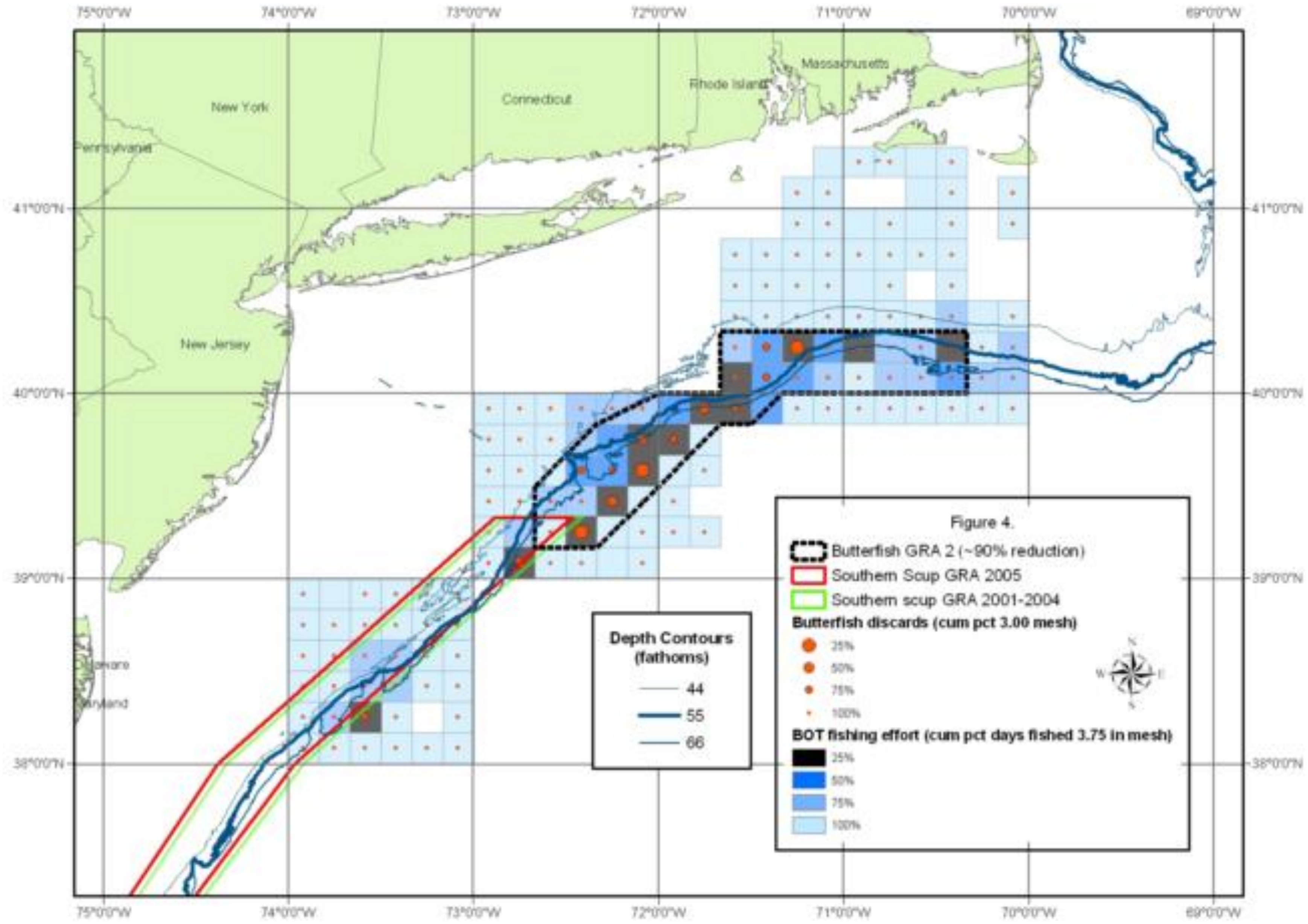
41°0'0"N
40°0'0"N
39°0'0"N
38°0'0"N
Massachusetts
Rhode Island
Connecticut
New York
Pennsylvania
New Jersey
Delaware
Maryland
Depth Contours (fathoms)
44
55
66
Figure 3.
Butterfish GRA 1 (~50% reduction)
Southern Scup GRA 2005
Southern scup GRA 2001-2004
Butterfish discards (cum pct 3.00 mesh)
25%
50%
75%
100%
BOT fishing effort (cum pct days fished 3.75 in mesh)
25%
50%
75%
100%
N
W
E
S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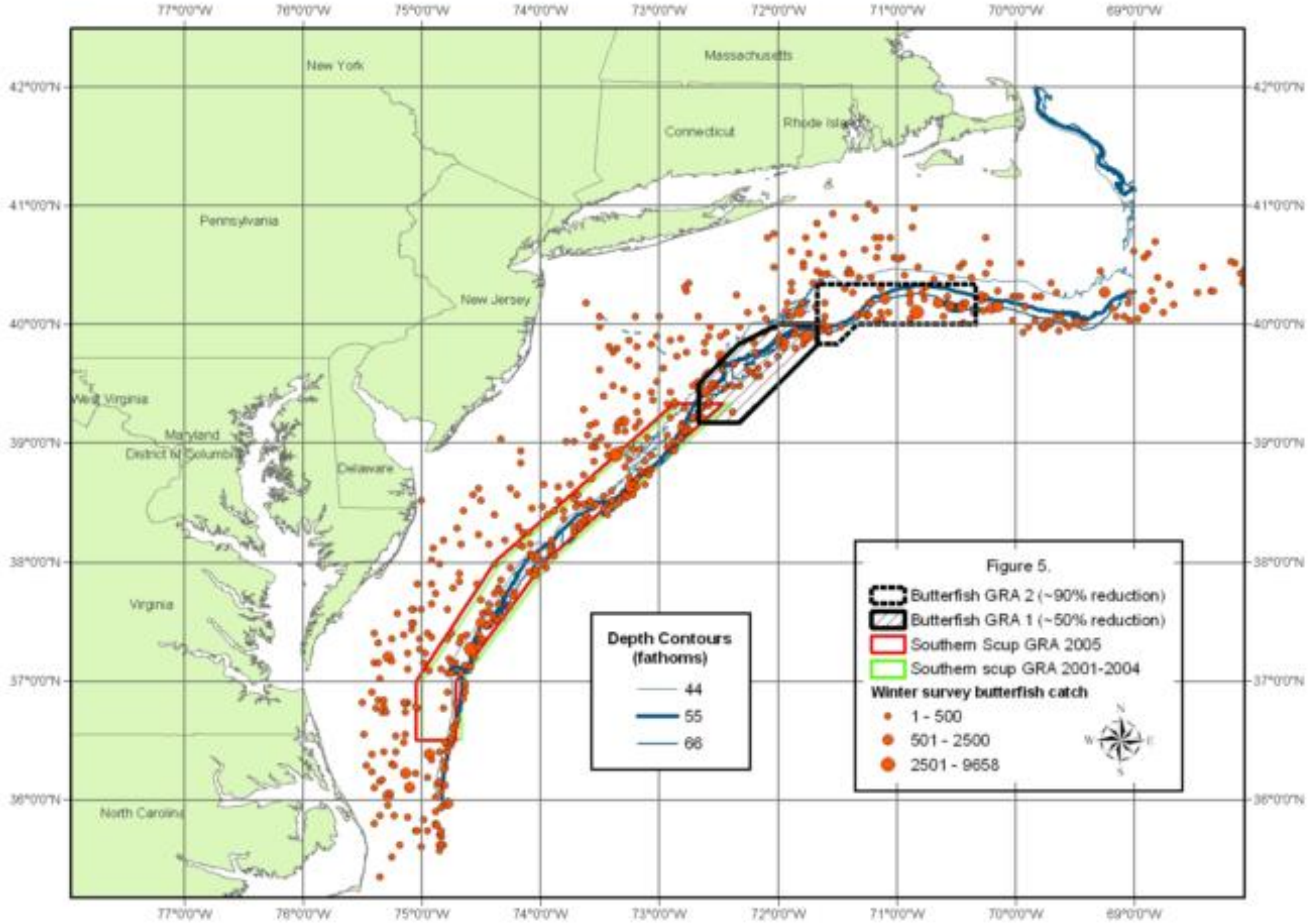
70°0'0"W
69°0'0"W
41°0'0"N
40°0'0"N
39°0'0"N
38°0'0"N
New York
Connecticut
Rhode Island
Massachusetts
Pennsylvania
New Jersey
Delaware
Maryland
Depth Contours (fathoms)
44
55
66
Figure 4.
Butterfish GRA 2 (~90% reduction)
Southern Scup GRA 2005
Southern scup GRA 2001-2004
Butterfish discards (cum pct 3.00 mesh)
25%
50%
75%
100%
BOT fishing effort (cum pct days fished 3.75 in mesh)
25%
50%
75%
100%
N
W
E
S


77°0'0"W
76°0'0"W
75°0'0"W
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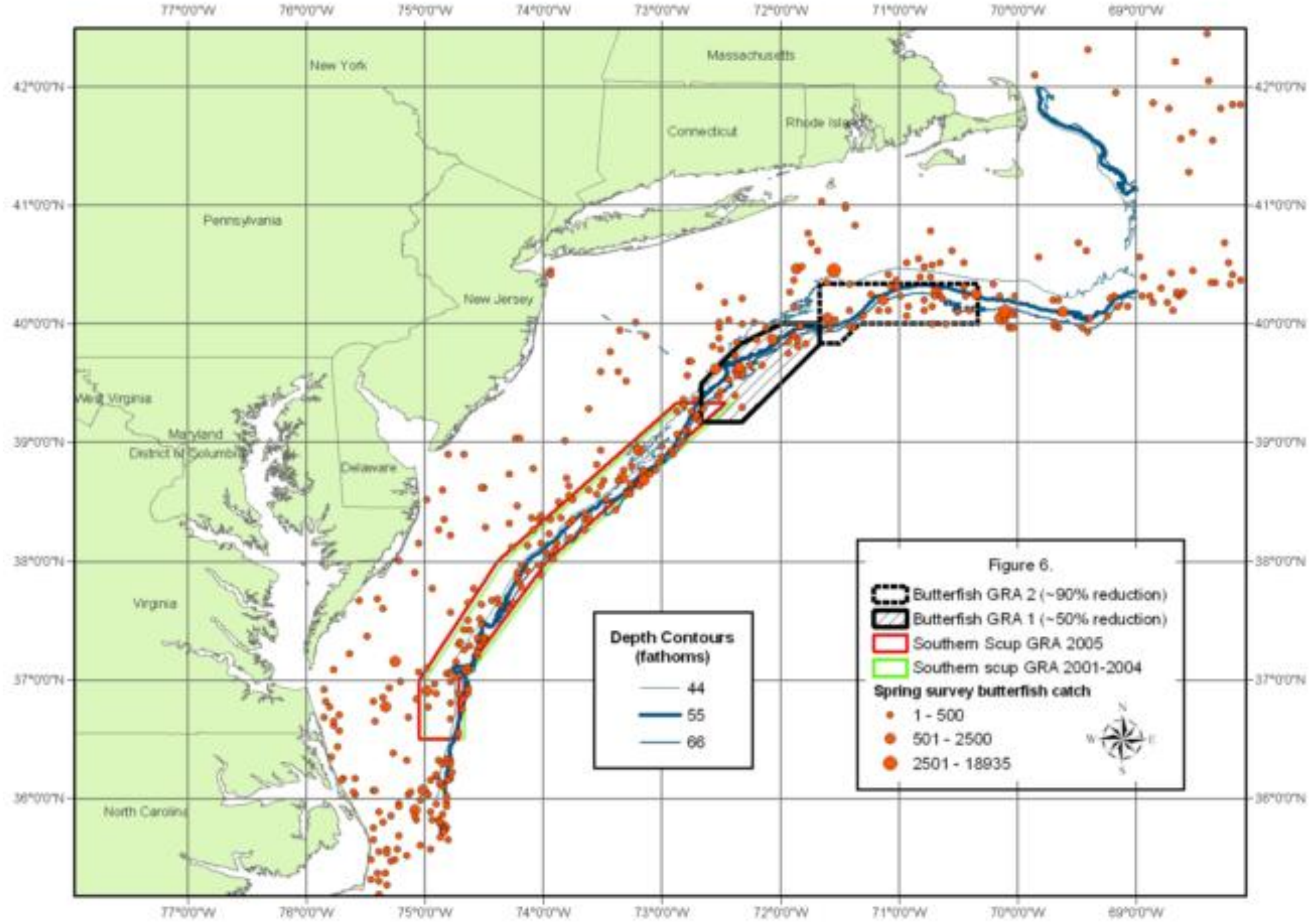
71°0'0"W
70°0'0"W
69°0'0"W
42°0'0"N
41°0'0"N
40°0'0"N
39°0'0"N
38°0'0"N
37°0'0"N
36°0'0"N
New York
Massachusetts
Connecticut
Rhode Island
Pennsylvania
New Jersey
West Virginia
Maryland
District of Columbia
Delaware
Virginia
North Carolina
Depth Contours (fathoms)
44
55
66
Figure 5.
Butterfish GRA 2 (~90% reduction)
Butterfish GRA 1 (~50% reduction)
Southern Scup GRA 2005
Southern scup GRA 2001-2004
Winter survey butterfish catch
1 - 500
501 - 2500
2501 - 9658
N
S
E
W


77°0'0"W
76°0'0"W
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70°0'0"W
69°0'0"W
42°0'0"N
41°0'0"N
40°0'0"N
39°0'0"N
38°0'0"N
37°0'0"N
36°0'0"N
New York
Massachusetts
Connecticut
Rhode Island
Pennsylvania
New Jersey
West Virginia
Maryland
District of Columbia
Delaware
Virginia
North Carolina
Depth Contours (fathoms)
44
55
66
Figure 6.
Butterfish GRA 2 (~90% reduction)
Butterfish GRA 1 (~50% reduction)
Southern Scup GRA 2005
Southern scup GRA 2001-2004
Spring survey butterfish catch
1 - 500
501 - 2500
2501 - 18935
N
S
E
W

Methods used by NEFSC staff to delineate small-mesh GRAs, by quarter-degree square, to reduce butterfish discards

Butterfish (*Peprilus triacanthus*) discards (lbs) for all observed otter trawl tows with codend mesh sizes less than 3.0 inches were extracted from the NEFSC Observer Database for the time periods of Jan.-April and Sept.-Dec, 1996-2003. A second data set which included the same two time periods was also extracted for observed otter trawl tows with codend mesh sizes of less than 3.75 inches. Discards were then summed by quarter-degree square (QDSQ), for each of the mesh size/time periods, and four maps were produced using ArcView. The objective was to determine which quarter-degree squares comprised a majority of the butterfish discards during 1996-2003. It should be noted that the resultant maps reflect the implementation of a management measure that prohibited small-mesh (< 4.5 in. codend mesh) fishing in two areas (scup Northern and Southern Gear Restricted Areas).

The maps showing the distribution of butterfish discards from the NEFSC Observer Database, by QDSQ, are very similar for the period Jan.-April (1996-2003) regardless of whether 3.0-inch (Fig. 1) or 3.75-inch (Fig. 2) codend mesh sizes were included in the analysis. The quarter-degree squares associated with the highest two discard categories, which comprised 83-84% of the total butterfish discards that were mapped, are the same for both mesh size ranges. The Sept.-Dec. (1996-2003) maps of butterfish discards are also similar regardless of whether 3.0-inch (Fig. 3) or 3.75-inch (Fig. 4) mesh was included in the analysis and the quarter-degree squares associated with the highest two discard categories, which comprised 92 % of the total butterfish discards that were mapped, are the same for both mesh size ranges. The QDSQ located at the head of Hudson Canyon (39723) was the only high-discard area common to both time periods.

Maps of butterfish discards that are based on data from the Observer Database represent a subsample of the total butterfish discards because not all vessels in the small-mesh fleet are sampled. As a result, the distribution of total effort (days fished) reported in the Vessel Trip Report Database, by otter trawlers fishing with 3.75-inch codend mesh during 1997-2003, was also mapped. The co-occurrence of butterfish and *Loligo* squid (% butterfish, in numbers) was computed for stations sampled in NEFSC research vessel surveys, for winter (Feb.) and spring (March) combined, and in autumn (Sept.-Oct.) during 1992-2003. The co-occurrence data points from the autumn survey were overlain on a map of the small-mesh fishing grounds (effort by QDSQ) for the period of Sept.-Dec. to determine whether areas outside those sampled by the Observer Program were fished heavily and to determine the spatial extent of butterfish and *Loligo* co-occurrence. Likewise, the combined winter and spring survey data points were overlain on a map of the fishing grounds for the period Jan-April.

Butterfish and *Loligo* co-occur across a smaller area, along the shelf edge, during the winter and spring (Fig. 5) than during autumn (Fig. 6). This aggregated distribution pattern lends itself more readily to the implementation of a small-mesh gear restriction area. The small-scale ranges of the two species indicates a high degree of spatial overlap near the shelf edge in winter and spring and suggest that the degree of co-occurrence varies in space during this time. Figure 5 indicates that areas with the highest amount of effort (highest two effort categories) occur across a broader expanse than indicated by the discard data mapped from the Observer Database (Fig. 4). Specifically, in addition to the squares containing the highest amounts of butterfish discards (e.g. the eight squares shaded dark and medium blue in Fig. 4), there is a high amount of effort and high incidence of butterfish and *Loligo* co-occurrence in QDSQ 40702. Thus, this QDSQ should also be considered along with the squares comprising the two highest butterfish discard categories (discards > 11,500 lbs) as potential butterfish Gear Restriction Areas during Jan.-April. The single southernmost square in this high-discard category straddles the existing Southern Gear Restriction Area for scup.

During Sept.-Dec., the distribution of stations with *Loligo* and butterfish co-occurrence is more dispersed, with high areas of concentration along the shelf edge as well as along the shoreline between Long Island and Cape Hatteras, North Carolina. Co-occurrence is generally low (1-25% butterfish, representing 75-99% *Loligo*) in the area located between the shelf edge and shoreline. Co-occurrence is quite prevalent throughout Georges Bank. The distribution of effort by QDSQ suggests that portions of the fishery were not sampled by the Observer Program during 1997-2003. The highest two categories of effort during Sept.-Dec. occurred in fourteen contiguous quarter-degree squares located in southern New England. However, according to the Observer Database, high amounts of discarding occurred in only one of these quarter-degree squares (QDSQ 39723). Although the VTR data indicate that fishing effort was low along the shelf edge in quarter-degree squares 37742, 37741, 36744, 36742 and 36744, high amounts of discarding occurred in these areas.

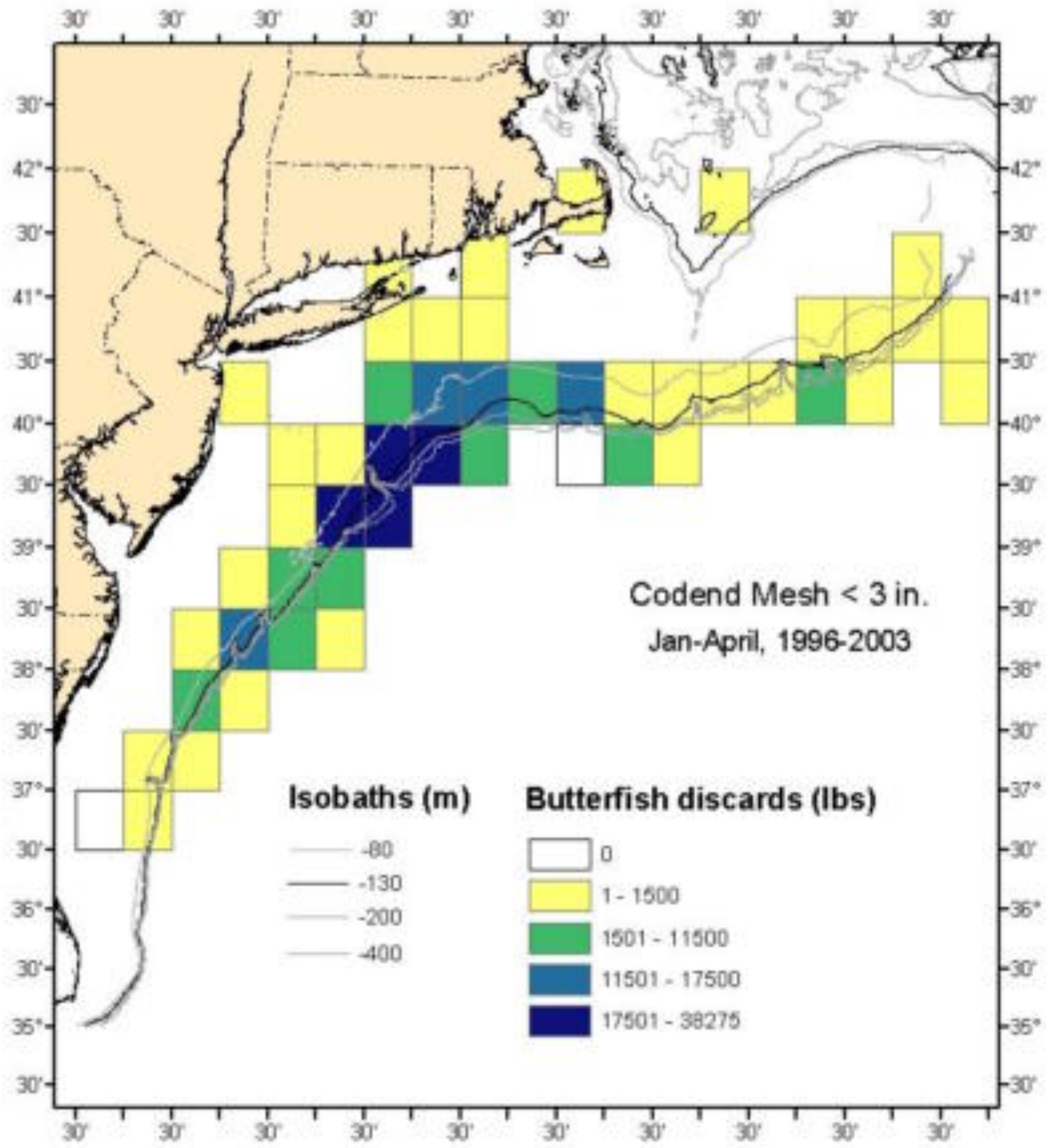

Figure 1. Distribution of butterfish discards, by quarter-degree square, of observed tows recorded in the NEFSC Observer Database for otter trawl fisheries using codend mesh sizes less then 3.0 inches during Jan.-April, 1996-2003.

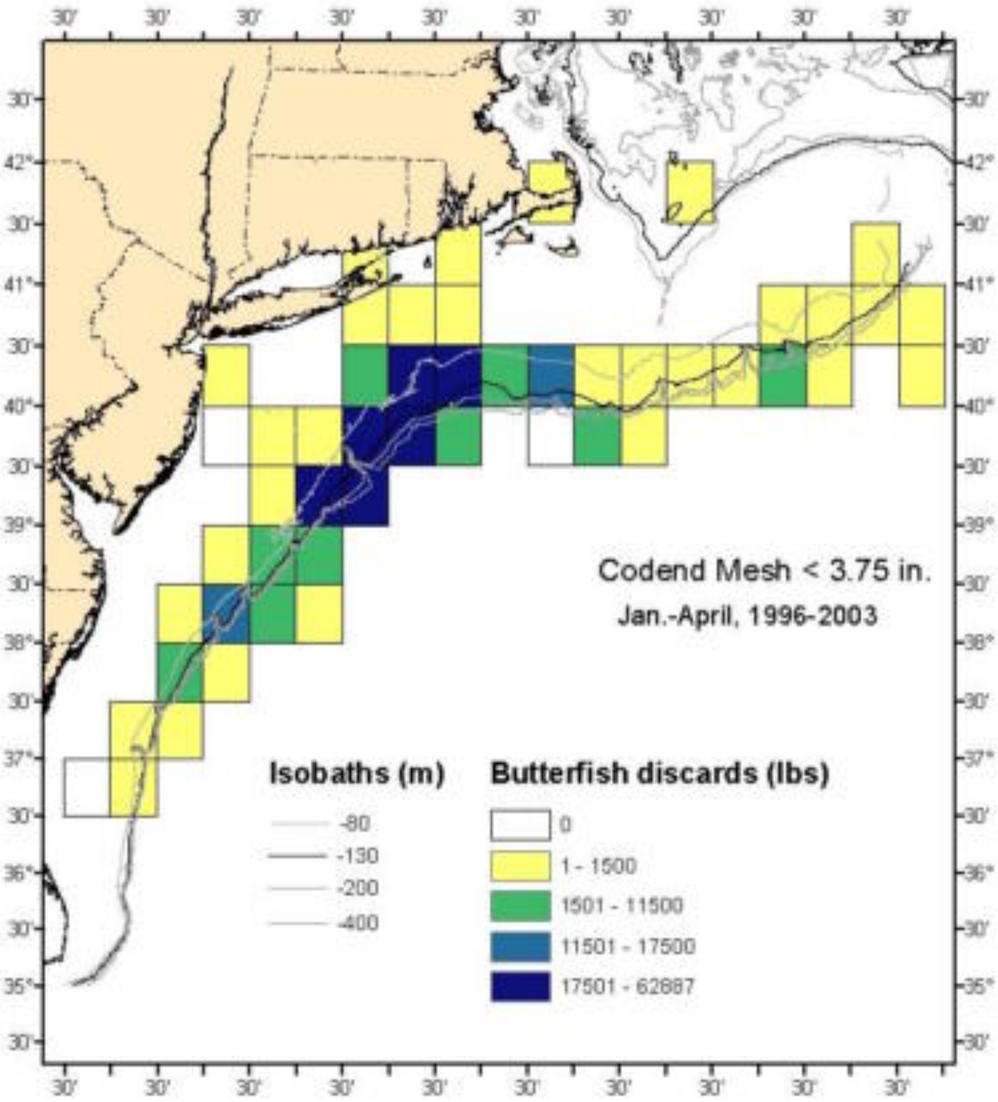

Figure 2. Distribution of butterfish discards, by quarter-degree square, of observed tows recorded in the NEFSC Observer Database for otter trawl fisheries using codend mesh sizes less then 3.75 inches during Jan.-April, 1996-2003.

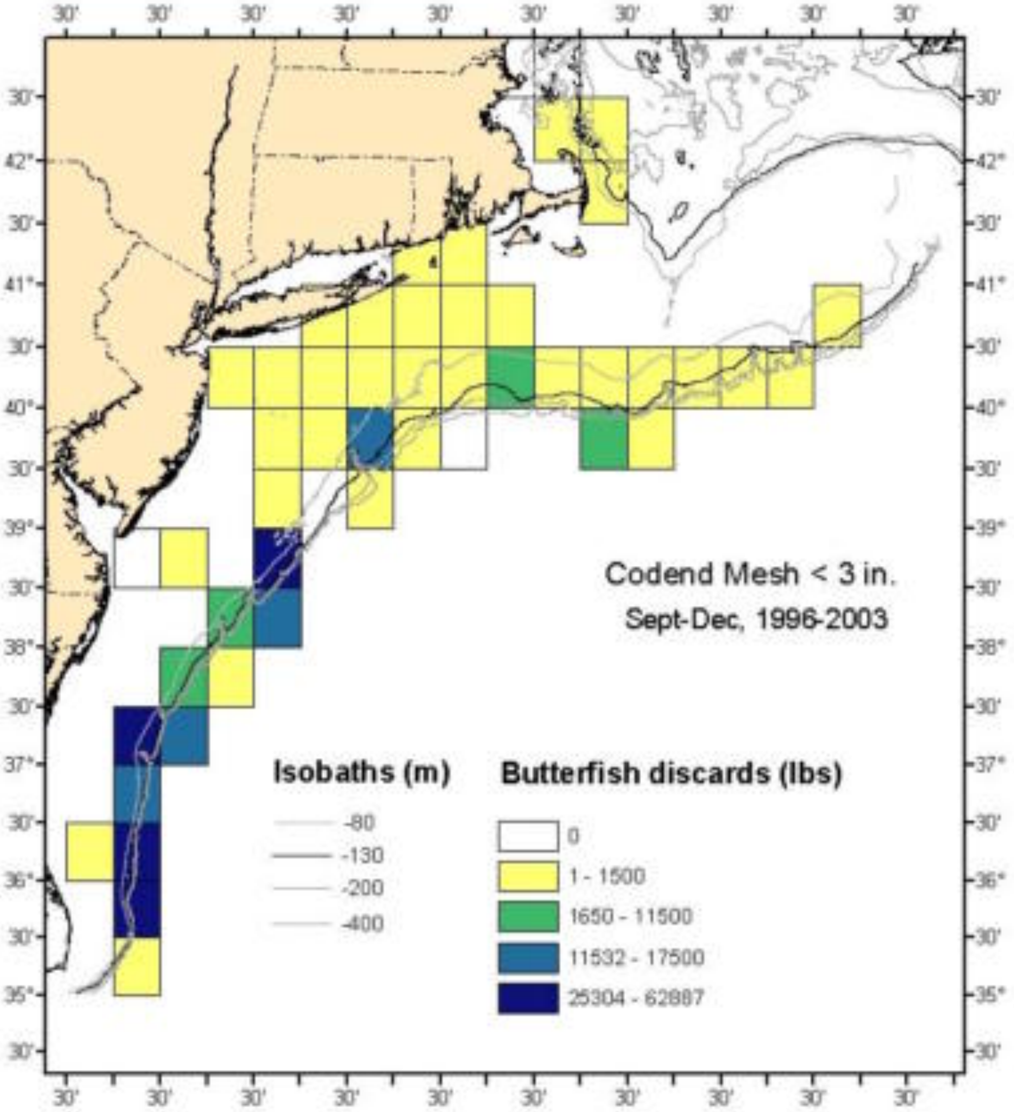

Figure 3. Distribution of butterfish discards, by quarter-degree square, of observed tows recorded in the NEFSC Observer Database for otter trawl fisheries using codend mesh sizes less then 3.0 inches during Sept.-Dec., 1996-2003.

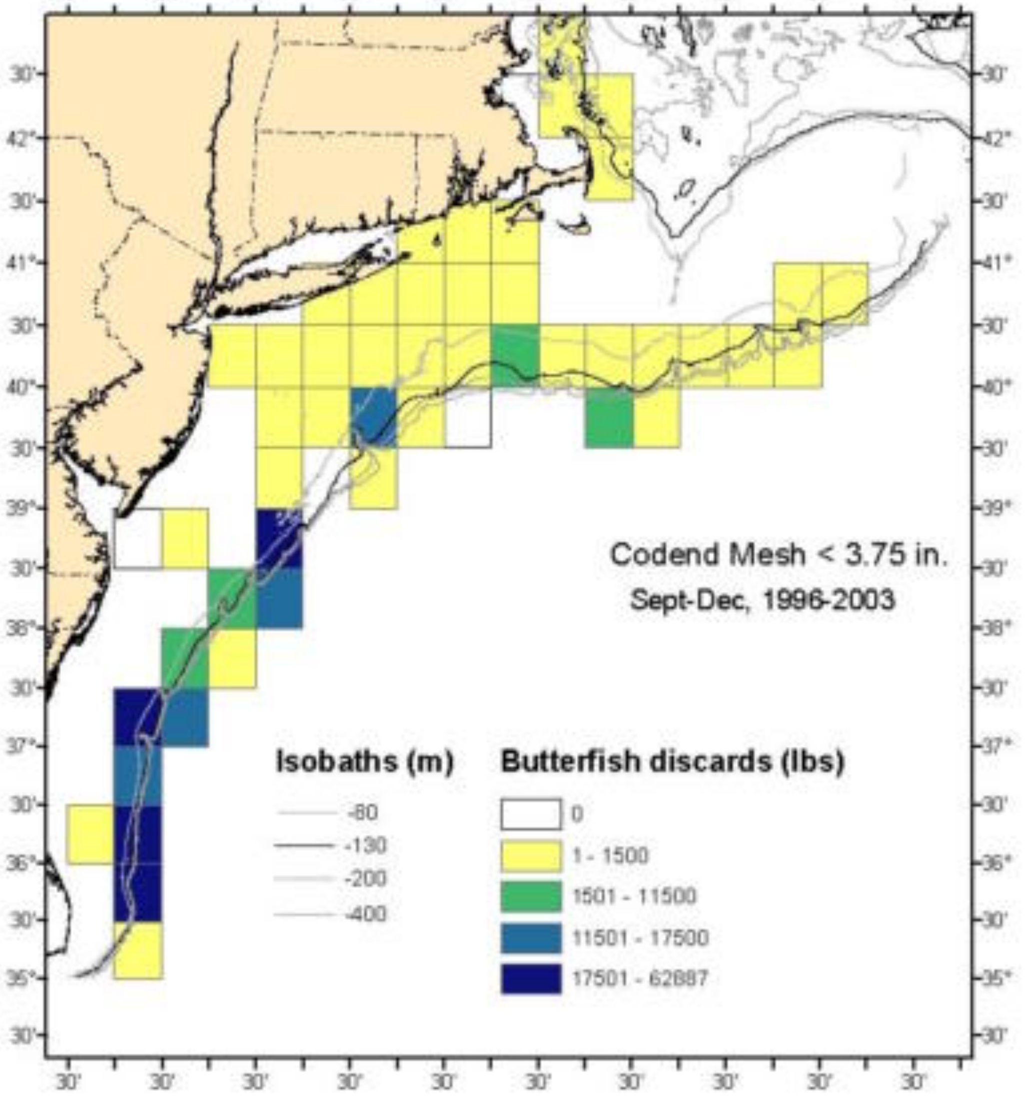

Figure 4. Distribution of butterfish discards, by quarter-degree square, of observed tows recorded in the NEFSC Observer Database for otter trawl fisheries using codend mesh sizes less then 3.75 inches during Sept.-Dec., 1996-2003.

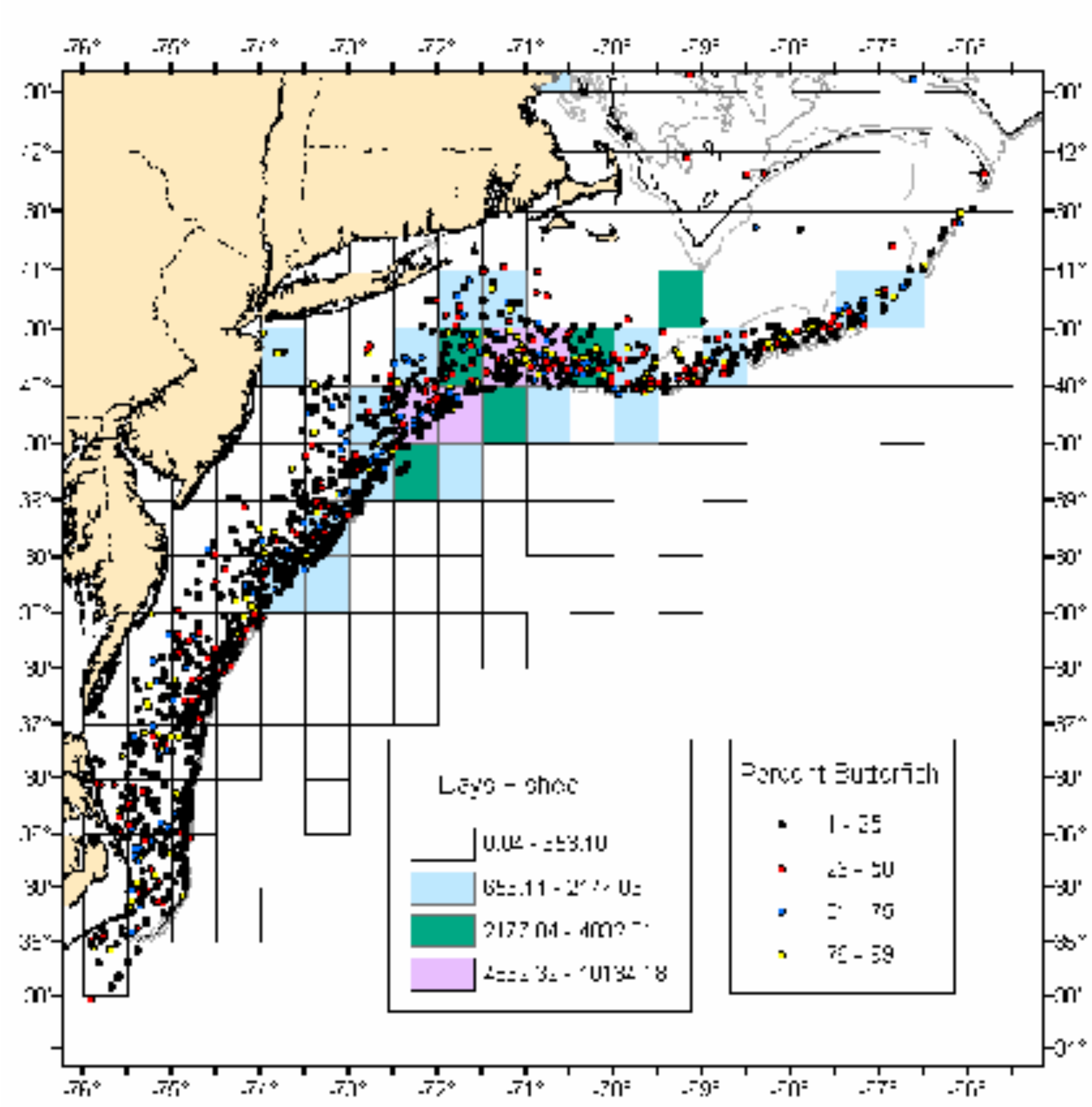

Figure 5. Co-occurrence of *Loligo* and butterfish in NEFSC winter (Feb.) and spring (Mar.) research vessel surveys during 1992-2003 and VTR effort (days fished) reported in the small mesh otter trawl fisheries (< 3.75 in. codend mesh) during Jan.-April, 1997-2003.

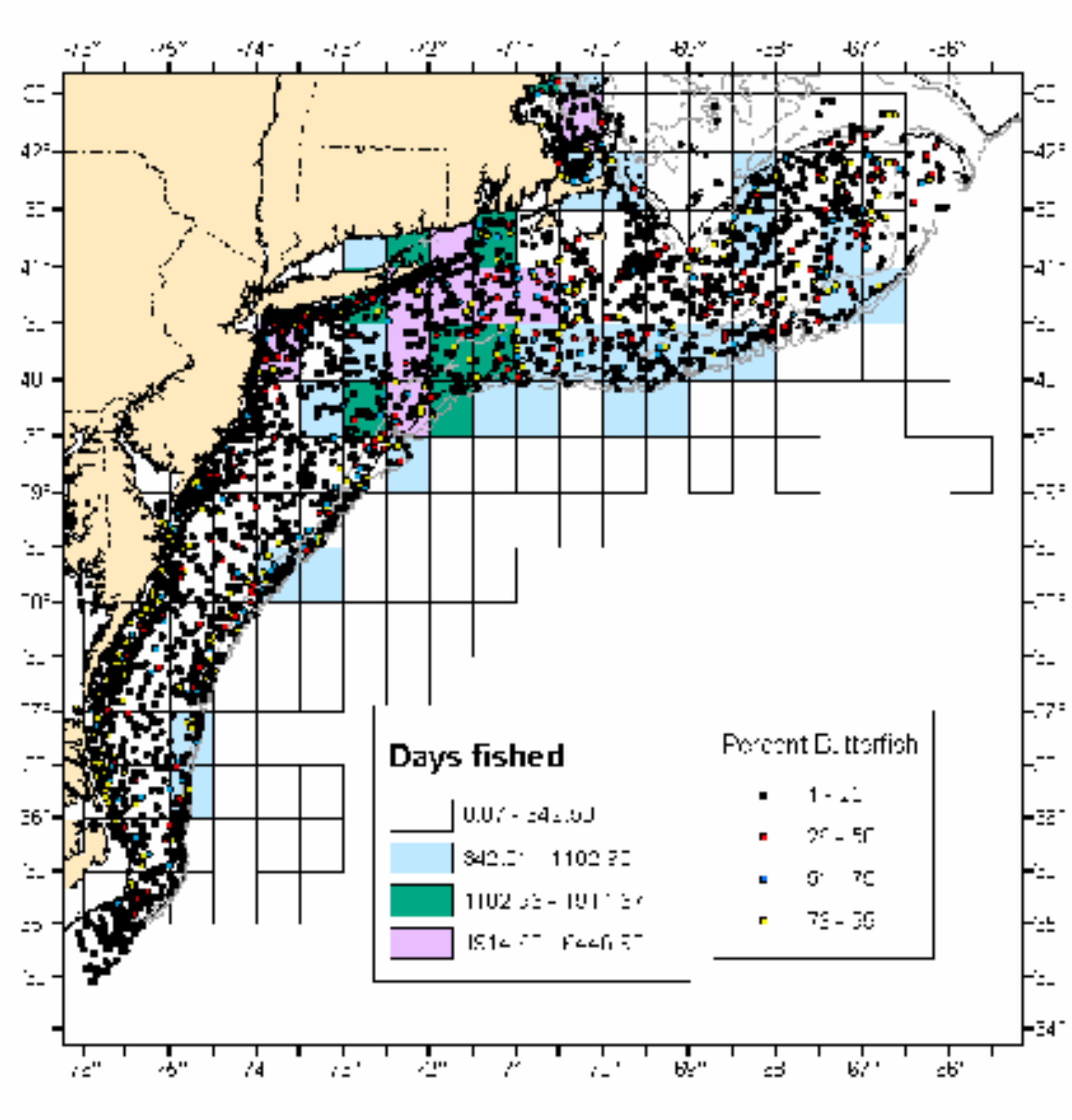

Figure 6. Co-occurrence of *Loligo* and butterfish in NEFSC autumn (Sept-Oct.) research vessel surveys during 1992-2003 and VTR effort (days fished) reported in the small mesh otter trawl fisheries (< 3.75 in. codend mesh) during Sept.-Dec., 1997-2003.

Appendix 2

Bottom trawl catches of *Loligo pealeii* during directed fishery closure periods

Bottom trawl catch data from the Vessel Trip Reports, Dealer Database and Observer Program Database were examined to determine the extent of *Loligo pealeii* landings that exceeded the 2,500 lb trip possession limit during directed fishery closure periods and to determine whether regulatory discarding of *L. pealeii* occurred during these closures (Table 1). The directed fishery was managed based on trimester quotas in 2000 and quarterly quotas thereafter.

1.0 Dealer Database

Based on data from the Dealer Database, *L. pealeii* was landed during 1,734 bottom trawl trips at levels which exceeded the regulatory trip possession limit (2,500 lbs) during directed fishery closure periods in 2000-2003. Both the number of trips and the percentage of the annual landings represented by these trips were highest in 2000 then declined thereafter (Table 2). *L. pealeii* landings from most of these trips were ≤ 2,500 lbs, but 6% to 19% of the trips each year exceeded the possession limit. Landings from trips which exceeded the possession limit equated to 34% of the total *L. pealeii* landings in 2000 and 1%, 7%, and 1% of the landings during 2001 through 2003, respectively. During the 2000 directed fishery closure, landings of *L. pealeii* **>** 2,500 lbs per trip were highest during June through August and October (Table 3). During all years, closure period trips with landings > 2,500 lbs were primarily directed *L. pealeii* trips, but silver hake and *Illex* were the second and third most predominant trip targets, respectively (Table 4). In summary, *L. pealeii* was landed during 2000-2003 directed fishery closure periods at quantities exceeding the regulatory trip possession limit.

2.0 Vessel Trip Report Database

Discard weights included in the Vessel Trip Report Database are self-reported. Therefore, discards reported in the Database represent minimum values as a result of trips with unreported discards and the potential for under-reporting of discard amounts. Over-reporting of discard amounts is considered less likely. In addition, the discard weights are estimated rather than actual measurements. Nevertheless, discard data from this source can be used to estimate whether regulatory discarding of *L. pealeii* occurred during directed fishery closures.

For bottom trawl trips during 2000-2003, the reporting frequency of *L. pealeii* discards was similar regardless of whether the directed fishery was closed or open (Table 5). Therefore, the annual discard to kept ratios of *L. pealeii* during closed versus open fishing periods can be compared to determine whether ratios were higher during closure periods, signaling the occurrence of regulatory discarding. The frequency of discard reporting declined between 2000 and 2003. During closed and open fishery periods, the percentage of trips with unreported *L. pealeii* discards was low (about 10%) during 2000, when the fishery was closed for a major portion of the year, then increased gradually to about 97%

during 2003. Trips with reports of zero *L. pealeii* discards declined from about 85% in 2000 to zero in 2003. For trips with reports of *L. pealeii* discards, most discarded ≤ 2,500 lbs. However, 2,501 lbs to 41,000 lbs of *L. pealeii* were discarded per trip during 2000 and 2002 regardless of whether the directed fishery was closed or open.

For the months during which directed fishery closures occurred in 2000-2003, most trips with *L. pealeii* discards occurred during June through November (Tables 6 and 7). During 2000 and 2002, *L. pealeii* discard to kept ratios were highest during August (0.23 - 0.77, respectively) and September (0.16 - 0.22, respectively). A comparison of annual discard to kept ratios during closed (Table 8) versus open fishery periods (Table 9) suggests that increased discarding of *L. pealeii* occurred during fishery closed periods. During 2000-2003, annual discard to kept ratios of *L. pealeii* during closed periods were 0.21, 0.05, 0.13 and 0.06, respectively, in comparison to ratios of 0.01, 0.03, 0.06, and 0.02, respectively, during open fishery periods. For months during which the directed fishery was both closed and open, monthly discard to kept ratios of *L. pealeii* also tended to be higher during closed periods (Tables 8 and 9). In summary, regulatory discarding of *L. pealeii* occurs during directed fishery closure periods.

3.0 Observer Program Database

Catch per tow data collected during 1998-2004, by observers from the NMFS Observer Program, indicate that vessels involved in the directed *L. pealeii* fishery are capable of catching at least 50,000 lbs per tow (Table 10). These data also indicate that the *L. pealeii* trip possession limit of 2,500 lbs is attainable as bycatch in a single tow during *Illex illecebrosus* trips and potentially attainable in two to five tows for trips targeting silver hake, summer flounder, scup, Atlantic mackerel, butterfish, spiny dogfish, and weakfish (Table 11). For the target species shown in Table 11, *L. pealeii* bycatch exceeded the closure period trip limit of 2,500 lbs for a percentage of trips targeting *I. illecebrosus* (69%), silver hake (97%), summer flounder (99%), and Atlantic mackerel (95%, Table 12). In summary, the *L. pealeii* trip limit of 2,500 lbs during directed fishery closures is attainable as bycatch in multiple bottom trawl fisheries and has been exceeded in the *I. illecebrosus*, silver hake, summer flounder and Atlantic mackerel fisheries during some trips. Exceeding the bycatch trip limit occurred most frequently in the *Illex* fishery whereby 31% of the trips had catches > 2,500 lbs. For the *Illex* fishery, most of the tows with *L. pealeii* bycatch were < 2,500 lbs (91%), but 7% of the tows had *L. pealeii* bycatch of 3,000-5,000 lbs 2% had bycatch of 5,500-6,800 lbs.

4.0 Conclusions

Landings of *L. pealeii* which exceeded the regulatory trip limit during directed fishery closures occurred in bottom trawl fisheries during 2000-2003. These landings represented 34% of the annual *L. pealeii* landings in 2000, but declined to a much lower percentage (1% to 7%) during 2001-2003. Regulatory discarding of *L. pealeii* occurred during directed fishery closures in 2000-2003. Discard to kept ratios of *L. pealeii* were higher during directed fishery closure periods than when the fishery was open. The NMFS Observer Program data indicated that regulatory discarding of *L. pealeii* occurred primarily in the *I. illecebrosus* fishery, but also in the silver hake, summer flounder and Atlantic mackerel fisheries. Regulatory discarding in these fisheries might be reduced to near zero, with the exception of the *I. illecebrosus* fishery, if the *L. pealeii* trip limit during directed fishery closures is increased to 5,000 lbs. A 5,000-lb trip limit would also reduce the number of *I. illecebrosus* trips with regulatory discards of *L. pealeii* by 13%. The Vessel Trip Report data indicated that the discard to kept ratios of *L. pealeii* and the percentage of trips which exceeded the closure period trip limit were highest during closures which occurred in June through October, coincident with the *Illex* fishing season. Therefore, an increase in the closure period trip limit to 5,000 lbs during June through October would be beneficial to the *L. pealeii* stock. Regulatory discards are difficult to estimate accurately and an increased trip limit would allow potential discards to be landed, resulting in a more accurate quantification of fishery removals. Increases in the bycatch trip limit to 7,500 lbs or 10,000 lbs, during June through October, would further reduce the number of *I. illecebrosus* trips with regulatory discarding of *L. pealeii* by another 5% and 10%, respectively. However, increasing the trip limit to these levels will result in little gain in regulatory discard reduction and may encourage directed fishing.

Table 1. *L. pealeii* fishery closure periods during 2000-2003.

2000	2001	2002	2003
3/25-4/30	5/29-6/30	5/28-6/30	5/25/5/31
7/1-8/31		8/16-9/30	
9/7-12/21		11/2-12/11	
		12/24-12/31	

Table 2. Bottom trawl landings of *Loligo pealeii* during directed fishery closure periods, in 2000-2003, when the *Loligo* possession limit is ≤ 2,500 pounds per trip.

Loligo Landings	2000		2001		2002		2003	
(lbs)	N trips	%	N trips	%	N trips	%	N trips	%
2,500	5,775	82.1	1,255	94.1	3,555	90.3	83	81.4
3,000	217	3.1	36	2.7	152	3.9	1	1.0
5,000	371	5.3	28	2.1	89	2.3	1	1.0
10,000	344	4.9	13	1.0	73	1.8	10	9.8
50,000	292	4.1	1	0.1	63	1.6	7	6.9
100,000	27	0.4	0	0.0	5	0.1	0	0.0
500,000	4	0.1	0	0.0	0	0.0	0	0.0
Total Trips	7,030		1,333		3,937		102	
Trips > 2,500 lbs of *L. pealeii*	1,255	17.9	78	5.9	382	9.7	19	18.6
% of annual landings		34		1		7		1
% of landings during closures		79		26		58		81

Table 3. Percentage of *Loligo pealeii* bottom trawl landings > 2,500 lbs, by year and month, during directed fishery closure periods in 2000-2003.

	Month during directed fishery closures									
Year	3	4	5	6	7	8	9	10	11	12
2000	5.2	2.2			21.3	15.0	5.7	46.7	2.8	1.2
2001			8.5	91.5						
2002			13.6	12.7		27.0	9.0		14.5	23.2
2003	100.0									

Table 4. Number of bottom trawl trips, by target species and year, with landings of *L. pealeii* that exceeded the possession limit of 2,500 lbs during directed fishery closures in 2000-2003.

Year	Monkfish	Butterfish	Winter Flounder	Scup	Black Sea Bass	Silver Hake	Sea Scallop	*Loligo*	*Illex*	Total Trips
2000	1	6			3	74		1,161	10	1,255
2001						1		77		78
2002			1	1		28	1	345	6	382
2003						3		16		19
Total Trips	1	6	1	1	3	106	1	1,599	16	1,734

Table 5. Trip discards (lbs) of *Loligo pealeii* in bottom trawls, by year, based on Vessel Trip Reports, 2000-2003. During directed fishery closures, the possession limit is 2,500 pounds per trip.

Loligo discards (lbs per trip)	Trips (%) during open fishery			
	2000	2001	2002	2003
unreported	8.91	72.17	93.09	94.45
0	86.63	22.58	0.78	0.01
2,500	4.47	5.24	6.06	5.53
3,000	0.00	0.00	0.02	0.00
5,000	0.00	0.01	0.02	0.01
10,000	0.00	0.00	0.03	0.00
50,000	0.00	0.00	0.01	0.00

Loligo discards (lbs per trip)	Trips (%) during closed fishery			
	2000	2001	2002	2003
unreported	11.37	84.62	90.90	96.88
0	82.51	8.80	0.73	0.00
2,500	5.96	6.58	8.28	3.13
3,000	0.00	0.00	0.03	0.00
5,000	0.03	0.00	0.00	0.00
10,000	0.05	0.00	0.03	0.00
50,000	0.08	0.00	0.03	0.00

Table 6. Number of bottom trawl trips with reports of *Loligo pealeii* discards, by year and month, during directed fishery closure periods in 2000-2003 based on Vessel Trip Reports.

	Month during directed fishery closure period										
Year	3	4	5	6	7	8	9	10	11	12	Total
2000	7	29			125	102	68	28	76	26	461
2001			12	77							89
2002			10	122		64	60		25	17	298
2003	2										2

Table 7. Percentage of bottom trawl trips with reports of *Loligo pealeii* discards, by year and month, during directed fishery closure periods in 2000-2003 based on Vessel Trip Reports.

	Month during directed fishery closure period										
Year	3	4	5	6	7	8	9	10	11	12	Total
2000	2%	6%			27%	22%	15%	6%	16%	6%	100%
2001			13%	87%							100%
2002			3%	41%		21%	20%		8%	6%	100%
2003	100%										100%

Table 8. Ratios of discard weight to kept weight of *Loligo pealeii* caught in bottom trawls, by year and month, during directed fishery closure periods in 2000-2003 based on Vessel Trip Reports.

	Month during directed fishery closures										
Year	3	4	5	6	7	8	9	10	11	12	Total
2000	0.10	0.12			0.13	0.23	0.77	0.06	0.08	0.12	0.21
2001			0.03	0.05							0.05
2002			0.02	0.06		0.16	0.22		0.12	0.08	0.13
2003	0.06										0.06

Table 9. Ratios of discard weight to kept weight of *Loligo pealeii* caught in bottom trawls, by year and month, when the directed fishery was open in 2000-2003 based on Vessel Trip Reports.

Year	1	2	3	4	5	6	7	8	9	10	11	12	Total
2000	0.03	0.01	0.01		0.01	0.01			0.01			0.09	0.01
2001	0.07	0.02	0.01	0.02	0.01		0.01	0.03	0.04	0.03	0.03	0.04	0.03
2002	0.05	0.03	0.05	0.02	0.03	0.06	0.06	0.05	0.14	0.03	0.09	0.07	0.06
2003	0.02	0.02	0.01	0.02	0.09	0.06	0.27	0.01	0.02	0.02	0.01	0.05	0.02

Table 10. *Loligo pealeii* catch (lbs) per tow in the directed fishery based on data collected by observers from the NMFS Fishery Observer Program during 1998-2004.

L. pealeii catch (lbs) per tow	N tows	%
1,000	1,595	58.8
2,500	751	27.7
3,000	100	3.7
5,000	177	6.5
10,000	75	2.8
20,000	11	0.4
50,000	4	0.1
Total	2,713	

Table 11. Maximum catches of *Loligo pealeii* that exceeded 500 lbs per tow, by target species and month, based on 1998-2004 data from the NMFS Observer Program Database.

	Month of Fishery											
Target Species	1	2	3	4	5	6	7	8	9	10	11	12
Illex illecebrosus					648	900	3,013	6,300	6,800			940
Silver Hake	1,800	1,500		630								1,380
Summer Flounder	599	800	623	630	840						2,000	540
Scup	575		2,000	600								
Atlantic Mackerel			980	600								
Butterfish		560										
Spiny dogfish											750	
Monkfish												557
Weakfish										700		

Table 12. Percentage of bottom trawl trips with *Loligo pealeii* bycatch, by amount and target species, based on trips recorded in the NMFS Observer Program Database during 1998-2004.

	N trips by target species							
L. pealeii bycatch, lbs	*Illex*	%	Silver Hake	%	Summer Flounder	%	Atlantic Mackerel	%
2,500	27	69.2	86	96.6	350	99.2	18	94.7
5,000	5	12.8	3	3.4	3	0.8	1	5.3
7,500	2	5.1	0	0.0	0	0.0	0	0.0
10,000	2	5.1	0	0.0	0	0.0	0	0.0
12,500	0	0.0	0	0.0	0	0.0	0	0.0
15,000	0	0.0	0	0.0	0	0.0	0	0.0
17,500	1	2.6	0	0.0	0	0.0	0	0.0
20,000	0	0.0	0	0.0	0	0.0	0	0.0
22,500	0	0.0	0	0.0	0	0.0	0	0.0
25,000	1	2.6	0	0.0	0	0.0	0	0.0
27,500	1	2.6	0	0.0	0	0.0	0	0.0
Total	39		89		353		19	

Appendix 3a

Codend mesh size regulation as a bycatch management measure in small-mesh fisheries

Historically, the regulation of codend mesh size in the squid fisheries (*Illex* and *Loligo*) in U.S. and Canadian (*Illex* only) waters was used as a bycatch management measure by the U.S. and by the International Commission for the Northwest Atlantic Fisheries (ICNAF, now NAFO). In addition, small-mesh bottom trawl fisheries were limited to specific offshore areas and seasons in both the U.S. and Canada. Since 1977, a minimum codend mesh size of 130 mm has been required for bottom trawl fishing on the Scotian Shelf shoreward of the 200 m isobath (ICNAF 1978). During 1978-1982, bottom trawlers engaged in directed fisheries for *Illex* and *Loligo* in U.S. waters were required to fish with a minimum codend mesh size of 60 mm (with specific chafing gear requirements) and were restricted to offshore fishing in specific areas and time periods; generally seaward of the 183 m isobath (ICNAF 1978). During this time, a portion of the bottom trawl fleet also targeted *Illex* with 80 to 90 mm-mesh codends (Hatanaka and Sato 1980; ICNAF 1979).

The Vessel Trip Report (VTR) database was used to identify the range of codend mesh sizes (primarily liner mesh sizes) currently in use by otter trawlers which retained either *Illex* or *Loligo* during 1997-2003. Based on unbinned codend mesh size data, a majority (41%) of the *Illex* landings were obtained with 60 mm mesh codends, with secondary mesh size modes at 48-50 mm (22%) and 35-38 mm (18%, Table 1). A majority (34%) of the *Loligo* landings were obtained using 50 mm mesh codends, with secondary mesh size modes at 60-63 mm (26%, comprised of 11% taken with 60 mm and 15% taken with 63 mm) and 76 mm (14%). Only 10% of the *Loligo* landings were taken with the use of the minimum legal mesh size of 48 mm. The retained portion of the catch, for both species combined, was taken primarily with 48-50 mm mesh (36%) and 60-63 mm mesh codends (32%), and smaller amounts were taken with 76-mm mesh (9%) and 35-38 mm mesh (7%).

Data from the NEFSC Observer Database was examined, for 1996-2003, to determine the mesh size of the codend cover (mesh size of the netting covering the liner), twine type and how the netting was hung, for tows where the captain indicated that the target species was *Loligo*. In the directed *Loligo* fishery, codend covers consisted primarily of double-twine, 140 to 160-mm diamond mesh.

Seasonal *Illex* mesh selectivity studies have been conducted for bottom trawl codend mesh sizes of 45, 60, 90, 100 and 130 mm. The loss of *Illex* catch with the use of 60 mm mesh was 13% during June and none during October. The loss of *Illex* catch with the use of 90 mm mesh was 21-23% and 1-2% during June and October, respectively (Amaratunga *et al.* 1979).

Trends in butterfish discards by mesh size

Management advice based on the most recent stock assessment of butterfish (*Peprilus triacanthus*) indicates that discards are more than twice the landings and should be reduced (NEFSC 2004). The stock assessment indicated that the "squid" fisheries represented the primary source of butterfish discards (NEFSC 2003). Butterfish discards ranged in size from 4 to 24 cm, but were predominantly less than 16 cm. Few butterfish live beyond age 3 and most are sexually mature at age 1 (female $L_{50\%}$ = 12 cm, Overholtz 2000).

Otter trawl codend mesh sizes were binned by 5 mm intervals for comparisons between VTR and Observer data. The VTR data indicate that a majority of *Illex* and *Loligo* landings are taken with codend mesh sizes of 40 to 65 mm, with a mesh size mode at 65 mm and 55 mm for landings of *Illex* and *Loligo*, respectively. Approximately 14% of the *Loligo* landings were taken with 80-mm codend mesh (Figure 1A). Data from the NEFSC Observer Program (1996-2003) were used to compare the percentage of otter trawl tows with butterfish discards, by codend mesh size, to all otter trawl tows sampled (Figure 1B) and to compare the percentage of discarded butterfish weight, by codend mesh size, to all otter trawl tows sampled (Figure 1C). For vessels fishing with liners, liner mesh size is indicated as codend mesh size. Regarding frequency of butterfish discard occurrence, the results indicate that 81% of the tows with butterfish discards occurred on otter trawlers with codend mesh sizes of ≤ 65 mm and 9% of the tows with codend mesh sizes of 66-80 mm (Figure 1B). The highest percentage of butterfish discards (92%) also occurred with the use of codend mesh ≤ 65 mm. Butterfish discards of 7% occurred with the use of codend mesh sizes of 66-80 mm mesh (Figure 1C). The target species *Loligo* and silver hake, as indicated by the captain prior to each tow, accounted for 77% and 11%, respectively, of the butterfish weight discarded in the 76-80 mm mesh range. For the ≤ 65 mm mesh range, target species and the percentages of butterfish discard weight that each represented were: *Loligo* (50%), *Illex* (30%), squid and mixed groundfish (6%), Atlantic mackerel (4%) and butterfish (2%).

Summary

During 1978-1982, a minimum codend mesh size of 60 mm was required in the directed squid fisheries in U.S. waters. Currently, a large portion of the *Loligo* (41%) and *Illex* (46%) landings are taken with codend mesh sizes between 60 mm and 76 mm. Only 10% of the *Loligo* landings are taken with the minimum legal codend mesh size of 48 mm. Mesh selectivity studies indicate that there is minimal loss of *Illex* catch with the use of a codend mesh size of 60 mm, and for mesh sizes between 60 mm and 90 mm, a loss of 13% to 23% occurs during June then decreases thereafter and becomes negligible (between 0 and 2%) by October.

Table 1. Percentages of *Illex* and *Loligo* retained (mt), by codend mesh size (mm), based on 1997-2003 Vessel Trip Reports.

Codend mesh size (mm)	*Loligo* (mt retained)	%	*Illex* (mt retained)	%	Both species (mt retained)	%
25	109.31	0.11	1,927.00	3.36	2,036.31	1.34
27	73.01	0.08	0.00	0	73.01	0.05
30	0.27	0.00	0.00	0	0.27	0.00
33	136.04	0.14	668.28	1.17	804.32	0.53
34	30.22	0.03	0.00	0	30.22	0.02
35	830.57	0.87	2,439.95	4.25	3,270.52	2.14
38	291	0.31	7,927.92	13.82	8,218.92	5.39
40	12.36	0.01	309.58	0.54	321.94	0.21
43	0.05	0.00	0.00	0.00	0.05	0.00
44	209.31	0.22	850.54	1.48	1,059.85	0.69
45	721	0.76	1,722.67	3.00	2,443.67	1.60
46	2.54	0.00	0.00	0.00	2.54	0.00
47	495.88	0.52	795.71	1.39	1,291.59	0.85
48	9,867.60	10.37	4,406.94	7.68	14,274.54	9.36
50	32,027.98	33.66	8,391.54	14.63	40,419.52	26.50
53	71.42	0.08	102.91	0.18	174.33	0.11
55	74.85	0.08	24.42	0.04	99.27	0.07
57	262.97	0.28	15.30	0.03	278.27	0.18
58	2,593.13	2.72	610.73	1.06	3,203.86	2.10
59	68.79	0.07	0.00	0.00	68.79	0.05
60	10,652.16	11.19	23,333.67	40.69	33,985.83	22.28
63	14,119.49	14.84	1,066.81	1.86	15,186.30	9.96
66	419.2	0.44	242.77	0.42	661.97	0.43
68	2.9	0.00	0.00	0.00	2.90	0.00
69	21.6	0.02	466.38	0.81	487.98	0.32
71	572.04	0.60	588.34	1.03	1,160.38	0.76
73	394.96	0.42	608.61	1.06	1,003.57	0.66
76	12,887.88	13.54	337.65	0.59	13,225.53	8.67
78	8.73	0.01	0.00	0.00	8.73	0.01
81	1.01	0.00	0.00	0.00	1.01	0.00
82	2.39	0.00	0.00	0.00	2.39	0.00
83	3.55	0.00	0.00	0.00	3.55	0.00
86	59.2	0.06	0.00	0.00	59.20	0.04
88	259.71	0.27	6.16	0.01	265.87	0.17
91	0.09	0.00	0.00	0.00	0.09	0.00
93	0.71	0.00	0.00	0.00	0.71	0.00
95	1.48	0.00	0.00	0.00	1.48	0.00
96	50.28	0.05	2.64	0.00	52.92	0.03
99	0.06	0.00	0.00	0.00	0.06	0.00
101	1,115.05	1.17	4.90	0.01	1,119.95	0.73
104	14.39	0.02	0.00	0.00	14.39	0.01
106	0.1	0.00	0.00	0.00	0.10	0.00
109	0.11	0.00	0.00	0	0.11	0.00
114	1,891.66	1.99	220.49	0.38	2,112.15	1.38

Table 1. Percentages of *Illex* and *Loligo* retained (mt), by codend mesh size (mm) based on 1997-2003 Vessel Trip Reports (cont.).

Codend mesh size (mm)	*Loligo* (mt retained)	%	*Illex* (mt retained)	%	Both species (mt retained)	%
115	0	0.00	0.00	0.00	0.00	0.00
116	0.11	0.00	0.00	0.00	0.11	0.00
120	5.44	0.01	0.00	0.00	5.44	0.00
121	0.35	0.00	0.00	0.00	0.35	0.00
124	13.86	0.01	0.00	0.00	13.86	0.01
127	1,449.62	1.52	133.37	0.23	1,582.99	1.04
128	0	0.00	0.00	0.00	0.00	0.00
129	0.03	0.00	0.00	0.00	0.03	0.00
134	1.99	0.00	0.00	0.00	1.99	0.00
135	0	0.00	0.00	0.00	0.00	0.00
137	0.06	0.00	0.00	0.00	0.06	0.00
139	701.93	0.74	25.86	0.05	727.79	0.48
141	0	0.00	0.00	0.00	0.00	0.00
142	0.03	0.00	0.00	0.00	0.03	0.00
147	2.59	0.00	0.00	0.00	2.59	0.00
152	2,629.69	2.76	116.12	0.20	2,745.81	1.80

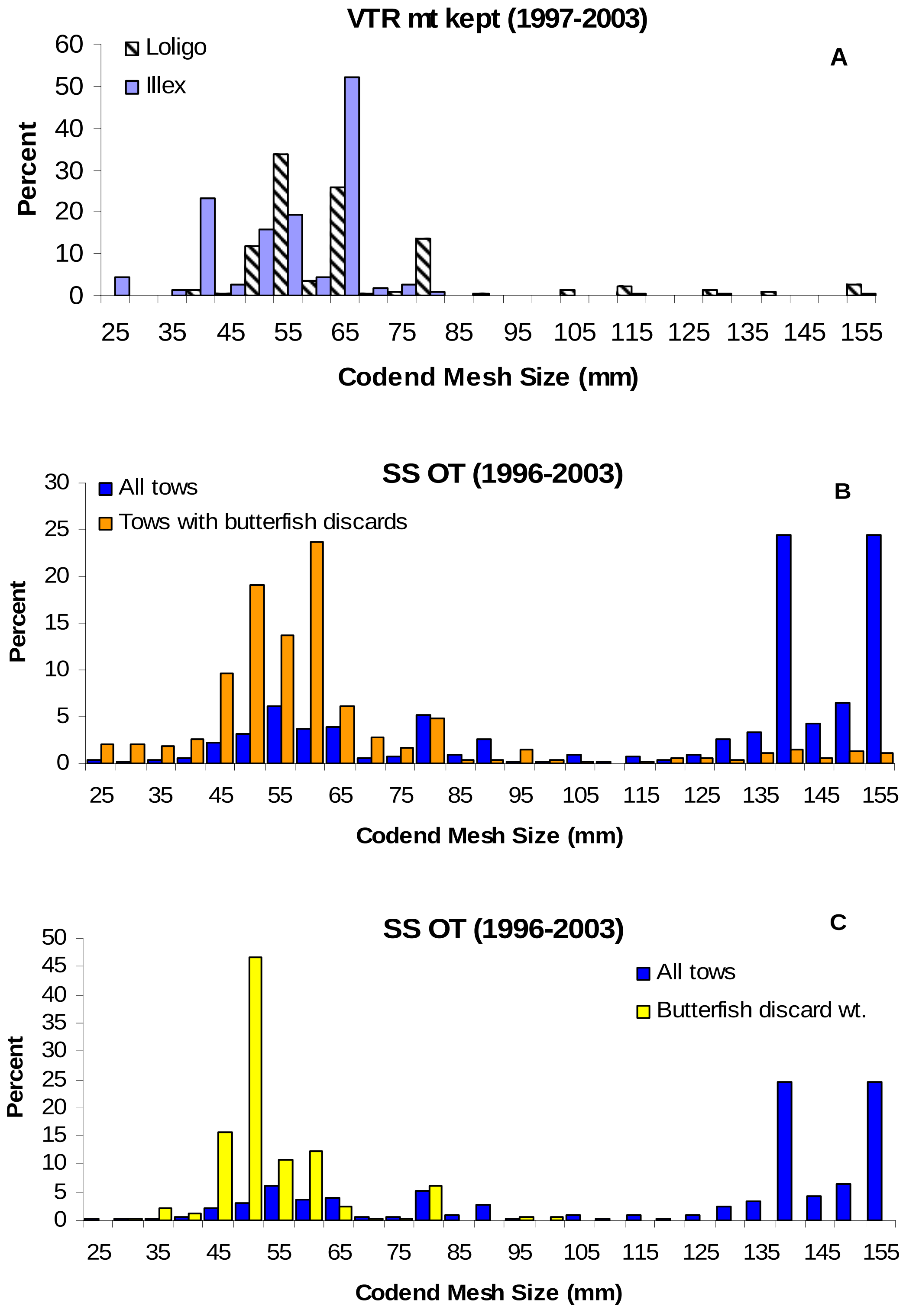

Figure 1. Percentages of *Illex* and *Loligo* catch retained, by codend mesh size, based on Vessel Trip Reports (A), otter trawl tows with butterfish discards versus all otter trawl tows, by codend mesh size (B), and discarded butterfish weight versus all otter trawl tows, by codend mesh size (C). For vessels with liners, the liner mesh size is shown.

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Appendix 3b

Analysis of non-target species discarding in SMB fisheries

There are two approaches to evaluating the discard problems for the species and fisheries managed under this FMP. The first is to evaluate the bycatch and discard of the four SMB species (Atlantic mackerel, *Loligo*, *Illex*, and butterfish) in all fisheries. The second approach is to evaluate bycatch of non-target species in the directed fisheries for Atlantic mackerel, *Illex*, *Loligo*, and butterfish. To evaluate the extent of catch and discarding of Atlantic mackerel, *Loligo* and *Illex* squid, and butterfish in various fisheries (i.e., in addition to the fisheries managed under this FMP), discard estimates from the most recent stock assessments for each species were examined.

In the case of Atlantic mackerel, no valid discard estimates are available from the most recent stock assessments. However, commercial fisheries that use gear types for which Atlantic mackerel are particularly vulnerable (e.g., mid-water and bottom otter trawls) are the most likely to contribute to the bycatch mortality of Atlantic mackerel. Based on a limited number of otter trawl trips sampled by the NEFSC Observer Program, the discard rate of mackerel in the directed mackerel fishery (defined as trips which landed greater than 5,000 pounds of mackerel) was fairly low (6% of the total amount of mackerel catch) during 1989-2003 (Table 1). During the same time period, the rate of mackerel discards in all of the other fisheries (non-directed trips) included in the Observer Program database was higher (64%), but the amount of mackerel taken on these trips was relatively small. However, there were no trips sampled in 1989 or 2003 so the directed fishery discards shown in Table 1 are for the period 1990-2002. In 2002, the characteristics of the directed mackerel fishery changed from a predominance of landings from bottom trawls to a predominance of landings from midwater trawls. Therefore, the 1990-2002 data are not likely reflective of current discard patterns in the directed mackerel fishery.

Illex discards estimates are available from SARC 42. *Illex* discards (mt) in the directed *Illex* and *Loligo* fisheries were estimated by month and year from data collected during trips sampled by the NEFSC Sea Sampling Program during 1995-2004. Annual estimates of *Illex* discards were computed by multiplying the discard ratio (*Illex* discarded/*Illex* or *Loligo* kept, by the respective landings of either *Illex* or *Loligo*). The annual sampling intensity of trips observed in both the *Illex* and *Loligo* fisheries was low during most years with the exception of 2004, so the discard estimates may be imprecise for most years. Data from observed trips from the NEFSC Observer Program database indicate that a majority of the *Illex* discards during 1995-2004 occurred in the offshore *Loligo* fishery during November –April and comprised more than 60% of the annual *Illex* discards during most years. During 2004, the year of highest observer coverage of the *Illex* and *Loligo* fisheries and also a year of high *Illex* abundance on the U.S. shelf, *Illex* discards by the *Illex* and *Loligo* fisheries comprised 22% and 68% of the annual total, respectively. Overall, annual discards of *Illex* during 1995-2004 ranged from 0.5 to 6.0% of the annual *Illex* landings.

Cadrin and Hatfield (1999) estimated discards of *Loligo* squid and concluded that the discards of this species are minor but indicated that precise estimates of discards were difficult to obtain and that discard rates likely vary by fishery, season, time of day, location and target species. In addition to reviewing published reports, Cadrin and Hatfield (1999) used data from 915 otter trawl trips in the NMFS observer database to calculate ratios of the weight of *Loligo* discarded divided by the weight of all species landed during 1989-1998. The ratios ranged 1%-14% and averaged 6%. The most recent estimates of *Loligo* discards were presented in SARC 34. NMFS observer data were used to estimate discard rates for *Loligo* squid during trips directed at key target species during 1997-2000. Target species was determined before each tow was completed by asking the captain which species was being targeted. Discard estimates were calculated as the product of average landings during 1997-2000 and discard rates from observer data for 1997-2000. For tows other than those where *Loligo* were targeted, the number of tows sampled was small. Results indicated that total *Loligo* discards averaged about 600 mt per year during 1997-2000 (Table 3). By comparison, *Loligo* landings averaged about 18,000 mt per year over the same time period, so that the ratio of discards to landings for *Loligo* was about 0.03. The bulk of average *Loligo* discards (about 500 mt per year) were from tows targeting *Loligo*. However, *Loligo* are taken in tows targeting many species, including target species not included in the SARC 34 analysis. SARC 34 noted that the estimated 3% discard rate for key target species was less than Cadrin and Hatfield's (1999) estimate for the entire bottom trawl fishery. Overall, discards of *Loligo* appear to be a relatively minor source of mortality relative to landings.

Butterfish discard estimates are available from SARC 38. Fisheries which potentially discard butterfish were identified based on a target species or a mix of species and the percent and frequency of butterfish catches in those fisheries during 1989-2002. Patterns in butterfish landings were examined by aggregating over a set of observed trips that caught butterfish during 1989-2003. The distribution suggested that a large number of trips landed a small amount of butterfish and many fewer trips accounted for the largest landings. Discard ratios were calculated using the VTR database for 1994-2002. Initially all gears that captured butterfish were examined for discards, but only data for otter trawls were included because butterfish discards by other gears such as gill nets were negligible. An aggregate approach was used to allocate landings and discards into the appropriate categories, so that all trips with some amount of landings or discard were included in the analysis. Sample sizes in each cell were relatively large under this stratification scheme using VTR data. Discard ratios were calculated by dividing discard by landings. Results from this approach indicate that discard ratios averaged less than 1 for both categories of landings. In many cases discard rates were very small on an annual basis, indicating that reporting rates for discards in vessel logbooks may be relatively low. As a result, SARC 38 concluded that VTR data could not be used to produce valid estimates of discards for butterfish.

A second butterfish discard analysis was conducted at SARC 38 using the NMFS Observer Program database. Only data from observed tows for otter trawl trips was analyzed. Data were stratified into half-year intervals and categories of 600 lbs or less and greater than 600 lbs. An aggregate approach including all trips with some landings or discard of butterfish was used to allocate trips into one of the four cells for each year during 1989-2002. Results showed that on average discard ratios were greater than 1 and in most cases significantly greater. With a few exceptions such as for some of the larger cells during 1997-2001, discard rates were greater than 1. Discard ratios in the 600 or less category during 1998-2002 were largest. Since the data were skewed, a log transformation of the data was completed. Since only matched trips were used for this analysis fewer samples were available, especially in the higher categories. Results from this approach produced discard ratios that were much less variable ranging from 0.5 - 4.6, and averaging 4.2 for <600 lbs and 1.7 for > 600 lbs. These discard ratios were used along with otter trawl landings by half year and the same landings categories to estimate discards (mt) for each cell in each year and then totaled for the year. Discard estimates ranged from 1,809-8,599 mt during 1989-2002 (Table 4). Discards were 4,442 mt in 1989, declined to 3,020 mt in 1990 and then increased steadily to 8,478 mt in 1993. After a decline to 3,701 mt in 1994, discards increased to 8,599 mt in 1995, followed by an almost steady decline to 2,427 mt in 2000 (Table 4). After increasing to 7,262 mt in 2001, discards declined to 1,809 mt in 2002. The size composition of discarded butterfish ranged from 4-24 cm depending on the year and the fishery, but discarded fish were generally less than 16 cm. Butterfish lengths for the kept fraction of the catches ranged from 10-22 cm and usually had a modal length from 16-18 cm. Over the entire time series (1989-2002), butterfish were caught frequently in the "squid" (*Illex* and *Loligo* combined), mixed groundfish, silver hake and fluke fisheries. Overall, fisheries for "squid" produced the highest level of butterfish discards during 1989-2002 and butterfish discards during this time period were estimated to be more than twice the butterfish landings.

As described above, the second approach is to examine the degree of bycatch of non-target species in the Atlantic mackerel, squid and butterfish fisheries. The fisheries managed under the MSB FMP are prosecuted primarily using small mesh otter trawls. As such, the small mesh gears utilized in these fisheries have the potential to retain non-target species taken incidentally which, if discarded, would fall under the definition of bycatch as defined in the SFA.

An exploratory analysis was conducted to determine if available data are sufficient to accurately describe discards in the Atlantic mackerel, squid, and butterfish fisheries. The analysis examined the adequacy of the bycatch information based on unpublished NMFS Dealer reports (NMFS Weighout database), vessel trip reports (VTR database) and at-sea fishery observations based on the NEFSC Observer Program database. The analysis considered the otter trawl sectors of these fisheries only since the vast majority of landings for these four fisheries are taken with otter trawls. Subsequent to determining the robustness of available data to describe discards, additional analyses were conducted to determine if available data are sufficient to support management measures to reduce discards in these fisheries, including time/ area gear restrictions.

The first step was to define the level of a directed trip for each fishery using dealer weighout data. The goal was to identify a threshold of trip level landings for each fishery below which landings did not contribute significantly to total landings for a given species. For each species, a range of trip-level landings levels in terms of both pounds and percent of total trip was considered. Total landings by year inclusive of all trips were tabulated for each fishery. These totals were compared to annual landings when trips below a given threshold level were eliminated. The relative contribution to total landings by trip-levels above the threshold could then be determined (Figures 1-8). Based on this evaluation, directed trips for *Loligo* and *Illex* were defined as trips comprising 50% or more by weight of the respective target species. Directed butterfish trips were defined as landings of 500 lbs or more of butterfish and directed mackerel trips were defined as landings of 5,000 lbs or more of mackerel.

The next step was to identify the species discarded in the Atlantic mackerel, squid and butterfish fisheries based on NMFS sea sampling data. Using the directed trip criteria established above for each species, the catch disposition for all species encountered on directed trips was characterized using the combined 1989-2003 sea sampling data. Species that comprised greater than 2% of the total discards by weight for each fishery were considered for additional analysis (Table 6). These were grouped into a composite suite of 16 species for which subsequent analyses of discarding patterns for these fisheries conducted (referred to hereafter as “the 16 species”). This suite of species included: butterfish, scup, silver hake, red hake, spiny dogfish, *Loligo* squid, fourspot flounder, *Illex* squid, Atlantic mackerel, sea robins, Atlantic herring, blueback herring, John Dory, skates, herring (NK), and chub mackerel.

Following identification of the species which are discarded in these fisheries, the relative contribution of Atlantic mackerel, squid and butterfish fisheries to the total discards of these species was evaluated. For example, discards of a given species by the Atlantic mackerel, squid and butterfish fisheries, even regularly, does not necessarily indicate that a discarding problem exists. Rather, the contribution by these fisheries to the overall discards of that species should be considered to determine the degree of the problem. This was determined by calculating the ratio of Atlantic mackerel, squid and butterfish fisheries discards to total annual discards for each of the top 16 species based on available NMFS sea sampling data (Tables 7-10). If these data are examined for consistently high ratios (i.e., >10%), a smaller subset of species can be identified. Highlighted cells in Tables 7-10 indicate ratios exceeding 10% and species names are highlighted in cases where discard ratios exceeded 10% for more than three of the last eight years. Note that the *Illex* and Atlantic mackerel fisheries appear to be relatively unimportant contributors to the overall discards for the majority of the 16 species.

Discards (lbs) for each of the 16 species were then tabulated by month and statistical area for each of the fisheries based on NMFS sea sampling and VTR data for 1996-2003. The number of trips contributing to recorded discards for each species was also tabulated to evaluate the voracity of the data to identify discard patterns. Discarding of a given species from a small number of observer trips is considered relatively less indicative of a pattern than discards from a large number of trips. NMFS statistical areas were identified which contributed greater than 5% of the observed discards by a given Atlantic mackerel, squid and butterfish fishery for species highlighted for that fishery (Table 11). At this level, additional consideration of discard reduction alternatives was abandoned for many fishery/discard species/area combinations due to the low number of observer trips that occurred in that area. The best case (i.e., the greatest number of observer trips for a fishery/discard species/area combination) was 32 *Loligo* trips which discarded butterfish in area 616. The number of directed *Loligo* trips reported in the VTR in area 616 is about 2,500, which corresponds to observer trip coverage of about 1.2 %. Additional consideration of discarding by a fishery in a given area was limited to areas where 15 or more observer trips occurred, and observer coverage (ratio of observer trips to VTR trips in that area) was greater than 1% (these areas are highlighted in Table 11).

Tows associated with fishery/discard species/area combinations highlighted in step 5 were mapped in order to determine the extent to which discarding occurs outside of time/area restrictions imposed by the current GRAs. The species of concern with the most available data include butterfish and red hake. Examination of these data maps suggest that high discards of butterfish in the *Loligo*, whiting and butterfish fisheries occur northeast of (in Statistical Areas 537 and 616) and in Statistical Areas 616 and 622, along the eastern edge of the southern GRA (Figures 9 and 10). The majority of the observed butterfish discards, in terms of weight, occur from January through April (Figures 11 and 12). Large quantities of red hake discards also occur east of the northern GRA (in Statistical Area 537) and appear to be concentrated in the first quarter (Figure 13). It should be noted that the discard maps reflect the implementation of a management measure that prohibited small-mesh (< 4.5 in. codend mesh) fishing in two areas (scup Northern and Southern Gear Restricted Areas or GRAs) during 2001-2004.

While the characterization of “directed” trip based on the greater than 50% threshold by weight kept is a reasonable approximation of a directed trip, defining directed trips for butterfish based on the criteria of greater than 500 pounds is problematic. For example, from 1996-2003 there were 26 directed butterfish trips (> 500 pounds of butterfish kept) observed during January through April in statistical areas 616 and 537. A closer inspection of the composition of landings by species for those 26 trips indicated that on only three of those trips did butterfish rank as the highest species kept by weight (Table 12). In fact, most of those trips would be characterized as directed whiting (n=9) or directed *Loligo* (n=8) trips or mixed trips for both species (n=4). There were 19 of those "directed" butterfish trips which also discarded red hake.

Characterization of Discards by mesh size

In addition to characterizing discards by target species, discards of butterfish were characterized by codend mesh size and season. Codend and liner mesh sizes are measured (mm) with calipers by trained NEFSC fishery observers. The mesh size data used in the following analysis represents the inside stretched mesh measurements of either the codend, or if used, the liner. A detailed description of the Observer Program data collection methodologies can be found at: http://www.nefsc.noaa.gov/femad/fishsamp/fsb/.

Butterfish discards (lbs) for all observed otter trawl tows with codend mesh sizes less than 3.0 inches (76 mm) were extracted from the NEFSC Observer Database for the time periods of Jan.-April and Sept.-Dec, 1996-2003. A codend mesh size of 3.0 in. was selected because 50% of the reproductively mature female butterfish (≥ 12 cm or 4.7 in. fork length) will escape through a codend of this mesh size based data from on a butterfish selectivity study conducted by Meyer and Merriner (1976) and the additional mesh constriction that occurs with the use of diamond mesh codends in squid trawls. A second data set which included the same two time periods was also extracted for observed otter trawl tows with codend mesh sizes of less than 3.75 inches (95 mm). Discards were then summed by quarter-degree square (QDSQ), for each of the mesh size/time periods. The objective was to determine which quarter-degree squares comprised a majority of the butterfish discards during 1996-2003. It should be noted that the resultant maps reflect the implementation of a management measure that prohibited small-mesh (< 4.5 in. codend mesh) fishing in two areas (scup Northern and Southern Gear Restricted Areas or GRAs) during 2001-2004.

The maps showing the distribution of butterfish discards from the NEFSC Observer Database, by QDSQ, are very similar for the period Jan.-April (1996-2003) regardless of whether 3.0-inch (Figure 14) or 3.75-inch (Figure 15) codend mesh sizes were included in the analysis. The quarter-degree squares associated with the highest two discard categories, which comprised 83-84% of the total butterfish discards that were mapped, are the same for both mesh size ranges. During January through April, the greatest amount of butterfish discarding occurred in the QDSQs surrounding Hudson Canyon and to the northeast. These areas with the highest concentrations of butterfish discards mapped by mesh size (Figure 14) are similar to the subset of butterfish discards mapped for the directed *Loligo* and butterfish fisheries during the same time period (Figures 11 and 12).

Maps of butterfish discards that are based on data from the Observer Database represent a subsample of the total butterfish discards because not all vessels in the small-mesh fleet are sampled. As a result, the distribution of total effort (days fished) reported in the Vessel Trip Report Database, by otter trawlers fishing with 3.75-inch codend mesh during 1997-2003 (Jan.-April), was mapped to define the fishing grounds. The co-occurrence of butterfish and *Loligo* squid (number of butterfish per tow divided by the total number of *Loligo* and butterfish per tow, expressed as a percentage) was computed for stations sampled in NEFSC research vessel bottom trawl surveys, for winter (Feb.) and spring (March) combined during 1992-2003. The co-occurrence data points from the two surveys were overlain on the map of the small-mesh fishing grounds (days fished by QDSQ) for the period of Jan.-April. to determine whether areas outside those sampled by the Observer Program were fished heavily and to determine the spatial extent of butterfish and *Loligo* co-occurrence. A similar fishing effort map was produced for the period Sept.-Dec. (1997-2003) with a co-occurrence point overlay of the Sept.-Oct. bottom trawl survey stations (1992-2003).

Butterfish and *Loligo* co-occur across a smaller area, along the shelf edge, during the winter and spring (Figure 16) than during autumn (Figure 17). This aggregated distribution pattern lends itself more readily to the implementation of a small-mesh gear restriction area during the period January through April. The small-scale ranges of the two species indicate a high degree of spatial overlap near the shelf edge in winter and spring and suggest that the degree of co-occurrence varies in space during this time. Figure 16 indicates that areas with the highest amount of effort (highest two effort categories) occur across a broader expanse than indicated by the discard data mapped from the Observer Database. Specifically, in addition to the squares containing the highest amounts of butterfish discards, there is a high amount of effort and high incidence of butterfish and *Loligo* co-occurrence in QDSQ 40702. Thus, this square should also be considered along with the squares comprising the two highest butterfish discard categories (discards > 11,500 lbs) as potential butterfish Gear Restriction Areas during Jan.-April. The single southernmost square in this high-discard category straddles the existing Southern Gear Restriction Area for scup. A comparison of the fishing effort/co-occurrence map (Figure 16) with the discard map (Figure 15) indicates that observer sampling coverage of the small-mesh fishery during Jan.-April of 1996-2003 is spatially representative of the fishing effort during this time period and that areas with the highest amount of butterfish discarding are associated with areas where the small-mesh fishing effort is highest.

During Sept.-Dec., the distribution of stations with *Loligo* and butterfish co-occurrence is more dispersed, with high areas of concentration along the shelf edge as well as along the shoreline between Long Island and Cape Hatteras, North Carolina (Figure 17). Co-occurrence is also quite prevalent throughout Georges Bank. A comparison of the fishing effort/co-occurrence map (Figure 17) with the butterfish discard map (Figure 18) indicates low butterfish discard levels in the areas of high fishing effort (Southern New England) and visa versa. This discard pattern is in contradiction to the pattern observed for similar maps from the Jan.-April period where high fishing effort resulted in high levels of butterfish discards. The fact that there is a high level of co-occurrence between the two species within the area of high fishing effort (Figure 17) suggests that the low discard levels are likely a result of low observer sampling coverage in Southern New England during Sept.-Dec. of 1997-2003 (Figure 18). Large numbers of juvenile butterfish occur inshore during the autumn surveys and this may result in low discard levels in terms of weight. However, butterfish discard levels in terms of numbers should also be evaluated in such situations.

Table 1. Discard (lbs) and kept (lbs) portions of Atlantic mackerel catches from the Atlantic mackerel fishery and all other fisheries in the NEFSC Observer Program database, 1989-2003).

	Mackerel Fishery		Total	All other fisheries		Total	Grand Total
YEAR	Discards	Kept		Discards	Kept		
1989				2,697	10,287	12,984	12,984
1990	268,377	546,000	814,377	7,233	14,640	21,873	836,250
1991	35,691	483,055	518,746	14,019	5,470	19,489	538,235
1992	3,901	113,282	117,183	13,632	13,033	26,665	143,848
1993	19,073	64,240	83,313	23,547	12,647	36,194	119,507
1994	4,603	190,145	194,748	18,078	2,382	20,460	215,208
1995				797	776	1,573	1,573
1996	62,354	297,480	359,834	9,053	4,698	13,751	373,585
1997	17	173,310	173,327	3,068	2,913	5,981	179,308
1998				668	774	1,442	1,442
1999	38,727	942,383	981,110	7,103	7,636	14,739	995,849
2000	11,050	1,063,510	1,074,560	11,628	20	11,648	1,086,208
2001	45	2,359,000	2,359,045	19,551	1,555	21,106	2,380,151
2002		1,096,955	1,096,955	4,075	247	4,322	1,101,277
2003				5,501	2,852	8,353	8,353
Grand Total	443,838	7,329,360	7,773,198	140,650	79,931	220,581	7,993,778

	Mackerel Fishery		Mack Total	All other fisheries		Other Total
YEAR	Discards	Kept		Discards	Kept	
1989			-	20.77%	79.23%	100.00%
1990	32.95%	67.05%	100.00%	33.07%	66.93%	100.00%
1991	6.88%	93.12%	100.00%	71.93%	28.07%	100.00%
1992	3.33%	96.67%	100.00%	51.12%	48.88%	100.00%
1993	22.89%	77.11%	100.00%	65.06%	34.94%	100.00%
1994	2.36%	97.64%	100.00%	88.36%	11.64%	100.00%
1995				50.67%	49.33%	100.00%
1996	17.33%	82.67%	100.00%	65.83%	34.17%	100.00%
1997	0.01%	99.99%	100.00%	51.30%	48.70%	100.00%
1998				46.31%	53.69%	100.00%
1999	3.95%	96.05%	100.00%	48.19%	51.81%	100.00%
2000	1.03%	98.97%	100.00%	99.83%	0.17%	100.00%
2001	0.00%	100.00%	100.00%	92.63%	7.37%	100.00%
2002	0.00%	100.00%	100.00%	94.29%	5.71%	100.00%
2003				65.85%	34.15%	100.00%
Grand Total	5.71%	94.29%	100.00%	63.76%	36.24%	100.00%
Relative Discards	5.6%			1.8%		

Table 2. Summary of *Illex* discards (mt), by year and fishery, estimated from data collected by observers from the NEFSC Observer Program during 1995-2004.

	Percentage of landings sampled for *Illex* discards										
	Illex Fishery		*Loligo* Fishery		***Illex* Discards (mt)**						
Year	*Illex* Landings (May-Oct, mt)	%	*Loligo* Landings (Nov-April, mt)	%	*Illex* Fishery	%	*Loligo* Fishery	%	Total	**Total *Illex* Landings (mt)**	***Illex* Discards (% of *Illex* landings)**
1995	13,494	0.01%	6,702	0.07%	64	98	1	2	65	14,058	0.5%
1996	15,563	5.36%	7,070	0.38%	82	23	280	77	362	16,969	2.1%
1997	12,709	8.79%	6,484	0.69%	56	34	107	66	163	13,629	1.2%
1998	23,091	0.67%	12,755	1.38%	150	33	303	67	453	23,597	1.9%
1999	7,115	1.28%	7,811	1.59%	58	22	207	78	265	7,388	3.6%
2000	8,901	4.54%	5,810	2.25%	29	40	43	60	72	9,011	0.8%
2001	3,452	0.00%	7,506	2.01%	No data		177		177	4,009	4.4%
2002	2,342	0.00%	6,107	0.98%	No data		53		53	2,750	2.0%
2003	5,887	21.22%	8,804	0.47%	6	2	344	98	350	6,389	5.5%
2004	26,011	4.47%	10,350	6.27%	344	22	1,222	78	1,566	26,087	6.0%

Table 3. Discard rate (weight longfin squid discarded / weight target species landed) and discard estimates (mt) for longfin squid in trips targeting key species during 1997-2000. Landings data for *Loligo* includes prorated unspecified squid. Landings data for herring includes "Herring NK" (herring species not known). No adjustments were made to landings data for any other species. Landings data from the commercial fisheries database (CFDETS1997-CFDETS2000). Discard rate estimates from NMFS observer data during 1997 to mid-2000 and Rutgers University personnel aboard 13 trips targeting black sea bass and scup. All available discard data were used.

Year	Black Sea Bass	Butterfish	Herring	*Loligo*	Mackerel	Scup	Hake	Total
Landings								
1997	1,203	2,798	97,055	16,308	9,539	1,659	15,534	144,097
1998	1,184	4,967	82,597	19,151	11,599	1,179	14,691	132,368
1999	1,337	2,112	79,652	19,386	8,774	1,056	13,443	125,760
2000	1,213	1,435	75,605	17,034	4,475	742	12,145	112,649
Average Landings	1,234	2,078	83,727	17,970	8,597	1,159	13,593	128,719
Observer Trips	5	3	0	111	15	18	32	184
Observer Tows	16	21	0	1,115	97	78	147	1474
Discard Rate	0	0.0095	0.0004	0.0277	0.0004	0.0125	0.0018	0.0046
Average Discards(MT)	0	20	34	498	4	14	25	596

Table 4. Discard ratios (retransformed), otter trawl landings (tonnes), discard by otter trawls (tonnes) for half year and landings category (<600, >600), and total otter trawl discards (tonnes) during 1989-2002.

Year	Half	D ratio		Landings		Discard		Total Discard
		600	>600	600	>600	600	>600	
1989	1	2.531	0.989	63.9	1097.9	161.7	1086.5	4441.9
	2	4.347	1.593	97.0	1740.0	421.7	2772.0	
1990	1	2.681	1.240	86.8	978.4	232.7	1213.5	3019.7
	2	3.621	1.479	98.6	822.7	357.0	1216.5	
1991	1	3.795	1.232	72.6	1092.3	275.5	1345.5	3451.5
	2	4.607	1.806	87.3	790.7	402.2	1428.2	
1992	1	3.142	2.025	70.2	1692.2	220.6	3427.0	5697.9
	2	2.298	2.497	93.3	735.3	214.4	1835.8	
1993	1	2.794	1.441	83.0	824.1	231.9	1187.9	8477.8
	2	3.222	2.012	95.1	3356.3	306.4	6751.6	
1994	1	0.472	0.472	102.6	2082.2	48.4	982.2	3700.7
	2	2.703	2.083	107.2	1142.9	289.7	2380.4	
1995	1	39.942	1.753	119.8	1065.0	4785.0	1867.1	8599.1
	2	2.794	2.794	182.2	514.7	509.0	1438.0	
1996	1	2.511	2.208	167.2	2222.7	419.8	4908.5	6822.8
	2	3.403	1.205	198.0	681.2	673.9	820.7	
1997	1	1.815	1.504	172.5	1435.2	313.0	2158.7	3852.2
	2	2.221	1.405	227.1	623.5	504.4	876.0	
1998	1	1.939	1.724	179.6	1140.9	348.2	1966.9	3274.4
	2	3.548	1.182	176.5	281.8	626.2	333.0	
1999	1	3.049	2.091	190.1	1023.2	579.5	2139.2	4115.4
	2	3.637	1.512	154.2	552.7	560.8	835.9	
2000	1	3.037	1.927	131.6	227.3	399.6	437.9	2427.0
	2	1.660	1.807	151.5	740.4	251.5	1337.9	
2001	1	2.132	1.734	156.1	3562.8	332.9	6179.4	7261.7
	2	1.418	1.418	147.6	380.8	209.3	540.1	
2002	1	4.240	1.885	123.8	371.3	525.0	699.8	1809.2
	2	2.924	1.765	114.6	141.3	335.1	249.3	

Table 5. Landings by species by gear type based on 1994-2003 NMFS dealer data.

Butterfish landings by gear (dealer weighout data 1994-2003 combined).

Gear	Lbs	Pct of total
TRAWL,OTTER,BOTTOM,FISH	47,806,485	94%
POUND NET, FISH	1,091,542	2%
GILL NET,SINK, OTHER	564,639	1%

Mackerel landings by gear (dealer weighout data 1994-2003 combined).

Gear	Lbs	Pct of total
TRAWL,OTTER,BOTTOM,FISH	178,836,927	54%
TRAWL,OTTER,MIDWATER	87,122,385	26%
TRAWL,OTTER,MIDWATER PAI	52,518,464	16%
POUND NET, OTHER	3,490,433	1%
FLOATING TRAP	3,340,383	1%

Loligo landings by gear (dealer weighout data 1994-2003 combined).

Gear	Lbs	Pct of total
TRAWL,OTTER	352,043,789	98%

Illex landings by gear (dealer weighout data 1994-2003 combined).

Gear	Lbs	Pct of total
TRAWL,OTTER,BOTTOM,FISH	241,713,571	97%
TRAWL,OTTER,MIDWATER	2,859,955	1.2%

Table 6. Summary of discards, by species and directed fishery, based on NEFSC Observer Program data, 1989-2003. Pct Disc (Overall) represents the discard weight of a species divided by the total discard weight of all species in the directed fishery expressed as a percentage. Pct Disc (Sp) represents the percentage of the catch, by species, which is discarded in the directed fishery.

Butterfish (N = 134 observed directed trips)

	Catch Disposition					
SPECIES	Disc	Kept	Grand Total	Pct Disc (Overall)	Pct Disc (Sp)	D:K Ratio
BUTTERFISH	629,167	737,372	1,366,539	22%	46%	0.853
HAKE, SILVER	436,587	752,314	1,188,901	15%	37%	0.580
HAKE, RED	397,293	62,030	459,323	14%	86%	6.405
SKATES	246,261	23,740	270,001	9%	91%	10.373
DOGFISH SPINY	227,413	4,998	232,411	8%	98%	45.501
SCUP	196,752	176,834	373,585	7%	53%	1.113
SQUID (LOLIGO)	112,042	1,530,191	1,642,233	4%	7%	0.073
MACKEREL, ATLANTIC	99,637	758,201	857,838	3%	12%	0.131
FLOUNDER, FOURSPOT	98,131	569	98,700	3%	99%	172.462
SKATE, LITTLE	78,557	16,114	94,671	3%	83%	4.875
SQUID (ILLEX)	50,728	1,074,339	1,125,067	2%	5%	0.047

Illex (N = 67 observed directed trips)

	Catch Disposition					
SPECIES	Disc	Kept	Grand Total	Pct Disc (Overall)	Pct Disc (Sp)	D:K Ratio
SQUID (ILLEX)	124,503	10,436,005	10,560,508	39%	1%	0.012
BUTTERFISH	59,447	75,335	134,782	19%	44%	0.789
MACKEREL, CHUB	53,481	10,127	63,608	17%	84%	5.281
MACKEREL, ATLANTIC	50,024	69	50,093	16%	100%	724.986
HAKE, SILVER	11,611	286	11,897	4%	98%	40.626
JOHN DORY	9,338	4,039	13,378	3%	70%	2.312

Loligo (N = 311 observed directed trips)

	Catch Disposition					
SPECIES	Disc	Kept	Grand Total	Pct Disc (Overall)	Pct Disc (Sp)	D:K Ratio
BUTTERFISH	567,206	100,494	667,700	26%	85%	5.644
HAKE, SILVER	347,550	216,419	563,969	16%	62%	1.606
SCUP	301,608	107,397	409,005	14%	74%	2.808
SKATES	123,977	2,375	126,352	6%	98%	52.201
HAKE, RED	111,925	5,367	117,292	5%	95%	20.854
SQUID (LOLIGO)	99,365	3,563,824	3,663,189	5%	3%	0.028
SKATE, LITTLE	85,230	15,704	100,934	4%	84%	5.427
DOGFISH SPINY	82,034	4,611	86,645	4%	95%	17.791
SEA ROBINS	68,757	391	69,148	3%	99%	175.849
FLOUNDER, FOURSPOT	47,948	429	48,377	2%	99%	111.767
SQUID (ILLEX)	44,269	30,352	74,621	2%	59%	1.459
MACKEREL, ATLANTIC	40,390	25,808	66,198	2%	61%	1.565

Mackerel (N = 40 observed directed trips)

	Catch Disposition					
SPECIES	Disc	Kept	Grand Total	Pct Disc (Overall)	Pct Disc (Sp)	D:K Ratio
MACKEREL, ATLANTIC	288,698	3,312,600	3,601,298	43%	8%	0.087
DOGFISH SPINY	76,560	8,885	85,445	11%	90%	8.616
HERRING, ATLANTIC	65,695	489,195	554,890	10%	12%	0.134
SCUP	62,153	27,375	89,528	9%	69%	2.270
HAKE, RED	45,131	4,771	49,902	7%	90%	9.459
HERRING, BLUE BACK	32,048	13,903	45,951	5%	70%	2.305
BUTTERFISH	31,578	41,037	72,616	5%	43%	0.769
HAKE, SILVER	29,756	58,757	88,513	4%	34%	0.506
SEA BASS, BLACK	11,409	7,854	19,263	2%	59%	1.453

Table 7. Ratio of species discards from directed *Loligo* trips to discards from all trips by year. Based on NEFSC Observer Program data, 1989-2003. Highlighted cells indicate ratios exceeding 10% and species names are outlined in cases where discard ratios exceeded 10% for more than three of the last eight years.

DISCARD SPECIES	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
BUTTERFISH	0.42	0.33	0.35	0.60	0.13	0.41	0.33	0.25	0.14	0.24	0.59	0.72	0.44	0.88	0.92
DOGFISH SPINY	0.16	0.01	0.05	0.04	0.01	0.04	0.02	0.11	0.06	0.30	0.08	0.10	0.29	0.09	0.03
FLOUNDER, FOURSPOT	0.19	0.04	0.27	0.19	0.03	0.06	0.10	0.06	0.05	0.71	0.29	0.66	0.06	0.42	0.18
HAKE, RED	0.09	0.05	0.03	0.06	0.00	0.02	0.01	0.13	0.21	0.46	0.15	0.90	0.19	0.12	0.03
HAKE, SILVER	0.05	0.05	0.19	0.18	0.00	0.15	0.02	0.08	0.68	0.31	0.51	0.89	0.56	0.12	0.30
HERRING, ATLANTIC	0.01	0.01	0.00	0.03	0.11	0.01	0.00	0.03	0.16	0.37	0.01	0.01	0.03	0.02	0.05
HERRING, BLUE BACK	0.46	0.03	0.07	0.10	0.03	0.00	0.02	0.02	0.00	0.42	0.84	0.39	0.12	0.04	0.21
JOHN DORY	0.60		0.02	0.96	0.00	0.11	0.00	0.02	0.05	0.99	0.92	0.19	0.90	1.00	0.07
MACKEREL, ATLANTIC	0.04	0.00	0.00	0.07	0.18	0.17	0.23	0.02	0.66	0.60	0.09	0.51	0.04	0.93	0.38
MACKEREL, CHUB			0.00					0.00	0.00	0.00		0.00	0.65		0.00
SCUP	0.21	0.43	0.33	0.39	0.07	0.07	0.59	0.11	0.11	0.98	0.02	0.73	0.01	0.12	0.04
SEA BASS, BLACK	0.37	0.22	0.30	0.52	0.89	0.06	0.02	0.16	0.13	0.73	0.01	0.13	0.45	0.11	0.36
SEA ROBINS	0.41	0.13	0.39	0.25	0.29	0.03	0.03	0.22	0.00	0.00	0.14	0.39	0.70	0.94	0.08
SKATE, LITTLE			1.00			0.00	0.03	0.01	0.07	0.02	0.03	0.01	0.01	0.02	0.00
SKATES	0.08	0.01	0.06	0.02	0.00	0.01	0.00	0.00	0.04	0.00	0.14	0.01	0.03	0.00	0.00
SQUID (ILLEX)	0.02	0.00	0.00	0.11	0.17	0.63	0.04	0.02	0.12	0.73	0.56	0.53	0.12	0.74	0.49
SQUID (LOLIGO)	0.25	0.19	0.34	0.55	0.07	0.04	0.43	0.72	0.33	0.60	0.82	0.76	0.56	0.84	0.86

Table 8. Ratio of species discards from directed *Illex* trips to discards from all trips by year. Based on NEFSC Observer Program data, 1989-2003. Highlighted cells indicate ratios exceeding 10% and species names are outlined in cases where discard ratios exceeded 10% for more than three of the last eight years.

DISCARD SPECIES	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
BUTTERFISH	0.00	0.00	0.10	0.00	0.00	0.00	0.00	0.07	0.02	0.00	0.21	0.01	0.02	0.00	0.00
DOGFISH SPINY	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00
FLOUNDER, FOURSPOT	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00
HAKE, RED	0.00	0.00	0.05	0.00	0.00	0.00	0.00	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00
HAKE, SILVER	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.10	0.00	0.00	0.01	0.04	0.01	0.00	0.00
HERRING, ATLANTIC	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
HERRING, BLUE BACK	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00
JOHN DORY	0.00		0.98	0.00	0.00	0.00	0.00	0.94	0.64	0.01	0.02	0.77	0.08	0.00	0.89
MACKEREL, ATLANTIC	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.84	0.00	0.03
MACKEREL, CHUB			1.00					1.00	1.00	1.00		1.00	0.35		1.00
SCUP	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SEA BASS, BLACK	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SEA ROBINS	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SKATE, LITTLE			0.00			0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SKATES	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SQUID (ILLEX)	0.00	0.00	0.49	0.00	0.00	0.00	0.00	0.69	0.84	0.25	0.17	0.18	0.83	0.00	0.40
SQUID (LOLIGO)	0.00	0.00	0.06	0.00	0.00	0.00	0.00	0.06	0.02	0.00	0.04	0.02	0.00	0.00	0.01

Table 9. Ratio of species discards from directed mackerel trips to discards from all trips by year. Based on NEFSC Observer Program data, 1989-2003. Highlighted cells indicate ratios exceeding 10% and species names are outlined in cases where discard ratios exceeded 10% for more than three of the last eight years.

DISCARD SPECIES	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
BUTTERFISH	0.00	0.07	0.00	0.04	0.02	0.07	0.00	0.39	0.01	0.00	0.03	0.00	0.00	0.00	0.00
DOGFISH SPINY	0.00	0.00	0.07	0.06	0.07	0.01	0.00	0.02	0.01	0.00	0.00	0.05	0.03	0.00	0.00
FLOUNDER, FOURSPOT	0.00	0.00	0.00	0.06	0.25	0.24	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00
HAKE, RED	0.00	0.00	0.02	0.00	0.18	0.26	0.00	0.00	0.01	0.00	0.09	0.00	0.00	0.00	0.00
HAKE, SILVER	0.00	0.00	0.02	0.01	0.07	0.16	0.00	0.19	0.01	0.00	0.01	0.00	0.00	0.00	0.00
HERRING, ATLANTIC	0.00	0.45	0.07	0.42	0.15	0.16	0.00	0.69	0.01	0.00	0.75	0.06	0.00	0.00	0.00
HERRING, BLUE BACK	0.00	0.00	0.09	0.50	0.41	0.24	0.00	0.76	0.54	0.00	0.00	0.38	0.00	0.00	0.00
JOHN DORY	0.00		0.00	0.87	0.01	0.15	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MACKEREL, ATLANTIC	0.00	0.95	0.53	0.22	0.46	0.23	0.00	0.87	0.01	0.00	0.84	0.42	0.00	0.00	0.00
MACKEREL, CHUB			0.00					0.00	0.00	0.00		0.00	0.00		0.00
SCUP	0.00	0.07	0.00	0.47	0.02	0.00	0.00	0.63	0.00	0.00	0.51	0.00	0.02	0.00	0.00
SEA BASS, BLACK	0.00	0.01	0.00	0.31	0.00	0.00	0.00	0.72	0.01	0.00	0.58	0.00	0.02	0.00	0.00
SEA ROBINS	0.00	0.00	0.00	0.08	0.18	0.05	0.00	0.27	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SKATE, LITTLE			0.00			0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SKATES	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SQUID (ILLEX)	0.00	0.02	0.00	0.00	0.03	0.29	0.00	0.08	0.00	0.00	0.03	0.00	0.00	0.00	0.00
SQUID (LOLIGO)	0.00	0.00	0.08	0.19	0.04	0.10	0.00	0.02	0.00	0.00	0.01	0.00	0.00	0.00	0.00

Table 10. Ratio of species discards from directed butterfish trips to discards from all trips by year. Based on NEFSC Observer Program data, 1989-2003. Highlighted cells indicate ratios exceeding 10% and species names are outlined in cases where discard ratios exceeded 10% for more than three of the last eight years.

DISCARD SPECIES	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
BUTTERFISH	0.68	0.45	0.69	0.75	0.75	0.66	0.40	0.60	0.89	0.82	0.15	0.82	0.50	0.46	0.06
DOGFISH SPINY	0.06	0.05	0.22	0.12	0.25	0.21	0.03	0.17	0.21	0.02	0.14	0.10	0.16	0.00	0.00
FLOUNDER, FOURSPOT	0.43	0.34	0.33	0.35	0.36	0.30	0.02	0.15	0.33	0.49	0.15	0.24	0.70	0.33	0.01
HAKE, RED	0.34	0.16	0.18	0.35	0.40	0.26	0.08	0.39	0.39	0.54	0.51	0.56	0.54	0.08	0.00
HAKE, SILVER	0.15	0.12	0.24	0.31	0.60	0.33	0.02	0.35	0.53	0.69	0.44	0.40	0.02	0.06	0.03
HERRING, ATLANTIC	0.15	0.00	0.02	0.07	0.05	0.01	0.02	0.15	0.18	0.74	0.70	0.00	0.42	0.00	0.00
HERRING, BLUE BACK	0.01	0.50	0.00	0.16	0.07	0.24	0.14	0.28	0.00	0.00	0.68	0.00	0.76	0.00	0.00
JOHN DORY	0.77		0.93	0.91	0.84	0.18	0.00	0.22	0.26	0.02	0.02	0.12	0.01	0.00	0.00
MACKEREL, ATLANTIC	0.07	0.00	0.36	0.06	0.28	0.17	0.34	0.32	0.73	0.33	0.84	0.02	0.11	0.79	0.01
MACKEREL, CHUB			0.82					0.51	0.00	0.00		0.00	0.00		0.00
SCUP	0.41	0.71	0.63	0.17	0.22	0.19	0.00	0.51	0.18	0.00	0.91	0.00	0.00	0.00	0.00
SEA BASS, BLACK	0.20	0.20	0.28	0.34	0.08	0.00	0.00	0.39	0.52	0.06	0.70	0.11	0.13	0.00	0.01
SEA ROBINS	0.05	0.12	0.19	0.15	0.13	0.11	0.10	0.34	0.49	0.00	0.02	0.00	0.00	0.00	0.00
SKATE, LITTLE			1.00			0.00	0.00	0.05	0.02	0.02	0.02	0.01	0.02	0.00	0.00
SKATES	0.11	0.01	0.04	0.06	0.25	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00
SQUID (ILLEX)	0.22	0.15	0.39	0.33	0.48	0.72	0.00	0.28	0.09	0.04	0.26	0.66	0.04	0.00	0.06
SQUID (LOLIGO)	0.47	0.24	0.48	0.68	0.80	0.13	0.03	0.55	0.55	0.44	0.62	0.51	0.40	0.02	0.02

Table 11. Summary of sampling coverage by the NEFSC Observer Program, in the *Loligo* and butterfish fisheries by statistical area (Total 1996-2003)

Stat areas with relatively high occurrence of **butterfish** discards in observer data

Butterfish Fishery

Area	% discards	Observer (N_trips)	VTR trips	Pct Coverage
616	22.0%	24	1,190	2.02%
636	19.8%	4	1	400.00%
632	16.9%	4	30	13.33%
537	12.7%	28	2,679	1.05%
613	9.6%	12	928	1.29%
525	5.5%	5	325	1.54%

Loligo Fishery

Area	% discards	Observer (N_trips)	VTR trips	Pct Coverage
616	28.2%	32	2,498	1.28%
636	15.7%	1	15	6.67%
622	14.0%	26	769	3.38%
626	11.9%	9	234	3.85%
525	9.2%	7	336	2.08%
632	7.5%	1	145	0.69%
537	5.7%	24	2,592	0.93%

Stat areas with relatively high occurrence of **dogfish** discards in observer data

Butterfish Fishery

Area	% discards	Observer (N_trips)	VTR trips	Pct Coverage
537	35.6%	25	2,679	0.93%
526	20.9%	3	87	3.45%
613	16.7%	9	928	0.97%
626	7.3%	3	50	6.00%

Loligo Fishery

Area	% discards	Observer (N_trips)	VTR trips	Pct Coverage
626	22.8%	6	2,498	0.24%
526	18.6%	6	15	40.00%
622	16.5%	24	769	3.12%
537	10.3%	17	234	7.26%
616	9.0%	23	336	6.85%
615	7.3%	5	145	3.45%

Stat areas with relatively high occurrence of **red hake** discards in observer data

Butterfish Fishery

Area	% discards	Observer (N_trips)	VTR trips	Pct Coverage
537	50.0%	27	2,679	1.01%
525	19.6%	4	325	1.23%
562	12.3%	2	42	4.76%
613	11.1%	12	928	1.29%

Loligo Fishery

Area	% discards	Observer (N_trips)	VTR trips	Pct Coverage
525	33.0%	4	336	1.19%
562	27.8%	2	81	2.47%
537	21.8%	16	2,592	0.62%
616	9.2%	21	2,498	0.84%

Stat areas with relatively high occurrence of **scup** discards in observer data

Butterfish Fishery

Area	% discards	Observer (N_trips)	VTR trips	Pct Coverage
616	34.8%	15	1,190	1.26%
613	23.1%	8	928	0.86%
622	21.3%	5	137	3.65%
626	12.2%	1	50	2.00%
537	6.2%	11	2,679	0.41%

Loligo Fishery

Area	% discards	Observer (N_trips)	VTR trips	Pct Coverage
623	81.4%	5	29	17.24%
622	10.2%	15	769	1.95%

Stat areas with relatively high occurrence of **silver hake** discards in observer data

Butterfish Fishery

Area	% discards	Observer (N_trips)	VTR trips	Pct Coverage
537	33.4%	24	2,679	0.90%
525	24.6%	4	325	1.23%
562	14.6%	2	42	4.76%
615	14.0%	2	60	3.33%
526	5.9%	5	87	5.75%

Loligo Fishery

Area	% discards	Observer (N_trips)	VTR trips	Pct Coverage
525	32.8%	7	336	2.08%
562	21.9%	3	81	3.70%
537	10.6%	20	2,592	0.77%
615	9.3%	5	277	1.81%
616	8.1%	24	2,498	0.96%
613	5.5%	25	10,739	0.23%
622	5.3%	19	769	2.47%

Stat areas with relatively high occurrence of **Loligo** discards in observer data

Butterfish Fishery

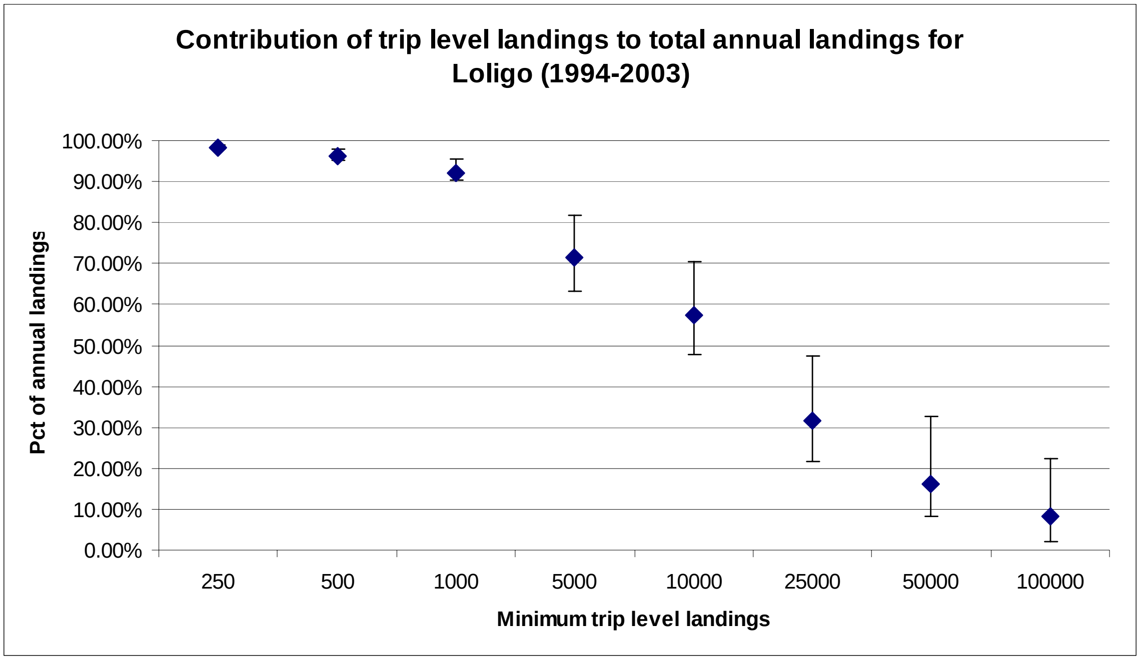
Area	% discards	Observer (N_trips)	VTR trips	Pct Coverage
537	55.1%	25	2,679	0.93%
616	16.3%	14	1,190	1.18%
613	6.2%	9	928	0.97%
526	5.4%	3	87	3.45%

Loligo Fishery

Area	% discards	Observer (N_trips)	VTR trips	Pct Coverage
537	44.9%	22	2,592	0.85%
613	11.7%	35	10,739	0.33%
616	11.2%	16	2,498	0.64%
622	10.4%	4	769	0.52%
525	5.5%	4	336	1.19%

Table 12. Retained catch (lbs) by species for trips identified as directed butterfish trips January - April in Statistical Areas 537, 616 during 1996-2003. The last column indicates total butterfish discards for each trip. Highlighted trips indicate butterfish discards >1,000 lbs. Data source: NEFSC Observer Program database.

	SPECIES										
LINK1	MACKEREL, ATLANTIC	SQUID (LOLIGO)	HAKE, SILVER	BUTTERFISH	FLOUNDER, SUMMER	ANGLER	HAKE, RED	SEA BASS, BLACK	TILEFISH	Butterfish Disc	
199701A24002		5,280	1,724	748	698	233	48	14	223	807	
199701A32001	7	773	1,706	1,105	880	500	1,623	70	376	1,961	
199701A49001		388	561	1,016	655	612	10	68	215	751	
199701A49002	120	2,471	121	8,045	322	1,099		24	811	1,567	
199701A49003	27	589	12,890	3,708	1,057	816	3,663	67		4,699	
199702A24007	6	3,661	238	20,731	44	299	24	27	71	713	
199702A25005		5,826	13,114	2,186	1,752	7,153	30	10	536	1,289	
199702A54005	33	15,289	8,740	12,774	1,061	735	50	1,203	32	30,773	
199703B15011	326	17,940	1,107	693	15	28			5	97	
199704B15015	1,243	26,640	955	1,957	5	51		5		2,549	
199801A25001		770	835	945	4,850	1,513	640	132	28	1,032	
199801B15002		6,830	4,900	740	115	342	540	3	4	54	
199801B16002		23,575		1,108						114	
199802A24005	98	36,508	2,298	3,110	64	790			87	792	
199803A24007	9	11,770	687	848	320	233	138	7	177	1,253	
199804A24008		4,311	6,228	873	1,029	177	733	107	211	15,274	
199901A24002		4,351	10,500	5,395	914	753	2,750	1,416	3	10,675	
199903A24003		37,093	3,068	590	357	60	375	2		4,154	
199904B14021	603,153	1,587		612						1,615	
200001B14002	10	2,160	135	568	275	145			113	9,876	
200101B82001		6,515	11,280	3,492	828	66	350	550	19	9,094	
200101B82004	30	1,645	9,050	1,185	560	127	292	409		2,348	
200101B82005	153	1,460	11,700	1,110	740	230	460	198		1,837	
200102B82006	10	7,460	12,950	790	990	98	2,100	99	44	2,371	
200104B82018	16	1,775	14,540	8,915	500	253	1,110	1,233		16,680	
200304C14012	250	4,940	1,110	989	143	361	25	47	210	5,160	
Grand Total	605,491	231,607	130,437	84,233	18,174	16,673	14,961	5,691	3,165	4,905	Mear butt_disc/trip



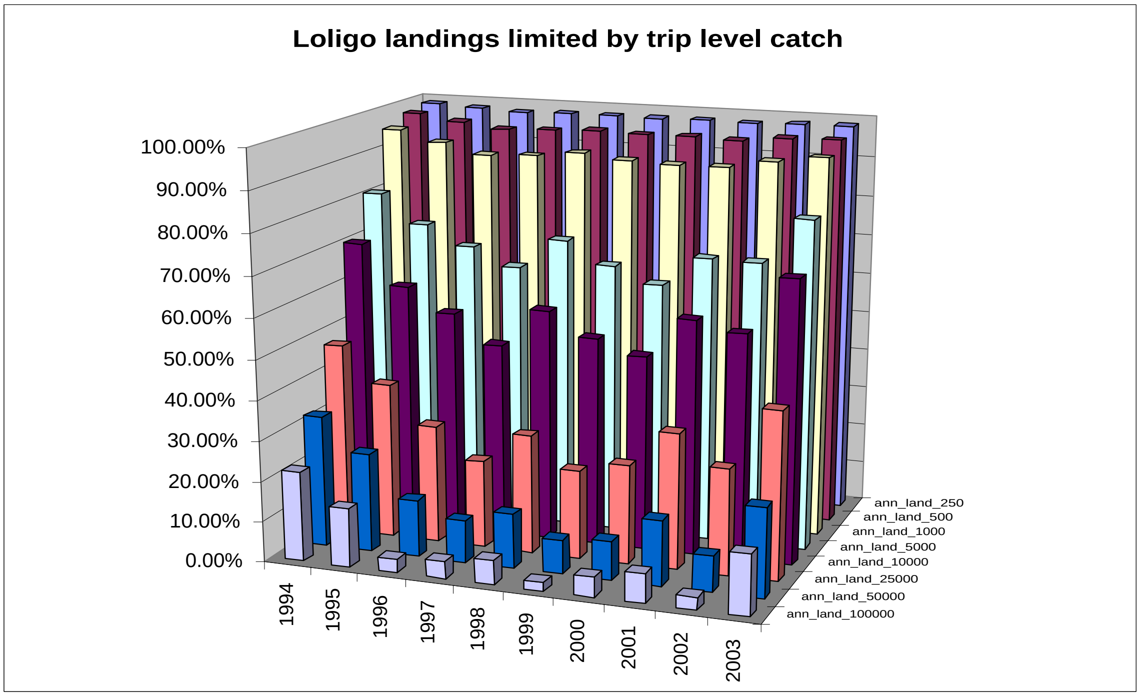
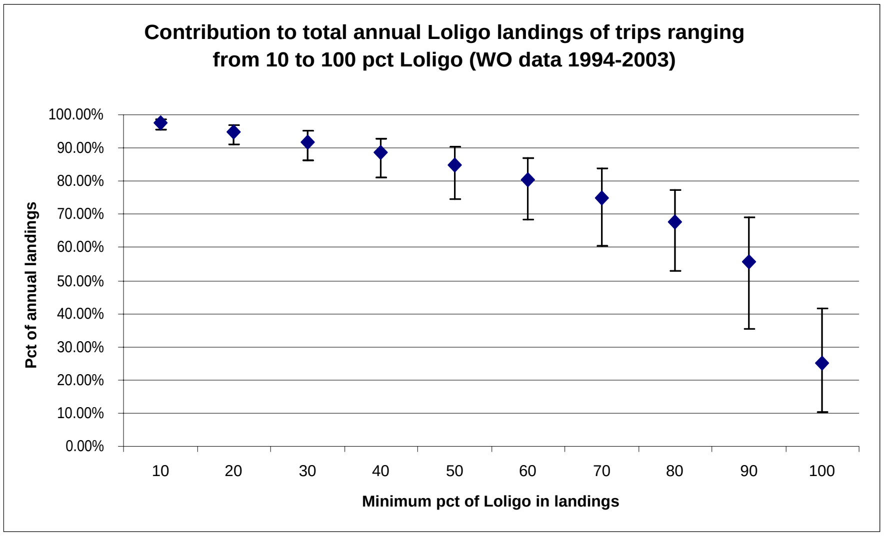


Figure 1. Percent contribution by trip level to total *Loligo* landings for the period 1994-2003 combined (top panel) and by year (lower panel).



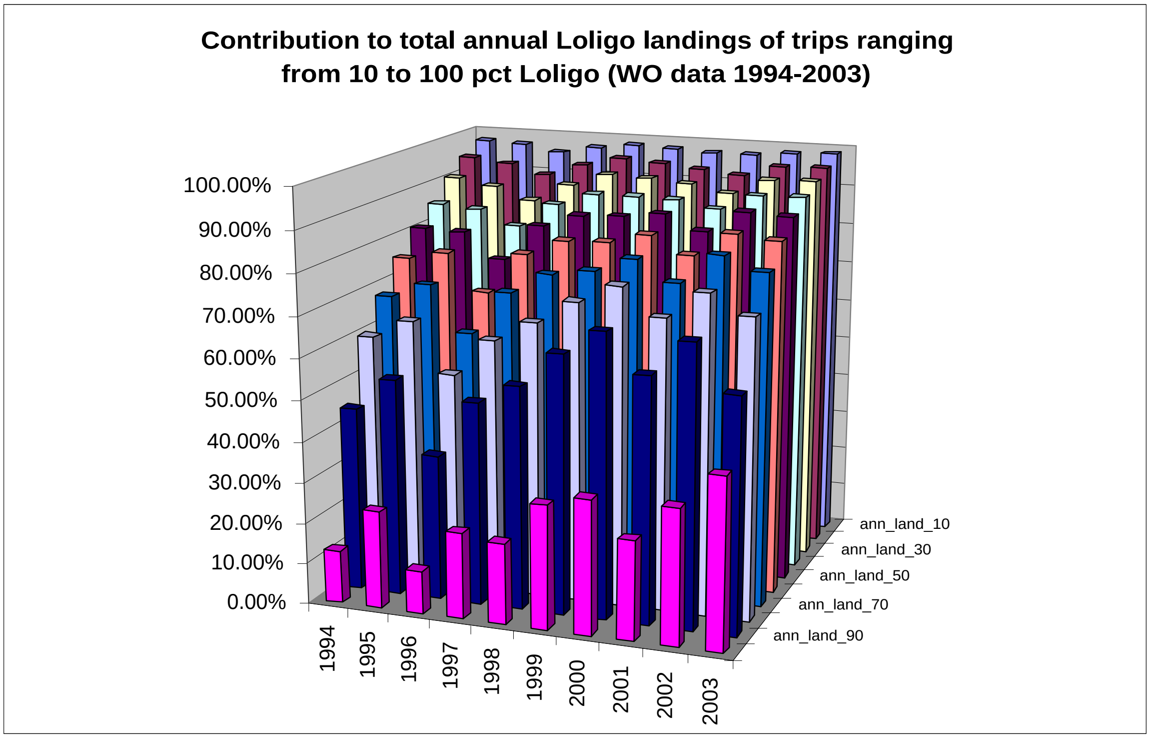
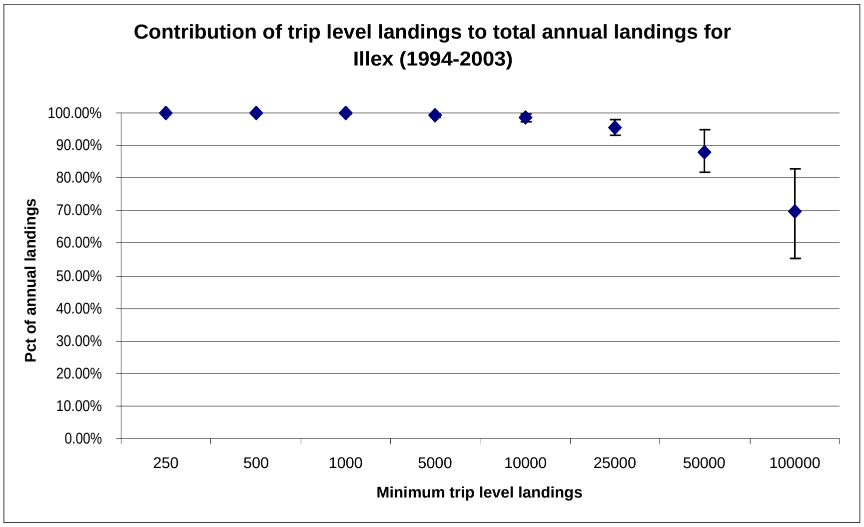


Figure 2. Contribution to total annual *Loligo* landings of trips ranging from 10-100 percent *Loligo* for the period 1994-2003 combined (top panel) and by year (bottom panel).



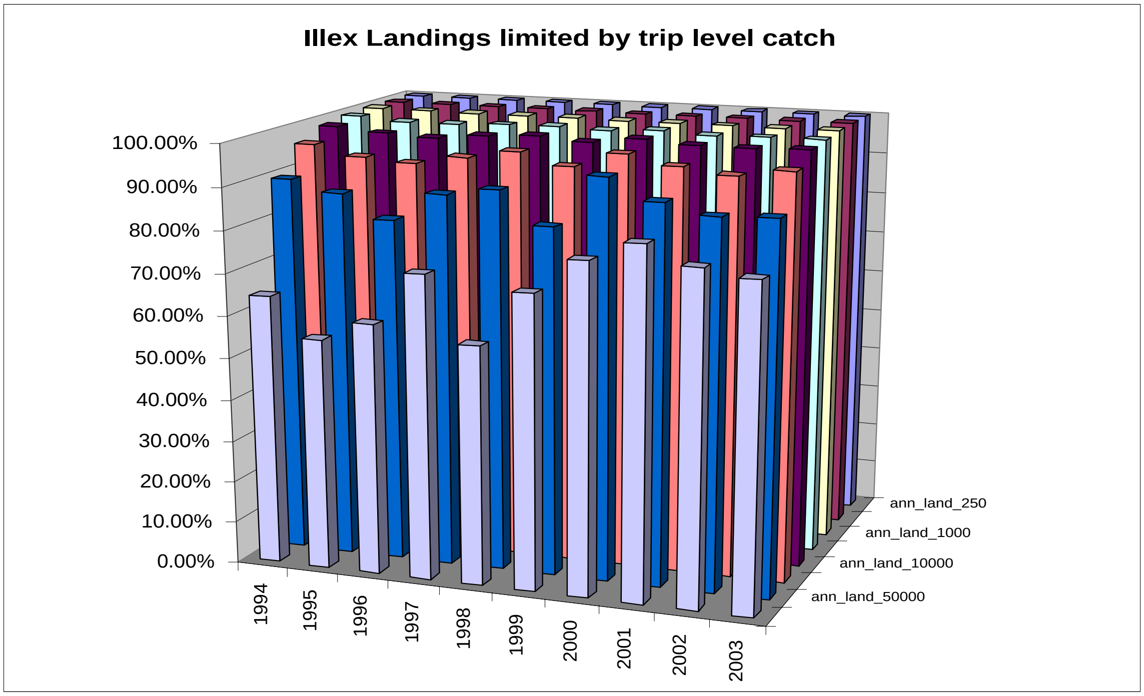
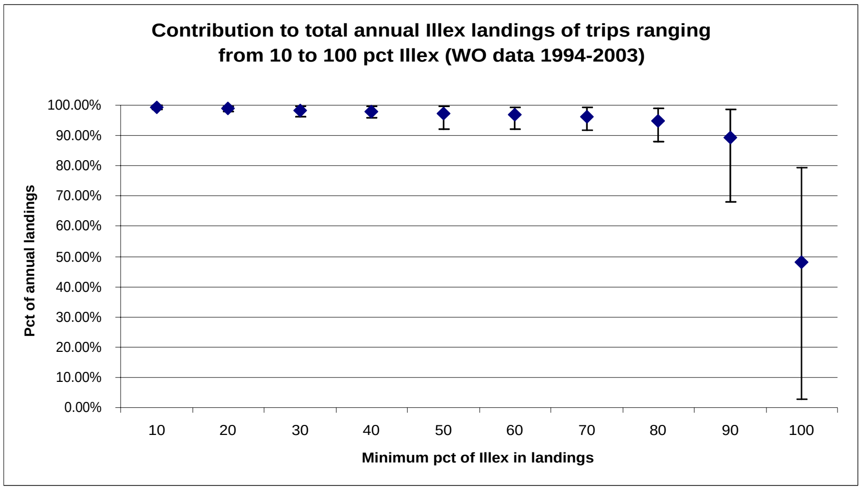


Figure 3. Percent contribution by trip level to total *Illex* landings for the for the period 1994-2003 combined (top panel) and by year (lower panel).



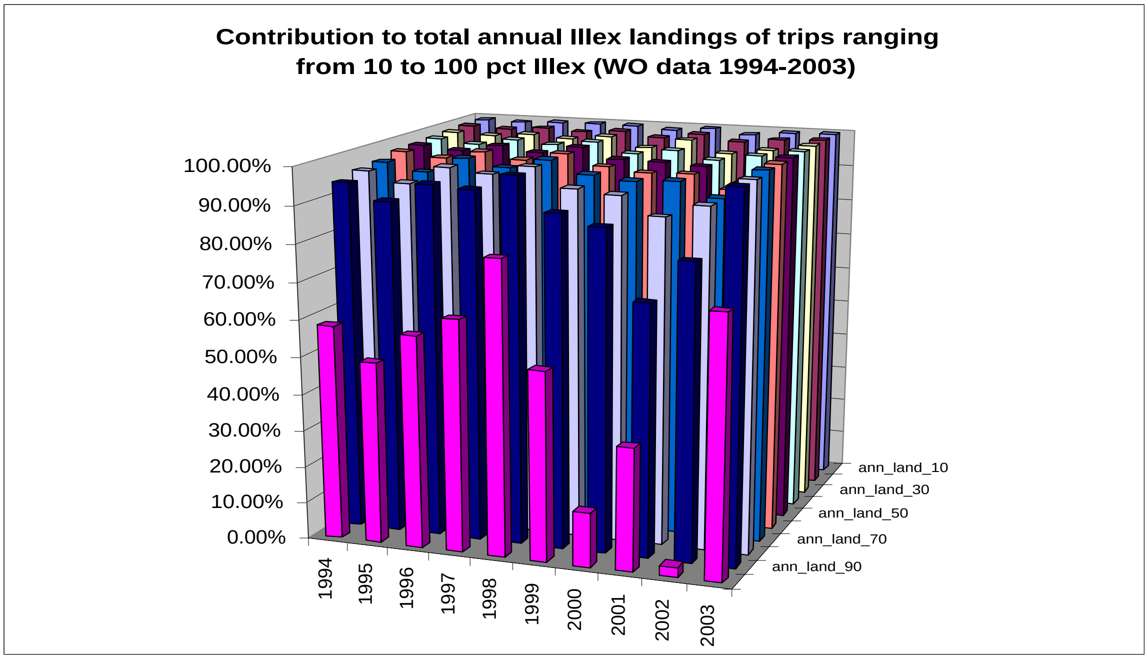
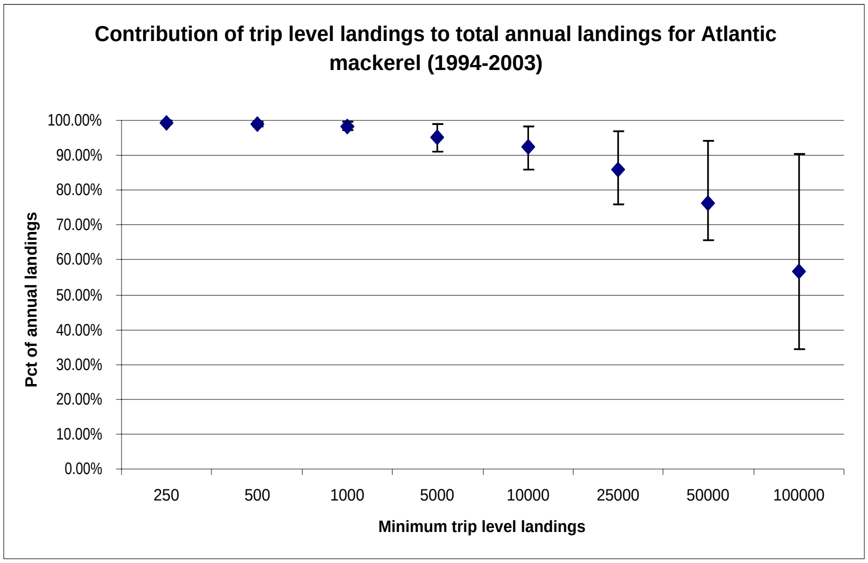


Figure 4. Contribution to total annual *Illex* landings of trips ranging from 10-100 percent *Illex* for the period 1994-2003 combined (top panel) and by year (bottom panel).



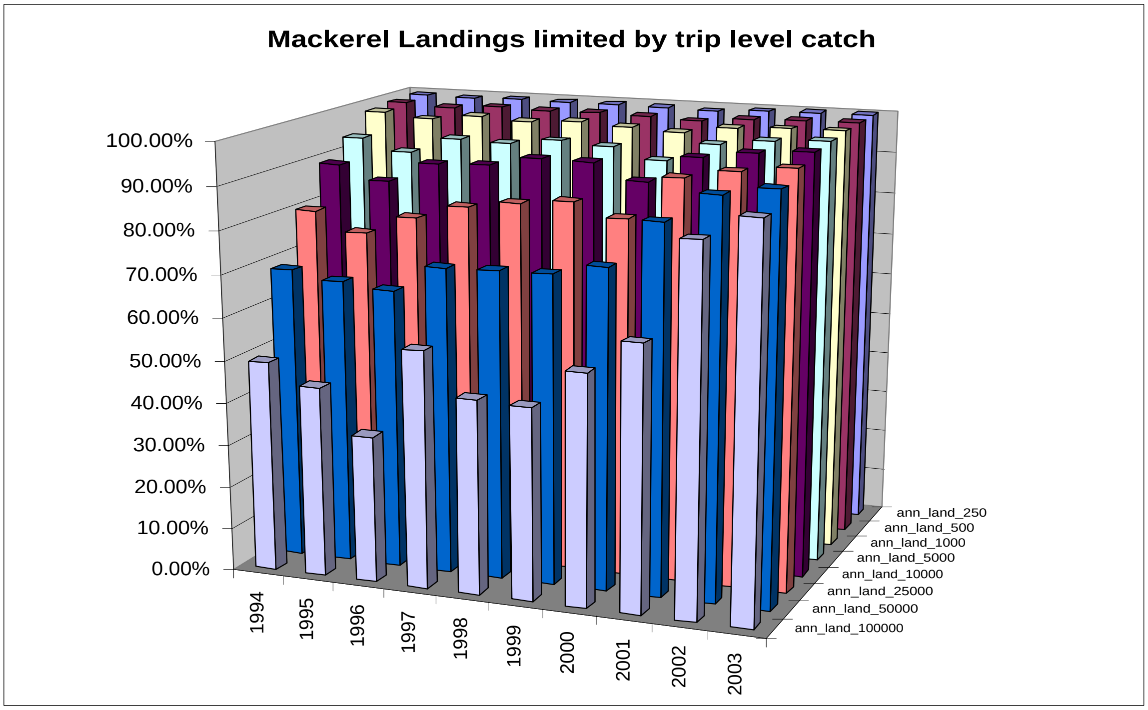
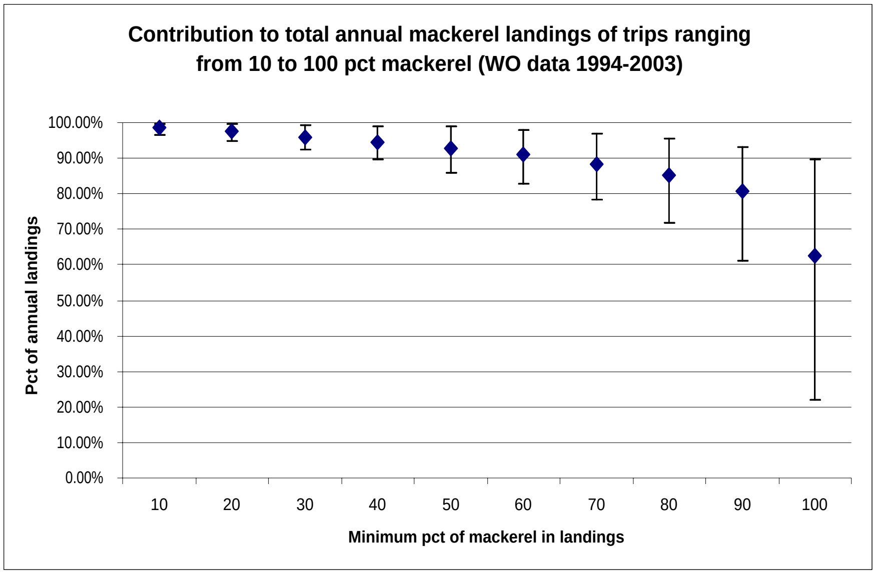


Figure 5. Percent contribution by trip level to total Atlantic mackerel landings for the for the period 1994-2003 combined (top panel) and by year (lower panel).



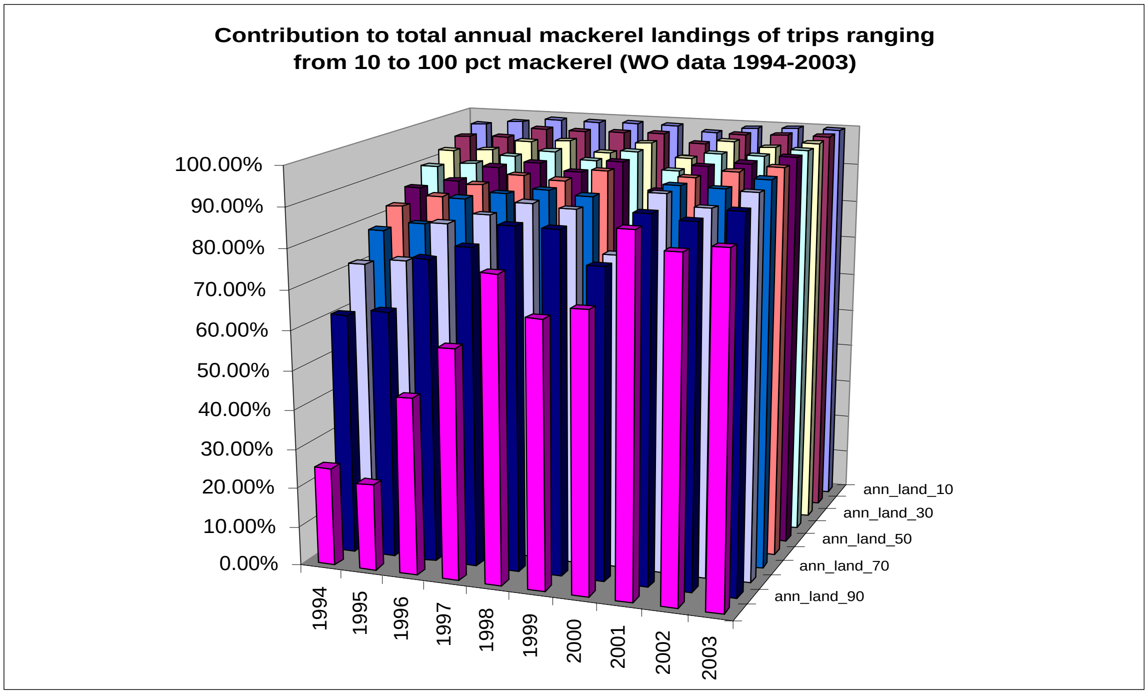
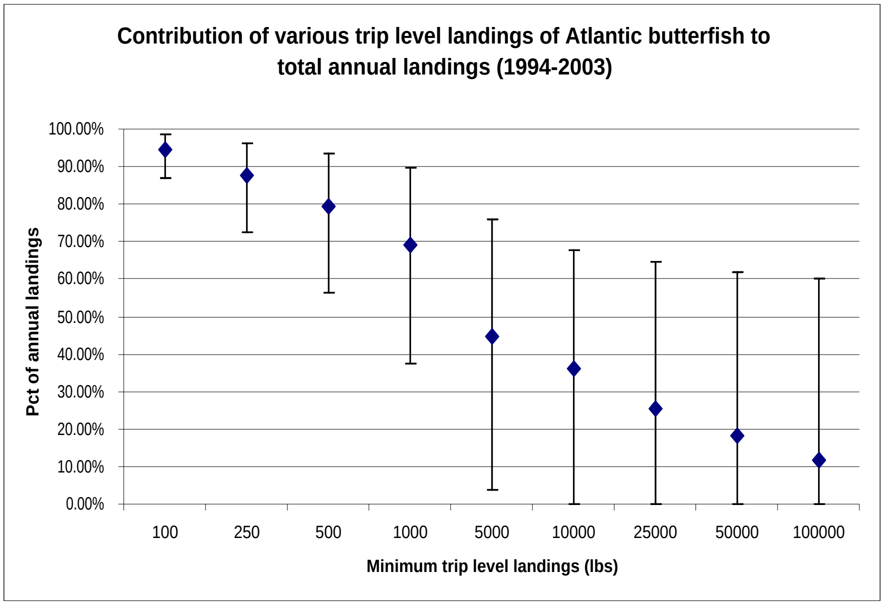


Figure 6. Contribution to total annual Atlantic mackerel landings of trips ranging from 10-100 percent *Loligo* for the period 1994-2003 combined (top panel) and by year (bottom panel).



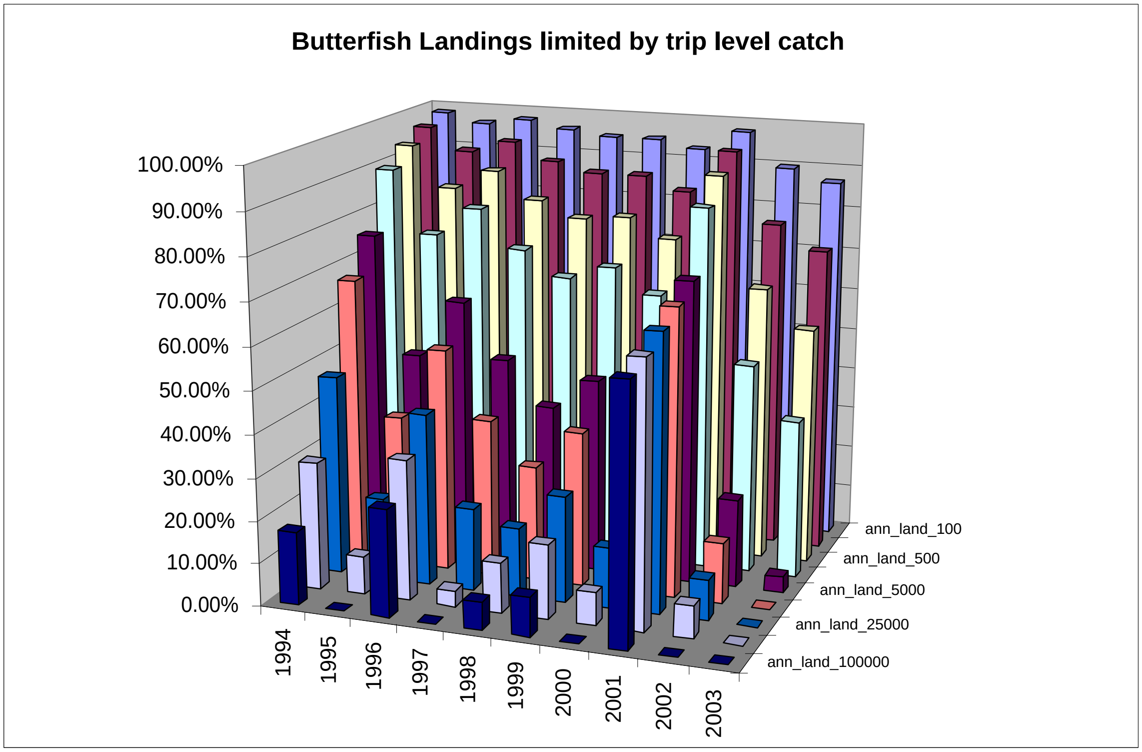
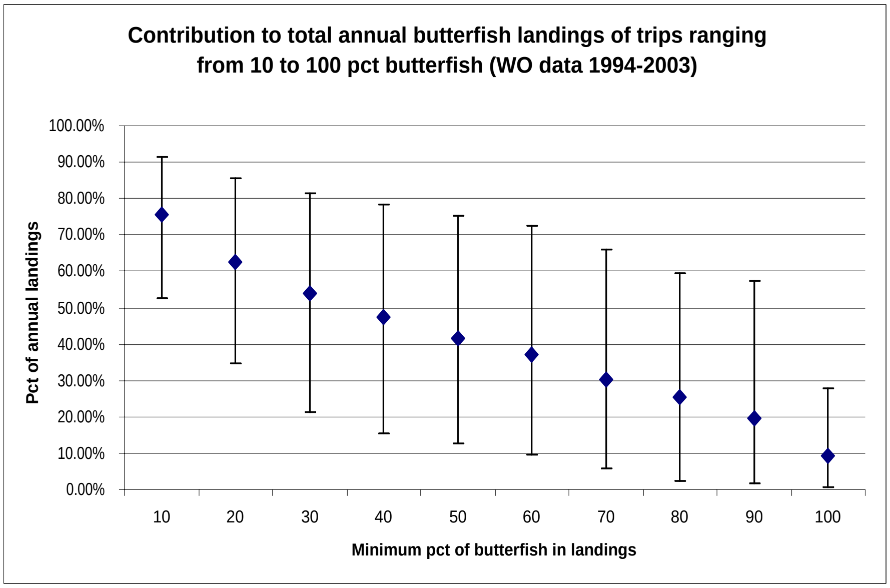


Figure 7. Percent contribution by various trip level to total butterfish landings for the period 1994-2003 combined (top panel) and by year (lower panel).



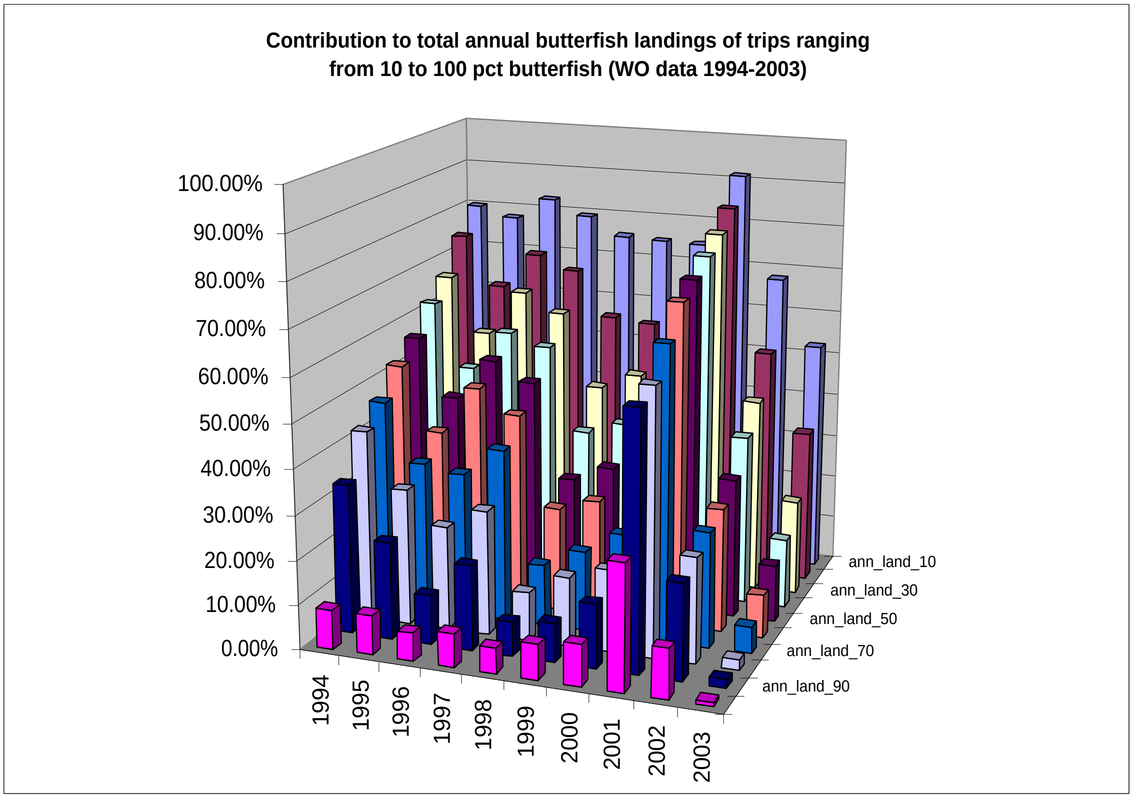


Figure 8. Contribution to total annual butterfish landings of trips ranging from 10-100 percent butterfish for the period 1994-2003 combined (top panel) and by year (bottom panel).

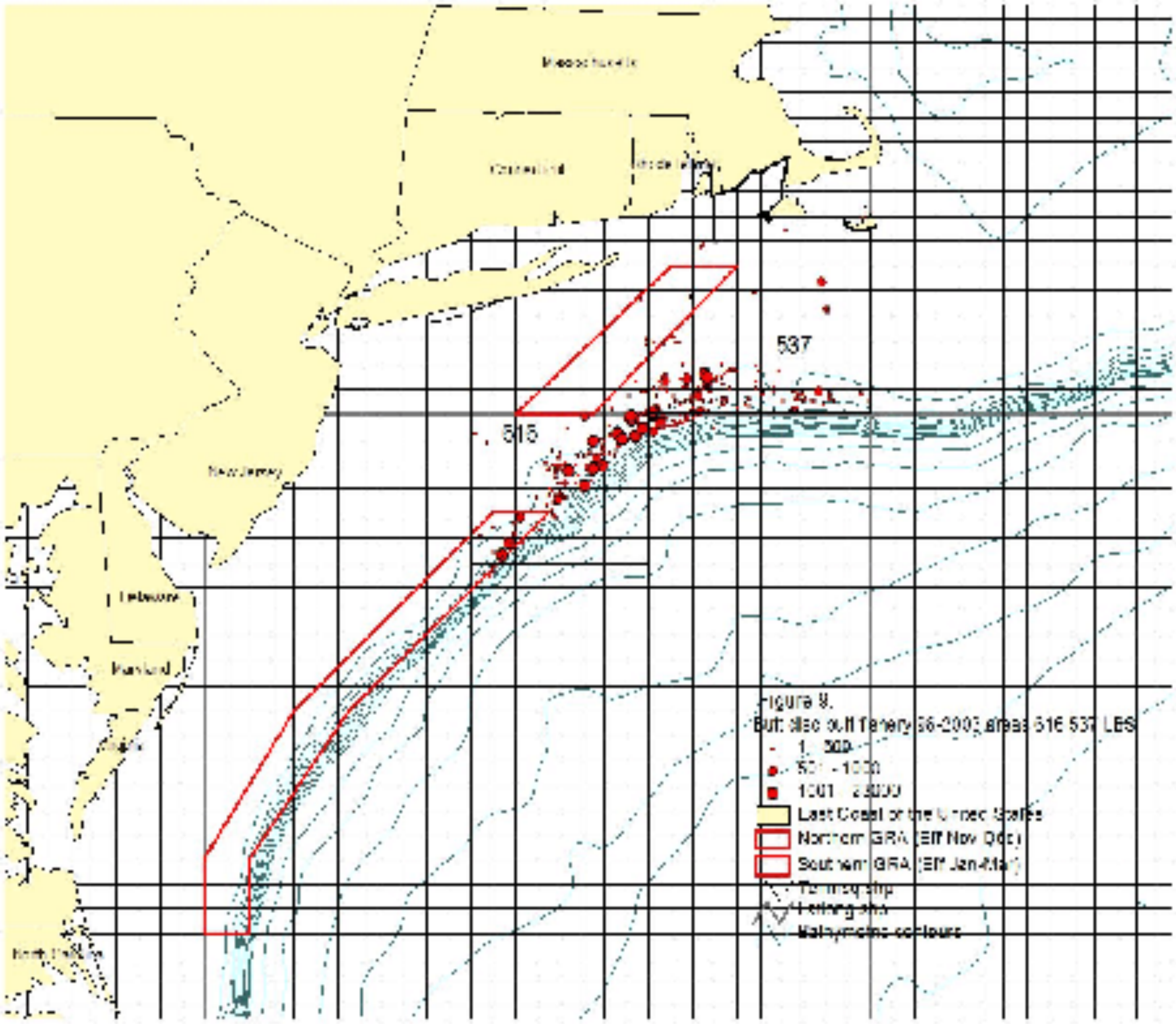


Figure 9. Butterfish discards observed on directed butterfish trips in statistical areas 616 and 537 based on 1996-2003 NMFS sea sampling data. Fishing for butterfish with a codend mesh size smaller than 11.4 cm (4.5 in.) was prohibited in both GRAs during 2001-2004.

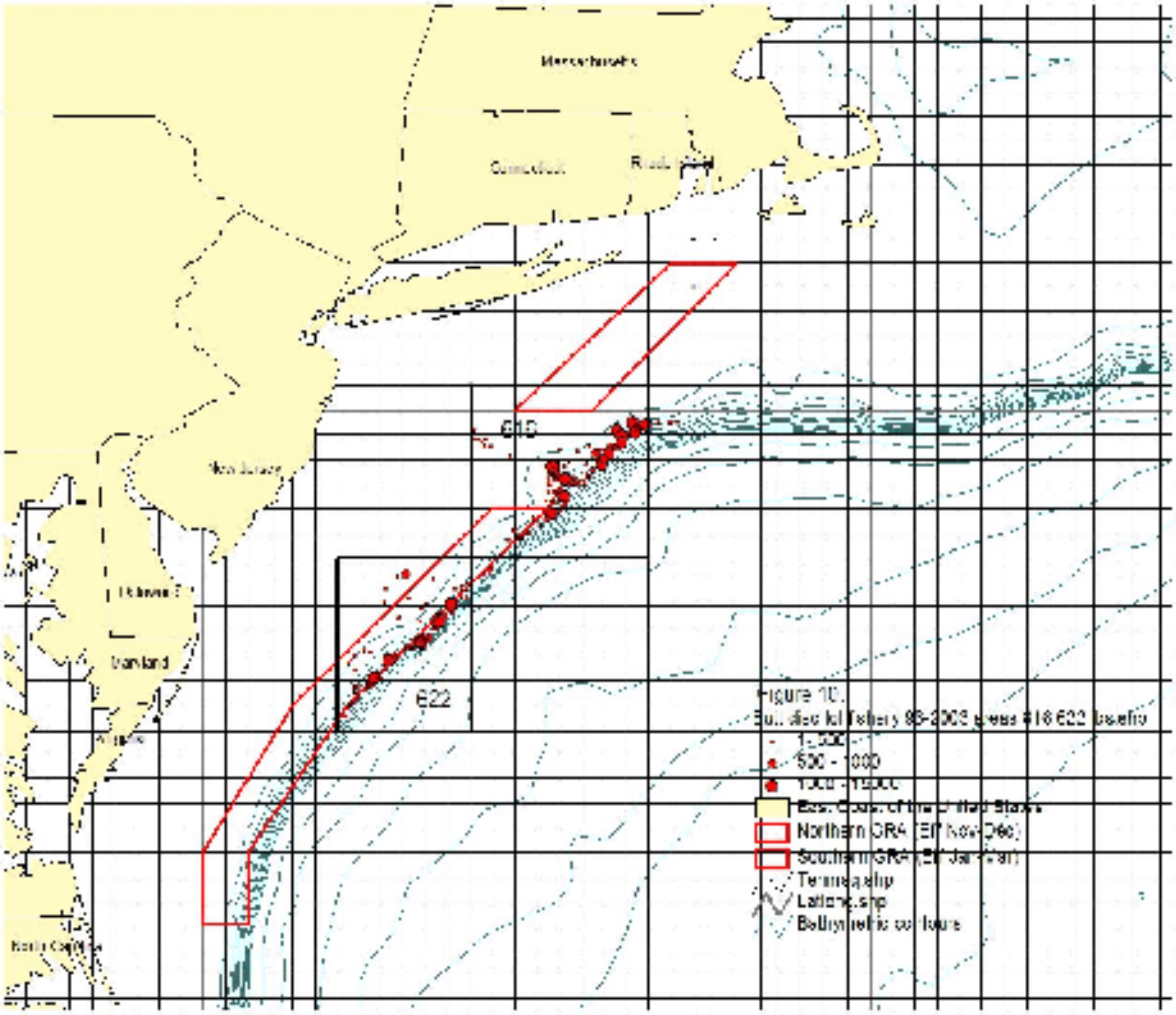


Figure 10. Butterfish discards observed on directed *Loligo* trips in statistical areas 616 and 622 based on 1996-2003 NMFS sea sampling data. *Loligo* fishing with a codend mesh size smaller than 11.4 cm (4.5 in.) was prohibited in both GRAs during 2001- 2004.

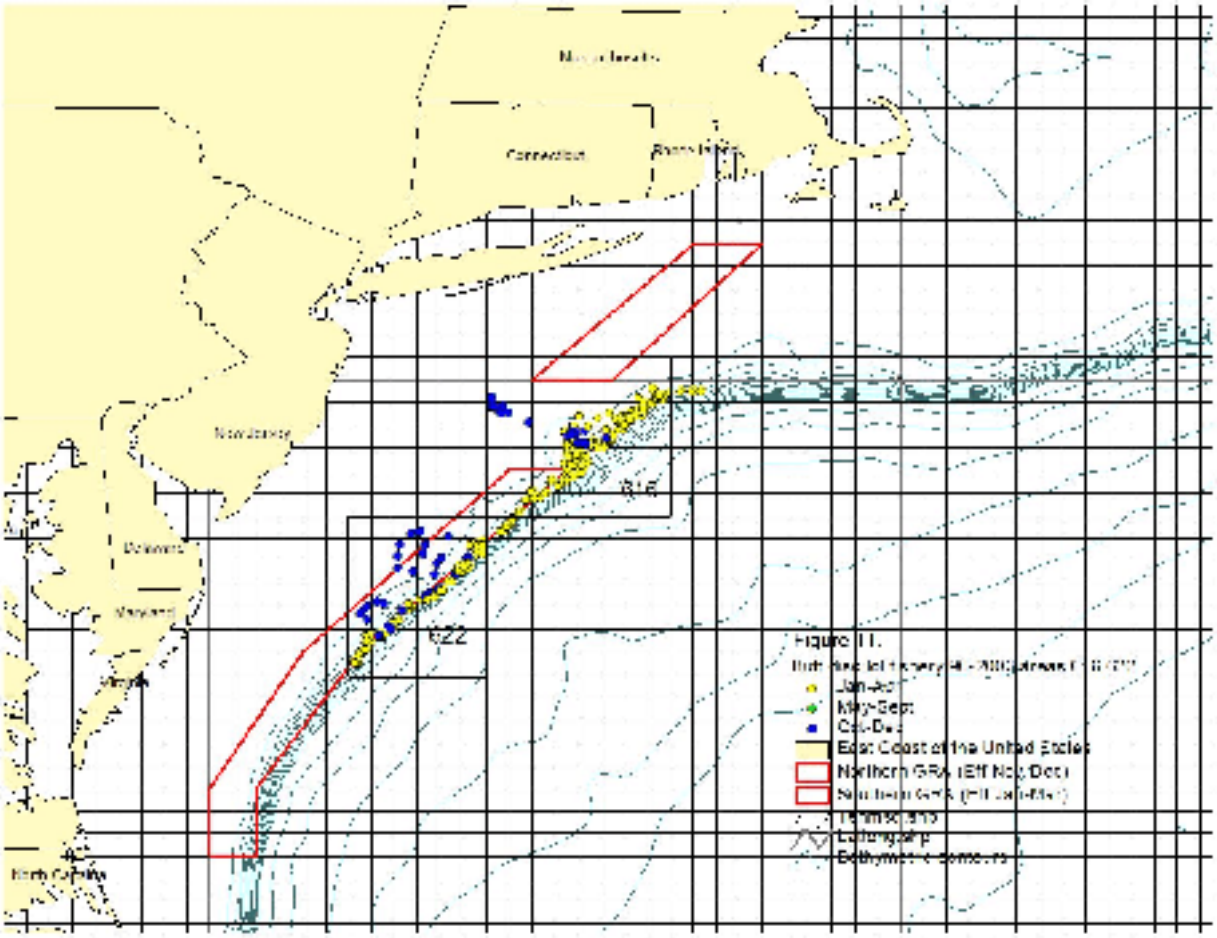


Figure 11. Butterfish discards observed on directed *Loligo* trips by season in statistical areas 616 and 622 based on 1996-2003 NMFS sea sampling data. *Loligo* fishing with a codend mesh size smaller than 11.4 cm (4.5 in.) was prohibited in both GRAs during 2001- 2004.

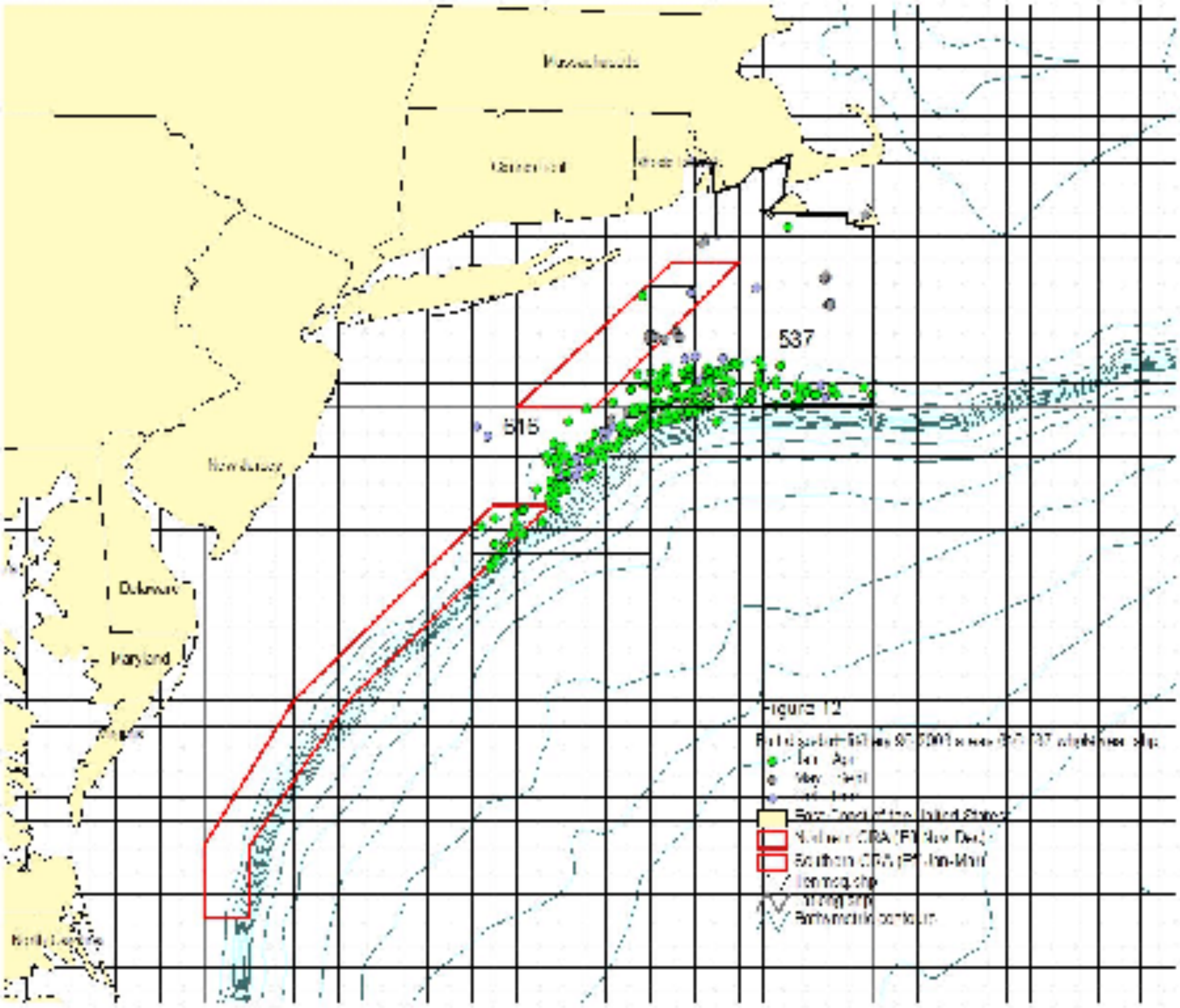


Figure 12. Butterfish discards observed on directed butterfish trips by season in statistical areas 616 and 537 based on 1996-2003 NMFS sea sampling data. Fishing for butterfish with a codend mesh size smaller than 11.4 cm (4.5 in.) was prohibited in both GRAs during 2001-2004.

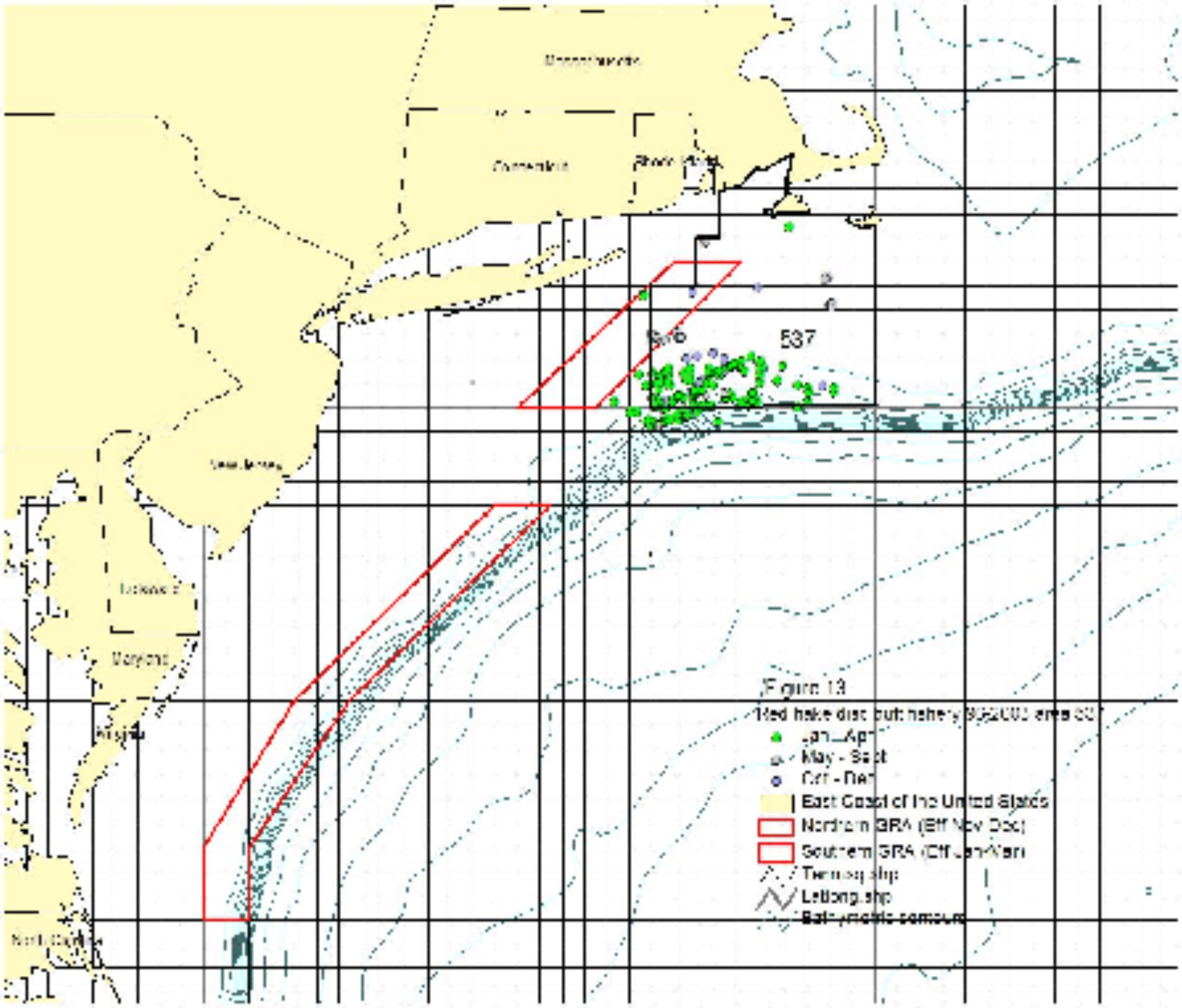


Figure 13. Red hake discards observed on directed butterfish trips by season in statistical area 537 based on 1996-2003 NMFS sea sampling data. Fishing for butterfish with a codend mesh size smaller than 11.4 cm (4.5 in.) was prohibited in both GRAs during 2001-2004.

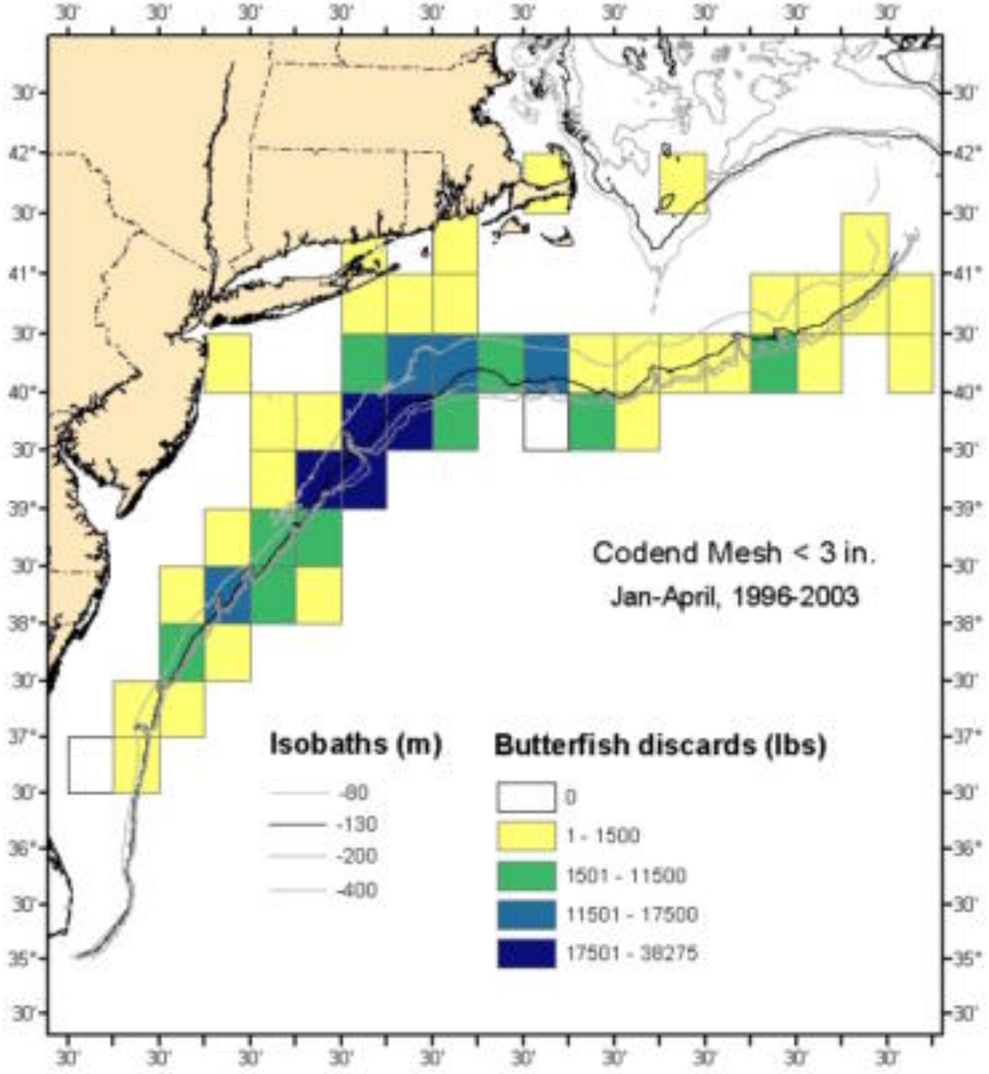


Figure 14. Distribution of butterfish discards, by quarter-degree square, of observed tows recorded in the NEFSC Observer Database for otter trawl fisheries using codend mesh sizes less than 3.0 inches during Jan.-April, 1996-2003.

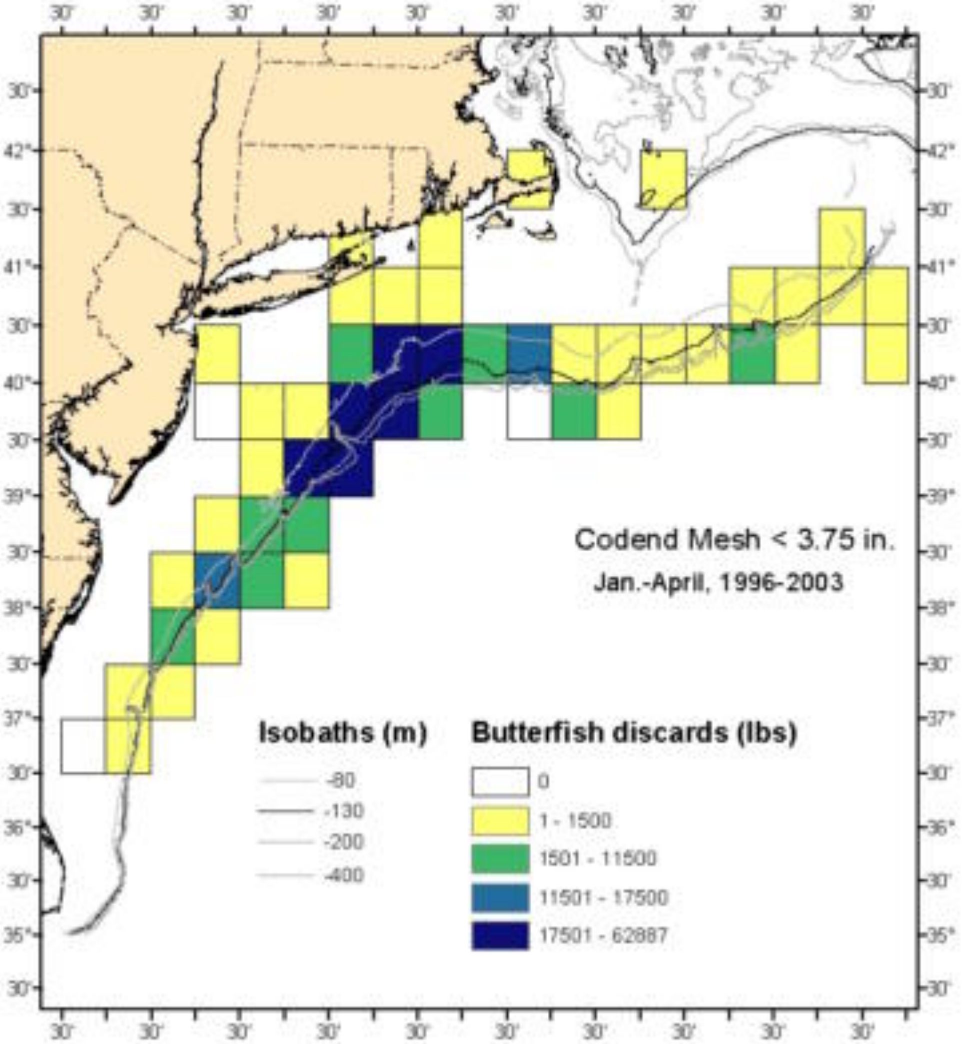


Figure 15. Distribution of butterfish discards, by quarter-degree square, of observed tows recorded in the NEFSC Observer Database for otter trawl fisheries using codend mesh sizes less than 3.75 inches during Jan.-April, 1996-2003.

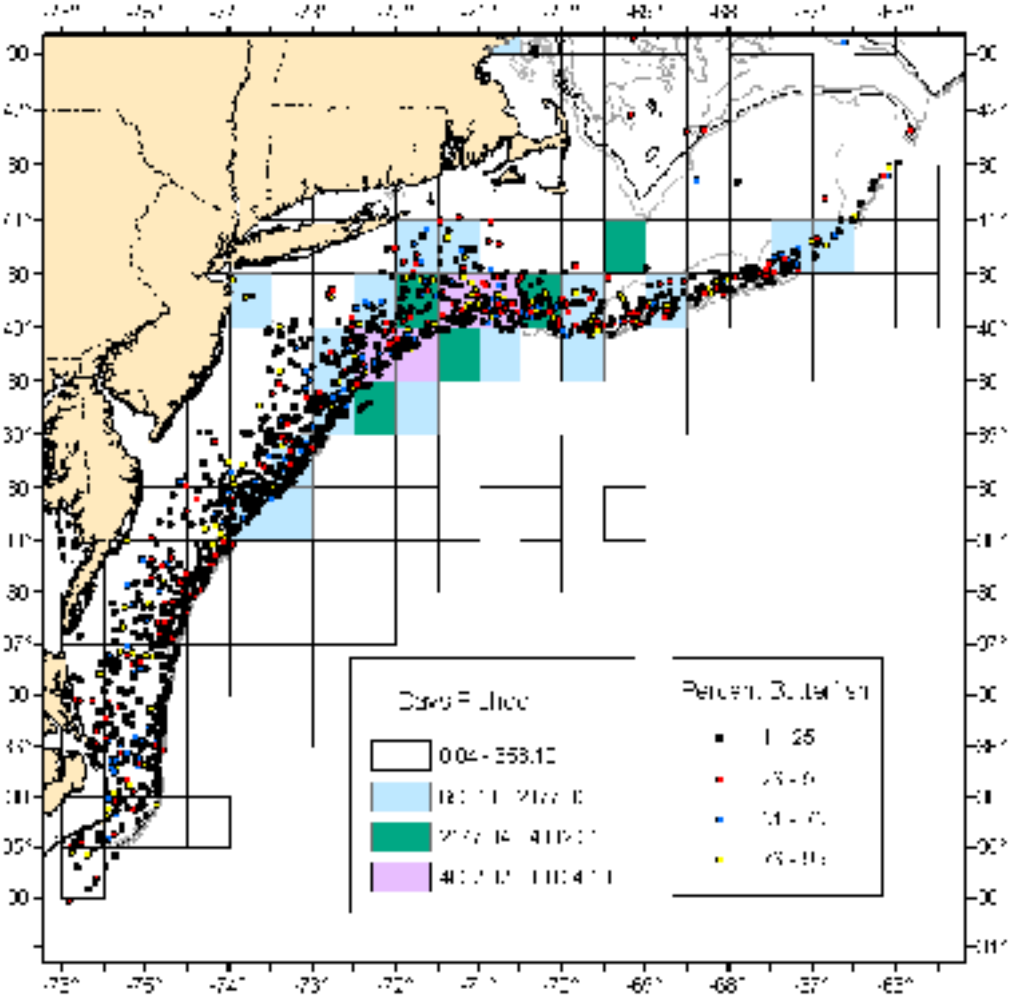


Figure 16. Co-occurrence of *Loligo* and butterfish in NEFSC winter (Feb.) and spring (Mar.) research vessel surveys during 1992-2003 and VTR effort (days fished) reported in the small mesh otter trawl fisheries (< 3.75 in. codend mesh) during Jan.-April, 1997-2003.

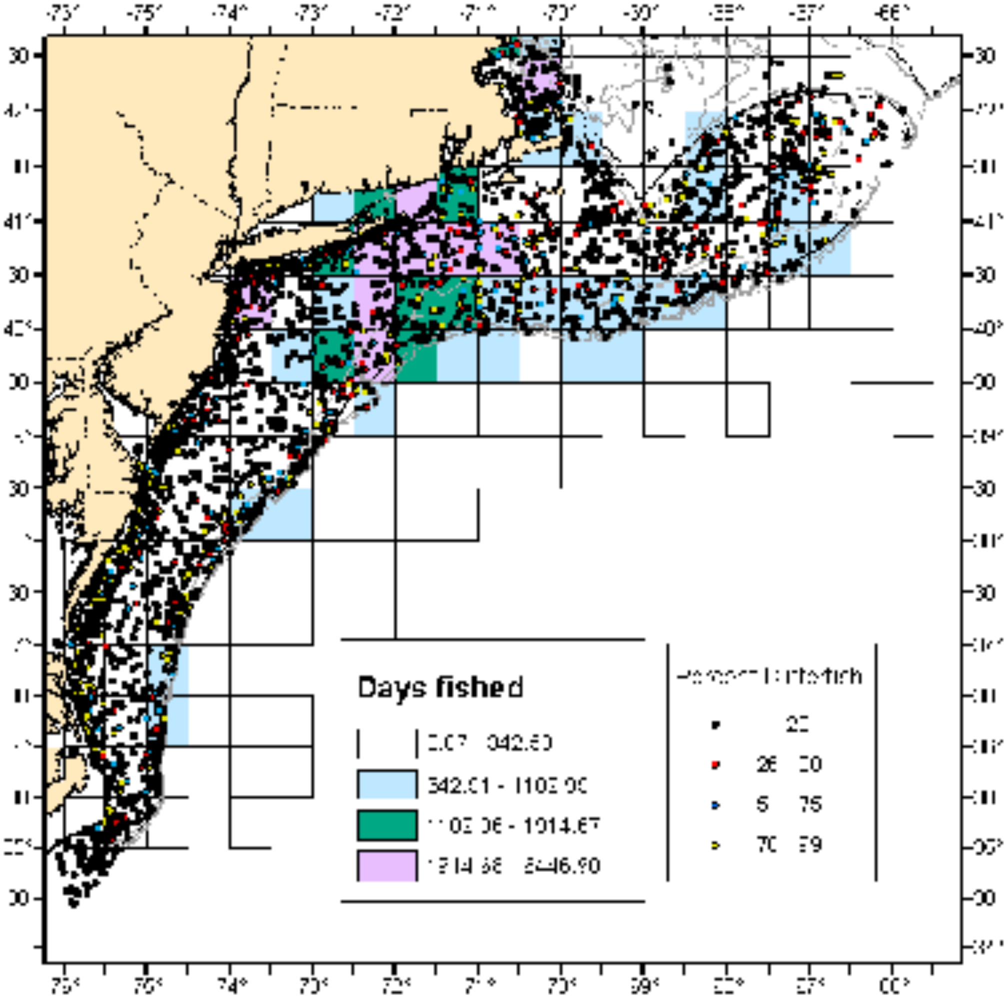


Figure 17. Co-occurrence of *Loligo* and butterfish in NEFSC autumn (Sept-Oct.) research vessel surveys during 1992-2003 and VTR effort (days fished) reported in the small mesh otter trawl fisheries (< 3.75 in. codend mesh) during Sept.-Dec., 1997-2003.

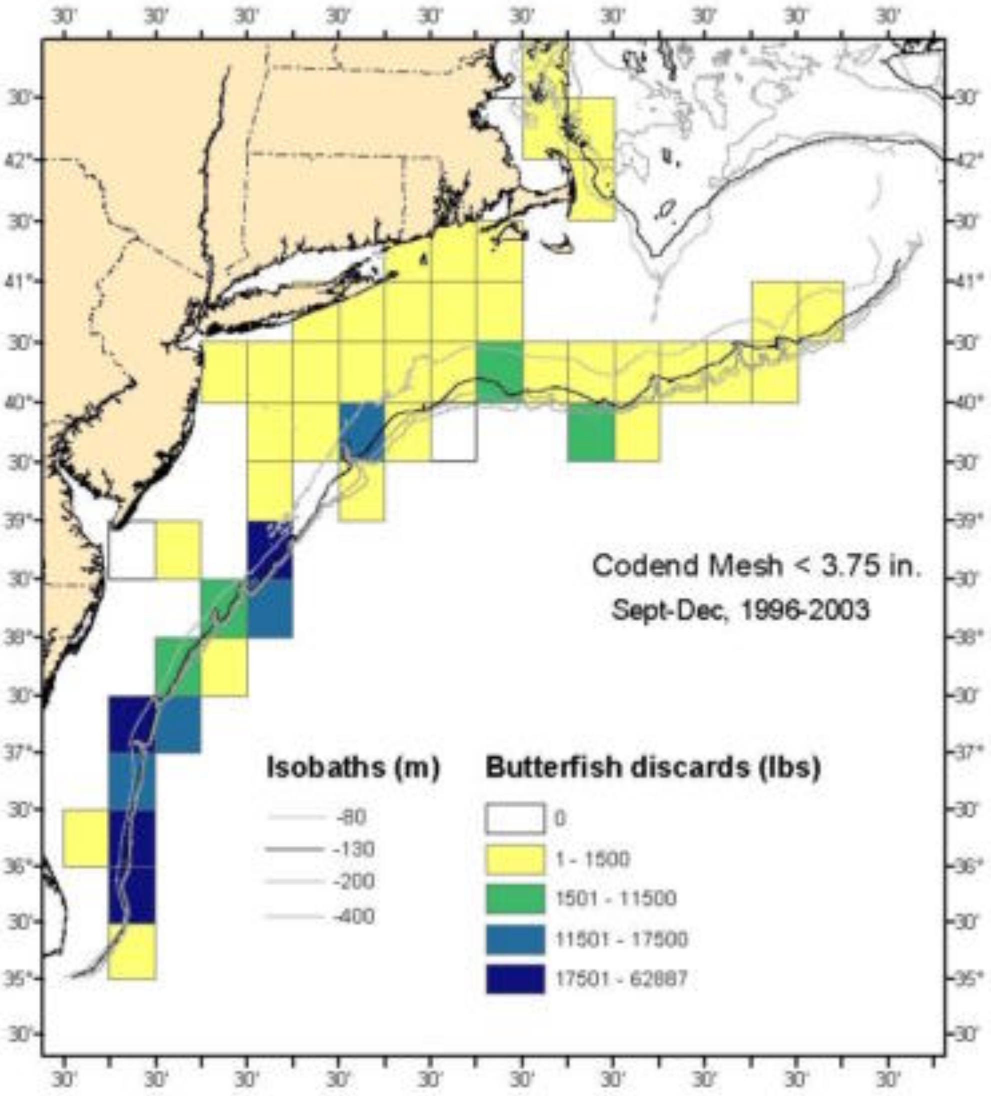


Figure 18. Distribution of butterfish discards, by quarter-degree square, of observed tows recorded in the NEFSC Observer Database for otter trawl fisheries using codend mesh sizes less than 3.75 inches during Sept.-Dec., 1996-2003.

Appendix 4

The Effects of Fishing on Marine Habitats of the Northeastern United States

A review of fishing gear utilized within the Northeast Region and its potential impacts on marine habitats

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1. INTRODUCTION

SCOPE OF THIS REPORT

This report characterizes the habitats of the Northeast shelf ecosystem, describes the fishing gears utilized throughout the area and their distribution of use, summarizes the results of scientific studies that form the basis for understanding the effects of fishing gears on marine benthic habitats in the region, and evaluates the vulnerability of benthic habitats which have been designated as “essential” to fishing gear effects for 42 species of federally-managed fish and shellfish species. This report was developed to provide assistance in meeting the Essential Fish Habitat (EFH) mandates of the Magnuson-Stevens Fishery Conservation and Management Act (MSA) for the Northeast region of the U.S. (Maine - North Carolina). The major emphasis of this report is on those fishing gears directly managed by the New England Fishery Management Council (NEFMC) and Mid-Atlantic Fishery Management Council (MAFMC) under the MSA, which requires that management plans for federally-managed marine fisheries in the U.S. minimize the adverse effects of fishing on EFH. The information in this report relates strictly to the direct physical and biological effects of fishing on benthic habitat; it does not include effects to resource populations or ecosystem-level effects that are caused by the removal of targeted species or by-catch.

This report includes detailed summaries of 73 research studies that were judged to be relevant for evaluating the effects of commercial fishing gears used in the Northeast region of the U.S. on benthic marine habitats that exist in the region. Each summary includes a description of the principal results and important features of the methodological approach. Critical evaluations of experimental design, sampling procedures or intensity, or analytical methods, are not provided. To the extent possible, the information is organized by gear and substrate type (mud, sand, gravel, rock and biogenic substrate). Summaries of the principal results of all studies for each individual gear and substrate type are also provided. Most of the studies described in this report were performed with otter trawls and various types of dredges. Gears that are not used in the region (or used very little), but which were judged to have a comparable effect on benthic habitats as gears that are used in the region, were also included. Information sources include articles in peer reviewed scientific journals, as well as non peer-reviewed reports. Some of the studies that are cited were conducted in the Northeast region, while others were conducted in other locations in the United States or in other countries. Most of the studies summarized in this report were also summarized in less detail in an earlier NMFS report that included gear types not used in the Northeast U.S. (Johnson 2002).

Other types of information used in this report to evaluate gear effects on benthic habitats in the Northeast region include a description of characteristic benthic habitats and species assemblages (invertebrates and fish) in four sub-regions of the Northeast, the extent and distribution of fishing activity for the major gears used in the region during 1995-2001, descriptions of 37 gear types used in state and federal waters in the Northeast, and rankings of EFH vulnerability to the three principal mobile gears used in federal waters in the region for 42 federally-managed species. Conclusions reached by a panel of experts that met in October, 2001, for the purpose of evaluating habitat effects in the Northeast region (NREFHSC 2002) were also incorporated. A preliminary draft of this report was distributed to the workshop panelists to assist them in conducting their evaluation.

This report differs in several important ways from other recent reviews of the gear effects literature (Auster and Langton 1999, Collie *et al*. 2000, Jennings and Kaiser 1998) and from recent broad-scale assessments of the effects of commercial fishing gear on benthic marine habitats and ecosystems (NRC 2002, Dayton *et al.* 2002). Rather than emphasizing general conclusions that apply to combined gear types (*e.g.*, "reduction of habitat complexity by mobile bottom-tending gear"), this report provides detailed summaries of individual studies for individual gear and habitat types of relevance to the Northeast region in text and tabular format. The intention was to provide enough information in each summary for the reader to understand where and how the research was conducted and what were the principal results. Each summary table contains information on location, substrate, depth, effects, recovery, and the methodological approach. No attempt was made to critically evaluate the research approach or the validity of the results unless there were issues (*e.g.*, a failure to replicate treatment sites, not enough samples) identified as problems by the authors themselves.

FISHING GEARS INCLUDED IN THIS REPORT

The Northeast region falls within the jurisdiction of the NEFMC and MAFMC as well as the individual states from Maine to North Carolina which are represented by the Atlantic States Marine Fisheries Commission (ASMFC). These organizations are responsible for the management of many different fisheries extending from the upper reaches of rivers and estuaries to the outer limit of the Exclusive Economic Zone (EEZ), located 200 miles offshore, well beyond the edge of the continental shelf (Figure 2.1).

Sixty types of fishing gear were identified as having been associated with landings of federal or state managed species based on a review of National Marine Fisheries Service commercial fisheries landings data for 1999 and an ASMFC report on gear impacts to submerged aquatic vegetation (Stephan *et al.* 2000).

Fishing gears considered in this report are those used to land any quantity of any species managed by either the NEFMC or MAFMC (Table 1.1) as well as gears that contributed 1% or more of any individual state's total landings for all species (Table 1.2). Although certain gear types are not managed under the auspices of the MSA, this methodology recognizes that certain gear utilized in state waters may have adverse impacts to EFH that is designated in nearshore, estuarine and riverine areas. Table 1.3 provides the list of all 60 gears considered and indicates whether the gear is utilized in estuaries, coastal waters (0-3 miles), or offshore waters (3-200 miles). Since the seabed is the location of the habitat types most susceptible to gear disturbances, Table 1.3 also indicates whether the gear contacts the bottom and if the use of the gear is regulated under a federal fishery management plan (FMP). This report considers gear to be regulated under a federal FMP if it is typically utilized to harvest fish under a federal vessel or operators permit.

STATUTORY REQUIREMENTS FOR EFH

The 1996 Amendments to the MSA require that FMPs minimize to the extent practicable adverse effects on EFH caused by fishing (MSA section 303(a)(7)). Pursuant to the EFH regulations (50 CFR 610.815(a)(2)), FMPs must include an evaluation of the potential adverse effects of fishing on EFH, including effects of each fishing activity regulated under Federal FMPs. The evaluation should consider the effects of each fishing activity on each type of habitat found within EFH. FMPs must describe each fishing activity, review and discuss all available and relevant information (such as information regarding the intensity, extent, and frequency of any adverse effect on EFH; the type of habitat within EFH that may be affected adversely; and the habitat functions that may be disturbed), and provide conclusions as to whether and how each fishing activity adversely affects EFH. The evaluation should also consider the cumulative effects of multiple fishing activities on EFH. In completing this evaluation, Councils should use the best scientific information available, as well as other appropriate information sources. Councils should consider different types of information according to their scientific rigor.

Additionally, FMPs must identify any fishing activities that are not managed under the MSA that may adversely affect EFH. Such activities may include fishing managed by state agencies or other authorities. However, Councils are not required to take action to minimize adverse effects from non-MSA fishing activities.

2. HABITAT CHARACTERIZATION OF THE NORTHEAST SHELF ECOSYSTEM

INTRODUCTION

Purpose

The Northeast Shelf Ecosystem includes a broad range of habitats with varying physical and biological properties. From the cold waters of the Gulf of Maine, south to the more tempered climate of the Mid-Atlantic Bight, oceanographic and biological processes interact to form a networked range of expansive to narrowly distributed habitat types. This brief review describes the oceanographic processes and habitat characteristics of the regional subsystems of this large marine ecosystem, as well as some information on the functions of different habitat types. It provides a portion of the background information needed to evaluate the effects of fishing on benthic habitats in the region.

Habitat Associations and Functions

From a biological perspective, habitats provide living things with the basic life requirements of nourishment and shelter. Habitats may also provide a broader range of benefits to the ecosystem. An illustration of the broader context is the way seagrasses physically stabilize the substrate, and help recirculate oxygen and nutrients. In this general discussion, we will focus on the first-level, direct value of habitats to federally managed species - food and shelter from predation.

The spatial and temporal variation of prey abundance influences the survivorship, recruitment, development, and spatial distribution of organisms at every trophic level. For example, phytoplankton abundance and distribution are a great influence on ichthyoplankton community structure and distribution. In addition, the migratory behavior of juvenile and adult fish is directly related to seasonal patterns of prey abundance and changes in environmental conditions, especially water temperature. Prey supply is particularly critical for the starvation-prone early life history stages of fish.

The availability of food for planktivores is highly influenced by oceanographic properties. The seasonal warming of surface waters in temperate latitudes produces vertical stratification of the water column, which isolates sunlit surface waters from deeper, nutrient-rich water, leading to reduced primary productivity. In certain areas, upwelling, induced by wind, storms, and tidal mixing, inject nutrients back into the photic zone, stimulating primary production. Changes in primary production from upwelling and other oceanographic processes affect the amount of organic matter available for other organisms higher up in the food chain, and thus influence their abundance and distribution. Some of the organic matter produced in the photic zone sinks to the bottom and provides food for benthic organisms. In this way, oceanographic properties can also influence the food availability for sessile benthic organisms. In shallower water, benthic macro and microalgae also contribute to primary production. Recent research on benthic primary productivity indicates that benthic microalgae may contribute more to primary production than has been originally estimated (Cahoon 1999).

Benthic organisms provide an important food source for many managed species. Populations of bottom-dwelling sand lance are important food sources for many piscivorous species, and benthic invertebrates are the main source of nutrition for many demersal fishes. Temporal and spatial variations in benthic community structure affect the distribution and abundance of bottom-feeding fish. Likewise, the abundance and species composition of benthic communities are affected by a number of environmental factors including temperature, sediment type, and the amount of organic matter.

A number of recent studies illustrate the research that has addressed habitat associations for demersal juvenile fish. In shallow, nearshore coastal and estuarine waters of the northeast region, effects of physical habitat factors and prey availability on the abundance and distribution of young-of-the-year flounder (various species) have been investigated in nearshore and estuarine habitats in Connecticut, New Jersey, and North Carolina (Phelan *et al.* 2001; Stoner *et al*. 2001; Manderson *et al.* 2000; Howell *et al.* 1999; Walsh *et al.* 1999; and Rountree and Able 1992). There are few comparable studies of more open, continental shelf environments. In the northeast U.S., Steves *et al.* (1999) identified depth, bottom temperature, and time of year as primary factors delineating settlement and nursery habitats for juvenile whiting and yellowtail flounder in the mid-Atlantic Bight. Also, in a series of publications, Auster *et al.* (1991, 1995, 1997) correlated the spatial distributions of benthic juvenile fish (*e.g.* whiting) with changes in micro-habitat type on sand bottom at various open shelf locations in southern New England.

In addition to providing food sources, another important functional value of benthic habitat is the shelter and refuge from predators provided by structure. Three dimensional structure is provided by physical features such as boulders, gravel and cobble, sand waves and ripples, and mounts, burrows and depressions created by organisms. Structure is also provided by emergent epifauna.

The importance of benthic habitat complexity was discussed by Auster (1998) and Auster and Langton (1999) in the context of providing a conceptual model to visualize patterns in fishing gear impacts across a gradient of habitat types. Based on this model, habitat value increases with increased structural complexity, from the lowest value in flat sand and mud to the highest value in piled boulders. The importance of habitat complexity to federally managed species is a key issue in the Northeast region. The question of whether removal of emergent epifauna from gravel and rocky habitat affects survival of juvenile cod and other species is of particular concern. There are field studies (in northeast US and eastern Canadian waters, and other locations), laboratory experiments and modeling studies addressing this question. Because of the importance of this issue in the Northeast region, this research is summarized below.

The first field study linking survival of juvenile cod and haddock to habitat type on Georges Bank was by Lough *et al.* (1989). Using submersibles, they observed that recently-settled 0-group juvenile cod (and haddock), < 10 cm long, were primarily found in pebble-gravel habitat at 70-100 m depths on eastern Georges Bank. They hypothesized that the gravel enhanced survival through predator avoidance; coloration of the fish mimicked that of the substrate, and from the submersible the fish were very difficult to detect against the gravel background. The authors considered increased prey abundance to be another, but less likely, explanation for the concentration of these fish on gravel. Presence of emergent epifauna, and any effects of epifauna on survival of the juveniles, were not noted.

Gregory and Anderson (1997), using submersibles in 18 to 150 m depths in Placentia Bay, Newfoundland, similarly found that the youngest cod observed (age 1, 10-12 cm long) were primarily associated with low-relief gravel substrate; their mottled color appeared to provide camouflage in the gravel. Older juveniles (ages 2-4) were most abundant in higher relief areas with coarser substrate, e. g., submarine cliffs. No selection by juvenile cod for substrates with macroalgae cover was seen, and emergent epifauna was not mentioned.

In the first study suggesting an added value of emergent epifauna on Georges Bank gravel, Valentine and Lough (1991) observed from submersibles that attached epifauna was much more abundant in areas of eastern Georges Bank that had not been fished (due to the presence of large boulders). They felt the increased bottom complexity provided by the epifauna might be an important component of fisheries habitat, but both trawled and un-trawled gravel habitats were considered important for survival of juvenile cod.

Other field studies on the relationship of juvenile cod abundance to habitat complexity have been in shallower inshore waters, and results may not be directly applicable to conditions on offshore banks like Georges Bank. In 2-12 m depths off the Newfoundland coast, Keats *et al.* (1987) found (in contrast to Gregory and Anderson 1997 [above]) juvenile cod to be much more abundant in macroalgae beds than in adjacent areas which had been grazed bare by sea urchins. This was true of 1-year-old fish (7.8-12.5 cm) as well as older, larger (12.6-23.5 cm) juveniles. The larger fish fed on fauna associated with the macroalgae, so enhanced food supply was a probable benefit of the increased complexity. The smallest 1-year-olds fed on plankton, and it was unlikely their growth was affected by presence of macroalgae.

Tupper and Boutilier (1995a), examined four habitat types (sand, seagrass, cobble, rock reef) in St. Margaret's Bay, Nova Scotia, and reported that cod settlement was equal in all habitats, but survival and juvenile densities were higher in the more complex habitats. Growth rate was highest in seagrass beds, but predator (larger cod) efficiency was lowest, and juvenile survival highest, on rock reef and cobble. The authors considered the different habitats to provide a tradeoff between enhanced foraging success and increased predation risk. In another study in St. Margaret's Bay, Tupper and Boutilier (1995b) found that cod settling on a rocky reef inhabited crevices in the reef, and defended territories around the crevices. Fish that settled earlier and at larger sizes grew more quickly and had larger territories. Size at settlement and timing of settlement were thus considered important in determining competitive success of individuals.

Habitat associations of juvenile cod were also examined by Gotceitas *et al.* (1997) using SCUBA divers in Trinity Bay, and beach seines in Trinity, Notre Dame and Bonavista bays, Newfoundland. In both types of surveys, almost all age-0 cod were found in eelgrass beds as opposed to less structurally complex areas, and eelgrass was suggested to be an important habitat for these fish. Older juveniles were more abundant on mud, sand and rocky bottoms than in eelgrass.

A seining study by Linehan *et al.* (2001) in Bonavista Bay, Newfoundland, found age 0 cod (< 10 cm long) to be more abundant in vegetated (eelgrass) than in unvegetated habitats, both day and night. However, potential predators of juvenile cod were also most abundant in eelgrass. Tethering experiments with age 0 cod at 6 sites in 0.7 - 20 m depths indicated that predation increased with depth, being about three times higher at deeper sites. At shallow sites, predation was generally higher in unvegetated sites than in eelgrass.

Habitat use of age 0 and 1 cod in state waters off eastern Massachusetts is discussed by Howe et al. (2000), based on analysis of 22 years (1978-1999) of data from spring and fall trawl surveys by the Massachusetts Division of Marine Fisheries. Results showed the survey area is important for cod settlement, with at least two pulses of newly-settled fish found in most years. Spatial distribution patterns of young cod were clear, stable, and strongly related to depth. In spring, just-settled cod were most abundant in depths <90'; in fall these age 0 cod were found in 31-180' depths, but were concentrated in 91-180'. Age 1 cod were more abundant in deeper waters (61-180' in spring, 121-180' in fall). Habitat complexity per se was not the primary focus of this analysis, and some of the most complex (e. g., rocky) habitats could not be sampled by the survey. However, the greater abundance of just-settled fish in shallower waters was thought to be linked to the higher complexity of these habitats. It was postulated that high densities of age 0 fish indicated areas of high productivity and preferred habitat. Given the abundance of juvenile cod in these surveys, eastern Massachusetts waters were recommended as a coastal "Habitat Area of Particular Concern" for the Gulf of Maine cod stock.

Kaiser *et al.* (1999) analyzed beam trawl catch data from a number of stations in the English Channel and reported that small gadoid species were present in deeper (>30 m), structurally-complex habitats with rocks, soft corals, bryozoans, hydroids, and sponges and absent in shallow water habitats which were inhabited by several species of flounder. Most of the structure-forming benthic species that were present in deeper water were also present in shallow water, but at reduced abundances, and the total biomass of sessile epibenthic species was higher in shallow water. These results suggest that depth and the amount of cover provided by certain types of emergent epifauna (*e.g.*, sponges) were the most important factors affecting habitat utilization by gadoid (and flounder) species.

Information on the effects of habitat complexity on juvenile cod survival is also available from several laboratory studies. Gotceitas and Brown (1993) compared substrate preferences of juvenile cod (6-12 cm) from among sand, gravel-pebble and cobble, before and after introduction of a larger cod. Before the predator was introduced, small cod preferred sand or gravel-pebble over cobble. In the presence of the predator, they chose cobble if available, and the cobble reduced predation. The experiment did not test effects of emergent epifauna on substrate choices or survival. Gotceitas *et al.* (1995) conducted a similar study, but with 3.5-8 cm cod in a tank with three substrates, either 1) sand, gravel, and 30 cm long strips of plastic to simulate kelp (*Laminaria* sp.), or 2) sand, cobble, and "kelp". Based on the authors' earlier study, cobble was considered to provide a "safe" habitat that reduced predation. Responses to introduction of two kinds of larger cod were tested: fish that actively attempted to eat the smaller cod, vs. "passive" predators that showed no interest in the smaller fish. In the presence of passive predators, small cod preferred sand substrates and avoided kelp. When exposed to an active predator, they hid in cobble if available, or kelp if there was no cobble. Both cobble and kelp significantly reduced predation, and small cod appeared able to modify their behavior based on the varying risk presented by different predators.

Fraser *et al.* (1996) tested responses of age 0 (5.2-8.2 cm) and age 1 (10.2-13.5 cm) cod to predators (3-year-old cod), using the same tanks as Gotceitas *et al.* (1995) but with only two substrate choices: sand vs. gravel, and sand vs. cobble. With no predator present, age 0 and 1 cod preferred sand to gravel or cobble, but if both age 0 and 1 fish were in the tank, the smaller fish tended to avoid the larger ones and to increase use of gravel/cobble. When a predator was introduced, both age 0 and 1 cod hid in cobble if available; in the sand/gravel trials, they attempted to flee from the predator. In the predator's presence, the avoidance of age 1 cod by age 0 cod disappeared; overall, however, there was some indication of habitat segregation between age 0 and age 1 cod.

Gotceitas *et al.* (1997) again used the same experimental system to compare use of sand, gravel and cobble substrates, and three densities of eelgrass, by age 0 cod (3.5-10 cm) in the presence and absence of a predator (age 3 cod). With no predator, the small cod preferred sand and gravel to cobble. When a predator was introduced and cobble was present, age 0 fish hid in the cobble or in dense eelgrass ($\geq$ 720 stems/m^2) if present. With no cobble, they hid in all three densities of eelgrass. Age 0 cod survival (time to capture and number of fish avoiding capture) was highest in cobble or $\geq$ 1000 eelgrass stems/m^2. In other combinations, time to capture increased with both presence and density of vegetation.

Borg *et al.* (1997) conducted a laboratory study of habitat choice by two size groups of juvenile cod (7-143 and 17-28 cm TL) on sandy bottoms with different vegetation types. Four habitats, typical of shallow soft bottom on the west coast of Sweden, were tested in six combinations. During daylight, fish preferred vegetation to bare sand, while at night – when juvenile cod feed in open, sandy areas – no significant choice was made. Both size classes preferred *Fucus*, the most complex habitat that was tested.

Lindholm *et al.* (1999) tested effects of five habitat types, representing a gradient of complexity, on survival of age 0 cod (7-10 cm) in the presence of age 3 conspecifics. Substrates were sand, cobble, sparse short sponge, dense short sponge, and tall sponge. Sponge presence significantly reduced predation compared to that on sand, with density of sponges being more important than sponge height. Increasing habitat complexity reduced the distance from which a predator could react to the prey. The authors concluded that alteration of seafloor habitat by fishing could lower survival of juvenile cod. [There was no significant increase in survival in epifauna compared to bare cobble, however.]

In a mesocosm experiment, Isakkson *et al.* (1994) compared the foraging efficiency of cod on three different prey species on bare sand and eel grass with varying percent cover of filamentous algae. Foraging efficiency of cod on sand shrimp and green crabs was greatest in unvegetated substrate. Survival of these two prey species was significantly enhanced by the addition of moderate amounts of algal cover to sand substrates. Shore shrimp were equally susceptible to predation in all habitat types.

The effects of habitat complexity on post-settlement survival of juvenile cod have been examined via modeling (Lindholm *et al.* 2001). Data from the Lindholm *et al.* (1999) laboratory study described above were used to assign maximum values of 0.98 for juvenile mortality in the least complex habitats, and 0.32 in habitats of greatest complexity. Twelve monthly runs of a dynamic model were made, with the first month representing settlement of the cod. Results indicated that reduction of habitat complexity by fishing had significant negative effects on survival of juvenile cod, and that preservation of complexity through use of marine protected areas could reduce these negative effects.

Elsewhere and for other species, Charton and Ruzafa (1998) correlated increased habitat complexity (numbers of rocky boulders) in the Mediterranean with higher numbers and abundances of reef fish. There is evidence provided by laboratory experiments that habitat complexity can benefit fish that inhabit open, sandy habitats by providing refuge from bottom currents in the troughs between sand ripples (Gerstner and Webb 1997; Gerstner 1998).

In some situations, other habitat characteristics may be equally or more important than complexity. As discussed above, Lough *et al.* (1989) hypothesized that gravel substrate enhanced survival of juvenile cod because the coloration of these juveniles mimicked the substrate. In a similar example, American plaice adults are thought use gravel-sand sediments as a coloration refuge (Scott 1982). It is apparent that in identifying habitat value, a broad range of characteristics associated with habitat structure and function, which may vary by species and life stage, must be considered. Evaluations cannot be limited to individual aspects such as substrate type. Unfortunately, the amount of information available for individual parameters is limited, especially quantitative information necessary for multivariate analyses. Further development of multivariate relationships between biological, chemical, and physical habitat features will increase our understanding of the marine environment and advance the evidence of direct links between habitat conditions and fishery productivity.

DESCRIPTION OF REGIONAL SYSTEMS

Introduction

The Northeast Shelf Ecosystem (Figure 2.1) has been described as including the area from the Gulf of Maine south to Cape Hatteras, extending from the coast seaward to the edge of the continental shelf, including the slope sea offshore to the Gulf Stream (Sherman *et al.* 1996). The continental slope of this region includes the area east of the shelf, out to a depth of 2000 m. A number of distinct sub-systems comprise the region, including the Gulf of Maine, Georges Bank, the Mid-Atlantic Bight, and the continental slope. Occasionally another subsystem, Southern New England, is described; however, we incorporated discussions of any distinctive features of this region into the sections describing Georges Bank and the Mid-Atlantic Bight.

The Gulf of Maine is an enclosed coastal sea, characterized by relatively cold waters and deep basins, with a patchwork of various sediment types. Georges Bank is a relatively shallow coastal plateau that slopes gently from north to south and has steep submarine canyons on its eastern and southeastern edge. It is characterized by highly productive, well-mixed waters and strong currents. The Mid-Atlantic Bight is comprised of the sandy, relatively flat, gently sloping continental shelf from southern New England to Cape Hatteras, NC. The continental slope begins at the continental shelf break and continues eastward with increasing depth until it becomes the continental rise. It is fairly homogenous, with exceptions at the shelf break, some of the canyons, the Hudson Shelf Valley and in areas of glacially rafted hard bottom.

Pertinent aspects of the physical characteristics of each of these systems are described below. This review is based on several summary reviews (Abernathy 1989, Backus 1987, Beardsley *et al.* 1996, Brooks 1996, Cook 1988, Dorsey 1998, Kelley 1998, Mountain 1994, NEFMC 1998, Reid and Steimle 1988, Schmitz *et al.* 1987, Wiebe et al. 1987, Sherman *et al.* 1996, Steimle *et al*. 1999b, Stumpf and Biggs 1988, Townsend 1992, Tucholke 1987). Literature citations are not included for generally accepted concepts; however, new research and specific results of research findings are cited.

Gulf of Maine

Although not obvious in appearance, the Gulf of Maine is actually an enclosed coastal sea, bounded on the east by Browns Bank, on the north by the Nova Scotian (Scotian) Shelf, on the west by the New England states, and on the south by Cape Cod and Georges Bank (Figure 2.2). The Gulf of Maine (GOM) was glacially derived, and is characterized by a system of deep basins, moraines and rocky protrusions with limited access to the open ocean. This geomorphology influences complex oceanographic processes that result in a rich biological community.

The Gulf of Maine is topographically unlike any other part of the continental border along the U.S. east coast. It contains 21 distinct basins separated by ridges, banks, and swells. The three largest basins are Wilkinson, Georges, and Jordan (Figure 2.2). Depths in the basins exceed 250 m, with a maximum depth of 350 m in Georges Basin, just north of Georges Bank. The Northeast Channel between Georges Bank and Browns Bank, leads into Georges Basin, and is one of the primary avenues for exchange of water between the GOM and the North Atlantic

Ocean.

High points within the gulf include irregular ridges, such as Cashes Ledge, which peaks at 9 m below the surface, as well as lower flat-topped banks and gentle swells. Some of these rises are remnants of the sedimentary shelf that was left after most of it was removed by the glaciers. Others are glacial moraines and a few, like Cashes Ledge, are out-croppings of bedrock. Very fine sediment particles created and eroded by the glaciers have collected in thick deposits over much of the Gulf of Maine, particularly in its deep basins (Figure 2.3). These mud deposits blanket and obscure the irregularities of the underlying bedrock, forming topographically smooth terrains. Some shallower basins are covered with mud as well, including some in coastal waters. In the rises between the basins, other materials are usually at the surface. Unsorted glacial till covers some morainal areas, as on Sewell Ridge to the north of Georges Basin and on Truxton Swell to the south of Jordan Basin. Sand predominates on some high areas and gravel, sometimes with boulders, predominates on others.

Coastal sediments exhibit a high degree of small-scale variability. Bedrock is the predominant substrate along the western edge of the Gulf of Maine north of Cape Cod in a narrow band out to a depth of about 60 m. Rocky areas become less common with increasing depth, but some rock outcrops poke through the mud covering the deeper sea floor. Mud is the second most common substrate on the inner continental shelf. Mud predominates in coastal valleys and basins which often border abruptly on rocky substrates. Many of these basins extend without interruption into deeper water. Gravel, often mixed with shell, is common adjacent to bedrock outcrops and in fractures in the rock. Large expanses of gravel are not common, but do occur near reworked glacial moraines and in areas where the sea bed has been scoured by bottom currents. Gravel is most abundant at depths of 20-40 m, except in eastern Maine where a gravel-covered plain exists to depths of at least 100 m. Bottom currents are stronger in eastern Maine where the mean tidal range exceeds 5 m. Sandy areas are relatively rare along the inner shelf of the western Gulf of Maine, but are more common south of Casco Bay, especially offshore of sandy beaches.

An intense seasonal cycle of winter cooling and turnover, springtime freshwater runoff, and summer warming influences oceanographic and biologic processes in the Gulf of Maine. The Gulf has a general counterclockwise nontidal surface current that flows around its coastal margin (Figure 2.4). It is primarily driven by fresh, cold Scotian Shelf water which enters over the Scotian Shelf and through the Northeast Channel, and freshwater river runoff, which is particularly important in the spring. Dense relatively warm and saline slope water entering through the bottom of the Northeast Channel from the continental slope also influences gyre formation. Counterclockwise gyres generally form in Jordan, Wilkinson, and Georges Basins and the Northeast Channel as well. These surface gyres are more pronounced in spring and summer; with winter, they weaken and become more influenced by the wind.

Stratification of surface waters during spring and summer seals off a mid-depth layer of water that preserves winter salinity and temperatures. This cold layer of water is called “Maine intermediate water” (MIW) and is located between more saline Maine bottom water and the warmer, stratified Maine surface water. The stratified surface layer is most pronounced in the deep portions of the western GOM. Tidal mixing of shallow areas prevents thermal stratification and results in thermal fronts between the stratified areas and cooler mixed areas. Typically, mixed areas include Georges Bank, the southwest Scotian Shelf, eastern Maine coastal waters, and the narrow coastal band surrounding the remainder of the Gulf.

The Northeast Channel provides an exit for cold MIW and outgoing surface water while it allows warmer more saline slope water to move in along the bottom and spill into the deeper basins. The influx of water occurs in pulses, and appears to be seasonal, with lower flow in late winter and a maximum in early summer.

Gulf of Maine circulation and water properties can vary significantly from year to year. Notable episodic events include shelf-slope interactions such as the entrainment of shelf water by Gulf Stream rings (see *Gulf Stream and Associated Features*), and strong winds which can create currents as high as 1.1 meters/second over Georges Bank. Warm core Gulf Stream rings can also influence upwelling and nutrient exchange on the Scotian shelf, and affect the water masses entering the GOM. Annual and seasonal inflow variations also affect water circulation.

Internal waves are episodic and can greatly affect the biological properties of certain habitats. Internal waves can shift water layers vertically, so that habitats normally surrounded by cold MIW are temporarily bathed in warm, organic-rich surface water. On Cashes Ledge, it is thought that deeper nutrient rich water is driven into the photic zone, providing for increased productivity. Localized areas of upwelling interaction occur in numerous places throughout the Gulf.

Characteristic Gulf of Maine Habitats

The Gulf of Maine's geologic features, when coupled with the vertical variation in water properties, result in a great diversity of habitat types. Most invertebrates in this region are classified as mollusks, followed by annelids, crustaceans, echinoderms and other (Theroux and Wigley 1998). By weight, the order of taxa changes to echinoderms, mollusks, other, annelids and crustaceans. Watling (1998) used numerical classification techniques to separate benthic invertebrate samples into seven types of bottom assemblages. These assemblages are identified in Table 2.1 and their distribution is indicated in Figure 2.5. This classification system considers benthic assemblage, substrate type and water properties.

An in-depth review of GOM habitat types has been prepared by Brown (1993). Although still preliminary, this classification system is a promising approach. It builds on a number of other schemes, including Cowardin *et al*. (1979), and tailors them to Maine's marine and estuarine environments. A significant factor that is included in this system but has been neglected in others is the amount of "energy" in a habitat. Energy could be a reflection of wind, waves, or currents present. This is a particularly important consideration in a review of fishing gear impacts since it indicates the natural disturbance regime of a habitat. The amount and type of natural disturbance is in turn an indication of the habitat's resistance to and recoverability from disturbance by fishing gear. Although this work appears to be complete in its description of habitat types, unfortunately, the distribution of many of the habitats are unknown.

Demersal fish assemblages for the Gulf of Maine and Georges Bank were part of broad scale geographic investigations conducted by Mahon *et al.* (1998) and Gabriel (1992). Both these studies and a more limited study by Overholtz and Tyler (1985) found assemblages that were consistent over space and time in this region. In her analysis, Gabriel found that the most persistent feature over time in assemblage structure from Nova Scotia to Cape Hatteras was the boundary separating assemblages between the Gulf of Maine and Georges Bank, which occurred at approximately the 100 m isobath on northern Georges Bank. Overholtz & Tyler (1985) identified five assemblages for this region (Table 2.2). The Gulf of Maine-deep assemblage included a number of species found in other assemblages, with the exception of American plaice and witch flounder, which was unique to this assemblage. Gabriel's approach did not allow species to co-occur in assemblages, and also classified these two species as unique to the deepwater Gulf of Maine-Georges Bank assemblage. Results of these two studies are compared in Table 2.2. Auster *et al.* (2001) went a step further and related species clusters on Stellwagen Bank to reflectance values of different substrate types in an attempt to use fish distribution as a proxy for seafloor habitat distribution. They found significant reflectance associations for twelve of 20 species, including American plaice (fine substrate), and haddock (coarse substrate). Species clusters and associated substrate types are given in Table 2.3.

Georges Bank

Georges Bank is a shallow (3-150 m depth), elongate (161 km wide by 322 km long) extension of the continental shelf which was formed by the Wisconsinian glacial episode. It is characterized by a steep slope on its northern edge and a broad, flat, gently sloping southern flank. The Great South Channel lies to the west. Natural processes continue to erode and rework the sediments on Georges Bank. It is anticipated that erosion and reworking of sediments will reduce the amount of sand available to the sand sheets, and cause an overall coarsening of the bottom sediments (Valentine *et al.* 1993).

Glacial retreat during the late Pleistocene deposited the bottom sediments currently observed on the eastern section of Georges Bank, and the sediments have been continuously reworked and redistributed by the action of rising sea level, and by tidal, storm and other currents. The strong, erosive currents affect the character of the biological community. Bottom topography on eastern Georges Bank is characterized by linear ridges in the western shoal areas; a relatively smooth, gently dipping sea floor on the deeper, easternmost part; a highly energetic peak in the north with sand ridges up to 30 m high and extensive gravel pavement, and steeper and smoother topography incised by submarine canyons on the southeastern margin (see *Continental Slope* for more on canyons). The nature of the sea bed sediments varies widely, ranging from clay to gravel (Figure 2.3). The gravel-sand mixture is usually a transition zone between coarse gravel and finer sediments.

The central region of the bank is shallow, and the bottom is characterized by shoals and troughs, with sand dunes superimposed upon them. The two most prominent elevations on the ridge and trough area are Cultivator and Georges Shoals. This shoal and trough area is a region of strong currents, with average flood and ebb tidal currents greater than 4 km per hour, and as high as 7 km per hour. The dunes migrate at variable rates, and the ridges may move, also. In an area that lies between the central part and northeast peak, Almeida *et al.* (2000) identified high-energy areas as between 35 – 65 m deep, where sand is transported on a daily basis by tidal currents, and a low-energy area at depths > 65 m that is affected only by storm currents.

The area west of the Great South Channel, known as Nantucket shoals (Figure 2.2), is similar in nature to the central region of the bank. Currents in these areas are strongest where water depth is shallower than 50 m. This type of travelling dune and swale morphology is also found in the mid-Atlantic bight, and further described in that section of the document. The Great South Channel separates the main part of Georges Bank from Nantucket Shoals. Sediments in this region include gravel pavement and mounds, some scattered boulders, sand with storm-generated ripples, scattered shell and mussel beds. Tidal and storm currents range from moderate to strong, depending upon location and storm activity (Valentine, pers. comm.).

Oceanographic frontal systems occur between water masses from the Gulf of Maine and Georges Bank. These water masses differ in temperature, salinity, nutrient concentration, and planktonic communities, which influence productivity and may influence fish abundance and distribution. Currents on Georges Bank include a weak, persistent clockwise gyre around the bank, a strong semidiurnal tidal flow predominantly northwest and southeast, and very strong, intermittent storm-induced currents, which can all occur simultaneously (Figure 2.4). Tidal currents over the shallow top of Georges Bank can be very strong, and keep the waters over the bank well mixed vertically. This results in a tidal front that separates the cool waters of the well-mixed shallows of the central bank from the warmer, seasonally stratified shelf waters on the seaward and shoreward sides of the bank. The clockwise gyre is instrumental in distribution of the planktonic community, including larval fish. For example, Lough and Potter (1993) describe passive drift of Atlantic cod and haddock eggs and larvae in a southwest residual pattern around Georges Bank. Larval concentrations are found at varying depths along the southern edge between 60 – 100 m.

Characteristic Georges Bank Habitats

The interaction of several environmental factors including availability and type of sediment, current speed and direction, and bottom topography have been found to combine to form seven sedimentary provinces on eastern Georges Bank (Valentine and Lough (1991), which are outlined in Table 2.4 and depicted in Figure 2.6.

Theroux and Grosslein (1987) identified four macrobenthic invertebrate assemblages that corresponded with previous work in the geographic area. They noted that it is impossible to define well-defined boundaries between assemblages because of the considerable intergrading that occurs between adjacent assemblages; however, the assemblages are distinguishable. Their assemblages are associated with those identified by Valentine and Lough (1991) in Table 2.4.

The Western Basin assemblage (Theroux and Grosslein 1987) is found in the upper Great South Channel region at the northwestern corner of the bank, in comparatively deep water (150-200 m) with relatively slow currents and fine bottom sediments of silt, clay and muddy sand. Fauna are comprised mainly of small burrowing detritivores and deposit feeders, and carnivorous scavengers. Representative organisms include bivalves (*Thyasira flexuosa, Nucula tenuis, Musculus discors*), annelids (*Nephtys incisa, Paramphinome pulchella, Onuphis opalina, Sternaspis scutata),* the brittle star *Ophiura sarsi,* the amphipod *Haploops tubicola*, and red crab (*Geryon quedens*). Valentine and Lough (1991) did not identify a comparable assemblage; however, this assemblage is geographically located adjacent to Assemblage 5 as described by Watling (1998) (Table 2.1, Figure 2.5)

The Northeast Peak assemblage is found along the Northern Edge and Northeast Peak, which varies in depth and current strength and includes coarse sediments, mainly gravel and coarse sand with interspersed boulders, cobbles and pebbles. Fauna tend to be sessile (coelenterates, brachiopods, barnacles, and tubiferous annelids) or free-living (brittlestars, crustaceans and polychaetes), with a characteristic absence of burrowing forms. Representative organisms include amphipods (*Acanthonotozoma serratum*, *Tiron spiniferum*), the isopod *Rocinela americana*, the barnacle *Balanus hameri*, annelids *Harmothoe imbricata*, *Eunice pennata*, *Nothria conchylega*, and *Glycera capitata*, sea scallops (*Placopecten magellanicus*), brittlestars (*Ophiacantha bidentata*, *Ophiopholis aculeata*), and soft corals (*Primnoa resedaeformis*, *Paragorgia arborea*).

The Central Georges Bank assemblage occupies the greatest area, including the central and northern portions of the bank in depths less than 100 m. Medium grained shifting sands predominate this dynamic area of strong currents. Organisms tend to be small to moderately large in size with burrowing or motile habits. Sand dollars (*Echinarachnius parma*) are most characteristic of this assemblage. Other representative species include mysids (*Neomysis americana*, *Mysidopsis bigelowi*), the isopod *Chiridotea tuftsi*, the cumacean *Leptocuma minor*, the amphipod *Protohaustorius wigleyi*, annelids (*Sthenelais limicola, Goniadella gracilis, Scalibregma inflatum*), gastropods (*Lunatia heros*, *Nassarius trivittatus*), starfish (*Asterias vulgaris*), *Crangon septemspinosa* shrimp and the crab *Cancer irroratus*.

The Southern Georges Bank assemblage is found on the southern and southwestern flanks at depths from 80 m to 200 m, where fine grained sands and moderate currents predominate. Many southern species exist here at the northern limits of their range. Dominant fauna include amphipods, copepods, euphausiids and starfish genus *Astropecten*. Representative organisms include amphipods (*Ampelisca compressa, Erichthonius rubricornis, Synchelidium americanum*), the cumacean *Diastylis quadrispinosa,* annelids (*Aglaophamus circinata*, *Nephtys squamosa, Apistobranchus tullbergi*), crabs (*Euprognatha rastellifera, Catapagurus sharreri*) and the shrimp *Munida iris*.

Along with high levels of primary productivity, Georges Bank has been historically characterized by high levels of fish production. Several studies have attempted to identify demersal fish assemblages over large spatial scales. Overholtz and Tyler (1985) found five depth-related groundfish assemblages for Georges Bank and the Gulf of Maine that were persistent temporally and spatially (Table 2.2). Depth and salinity were identified as major physical influences explaining assemblage structure. Gabriel identified six assemblages, which are compared with the results of Overholtz & Tyler (1985) in Table 2.2. Mahon *et al.* (1998) found similar results.

Mid-Atlantic Bight

The Mid-Atlantic Bight includes the shelf and slope waters from Georges Bank south to Cape Hatteras, and east to the Gulf Stream (Figure 2.1). Like the rest of the continental shelf, the topography of the Mid-Atlantic Bight was shaped largely by sea level fluctuations caused by past ice ages. The shelf’s basic morphology and sediments derive from the retreat of the last ice sheet, and the subsequent rise in sea level. Since that time, currents and waves have modified this basic structure.

Shelf and slope waters of the Mid-Atlantic Bight have a slow southwestward flow which is occasionally interrupted by warm core rings or meanders from the Gulf Stream. On average, shelf water moves parallel to bathymetry isobars at speeds of 5-10 cm/second at the surface and 2 cm/second or less at the bottom. Storm events can cause much more energetic variations in flow. Tidal currents on the inner shelf have a higher flow rate of 20 cm/second that increases to 100 cm/second near inlets.

Slope water tends to be warmer than shelf water because of its proximity to the Gulf Stream, and also tends to be more saline. The abrupt gradient where these two water masses meet is called the shelf-slope front. This front is usually located at the edge of the shelf and touches bottom at about 75-100 m depth of water, and then slopes up to the east toward the surface. It reaches surface waters approximately 25-55 km further offshore. The position of the front is highly variable, and can be influenced by many physical factors. Vertical structure of temperature and salinity within the front can develop complex patterns because of the interleaving of shelf and slope waters – for example cold shelf waters can protrude offshore, or warmer slope water can intrude up onto the shelf.

The seasonal effects of warming and cooling increase in shallower, nearshore waters. Stratification of the water column occurs over the shelf and the top layer of slope water during the spring-summer and is usually established by early June. Fall mixing results in homogenous shelf and upper slope waters by October in most years. A permanent thermocline exists in slope waters from 200-600 m deep. Temperatures decrease at the rate of about 0.02º C per meter and remain relatively constant except for occasional incursions of Gulf stream eddies or meanders. Below 600 m, temperature declines, and usually averages about 2.2º C at 4000 m. A warm, mixed layer approximately 40 m thick resides above the permanent thermocline.

The “cold pool” is an annual phenomenon particularly important to the Mid-Atlantic Bight. It stretches from the Gulf of Maine along the outer edge of Georges Bank and then southwest to Cape Hatteras. It becomes identifiable with the onset of thermal stratification in the spring and lasts into early fall until normal seasonal mixing occurs. It usually exists along the bottom between the 40 and 100 m isobaths and extends up into the water column for about 35 m, to the bottom of the seasonal thermocline. The cold pool usually represents about 30% of the volume of shelf water. Minimum temperatures for the cold pool occur in early spring and summer, and range from 1.1º C to 4.7º C.

The shelf slopes gently from shore out to between 100 and 200 km offshore where it transforms to the slope (100 – 200 m water depth) at the shelf break. In both the Mid-Atlantic and on Georges Bank, numerous canyons incise the slope, and some cut up onto the shelf itself (see section on Continental Slope). The primary morphological features of the shelf include shelf valleys and channels, shoal massifs, scarps, and sand ridges and swales (Figures 2.7 and 2.8).

Most of these structures are relic except for some sand ridges and smaller sand-formed features. Shelf valleys and slope canyons were formed by rivers glacier out-wash that deposited sediments on the outer shelf edge as they entered the ocean. Most valleys cut about 10 m into the shelf, with the exception of the Hudson Shelf Valley that is about 35 m deep. The valleys were partially filled as the glacier melted and egressed across the shelf. The glacier also left behind a lengthy scarp near the shelf break from Chesapeake Bay north to the eastern end of Long Island

(Figures 2.7 and 2.8). Shoal retreat massifs were produced by extensive deposition at a cape or estuary mouth. Massifs were also formed as estuaries retreated across the shelf.

The sediment type covering most of the shelf in the Mid-Atlantic Bight is sand, with some relatively small localized areas of sand-shell and sand-gravel. On the slope, silty-sand, silt and clay predominate.

Some sand ridges (Figure 2.7) are more modern in origin than the shelf's glaciated morphology. Their formation is not well understood; however, they appear to develop from the sediments that erode from the shore face. They maintain their shape, so it is assumed that they are in equilibrium with modern current and storm regimes. They are usually grouped, with heights of about 10 m, lengths of 10-50 km and spacing of 2 km. Ridges are usually oriented at a slight angle towards shore, running in length from northeast to southwest. The seaward face usually has the steepest slope. Sand ridges are often covered with smaller similar forms such as sand waves, megaripples, and ripples. Swales occur between sand ridges. Since ridges are higher than the adjacent swales, they are exposed to more energy from water currents, and experience more sediment mobility than swales. Ridges tend to contain less fine sand, silt and clay while relatively sheltered swales contain more of the finer particles. Swales have greater benthic macrofaunal density, species richness and biomass, due in part to the increased abundance of detrital food and the physically less rigorous conditions.

Sand waves are usually found in patches of 5-10 with heights of about 2 m, lengths of 50-100 m and 1-2 km between patches. Sand waves are primarily found on the inner shelf, and often observed on sides of sand ridges. They may remain intact over several seasons. Megaripples occur on sand waves or separately on the inner or central shelf. During the winter storm season, they may cover as much as 15% of the inner shelf. They tend to form in large patches and usually have lengths of 3-5 m with heights of 0.5-1 m. Megaripples tend to survive for less than a season. They can form during a storm and reshape the upper 50-100 cm of the sediments within a few hours. Ripples are also found everywhere on the shelf, and appear or disappear within hours or days, depending upon storms and currents. Ripples usually have lengths of about 1-150 cm and heights of a few centimeters.

Sediments are fairly uniformly distributed over the shelf in this region (see Figure 2.3). A sheet of sand and gravel varying in thickness from 0 to 10 m covers most of the shelf. The mean bottom flow from the constant southwesterly current is not fast enough to move sand, so sediment transport must be episodic. Net sediment movement is in the same southwesterly direction as the current. The sands are mostly medium to coarse grains, with finer sand in the Hudson Shelf Valley and on the outer shelf. Mud is rare over most of the shelf, but is common in the Hudson Shelf Valley. Occasionally relic estuarine mud deposits are re-exposed in the swales between sand ridges. Fine sediment content increases rapidly at the shelf break, which is sometimes called the "mud line," and sediments are 70-100% fines on the slope.

The northern portion of the mid-Atlantic bight is sometimes referred to as southern New England. Most of this area was discussed under Georges Bank; however, one other formation of this region deserves note. The mud patch is located just southwest of Nantucket Shoals and southeast of Long Island and Rhode Island (Figure 2.3). Tidal currents in this area slow significantly, which allows silts and clays to settle out. The mud is mixed with sand, and is occasionally resuspended by large storms. This habitat is an anomaly of the outer continental shelf.

Artificial reefs are another significant mid-Atlantic habitat, formed much more recently on the geologic time-scale than other regional habitat types. These localized areas of hard structure have been formed by shipwrecks, lost cargoes, disposed solid materials, shoreline jetties and groins, submerged pipelines, cables, and other materials (Steimle and Zetlin 2000). While some of materials have been deposited specifically for use as fish habitat, most have an alternative primary purpose; however, they have all become an integral part of the coastal and shelf ecosystem. It is expected that the increase in these materials has had an impact on living marine resources and fisheries, but these effects are not well known. In general, reefs are important for attachment sites, shelter, and food for many species, and fish predators such as tunas may be attracted by prey aggregations, or may be behaviorally attracted to the reef structure. The overview by Steimle and Zetlin (2000) used NOAA hydrographic surveys to plot rocks, wrecks, obstructions, and artificial reefs, which together were considered a fairly complete list of non-biogenic reef habitat in the mid-Atlantic estuarine and coastal areas (Figure 2.9).

Characteristic Mid-Atlantic Bight Habitats

Three broad faunal zones related to water depth and sediment type were identified in the Mid-Atlantic by Pratt (1973). The “sand fauna” zone was defined for sandy sediments (1% or less silt) which are at least occasionally disturbed by waves, from shore out to 50 m (Figure 2.10). The “silty sand fauna” zone occurred immediately offshore from the sand fauna zone, in stable sands containing at least a few percent silt and slightly more (2%) organic material. Silts and clays become predominant at the shelf break and line the Hudson Shelf Valley, and support the “silt-clay fauna.”

Building on Pratt’s work, the Mid-Atlantic shelf was further divided by Boesch (1979) into seven bathymetric/morphologic subdivisions based on faunal assemblages (Table 2.5). Sediments in the region studied (Hudson Shelf Valley south to Chesapeake Bay) were dominated by sand with little finer materials. Ridges and swales are important morphological features in this area. Sediments are coarser on the ridges, and the swales have greater benthic macrofaunal density, species richness and biomass. Faunal species composition differed between these features, and Boesch incorporated this variation in his subdivisions (Table 2.5). Much overlap of species distributions was found between depth zones, so the faunal assemblages represented more of a continuum than distinct zones.

Wigley and Theroux (1981) found a general trend in declining macrobenthic invertebrate density from coastal areas offshore to the slope, and on the shelf from southern New England south to Virginia/North Carolina. There were no detectable trends in density from north to south on the slope. Number of individuals was greatest in gravel sediments, and declined in sand-gravel, sand-shell, sand, shell, silty sand, silt and finally clay. However, biomass of benthic macrofauna was greatest in shell habitat, followed by silty sand, gravel, sand-gravel, sand, sand-shell, silt and clay.

Demersal fish assemblages were described at a broad geographic scale for the continental shelf and slope from Cape Chidley, Labrador to Cape Hatteras, North Carolina (Mahon *et al.* 1998) and from Nova Scotia to Cape Hatteras (Gabriel 1992). Factors influencing species distribution included latitude and depth. Results of these studies were similar to an earlier study confined to the Mid-Atlantic Bight continental shelf (Colvocoresses and Musick 1983). In this study, there were clear variations in species abundances, yet they demonstrated consistent patterns of community composition and distribution among demersal fishes of the Mid-Atlantic shelf. This is especially true for five strongly recurring species associations that varied slightly by season (Table 2.6). The boundaries between fish assemblages generally followed isotherms and isobaths. The assemblages were largely similar between the spring and fall collections, with the most notable change being a northward and shoreward shift in the temperate group in the spring.

In an overview discussion of mid-Atlantic reef habitats, Steimle and Zetlin (2000) described representative epibenthic/epibiotic, motile epibenthic, and fish species associated with this sparsely scattered habitat type consisting mainly of manmade structures (Table 2.7). In their work, geographic differences between areas of the mid-Atlantic were also identified.

Continental Slope

The continental slope extends from the continental shelf break, at depths between 60 m and 200 m, eastward to a depth of 2000 m. The width of the slope varies from 10-50 km, with an average gradient of 3-6°; however, local gradients can be nearly vertical. The base of the slope is defined by a marked decrease in seafloor gradient where the continental rise begins.

The morphology of the present continental slope appears largely to be a result of sedimentary processes that occurred during the Pleistocene, including:

1) slope up-building and progradation by deltaic sedimentation principally during sea-level low-stands;

2) canyon-cutting by sediment mass movements during and following sea-level low-stands;

3) sediment slumping.

The slope is cut by at least 70 large canyons between Georges Bank and Cape Hatteras (Figure 2.11) and numerous smaller canyons and gullies, many of which may feed into the larger canyon systems. The New England Seamount Chain including Bear, Mytilus, and Balanus Seamounts, occurs on the slope southwest of Georges Bank. A smaller chain (Caryn, Knauss, etc.) occurs in the vicinity in deeper water.

A “mud line” occurs on the slope at a depth of 250 m – 300 m, below which fine silt and clay-size particles predominate (Figure 2.3). Localized coarse sediments and rock outcrops are found in and near canyon walls, and occasional boulders occur on the slope as a result of glacial rafting. Sand pockets may also be formed as a result of downslope movements.

Gravity induced downslope movement is the dominant sedimentary process on the slope, and includes slumps, slides, debris flows, and turbidity currents, in order from thick cohesive movement to relatively non-viscous flow. Slumps may involve localized, short, down-slope movements by blocks of sediment. However, turbidity currents can transport sediments thousands of kilometers.

Submarine canyons are not spaced evenly along the slope, but tend to decrease in areas of increasing slope gradient. Canyons are typically "v"-shaped in cross section and often have steep walls and outcroppings of bedrock and clay. The canyons are continuous from the canyon heads to the base of the continental slope. Some canyons end at the base of the slope, but others continue as channels onto the continental rise. Larger and more deeply incised canyons are generally significantly older than smaller ones, and there is also evidence that some older canyons have experienced several episodes of filling and re-excavation. Many, if not all, submarine canyons may first form by mass-wasting processes on the continental slope, although there is evidence that some canyons formed as a result of fluvial drainage (*i.e.*, Hudson Canyon).

Canyons can alter the physical processes in the surrounding slope waters. Fluctuations in the velocities of the surface and internal tides can be large near the heads of the canyons, leading to enhanced mixing and sediment transport in the area. Shepard *et al.* (1979) concluded that the strong turbidity currents initiated in study canyons were responsible for enough sediment erosion and transport to maintain and modify those canyons. Since surface and internal tides are ubiquitous over the continental shelf and slope, it can be anticipated that these fluctuations are important for sedimentation processes in other canyons as well. In Lydonia Canyon, Butman *et al.* (1982) found that the dominant source of low-frequency current variability was related to passage of warm core Gulf Stream rings rather than the atmospheric events that predominate on the shelf.

The water masses of the Atlantic continental slope and rise are essentially the same as those of the North American Basin (defined in Wright and Worthington 1970). Worthington (1976) divided the water column of the slope into three vertical layers: deep water (colder than 4°C), the thermocline (4°-17°C), and surface water (warmer than 17°C). In the North American Basin deep water accounts for two-thirds of all the water, the thermocline for about one-quarter, and surface water the remainder. In the slope water north of Cape Hatteras, the only warm water occurs in the Gulf Stream and in seasonally influenced summer waters.

The principal cold water mass in the region is the North Atlantic Deep Water. North Atlantic Deep Water is comprised of a mixture of five sources: Antarctic Bottom Water, Labrador Sea Water, Mediterranean Water, Denmark Strait Overflow Water, and Iceland-Scotland Overflow Water. The thermocline represents a fairly straightforward water mass compared with either the deep water or the surface water. Nearly 90% of all thermocline water comes from the water mass called the Western North Atlantic Water. This water mass is slightly less saline northeast of Cape Hatteras due to the influx of southward flowing Labrador Coastal Water. Seasonal variability in slope waters penetrates only the upper 200 m of the water column.

In the winter months, cold temperatures and storm activity create a well-mixed layer down to about 100-150 m, but summer warming creates a seasonal thermocline overlain by a surface layer of low-density water. The seasonal thermocline, in combination with reduced storm activity in the summer, inhibits vertical mixing and reduces the upward transfer of nutrients into the photic zone.

Two currents found on the slope, the Gulf Stream and Western Boundary Undercurrent, together represent one of the strongest low frequency horizontal flow systems in the world. Both currents have an important influence on slope waters. Warm and cold core rings that spin off the Gulf

Stream are a persistent and ubiquitous feature of the Northwest Atlantic Ocean (see section on Gulf Stream). The Western Boundary Undercurrent flows to the southwest along the lower slope and continental rise in a stream about 50 km wide. The boundary current is associated with the spread of North Atlantic Deep Water, and it forms part of the generally westward flow found in slope water. North of Cape Hatteras it crosses under the Gulf Stream in a manner not yet completely understood.

Gulf Stream and Associated Features

Shelf and slope waters of the Northeast are intermittently but intensely affected by the Gulf Stream. The Gulf Stream begins in the Gulf of Mexico and flows northeastward at an approximate rate of 1 m/second (2 knots), transporting warm waters north along the eastern coast of the United States, and then east towards the British Isles. Conditions and flow of the Gulf Stream are highly variable on time scales ranging from days to seasons. Intrusions from the Gulf Stream constitute the principal source of variability in slope waters off the northeastern shelf.

The location of the Gulf Stream's shoreward, western boundary is variable because of meanders and eddies. Gulf Stream eddies are formed when extended meanders enclose a parcel of sea water and pinch off. These eddies can be cyclonic, meaning they rotate counterclockwise and have a cold-core formed by enclosed slope water (cold core ring), or anticyclonic, meaning they rotate clockwise and have a warm core of Sargasso Sea water (warm core ring). The rings are shaped like a funnel, wider at the top and narrower at the bottom, and can have depths of over 2000 m. They range in size from approximately 150-230 m in diameter. There are 35% more rings and meanders in the vicinity of Georges Bank than in the Mid-Atlantic region. A net transfer of water on and off the shelf may result from the interaction of rings and shelf waters. These warm or cold core rings maintain their identity for several months until they are reabsorbed by the Gulf Stream. The rings and the Gulf Stream itself have a great influence over oceanographic conditions all along the continental shelf.

Characteristic Slope Habitats

Polychaetes represent the most important slope faunal group in terms of numbers of individuals and species (Wiebe *et al.* 1987). Ophiuroids are considered to be among the most abundant slope organisms, but this group is comprised of relatively few species. The taxonomic group with the highest species diversity includes the peracarid crustaceans represented by Amphipoda, Cumacea, Isopoda, and the Tanaidacea. Some species of the slope are widely distributed, while others appear to be restricted to particular ocean basins. The ophiuroids and bivalves appear to have the broadest distributions, while the peracarid crustaceans appear to be highly restricted because they brood their young, and lack a planktonic stage of development. In general, gastropods do not appear to be very abundant; however past studies are inconclusive since they have not collected enough individuals for large-scale community and population studies.

In general, slope-inhabiting benthic organisms are strongly zoned by depth and/or water temperature, although these patterns are modified by the presence of topography, including canyons, channels, and current zonations (Hecker 1990). Moreover, at depths of less than 800 meters, the fauna is extremely variable and the relationships between faunal distribution and substrate, depth, and geography are less obvious (Wiebe *et al.* 1987). Fauna occupying hard-surface sediments is not as dense as in comparable shallow-water habitats (Wiebe *et al.* 1987), but there is an increase in species diversity from the shelf to the intermediate depths of the slope. Diversity then declines again in the deeper waters of the continental rise and plain. Hecker (1990) identified four megafaunal zones on the slope of Georges Bank and southern New England (Table 2.8).

One group of organisms of interest because of the additional structure they can provide for habitat and their potential long life span are the Alcyonarian soft corals. Soft corals can be bush or treelike in shape; species found in this form attach to hard substrates such as rock outcrops or gravel. These species can range in size from a few millimeters to several meters, and the trunk diameter of large specimens can exceed 10 cm. Other Alcyonarians found in this region include sea pens and sea pansies (Order Pennatulacea), which are found in a wider range of substrate types. In their survey of northeastern U.S. shelf macrobenthic invertebrates, Theroux and Wigley (1998) found Alcyonarians (including soft corals *Alcyonium sp.*, *Acanella sp.*, *Paragorgia arborea, Primnoa reseda* and sea pens) in limited numbers in waters deeper than 50 m, and mostly at depths from 200-500 m. Alcyonarians were present in each of the geographic areas identified in the study (Nova Scotia, Gulf of Maine, Southern New England Shelf, Georges Slope, Southern New England Slope) except Georges Bank. However, *Paragorgia* and *Primnoa* have been reported in the Northeast Peak region of Georges Bank (Theroux and Grosslein 1987). Alcyonarians were most abundant by weight in the Gulf of Maine, and by number on the Southern New England Slope (Theroux and Wigley 1998). In this study, Alcyonarians other than sea pens were collected only from gravel and rocky outcrops. Theroux and Wigley (1998) also found stony corals (*Astrangia danae* and *Flabellum sp.*) in the northeast region, but they were uncommon. In similar work on the mid-Atlantic shelf, the only Alcyonarians encountered were sea pens (Wigley and Theroux 1981). The stony coral *Astrangia danae*, was also found, but its distribution and abundance was not discussed, and is assumed to be minimal.

As opposed to most slope environments, canyons may develop a lush epifauna. Hecker *et al.* (1983) found faunal differences between the canyons and slope environments. Hecker and Blechschmidt (1979) suggested that faunal differences were due at least in part to increased environmental heterogeneity in the canyons, including greater substrate variability and nutrient enrichment. Hecker *et al.* (1983) found highly patchy faunal assemblages in the canyons, and also found additional faunal groups located in the canyons, particularly on hard substrates, that do not appear to occur in other slope environments. Canyons are also thought to serve as nursery areas for a number of species (Hecker 2001; Cooper *et al.* 1987). The canyon habitats in Table 2.9 were classified by Cooper *et al.* (1987).

Most finfish identified as slope inhabitants on a broad spatial scale (Gabriel 1992; Overholtz and Tyler 1985; and Colvocoresses and Musik 1983) (Tables 2.2 and 2.6) are associated with canyon features as well (Cooper *et al.*1987) (Table 2.9). Finfish identified by broad studies that were not included in Cooper *et al.* (1987) include offshore hake, fawn cusk-eel, longfin hake, witch flounder and armored searobin. Canyon species (Cooper *et al.* 1987) that were not discussed in the broad scale studies include squirrel hake, conger eel and tilefish. Cusk and ocean pout were identified by Cooper *et al.* (1987) as canyon species, but classified in other habitats by the broad scale studies.

Coastal Features

Coastal and estuarine features such as salt marshes, mud flats, rocky intertidal zones, sand beaches, and submerged aquatic vegetation are critical to inshore and offshore habitats and fishery resources of the Northeast. For example, coastal areas and estuaries are important for nutrient recycling and primary production, and certain features serve as nursery areas for juvenile stages of economically important species. Salt marshes are found extensively throughout the region. Tidal and subtidal mud and sand flats are general salt marsh features and are also occur in other estuarine areas . Salt marshes provide nursery and spawning habitat for many finfish and shellfish species. Salt marsh vegetation can also be a large source of organic material that is important to the biological and chemical processes of the estuarine and marine environment.

Rocky intertidal zones are periodically submerged, high-energy environments found in the northern portion of the Northeast system. Sessile invertebrates and some fish inhabit rocky intertidal zones. A variety of algae, kelp, and rockweed are also important habitat features of rocky shores. Fishery resources may depend upon particular habitat features of the rocky intertidal that provide important levels of refuge and food.

Sandy beaches are most extensive along the Northeast coast. Different zones of the beach present suitable habitat conditions for a variety of marine and terrestrial organisms. For example, the intertidal zone presents suitable habitat conditions for many invertebrates, and transient fish find suitable conditions for foraging during high tide. Several invertebrate and fish species are adapted for living in the high-energy subtidal zone adjacent to sandy beaches.

3. FISHING GEAR DESCRIPTIONS AND USE

BOTTOM-TENDING MOBILE GEAR

Otter Trawls

Trawls are classified by their function, bag construction, or method of maintaining the mouth opening. Function may be defined by the part of the water column where the trawl operates (*e.g.*, bottom) or by the species that it targets (Hayes 1983). There is a wide range of otter trawl types used in the Northeast as a result of the diversity of fisheries prosecuted and bottom types encountered in the region (NREFHSC 2002). The specific gear design used is often a result of the target species (whether they are found on or off the bottom) as well as the composition of the bottom (smooth versus rough and soft versus hard). There are two three components of the otter trawl that come in contact with the sea bottom: the doors, the ground cables and bridles which attach the doors to the wings of the net, and the sweep (or foot-rope) which runs along the bottom of the net mouth. Bottom trawls are towed at a variety of speeds, but average about 5.5 km/hr (3 knots or nmi/hr).

Doors

The traditional otter board is a flat, rectangular wood structure with steel fittings and a stell "shoe" along the bottom that prevents the bottom of the door from damage and wear as it drags over the bottom. Other types include the V-type (steel), polyvalent (steel), oval (wood), and slotted spherical otter board (steel) (Sainsbury 1996). It is the spreading action of the doors resulting from the angle at which they are mounted that creates the hydrodynamic forces needed to push them apart. These forces also push them down towards the sea floor. On fine-grained sediments, the doors also function to create a silt cloud that aids in herding fish into the mouth of the net (Carr and Milliken 1998). In shallow waters, light-weight doors are typically used to ensure that the doors and the net spread fully. In these cases, light, foam filled doors can be used (Sainsbury 1996). Vessels fishing large nets in deeper water require very large spreading forces from the doors. In these cases, a 15 m^2 (49 ft^2) V-door weighing 640 kg (1480 lbs) can provide 9 metric tons of spreading force (Sainsbury 1996).

Ground Cables and Bridles

Steel cables are used to attach the doors to the wings of the net. The ground cables run along the bottom from each door to two cables (the "bridle") that diverge to attach to the top and bottom of the net wing. The bottom portion of the bridle also contacts the bottom. In New England, fixed rubber discs ("cookies") or rollers are attached to the ground cables and lower bridle. In general, bridles vary in length from 9 m to 73 m (30 - 200 ft) while ground cables can be from 0 to 73 m (200 ft) depending upon bottom conditions and towing speed (Sainsbury 1996). The length of these cables can therefore increase the area swept by the trawl by as much as three fold.

Sweeps

On smooth bottoms, the sweep may be a steel cable weighted with chain, or may be merely rope wrapped with wire. On rougher bottoms, rubber discs ("cookies") or rollers are attached to the sweep to assist the trawl's passage over the bottom (Sainsbury 1996). There are two main types of sweep used in smooth bottom in New England (Mirarchi 1998). In the traditional chain sweep, loops of chain are suspended from a steel cable, with only 2-3 links of the chain touching bottom. Contact of the chain with the bottom reduces the buoyancy of the trawl – which would otherwise be negatively buoyant – to the point where it skims along just a few inches above the bottom to catch species like squid and scup that swim slightly above the bottom. The other type of sweep is heavier and is used on smooth bottom to catch flounder. Instead of a cable, rubber cookies stamped from automobile tires are attached to a heavy chain. This type of sweep is always in contact with the bottom. Cookies vary in diameter from 1.5 to 6.5 cm (4 to 16 inches) and do not rotate (Carr and Milliken 1998).

Roller sweeps and rockhoppers are used on irregular bottom (Carr and Milliken 1998). Vertical rubber rollers rotate freely and are as large as 14.5 cm (36 inches) in diameter. In New England, the rollers have been largely replaced with "rockhopper" gear that uses larger fixed rollers and are designed to "hop" over rocks as large as 1 meter in diameter. Small rubber "spacer" discs are placed in between the larger rubber discs in both types of sweep. Rockhopper gear is no longer used exclusively on hard bottom habitats, but is actually quite versatile and used in a variety of habitat types (NREFHSC 2002). "Street-sweepers" were first used in Massachusetts in 1995, replacing heavier rockhopper gear, and consist of circular brushes up to 12.5 cm (31 inches) in diameter. They are lighter than rubber rockhopper gear and can probably fish much rougher bottom than other sweep designs (Carr and Milliken 1998).

Flatfish are primarily targeted with a mid-range mesh flat net that has more ground rigging and is designed to get the fish up off the bottom. A high rise or fly net with larger mesh is used to catch demersal fish that rise higher off the bottom than flatfish (NREFHSC 2002). Crabs, scallops, and lobsters are also harvested in large mesh bottom trawls.

Small mesh bottom trawls are used to capture northern and southern shrimp, whiting, butterfish and squid and usually employ a light chain sweep. Small-mesh trawls are designed, rigged, and used differently than large-mesh fish trawls. Bottom trawls used to catch northern shrimp in the Gulf of Maine, for example, are smaller than most fish trawls and are towed at slower speeds (<2 knots versus 4 knots or so for a fish trawl). Footropes range in length from 12 m to over 30 m (40 - 100 ft), but most are 15 to 27 m (50 - 90 ft). Because shrimp inhabit flatter bottom than many fish do, roller gear tend to be smaller in diameter on shrimp nets because they are not towed over rough bottom (Dan Schick, Maine Dept. of Marine Resources, personal communication). Because shrimp can not be herded in the same manner as fish, footropes on shrimp trawls are bare (no cookies) and are limited to 27 m (90 ft) in length (D. Schick, personal communication). Northern shrimp trawls are also equipped with Nordmore grates in the funnel of the net to reduce the by-catch of groundfish. Southern shrimp trawlers that catch brown and white shrimp typically tow 2-4 small trawls from large booms extended from each side of the vessel (DeAlteris 1998). Northern shrimp trawlers tow a single net astern.

The raised-footrope trawl was designed especially for fishing for whiting, red hake, and dogfish. It was designed to provide vessels with a means of continuing to fish for small mesh species without catching groundfish. In this type of trawl, 1 m (42 inches) long chains connect the sweep to the footrope, which results in the trawl fishing about 0.45 to 0.6 m (1.5-2 ft) above the bottom (Carr and Milliken 1998). The raised footrope and net allows complete flatfish escapement, and theoretically travels over codfish and other roundfish (whiting and red hake tend to swim slightly above the other groundfish). Although the doors of the trawl still ride on the bottom, Carr and Milliken (1998) report that studies have confirmed that the raised footrope sweep has much less contact with the sea floor than does the traditional cookie sweep that it replaces.

An important consideration in understanding the relative effects of different otter trawl configurations is their weight in water relative to their weight in air. Rockhopper gear is not the heaviest type of ground gear used in this region since it loses 80% of its weight in water (*i.e.*, a rockhopper sweep that weighs 1000 pounds on land may only weigh 200 pounds in water) (NREFHSC 2002). Streetsweeper gear is much heavier in the water due to the use of steel cores in the brush components. Plastic-based gear has the smallest weight in water to weight in air ratio (approximately 5%) (NREFHSC 2002). For the same reasons, steel doors are much heavier in water than wooden doors (Mirarchi 1998).

Beam Trawls

The beam trawl is much like an otter trawl except the net is spread horizontally by a steel beam that runs the horizontal width of the net rather than with otter boards. The net is spread vertically by heavy steel trawl heads that generally have skid-type devices with a heavy shoe attached (Sainsbury 1996). Beam trawls currently in use in Europe are up to 12 m (40 ft) in width and very heavy, increasing in weight from 3.5 mt (7,700 lbs) in the 1960s to as much as 10 mt (22,000 lbs) in the 1980s (Rogers *et al.* 1998). Despite the weight of the gear, increased towing power and size of trawlers have allowed towing speeds to reach 14.8 km/hr (8 knots or nmi/hr).

It is believed that beam trawls are not currently used in the Northeast U.S. (NREFHSC 2002). A few beam trawls were used in the 1970s to catch monkfish, but the fishery was unsuccessful. In the mid 1990s, a number of boats off New Bedford, MA used what were referred to as beam trawls, but the gear more closely resembled a scallop dredge rather than the traditional, European beam trawls. There are a few boats that are currently recorded as using beam trawls in the NMFS fishery landings database, but it is believed these were most likely mis-characterized and are actually otter trawls being deployed from the side of the vessels (NREFHSC 2002).

It is unlikely that fishermen would begin using beam trawls in the Northeast U.S. Beam trawls are prevalent in the North Sea where the water is dark and murky and the fisheries target flatfishes, which sit slightly under the sediments. In these fisheries, the beam trawl acts to sieve the fish up off the seafloor. The lack of conventional herding effect and small mouth opening of the beam trawl would not be effective for harvesting U.S. target species. Furthermore, most vessels being used in the Northeastern U.S. do not have the size or power required to handle a beam trawl (NREFHSC 2002). Therefore, beam trawls will not be considered further in this report as a gear type potentially impacting marine habitats off the Northeastern U.S.

Hydraulic Clam Dredges

Hydraulic clam dredges have been used in the surfclam (*Spisula solidissima*) fishery for over five decades and in the ocean quahog (*Arctica islandica*) fishery since its inception in the early 1970s. These dredges are highly sophisticated and are designed to: 1) be extremely efficient (80 to 95% capture rate); 2) produce a very low bycatch of other species; and 3) retain very few undersized clams (NREFHSC 2002).

The typical dredge is 3.7 m (12 feet) wide and about 6.7 m (22 feet) long and uses pressurized water jets to wash clams out of the seafloor. Towing speed at the start of the tow is about 4.5 km/hr (2.5 knots or nmi/hr) and declines as the dredge accumulates clams. The dredge is retrieved once the vessel speed drops below about 3 km/hr (1.5 knots), which can be only a few minutes in very dense beds. However, a typical tow lasts about 15 minutes. The water jets penetrate the sediment in front of the dredge to a depth of about 20 - 25 cm (8 - 10 inches), depending on the type of sediment and the water pressure. The water pressure that is required to fluidize the sediment varies from 50 pounds per square inch (psi) in coarse sand to 110 psi in finer sediments. The objective is to use as little water as possible since too much pressure will blow sediment into the clams and reduce product quality. The “knife” (or “cutting bar”) on the leading bottom edge of the dredge opening is 14 cm (5.5 inches) deep for surfclams and 8.9 cm (3.5 inches) for ocean quahogs. The knife “picks up” clams that have been separated from the sediment and guides them into the body of the dredge (“the cage”). If the knife size is not appropriate, clams can be cut and broken, resulting in significant mortality of clams left on the bottom. The downward pressure created by the runners on the dredge is about 1 psi (NREFHSC 2002).

The high water pressure associated with the hydraulic dredge can cause damage to the flora and fauna associated with bottom habitats. However, water pressure greater than that required for harvesting will reduce the quality of the clams by loading them with sand and increase the rate of clam breakage. Therefore higher, more damaging water pressures are usually not used.

Before 1990, two types of hydraulic dredges were common in the fishery, stern rig dredges and side rig dredges. A side rig dredge has a chain bag that drags behind the dredge and smooths out the trench created by the dredge. The chain bag results in significantly more damage to small clams and other bycatch than occurs with the stern rig dredge. Currently, most of the dredges in the fishery are stern rig dredges, which are basically giant sieves. Small clams and bycatch fall through the bottom of the cage into the trench and damage or injury to benthic organisms is minimal. Improvements in gear efficiency have reduced bottom time and helped to confine the harvest of surfclams to a relatively small area in the mid-Atlantic Bight (NREFHSC 2002).

Hydraulic clam dredges can be operated in areas of large grain sand, fine sand, sand and small grain gravel, sand and small amounts of mud, and sand and very small amounts of clay. Most tows are made in large grain sand. Dredges are not fished in clay, mud, pebbles, rocks, coral, large gravel greater than one half inch, or seagrass beds (NREFHSC 2002).

In the soft-clam (*Mya arenaria*) fishery, the dredge manifold and blade are located just forward of an escalator, or conveyor belt, that carries the clams to the deck of the vessel. These vessels are restricted to water depths less than one-half the length of the escalator and are typically operated from 15 m (49ft) vessels in water depths of 2-6 m (6.6 - 20 ft) (DeAlteris, 1998). The escalator dredge is not managed under federal fishery management plans. A variation of this type of dredge, the suction dredge, is used in Europe to harvest several bivalve species. Sediment and clams that are dislodged by water pressure are sucked through a hose to the vessel. These dredges are also restricted to shallow water.

Sea Scallop Dredges

The New Bedford scallop dredge is the primary gear used in the Georges Bank and mid-Atlantic sea scallop (*Placopecten magellanicus*) fishery and is very different than dredges utilized in Europe and the Pacific because it is a toothless dredge.

The forward edge of the New Bedford dredge includes the cutting bar, which rides above the surface of the substrate, creating turbulence that stirs up the substrate and kicks objects (including scallops) up from the surface of the substrate into the bag. Shoes on the cutting bar are in contact with and ride along the substrate surface (NREFHSC 2002). A sweep chain is attached to each shoe and attaches to the bottom of the ring bag (Smolowitz 1998). The bag is made up of metal rings with chafing gear on the bottom and twine mesh on the top, and drags on the substrate when fished. Tickler chains run from side to side between the frame and the ring bag and, in hard bottom scalloping, a series of rock chains run from front to back to prevent large rocks from getting into the bag (Smolowitz 1998). New Bedford dredges are typically 4.3 m (14 feet) wide; two of them are towed by a single vessel at speeds of 4 to 5 knots. New Bedford dredges used along the Maine coast are smaller. Towing times are highly variable, depending on how many marketable sized scallops are on the bottom and the location.

In the Northeast region, scallop dredges are used in high and low energy sand environments, and high energy gravel environments. Although gravel exists in low energy environments of deepwater banks and ridges in the Gulf of Maine, the fishery is not prosecuted there (NREFHSC 2002).

The leading edge of scallop dredges used in Europe, Australia, and New Zealand to catch other species of scallop that "dig" into the bottom have teeth which dig into the substrate. This type of dredge is used by smaller vessels that are not able to tow a non-toothed dredge fast enough (4-5 knots) to fish effectively (NREFHSC 2002). Some of the European scallop dredges are spring-loaded so that the cutting bar flexes backward when it contacts a hard object on the bottom, then springs back when the dredge passes over the obstacle. These dredges are approximately 0.75 m (2.5 ft) wide and may be fished in gangs of 3-9 dredges on either side of the vessel (Kaiser *et al.* 1996a). A typical tooth bar bears 9 teeth, 11 cm (4.3 inches) long, spaced about 8 cm (3 inches) apart. French dredges, 2 m (6.6 ft) wide, are not spring-loaded and generally are fished on cleaner ground. They are fitted with a diving vane to improve penetration of the bottom. Scallop dredges used in Australia and New Zealand are heavy, rigid, wire mesh "boxes" that do not have a chain bag (McLoughlin *et al.* 1981). A very limited amount of scallop dredging with toothed dredges (*e.g.*, the "Digby" dredge) takes place along the U.S. and Canadian coast of the Gulf of Maine.

Other Non-Hydraulic Dredges

Quahog Dredge

Mahogany quahogs (same species, *Arctica islandica*, as harvested in the mid-Atlantic) are harvested in eastern Maine coastal waters using a dredge that is essentially a large metal cage on skis with 15 cm (6 inch) long teeth projecting at an angle off the leading bottom edge (Pete Thayer, Maine Dept. of Marine Resources, personal communication). Maine state regulations limit the length of the cutter bar to 91 cm (36 inches). The teeth rake the bottom and lift the quahogs into the cage. This fishery takes place in small areas of sand and sandy mud found among bedrock outcroppings in depths of 9 to > 76 m (30 - 250 ft) in state and federal coastal waters north of 43°20' N latitude. These dredges are used on smaller boats, about 9 - 12 m long (30 to 40 ft) and are pulled through the seabed using the boat's engine (NREFHSC 2002). This dredging activity is managed under a federal fishery management plan.

Oyster or Crab Dredge/Scrape/Mussel Dredge

The oyster dredge is a toothed dredge consisting of a steel frame 0.5-2.0 m (1.6 -6.6 ft.) in width, a tow chain or wire attached to the frame, and a bag to collect the catch. The bag is constructed of rings and chain-links on the bottom to reduce the abrasive effects of the seabed, and twine or webbing on top. The dredge is towed slowly (<1 m/sec) in circles, from vessels 7 to 30 m (23 - 98 ft.) in length (DeAlteris 1998). Crabs are harvested with dredges similar to oyster dredges. Stern-rig dredge boats (approximately 15 m (49') in length) tow two dredges in tandem from a single chain warp. The dredges are equipped with 10 cm (4 inch) long teeth that rake the crabs out of the bottom. (DeAlteris 1998). The toothed dredge is also used for harvesting mussels (Hayes 1983). These dredging activities are not managed under federal fishery management plans

Bay Scallop Dredge

Bay scallops usually reside on the bottom. The bay scallop dredge may be 1 to 1.5 m (3.3 - 4.9 ft.) wide and about twice as long. The simplest bay scallop dredge can be just a mesh bag attached to a metal frame that is pulled along the bottom. For bay scallops that are located on sand and pebble bottom, a small set of raking teeth are set on a steel frame, and skids are used to align the teeth and the bag (Sainsbury 1996). This dredging activity is not managed under federal fishery management plans.

Sea Urchin Dredge

Similar to a simple bay scallop dredge, the sea urchin dredge is designed to avoid damaging the catch. It has an up-turned sled-like shape at the front that includes several leaf springs tied together with a steel bar. A tow bail is welded to one of the springs and a chain mat is rigged behind the mouth box frame. The frame is fitted with skids or wheels. The springs act as runners, enabling the sled to move over rocks without hanging up. The chain mat scrapes up the urchins. The bag is fitted with a codend for ease of emptying. This gear is generally only used in waters up to 100 m (330 ft.) deep (Sainsbury 1996). This dredging activity is not managed under federal fishery management plans.

Clam “Kicking”

Clam kicking is a mechanical form of hard clam harvest practiced in North Carolina which involves the modification of boat engines so that the propeller is directed downwards instead of backwards (Guthrie and Lewis 1982). In shallow water the propeller wash is powerful enough to suspend bottom sediments and clams into a plume in the water column, which allows them to be collected in a trawl net towed behind the boat (Stephan *et al.* 2000). This activity is not managed under federal fishery management plans.

Seines

Haul Seines

Haul seining is a general term describing operations where a net is set out between the surface and sea bed to encircle fish. It may be undertaken from the shore (beach seining), or away from shore in the shallows of rivers, estuaries or lakes (Sainsbury 1996). Seines typically contact the sea bottom along the lead line. Additionally the net itself may scrape along the bottom as it is dragged to shore or the recovery vessel. This activity is not managed under federal fishery management plans.

Beach Haul Seines

The beach seine resembles a wall of netting of sufficient depth to fish from the sea surface to the sea bed, with mesh small enough that the fish do not become gilled. A floatline runs along the top to provide floatation and a leadline with a large number of weights attached ensures that the net maintains good contact with the bottom. Tow lines are fitted to both ends. The use of a beach seine generally starts with the net on the beach. One end is pulled away from the beach, usually with a small skiff or dory, and is taken out and around and finally back in to shore. Each end of the net is then pulled in towards the beach, concentrating the fish in the middle of the net. This is eventually brought onshore as well and the fish removed. This gear is generally used in relatively shallow inshore areas. (Sainsbury 1996). This activity is not managed under federal fishery management plans

Long Haul Seines

The long haul seine is set and hauled in shallow estuarine and coastal areas from a boat typically 15 m (49 ft.) long. The net is a single wall of small mesh webbing less than 5 cm (2 inches), and is usually greater than 400 m (1440 ft.) in length and about 3 m (9.8 ft.) in depth. The end of the net is attached to a pole driven into the bottom, and the net is set in a circle so as to surround fish feeding on the tidal flat. After closing the circle, the net is hauled into the boat, reducing the size of the circle, and concentrating the fish. Finally, the live fish are brailed or dip-netted out of the net. (DeAlteris 1998). This activity is not managed under federal fishery management plans

Stop Seines

These are seines that are used in coastal embayments to close off the opening to a small cove or bight. This method is used in Maine to harvest schools of juvenile herring (Everhart and Youngs 1981). This activity is not managed under federal fishery management plans

Danish and Scottish Seines

Danish or Long seining or anchor dragging was developed in the 1850s prior to the advent of otter trawling. The Danish seine is a bag net with long wings, that includes long warps set out on the seabed enclosing a defined area. As the warps are retrieved, the enclosed area (a triangle) reduces in size. The warps dragging along the bottom herd the fish into a smaller area, and eventually into the net mouth. The gear is deployed by setting out one warp, the net, then the other warp. On retrieval of the gear, the vessel is anchored. This technique of fishing is aimed at specific schools of fish located on smooth bottom. In contrast to Danish seining, if the vessel tows ahead while retrieving the gear, then this is referred to as Scottish seining or fly-dragging. This method of fishing is considered more appropriate for working small areas of smooth bottom, surrounded by rough bottom. Scottish and Danish seines have been used experimentally in U.S. demersal fisheries. Space conflicts with other mobile and fixed gears, have precluded the further development of this gear in the U.S., as compared to Northern Europe (DeAlteris 1998). This activity is managed under federal fishery management plans

BOTTOM-TENDING STATIC GEAR

Pots

Pots are portable, rigid devices that fish and shellfish enter through small openings, with or without enticement by bait (Everhart and Youngs 1981; Hubert 1983). They are used to capture lobsters, crabs, black sea bass, eels and other bottom dwelling species seeking food or shelter (Everhart and Youngs 1981; Hubert 1983). Pot fishing can be divided into two general classifications: 1) inshore potting in estuaries, lagoons, inlets and bays in depths up to about 75 m (250 ft.) and; 2) Offshore pottting using larger and heavier vessels and gear in depths up to 730 m (2400 ft.) or more (Sainsbury 1996).

Lobster Pots

Lobster pots are typically rectangular and are divided into two sections, the chamber and the parlor. The chamber has an entrance on both sides of the pot and is usually baited. Lobsters then move to the parlor via a tunnel (Everhart and Youngs 1981). Escape vents are installed in both areas of the pot to minimize the retention of sub-legal sized lobsters (DeAlteris 1998).

Lobster pots are fished as either 1) a single pot per buoy (although two pots per buoy are used in Cape Cod Bay, and three pots per buoy in Maine waters), or 2) a “trawl” or line with up to 100 pots. According to NREFHSC (2002) important features of lobster pots and their use are the following:

- About 95% of lobster pots are made of plastic-coated wire.
- Floating mainlines may be up to 7.6 m (25 ft.) off bottom.
- Sinklines are sometimes used where marine mammals are a concern – neutrally buoyant lines may soon be required in Cape Cod Bay.
- Soak time depends on season and location - usually 1-3 days in inshore waters in warm weather, to weeks in colder waters.
- Offshore pots are larger (more than 1 m (4 ft) long) and heavier (~ 100 lb or 45 kg), with an average of ~ 40 pots/trawl and 44 trawls/vessel. They have a floating mainline and are usually deployed for a week at a time.
- There has been a three-fold increase in lobster pots fished since the 1960s, with more than four million pots now in use.

Although the offshore component of the fishery is regulated under federal rules, American lobster is not managed under a federal fishery management plan.

Fish Pots

Black sea bass pots are similar in design to lobster pots. They are usually fished singly or in trawls of up to 25 pots, in shallower waters than the offshore lobster pots or red crab pots. Pots may be set and retrieved 3-4 times/day when fishing for scup (NREFHSC 2002). This activity is managed under a federal fishery management plan. Hagfish pots (40 plastic gallon barrels) are fished in deep waters, on mud bottoms. Cylindrical pots are typically used for capturing eels in Chesapeake Bay, however, half-round and rectangular pots are also used and all are fished in a manner similar to that of lobster pots (Everhart and Youngs 1981). Hagfish and eel activities are not managed under a federal fishery management plan.

Crab Pots

Crabs are often fished with pots consisting of a wire mesh. A horizontal wire partition divides the pot into an upper and lower chamber. The lower chamber is entered from all four sides through small wire tunnels. The partition bulges upward in a fold about 20 cm (8 inches) high for about one third of its width. In the top of the fold are two small openings that give access to the upper chamber (Everhart and Youngs 1981).

Crab pots are always fished as singles and are hauled by hand from small boats, or with a pot hauler in larger vessels. Crab pots are generally fished after an overnight soak, except early and late in the season (DeAlteris 1998). These pots are also effective for eels (Everhart and Youngs 1981). This activity is not managed under a federal fishery management plan.

Deep sea red crab pots are typically wood and wire traps 1.2 m by 0.75 m (48 by 30 inches) with top entry. Pots are baited and soak for about 22 hours before being hauled. Currently, vessels are using an average of 560 pots in trawls of 75- 180 pots per trawl along the continental slope at depths from 400 to 800 m (1300 - 2600 ft). These vessels are typically 25 - 41 m (90 - 150 ft) in length. Currently there are about 6 vessels engaged in this fishery (NEFMC 2002). This activity is managed under a federal fishery management plan.

Traps

A trap is generally a large scale device that uses the seabed and sea surface as boundaries for the vertical dimension. The gear is installed at a fixed location for a season, and is passive, as the animals voluntarily enter the gear. Traps are made of a leader or fence, that interrupts the coast parallel migratory pattern of the target prey, a heart or parlor that leads fish via a funnel into the bay or trap section that serves to hold the catch for harvest by the fishermen. The non-return device is the funnel linking the heart and bay sections (DeAlteris 1998). This activity is not managed under a federal fishery management plan.

Fish Pound Nets

Pound nets are constructed of netting staked into the sea bed by driven piles (Sainsbury 1996). Pound nets have three sections: the leader, the heart, and the pound. The leader (there may be more than one) may be as long as 400 m (1300 ft) and is used to direct fish into the heart(s). One or more hearts are used to further funnel fish into the pound and prevent escapement. The pound may be 15 m (49 ft) square and holds the fish until the net is emptied. These nets are generally fished in waters less than 50 m (160 ft) deep. Pound nets are also used to catch crabs. This activity is not managed under a federal fishery management plan.

Fyke and Hoop Nets

Constructed of wood or metal hoops covered with netting, hoop nets are 2.5 to 5 m (8.2 - 16 ft) long, "Y-shaped" nets, with wings at the entrance and one or more internal funnels to direct fish inside, where they become trapped. Occasionally, a long leader is used to direct fish to the entrance. Fish are removed by lifting the rear end out of the water and loosening a rope securing the closed end. These nets are generally fished to about 50 m (160 ft) deep (Sainsbury 1996). A common fyke net is a long bag mounted on one or several hoops which keep the net from collapsing as well as provide an attachment for the base of the net funnels to prevent the fish from escaping. This gear is used in shallow water and extensively in river fisheries. (Everhart and Youngs 1981). This activity is not managed under a federal fishery management plan.

Weirs

A weir is a simple maze that intercepts species that migrate along the shoreline. Brush weirs are used in the Maine sardine/herring fishery. These are built of wooden stakes and saplings driven into the bottom in shallow waters. The young herring encounter the lead which they follow to deeper water, finally passing into an enclosure of brush or netting. The concentrated fish are then removed with a small seine (Everhart and Youngs 1981). This activity is not managed under a federal fishery management plan.

Shallow Floating Traps

In New England, much of the shoreline and shallow subtidal environment is rocky and stakes can not be driven into the bottom. Therefore, the webbing of these traps is supported by floats at the sea surface, and held in place with large anchors. These traps are locally referred to as "floating traps." The catch, design elements and scale of these floating traps is similar to pound nets (DeAlteris 1998).

The floating trap is designed to fish from top to bottom, and is built especially to suit its location. The trap is held in position by a series of anchors and buoys. The net is usually somewhat "T-shaped," with the long portion of the net (the leader net) designed to funnel fish into a box of net at the top of the T. The leader net is often made fast to a ring bolt ashore (Sainsbury 1996). This activity is not managed under a federal fishery management plan.

Sink Gill Nets and Bottom Longlines

Sink/Anchor Gill Nets

Individual gill nets are typically 91 m (300 feet) long, and are usually fished as a series of 5-15 nets attached end-to-end. Gill nets have three components: leadline, webline and floatline. Fishermen are now experimenting with two leadlines. Leadlines used in New England are ~65 lb (30 kg.)/net; in the Middle Atlantic leadlines may be heavier. Weblines are monofilament, with the mesh size depending on the target species. Nets are anchored at each end, using materials such as pieces of railroad track, sash weights, or Danforth anchors, depending on currents. Anchors and leadlines have the most contact with the bottom. Some nets may be tended several times/day, (*e.g.*, when fishing for bluefish in the Middle Atlantic). For New England groundfish, frequency of tending ranges from daily to biweekly (NREFHSC 2002). These activities are managed under federal fishery management plans.

Stake Gill Nets

Generally a small boat is used inshore so that a gill net is set across a tidal flow and is lifted at slack tide to remove fish. Wooden or metal stakes run from the surface of the water into the sediment and are placed every few meters along the net to hold it in place. When the net is lifted, the stakes remain in place. These nets are generally fished from the surface to about 50 meters deep (Sainsbury 1996). These activities are not managed under federal fishery management plans.

Bottom Longlines

Longlining for bottom species on continental shelf areas and offshore banks is undertaken for a wide range of species including cod, haddock, dogfish, skates, and variuos flatfishes (Sainsbury 1996). A 9.5 m (31 ft) vessel can fish up to 2500 hooks a day with a crew of one and double that with 2 crew members. Mechanized longlining systems fishing off larger vessels up to 60 m (195 ft) can fish up to 40,000 hooks per day (Sainsbury 1996).

In the Northeast up to six individual longlines are strung together, for a total length of about 460 m (1500 ft), and are deployed with 20-24 lb (9 - 11 kg) anchors. The mainline is parachute cord or sometimes stainless steel wire. Gangions (lines from mainline to hooks) are 38 cm (15 inches) long and 1-2 m (3-6 ft) apart. The mainline, hooks, and gangions all come in contact with the bottom. Circle hooks are potentially less damaging to habitat features than other hook shapes. These longlines are usually set for only a few hours at a time (NREFHSC 2002). Longlines used for tilefish are deployed in deep water, may be up to 40 km (25 miles) long, are stainless steel or galvanized wire, and are set in a zig-zag fashion (NREFHSC 2002). These activities are managed under federal fishery management plans.

PELAGIC GEAR

Mid-Water Otter Trawl

The mid-water trawl is used to capture pelagic species that school between the surface and the sea bed throughout the water column. The mouth of the net can range from 110 m to 170 m (360 - 560 ft.) and requires the use of large vessels (Sainsbury 1996). Successful mid-water trawling requires the effective use of various electronic aids to find the fish and maneuver the vessel while catching them (Sainsbury 1996). This activity is managed under federal fishery management plans. This gear is not expected to have contact with or impacts upon bottom habitats.

Paired Mid-Water Trawl

Pair-trawling is used by smaller vessels which herd small pelagics such as herring and mackerel into the net (Sainsbury 1996). Large pelagic species are also harvested with a huge pelagic pair trawl towed at high speed near the surface. The nets have meshes exceeding 10 m (33 ft.) in length in the jibs and first belly sections, and reduce to cod-end mesh sizes of 20 cm (8 inches) (DeAlteris 1998). This activity is managed under federal fishery management plans. This gear is not expected to have contact with or impacts upon bottom habitats.

Purse Seines

Purse seines are very efficient for taking pelagic schooling species. The purse seine is a continuous deep ribbon of web with corks on one side and leads on the other. Rings are fastened at intervals to the lead line and a purse line runs completely around the net through the rings (Everhart and Youngs 1981). One end of the net is fastened to the vessel and the other end to a skiff. The vessel then encircles a school of fish with the net, the net pursed and hauled back to the vessel. Purse seines vary in size according to the vessel size, the size of the mesh, the species sought and the depth to be fished. Tuna seines are nearly one kilometer (0.6 miles) long and fish from 55 - 640 m (180 - 2100 ft.) (Everhart and Youngs 1981) . Due to the large depth of the net for tuna purse seines, they have been shown to contact and interact with the sea bottom when fishing in some shallow water locations such as Massachusetts Bay and vicinity (NMFS 2001). However, these interactions are unintended and rare. This activity is managed under federal fishery management plans.

Drift Gill Nets

Gillnets operate principally by wedging and gilling fish, and secondarily by entangling (DeAlteris 1998). The nets are a single wall of webbing, with float and lead lines. Drift gillnets are designed so as to float from the sea surface and extend downward into the water column and are used to catch pelagic fish. In this case the buoyancy of the floatline exceeds the weight of the leadline. Drift gillnets may be anchored at one end or set-out to drift, usually with the fishing vessel attached at one end (DeAlteris 1998). This activity is managed under federal fishery management plans. This gear is not expected to have contact with or impacts upon bottom habitats.

Pelagic Longline Gear

The pelagic or subsurface longline is a technique directed mostly towards tunas, swordfish, sailfish, dolphin (dorado), and sharks. The gear is typically set at depths from the surface to around 330 m (1100 ft.). The gear can also be set with a main line hanging in acrs below the bouy droplines to fish a band of depths (Sainsbury 1996). The gear is set across an area of known fish concentration or movement, and may be fished by day or night depending upon the species being sought (Sainsbury 1996). The length of the mainline can vary up to108 km (67 miles) depending on the size of the vessel. If the mainline is set level at a fixed depth, then the leader or gangion lengths vary from 2-40 m (6.6 - 130 ft.), so as to ensure the hooks are distributed over a range of depths (DeAlteris 1998). If a line-shooter is used to set the mainline in a catenary shape with regard to depth, then the gangions are usually a single minimal length, but are still distributed by depth (DeAlteris 1998). Each gangion typically contains a baited hook and chemical night stick to attract the fish. Traditional or circle hooks may be used. Swordfish vessels typically fish 20 to 30 hooks per 1.6 km (1 mile) of mainline between 5 and 54 km (3 - 34 miles) in length (Sainsbury 1996). This activity is managed under federal fishery management plans. This gear is not expected to have contact with or impacts upon bottom habitats.

Troll Lines

Trolling involves the use of a baited hook or lure maintained at a desired speed and depth in the water (Sainsbury 1996). Usually, two to four or more lines are spread to varying widths by the use of outrigger poles connected to the deck by hinged plates. Line retrieval is often accomplished by means of a mechanized spool. Each line is weighted to reach the desired depth and may have any number of leaders attached, each with a hook and bait or appropriate lure. This gear is generally fished from the surface to about 20 meters (Sainsbury 1996). This activity is managed under federal fishery management plans. This gear is not expected to have contact with or impacts upon bottom habitats.

OTHER GEAR

Rakes

A bull rake is manually operated to harvest hard clams and consists of a long shaft with a rake and basket attached. The length of the shaft can be variable but usually does not exceed three times the water depth. The length and spacing of the teeth as well as the openings of the basket are regulated to protect juvenile clams from harvest (DeAlteris 1998). Rakes are typically fished off the side of a small boat. This activity is not managed under federal fishery management plans

Tongs

Tongs are a more efficient device than rakes for harvesting shellfish. Shaft-tongs are a scissor-like device with a rake and basket at the end of each shaft. The fisherman stands on the edge of the boat and progressively opens and closes the baskets on the bottom gathering the shellfish into a mound. The tongs are closed a final time, brought to the surface, and the catch emptied on the culling board for sorting. The length of the shaft must be adjusted for water depth. Oysters are traditionally harvested with shaft tongs in water depths up to 6 m (21 ft.), with shaft tongs 8 m (29 ft.) in length (DeAlteris 1998). Patent tongs are used to harvest clams and oysters and are opened and closed with a drop latch or with a hydraulic ram and require a mechanized vessel with a mast or boom and a winch (DeAlteris 1998). Patent tongs are regulated by weight, length of teeth, and bar spacing in the basket. This activity is not managed under federal fishery management plans

Line Fishing

Hand Lines

The simplest form of hook and line fishing is the hand line. It consists of a line, sinker, leader and at least one hook. The line is usually stored on a small spool and rack and can vary in length. The line varies in material from a natural fiber to synthetic nylon. The sinkers vary from stones to cast lead. The hooks are single to multiple arrangements in umbrella rigs. An attraction device must be incorporated into the hook, usually a natural bait and artificial lure (DeAlteris 1998). Although not typically associated with bottom impacts, this gear can be fished in such as manner so as to hit bottom and bounce or be carried by currents until retrieved. This activity is managed under federal fishery management plans.

Mechanized Line Fishing

Mechanized line hauling systems have been developed to allow more lines to be worked by smaller crews and use electrical or hydraulic power to work th elines on the spools or jigging machines (Sainsbury 1996). These reels, often termed bandits, are mounted on the vessel bulwarks and have a spool around which the mainline is wound (Sainsbury 1996). Each line may have a number of branches and baited hooks, and the line is taken from the spool over a block at the end of a flexible arm. This gear is used to target several species of groundfish, especially cod and pollock and it has the advantage of being effective in areas where other gears cannot be used. Jigging machine lines are generally fished in waters up to 600 m (2000 ft) deep (Sainsbury 1996). This gear may also have the ability to contact the bottom depending upon the method selected to fish. This activity is managed under federal fishery management plans.

Hand Hoes

Intertidal flats are frequently harvested for clams and baitworms using hand-held hoes. These are short handled rake-like devices which are often modified gardening tools (Creaser et. al. 1983). Baitworm hoes have 5 to 7 tines, 21 to 22 cm (8.3 - 8.7 ft) in length for bloodworms and 34 to 39 cm (13 - 15 inches) for sandworms. Clam hoes in Maine typically have 4 to 5 tines, 15 cm (6 inches) long (Wallace 1997). This activity is not managed under federal fishery management plans.

Diving

By either free diving or using SCUBA, divers collect crustaceans, mollusks and some reef fish in shallow water. Most often a support vessel is used to transport the diver(s) to the fishing site and carry the landings to port. In deeper waters, helmet diving systems are used and the diver is tethered to the vessel with air pumped from the surface. This method is most often used by sea urchin divers and some lobster divers. Divers normally use small rakes or hoes to scrape creatures off rocks or dig them out of the seabed. Generally, the catch is placed in bags which are either towed to the surface by the boat or floated to the surface using an air source and a lift bag. Divers rarely work deeper than about 20 m (66 ft) (Sainsbury 1996). This activity is not managed under federal fishery management plans.

Spears

Spears came into use when it was found that a pole or shaft with a point on it could be used by a fisherman operating from shore, floating raft, or boat to capture animals previously out-of-reach (DeAlteris 1998). However, the single prong spear required an accurate aim, and fish easily escaped. With the addition of a barb, fish retention was improved; and spears with multi-prong heads increased the likelihood of hitting the target. Spears were initially hand-held, then thrown, then placed in launching devices including cross-bows, spear guns for divers, etc. Spears with long shafts (gigs) are used by fishermen in small boats at night in the Carolina sounds for flounder, through the ice for eels in New England bays, and by divers for fish in coastal waters (DeAlteris 1998). This activity is not managed under federal fishery management plans.

4. DISTRIBUTION OF FISHING ACTIVITY BY GEAR TYPE

This section of the report includes a series of GIS figures that represent the distribution of fishing activity during 1995-2001 by ten minute squares of latitude and longitude for eleven gear types used in the Northeast region. Each "square" is about 77 square nautical miles in size. The data used to create these plots were extracted from NMFS vessel trip report (VTR) and clam logbook databases. Data included in the analysis are provided by vessels operating with federal permits and participating in the following fisheries: northeast multispecies; sea scallops; surf clams and ocean quahogs; monkfish; summer flounder; scup; black sea bass; squid, mackerel, and butterfish; spiny dogfish; bluefish; Atlantic herring; and tilefish. Data for lobster pots were provided by vessels with multispecies permits. Vessels that operate strictly within state waters (0-3 miles from shore) are not required to have a federal permit and therefore do not submit trip reports. For this reason, fishing trips in nearshore ten minute squares that include a significant proportion of state water are under-represented.

Permit holders are required to fill out a VTR form or make a logbook entry for each trip made by the vessel, *i.e.*, each time the vessel leaves and returns to port. Fishermen report the general location where most of their fishing effort occurred during a trip and the date and time that the vessel left and returned to port. They are given the choice of reporting the location of a trip as a point (latitude and longitude or Loran bearings) or simply assign it to a statistical area (these areas are quite large and include many ten minute squates). Only trips which were reported as a point location and therefore could be assigned to a ten minute square (TMS) were included in this analysis. Most trips are reported this way. Fishermen are also asked to record the number of hauls (tows or sets) made during each trip and the average time (*e.g.*, per tow) when the gear was fishing, but this information was too unreliable and incomplete for use in this analysis. Logbook entries in the clam dredge fishery include time spent fishing: these data are more reliable and were used in this analysis. Data for gears used mostly in state waters and/or that are not well represented in the VTR database (*e.g.*, mussel and sea urchin dredges, Danish seines, shrimp pots) or gears that do not normally contact the bottom (*e.g.*, purse seines, mid-water trawls, pelagic longlines, floating gill nets) were not displayed. Data reported south of Cape Hatteras, North Carolina (35° N) and north of 45° N latitude in the Gulf of Maine were excluded from analysis.

Mobile gear (scallop dredges and three types of otter trawls) fishing activity was calculated as the total number of days absent from port. Fixed gear (bottom longlines, sink gill nets, and four types of pots) activity was calculated as the total number of trips. Days absent for each trip were calculated based on the date and time of departure from and return to port in hours and converted to fractions of 24-hr days. Trips made to more than one statistical area (for which two locations are noted) were excluded from the analysis. Logbook data for hydraulic clam dredges were also converted to 24-hr days. The clam dredge data excluded trips made by "dry" quahog dredge vessels in Maine which are included in the logbook database.

Days absent calculations for trawl and scallop dredge vessels are clearly preferable to simply summing the number of trips, but over-estimate actual fishing time since they include travel time and any other non-fishing-related activity while vessels are away from port. Thus, the GIS plots do not represent fishing effort. They indicate the relative, not the absolute, distribution of fishing activity within the Northeast region. In order to emphasize the relative nature of the fishing activity plots, all GIS input data were compiled and sorted into three categories: low, medium, and high degrees of activity. These categories corresponded to cumulative percentages of 90, 75, and 50% of the total number of trips, days at sea, or days spent fishing for each gear type during the seven-year time period. Implicit in this approach is the fact that fishing activity is most intense (high density) in ten minute squares which account for 50% of the total number of trips or days and much less intense (low density) in TMS that account for 90% of all trips or days. Exclusion of "low end" data (TMS with only a few trips or days) eliminated a large number of spatially misreported trips from the plots.

In each GIS plot (Figures 4.1 – 4.11), the number of trips or days that accounted for 90% (cumulative) of the total number of trips or days is shown as "N" at the top of the figure. The total number (100%) of trips or days is slightly higher. The depth contours shown in these figures are 50 and 100 fathoms (approximately 100 and 200 meters). The U.S.-Canada border and the outer boundary of the U.S. Exclusive Economic Zone (EEZ) is also shown on each figure. Three areas on Georges Bank that were closed in December 1994 to all bottom-tending mobile gears that catch groundfish and remained closed to bottom trawls during the entire seven-year period are shown in Figures 4.1 and 4.4. Scallop dredge vessels were allowed into the southern portion of CA2 in June 1999 and into portions of the other two areas a year later. Scallop fishing was also prohibited for three years in two additional areas in the Mid-Atlantic region (not shown in Figure 4.4) that were heavily dredged before and after the closure. Some idea of the predominant sediment types where each gear is used can be gained by comparing the fishing activity plots with the sediment distribution map for the region (Figure 2.3).

BOTTOM OTTER TRAWLS – FISH

Most of the reported otter trawl activity (Fig. 4.1) is directed at the capture of fish (rather than shrimp or scallops, see Figs. 4.2 and 4.3). More than any other gear, bottom otter trawling for fish during 1995-2001 was widespread in coastal and offshore waters throughout most of the Northeast region. Areas of highest activity were located in southwestern and central portions of the Gulf of Maine, along the western side of the Great South Channel, north of Closed Area 1 and on the northern part of Georges Bank west of Closed Area 2, in coastal waters of Rhode Island and Long Island, in the mid-shelf region of southern New England, and along the shelf break, especially north and south of 40ºN between 70º and 73º W longitude and in the Hudson Canyon area. Bottom trawling was not actively conducted in the three groundfish closed areas on Georges Bank, nor in a large area of the continental shelf off southern New Jersey, Maryland, and Virginia.

BOTTOM OTTER TRAWLS – SHRIMP

Shrimp trawling was localized in two areas, coastal waters of the Gulf of Maine, primarily between Cape Ann and Penobscot Bay, and in nearshore waters of North Carolina, particularly inside the barrier islands (Fig. 4.2). The shrimp fishery in the Gulf of Maine targets pandalid (or northern) shrimp while the fishery in North Carolina is on penaeid shrimp.

BOTTOM OTTER TRAWLS – SCALLOPS

The scallop trawl fishery is conducted on the outer Mid-Atlantic shelf, primarily between 40º and 37ºN in depths less than 50 fathoms (Fig. 4.3).

SCALLOP DREDGES

Scallop dredges were used primarily in a broad area of the Mid-Atlantic shelf from Long Island to Virginia, in Massachusetts Bay (north of Cape Cod) and the Great South Channel, in localized areas of Georges Bank northeast of Closed Area 1 and west of the northern portion of Closed Area 2, and in a larger area on the southeast flank of the bank that included the southern portion of Closed Area 2 that was opened to limited scallop dredging in 1999 (Fig. 4.4). Some scallop dredging was also reported from eastern Maine coastal waters. No active scallop dredging was reported in shallow open areas on Georges Bank, in southern New England, nor in inner shelf waters of the Mid-Atlantic Bight.

HYDRAULIC CLAM DREDGES

The largest area of hydraulic clam dredging activity was located in a small area off the central New Jersey coast, with smaller areas extending north and east to southern New England and south to the DelMarVa Peninsula (Fig. 4.5). Hydraulic clam dredges are not used to harvest clams on Georges Bank because of the presence of red tide-causing micro-organisms in ocean quahogs, nor are they used in the Gulf of Maine due to the prevalence of gravel and rocky bottom where hydraulic dredges can not operate. There is a localized fishery for ocean quahogs in eastern Maine, but the dredges used there are not hydraulically operated.

BOTTOM LONGLINES

Longline trips during 1995-2001 were reported primarily in ten minute squares in the western Gulf of Maine (Massachusetts Bay) and along the western side of the Great South Channel (Fig. 4.6). There were a few trips reported in deep water along the shelf break, in Rhode Island and central Maine coastal waters, and in offshore locations of the Gulf of Maine.

BOTTOM GILL NETS

Bottom gill net trips were made in the western Gulf of Maine and along the western side of the Great South Channel, extending north of Cape Ann and on Jeffreys Ledge, and also in a few ten minute squares in the outer gulf (Fig. 4.7). Gill nets were also used in Rhode Island coastal waters, along the outer shore of Long Island, off northern New Jersey, the DelMarVa Peninsula, and in North Carolina. Gill net fishing activity was highest in the western Gulf of Maine and the Great South Channel in areas that were also actively fished with longlines, bottom trawls, and scallop dredges.

LOBSTER POTS

Lobster pot trips during 1995-2001 were reported primarily in coastal waters of the Gulf of Maine from the Canadian border to Cape Cod, in nearshore Rhode Island waters, and in the New York Bight (Fig. 4.8). Fewer trips were made to more offshore locations in southern New England and along the shelf break in depths greater than 100 fathoms.

FISH POTS

Most fish pot trips were reported on the south shore of Massachusetts and Rhode Island, Long Island, and off southern New Jersey, Delaware, and Maryland (Fig. 4.9). Other areas where fewer trips were reported were located on Jeffreys Ledge in the western Gulf of Maine, east of Long Island and south of Nantucket and Martha’s Vineyard, along the outer edge of the continental shelf in the southern mid-Atlantic Bight, and off the entrance to Chesapeake Bay.

CONCH AND WHELK POTS

Most fishing activity was reported in Nantucket Sound and inshore waters of southern Massachusetts, in a single TMS south of Rhode Island, and in coastal waters of southern New Jersey and the DelMarVa Peninsula, extending south to North Carolina (Fig. 4.10).

CRAB POTS

Crab pot trips were reported in a number of TMS in deep water along the shelf break from eastern Georges Bank all the way to Cape Hatteras, in a single TMS south of Nantucket, in several nearshore locations in the Gulf of Maine, Nantucket Sound, Cape May (New Jersey), and in inshore waters behind the North Carolina barrier islands (Fig. 4.11).

5. REVIEW OF FISHING GEAR EFFECTS LITERATURE

INTRODUCTION

Seventy-one publications were included in the gear effects literature review. An attempt was made to include all available, relevant, English-language, scientific publications that could be used to determine what is known about the effects of the principal commercial fishing gears used in the Northeast U.S. on benthic marine habitat types that exist in the region. Habitat types were defined in terms of the predominant substrate. Gear types that were selected were gears that are currently used in the region, or gears that are used elsewhere but were judged to have similar effects as gears that are used in the region. Gears that are used strictly in state waters to harvest species that are not federally managed were not included. This review provides a detailed account of individual scientific studies and summarizes what is known about each gear and substrate type, but does not evaluate scientific methodologies or the validity of published results. Both peer-reviewed and non-peer-reviewed publications were included, but the emphasis was on the former. Information summarized in this review was, in all cases, based on primary source documents. An attempt was made to include all relevant publications available through early 2002.

METHODS

The review is organized by gear and substrate type. Nine of the 71 studies that were reviewed included information for more than one gear type or for one gear type in more than one substrate or study area and were therefore summarized in more than a single gear/substrate category. In all, there were 80 descriptions for seven gear types and five substrates (Tables 5.1 – 5.3). Cases in which the effects of more than one gear type were evaluated in a single study and could not be distinguished were categorized as multiple gears. The same approach was used for studies conducted in mixed substrates that could not be defined as mud, sand, gravel/rock, or biogenic. Over half (65%) of the descriptions in this report are for otter trawls and scallop dredges and all but one are for different kinds of mobile bottom-tending gear. Thirty-four of the studies were done in sandy substrate, 12 in mud, 7 in different types of biogenic substrate, 5 in gravel and rocky bottom, and 22 in mixed substrate. Most of them were peer-reviewed and most were published after 1990. Geographically, 21 were conducted in the Northeast U.S. (North Carolina to Maine), 19 elsewhere in North America (U.S. and Canada), 28 in Europe and Scandinavia, and 12 in Australia and New Zealand.

Within each gear/substrate sub-section, individual studies are described in detail in 1-2 paragraphs that include the following information, when available:

- Citation (authors and date of publication)
- Location of study
- Depth
- Substrate type and/or composition
- Detailed information on gear used, especially for otter trawls
- Type of study (observational or experimental)
- Were experiments set up to test for time and location effects?

- Type(s) of organisms sampled (infauna vs. epifauna)
- Duration and intensity of fishing (number of tows, duration of each fishing event, total duration of fishing disturbance, frequency of fishing events, etc.)
- Timing of sampling or observations (how often, how long before or after fishing, etc.)
- Timing and frequency of sampling or observations to determine recovery
- Whether study was done in a commercially exploited or unexploited area
- If unexploited, for how long and what gears were excluded?

Details that were not generally included were descriptions of sampling gears and procedures, sample processing information (*e.g.*, the mesh size used to sieve grab samples), taxonomic categories used (families, groups of species, individual species), and data analysis procedures (*e.g.*, statistical tests). General conclusions, when they are included, were the author's own statements; no speculations regarding the study in question or any re-statements made by the authors regarding anybody else's research were ever included. Results which are described as "significant" are results which were statistically significant. To avoid confusion, the term was not used in any other context.

Each gear/substrate category also includes a table summarizing the setting (location, depth, and sediment type), general methodological approach, and primary results of each study. Results are divided into an effects and a recovery column. Results summarized in the tables include positive and negative results, *e.g.*, increases and decreases in abundance caused by fishing, as well as instances when there were no detectable effects of fishing. Blank cells in the recovery column indicate that the study was not designed to provide information on recovery times. Information in the last column includes the nature of the research (experimental or observational), whether or not the study area was being commercially fished at the time of the study, and how the experimental fishing was conducted (single or multiple tows, discrete or repeated disturbance events, and – if known – the average number of tows to which any given area of bottom was exposed).

This report also includes a summary of results for all the studies in each gear-substrate category. Each summary begins with an introductory paragraph that includes general information, such as:

- the number of studies that examined physical and biological effects,
- how many studies were done in different geographic areas and depth ranges,
- how many examined recovery of affected habitat features,
- the number of studies performed in areas that were closed to commercial fishing vs. areas that were commercially fished at the time of the study,
- how many involved single vs. multiple tows, and
- how many were conducted either during a single, discrete time period or during a more prolonged period of time that was intended to simulate actual commercial fishing activity.

Physical and biological effects for each gear-substrate category are summarized in separate paragraphs. When necessary, biological effects are presented separately for single disturbance and repeated disturbance experimental studies, and for observational studies.

OTTER TRAWLS

Otter Trawls - Mud (Table 5.4)

(1). Ball et al. (2000) sampled benthic macrofauna before and 24 hrs after trawling at a heavily-fished site within an offshore prawn (*Nephrops*) trawl fishing ground in the Irish Sea and at an un-fished "pseudo-control" site near a shipwreck at the same depth (75 m), a site that had not been fished for about 50 years. Sediments were sandy silt. No information on the duration of experimental trawling or the type of net used was provided. Due to the paucity of organisms and low biomass, and the resulting high inter-sample variance, it was not possible to quantitatively evaluate the short-term effects of trawling at the fished site. There were, however, considerably fewer species and individuals, and lower species diversity and richness, in the commercially trawled area than near the shipwreck. At the shipwreck site, the number of species, number of individuals, and biomass decreased with increasing distance from the wreck. High inter-sample variance in biomass estimates near the wreck impeded comparisons with the trawled site. Sixty-nine species found at the wreck site were not found at the experimental fishing site. These included polychaetes, crustaceans, bivalves, gastropods, and echinoderms. Large specimens of some molluscs and echinoderms were most common near the wreck, whereas only juveniles of these species were sampled in the trawled area.

(2). Brylinsky et al. (1994) examined physical and biological effects of 18-24 m-wide flounder trawls with 180-270 kg doors, 29 cm-diameter rubber rollers and no tickler chains in an intertidal estuary in the upper Bay of Fundy, Nova Scotia. The study area was commercially fished for flounder by trawlers. Four trawling experiments were conducted at 2 sites in 6-8 m of water (at high tide) in 1990 and 1991. Repeated tows were made during a single day at each site, but not over the same bottom area. Samples of meiofauna and chlorophyll were collected at variable intervals for 1.5-4 months after trawling. One site was characterized by coarse sand overlain with silt to a thickness of several centimeters, the other had siltier sediment to a depth of at least 10 cm. The study area is a high-energy environment, owing to the extreme tidal range (average 11 m with a maximum of 16 m) and tidal currents which frequently exceed 2 knots. Trawl doors made furrows 1-5 cm deep and berms that were visible for at least 2-7 months and rollers compressed sediments. The amount of disturbance varied markedly and seemed to be influenced primarily by the kind of sediment and the type of door used, being more pronounced in the finer sediments and when heavier doors were used. Benthic diatoms (measured as chlorophyll a) decreased in door furrows at some stations, but recovered within 1-3 months. No significant impacts were observed on macrobenthos, which was dominated by polychaetes. The numbers of nematodes in door furrows were reduced, but only for 1-1.5 months, and may only have been displaced by the doors. Benthic taxa such as molluscs, crustaceans, and echinoderms that are known to be more susceptible to trawling were not present in the study site.

(3). DeAlteris et al. (1999) analyzed data from a 1995 side-scan sonar survey to locate and map trawl tracks in shallow sand and mud sediments in lower Narragansett Bay, Rhode Island. At the deeper (14 m) mud-bottom site, trawl doors produced smooth tracks 5-10 cm deep with berms on the inside edge that were 10-20 cm high. The longevity of hand-dug trenches (dug to simulate tracks left by trawl doors) was monitored using SCUBA divers. The trenches were observed unchanged for the duration of the study (more than 60 days), and were occupied by rock crabs.

Natural erosion at this site was predicted to occur less than 5% of the time.

(4). Drabsch et al. (2001) used divers to sample benthic infauna before and after experimental trawling in an area of South Australia (Gulf of St. Vincent) where little or no fishing had occurred for 15 years. Three study sites were used (one in mud and two in sand), with adjacent trawled and control corridors at each site. Two series of ten adjacent tows were made in one treatment site during one day in October 1999 using triple prawn trawls with two doors (1 x 2 m, 200 kg each) and a combined sweep length of about 20 m. Trawl doors left tracks in all trawl corridors and the footline and net smoothed topographic features and removed 28% of the epifauna in mud and sand substrate. Epifauna in all trawled quadrats showed signs of damage. Bottom sediments at the mud study site were fine silt sediments and the depth was 20 m. Total infaunal abundance and the abundance of one family of polychaetes (Ctenodrilidae) were significantly reduced one week after trawling at the mud bottom site. No significant changes were evident for any other taxon.

(5). Frid et al. (1999) examined the long-term effects of fishing with prawn (*Nephrops norvegicus*) otter trawls by comparing temporal changes on macrobenthic communities at a lightly-fished (LF) and a heavily-fished (HF) location off the northeast coast of England (North Sea) over a 27-year time period. The depth at the HF site was 80 m and the substrate was predominantly (>50%) silt-clay. Grab samples were collected at this site every year during January. Fishing activity within the statistical area that includes both sites was divided into three periods of low (1971-1981), high (1982-1989), and moderate (1990-1997) fishing effort. Benthic taxa were divided into two groups that were predicted to respond negatively (decreased abundance) or positively (increased abundance) to increased trawling activity, based on published accounts. The total number of individuals in the positive response group conformed to predictions by increasing significantly between the periods of low and high fishing effort and then declining when fishing dropped to moderate levels, but the total abundance of taxa in the negative response group did not vary significantly between time periods. The only taxonomic group that increased significantly when fishing effort was high was the errant polychaetes. Echinoids, as predicted, decreased in abundance (to zero) at high fishing effort. Taxa in the negative response group that did not decrease in abundance were sedentary annelids and large bivalves. Starfish and brittlestars were more abundant when fishing effort was high, but not significantly. Benthic macrofaunal abundance at this site was low at the beginning of the time series when phytoplankton production was also low, but once fishing effort increased, there was no longer any correlation between the two. (See p. __ for a summary of results at the LF site which had a sandy substrate).

(6). Hansson et al. (2000) examined the effects of trawling on clay bottom habitats at 75-90 m in a Swedish fjord. Benthic infauna were collected 1-5 months before trawling began at three experimental sites and three control sites and during the last 5 months of a one year trawling experiment . All sites were located in an area that had been closed to fishing for 6 years. The otter trawl that was used was a commercial shrimp trawl with a 14 m ground rope with 20 kg of lead distributed along it, and 125 kg otterboards. Eighty hauls were made at each treatment site during a one year period starting in December 1996 at a frequency of 2 hauls per week. It was estimated that any given area was passed over 24 times by the trawl during the experiment. For 61% of the species sampled, abundances tended to be negatively affected by trawling, *i.e.*, abundances decreased more or increased less in the trawled sites compared to the control sites during the experiment. Total biomass decreased significantly at all 3 trawled sites, and the total number of individuals at 2 trawled sites, but in both cases significant reductions were also observed at one of the control sites, thus these changes could not be attributed solely to trawling. Total abundance and biomass at trawled sites was reduced by 25 and 60%, respectively, compared to 6 and 32% in control sites. Individual phyla responded differently to trawling. Echinoderms (mostly brittlestars) decreased significantly in abundance, total abundance of polychaetes was not affected (although some families increased and some families decreased), and amphipods and molluscs were not affected.

(7). Mayer et al. (1991) examined the immediate effects of a single tow with an otter trawl on mud substrate at a depth of 20 m in a bay on the coast of Maine. The trawl had an 18 m footrope with an attached tickler chain and 90 kg doors. Core samples were taken inside and outside the drag line the day after trawling and were analyzed for porosity, chlorophyll, pheophytin, total organic matter, protein, extracellular proteolytic activity, and beryllium-7 to a sediment depth of 18 cm. Downcore profiles were similar between the dragged and control sites, indicating that trawling did not “plow” the bottom and bury surficial sediments. The trawl doors did produce furrows several centimeters deep and the chain and net caused a very thin, and inconsistent, planing of surficial features. A high value of beryllium-7 in surficial sediments at the control site, but not at the trawled site, indicated that fine sediments were dispersed laterally, away from the area of dragging.

(8). Pilskaln et al. (1998) collected large, immobile, infaunal worms in sediment traps deployed 25-35 m above the bottom in two deep (250 m) basins in the Gulf of Maine during 1995. Many more worms were collected in Wilkinson Basin, which is located in a more heavily-trawled area in the gulf, than in Jordan Basin, which is located in a region of the gulf with very little trawling activity. Higher abundance coincided with seasons of greater trawling activity in the southwestern Gulf of Maine. The authors concluded that the worms are dislodged and suspended in the near-bottom water column by trawling because there was no other reason why they would leave their natural habitat in the bottom. They also note that the re-suspension of fine sediment by bottom trawls releases nutrients such as nitrogen and silica from bottom sediments.

(9). Sanchez et al. (2000) examined the effects of otter trawling in a commercially-trawled area with muddy substrate (depth 30-40 m) in the northwest Mediterranean Sea off the coast of Spain. A commercial otter trawl was towed repeatedly during daylight for a single day (3.5 hrs towing) at one site and during a 23-hr period (7 hrs towing) at a second site in July 1997, so that each trawl line was swept entirely either once or twice. Infaunal grab samples were collected prior to fishing and at various times after fishing (up to a maximum of 150 hrs) in each trawl wayline and at un-fished sampling locations adjacent to each wayline. A number of taxa (mostly families) were significantly more abundant in the lightly trawled wayline than in the adjacent un-trawled area after 150 hrs, primarily due to decreased abundance outside the wayline. The total numbers of individuals and taxa were also significantly reduced outside, but not inside, the wayline 150 hrs after trawling. There were no differences in the number of taxa or individuals inside and outside the more intensively trawled wayline after 72 hrs. The percentage abundance of major taxa (*i.e.*, polychaetes, crustaceans, and molluscs) were similar in the trawled waylines and the control locations throughout the experiment and trawling produced no changes in community structure in either wayline. Side scan sonar images of the trawl waylines showed furrows left by the trawl doors which remained visible throughout the experiment.

(10). Sparks-McConkey and Watling (2001) investigated the effects of trawling on geochemical sediment properties and benthic infauna in Penobscot Bay, Maine. The study site was selected because it was fairly deep (60 m) and bottom sediments were not exposed to storm events or tidal scouring. Sediment particle size was homogeneous spatially and temporally within the study area. There had been no commercial trawling in the area for 20 years. Trawling was conducted at two stations in December 1997 with a 12-m commercial whiting net that was modified (increased mesh size and decreased diameter of float-rollers) to reduce impacts to the seafloor. Four tows were made at each station during a single day. An attempt was made to tow the same area of bottom each time. Sampling was conducted at the experimental stations and at seven reference stations for a year before trawling, five days after trawling, and three-and-a-half and five months after trawling. An underwater video camera was used to verify that post-trawl grab samples were taken in trawl tracks. Trawling caused immediate and significant reduction in porosity, an increase in the food value of surface sediments (upper 2 cm), and stimulated chlorophyll production, but none of these properties were any different at the trawled stations after three-and-a-half and five months. Trawling also had immediate and significant effects on benthic infauna, reducing the number of individuals and species, reducing taxonomic diversity, and increasing species dominance. There were no longer any significant differences in any of these parameters after three-and-a-half months when mobile species recruited to the benthos. Four polychaete species were significantly less abundant at the trawled stations five days after trawling, but three of them were present in equal densities at treatment and control stations three-and-a-half months later. Two species of bivalve were reduced in abundance by trawling, one of them for three-and-a-half months. Nemerteans were significantly more abundant at the trawled stations during all three post-trawl sampling dates.

(11). Tuck et al. (1998) conducted experimental trawling in a sea loch in Scotland that had been closed to fishing for over 25 years. Trawling was conducted one day per month (for 7.5 hrs) for 16 months in a single treatment site (95% silt/clay, depth 30-35 m) starting in January 1994. Infaunal surveys were completed in the trawled site and a nearby reference site after 5, 10, and 16 months of disturbance and, once trawling ended, after 6, 12, and 18 months of recovery. Trawl doors produced furrows in the sediment, which were still evident in side scan sonar images after 18 months. Trawling had no effect on sediment characteristics, but bottom “roughness” in the trawled area increased during the disturbance period and declined during the recovery period. There were no significant differences in the number of infaunal species in the experimental and reference sites prior to the beginning of the experiment or during the first 10 months of disturbance, but there were more species in the trawled site after 16 months of disturbance and throughout the recovery period. In contrast, there were significantly more individuals in the trawled site before trawling began. This difference was maintained after 10 and 16 months of fishing and 6 and 12 months of recovery, but after 18 months there was no difference between the two sites. Taxonomic diversity and evenness indices were significantly lower in the experimental site for the first 22 months of the experiment, but after 12 months of recovery there were no longer any differences. Some species (primarily opportunistic polychaetes) increased significantly in abundance in the trawled plot in response to the disturbance while others (*e.g.*, bivalve molluscs) declined significantly in abundance relative to the reference area. Biomass was significantly higher in the control site before trawling started, but not during the rest of the experiment. Two different measures of community structure were applied. One of them indicated that the two sites became significantly different after only 5 months of disturbance and remained so throughout the experiment. According to the other one, the treatment site reached a similar condition to the reference site at the end of the recovery period. Trawling effects on epifauna could not be evaluated in this study because organisms were present in very low densities and because the trawl was not equipped with a net, thus any impacts on epifauna would have been under-estimated.

Summary

Results of 11 studies are summarized. All of them were conducted during the last 11 years, five in North America, four in Europe, and one in Australia. One was performed in an inter-tidal habitat, one in very deep water (250 m), and the rest in a depth range of 14-90 meters. Seven of them were experimental studies, three were observational, and one was both. Two examined physical effects, six of them assessed biological effects, and three studies examined physical and biological effects. One study evaluated geochemical sediment effects. In this habitat type, biological evaluations focused on infauna: all nine biological assessments examined infaunal organisms and four of them also included epifauna. Habitat recovery was monitored on five occasions. Two studies evaluated the long-term effects of commercial trawling, one by comparing benthic samples from a fishing ground with samples collected near a shipwreck, while another evaluated changes in macrofaunal abundance during periods of low, moderate, and high fishing effort during a 27-year time period. Four of the experimental studies were done in closed or previously un-trawled areas and three in commercially fished areas. One study examined the effects of a single tow and six involved multiple tows, five restricted trawling to a single event (*e.g.*, one day) and two examined the cumulative effects of continuous disturbance.

Physical Effects

Trawl doors produce furrows up to 10 cm deep and berms 10-20 cm high on mud bottom. Evidence from four studies (2,3,7,9) indicates that there is a large variation in the duration of these features (2-18 months). There is also evidence that repeated tows increase bottom roughness (11), fine surface sediments are re-suspended and dispersed (7), and rollers compress sediment (2). A single pass of a trawl did not cause sediments to be turned over (7), but single and multiple tows smoothed surface features (4,7).

Biological Effects

Single disturbance experimental studies

Two single-event studies (2,9) were conducted in commercially-trawled areas. Experimental trawling in intertidal mud habitat in the Bay of Fundy (Canada) disrupted diatom mats and reduced the abundance of nematodes in trawl door furrows, but recovery was complete after 1-3 months (2). There were no effects on infaunal polychaetes. In a sub-tidal mud habitat (30-40 m deep), benthic infauna were not affected (9). In two assessments performed in areas that had not been affected by mobile bottom gear for many years (4,10), effects were more severe. In both cases, total infaunal abundance and the abundance of individual polychaete and bivalve species declined immediately after trawling (4,10). In one of these studies (10), there were also immediate and significant reductions in the number of species and species diversity. Positive effects included reduced porosity, increased food value, and increased chlorophyll production in surface sediments. Most of these effects lasted less than three-and-a-half months. In the other (4), two tows removed 28% of the epifauna on mud and sand substrate and epifauna in all trawled quadrats showed signs of damage. These results were not reported separately for mud bottom.

Repeated disturbance experimental studies

Two studies of the effects of repeated trawling were conducted in areas that had been closed to fishing for six years and >25 years. In one (6), multiple tows were made weekly for a year and, in the other (11), monthly for 16 months. In one case, 61% of the benthic species sampled tended to be negatively affected, but significant reductions were only noted for brittlestars (6). In the other, repeated trawling had no significant effect on the numbers of infaunal individuals or biomass (11). In this study, the number of infaunal species increased by the end of the disturbance period. Some species (*e.g.*, polychaetes) increased in abundance, while others (*e.g.*, bivalves) decreased. Community structure was altered after five months of trawling and did not fully recover until 18 months after trawling ended.

Observational studies

An analysis of benthic sample data collected from a fishing ground over a 27-year period of high, medium, and low levels of fishing effort showed an increased abundance of organisms belonging to taxa that were expected to increase at higher disturbance levels, whereas those that were expected to decrease did not change in abundance (5). Results of another study indicated that a trawling ground had fewer benthic organisms and fewer species than an un-exploited site near a shipwreck (1). Trawling in deep water apparently dislodged infaunal polychaetes, causing them to be suspended in near-bottom water (8).

Otter Trawls – Sand (Table 5.5)

(1). Ball et al. (2000) sampled benthic macrofauna in a lightly-fished inshore prawn trawl fishing ground in the Irish Sea before and 24 hours after trawling and at an unfished (for about 50 years) “pseudo-control” site near a shipwreck. Sediments at these two sites were muddy sand and the depth was 35 m. No information on the duration of experimental trawling or the type of net used was provided. There were no obvious short-term effects of experimental trawling. Chronic effects, as indicated by differences between the fished site and the wreck site before experimental trawling began, were similar in kind, but less pronounced than at the heavily-fished, mud-bottom offshore site (see p. __). Mean numbers of species and total number of individuals were higher at the un-fished wreck site, as were indices of species diversity and richness. High inter-sample variance in biomass estimates near the wreck impeded comparisons with the trawled site. Fifty-eight species found at the inshore wreck site were not found at the experimental fishing site. These included predatory and tube-dwelling polychaetes as well as a number of bivalves and echinoderms. Other types of polychaetes were more common at the fished site.

(2). Bergman and Santbrink (2000) calculated mortality rates for a number of sedentary and relatively immobile megafauna (>1 cm) caught or damaged by a flatfish otter trawl at six commercially-exploited sites in the southern North Sea during 1992-1995. The substrate at two deeper sites (40-50 m) was silty sand (3-10% silt) and at four shallower sites (<30-40 m) was sand (1-5% silt). At each site, benthic invertebrates were sampled before and 24-48 hours after trawling in four corridors with a dredge which was designed to sample relatively large, relatively low-abundance in- and epifaunal species. The fishing gear was a commercial flatfish trawl that measured 35-55 m between the doors (15-20 m between the wings) when underway with 20 m of net (32 m with bridles) in contact with the seafloor, 20-cm roller gear and 8-10 cm mesh in the codend. Three corridors were trawled in silty sand substrate and one in sandy substrate. The surface of each corridor was trawled on average 1.5 times. Mortalities were calculated as the percent reduction in initial density after a single trawl tow and ranged from <0.5 to 52% for 9 species of bivalves, 16-26% for a sea urchin, 3-30% for a crustacean, and 2-33% for other species. Overall, mortality rates for six species ranged from 20-50% and for ten other species were below 20%. Significant before and after differences were detected on only 11 of 54 occasions. Some species experienced higher mortalities in the silty sand substrate and some in the sandy substrate.

(3). DeAlteris et al. (1999) used divers to determine that simulated trawl door tracks only lasted 1-4 days at a 7 m-deep sandy site in Narragansett Bay, Rhode Island (USA). Natural erosion at this site was predicted to occur on a daily basis, much more rapidly than in deeper water with a mud substrate (see p. __ for a summary of the mud-bottom results).

(4). Drabsch et al. (2001), in addition to sampling a mud-bottom site in South Australia before and after trawling (see p. __), also sampled two additional sites (20-m depth) with medium-coarse sand sediments and shell fragments. Trawling effects were evaluated at one of the sites a week after fishing and after 3 months at the second site. Trawl doors left tracks in the sediment and the footline and net smoothed topographic features and removed epifauna. In contrast to results obtained at the mud-bottom site, trawling at the sand-bottom sites did not significantly affect infaunal abundance. The only significant change which could be attributed to trawling was a reduction in density of one family of polychaetes (Tanidaceae) one week after trawling. Three months after trawling, infaunal abundance had declined dramatically in the treatment and reference sites and there were no significant differences between them.

(5). Frid et al. (1999) examined the long-term effects of fishing with prawn otter trawls in the North Sea by comparing temporal changes on macrobenthic communities at a lightly-fished, (LF) sandy-bottom site and a heavily-fished (HF) mud-bottom site during three time periods when fishing effort was low, moderate, and heavy (see p. ___ for results relating to the HF site). The LF site was located in 55 m of water and had a predominantly sand substrate (20% silt/clay). Benthic taxa collected at the LF site were divided into two groups that were predicted to respond negatively (decreased abundance) or positively (increased abundance) to increased trawling activity, based on published accounts. Fluctuations in macrofaunal abundance at the LF site were correlated with the abundance of phytoplankton two years previously, indicating that benthic organisms were more abundant when greater amounts of organic matter were available to stimulate benthic production and vice-versa. There was no correlation with changes in fishing effort and no change in the proportions of organisms in the positive and negative response groups over time.

(6). Gibbs et al. (1980) sampled benthic epifauna and infauna prior to and immediately after repeated trawling for a period of one week in October 1975 (using a 10-m otter trawl with 1 by 0.5 m flat otter boards and chain spiders) in a shallow estuary in New South Wales, Australia. Experimental trawling was conducted before the opening of the seasonal prawn fishery. Additional samples were collected at the end of the 6-month fishing season. Grab samples were taken over muddy sand (0-30 % mud/clay) at three sites within the fishing grounds in Botany Bay and at an un-fished control site in Jervis Bay, located about 200 km south of Botany Bay. Trawl footropes lightly skimmed the bottom and disturbed very little sand. Trawling did create a plume of sand, but after repeated trawls, the seafloor was only slightly modified. Community diversity indices were not significantly different between the three study sites and the control site before or immediately after experimental trawling or after the fishing season. The authors therefore concluded that there were no detectable effects of trawling.

(7). Gilkinson et al. (1998) studied the effects of trawl door scouring on several species of infaunal bivalves by observing an otter door model deployed in a test tank with sand bottom, designed to simulate the sediment of the northeastern Grand Banks. The trawl door created a berm in the sediment (average height 5.5 cm) with an adjacent 2-cm-deep scour furrow. All 42 bivalves within the scour path were displaced, but only two were damaged.

(8). Hall et al. (1993) sampled benthic infauna from a fishing ground in the North Sea using distance from a shipwreck as a proxy for changes in trawling intensity. The sediment was coarse sand and the depth was 80 m. Benthic infauna were sampled at intervals along three transects that started 5 m from the wreck and extended to a distance of 350 m from the wreck. Infaunal community structure was closely related to grain size and organic carbon content which varied within concentric rings or linear waves of coarser and finer sand, not to distance from the wreck. The authors concluded that the observed differences in infaunal abundance did not appear to be consistent with an effect of fishing disturbance, which would most likely not follow the same pattern of fluctuating high and low intensity at increasing distance from the wreck. Epifaunal taxa were not included in this analysis.

(10). McConnaughey et al. (2000) examined chronic trawling effects on epifauna in a high-energy sandy habitat in the eastern Bering Sea, in Alaska (USA). Samples were collected in 1996 just inside and outside an area that was closed to trawling in 1959 using an otter trawl that was modified to improve the catch and retention of large epi-benthic organisms. The net had a 34-m footrope with a tickler chain and a hula skirt and 1 mt steel V-doors with 55-m paired dandylines. Each lower dandyline had a 0.6-m chain extension connected to the lower wing edge to improve bottom-tending characteristics. Sampling sites were selected along the outside edge of the closed area boundary where commercial trawling is intense and were located within 1 nautical mile of stations located inside the closed area. The bottom at the study site was 44-52 m deep with sand ripples and strong rotary tidal currents and was well within the depth range that is affected by storm waves. Sedentary taxa (*e.g.*, anemones, whelk eggs, soft corals, stalked tunicates, bryozoans, and sponges) were more abundant in the unfished (UF) area than in the heavily fished (HF) area. Differences (UF>HF) were significant for sponges and anemones. Mixed non-significant responses were observed within motile groups (*e.g.*, crabs, sea stars, buccinid whelks) and infaunal bivalves. Species diversity of sedentary taxa was significantly higher in the UF area, owing to the greater dominance of a seastar in the HF area. Attached epifauna (*e.g.*, sponges, anemones, soft corals, stalked tunicates) had a significantly more patchy distribution in the HF area.

(11). Moran and Stephenson (2000) conducted an experimental study of otter trawling effects on an unexploited area with dense macrobenthos at depths of 50-55 m on the continental shelf of northwest Australia. No information on bottom type was provided, but it was presumed to be sand (see Sainsbury *et al.* 1997). A video camera mounted on a sled was used to survey attached macrobenthos (>20 cm) before and after individual trawling events in experimental and control sites. There were four trawling events scheduled at two-day intervals. During each trawling event, four tows were required to cover the area of each of two experimental blocks so that any unit area of bottom was trawled once. Trawled and control sites were surveyed before and after each trawling event and on alternate days during trawling. Mean density of benthos declined exponentially (and significantly) with increasing tow numbers with four tows reducing the density by about 50% and a single tow reducing density by about 15%. This estimated removal rate is much lower than what was estimated by Sainsbury *et al.* (1997) for sponges in the same general location (89%, see p. __). The authors believe this disparity may be explained by the fact that the trawl used in their study was lighter, with 20 cm disks separated by 30-60 cm long spacers of 9 cm diameter, and may have lifted over some benthic organisms rather than removing them. Also, sponges are more susceptible to removal than other benthic organisms.

(13). Sainsbury et al. (1997) reported the results of surveys on the continental shelf (<200 m) in northwestern Australia that documented a shift in the dominance of fish species from those that occur predominantly within habitats that contain large epibenthic organisms (*Lethrinus* and *Lutjanus*) to those that favor open sandy habitats *(Nemipterus* and *Saurida),* in conjunction with the development of a commercial stern and pair trawling fishery. After 5 years, trawl closure areas implemented in response to these changes resulted in increased catch rates of *Lutjanus* and *Lethrinus* and increased abundance of small benthos (<25 cm), with no change in the abundance of large benthos. The abundance of these fishes and of both large and small benthos continued to decrease in the area left open to trawling. These results increased the probability placed on a habitat limitation model and decreased the probability of an intraspecific control model (Sainsbury 1991), indicating that changes in species abundance and composition were at least in part a result of the damage inflicted on the epibenthic habitat by demersal trawling gear. Video observations provided by a camera mounted on a trawl showed that during those encounters with the groundline where the outcome was observable, sponges >15 cm were removed from the substrate 89% of the time. The groundline consisted of a 15 cm-diameter rubber roller made from rubber discs packed together and threaded on the groundline, with 14-cm spacers between packs of discs.

Grand Banks, Newfoundland: A number of investigators (see next three summaries) have examined the physical and biological effects of sustained otter trawling in a relatively deep sand habitat (120-146 m) in a 100 nmi^2 area of the Grand Banks, Newfoundland, that was closed to commercial trawling in 1992. Analysis of fishing effort records indicated that it had not been fished intensively since the early 1980s (Kulka 1991). (The estimated intensity of seabed disturbance by otter trawling in the study area in 1990 was less than 8%, or 1 set every 12 years).

Sediments at this site were moderately to well sorted fine- to medium-grain sand. The seabed is smooth and relatively stable with no evidence of wave-induced ripples. However, interannual variations in grain size and acoustic properties were observed during the study, possibly caused by winter storms (Schwinghamer *et al.* 1998). Twelve experimental trawl tows (31-34 hours of trawling) were made in three 13-km-long corridors with an Engel 145 otter trawl with 1250 kg oval otter boards and 46 cm diameter rock hopper gear during a 5-day period in late June/early July of 1993, 1994, and 1995. Since the width of the trawl opening (60 m) was considerably less than the width of the disturbance zones created (120-250 m), the average trawling intensity was estimated to be 3-6 sets per year per unit bottom area. Physical and biological effects of trawling were evaluated within a few hours or days after trawling ended and a year later, when two of the experimental corridors and a reference corridor located parallel to each experimental corridor were sampled prior to trawling. Samples were also collected in reference and experimental corridors in September 1993, two months after trawling.

(9). Kenchington et al. (2001) analyzed the effects of otter trawling at the Newfoundland study site on benthic infauna and epifauna collected in grab samples in two of the three experimental corridors. The most prominent feature of the data was a significant natural decline in the total number of individuals, number of species, and the numbers and biomass of a number of selected species in the trawled and un-trawled corridors between July 1993 and July 1995. Total abundance declined by 50% during the two-year time period. There were also significant effects of trawling on mean total abundance and the abundances of 15 individual taxa (mostly polychaetes), but only in 1994. In that year, immediate declines in abundance for these 15 taxa ranged from 33 to 67%. There were o significant trawling-induced changes in total biomass at any point during the experiment. Likewise, none of the community indices (taxonomic diversity and evenness) showed a significant effect of trawling in any of the years and the only change in community structure that could be attributed to trawling occurred in 1994. Recovery for species that were affected by trawling in 1994 required less than a year. Within this time frame, however, the actual recovery period could not be determined. The authors concluded there was no consistent, long-term effect that could be attributed to trawling and that the effects of otter trawling on infauna in this relatively stable, deep-water sand habitat were limited and short-term. When trawling disturbance was indicated, it appeared to mimic natural disturbance.

(12). Prena et al. (1999) examined trawl by-catch and the effects of trawling on benthic epifauna. The codend of the Engel 145 otter trawl was fitted with a 30 mm square mesh liner. Epifauna (and some infauna) were collected with an epibenthic sled in two reference corridors before trawling and in two trawled corridors before and after trawling (see above). There was a significant reduction in trawl by-catch biomass during the first 6 sets (15-17 hrs), due primarily to a decline in snow crabs, with relatively constant levels during the last 6 sets when snow crabs migrated into the trawled corridors to feed on dead and damaged organisms. Epifaunal biomass was lower in trawled corridors than in reference corridors in all three years (on average, 24% lower) and remained relatively constant with time, whereas biomass in reference corridors was highly variable from year to year. There were significant trawling and year effects on total epifaunal biomass and trawling effects on mean individual biomass, indicating that individuals in the trawled corridors had a smaller average size. At the species level, the biomass of 5 of the 9 dominant epifaunal species (a sand dollar, brittle star, soft coral, snow crab, and a sea urchin) was significantly lower in the trawled corridors than in the reference corridors. There was also a general trend of greater damage to benthic invertebrates in the trawled corridors, especially for three species of brittlestar, sea urchin, and sand dollar. There were no significant effects on the abundance of four dominant mollusc species.

(14). Schwinghamer et al. (1998) sampled surface sediments (top 2 cm) and conducted video and acoustic surveys at the Newfoundland study site before, after, and during trawling in two experimental corridors. Tracks and berms left by the trawl doors increased bottom relief and roughness. In 1993, door tracks 5 cm deep and 1 m wide were still clearly visible in side scan sonar records after two months, but they were not visible at the beginning of trawling in 1994. Tracks made in 1994 were faintly visible at the beginning of trawling in 1995. On a small scale, trawling suspended and dispersed sediment, flattened the seafloor and removed biogenic mounds and organic matter deposited in depressions. Seafloor topography recovered within a year's time. Sediment grain size varied significantly between corridors and between years, but there was no evidence that it was affected by trawling. Large, epibenthic organisms (*e.g.*, basket stars, snow crabs, and brittle stars) were readily visible in experimental and reference corridors, but tended to be arranged in linear features parallel to the axis of trawling in the experimental corridors. The authors concluded that even at a depth of 120-146 m, natural disturbances such as bioturbation and storms may cause more pronounced physical changes to the bottom than those caused by trawling.

Summary

Results of 14 studies are summarized. One of them was described in a 1980 publication, all the rest have been published since 1998. Six studies were conducted in North America (three in a single long-term experiment on the Grand Banks), four in Australia, and four in Europe. Ten are experimental studies. Eight of them were done in depths less than 60 m, one at 80 m, and four in depths greater than 100 m. Three studies examined the physical effects of trawling, ten were limited to biological effects, and one examined both. Five of the biological studies were restricted to epifauna, one only examined infauna, and five included epifauna and infauna. The only experiment that was designed to monitor recovery was the one on the Grand Banks, although surveys conducted in Australia documented changes in the abundance of benthic organisms five years after closed areas were established. Two studies compared benthic communities in trawled areas of sandy substrate with undisturbed areas near a shipwreck. Six studies were performed in commercially exploited areas, five in closed areas, two compared closed and open areas, and one was done in a test tank. All the experimental studies examined the effects of multiple tows (up to 6 per unit area of bottom) and observational studies in Australia assessed the effects of 1-4 tows on emergent epifauna. Trawling in four studies was limited to a single event (1 day to 1 week), whereas the Grand Banks experiment was designed to evaluate the immediate and cumulative effects of annual 5-day trawling events in a closed area over a three-year period.

Physical effects

A test tank experiment showed that trawl doors produce furrows in sandy bottom that are 2 cm deep, with a berm 5.5 cm high (7). In sandy substrate, trawls smoothed seafloor topographic features (4,14), re-suspended and dispersed finer surface sediment (7), but had no lasting effects on sediment composition (14). Trawl door tracks lasted up to one year in deep water (14), but only for a few days in shallow water (3). Seafloor topography recovered within a year (14).

Biological effects

Single disturbance experimental studies

Two single-event studies (2,6) were conducted in commercially-trawled areas. In one of these studies (2), otter trawling caused high mortalities of large sedentary and/or immobile epifaunal species. In the other (6), there were no effects on benthic community diversity. Neither of these studies investigated effects on total abundance or biomass. Two studies were performed in un-exploited areas. One study documented effects on attached epifauna. In one (11), single tows reduced the density of attached macrobenthos (>20 cm) by 15% and four tows by 50%. In the other (4), two tows removed 28% of the epifauna on mud and sand substrate and epifauna in all trawled quadrats showed signs of damage. These results were not reported separately for sand bottom. Total infaunal abundance was not affected, but the abundance of one family of polychaetes was reduced.

Repeated disturbance experimental studies

Intensive experimental trawling on the Grand Banks reduced the total abundance and biomass of epibenthic organisms and the biomass and average size of a number of epibenthic species (12). Significant reductions in total infaunal abundance and the abundance of 15 taxa (mostly polychaetes) were detected during only one of three years, and there were no effects on biomass or taxonomic diversity (9).

Observational studies

Changes in macrofaunal abundance in a lightly-trawled location in the North Sea were not correlated with historical changes in fishing effort (5), but there were fewer benthic organisms and species in a trawling ground in the Irish Sea than in an un-exploited site near a shipwreck (1). In the other "shipwreck study," however, changes in infaunal community structure at increasing distances from the wreck were related to changes in sediment grain size and organic carbon content (8). The Alaska study (10) showed that epifauna attached to sand were less abundant inside a closed area, significantly so for sponges and anemones. A single tow in a closed area in Australia removed 89% of the large sponges in the trawl path (13).

Otter Trawls – Gravel/Rocky Substrate (Table 5.6)

(1). Auster et al. (1996) observed bottom conditions during a July 1987 submersible dive at a depth of 94 m near the northern end of Jeffreys Bank, in a gravel area where there were large (>2m diameter) boulders. A thin layer of mud covered the gravel and boulders and the rock surfaces supported large numbers of erect sponges, sea spiders, bryozoans, hydroids, anemones, crinoid sea stars, and ascidians. Smaller mobile fauna, including several species of crustaceans, snails, and scallops, were also abundant. When the area was resurveyed in August 1993, much of the mud veneer was gone and there was evidence that boulders had been moved. . Abundance of erect sponges was greatly reduced, and most of the associated epifaunal species were not present. The authors attributed this disturbance to otter trawling which was occurring in the area during the second survey and was not conducted in this area until after 1987, when modifications to fishing gear allowed fishermen to trawl rocky, boulder habitat in the Gulf of Maine.

(2). Freese et al. (1999) documented the effects of single tows with a bottom trawl in an area that had been exposed to very little or no commercial trawling since the 1970s in the eastern Gulf of Alaska. The trawl was a 42.5 meter “Nor'easter” otter trawl with 0.6 m diameter rubber tire groundgear attached to the footrope and 0.45 m diameter rockhopper discs and steel bobbins along the wings. Eight tows were made on predominantly pebble substrate (some cobble and boulders were also present) at depths of 206-274 m in August 1996. Quantitative video transects were made using a 2-man submersible down the center of each trawl path within 2-5 hrs after each tow and in adjacent reference areas. The trawl moved 19% of the boulders (median size 0.75 m) it encountered and, in less compact substrate, tire gear left a series of furrows that were 1-8 cm deep. On compact substrate (with a greater percentage of cobble) the tire gear left no furrows, but the trawl removed an overlying layer of silt. Single tows caused significant decreases in the density of undamaged vase sponges, morel sponges, sea whips, and anemones. Non-significant reductions in density were also observed for finger sponges, brittle stars, sea urchins, and one species of sea cucumber. None of the five groups of motile invertebrates showed a significant reduction in density as a result of trawling. In fact, arthropods and molluscs were more abundant in the trawled areas. Trawling also caused considerable damage to sponges and sea whips. More than 50% of the vase sponges and sea whips in the trawl transects were either damaged or removed from the substrate. Morel sponges were also damaged, but damage could not be quantified because this species is much more brittle and friable than the vase sponges and specimens crushed by the trawl were completely torn apart and scattered. Some finger sponges were also knocked over on to the substrate. Brittle stars were also damaged, but reticulate anenomes and motile invertebrates were not. Observations of fishes made during this study showed that rockfish (*Sebastes* spp.) use cobble-boulder and epifaunal invertebrates for cover.

(3). Van Dolah et al. (1987) assessed the effects of a single trawl tow on attached sponges and corals (depth 20 m) in an un-exploited area on the coast of Georgia, in the southeast U.S. The bottom was smooth rock with a thin layer of sand with extensive sessile invertebrate growth. The trawl was a 40/54 fly net with a 12.2-m headrope and a 16.5-m footrope equipped with six 30-cm rubber rollers separated by numerous 15-cm diameter rubber discs, and was attached to 1.8 x 1.2-m China-V doors using 30.5-m leg lines. were selected for assessment. Densities of three of the most abundant large sponges, three dominant soft corals, and one hard coral were determined by divers before trawling and again immediately after trawling, and 12 months after trawling, inside and outside the trawl path. Sponges and soft corals smaller than 10 cm in height were not counted, but all hard corals were counted. In addition, the degree of damage was evaluated.

The trawl damaged some specimens of all species, sponges more notably than corals. Undamaged sponges were less abundant immediately after trawling, significantly so in two transects that had higher pre-trawl sponge densities. Damage was noted for 31.7% of the sponges that remained in the trawled transects immediately after trawling. Most of the reduction in, and damage to, sponges was for the most abundant species, a barrel sponge. Twelve months later, the abundance of sponges in the trawled quadrats had increased to pre-trawl densities or higher and all damaged sponges had re-generated new tissue. Effects on the other large sponges were not as severe: there were no significant differences in density between sampling periods for vase sponges or finger sponges, although there was some evidence of trawl damage. Total abundance of soft corals declined in the trawl alley after trawling and a few damaged specimens were found, but effects were minimal compared to the sponges. There were no differences between pre-trawl and post-trawl density estimates for fan and whip corals. The more abundant stick coral was less abundant immediately after trawling and had recovered completely 12 months later, but the density estimates were not significantly different. Divers counted 30% fewer undamaged stony corals in the trawled quadrats immediately after trawling (the reduction was not significant). Of the seven colonies affected by the trawl, four were moderately to heavily damaged and three were damaged only slightly. Twelve months later stony corals were more abundant than they were before trawling and no damage could be detected.

Summary

Three studies of otter trawl effects on gravel and rocky substrate are summarized in this report. All three were conducted in North America. Two were done in glacially-affected areas in depths of about 100 to 300 meters using submersibles and the third was done in a shallow coastal area in the southeast U.S. One involved observations made in a gravel/boulder habitat in two different years before and after trawling affected the bottom. The other two were experimental studies of the effects of single trawl tows. One of these was done in a relatively un-exploited gravel habitat and the other on a smooth rock substrate in an area not affected by trawling. Two studies examined effects to the seafloor and on attached epifauna and one only examined effects on epifauna. There were no assessments of effects on infauna. Recovery was evaluated in one case for a year.

Physical effects

Trawling displaced boulders and removed mud covering boulders and rocks (1) and rubber tire groundgear left furrows 1-8 cm deep in less compact gravel sediment (2).

Biological effects

Trawling in gravel and rocky substrate reduced the abundance of attached benthic organisms (*e.g.*, sponges, anemones, and soft corals) and their associated epifauna (1,2,3) and damaged sponges, soft corals, and brittle stars (2,3). Sponges were more severely damaged by a single pass of a trawl than soft corals, but 12 months after trawling all affected species – including one species of stony coral – had fully recovered to their original abundance and there were no signs of damage (3).

Otter Trawls – Mixed Substrates (Table 5.7)

(1). The Canadian Department of Fisheries and Oceans **(DFO 1993)** conducted a side scan sonar survey in the Bras D'Or Lakes system in Nova Scotia to document the physical effects of various mobile fishing gears one year after the area was closed to mobile gear. Water depths ranged from 10 - 500 m, and bottom sediments included rich organic mud, clay, pebbly mud, well-sorted sand, gravel and boulders. Otter doors left parallel marks in the sediments, with spoil ridges or berms faintly visible along their inner margins and fainter marks between the two door marks apparently produced by the trawl footgear. These marks were seen predominantly in muddy sediments.

(2). Engel and Kvitek (1998) compared a lightly and a heavily fished area off central California with similar sediments (gravel, sand, silt/clay) and depths (180 m) using still and video photographs taken from a submersible in October 1994 and grab samples collected during 1994, 1995, and 1996. There were no differences in sediment composition between the two study sites. They estimated that any square meter of bottom area in the heavily fished (HT) area was exposed to 12 times more trawling effort during 1989-1996 than the lightly fished (LT) area. Results indicated that the HT area had significantly more trawl tracks, exposed sediment and shell fragments, fewer rocks and mounds, and less flocculent material. The densities of all six large invertebrate epifauna counted in video transects were higher in the LT area, significantly so for seapens, seastars, sea anemones, and sea slugs. The number of polychaete species was higher in the LT area in 1994 and 1996, and densities of nematodes, oligochaetes, and brittlestars were higher in the HT area in all three years (although differences, in most cases, were insignificant). No consistent (or significant) differences were detected for crustaceans, molluscs, or nemerteans. One polychaete species that was the most important prey item for three species of flounder was more abundant in the HT area in all three years, significantly so in 1994 and 1996.

The authors concluded that trawling reduces habitat complexity and biodiversity while increasing opportunistic infauna and prey important in the diet of some commercially important fish species, but conceded that, since the study lacked controls, there was no way to be sure that the observed differences between the two areas were, in fact, due to differences in trawling intensity.

(3). Smith et al. (1985) reported that diver observations showed minor surface sediment disturbance (less than 2.5 cm deep) within the sweep path of an otter trawl with 6 ft (1.8 m) doors and 3/8" (1 cm) footrope chain in Long Island Sound . Sediments in the study area were described as sand with mud and clay. Much of the disturbance was created by turbulence suspending small epifaunal organisms, silt and flocculent material as the net passed, rather than by direct physical contact of the net with the bottom. Trawl door tracks (in sand, less than 5 cm deep; in mud, 5-15 cm deep) were the most notable evidence of trawl passage. These tracks were soon obscured by the effect of tidal currents, but attracted mobile predators. Alteration of existing lobster burrows was minor and appeared easily repairable by resident lobsters. Roller gear of unspecified size on mud bottom left shallow scoured depressions; spacers between discs reduced scouring.

Summary

Three studies of the effects of otter trawls on mixed substrates are summarized. All three were conducted in North America and relied on sonar and observations made by divers or from a submersible. One of them (2) combined submersible observations and benthic sampling to compare the physical and biological effects of trawling in a lightly fished and heavily fished location in California with the same depth and variety of sediment types. One was a survey of seafloor features produced by trawls in a variety of bottom types (1) and the other primarily examined the physical effects of single trawl tows on sand and mud bottom (3).

Physical effects

Trawl doors left tracks in sediments that ranged from less than 5 cm deep in sand to 15 cm deep in mud (1,3). In mud, fainter marks were also made between the door tracks, presumably by the footgear (1). A heavily trawled area had fewer rocks, shell fragments, and biogenic mounds than a lightly trawled area (2).

Biological effects

The heavily-trawled area in California had lower densities of large epifaunal species (*e.g.*, sea slugs, sea pens, starfish, and anemones) and higher densities of brittlestars and infaunal nematodes, oligochaetes, and one species of polychaete (2). There were no differences in the abundance of molluscs, crustaceans, or nemerteans between the two areas. However, since this was not a controlled experiment, these differences could not be attributed to trawling. Single trawl tows in Long Island Sound attracted predators and suspended epibenthic organisms into the water column (3).

NEW BEDFORD SCALLOP DREDGES

New Bedford Scallop Dredges – Sand (Table 5.8)

(1). Auster et al. (1996) mapped Stellwagen Bank (Gulf of Maine, USA) in 1993 (depth 20-55 m) using side-scan sonar and showed it to be covered by large expanses of sand, gravelly sand, shell deposits, and gravel . Waves produced by large storms from the northeast create ripples in coarse sand that measure 30-60 cm between crests and 10-20 cm in height and deposit large sheets of fine sand with low sand waves 15-35 m between crests. The troughs of these sand waves are filled with shell debris. Gear tracks produced by trawls and scallop dredges could be distinguished in the sonar images. Examination of gear tracks in sonar images showed that scallop dredges disturb sand ripples and disperse shell deposits.

(2). Langton and Robinson (1990) analyzed visual and photographic observations made during submersible transects on an offshore bank in the Gulf of Maine (Fippennies Ledge) in July 1986 and June 1987. There was little evidence of scallop dredging at the dive site 1986, but it was heavily dredged sometime between the 1986 and 1987 submersible observations (Langton and Robinson 1988). Depth in the vicinity of the study transects (southeastern end of the ledge) range from 80-100 m. In the areas of highest scallop density, the surficial sediments were usually sand with occasional shell hash and small rocks. Where there were tubes formed by amphipods or polychaete worms, the sediment surface was visually a more silty-organic sand. Grain size analysis revealed that the upper 5 cm of sediment were quite uniform throughout the area and averaged 84% sand, with some gravel. Dredged areas observed in 1987 were clearly distinguishable from un-dredged, or not recently dredged, areas. The most obvious result of dredging was a change from organic silty-sand to gravelly sand. This was apparently due to the disruption of amphipod tube mats. Occasionally, piles of rock and scallop shells were observed, apparently deposited there when dredges were emptied at the surface. Densities of three dominant megafaunal species (scallops, burrowing anemones and a tube-dwelling polychaete) declined significantly between 1986 and 1987, apparently as a result of dredging.

(3). Watling et al. (2001) evaluated the geochemical and biological effects of scallop dredging in a shallow (15 m), silty-sand estuarine environment (Damariscotta River, Maine, USA. Bottom samples for sediment chemistry, micro-biology and fauna were collected by divers in a control and an experimental plot before and after intensive dredging (23 tows in one day) using a 2 m-wide chain sweep dredge towed at a speed of 2 knots (nmi/hr). The study area was located on one side of the estuary in an unexploited area with a low density of scallops. Sampling of benthic macrofauna (primarily infauna) was conducted four and five months before dredging, immediately before and immediately (one day) after dredging, and four and six months after dredging, by divers with push cores. The immediate effects of dragging were the loss of fine material from the top few centimeters of the sediment surface and a reduction in its food value (significant reductions in enzymatically hydrolysable amino acids and total microbial biomass). There was little discernible difference in the number of macrofauna taxa present after dragging, but the numbers of individuals were greatly (and significantly) reduced. Some taxa (families) showed little difference between the control and treatment site the day after dredging while others were reduced in abundance. Significant reductions were noted for one family of polychaetes (Nephtyidae) and photid amphipods. Fine sediments still had not been restored six months after dragging, whereas the food value of the sediments in the experimental plot had complete recoveredafter six months. Total macrofaunal abundance was still significantly lower four months afterwards, but after six months there was no longer any significant difference in the number of individuals in the two plots. Some taxa recovered sooner than others.

Summary

Three studies of the effects of New Bedford scallop dredges on sand substrate are summarized, all performed since 1990. One was conducted in an estuary on the Maine coast (3) and two on offshore banks in the Gulf of Maine (1,2). Two of them were observational in nature, but didn't include any direct observations of dredge effects. The other one was a controlled experiment conducted in an unexploited area in which a single dredge was towed repeatedly over the same area of bottom during a single day. One study examined physical effects and two examined physical and biological effects. One of them included an analysis of geochemical effects to disturbed silty-sand sediments.

Physical effects

Dredging disturbed physical and biogenic benthic features (sand ripples and waves, shell deposits [1], and amphipod tube mats [2]), caused the loss of fine surficial sediment (3), and reduced the food quality of the remaining sediment (3). Sediment composition was still altered six months after dredging, but the food quality of the sediment had recovered by then.

Biological effects

There were significant reductions in the total number of infaunal individuals in the estuarine location immediately after dredging and reduced abundances of some species (particularly one family of polychaetes and photid amphipods), but no change in the number of taxa (3). Total abundance was still reduced four months later, but not after six months. The densities of two megafaunal species (a tube-dwelling polychaete and a burrowing anemone) on an offshore bank were significantly reduced after commercial scallop vessels had worked the area (2).

New Bedford Scallop Dredges - Mixed Substrates (Table 5.9)

(1). Caddy (1968) described diver observations of dredge effects in shallow scallop (*Placopecten magellanicus*) beds in the Northumberland Strait (Gulf of St. Lawrence, Canada). The depth was about 20 m and the sediments ranged in texture from mud to clean sand. Fishing operations were conducted with a 2.4 m wide offshore chain sweep scallop dredge (no teeth) that was modified to reduce its weight by replacing the forward drag bars with chains. The dredge weighed 0.36 mt (800 lb) out of the water. Divers attached to the dredge made direct observations during two 5-minute tows that were made at a speed of about 2 knots (nmi/hr). The lateral skids, located at each end of the pressure plate produced two parallel furrows approximately 3 cm deep; a series of smooth ridges between them were caused by the rings in the chain belly of the dredge. Dislodged pieces of dead shell were more evident within the drag tracks than on the surrounding bottom.

(2). Caddy (1973) used a two-man submersible to observe the effects of a 2.4 m wide chain sweep dredge (no teeth, weight 0.6 mt or 1300 lb out of the water) and a gang of three 0.8 m wide Alberton style toothed dredges in a previously dredged area of Chaleur Bay, in the Gulf of St. Lawrence (Canada). (See p. __ for a summary of the toothed dredge results). Observations were made inside and outside dredge tracks within an hour of each tow. Depth varied from 40 to 50 m and the substrate was sand overlaid by glacial gravel, 1-10 cm in diameter, with occasional boulders up to 60 cm in diameter embedded in the gravel. Dredging suspended fine sediments and reduced visibility from 4-8 m to less than 2 m within 20-30 m of the track, but the silt cloud dispersed within 10-15 min of the tow, coating the gravel in the vicinity of the track with a thin layer of fine silt. The chain sweep dredge left a flat track that increased in depth from just below the sediment surface to several cm deep at the end (tows were 0.8-1.2 km long). Over areas of sand and fine gravel, marks were left by individual belly rings and the tow bar left a narrow depression in the center of the track. The edge of the track was sometimes marked by an impression left by the lateral skids. Gravel fragments were less frequent inside the track, and many were overturned. Rocks 20-40 cm in diameter were dislodged every 10-30 m of track. Some boulders were overturned and others were plowed along, leaving a groove several meters long. Empty holes left by some of the rocks were clearly evident.

(3). Mayer et al. (1991) investigated the effects of scallop dredging at a shallow (8 m) nearshore site on the Maine coast with a mixed mud, sand, and shell hash substrate. The site was dragged with a New Bedford style chain sweep dredge (presumably once, although no information was provided) and core samples were collected before dragging and one day after dragging inside and outside the dragged track. Dredging lowered the substrate by 2 cm and tilled the sediment to a depth of 9 cm, causing finer material (sand and mud) to be injected into the lower 5-9 cm of the sediment profile and increasing mean sediment grain size above 5 cm. (No statistical tests were performed with these data). Organic matter profiles were strongly affected by dragging. Total organic carbon and nitrogen at the new sediment-water interface were markedly reduced in concentration after dragging and carbon concentrations in the 5-9 cm sediment depth interval were considerably higher in the dredged site. A diatom mat on the surface of the sediment was disrupted by the dredge and partially buried. The microbial community of the surface sediments increased in biomass following dragging.

Summary

Three studies have been conducted on mixed glacially-derived substrates, two of them over 20 years ago and one 10 years ago. All were done in the northwest Atlantic (one in the U.S. and two in Canada) at depths of 8 to 50 m. Two observational studies examined physical effects and one experimental study examined effects on sediment composition to a sediment depth of 9 cm. The experimental study evaluated the immediate effects of a single dredge tow. None of these studies evaluated habitat recovery or biological effects, although one (3) examined geochemical effects.

Physical effects

Direct observations in dredge tracks in the Gulf of St. Lawrence documented a number of physical effects to the seafloor, including bottom features produced by dredge skids, rings in the chain bag, and the tow bar (1,2). Gravel fragments were moved and overturned and shells and rocks were dislodged or plowed along the bottom (2). Sampling one day after a single dredge tow revealed that surficial sediments were re-suspended and lost and that the dredge tilled the bottom, burying surface sediments and organic matter to a depth of 9 cm, increasing the grain size of sediments above 5 cm, and disrupting a surface diatom mat (3). Microbial biomass at the sediment surface increased as a result of dredging.

TOOTHED SCALLOP DREDGES

Toothed Scallop Dredges – Sand (Table 5.10)

Port Phillip Bay, Australia: The physical and biological effects of toothed scallop dredges were evaluated at three sites in a large, relatively low-energy, predominantly tidal embayment in southeast Australia in 1991 that had been commercially dredged for *Pecten fumatus* since 1963. These studies were described in four separate publications (see below). Depths at the three sites were similar (about 15 m), but each site had different sediments and was exposed to different current strengths and wave characteristics. Sediments at the three sites were fine and very fine sand with 15% silt/clay (St. Leonards), medium-fine sandwith 7% silt/clay (Dromana), and muddy sand with shell fragments and 30% silt/clay (Portarlington). Habitat-related objectives of these studies were to test whether dredging alters turbidity and sedimentation patterns in the bay, to evaluate the physical effects of dredging on the seafloor, and to determine the magnitude and direction of changes to the benthic community caused by dredging.

Three large (0.36 km^2) experimental plots (one per site) located within larger (20-30 km^2) areas which were closed to dredging in 1991 were dredged repeatedly by a fleet of 5-7 commercial draggers using 3-m wide “Peninsula” style box dredges fitted with cutter bars that did not extend below the skids. Experimental dredging intensity at Portarlington (716 tows in four days during a three-week period) was equivalent, on average, to four tows per unit area and duplicated heavy commercial dredging intensity, based on historical levels of fishing effort in the bay. Dredging at the other two sites was less intensive (382 and 459 tows and an average of two tows per unit area) and limited to 2-3 day periods. The amount of commercial dredging activity in the bay declined dramatically after 1987 (Currie and Parry 1996), so the study sites had been virtually undisturbed for four years when the research was conducted.

Black and Parry (1994[1], 1999[2]) and **Currie and Parry (1996[3], 1999a[4])** evaluated the physical effects of experimental dredging in Port Phillip Bay by using a variety of field sampling techniques at all three sites. Turbidity levels and dredge penetration depths were measured immediately after dredging. Visually apparent changes to the seafloor were assessed by divers with video cameras at various times before and after dredging. The last observations were made at St. Leonards 11 months after dredging, at Portarlington seven months after dredging, and at Dromana after five days. Dredging disturbed the top 1-2 cm of sediment, but sometimes penetrated up to 6 cm in softer sediments. Turbidity plumes extending 1-2 m into the water column were created immediately behind the dredge, reaching turbidity levels 2-3 orders of magnitude greater than the turbidity caused by storms within 2-16 seconds after dredging. Dredging-related sediment concentrations returned to natural storm levels after about 9 minutes at sites 60 and 80 m downcurrent of the nearest boundary of the experimental dredging plots.

Video observations showed that the sediment plume was entrained across the full width of the dredge, mostly by the cutterbar. As the dredge traveled across the irregular seabed, the cutterbar trimmed off the high regions, creating turbulent pulses of sediment. Smaller sediment plumes were also produced by the skids. Dredging at one of the experimental sites had a grader-like effect on the sea bed, flattening low-relief mounds produced by burrowing callianisid shrimp and filling in depressions between them. Parallel tracks up to 2.5 cm deep were produced by the dredge skids. The mounds re-formed after six months. Flat areas between the mounds were still visible after six months, but 11 months after dredging there were no visible differences in topography between the control plot and the dredged plot. The tracks were still visible a month after dredging, but not after six months. At one of the other two sites, small parallel sand ripples in part of the dredged plot were obliterated by dredging, but re-formed immediately following a storm that occurred five days after the area was dredged and mounds were re-formed seven months after dredging, but were still smaller than in the control plot.

Currie and Parry (1996[3], 1999a[4]) evaluated the biological impacts of dredging on benthic infauna in Port Philip Bay. At the most intensively-sampled site (St. Leonards) grab samples were collected in a dredged plot and an adjacent control plot on three occasions before dredging, and again immediately after dredging, and at intervals of 3 weeks, and 3.5, 5, 8, and 14 months after dredging. Sampling at the other two sites was intended to evaluate very short-term biological effects and was limited to the dredged plots: grab samples were taken 8 days before and 2 days after dredging at Dromana and 10 days before and one day afterwards at Portarlington. In addition, a plankton net was attached to the top of the dredge to sample animals thrown up by the dredge during each tow at St. Leonards. At this site, there was a significant decrease in the number of infaunal species in the dredged plot relative to the control plot three weeks after dredging that persisted for 14 months, but there was no effect on the total number of individuals. In the 3.5 months following dredging, 6 of the 10 most common benthic species showed significant decreases in abundance of 28 to 79% on at least one half of the experimental plot; most species decreased in abundance by 20-30%. Two and three of the ten most common species at the other two sites were significantly reduced in abundance within 1-2 days after dredging, but reduced sampling intensity limited the statistical power of the tests. Of the six species whose abundance was reduced significantly over the first 3.5 months at the St. Leonards site, two were affected for 3.5 months, two for 8 months, and two for 14 months. Dredging impacts at this site became undetectable for most species following their annual recruitment; most species recruited within six months, but a few still had not recruited after 14 months. Species that occurred on or near the sediment surface (*e.g.*, tube-dwelling amphipods) were released into the water column right away, whereas species inhabiting deeper sediments (*e.g.*, burrowing polychaetes) were dislodged as dredging continued. More mobile, opportunistic species inhabiting surface sediments increased in abundance during the 3.5 months after dredging, perhaps because the removal of other species increased their food supply. Dissimilarity measures between the two plots increased after dredging, reaching a maximum three weeks after dredging, and suggesting that there were delayed effects on community structure such as increased predation of infaunal organisms that were uncovered by dredging.

Although this research clearly demonstrates that there were biological impacts of scallop dredging to benthic habitats in Port Phillip Bay, the reductions in density caused by dredging were small compared to natural changes in population densities during the year (Currie and Parry

1996**)**. Furthermore, changes to infauna caused by dredging in 1991 were smaller than the cumulative changes to infaunal community structure in Port Philip Bay over the preceding 20 years (Currie and Parry 1999b). Currie and Parry (1999a) also concluded that changes to benthic community structure (species composition) caused by dredging in the bay were small compared with natural differences between study areas.

(2). Butcher et al. (1981) documented diver observations of scallop dredging in Jervis Bay, New South Wales, Australia, over large-grained firm sand shaped in parallel ridges at depths below 13 m. The dredge design was not described, but had teeth which extended up to 5 cm below the leading edge of the dredge. Dredging flattened sand ridges and produced a sediment plume extending up to 5 m into the water column which settled out within 15 minutes. Dredge paths were clearly visible and “old” dredge paths could be seen.

(6). Eleftheriou and Robertson (1992) examined the incremental effects of repeated scallop dredge tows in Firemore Bay, a shallow, sandy bay in Loch Ewe on the west coast of Scotland in July-August 1985. The depth at the study site was about 5 m and the sediment was well-sorted sand. It was a high-energy environment exposed to wave action. Fishing (divers and beam trawls) took place in the bay during the 1970s and 1980s. A 1.2-m wide scallop dredge with nine, 12-cm long teeth was towed 25 times over the same track during a 7-day period (2 tows on day 2, 2 on day 3, 8 on day 4, and 13 on day 8). The chain bag was removed from the dredge so that all organisms that passed through the mouth of the dredge were returned to the bottom for observation. Grab samples were collected in the dredge track before and after each set of tows. Qualitative assessments of the epifaunal and large specimen infaunal community were conducted by divers using still cameras. There was no control (undredged site) in this study and thus no means to statistically evaluate the effects of location or natural changes in the abundance or composition of the benthic community in the bay that could have occurred during the course of this study.

Dredge teeth penetrated the bottom to a depth of 3-4 cm. Dredging created furrows, eliminated natural bottom features, and dislodged large shell fragments and small stones. Sediments in this location are well mixed by wave action to a depth below 3-4 cm, thus the dredge had no effect on the vertical distribution of grain size, organic carbon, or chlorophyll-a. Grooves and furrows created by the dredge were eliminated shortly after dredging, the length of time depending on wave action and tidal conditions. Infaunal invertebrates that were adapted to the stresses of a high-energy environment (*e.g.*, amphipods and bivalves) were not affected in any significant way. Sedentary polychaetes declined in abundance after 12 tows, then increased after 25 tows. Small crustaceans – mostly cumaceans – increased in abundance after the first two tows and between tows 4 and 25. There were no significant changes in biomass of the different infaunal taxa. Organisms such as small infaunal crustaceans, crabs, and starfish were attracted to feed on dead and damaged organisms left behind the dredge. Visual counts of living, damaged, and dead epifaunal organisms before and after each dredging event indicated some damage and mortality to organisms such as sea urchins, starfish, scallops, and crabs. Razor clams were dug up by the dredge and lay partially buried with their valves gaping and large numbers of sand eels (*Ammodytes* spp.) were killed. The plowing effect of the dredge buried, damaged, or chased away organisms such as brittlestars, burrowing anemones, and swimming crabs.

(7). Thrush et al. (1995) conducted an experimental study of scallop dredging at two sites 14 km apart in the Mercury Bay area of the Coromandel Peninsula in New Zealand in 1991. At each site, half of a plot measuring 70 x 20 m was dredged (five parallel tows in a single day) using a 2.4 m- wide box dredge with 10 cm long teeth on the lower leading edge of the dredge. Divers collected core samples and made visual observations in the dredged and undredged halves of each plot before dredging, within two hrs after dredging, and three months after dredging. Results from the two sites were treated separately because the macrobenthic communities were distinctly different. Both sites were dominated by small, short-lived benthic species. One site was a commercial scallop fishing ground and the other was not. The sediment at both sites was coarse sand, but was more poorly sorted and had a large fraction of shell hash at the exploited site. The depth was about 24 m at each site.

At both sites, the dredge broke down the natural surface features (*e.g.*, emergent tubes and sediment ripples) and the teeth created grooves approximately 2-3 cm deep. Dredging produced changes in community structure that persisted for three months at each site. At both sites, significant differences in benthic community structure (numbers of individuals and taxa) and in the densities of common macrofauna (infauna and epifauna) were apparent immediately after dredging. The initial community-level responses at both sites were negative, *i.e.*, significantly lower total densities and numbers of taxa in the dredged plots than in the adjacent reference plots. The responses noted three months later were more complex, with differences between the two sites. Effects were more pronounced and more often negative at the previously unexploited site where total density remained significantly lower in the dredged plot three months after dredging. Six of the 13 most common taxa at this site were significantly less abundant in the dredged plot two hours after dredging and five of them (two phoxocephalid crustaceans and three polychaetes) were still less abundant three months later. In contrast, there was a significant recovery in total density in the dredged plot at the exploited site after three months, to the point that the total densities in the two plots were the same. Four of the 13 most common taxa at this site were significantly less abundant two hours after dredging and three of them (ostracods, two species of bivalve) still had not recovered three months later. Four taxa that were negatively affected two hours after dredging at the exploited site were more abundant in the dredged plot than in the control plot three months after dredging. The authors concluded that the differences in the recovery processes at the two sites were likely to relate to differences in the initial community composition and to differing environmental characteristics.

Summary

Seven studies of the effects of toothed scallop dredges on sandy bottom habitat are summarized in this report, six of them for box dredges in Australia and New Zealand and one for Newhaven-style dredges in Scotland. All of them except one were published during the last ten years. Four of the Australian studies were done in the same location (Port Phillip Bay). All were performed in relatively shallow water (5-24 m). Five of these studies were controlled experiments and two were observational in nature. Three studies examined physical effects, and five evaluated physical and biological effects. Five studies were conducted in areas that had been exposed to little or no commercial dredging for at least three years prior to the study and one compared effects at a commercially exploited site and an unexploited site with different benthic communities. The Australian experimental studies (1,2,4,5) simulated commercial dredging activity, whereas the New Zealand study (7) evaluated the effects of multiple side-by-side tows, and the Scottish study (6) examined the incremental effects of multiple tows on the same area of bottom. In all cases, experimental dredging was limited to a single event that never lasted for more than a week. Recovery was monitored for three months in one case and up to 14 months in another.

Physical Effects

Physical effects included sediment plumes (which lasted for 9-15 minutes), the smoothing of the seafloor, tracks made by dredge skids, and furrows 2-4 cm deep created by the dredge teeth (1-7). Dredging disturbed bottom sediments to a maximum depth of 6 cm (1-2). There was no effect on sediment composition at a shallow, high-energy site and dredge tracks were obliterated within a few days (6). Sand ripples at a deeper, less exposed, site that were smoothed by dredging re-formed within five days (5), biogenic mounds were restored after 6-7 months (5), and dredge tracks that were still visible after a month had disappeared after six months (4).

Biological effects were variable and depended on the degree of natural disturbance, how well individual species were adapted to sediment disturbance, and whether a single dredge tow or multiple tows were made over the same area of bottom.

Biological effects

Two studies conducted in a relatively low-energy, enclosed bay in Australia, showed that the abundance of most infaunal species was reduced by 20-30% during the first 3.5 months after the area was dredged repeatedly during a three-day period (4,5). There were no effects of dredging on the total number of individuals, but there were significantly fewer species in the dredged plot three weeks after dredging. Dredging significantly reduced the densities of six of the 10 most common infaunal taxa, and increased the abundance of more mobile, opportunistic species within the first 3.5 months of the experiment. (Two and three of the 10 most common taxa were significantly reduced in abundance 1-2 days after dredging at two other sites). Research at this location also revealed that surface-dwelling infauna are released into the water column right away, whereas burrowing organisms are released during later dredge tows. Most of the affected species in Port Phillip Bay recovered within 8 months, but some were still less abundant in one of the dredged plots after 14 months.

At two slightly deeper, open coastal sites in New Zealand, single tows resulted in immediate and significant decreases in the number of macrobenthic individuals and species (7). The immediate effects of dredging at an unexploited site were more pronounced and, for individual taxa, more often negative (significant reductions in six of the 13 most common taxa) than at the site that was located in a commercial scallop dredging ground (significant reductions in four of 13 taxa). Also, total abundance was the same in the dredged and control plots at the exploited site three months after dredging, but at the unexploited site total density was still significantly higher in the control plot. Repeated dredge tows in a very shallow, high-energy location in Scotland significantly reduced the abundance of small infaunal crustaceans and sedentary polychaetes, but taxa that are adapted to dynamic environments were not affected (6). Dredging also caused considerable damage and mortality to large epifauna and infauna in this study.

Toothed Scallop Dredges - Biogenic Substrate (Table 5.11)

Hall-Spencer and Moore (2000a) described the effects of scallop dredging on maerl beds, a biogenic substrate which is derived from living calcareous rhodophytes. These beds take hundreds to thousands of years to accumulate because the growth rates of the macroalgae are very slow and are particularly vulnerable to damage from mobile bottom fishing gear (Hall-Spencer and Moore 2000b). Single tows were made at depths of 10-15 m along each of three 100 m transects in an area in the Clyde Sea in Scotland that had been commercially dredged for 40 years and at a previously undredged area. Tows were made using a gang of three Newhaven dredges with 10 cm-long spring-loaded teeth mounted 8 cm apart on a horizontal metal bar that was held off the seabed by a rubber roller at each end. Immediate effects of dredging were noted and one transect at each site was monitored by divers 2-4 times a year over the following four years.

Video recordings showed, at both sites, that the rollers and chain rings were in contact with the bottom while the dredge teeth projected fully into the maerl substratum (10 cm) and harrowed the seabed, creating a cloud of suspended sediment. Rocks and boulders <1 m^3 in diameter were dislodged and overturned and cobbles often became wedged between the teeth and were dragged through the sediment. Dredges created 2.5-m wide tracks along which natural bottom features (*e.g.*, crab pits and burrow mounds) were erased. Sand and silt was brought to the sediment surface and living maerl was buried. Dredge tracks remained visible for 0.5-2.5 years depending on depth and exposure to wave action. Most megafauna on or within the top 10 cm of the maerl were either caught in the dredges or left damaged on the dredge track. Large, fragile organisms (*e.g.*, sea urchins and starfish) were usually broken on impact, whereas strong-shelled organisms (scallops, gastropods) usually passed into the dredge intact. Deep-burrowing species escaped dredge damage. Predatory species (*e.g.*, whelks, crabs, and brittlestars) rapidly aggregated in the dredge track to feed. Recovery rates for affected benthic species also varied considerably. Species with regular recruitment and rapid growth recovered quickly, as did mobile epibenthic species which migrated into test plots soon after dredging. Slow-growing species and/or infrequently recruiting sessile organisms remained depleted on test plots at the undredged site 4 years after dredging occurred, whereas the previously dredged macrobenthic community returned to pre-experimental status within 2 years.

Summary

The immediate physical and biological effects of single dredge tows were evaluated on maerl substrate in Scotland. Recovery was monitored over a four-year period. Dredging penetrated the seafloor to a depth of 10 cm, suspending sediment, overturning boulders, erasing bottom features, and burying living maerl in dredge tracks. Some dredge tracks were only visible for six months while others remained visible for 2.5 years, depending on depth and exposure to wave action. Most megafauna in the top 10 cm of the substrate were either caught in the dredge or left damaged in the dredge track. Large, fragile organisms were most vulnerable. Recovery of the epibenthic community was complete at a previously dredged site within two years, but some species at an unexploited site still had not recovered after four years. Slow-growing species, and species that infrequently recruited to the benthos, took much longer to recover than species with regular recruitment patterns and faster growth rates.

Toothed Scallop Dredges - Mixed Substrates (Table 5.12)

(1). Bradshaw et al. (2002) compared historical and recent benthic sample data from seven sites located south and west of the Isle of Man (in the Irish Sea) exposed to different amounts of fishing effort during the past 60 years. Sample data were available for the period 1938-1952, when scallop dredging in the area was still very limited, and from the 1990s. Some of these data were analyzed in an earlier paper by Hill *et al.* (1999). Analysis of sediment samples indicated that five of the sites were predominantly sand and two were gravel. No depth information was provided. Fishing disturbance for each site was evaluated in terms of total fishing effort of a sample fleet during 1981-1993 and its coefficient of variation (greater values indicate a more even distribution of fishing disturbance from year to year), the number of years since fishing began, and a fisherman's ranked index of total fishing effort at each site since the start of the fishery. Small-scale (*e.g.*, grab) and large-scale (*e.g.*, trawls) samples were pooled at each site so that the analysis would include the greatest possible range of infaunal and epifaunal animals.

There was a significant temporal effect across all sites and, at two sites where spatial and temporal replicate samples were available, the historical samples were distinct from the recent samples. Taxa that decreased in abundance between the two time periods included species of brittlestars, hydroids, upright and encrusting bryozoans, encrusting worms, and barnacles. Taxa that were more abundant in recent samples included large-bodied tunicates, mobile crustaceans (shrimp, spider crabs and squat lobsters) and robust scavengers (whelks, hermit crabs, and starfish). Taxa that became more abundant , on average, scored higher in terms of life-history characteristics that would increase their ability to survive dredging (highly mobile, deep burrowers, scavengers, prefer mud/sand sediment, robust body types, good powers of regeneration/recolonization) than those that decreased in abundance (sessile, shallow burrowers/nest builders, suspension or filter feeders, prefer shell/stones, fragile body types, poor powers of regeneration/recolonization). For individual sites, mean faunal similarities between the two time periods decreased significantly as the fishermen's index of effort and the number of years since fishing began increased. Similarly, the proportion of species "lost" between the two sampling periods increased significantly as the number of years of fishing increased. Faunal similarities and proportions of lost species between time periods were not significantly related to increased fishing effort, as estimated from fishermen's logbooks. These results suggested to the authors that it was the length of time over which fishing occurred, rather than absolute levels of effort, which was important in structuring benthic communities. For all sites, there was also no clear evidence of a relationship between changes in taxonomic diversity and fishing effort, although taxonomic distinctness – probably the best indicator of changes in biodiversity – decreased over time at two of the most heavily fished sites.

(2). Bradshaw et al. (2000) analyzed density estimates of epibenthic animals made during diver surveys in the undisturbed portion of the closed area. Surveys started in 1989, the year the area was closed, and were repeated in 1990 and then every other year until 1998. A number of epifaunal species increased significantly in abundance over the nine-year period, including brittlestars, a spider crab, scallops, hermit crabs, and one species of starfish. The most significant changes occurred in the fifth, seventh, and ninth years after the area was closed.

(3). Bradshaw et al. (2001) assessed the effects of scallop dredging on benthic communities inhabiting mixed substrates in a 2 km^2 area near the Isle of Man, in the Irish Sea, that was closed to commercial fishing by towed gear in 1989. The entire area adjacent to and inside the closed area had been heavily dredged for 50 years prior to the closure. Two experimental plots inside the closed area were dredged every two months or so starting in January 1995, using two sets of four spring-loaded Newhaven-type scallop dredges towed 10 times along a single dredge track in each plot. Two control plots were established inside the closed area and three plots were located outside the closed area in a commercial scallop dredging ground. Depth in the study area ranged from about 25 to 40 m and the seabed was a mixture of gravel, sand, and mud. Grab samples were collected twice a year starting in 1995 in all seven plots. After the first six months of experimental dredging, benthic community structure in the dredged plots was more similar to the commercially dredged plots and less similar to the control plots than it had been before dredging began. This trend continued over the next three years of the experiment. However, none of these differences were significant, nor were there any clear trends for particular species or groups of species. Dredging also had no significant effect on total species number or richness, but there was evidence that dredging reduced benthic community heterogeneity. Sessile epifaunal organisms were considered to be especially sensitive to dredging disturbance and were analyzed separately; one dataset (March 1998) revealed that encrusting bryozoans, encrusting sponges, and small ascidians were more common in dredged plots, while upright forms such as bryozoans and hydroids were more common in the undredged plots.

(4). Caddy (1973) used a two-man submersible to observe the effects of 0.8 m-wide toothed dredges in Chaleur Bay, Gulf of St. Lawrence, in August 1971. A gang of three dredges was attached to a common steel towing bar. The upper and lower edges of each dredge mouth were armed with blunt teeth 4 cm long. Observations were made inside and outside dredge tracks within an hour of each tow. Depth varied from 40 to 50 m and the substrate was sand overlaid by glacial gravel, 1-10 cm in diameter, with occasional boulders up to 60 cm across embedded in the gravel. Tracks left by these dredges were shallow with a flat floor. Gravel was sparser inside than outside the track and dislodged boulders were commonly observed. Tooth marks were seen over sandy bottom. Spoil ridges were left between adjacent dredges and piles of small rocks were seen at intervals along the track. Small rocks were also "bulldozed" along in front of the dredge.

(5). The Canadian Department of Fisheries and Oceans **(DFO 1993)** conducted a side scan sonar survey in the Bras D'Or Lakes system in Nova Scotia to document the physical effects of various mobile fishing gears one year after the area was closed to mobile gear. Dredge tracks consisting of a series of parallel furrows made by the dredge teeth were observed in gravelly bottoms and occasionally in silty bottoms. On the older or degraded dredge tracks, the furrows left by the teeth were not always resolved. In a soft bottom area, berms were visible at the outer edges of the dredge track. Similar berms were not seen in harder bottom areas.

(6). Kaiser et al. (1996a) compared the immediate effects of beam trawling and scallop dredging on large epibenthic fauna on a heavily fished scallop ground off the southwest coast of the Isle of Man, adjacent to the closed area studied by Bradshaw *et al.* (2001**)**. Three parallel waylines, 500 m apart and 1 n mi long, were established: one was fished ten times with a 4-m commercial beam trawl fitted with a 80 mm diamond mesh codend, one was left undisturbed, and one was fished ten times with two gangs of four Newhaven spring-toothed dredges. The benthos in all three waylines was surveyed using a 2.8 m beam trawl with a 40 mm square mesh codend before, and 24 hours after, fishing. Prior to fishing, there were no significant differences between the epibenthic communities on the three waylines. Both gears greatly reduced the abundance of most species and altered community structure, but there were no significant differences in community structure between the two experimental waylines after fishing. The scallop dredges caught a lower proportion of non-target species.

(7). Kaiser et al. (2000a) examined the structure of infaunal and epifaunal benthic communities exposed to either high or low scallop dredging activity in the Irish Sea over a ten year period. Samples were collected with an anchor dredge, a grab sampler, and with a small beam trawl from five sites subjected to low fishing effort and five sites subjected to high fishing effort, based on fishing effort data collected between 1986 and 1996. Only large infaunal organisms (>10 mm) were retained in sediment samples since they were judged to be more sensitive to physical disturbance. The study area was located south of the Isle of Man, in the Irish Sea, in the center of one of the most heavily fished scallop grounds in Europe, in gravel and coarse sand sediments. After accounting for habitat effects (caused by variations in median sediment grain size and depth), the only significant response to increased fishing was a higher number of epifaunal organisms. There were no significant effects on the number or diversity of epifaunal species or on any of the community indices for infauna. Communities in the heavily fished areas were dominated by higher abundances of smaller-bodied organisms, whereas the less intensely fished areas were dominated by fewer, larger-bodied biota. Species with higher mean densities or catch rates in the low effort sites included a soft coral, two species of sea urchin, a bivalve, and two gastropods. Species that were more abundant in the high effort sites included three species of brittlestar and a sea urchin.

(8). Veale et al. (2000) compared samples of epibenthic organisms collected with a gang of four Newhaven type spring-toothed scallop dredges in 1995 on 13 different commercial fishing grounds in the Irish Sea that had been exposed to different amounts of fishing effort during the preceding 60 years. Annual estimates of fishing effort were available from detailed, high-resolution fishermen’s logbooks. Depths ranged from 20 to 67 m and sediment types were generally coarse sand and gravel, overlain with pebbles, cobbles, and dead shell. The dredges were equipped with short teeth (76 mm) and small belly rings (57 mm). Of all the environmental parameters examined (including depth, bottom hardness and texture), a combination of long- and short-term fishing effort best explained the observed differences in dredge by-catch assemblages across sampling sites. Species diversity and richness, total number of species, and total number of individuals all decreased significantly with increasing fishing effort. Total abundance, biomass and production, and the production of most of the major individual taxa investigated, decreased significantly with increasing effort. Species that were more abundant at the high-effort sites included starfish and the crab *Cancer pagurus*. Spider crabs and soft corals were more abundant at the medium and high-effort sites.

Summary

This report summarizes the results of eight studies that assessed the effects of toothed scallop dredges on mixed glacially-derived substrates. All but one of these studies were done during the last ten years. Six of them were conducted in the Irish Sea and two in eastern Canada. The Canadian studies (4,5) examined physical effects to the seafloor and the Irish Sea studies evaluated effects on benthic infauna and epifauna. Two of the Irish Sea studies (2,6) were experimental. One (1) compared benthic sample data collected at sites exposed to variable amounts of historical fishing effort, and another (3) involved diver surveys in a closed area. One of the two experimental studies (6) evaluated the effects of a discrete scallop dredging and beam trawling event on large epifauna in a commercially exploited area, and the other (2) examined the incremental effects of repeated, bi-monthly tows over a three-year period in a closed area.

Physical effects

Physical effects of scallop dredging in mixed substrates included furrows made by the teeth, shallow, flat tracks with spoil ridges or berms at the edges, dislodged boulders, and the “bulldozing” of small rocks by the dredge (4,5). No information on recovery times was available.

Biological effects

In the closed area study (3), six months of experimental dredging (total of 30-40 tows with 8 dredges on three or four different occasions) following a six-year period with no dredging altered benthic community structure, but not significantly. There were no trends in the abundance of individual species or number of species, but there was evidence of reduced community heterogeneity. Three years after dredging began, upright species were less abundant, and encrusting species were more abundant. (These changes may have occurred earlier, but this could not be verified). A number of epifaunal species increased significantly in abundance in the closed area five to nine years after the area was closed (2).

Experimental dredging in commercial fishing grounds in the Irish Sea altered the community structure of large epifaunal populations (6), while areas exposed to ten years of high fishing effort were characterized by significantly higher numbers of epifaunal organisms (7). Chronic exposure to high fishing effort did not significantly affect infaunal communities and there were no significant effects of increasing scallop dredging activity on the number of epifaunal species or species diversity, but there was a shift from benthic communities dominated by greater numbers of larger species to fewer numbers of smaller species (7). Sites exposed to low fishing activity 50-60 years ago and high fishing activity during the 1990s were characterized by fewer “disturbance-vulnerable” species and more “disturbance-tolerant” species (1). Furthermore, faunal differences and the percentage of species “lost” between the low and high-effort time periods increased as the number of years since fishing began increased. Overall, there was no clear evidence of reduced species diversity between the two time periods. Invertebrate by-catch collected in dredges at high-effort sites was composed of significantly fewer species and individuals than at low and medium-effort sites, and total abundance, biomass, and production, and the production of individual taxa declined significantly with increasing fishing effort (8).

OTHER NON-HYDRAULIC DREDGES

Other Non-Hydraulic Dredges - Biogenic Substrate (Table 5.13)

(1). Fonseca et al. (1984) conducted research near Beaufort, North Carolina (USA), in 1982 to determine the effects of small, hand-pulled bay scallop dredges on eelgrass. Two 65-cm-wide, light-weight dredges (no teeth on the dredge foot) were fixed to a single tow bar. Two study sites were selected, an exposed site with compacted silty-sand sediments (19.8% silt and clay), and a protected site where sediments were less compact and had a slightly higher silt-clay content (22.3%). Three small quadrats at each site were dredged 15 times, three were dredged 30 times, and three were not dredged at all. There was a significant decrease in both the number of eelgrass shoots and biomass with increasing dredging effort at each site. Both shoot number and leaf biomass were reduced to zero at the soft-bottom site after 30 dredge pulls, but the hard-bottom site lost more biomass than the soft-bottom site because the initial biomass there was higher. The proportional reduction in shoot number was greater at the soft-bottom site. The authors concluded that intensive scallop dredging for bay scallops with this gear or with the heavier dredges that are pulled by power boats has the potential for immediate as well as long-term reduction of eelgrass nursery habitat.

(2). Langan (1998) conducted a study in 1994 to determine the effects of dredge harvesting on an oyster population and its associated benthic community in the Piscataqua River, which divides the states of New Hampshire and Maine **(**USA**)**. An oyster bed approximately 18 acres in size in the river channel is divided nearly equally by the border between the two states. Maine allows commercial harvesting of oysters, but New Hampshire had not for many years prior to the study. The dredge used on the Maine side of the river is 30 inches wide, weighs approximately 27 kg, and has blunt, 8 mm teeth and a chain mesh bag. Commercial dredging on the Maine side of the river (with one dredge, about twice a week) had continued for five years prior to the study. A limited number of benthic samples were collected by divers on each side of the river on one sampling occasion. No significant differences were found in the number, species richness, or diversity of epifaunal or infaunal invertebrates between the two areas. The concentration of suspended sediment in near-bottom water during a dredge tow was slightly more than double the ambient level 10 m behind the dredge and dropped off to the ambient level 110 m behind the dredge.

(3). Lenihan and Peterson (1998) conducted a study in the Neuse River estuary in North Carolina (USA) to determine if the loss of oysters (*Crassostrea virginica*) from the river was in part due to the lowering of oyster reefs by oyster dredges. Eight one meter tall oyster-shell reefs were constructed in two depths (3 and 6 m). Nineteen months later, four of the eight reefs were dredged by a commercial dredge vessel for a week until the catch of market-sized oysters in each haul declined to near zero and remained constant. The height of harvested and un-harvested reefs was measured three days before and two days after dredging stopped. Dredging reduced the mean height of the 1-m reefs by 29 (plus or minus 6) cm. Unharvested reefs lost only 1 (plus or minus 1) cm of height over the one week duration of the experiment.

(4). Riemann and Hoffmann (1991) assessed the water column effects of mussel dredging in a shallow, eutrophic sound (Limfjord) in Denmark with a mean depth of 7 m and a maximum depth of 15 m. Suspended particulate matter, oxygen, and nutrient (phosphorus and nitrogen) levels were measured at a number of stations throughout the water column at a dredged and a control site before dredging, immediately afterwards, and 30 and 60 minutes later. No information on sediment type was given. Dredging was performed for 15 minutes with a 2-m wide mussel dredge weighing about 100 kg. Average suspended particulate matter increased significantly immediately after dredging, but returned to pre-dredge levels 60 minutes later. Particulate matter also increased markedly on a day with high wind velocity. Oxygen decreased significantly immediately after dredging, particularly near the bottom. Average ammonia content also increased after dredging, but large horizontal variations prevented detailed interpretation of these increases.

Summary

Four studies are summarized. Three were conducted on the U.S. Atlantic coast and one in Denmark. All were performed in shallow water, two in rivers and two in coastal waters with a maximum depth of 15 m. Two studies evaluated biological effects, one examined physical effects, and one examined geochemical effects in the water column. Three studies were experimental and one was observational.

Physical and biological effects

These studies showed that dredging lowers the height of oyster reefs (3) and, in a shallow, enclosed fjord, temporarily increased water column turbidity and lowered dissolved oxygen concentrations, especially near the bottom (4). There were no detectable effects of five years of oyster dredging on benthic invertebrate abundance, species richness or diversity (2). Repeated tows with hand-hauled bay scallop dredges significantly reduced eelgrass biomass (1).

HYDRAULIC CLAM DREDGES

Hydraulic Clam Dredges – Mud (Table 5.14)

Hall and Harding (1997) evaluated the effects of suction dredging on intertidal infaunal communities in Auchencairn Bay, on the north side of the Solway Firth, on the west coast of Scotland. Sediments were 60-90% silt/clay in the interior of the bay and 25-60% silt/clay in the center and outer parts of the bay. Commercial dredging for cockles (*Cerastoderma edule*) in the bay was prohibited four and a half months before experimental dredging began. Core samples were collected in control plots prior to dredging, and in experimental plots immediately after, and one, four, and eight weeks after dredging. Dredge tracks could not be seen after the first day. The total number of infaunal individuals and species increased in both plots over time, but were significantly lower in the experimental plots than in the control plots immediately after dredging and after four weeks. Species diversity also increased significantly over time, but was not significantly different in the two plots at any point during the experiment. Three of the five dominant species were significantly reduced by dredging over the course of the study. By the end of the study (eight weeks), much of the difference between dredged and control sites had been lost, but the disturbed plots still had a higher partial-dominance index.

Summary

Results of a single experimental study are summarized. It examined the physical and biological effects of individual suction dredge passes in an intertidal mud habitat and monitored recovery for eight weeks. Dredging produced dredge tracks that disappeared after one day. There were significant reductions in the total number of infaunal individuals and species that lasted four weeks, and three out of five dominant species were reduced in abundance during the entire eight-week duration of the experiment. However, infaunal community structure recovered nearly completely by the end of the experiment.

Hydraulic Clam Dredges – Sand (Table 5.15)

(1). Hall et al. (1990) studied the physical and biological effects of a commercial escalator dredge used to harvest razor clams (*Ensis* spp.) in a shallow sea loch (Loch Gairloch) on the west coast of Scotland in November 1989. The depth at the study site was 7 m and the sediment was fine sand. It was located near a recently-dredged area, but was not exploited itself. Experimental and control plots were visually inspected and sampled by divers immediately after dredging and 40 days later. Each experimental plot **[size?]** was dredged intensively for approximately five hours in order to simulate commercial fishing activity. After dredging, the experimental plots were crisscrossed by shallow trenches (0.5 m wide and 0.25 m deep) interspersed with larger holes (up to 3.5 m wide and 0.6 m deep) that were presumably produced when the dredge remained stationary for a brief period. Sediment in the holes and trenches was "almost fluidized" and sand in the bottom of the trenches had a significantly higher median particle size. After 40 days, however, none of these features remained.

The number of infaunal species and individuals were reduced in the experimental plots immediately after dredging (significantly, for individuals), but there were no detectable differences between experimental and control plots 40 days later. There were no significant differences in the abundance of individual species in the control and experimental plots on either sampling occasion. The authors concluded that dredging caused a short-term, non-selective reduction in the numbers of all infaunal species and that recovery from physical effects was accelerated by a series of winter storms and considerable sediment disturbance in the study area. No attempt was made to assess the mortality of large polychaetes and crustacea that were observed to be retained on the wire mesh conveyor belt or fell off the end of the belt, or ocean quahogs (*Arctica islandica*) that were often cracked by the dredge.

(2). Kaiser et al. (1996b) investigated the effects of suction dredging for cultivated manila clams (*Tapes philippinarum*) on a muddy sand intertidal flat in southeast England in December 1994. Samples of benthic infauna and sediment were collected prior to, three hours after, and seven months after harvest in one cultivated plot and in nearby control locations. There were significantly higher densities of infaunal organisms in the cultivated plot prior to dredging, but no differences in the number of species or in four indices of taxonomic diversity. Large amounts of fine sand were re-suspended by the dredge, exposing the underlying clay. There were also significant reductions in the mean numbers of infaunal species and individuals in the dredged plot immediately after harvest, to values that were statistically the same as in the control locations. Crustaceans and bivalve mollusks were particularly affected. Seven months later there were no significant differences between the benthic community in the harvested plot and in the control locations and the proportion of fine sand in the harvested plot had increased significantly, indicating that recovery from the effects of clam cultivation and harvesting was complete.

(3). MacKenzie (1982) sampled benthic invertebrate assemblages in three ocean quahog beds with contrasting fishing histories located about 65 km east of Cape May, New Jersey (USA), in the mid-Atlantic Bight, in October 1978. One bed had never been fished, one had been actively fished for two years, and one had been fished for about a year but then abandoned 4-5 months prior to this study. All three beds were in very fine to medium sand sediments in 37 m of water. Commercial dredging was conducted with cage dredges in this area. Sampling was limited to a total of 30 grab samples from all three sites. No significant differences were found in numbers of invertebrate individuals or species, or in species composition, between previously dredged and un-dredged areas or between dredged and un-dredged sample locations at the two fished sites. Hydraulic dredging thus did not appear to have any lasting effect on the invertebrate populations in these beds. Comparison of samples from previously dredged and un-dredged sample locations also indicated that hydraulic jetting of the bottom re-sorts bottom sediments, leaving shell fragments on the surface and coarser sediments at the bottom of dredge tracks.

(4). Maier et al. (1995) assessed the effects of escalator dredges in four muddy sand tidal creeks in South Carolina (USA) by comparing pre- and post-dredging turbidity levels and benthic infaunal assemblages. Turbidity was monitored two weeks before, during, and two weeks after dredging at one location and during and immediately after dredging at another. Infaunal samples were collected three weeks before and two weeks after dredging in a creek that had been commercially dredged five years prior to the study and in a creek that had never been dredged before. **[What about the other two creeks?]** Turbidity was elevated in the vicinity of the dredge and immediately downstream while it was operating, but the sediment plumes only persisted for a few hours. Sampling failed to detect any significant changes in the abundance of dominant infaunal taxa, or in the total numbers of individuals, after dredging.

(5). Medcof and Caddy (1971) utilized divers and a submersible to compare the physical effects of a hydraulic cage dredge and a non-hydraulic toothed scallop dredge in shallow water (7-12 m) sand inlets in southern Nova Scotia (Canada). (See p. __ for a summary of the scallop dredge results). On sand and sand-mud habitats, hydraulic dredges left smooth tracks with steeply cut walls that averaged 20 cm deep and slowly filled in by slumping. The hydraulic dredge raised a sediment cloud which seldom exceeded 0.5 m in height and usually settled within 1 minute. Dredge tracks were still easily recognizable after 2-3 days.

(6). Meyer et al. (1981) observed the effects of a small (1.2 m wide) hydraulic clam cage dredge in an un-harvested surfclam bed located near Rockaway Beach on the south shore of Long Island, New York (USA). The study was conducted in 1977, three years after the area was closed to commercial clamming. The sediment in the study area was fine to medium sand covered with a 7.5 cm-thick layer of silt and the maximum depth was 30 m. The study area was exposed to strong bottom currents that caused considerable movement of sand. As part of a larger study to evaluate gear performance, the effects of dredging on bottom substrate and fauna were assessed by divers during a single 2-minute tow immediately after and 2 and 24 hrs after dredging. The dredge formed trenches which were initially rectangular, as wide as the dredge, and over 20 cm deep. Mounds of sand 15-35 cm wide and 5-15 cm high were formed on either side of the trench. The dredge raised a cloud of silt 0.5- 1.5 m in height, which settled within four minutes. Slumping of the trench walls began immediately after the tow and became more apparent with time. Two hours after dredging, slumping of the trench walls had rounded the depression. After 24 hours the dredge track was less distinct, appearing as a series of shallow depressions, and was difficult to recognize. The dredging attracted predators, with lady and rock crab preying on damaged clams, and starfish, horseshoe crabs and moon snails attacking exposed but undamaged clams. By 24 hours after dredging, the abundance of predators appeared to have returned to normal, and the most obvious evidence of dredging was whole and broken clam shells without meat.

(7). Pranovi and Giovanardi (1994) studied the effects of a 2.7-m wide hydraulic cage dredge in 1.5-2 m depths in the Venice Lagoon (Italy, Adriatic Sea). Divers collected samples of sediment and benthic organisms from experimentally-dredged and control areas at two sites inside and outside a commercial fishing ground immediately after experimental dredging and every three weeks for two months. A single tow with a commercial dredge was made at each site. The dredge created 8-10 cm-deep furrows, one of which was clearly visible two months later. In this study, sediment grain size was not significantly affected by dredging, although portions of the fishing grounds which had been predominantly silt and clay 15 years earlier had a considerably higher sand content at the time of the study. Hydraulic dredging in this area often cracks the shells of bivalves. Within the fishing grounds, total numbers and biomass of benthic infauna and epifauna were significantly reduced in the experimental plot immediately following dredging. Densities, especially of small species and epibenthic species, recovered two months later, but biomass did not. Inside the fishing ground, there were also fewer species in the dredged area than in the control area immediately after, and three and six weeks after, dredging, but no differences two months afterwards. Outside the fishing ground, immediately after passage of the dredge, there were no significant faunal differences between dredged and undredged areas.

(8). Tuck et al. (2000) examined the effects of hydraulic dredging on the seabed and benthic community in a shallow (2-5 m), sandy site in the Outer Hebrides (Sound of Ronay), on the west coast of Scotland in March 1998 that was closed to commercial dredging. Sediments in the study area consisted of moderately well-sorted medium or fine sand and tidal currents reached speeds as high as three knots. Divers collected core samples and made observations and video recordings, before, during, and after dredging inside and outside six dredge tracks and returned to re-examine the site 5 days and 11 weeks after dredging. The dredge was a commercial dredge used to harvest razor clams that employs a hollow blade that protrudes 0.3 m into the sediment with holes that direct pressurized water forward into the sediment.

Immediately after dredging the track had distinct vertical walls and a depth similar to the dredge blade. However, once the dredge was hauled, the side walls collapsed and the tracks had a flat-bottomed “V” shape. The sediment within the base of the tracks was fluidized to a depth of approximately 0.3 m and within both side walls to approximately 0.15 m. The tracks were still clearly visible after five days, but less pronounced, and the depth of fluidized sediment remained the same. After 11 weeks the tracks were no longer visible, but 0.2 m of sand was still fluidized. Immediately after fishing, there was significantly less silt in the sediments inside the tracks than outside, but there was no difference after five days. Numerically, the infauna at the study site was dominated by polychaetes. There was a significant decrease in the proportion of polychaetes, and an increase in amphipods, in the dredge tracks within five days ofdredging, but not after 11 weeks. Bivalves were not affected by dredging. Within a day of dredging the total number of species and individuals was significantly lower in the dredge tracks, but there was no difference after five days. Dredging had an immediate effect on the abundance of a number of individual species, but no effects were detected 11 weeks after dredging. Owing to the strong currents, there was a very sparse epifauna in the area: the only observed effect of dredging was the attraction of crabs into the area to scavenge on material disturbed by the dredge.

Summary

Results of eight hydraulic dredge studies in sandy substrates are summarized in this report. Five of them examined the effects of “cage” dredges of the type used in the Northeast region of the U.S. (3,5-8) and three examined the effects of escalator and suction dredges. Three of them were published prior to 1990, and five since then. Four were performed in North America, one in the Adriatic Sea and three in the United Kingdom. One study was conducted on the U.S. continental shelf at a depth of 37 m, five in shallower, nearshore waters (1.5 – 12 m), and two in intertidal environments. Three studies were observational in nature and five were controlled experiments. Three studies compared effects in commercially-dredged and un-dredged areas and four were conducted in previously un-dredged areas. Six studies examined the effects of individual dredge passes, one evaluated the effects of repeated passes in the same area during a short period of time, and one compared infaunal communities in an actively dredged, a recently dredged, and an un-dredged location. Seven studies examined physical and biological effects and one was limited to physical effects. All of the biological studies examined effects to infauna. Recovery was evaluated in four cases for periods ranging from 40 days to seven months.

Physical effects

Hydraulic clam dredges created steep-sided trenches 8-30 cm deep that started deteriorating immediately after they were formed (1, 5-8). Trenches in a shallow, inshore location with strong bottom currents filled in within 24 hours (6). Trenches in a shallow, protected, coastal lagoon were still visible two months after they were formed (7). Hydraulic dredges also fluidized sediments in the bottom and sides of trenches (1,8), created mounds of sediment along the edges of the trench (6), re-suspended and dispersed fine sediment (2, 4-6), and caused a re-sorting of sediments that settled back into trenches (3). In one study (8), sediment in the bottom of trenches was initially fluidized to a depth of 30 cm and in the sides of the trench to 15 cm. After 11 weeks, sand in the bottom of the trench was still fluidized to a depth of 20 cm. Silt clouds only last for a few minutes or hours (4-6). Complete recovery of seafloor topography, sediment grain size, and sediment water content was noted after 40 days in a shallow, sandy environment that was exposed to winter storms (1).

Biological effects

Some of the larger infaunal organisms (*e.g.*, polychaetes, crustaceans) retained on the wire mesh of the conveyor belt used in an escalator dredge, or that drop off the end of the belt, presumably die (1). Benthic organisms that are dislodged from the sediment, or damaged by the dredge, temporarily provided food for foraging fish and invertebrates (1,6). Predator densities returned to normal within 24 hours in one study (6). Hydraulic dredging caused an immediate and significant reduction in the total number of infaunal organisms in three separate studies (1,2,8) (but not in another (4)) and in the number of macrofaunal organisms in a fourth study (7). There were also significant reductions in the number of infaunal species in two cases (2,8) and in the number of macrofaunal species and biomass in a third case (7). In one study, polychaetes were most affected (7). Two studies failed to detect any reduction in the abundance of individual taxa (1,4). Evidence from the study conducted off the New Jersey coast indicated that the number of infaunal organisms and species, and species composition, were the same in actively dredged and un-dredged locations (3).

Recovery times for infaunal communities were estimated in four studies. Three of these studies (1,7,8) were conducted in very shallow (1.5-7 m) water and one (2) in an intertidal environment. Total infaunal abundance and species diversity had fully recovered only five days after dredging in one location where tidal currents reach maximum speeds of three knots (8). Some species had recovered after 11 weeks. Total abundance recovered 40 days after dredging in another location exposed to winter storms, when the site was re-visited for the first time (1). Total infaunal abundance (but not biomass) recovered within two months at a protected, commercially-exploited site (7), where recovery was monitored at three-week intervals for two months, but not at a nearby unexploited site. Full recovery at the intertidal site was noted seven months after it was suction dredged when it was re-visited for the first time (2). Actual recovery times at this site and at one of the exposed sub-tidal sites (1) may have been much quicker than seven months and 40 days.

Hydraulic Clam Dredges - Mixed Substrates (Table 5.16)

Murawski and Serchuk (1989) used manned submersibles to observe effects of hydraulic dredging on sand, mud, and gravel bottom habitats in a number of offshore locations in the mid-Atlantic Bight (U.S. Atlantic coast) between Delaware Bay and Long Island (water depths not reported). They reported that hydraulic cage dredges penetrate deeper into the sediments and, on a per-tow basis, result in greater short-term disruption of the benthic community and underlying sediments than do scallop dredges (no data were provided). In coarse gravel, the sides of hydraulic dredge trenches soon collapsed, leaving little evidence of dredge passage. There was also a transient increase in bottom water turbidity. In finer-grained, hard-packed sediments, tracks persisted for several days after dredging. Non-harvested benthic organisms (*e.g.*, sand dollars, crustaceans, polychaetes) were substantially disrupted by the dredge. Sand dollar assemblages appeared to recover quickly, but short-term reductions in infaunal biomass were considered likely. Numerous predatory fish (*e.g.*, red hake, spotted hake, and skates) and invertebrates (rock crabs and starfish) were observed in and near dredge tracks consuming broken quahogs. Densities of crabs and starfish were estimated to be 2.5 times higher in dredge tracks than in nearby undredged areas within one hour of experimental tows and >10 higher 8 hrs after dredging. Presumably, benthic infauna "tilled up" by the dredge were also being consumed, since not all predators observed foraging in the dredge paths were eating damaged shellfish.

Summary

An *in situ* evaluation of hydraulic dredge effects in sand, mud, and coarse gravel in the mid-Atlantic Bight indicated that trenches fill in quickly, within several days in fine sediment and more rapidly than that in coarse gravel. Dredging dislodged benthic organisms from the sediment, attracting predators.

Hydraulic Dredges - Biogenic Substrate (Table 5.17)

(1). Godcharles (1971) evaluated the physical effects of escalator dredging in seagrass (*Thallasia testudineum* and *Syringodinium filiforme*) beds, *Caulerpa* algae beds, and bare sand bottoms (depth not given) in Tampa Bay, Florida (USA) in 1968. Dredging was conducted with a commercial dredge at six sites **[single passes on one occasion?]**. Water jets penetrated sediments to a maximum depth of 45 cm and left trenches that varied from 15-45 cm deep. Trenches were deeper in shallow areas where propellor wash scoured loose sediments from trenches and prevented redeposition of suspended sediments. The proportion of fine sediment in some trenches decreased immediately after passage of the dredge. Virtually all attached vegetation in the path of the dredge was uprooted, leaving open bottom areas. Trenches in grass beds remained visible longest (up to 86 days) while those in sandy areas filled in immediately. Most fluidized sediments hardened within a month, but some spots were still soft 500 days after dredging. Differences in silt/clay content between tracks and undisturbed areas became negligible after a year, but seagrasses had still not re-colonized disturbed areas. New algal growth was noted in some dredged areas after 86 days and after a year dredge tracks were completely covered.

(2). Orth et al. (1998) assessed damage to submerged aquatic vegetation (SAV) caused by escalator dredges in Chincoteague Bay, Virginia (USA) during 1996, 1997, and 1998. They reported a large number of circular “scars” in the vegetation, with 70-100% seagrass cover outside the scarred areas and an abrupt reduction to 15% or less at the scar edge. The percent cover of seagrass was low across the scar until a second abrupt increase in cover occurred at the center where seagrass had not been disturbed. There were no measurable differences in percent cover estimates in the scarred portions of areas that were dredged during the three years of observation, indicating that re-vegetation was proceeding very slowly. There were two factors that they believed were delaying re-vegetation: an increase in depth of 10-20 cm in the dredge tracks and large holes inside the un-vegetated portions of the scars made by organisms such as foraging cownose rays. The authors concluded that even the most lightly impacted areas would require a minimum of five years to fully recover.

Summary

Two studies were performed in the southeast U.S. in shallow, sub-tidal, vegetated habitats. One of them was a controlled experiment that compared the effects of escalator dredges in vegetated (seagrass and algae) and un-vegetated areas and the other evaluated damage to seagrass beds caused by commercial escalator dredging. In the experimental study (1), water jets penetrated sand substrate to a maximum depth of 45 cm, created trenches up to 30 cm deep, up-rooted vegetation, and increased the silt/clay content of sediments in dredge tracks. Recovery times were extremely variable. In some cases, trenches were visible for only a day and in other cases for three months. In most cases, sediments hardened within a month, but in some tracks sediments were still fluidized 500 days after dredging. After a year sediment composition in dredge tracks had returned to normal, but seagrass had not re-colonized disturbed areas. There were no signs of recovery of seagrass in commercially-dredged areas three years after dredging (2).

POTS AND TRAPS

Pots and Traps - Mixed Substrates (Table 5.18)

Eno et al. (2001) evaluated the effects of crab and lobster pots on attached epibenthic megafauna (sponges, bryozoans, ascidians, soft corals, and tube worms) at three locations in Great Britain. The effects of dropping pots on to sea pens were observed by divers in a soft mud pot-fishing ground on the west coast of Scotland (depths not given) in 1995. In addition, three experiments were conducted to assess sea pen recovery and survival following dragging, up-rooting, and smothering by lobster pots. In one experiment, divers dragged pots over marked areas of the seabed and recorded the fate of sea pens for three days after the disturbance. In the second, groups of sea pens removed from the seabed by the pots were re-located to an undisturbed location and their behavior and survival was observed over a four-day period. Finally, 60 pots were dropped on to individual or small groups of sea pens and removed after 24-48 hrs to simulate the effects of smothering that would occur during commercial operations. Video observations showed that the pressure wave created by pots as they sink to the bottom was sufficient to bend sea pens away from the pot just before contact. Results of the three experiments revealed that all sea pens were able to fully recover from pot impact. Furthermore, all sea pens recovered from the effects of dragging within 24-72 hrs. Up-rooted sea pens reinserted themselves into the sediment, providing the peduncle gained contact with the mud surface. Following smothering for 24-48 hrs, it took 72-96 and 96-144 hrs, respectively, for all three species of sea pen to fully recover an upright position.

SCUBA divers assessed the immediate effects of pot hauling at five coastal sites in Lyme Bay, England, in different habitats at depths of 14-20 m in September and October 1995. Habitats varied from exposed limestone slabs and bedrock covered by sediment to large boulders with mixtures of various rocky substrates interspersed with coarse sediment. A variety of fragile epifaunal species, including a sea fan and ross coral, were present. Two lines of three pots were deployed at each site. Immediately after deployment, divers video recorded pots on the seabed as they landed, and then followed them as they were hauled and backtracked along the path of each pot after removal. In addition, the effects of potting on selected epibenthic species were quantified at Greenala Point, West Wales and in Lyme Bay where sites with rocky substrates, water depths less than 23 m, and with fragile epifaunal species were identified. Pot fishing for crabs (*Cancer pagurus*) and lobsters (*Homarus gammarus*) is carried out in these two locations and common epifaunal species included a sea fan and a colonial, emergent bryozoan. Each study area was divided into two control and two experimental plots. Pots were set in the experimental plots and hauled every two or three days for four weeks, such that at least 30 pots and 10 anchor weights landed in each experimental plot over the course of the study. There were very few signs of impact on epifaunal species at any of the five sites. Gorgonians (soft corals) were frequently seen to bend under the weight of pots then spring back once the pots had passed. When pots were hauled back along the bottom, a track was left in the sediments, but the abundance of sponges, soft corals, bryozoans, and ascidians within the experimental plots was not any lower than in the control plots after four weeks of pot fishing. In fact, at the West Wales site, the abundance of four sponge species increased significantly in the experimental plots after four weeks of potting, but not in the control plots. In Lyme Bay, three species of sponge increased significantly in abundance in the experimental plots only.

Summary

Observations and experiments were carried out in a single study conducted at three coastal locations in Great Britain to evaluate the effects of crab and lobster pot fishing on attached epibenthic megafauna. Sea pens underneath pots were bent over and some were up-rooted when pots were dragged over mud sediments, but they fully recovered within 72-144 hours after pots left on the bottom for 24 or 48 hrs were removed. When pots were dragged over the bottom they left tracks, but four weeks of simulated commercial pot fishing had no negative effect on the abundance of attached benthic epifauna. In fact, sponges increased in abundance in the experimental plots.

MULTIPLE GEAR TYPES

Multiple Gear Types – Sand (Table 5.19)

(1). Almeida et al. (2000) surveyed the southern half of closed area II on Georges Bank in June 1999, 4.5 years after it was closed to groundfish gear (trawls, scallop dredges, longlines, and gill nets) . This portion of the closed area ranges in depth from slightly <50 m to slightly >90 m, the substrate is sand, and there are sand ripples and bedforms in the shallower, northwest “high-energy” portion of the survey area where bottom tidal currents are stronger. These features are generally absent from the deeper (>65 m) “low-energy” southeast portion of the survey area.

Still photographs and video imagery were used to assess the relative abundance of microhabitats at a series of paired stations just inside and outside the closed area boundary. No significant differences were found for any habitat type except emergent sponge epifauna (*e.g.*, *Suberites ficus* and *Polymastia* sp.) which was more abundant inside the closed area.

(2). Kaiser et al. (2000b) sampled infauna and epifauna with a 2-m beam trawl and an anchor dredge along the south Devon coast in England in three high fishing effort areas open to all fishing (otter trawl, beam trawl, scallop dredge and pots), two medium fishing effort areas open to mobile gear for six months out of the year and pots year round, and one low fishing effort area only open to pots. Sampling within each of the six areas was distributed among three sites. Sediments followed a gradient from fine sand to medium sand and coarse-medium sand. Fine sand areas (inshore site) were located at 15-17 m depth. The two offshore sites were located at 53-70 m depth.

For epifauna, there were significant habitat (depth and substrate) effects on the numbers of species and individuals, and on two indices of species diversity, but no significant differences between high vs. low fishing effort for any of these parameters. In general, however, as fishing disturbance increased, less mobile, larger-bodied, and more fragile epifaunal species decreased in abundance while mobile, more resilient species increased in abundance. Areas closed to draggers had higher abundances of emergent fauna (*i.e.*, soft corals and hydroids) that increased habitat complexity. For infauna, there were significant habitat differences in the number of species and diversity (one index) between the two offshore sites, but no consistent effects of increasing fishing effort across all three sites, and only one significant effect of fishing (on species diversity) between the two deeper offshore sites. Infaunal biota in the three different habitats were affected to different extents by increasing levels of fishing. The deeper, medium-coarse sand habitat seemed most severely affected by fishing. Several infaunal species in this habitat had significantly lower biomasses and abundances. Areas subjected to lower fishing effort were dominated by epifaunal and infaunal organisms with relatively high biomass, whereas areas subjected to high fishing effort had fewer high-biomass organisms and greater abundances of smaller-bodied species.

Summary

The results of two observational studies of multiple gear types on sand habitats (at depths that varied from 15 to over 90 m) are summarized in this report. A recent study in U.S. waters on eastern Georges Bank (1) compared the amount of cover provided by different habitat types inside and outside an area closed to trawls, dredges, longlines, and gill nets for four-and-a-half years. Another recent study (2) compared sandy shallow and deep water sites on the south coast of England that were exposed to low, medium, and high levels of fishing effort by mobile and fixed gear.

On Georges Bank, the only significant difference was a higher abundance of emergent sponges inside the closed area (1). Low effort areas on the south coast of England that were closed to trawls and dredges had more emergent epifauna (soft corals and hydroids) and were dominated by relatively high-biomass epifauna and infauna, whereas high effort areas fully exposed to fixed and mobile gear had higher abundances of small-bodied organisms (2). Deep (53-70 m) coarse-medium sand offshore sites were more affected by fishing than deep, medium sand or shallow (15-17 m), inshore, fine sand sites (2).

Multiple Gear Types – Gravel/Rock (Table 5.20)

(1). Collie et al. (1997) sampled two shallow (42-47 m) and four deep (80-90 m) gravel sites in U.S. and Canadian waters on eastern Georges Bank during two cruises in 1994 that were classified as disturbed (D) or undisturbed (U) by bottom-tending mobile gear based on the number of dredge and trawl tracks in side-scan sonar images, the presence or absence of large boulders and epifauna in bottom photographs, and 1993 records of scallop dredging effort in ten minute squares of latitude and longitude in U.S. waters on the bank. There were three U sites and one D site in deep water and one U and one D site in shallow water. Bottom substrates were predominantly pebble/cobble with or without encrusting organisms, with some overlying sand. Quantitative samples of epibenthic organisms (>10 mm) were collected with a 1 m-wide Naturalists' dredge fitted with a 6.4 mm square mesh liner. Organisms such as colonial sponges, bryozoans, hydroids, and the tube-dwelling polychaete *Filograna implexa* that were not quantitatively sampled by the dredge were excluded from analysis.

There were significant effects of fishing and depth on total density, biomass, and an evenness diversity index based on abundance and some evidence of a gradient in abundance, biomass, and species diversity from deep, undisturbed sites (high values) to shallow, disturbed sites (low values). However, because of the significant depth effects and depth x disturbance interactions, fishing disturbance alone was not a significant factor. Cluster analysis identified a group of six species that were abundant at U sites and rare or absent at D sites and were not affected by depth: this group included two species of shrimp, a tube-dwelling polychaete, a nemertean, horse mussels, and a bloodstar. Six other species groups were defined either by depth or some combination of depth and disturbance level, or included species that were ubiquitous.

(2). Collie et al. (2000), in a follow-up publication, analyzed video images and still photographs recorded at five of the six study sites surveyed in the two 1994 research cruises to George Bank (see above). In the videotapes, the U sites at both depths had slightly coarser sediments (higher frequency of pebble-gravel than sand-gravel); in the still photos, there was a higher frequency of sand and cobble in U sites and a lower frequency of pebbles. Bottom photos showed a high percent cover of colonial hydroids and bryozoans at one of the deep U sites and of the rock-encrusting polychaete, *Filograna implexa,* at both deep U sites. In contrast, at the D sites the gravel was free of epifaunal cover and few animals were visible. Statistical analysis confirmed that the U sites had a significantly higherhigh percent cover of *Filograna implexa*.. However, cover provided by this species was also significantly greater in deeper water than in shallow water. Emergent hydroids and bryozoans were significantly more abundant in the deep U sites, but less abundant at the shallow U site. Overall, the percent cover of all emergent epifauna was significantly higher at the deep sites, but there was no significant disturbance effect.

Summary

Two recent observational studies of mobile gear effects on sediments and epifauna in gravel bottom on the northern edge of eastern Georges Bank (42-90 m) are summarized. Study sites were distinguished by depth and the presence or absence of fishing disturbance. Sediments in undisturbed sites were slightly coarser with more sand and cobble. There were significantly more organisms, higher biomass, and greater species diversity at the undisturbed sites in both depths, but there were also significantly higher values in disturbed and undisturbed deep sitesthan in disturbed and undisturbed shallow sites. Percent cover of an encrusting colonial polychaete was also significantly higher at these sites, but emergent hydroids and bryozoans were significantly more abundant in deep, undisturbed sites and at shallow, disturbed sites. Overall, emergent epifauna was more abundant in deep water, but there was no significant disturbance effect.

Multiple Gear Types - Mixed Substrates (Table 5.21)

(1). Auster et al. (1996) used a remotely operated vehicle (ROV) In July 1993 to compare conditions inside and outside an inshore area (depth 30-40 m) in the Gulf of Maine (USA) that was closed to mobile fishing gear in 1983. Video transects indicated that on sand/shell bottom, habitat complexity was provided mostly by sea cucumbers attached to shell and other biogenic debris and by bottom depressions created by mobile fauna. Both of these habitat features were significantly less common outside the closed area, a difference that was attributed to the incidental exploitation of sea cucumbers and the harvest of lobsters, scallops, crabs, and white hake – all animals that produce depressions. On cobble/shell bottom, habitat complexity was provided mostly by emergent epifauna (*i.e.*, hydroids, bryozoans, sponges, serpulid worms) and sea cucumbers. These species were less common outside the closed area. Their reduced abundance was attributed to removal by mobile fishing gear. Cleared swaths in epifaunal cover were observed at the border of the closed area that were presumed to be caused by scallop dredges and trawl doors.

(1). Auster et al. (1996) also conducted side-scan sonar surveys of Stellwagen Bank (Gulf of Maine, USA) in 1993 (depth 20-55 m) that showed large expanses of sand, gravelly sand, shell deposits, and gravel. The authors reported that waves produced by large storms from the northeast create ripples in coarse sand that measure 30-60 cm between crests and 10-20 cm in height and deposit large sheets of fine sand with low sand waves 15-35 m between crests. The troughs of these sand waves are filled with shell debris (mostly ocean quahogs, *Arctica islandica*). Examination of sonar images showed scallop dredge and trawl tracks that disturbed sand ripples and dispersed shell deposits. ROV observations on the bank's crest (32-43 m deep) indicated that aggregations of emergent hydrzoans were missing and benthic microalgal cover was disturbed in gear tracks. Observations on the crest of the bank in July 1994 showed that an ascidian species was widely distributed, but was not present in otter trawl tracks.

(2-4). Reise and Schubert (1987), Riesen and Reise (1982), and Reise (1982) compared invertebrate surveys in the Wadden Sea (Netherlands) made between 1869 and 1986. Bottom sediments in these areas currently range from mud to coarse sand and some pebbles. The area is made up of tidal flats, shallow sub-tidal banks, and channels that reach depths of 23 m. Surveys were completed using oyster dredges and grabs. During the period of time encompassed by the various surveys, abundant oyster reefs were overexploited, seagrass beds were lost to a natural epidemic, and *Sabelleria* reefs were destroyed by heavy trawl gear. The area is now dominated by soft sediments and mussel beds, which prior to 1920 were restricted to very shallow water. Comparisons show that 28 species (eight associated with oyster beds, eight with *Sabelleria*, and seven with seagrasses) have declined in abundance. Twenty-three species (half of them polychaetes) that were missing or rare in earlier surveys were common in 1986. Epifauna were more abundant in the 1920s, and infauna were more abundant in the 1980s.

(5). Thrush et al. (1998) tested ten predictions regarding the effects of increasing fishing pressure on benthic communities in the Hauraki Gulf, New Zealand. Core, grab, and suction dredge samples were taken from 18 stations exposed to varying levels of commercial fishing effort by otter trawls, Danish seines, and toothed scallop dredges. Additional data were obtained from video images using a ROV and from sediment samples collected by divers. Sediments ranged from sand (<1% silt and clay) to mud (nearly 50% silt/clay) and depths from 17 to 35 m. After accounting for the effects of location, depth, and sediment characteristics (grain size and organic matter content), 15-20% of the variability in macrofauna (>0.5 mm) community composition was attributed to fishing pressure. Most of the predictions were supported by analysis of the core data. Three predicted results of increasing fishing pressure were confirmed at $p < 0.05$: decreased density of large epifauna (video transects), decreased species diversity and richness (core samples), and decreased echinoderm density (cores). Four additional predictions were confirmed at $p < 0.10$: decreased number of individuals (grabs), increased density of small opportunistic species (cores), decreased density of long-lived surface dwellers (cores), and increased density of deposit feeders (cores). Large epifauna were also less abundant in grab samples collected from more heavily-fished sites ($p <0.10$). Results, in some cases, were not consistent between sample types. Species diversity and richness, for example, were not even identified as significant model variables in the grab sample data, nor was the number of individuals in the core samples, and deposit feeders collected in grab samples were significantly <u>less</u> abundant at sites exposed to increased fishing pressure. Two predictions were contradicted by the results of this study: the ratio of polychaetes to molluscs (in cores) decreased rather than increased with greater fishing pressure, and the ratio of small to large individuals, for one common species of sea urchin, increased rather than decreased (also in cores). Scavengers were predicted to increase with increasing fishing pressure, but there was no evidence from this study that they responded either positively or negatively to changes in fishing intensity.

(6). Valentine and Lough (1991) used side scan sonar and a submersible to describe the effects of scallop dredges and trawls on sand and gravel bottom habitats on eastern Georges Bank. They noted that the most evident signs of disturbance occurred on gravel pavement, where they observed long, low mounds of gravel that presumably had been produced by trawling and dredging. In some areas the sea bed was covered by trawl and dredge tracks. Gravel areas which were not accessible to bottom-tending mobile gear (due to the presence of large boulders) had a biologically diverse community with abundant attached organisms. Conversely, the attached epifaunal community was sparse, and the bottom was smoother, in areas that had been disturbed by dredging and trawling.

Summary

Six observational studies of the effects of multiple gear types on mixed substrates are summarized. Surveys were conducted in the Gulf of Maine inside and outside an inshore area closed to mobile fishing gear and in an offshore area that was disturbed by mobile fishing gear (1). A series of three publications examined long-term (100+ years) changes in benthic habitats and communities in the Wadden Sea, some of which were attributed to fishing (2-4). A study in

New Zealand (5) tested ten predictions of how increasing fishing activity affects benthic communities by comparing benthic samples and underwater video footage from areas exposed to varying degrees of commercial fishing effort. A sixth study (6) examined areas on eastern Georges Bank that were affected by mobile bottom gear.

Significant increases were observed in the abundance of sea cucumbers and emergent epifauna, and in the number of bottom depressions created by organisms such as lobsters, scallops, and crabs, on sand-cobble-shell substrate inside the Gulf of Maine closed area (1). Side scan sonar and ROV surveys of Stellwagen Bank revealed evidence that otter trawls and New Bedford scallop dredges disturb sand waves and ripples, disperse shell deposits, remove emergent epifauna, and disturb microalgal cover (1). Disturbed sand and gravel areas of Georges Bank were characterized by trawl and dredge tracks, sparse epifauna, mounds of gravel presumably produced by fishing gear, and smoother bottom (6). In the New Zealand study (5), there were four significant effects of increased fishing activity by bottom trawls, Danish seines, and toothed scallop dredges in mud and sand substrates that were consistent across all sampling methodologies. These were reduced density of large epifauna, echinoderms, and long-lived surface dwelling organisms, and an increased density of small, opportunistic species. The loss of biogenic reefs and changes in benthic community composition (fewer mollusc and amphipod species and more polychaete species) in the Wadden Sea were in part attributed to fishing activity (2-4).

6. Vulnerability of Essential Fish Habitat to Bottom-Tending Fishing Gears

The purpose of this section is to evaluate potential adverse effects of bottom-tending fishing gears regulated by the Magnuson-Stevens Act (MSA) on benthic EFH in the Northeast region of the U.S. as required by the EFH final rule, 50 CFR 600.815(a)(2)(I). The EFH final rule recommends that the evaluation consider the effects of each fishing activity on each type of habitat found within the EFH for any affected species and life stage. The EFH rule further recommends that the following information be reviewed in making an evaluation: intensity, extent, and frequency of any adverse effects on EFH; the types of habitat within EFH that may be adversely affected; habitat functions that may be disturbed; and conclusions regarding whether and how each fishing activity adversely affects EFH.

The EFH final rule requires that EFH designations be based upon the best available information. This information may fall into four categories that range from the least specific (Level 1) to the most specific (Level 4). These categories are defined as follows:

- <u>Level 1</u>: Presence/absence data are available to describe the distribution of a species (or life history stage) in relation to potential habitats for portions of its range.
- <u>Level 2</u>: Quantitative data (*i.e.*, density or relative abundance) are available for the habitats occupied by a species or life history stage.
- <u>Level 3</u>: Data are available on habitat-related growth, reproduction, and/or survival by life history stage.
- <u>Level 4</u>: Data are available that directly relate the production rates of a species or life history stage to habitat type, quantity, and location.

Existing EFH designations in the Northeast region are based primarily on Level 2 information. This level of information is inadequate for making definitive determinations of the consequences of fishing-related habitat alterations on EFH for any species or life stage in the Northeast region because the habitat alterations caused by fishing can not be linked to any known effect on species productivity. Therefore, this section of the report qualitatively evaluates the vulnerability of benthic EFH for each species and life history stage (eggs, larvae, juveniles, adults, and spawning adults) in the Northeast region to the effects of five bottom-tending fishing gear types. Given the limited nature of the information available for this evaluation, emphasis was placed on the identification of <u>potential</u> adverse impacts of fishing on benthic EFH. Vulnerability is defined as the likelihood that the functional value of EFH would be adversely affected as a result of fishing.

Information used to perform these evaluations included: 1) the EFH designations adopted by the Mid-Atlantic, New England, and South Atlantic Fishery Management Councils; 2) the results of a Fishing Gear Effects Workshop convened in October 2001 (NREFHSC 2002); 3) the information provided in this report, including the results of existing scientific studies, and the geographic distribution of fishing gear use in the Northeast region; and 4) the habitats utilized by each species and life stage as indicated in their EFH designations and supplemented by other references.

The following five fishing gear classifications were evaluated: otter trawls (OT); New Bedford style scallop dredges (SD); hydraulic clam dredges (CD); pots and traps (PT); and sink gill nets and bottom long lines (NL). Vulnerability was ranked as none (0), low (L), moderate (M), and high (H), based upon a matrix analysis of habitat function, habitat sensitivity and gear use for each benthic life stage and species. Adult and spawning adult life stages were combined due to the difficulty in distinguishing between the two. In some cases (*e.g.*, pelagic life stages that are not vulnerable to bottom-tending fishing gear effects) a vulnerability ranking was not applicable (NA).

The pot/trap and net/line gear types were considered to have the least impact of the five gear types evaluated. Based on the limited information available (Eno et al. 2001, NREFHSC 2002), the vulnerability of all EFH to pot and trap usage was considered to be low. Similarly, there is little scientific information that evaluates the effects of gill nets and long-lines on benthic marine habitats, and none evaluates these effects in the Northeast region. The panel of experts that met in October 2001 ranked their concern over impacts from fixed gear well below concerns about mobile bottom-tending gears (NREFHSC 2002). Like pots and traps, the vulnerability of EFH for all benthic species and life stages to nets and lines was rated as low (L) and is not discussed in the species accounts (Tables 6.2 – 6.43).

The greatest concern is for the vulnerability of benthic EFH to mobile bottom-tending gears. In the Northeast U.S., these gear types include various types of bottom otter trawls, New Bedford scallop dredges, and hydraulic clam dredges. Otter trawls are responsible for most of the fisheries landings throughout the Northeast region. They are used in a variety of substrates, depths, and areas. Scallop dredges are used in sand and gravel substrates, and hydraulic dredges are used only in sand, shell, and small gravel within well-defined areas (see sections 3 and 4).

A simple matrix was developed for the benthic life stages of each federally-managed species in the Northeast region to determine the vulnerability of its EFH to effects from otter trawls, scallop dredges, and hydraulic clam dredges. The matrix is shown in Figure 6.1. Five criteria were qualitatively evaluated for each life stage based upon existing information. Each evaluation consisted of a score based upon predefined scoring criteria. The first three criteria were related to habitat function and included shelter, food and reproduction. Scores for these criteria were determined as follows:

Shelter (scored from 0-2): If the life stage is not dependent upon bottom habitat to provide shelter then a 0 was selected. Almost every life stage evaluated has some dependence upon the bottom for shelter so, with the exception of a few egg life stages, 0 was seldom used. If the life stage has some dependence upon unstructured or non-complex habitat for shelter it was scored a 1. For example, flatfishes that rely primarily on cryptic coloration for predator avoidance, or on sand waves for refuge from bottom currents, were scored a 1. If the life stage has a strong reliance on complex habitats for shelter it was scored a 2. For example, species such as juvenile cod and haddock that are heavily reliant on structure or complex habitat for predator avoidance were scored a 2.

Food (scored from 0-2): If the life stage is not dependent on benthic prey it was scored a 0. For example, eggs were always scored a 0, as were life stages that fed exclusively on plankton. If the life stage utilizes benthic prey for part of its diet, but is not exclusively a benthic feeder, it was scored a 1. For example, species feeding opportunistically on crabs as well as squid or fish were scored a 1. If the life stage feeds exclusively on benthic organisms and cannot change its mode of feeding it was scored a 2.

Reproduction (scored from 0-1): If the species is not dependent upon bottom habitats for spawning or its life stage was not a reproductive stage it was scored a 0. For example, species that spawn in the water column, as well as juveniles of all species, were scored a 0. If the species is somewhat dependent upon bottom habitats for spawning it was scored a 1. For example, species that spawn on or over the bottom were scored a 1. This criteria was the most difficult to assess since there is limited knowledge on spawning behavior and habitat for many species.

The fourth criterion was **Habitat Sensitivity** (scored from 0-2): This criterion does not evaluate the function of the habitat but instead accounts for its overall sensitivity to disturbance in a relative fashion. The type of benthic habitat (defined primarily in terms of depth, energy regime, and substrate) inhabited by each species and life stage was based primarily upon its EFH designation. If a habitat was not considered sensitive to disturbance it was scored a 0. However, a score of 0 was not used for any benthic habitat type. If the habitat was considered to have a low sensitivity it was scored a 1. For example, habitats that are typically characterized as high-energy environments without structural complexity or have rapid recovery rates were scored a 1 (*e.g.* high energy sand environments). If the habitat type was considered highly sensitive it was scored a 2. For example, habitats that are characterized as structurally complex (such as habitats supporting epibenthic communities, boulder piles, etc.) or have very slow recovery rates (such as low-energy deep-water environments) were scored a 2. These scores were based upon existing conceptual models that show a direct relationship between higher structural complexity of the habitat, longer recovery time, and increased vulnerability to disturbance (NREFHSC 2002). **[**

Habitat Rank: Habitat rank was determined quantitatively as the sum of the scores for the previous four criteria (shelter + food + reproduction + habitat sensitivity). Another way to characterize the habitat rank is the relative vulnerability of the habitat to non-natural physical disturbance. The rank scores ranged from 0-7, with 7 being the most vulnerable.

The fifth criterion was **Gear Distribution** (scored from 0-2)**:** This criterion factors in the use of each mobile gear type (otter trawl, scallop dredge, hydraulic clam dredge) in areas designated as EFH for a given species and life stage. If the gear is not currently used within the area described as EFH it was scored a 0. If the gear operates in only a small portion of the described EFH area it was scored a 1. If the gear operates in more than a small amount of the described EFH area it was scored a 2. The spatial distribution of fishing activity for each gear was determined from reports of the number of days absent from port or days fishing for individual ten minute squares of latitude and longitude for the period 1995-2001 (see Section 4 of this report). Maps of ten minute squares designated as EFH are available in NEFMC (1998) and in various fishery management plans developed by the Mid-Atlantic and South Atlantic Fishery Management Councils and have not been reproduced for this report.

Gear Rank: The gear rank assesses the overall vulnerability of EFH to impacts from fishing with each mobile gear type and was calculated as the product of the Habitat Rank and the Gear Distribution Rank. Based upon natural breaks in the rankings frequency distribution the following rank categories were defined:

0 = no vulnerability to the gear. This score could only be attained if the gear was not used in the habitat (gear distribution = 0).
1 - 6 = low vulnerability to the gear. This score generally occurred where the gear has minimal overlap with EFH (Gear Distribution = 1) and Habitat Rank was less than 7. Additionally, low vulnerability scores occurred in habitats with high gear overlap (Gear Distribution = 2) but where Habitat Rank was low (3 or less).
7 - 9 = moderate vulnerability to the gear. This score typically occurred where gear overlap with EFH was high (Gear Distribution = 2) and Habitat Rank was 4 or, overlap with EFH was low (Gear Distribution = 1) and Habitat Rank was 7.
10 - 14 = high vulnerability to the gear. This score occurred only if the gear overlap with EFH was high (Gear Distribution = 2) and the Habitat Rank was 5 or more.

Table 6.1. EFH Vulnerability Matrix Analysis for Benthic Life Stages of Federally-Managed Fish and Shellfish Species in the Northeast Region of the U.S.

Species	Shelter	Food	Repro	Habitat Sensitivity	Habitat Rank	OT Dist.	SD Dist.	CD Dist.	OT Rank	SD Rank	CD Rank	OT Vuln.	SD Vuln.	CD Vuln.
American Plaice (A)	1	2	1	1	5	2	2	0	10	10	0	High	High	None
American Plaice (J)	1	2	0	1	4	2	2	0	8	8	0	Mod	Mod	None
Atlantic Cod (A)	1	1	0	2	4	2	2	1	8	8	4	Mod	Mod	Low
Atlantic Cod (J)	2	1	0	2	5	2	2	0	10	10	0	High	High	None
Atlantic Halibut (A)	1	1	1	1	4	2	2	0	8	8	0	Mod	Mod	None
Atlantic Halibut (J)	1	2	0	1	4	2	2	0	8	8	0	Mod	Mod	None
Atlantic Herring (E)	0	0	1	1	2	2	2	0	4	4	0	Low	Low	None
Atlantic Herring (SA)	0	0	1	1	2	2	2	0	4	4	0	Low	Low	None
Atlantic Scallops (A)	1	0	1	1	3	2	2	2	6	6	6	Low	Low	Low
Atlantic Scallops (J)	2	0	0	2	4	2	2	2	8	8	8	Mod	Mod	Mod
Barndoor Skate (A)	1	1	1	1	4	2	2	1	8	8	4	Mod	Mod	Low
Barndoor Skate (J)	1	2	0	1	4	2	2	1	8	8	4	Mod	Mod	Low
Black Sea Bass (A)	2	1	0	2	5	2	2	2	10	10	10	High	High	High
Black Sea Bass (J)	2	1	0	2	5	2	2	2	10	10	10	High	High	High
Clearnose Skate (A)	1	1	1	1	4	2	2	2	8	8	8	Mod	Mod	Mod
Clearnose Skate (J)	1	2	0	1	4	2	2	2	8	8	8	Mod	Mod	Mod
Golden Crab (J,A)	1	1	1	2	5	1	0	0	5	0	0	Low	None	None
Haddock (A)	1	2	0	2	5	2	2	1	10	10	5	High	High	Low
Haddock (J)	2	2	0	2	6	2	2	1	12	12	6	High	High	Low
Little Skate (A)	1	1	1	1	4	2	2	2	8	8	8	Mod	Mod	Mod
Little Skate (E)	0	0	1	1	2	2	2	2	4	4	4	Low	Low	Low
Little Skate (J)	1	2	0	1	4	2	2	2	8	8	8	Mod	Mod	Mod
Monkfish (A)	1	1	0	1	3	2	2	2	6	6	6	Low	Low	Low
Monkfish (J)	1	1	0	1	3	2	2	2	6	6	6	Low	Low	Low
Ocean Pout (A)	2	2	1	2	7	2	2	2	14	14	14	High	High	High
Ocean Pout (E)	2	0	1	2	5	2	2	2	10	10	10	High	High	High
Ocean Pout (J)	2	2	0	2	6	2	2	2	12	12	12	High	High	High
Ocean Quahog (A)	1	0	1	1	3	2	2	2	6	6	6	Low	Low	Low
Ocean Quahog (J)	1	0	0	1	2	2	2	2	4	4	4	Low	Low	Low
Offshore Hake (A)	1	1	0	1	3	2	1	0	6	3	0	Low	Low	None
Offshore Hake (J)	1	1	0	1	3	2	1	0	6	3	0	Low	Low	None
Pollock (A)	1	1	1	1	4	2	2	1	8	8	4	Mod	Mod	Low
Pollock (J)	1	1	0	1	3	2	2	1	6	6	3	Low	Low	Low
Red Crab (A)	1	1	1	2	5	1	0	0	5	0	0	Low	None	None
Red Crab (J)	1	1	0	2	4	1	0	0	4	0	0	Low	None	None
Red Drum (A)	1	1	0	1	3	2	2	2	6	6	6	Low	Low	Low
Red Drum (J)	2	1	0	2	5	1	0	0	5	0	0	Low	None	None
Red Hake (A)	1	2	0	1	4	2	2	1	8	8	4	Mod	Mod	Low

Red Hake (J)	2	2	0	2	6	2	2	2	12	12	12	High	High	High
Redfish (A)	1	1	0	2	4	2	2	0	8	8	0	Mod	Mod	None
Redfish (J)	2	1	0	2	5	2	2	0	10	10	0	High	High	None
Rosette Skate (A)	1	1	1	1	4	2	2	2	8	8	8	Mod	Mod	Mod
Rosette Skate (J)	1	2	0	1	4	2	2	2	8	8	8	Mod	Mod	Mod
Scup (A)	1	1	0	1	3	2	2	2	6	6	6	Low	Low	Low
Scup (J)	1	2	0	1	4	2	2	2	8	8	8	Mod	Mod	Mod
Silver Hake (A)	1	1	0	1	3	2	2	2	6	6	6	Low	Low	Low
Silver Hake (J)	1	1	0	2	4	2	2	2	8	8	8	Mod	Mod	Mod
Smooth Skate (A)	1	2	1	1	5	2	2	0	10	10	0	High	High	None
Smooth Skate (J)	1	2	0	1	4	2	2	0	8	8	0	Mod	Mod	None
Spiny Dogfish (A)	1	1	0	1	3	2	2	2	6	6	6	Low	Low	Low
Spiny Dogfish (J)	1	1	0	1	3	2	2	2	6	6	6	Low	Low	Low
Summer Flound. (A)	1	1	0	1	3	2	2	2	6	6	6	Low	Low	Low
Summer Flound. (J)	1	1	0	1	3	2	2	2	6	6	6	Low	Low	Low
Surfclam (A)	1	0	1	1	3	2	2	2	6	6	6	Low	Low	Low
Surfclam (J)	1	0	0	1	2	2	2	2	4	4	4	Low	Low	Low
Thorny Skate (A)	1	1	1	1	4	2	2	0	8	8	0	Mod	Mod	None
Thorny Skate (J)	1	2	0	1	4	2	2	0	8	8	0	Mod	Mod	None
Tilefish (A)	2	2	0	1	5	2	1	0	10	5	0	High	Low	None
Tilefish (J)	2	2	0	1	5	2	1	0	10	5	0	High	Low	None
White Hake (A)	1	1	0	1	3	2	2	0	6	6	0	Low	Low	None
White Hake (J)	1	2	0	1	4	2	2	0	8	8	0	Mod	Mod	None
Windowpane Flndr (A)	1	0	0	1	2	2	2	2	4	4	4	Low	Low	Low
Windowpane Flndr (J)	1	1	0	1	3	2	2	2	6	6	6	Low	Low	Low
Winter Flounder (A)	1	1	1	1	4	2	2	2	8	8	8	Mod	Mod	Mod
Winter Flounder (E)	0	0	1	1	2	2	2	2	4	4	4	Low	Low	Low
Winter Flounder (J)	1	1	0	1	3	2	2	2	6	6	6	Low	Low	Low
Winter Skate (J)	1	2	0	1	4	2	2	2	8	8	8	Mod	Mod	Mod
Winter Skate(A)	1	1	1	1	4	2	2	2	8	8	8	Mod	Mod	Mod
Witch Flounder (A)	1	2	0	1	4	2	1	1	8	4	4	Mod	Low	Low
Witch Flounder (J)	1	2	0	1	4	2	1	0	8	4	0	Mod	Low	None
Yellowtail Flounder (A)	1	2	0	1	4	2	2	2	8	8	8	Mod	Mod	Mod
Yellowtail Flounder (J)	1	2	0	1	4	2	2	2	8	8	8	Mod	Mod	Mod

KEY:
Shelter: 0= no dependence; 1= lower dependence, not reliant on complex structure; 2= strong dependence, reliant on complex structure
Food: 0= no dependence on benthic prey; 1= includes benthic prey; 2= relies exclusively on benthic prey
Reproduction: 0= no dependence, *e.g.* spawns in water column, or life stage not reproductive; 1= dependence, *e.g.* spawns on or over bottom
Habitat Sensitivity: 0= not sensitive; 1= low sensitivity *i.e.* no habitat structural/complexity issues, rapid recovery rates, *e.g.* high energy sand habitats; 2= highly sensitive, *e.g.* habitat structural/complexity issues, slow recovery rates, deep water/low energy habitats.
Habitat Rank: = Sum of Shelter + Food + Reproduction + Habitat Sensitivity
Gear Distribution: 0= gear not utilized in this habitat; 1= gear operates in a small portion of this habitat; 2= gear operates in much of this habitat
OT = Otter Trawl; SD = New Bedford Scallop Dredge; CD = Hydraulic Clam Dredge
Gear Rank (Vulnerability of EFH to particular gear) = Habitat Rank x Gear Distribution. This is the vulnerability of EFH to the gear type.
Gear Ranks were assigned as follows: 0 = none, 1-6 = low vulnerability, 7-9 = moderate vulnerability, 10-14 = high vulnerability.

The rationale for each determination is outlined by species in Tables 6.2 through 6.43. First, the habitat's value to each species and life stage was characterized to the extent possible, based on its function in providing shelter, food and/or the right conditions for reproduction. For example, if the habitat provided shelter from predators for juvenile or other life stages, gear impacts that could reduce shelter were of greater concern. In cases where a food source was closely associated with the benthos (*e.g.* infauna), the ability of a species to use alternative food sources was evaluated. Additionally, since benthic prey populations may also be adversely affected by fishing, gear impacts that could affect the availability of prey for bottom-feeding species or life stages were of greater concern than if the species or life stages were piscivorous. In most cases habitat usage was determined from the information provided in the EFH Source Documents

(NOAA Technical Memorandum NMFS-NE issues 123-153) with additional information from Colette and Klein-MacPhee (2002).

The information in the species EFH vulnerability tables is arranged in columns that summarize the geographical extent of EFH for each life stage, its depth range, seasonal occurrence, and a brief EFH description that includes – for benthic life stages – substrate characteristics. The information in columns 2-5 was derived from EFH designations that have been adopted by the three Atlantic coast Fishery Management Councils. Additional information is provided at the bottom of each table to explain the rationale that was used in making the gear-specific EFH vulnerability rankings. This information was extracted from the EFH source documents and other sources and sometimes differs somewhat from the information included in the EFH designation.

Table 6.2 **American Plaice EFH - Vulnerability to Effects of Bottom-Tending Fishing Gear**

Life Stage	Geographic Area of EFH	Depth (m)	Seasonal Occurrence	EFH Description	EFH Vulnerability*				
					OT	SD	CD	PT	NL
Eggs	GOME, GB and estuaries from Passamaquoddy Bay to Saco Bay, ME and from Mass. Bay to Cape Cod Bay, MA	30 - 90	All year in GOME Dec - June on GB Peaks April & May both	Surface waters	NA	NA	NA	NA	NA
Larvae	GOME, GB, Southern NE and estuaries from Passamaquoddy Bay to Saco Bay, ME and from Mass Bay to Cape Cod Bay, MA	30-130	Between January and August, with peaks in April and May	Surface waters	NA	NA	NA	NA	NA
Juveniles	GOME and estuaries from Passamaquoddy Bay to Saco Bay, ME and from Mass Bay to Cape Cod Bay, MA	45-150		Bottom habitats with fine-grained sediments or substrate of sand or gravel	M	M	0	L	L
Adults	GOME, GB and estuaries from Passamaquoddy Bay to Saco Bay, ME and from Mass Bay to Cape Cod Bay, MA	45-175		Bottom habitats with fine-grained sediments or a substrate of sand or gravel	H	H	0	L	L
Spawning Adults	GOME, GB and estuaries from Passamaquoddy Bay to Saco Bay, ME and from Mass Bay to Cape Cod Bay, MA	<90	March through June	Bottom habitats of all substrate types	H	H	0	L	L

Rationale: American plaice *(Hippoglossoides platessoides*) juveniles, adults, and spawning adults are concentrated in the Gulf of Maine, where they occupy a variety of habitat types with substrates of gravel or fine grained sediments including sand. Plaice avoid rocky and hard bottom areas and prefer fine, sticky but gritty sand mixtures and mud, as well as oozy mud in deep basins (Klein-MacPhee 2002a). Plaice have been caught a considerable distance off the bottom and move off the bottom at night (Klein-MacPhee 2002a). They feed primarily on epibenthic invertebrates (mostly echinoderms and amphipods), so there is a potential that prey resources may be affected adversely by otter trawls and scallop dredges, particularly in areas of lower energy and expected slower habitat recovery. EFH vulnerability to these gears was rated as high for adults and moderate for juveniles primarily because spawning occurs on the bottom. Since hydraulic clam dredges do not typically operate in the Gulf of Maine, vulnerability for this gear was rated as none.

Definitions: GOME - Gulf of Maine; GB - Georges Bank; NE - New England; HAPC - Habitat Area of Particular Concern; YOY - Young-of-Year;OT - Otter Trawls; SD - New Bedford Scallop Dredge; CD - Hydraulic Clam Dredge; PT Pots and Traps; NL - Gill Nets and Longlines; NA - not applicable; 0 –No vulnerability; L - Low vulnerability; M - Moderate vulnerability; H - High vulnerability; EFH - essential fish habitat; * derived from matrix analysis – see appendix. **Note that the information presented in columns 2-5 is derived from the EFH descriptions and may not completely agree with information provided in the rationale.**

Table 6.3 Atlantic Cod EFH - Vulnerability to Effects of Bottom-Tending Fishing Gear

Life Stage	Geographic Area of EFH	Depth (m)	Seasonal Occurrence	EFH Description	EFH Vulnerability*				
					OT	SD	CD	PT	NL
Eggs	GOME, GB, eastern portion of continental shelf off southern NE and following estuaries: Englishman/ Machias Bay to Blue Hill Bay; Sheepscot R., Casco Bay, Saco Bay, Great Bay, Mass Bay, Boston Harbor, Cape Cod Bay, Buzzards Bay	<110	Begins in fall, peaks in winter and spring	Surface waters	NA	NA	NA	NA	NA
Larvae	GOME, GB, eastern portion of continental shelf off southern NE and following estuaries: Passamaquoddy Bay to Penobscot Bay; Sheepscot R., Casco Bay, Saco Bay, Great Bay, Mass Bay, Boston Harbor, Cape Cod Bay, Buzzards Bay	30-70	Spring	Pelagic waters	NA	NA	NA	NA	NA
Juveniles	GOME, GB, eastern portion of continental shelf off southern NE and following estuaries: Passamaquoddy Bay to Saco Bay; Mass Bay, Boston Harbor, Cape Cod Bay, Buzzards Bay	25 - 75		Bottom habitats with a substrate of cobble or gravel	H	H	0	L	L
Adults	GOME, GB, southern NE, middle Atlantic south to Delaware Bay and following estuaries: Passamaquoddy Bay to Saco Bay; Mass Bay, Boston Harbor, Cape Cod Bay, Buzzards Bay	10-150		Bottom habitats with a substrate of rocks, pebbles, or gravel	M	M	L	L	L
Spawning Adults	GOME, GB, southern NE, middle Atlantic south to Delaware Bay and following estuaries: Englishman/ Machias Bay to Blue Hill Bay; Sheepscot R., Mass Bay, Boston Harbor, Cape Cod Bay, MA	10-150	Spawn during fall, winter, and early spring	Bottom habitats with a substrate of smooth sand, rocks, pebbles, or gravel	M	M	L	L	L

Rationale: Atlantic cod (*Gadus morhua*) are distributed regionally from Greenland to Cape Hatteras, NC, from nearshore to depths greater than 400 m. In U.S. waters, they are concentrated on Georges Bank and in the Gulf of Maine, on rough bottom from 10 - 150 m (Klein-MacPhee 2002b; Fahay *et al.* 1999). Eggs and larvae are pelagic so EFH vulnerability is not applicable.

Juvenile cod are found mostly in nearshore shoal waters or on offshore banks. Cobble is preferred over finer grained sediments, and this life stage appears to use benthic structure and cryptic coloration to escape from predation (Fahay *et al.* 1999). Juvenile cod may benefit, perhaps strongly, from physical and biological complexity (Lindholm *et al.* 2001) (see discussion in Section 2). Otter trawls and scallop dredges have been shown to reduce habitat complexity (see Section 5), therefore EFH vulnerability to these gear types is rated as high since the gear may affect the functional value of EFH for this life stage. Vulnerability to clam dredges was rated as none since this gear is not operated in juvenile cod EFH (see Section 4).

Adults and spawning adults occupy a variety of hard bottom habitat types including rock, pebbles, and gravel, and tend to avoid finer sediments. Cod are euryphagous, eating a wide variety of prey including fish, decapods, amphipods, and polychaetes (Fahay *et al.* 1999). Although adult cod are primarily found on rough bottom, the scientific literature does not indicate that this habitat type serves the same function as it does for juvenile cod. Based on the variable diet and lack of evidence for direct functional value of benthic habitat, EFH vulnerability to otter trawls and scallop dredges is rated as moderate. Adult cod may use areas where clam dredges operate, such as the nearshore waters of New Jersey, on a seasonal basis. Clam dredges operate only in sand (NREFHSC 2002), and the recovery of benthic communities from the effects of clam dredging in nearshore, sandy habitats is fairly rapid (Table 5.15). Clam beds are not chronically disturbed by dredging since the population of clams, which are benthic infauna, must recover before fishing is again profitable (NREFHSC 2002). Based on this information and the rationale described for otter trawls and scallop dredges, habitat vulnerability for hydraulic clam dredges was rated as low. EFH vulnerability for adults applies to spawning adults as well.

Definitions: GOME - Gulf of Maine; GB - Georges Bank; NE - New England; HAPC - Habitat Area of Particular Concern; YOY - Young-of-Year: OT - Otter Trawls; SD - New Bedford Scallop Dredge; CD - Hydraulic Clam Dredge; PT- Pots and Traps; NL - Gill Nets and Longlines. NA - not applicable; 0 – No vulnerability; L - Low vulnerability; M - moderate vulnerability; H - high vulnerability; EFH - essential fish habitat; * derived from matrix analysis – see appendix. **Note that the information presented in columns 2-5 is derived from the EFH descriptions and may not completely agree with information provided in the rationale.**

Table 6.4 Atlantic Halibut EFH - Vulnerability to Effects of Bottom-Tending Fishing Gear

Life Stage	Geographic Area of EFH	Depth (m)	Seasonal Occurrence	EFH Description	EFH Vulnerability*				
					OT	**SD**	**CD**	**PT**	**NL**
Eggs	GOME, GB		Between late fall and early spring, peak Nov. and Dec.	Pelagic waters to the sea floor	0	0	0	0	0
Larvae	GOME, GB			Surface waters	NA	NA	NA	NA	NA
Juveniles	GOME, GB	20 - 60		Bottom habitats with a substrate of sand, gravel, or clay	M	M	0	L	L
Adults	GOME, GB	100-700		Bottom habitats with a substrate of sand, gravel, or clay	M	M	0	L	L
Spawning Adults	GOME, GB	<700	Between late fall and early spring, peaks in Nov. and Dec.	Bottom habitats with a substrate of soft mud, clay, sand, or gravel; rough or rocky bottom locations along slopes of the outer banks	M	M	0	L	L

Rationale: Atlantic halibut (*Hippoglossus hippoglossus*) are found in the boreal and subarctic Atlantic, south to New Jersey, and were once fairly common from Nantucket Shoals to Labrador (Klein-MacPhee 2002a). They have been found at depths from 25 m to 1000 m, but 700 - 900 m is probably the deepest they are found in any numbers.

Atlantic halibut eggs are bathy-pelagic and are fertilized on the bottom (Klein-MacPhee 2002a, Cargnelli *et al.* 1999g). Since eggs occur close to, but not on the bottom, scallop dredges, otter trawls, and hydraulic clam dredges are not expected to affect the functional value of the habitat for this life stage and EFH vulnerability was rated as none.

Juvenile, adult and spawning adult halibut occupy a variety of habitat types north of Nantucket Shoals. Adults are not found on soft mud or on rock bottom (Cargnelli *et al.* 1999g). Spawning is occasionally associated with complex habitats. Juvenile halibut feed mostly on annelid worms and crustaceans, then transition to a diet of mostly fish as adults (Klein-MacPhee 2002a). EFH vulnerability to scallop dredges and otter trawls was rated as moderate for juveniles and adults. EFH vulnerability for clam dredges was rated as none since this gear type does not operate in halibut EFH (see Section 4).

Definitions: GOME - Gulf of Maine; GB - Georges Bank; NE - New England; HAPC - Habitat Area of Particular Concern; YOY - Young-of-Year: OT - Otter Trawls; SD - New Bedford Scallop Dredge; CD - Hydraulic Clam Dredge; PT- Pots and Traps; NL - Gill Nets and Longlines. NA - not applicable; 0 - No vulnerability; L - Low vulnerability; M - moderate vulnerability; H - high vulnerability; EFH - essential fish habitat; * derived from matrix analysis – see appendix. **Note that the information presented in columns 2-5 is derived from the EFH descriptions and may not completely agree with information provided in the rationale.**

Table 6.5 **Atlantic Herring EFH - Vulnerability to Effects of Bottom-Tending Fishing Gear**

Life Stage	Geographic Area of EFH	Depth (m)	Seasonal Occurrence	EFH Description	EFH Vulnerability*				
					OT	SD	CD	PT	NL
Eggs	GOME, GB and following estuaries: Englishman/ Machias Bay, Casco Bay, & Cape Cod Bay	20 - 80	July through November	Bottom habitats with a substrate of gravel, sand, cobble, shell fragments & aquatic macrophytes, tidal currents 1.5-3 knots.	L	L	0	L	L
Larvae	GOME, GB, Southern NE and following estuaries: Passamaquoddy Bay to Cape Cod Bay, Narragansett Bay, & Hudson R./ Raritan Bay	50 - 90	Between August and April, peaks from Sept. - Nov.	Pelagic waters	NA	NA	NA	NA	NA
Juveniles	GOME, GB, Southern NE and Middle Atlantic south to Cape Hatteras and following estuaries: Passamaquoddy Bay to Cape Cod Bay; Buzzards Bay to Long Island Sound; Gardiners Bay to Delaware Bay	15-135		Pelagic waters and bottom habitats	NA	NA	NA	NA	NA
Adults	GOME, GB, southern NE and middle Atlantic south to Cape Hatteras and following estuaries: Passamaquoddy Bay to Great Bay; Mass Bay to Cape Cod Bay; Buzzards Bay to Long Island Sound; Gardiners Bay to Delaware Bay; & Chesapeake Bay	20-130		Pelagic waters and bottom habitats	NA	NA	NA	NA	NA
Spawning Adults	GOME, GB, southern NE and middle Atlantic south to Delaware Bay and Englishman/ Machias Bay Estuary	20 - 80	July through November	Bottom habitats with a substrate of gravel, sand, cobble and shell fragments, also on aquatic macrophytes	L	L	0	L	L

Rationale: Atlantic herring (*Clupea harengus***)** is a coastal pelagic species ranging from Labrador to Cape Hatteras in the western Atlantic (Reid *et al.* 1999, Munroe 2002). For most pelagic life stages (larvae, juveniles, adults) EFH vulnerability to bottom-tending fishing gear is not applicable. Atlantic herring eggs are laid in high energy, benthic habitats on rocky, pebbly, gravelly or shell substrates or macrophytes (Reid *et al.* 1999, Munroe 2002). These habitats are less susceptible to fishing gear impacts since they have evolved under a high energy disturbance regime (strong bottom currents). Vulnerability of herring egg EFH to scallop dredges and otter trawls is considered to be low. Although these gears may directly effect the eggs, only the effect of the gear on the functional value of the habitat was considered for this evaluation. EFH vulnerability from clam dredges were considered to be none since this gear does not operate in areas of herring egg EFH.

Spawning adults are closely associated with the bottom. Effects on the functional value of habitat from mobile gears are unknown and were rated as low since spawning occurs on the bottom. EFH vulnerability from clam dredges was rated as none for the reasons described above. Spawning could be disrupted by noise associated with these gears, but this issue was not addressed as a habitat related issue.

Definitions: GOME - Gulf of Maine; GB - Georges Bank; NE - New England; HAPC - Habitat Area of Particular Concern; YOY - Young-of-Year: OT - Otter Trawls; SD - New Bedford Scallop Dredge; CD - Hydraulic Clam Dredge; PT- Pots and Traps; NL - Gill Nets and Longlines. NA - not applicable; 0 - No vulnerability; L - Low vulnerability; M - moderate vulnerability; H - high vulnerability; EFH - essential fish habitat; * derived from matrix analysis – see appendix. **Note that the information presented in columns 2-5 is derived from the EFH descriptions and may not completely agree with information provided in the rationale.**

Table 6.6 Atlantic Salmon EFH - Vulnerability to Effects of Bottom-Tending Fishing Gear

Life Stage	Geographic Area of EFH	Depth (cm)	Seasonal Occurrence	EFH Description	EFH Vulnerability*				
					OT	SD	CD	PT	NL
Eggs	Rivers from CT to Maine: Connecticut, Pawcatuck, Merrimack, Cocheco, Saco, Androscoggin, Presumpscot, Kennebec, Sheepscot, Ducktrap, Union, Penobscot, Narraguagus, Machias, East Machias, Pleasant, St. Croix, Denny's, Passagassawaukeag Aroostook, Lamprey, Boyden, Orland Rivers, and the Turk, Hobart & Patten Streams; and the following estuaries for juveniles and adults: Passamaquoddy Bay to Muscongus Bay; Casco Bay to Wells Harbor; Mass Bay, Long Island Sound, Gardiners Bay to Great South Bay. All aquatic habitats in the watersheds of the above listed rivers, including all tributaries to the extent that they are currently or were historically accessible for salmon migration.	30-31	Between October and April	Bottom habitats with a gravel or cobble riffle (redd) above or below a pool in rivers	NA	NA	NA	NA	NA
Larvae			Between March and June for alevins/fry	Bottom habitats with a gravel or cobble riffle (redd) above or below a pool in rivers	NA	NA	NA	NA	NA
Juveniles		10- 61		Bottom habitats of shallow gravel/cobble riffles interspersed with deeper riffles and pools in rivers and estuaries, water velocities between 30 – 92 cm/sec	NA	NA	NA	NA	NA
Adults				Oceanic adult Atlantic salmon are primarily pelagic and range from waters of the continental shelf off southern NE north throughout the GOME, dissolved oxygen above 5 ppm for migratory pathway	NA	NA	NA	NA	NA
Spawning Adults		30- 61 cm	October and November	Bottom habitats with a gravel or cobble riffle (redd) above or below a pool in rivers	NA	NA	NA	NA	NA

Rationale: Atlantic salmon (*Salmo salar*) eggs and larvae are found in riverine areas where the fishing gears under consideration are not used, so EFH vulnerability is not applicable. It is important to note that these life stages are particularly vulnerable to non-fishing related impacts such as point source discharges and polluted runoff. Juveniles and adults are pelagic in nature, and vulnerability of EFH to bottom-tending fishing gear is not applicable for these life stages.

Definitions: GOME - Gulf of Maine; GB - Georges Bank; NE - New England; HAPC - Habitat Area of Particular Concern; YOY - Young-of-Year: OT - Otter Trawls; SD - New Bedford Scallop Dredge; CD - Hydraulic Clam Dredge; PT- Pots and Traps; NL - Gill Nets and Longlines. NA - not applicable; 0- No vulnerability; L - Low vulnerability; M - moderate vulnerability; H - high vulnerability; EFH - essential fish habitat; * derived from matrix analysis – see appendix. **Note that the information presented in columns 2-5 is derived from the EFH descriptions and may not completely agree with information provided in the rationale.**

Table 6.7 Atlantic Sea Scallop EFH - Vulnerability to Effects of Bottom-Tending Fishing Gear

Life Stage	**Geographic Area of EFH**	**Depth (m)**	**Seasonal Occurrence**	**EFH Description**	**EFH Vulnerability***				
					OT	**SD**	**CD**	**PT**	**NL**
Eggs	GOME, GB, southern NE and middle Atlantic south to Virginia-North Carolina border and following estuaries: Passamaquoddy Bay to Sheepscot R.; Casco Bay, Mass Bay, and Cape Cod Bay		May through October, peaks in May and June in middle Atlantic area and in Sept. and Oct. on GB and in GOME	Bottom habitats	L	L	L	L	L
Larvae	GOME, GB, southern NE and middle Atlantic south to Virginia-North Carolina border and following estuaries: Passamaquoddy Bay to Sheepscot R.; Casco Bay, Mass Bay, and Cape Cod Bay			Pelagic waters and bottom habitats with a substrate of gravelly sand, shell fragments, pebbles, or on various red algae, hydroids, amphipod tubes and bryozoans	NA	NA	NA	NA	NA
Juveniles	GOME, GB, southern NE and middle Atlantic south to Virginia-North Carolina border and following estuaries: Passamaquoddy Bay to Sheepscot R.; Casco Bay, Great Bay, Mass Bay, and Cape Cod Bay	18-110		Bottom habitats with a substrate of cobble, shells, and silt	M	M	M	L	L
Adults	GOME, GB, southern NE and middle Atlantic south to Virginia-North Carolina border and following estuaries: Passamaquoddy Bay to Sheepscot R.; Casco Bay, Great Bay, Mass Bay, and Cape Cod Bay	18-110		Bottom habitats with a substrate of cobble, shells, coarse/gravelly sand, and sand	L	L	L	L	L
Spawning Adults	GOME, GB, southern NE and middle Atlantic south to Virginia-North Carolina border and following estuaries: Passamaquoddy Bay to Sheepscot R.; Casco Bay, Mass Bay, and Cape Cod Bay	18-110	May through October, peaks in May and June in middle Atlantic area, and in Sept. and Oct. on GB and in GOME	Bottom habitats with a substrate of cobble, shells, coarse/gravelly sand, and sand	L	L	L	L	L

Rationale: Atlantic sea scallops (*Placopecten magellanicus***)** are found on the continental shelf of the northwest Atlantic, from the Gulf of St. Lawrence south to Cape Hatteras (Packer *et al.* 1999a). Benthic life stages occur at depths from shore out to approximately 110 m. Larvae are pelagic, and EFH vulnerability to fishing gear impacts is not applicable.

Scallop eggs are heavier than seawater and are thought to remain on the bottom during development, but the functional value of this habitat for eggs is unknown. EFH vulnerability for eggs has been rated as low for all mobile gear types. Early juvenile scallops or spat (described as late stage larvae in the EFH descriptions) settle in areas of gravelly sand with shell fragments (Packer *et al.* 1999a). Larsen and Lee (1978) indicated that spat may obtain a survival advantage in areas of increased structure, including sessile branching plants and animals. The availability of suitable hard surfaces on which to settle appears to be a primary requirement for successful reproduction (Packer *et al.* 1999a). There is a close association between the bryozoan, *Eucratea loricata,* and spat. *Eucratea* attach to adult scallops, and have been found to contain large numbers of spat (Packer *et al.* 1999a). Juvenile scallops (spat) are very delicate and do not survive on shifting sand bottoms Packer *et al.* 1999a). Since otter trawls, scallop dredges and hydraulic clam dredges can reduce the amount of benthic structure important to juveniles (see Section 5), the vulnerability of juvenile scallop EFH to mobile benthic gears has been rated as moderate.

Adults are found in benthic habitats with some water movement, which is critical for feeding, oxygen and removal of waste; optimal growth for adults occurs at currents of 10 cm/sec (Packer *et al.* 1999a). Adult scallops inhabit coarse substrates, usually gravel, shell, and rocks. They are less likely to be found in areas with fine clay particles. No scientific information exists that indicates mobile fishing gear has a negative impact on the functional value of adult scallop EFH. The vulnerability of adult scallop EFH to mobile benthic gears has therefore been rated as low.

Definitions: GOME - Gulf of Maine; GB - Georges Bank; NE - New England; HAPC - Habitat Area of Particular Concern; YOY - Young-of-Year: OT - Otter Trawls; SD - New Bedford Scallop Dredge; CD - Hydraulic Clam Dredge; PT- Pots and Traps; NL - Gill Nets and Longlines. NA - not applicable; 0 - No vulnerability; L - Low vulnerability; M - moderate vulnerability; H - high vulnerability; EFH - essential fish habitat; * derived from matrix analysis – see appendix. **Note that the information presented in columns 2-5 is derived from the EFH descriptions and may not completely agree with information provided in the rationale.**

Table 6.8 Haddock EFH - Vulnerability to Effect of Bottom-Tending Fishing Gear

Life Stage	Geographic Area of EFH	Depth (m)	Seasonal Occurrence	EFH Description	EFH Vulnerability*				
					OT	**SD**	**CD**	**PT**	**NL**
Eggs	GB southwest to Nantucket Shoals and coastal areas of GOME and the following estuaries: Great Bay, Mass Bay, Boston Harbor, Cape Cod Bay, Buzzards Bay	50 - 90	March to May, peak in April	Surface waters	NA	NA	NA	NA	NA
Larvae	GB southwest to the middle Atlantic south to Delaware Bay and the following estuaries: Great Bay, Mass Bay, Boston Harbor, Cape Cod Bay, Buzzards Bay, and Narragansett Bay	30 - 90	January to July, peak in April and May	Surface waters	NA	NA	NA	NA	NA
Juveniles	GB, GOME, middle Atlantic south to Delaware Bay	35-100		Bottom habitats with a substrate of pebble gravel	H	H	L	L	L
Adults	GB and eastern side of Nantucket Shoals, throughout GOME, *additional area of Nantucket Shoals, and Great South Channel	40-150		Bottom habitats with a substrate of broken ground, pebbles, smooth hard sand, and smooth areas between rocky patches	H	H	L	L	L
Spawning Adults	GB, Nantucket Shoals, Great South Channel, throughout GOME	40-150	January to June	Bottom habitats with a substrate of pebble gravel or gravelly sand	H	H	L	L	L

Rationale: Haddock (*Melanogrammus aeglefinus***)** are found from Greenland to Cape Hatteras and are common throughout the Gulf of Maine, Georges Bank, and southern New England (Cargnelli *et al.* 1999f, Klein-MacPhee 2002b). Juveniles older than 3 months and adults are demersal and generally found in waters from 10 to 150 m in depth. Juveniles are usually found in waters shallower than 100 m. Haddock spawn over pebble gravel substrate, and avoid ledges, rocks, kelp and soft mud (Cargnelli *et al.* 1999f). Haddock eggs and larvae are pelagic, and EFH vulnerability to fishing gear is not applicable.

Juvenile haddock, like juvenile cod, may benefit, perhaps strongly, from physical and biological complexity (see discussion in Section 2). In general, haddock have a stronger benthic affinity than cod (Klein-MacPhee 2002b). Juvenile haddock are chiefly found over pebble gravel substrates (Cargnelli *et al.* 1999f). Once demersal, they feed on benthic fauna, and their primary prey items are crustaceans and polychaetes. The habitat complexity that appears to be important to juvenile haddock can be reduced by otter trawls and scallop dredges, and benthic prey may be affected (see Section 5). Juvenile haddock EFH is considered to be highly vulnerable to these two gear types. Vulnerability to clam dredges was rated as low since there is some use of this gear in juvenile EFH.

Adult haddock are found on broken ground, gravel, pebbles, clay, smooth sand, and sticky sand of gritty consistency, with a preference for smooth areas around rock patches (Klein-MacPhee 2002b). They feed indiscriminately on benthic invertebrates, and occasionally on fish. Adults (including spawning adults) occupy a variety of habitat types which may be affected by otter trawls and scallop dredges. Adults may be less closely linked to complex habitats then juveniles, but there is still some association. Haddock are expected to be more strongly linked to benthic habitats than cod since haddock primarily feed on benthic invertebrates while cod are primarily piscivorous. Benthic prey resources for haddock may be adversely affected by scallop dredges or otter trawls in areas of lower energy and expected slower habitat recovery. Overall, adult EFH vulnerability to these gear types is rated as high. Clam dredges operate only in sand and the associated recovery period is short (Table 5.15). Moreover, clam dredging is not expected to create a chronic disturbance in these areas since the population of clams, which are benthic infauna, must recover before fishing is again profitable therefore, habitat vulnerability for clam dredges is rated as low.

Definitions: GOME - Gulf of Maine; GB - Georges Bank; NE - New England; HAPC - Habitat Area of Particular Concern; YOY - Young-of-Year: OT - Otter Trawls; SD - New Bedford Scallop Dredge; CD - Hydraulic Clam Dredge; PT- Pots and Traps; NL - Gill Nets and Longlines. NA - not applicable; 0 - No vulnerability; L - Low vulnerability; M - moderate vulnerability; H - high vulnerability; EFH - essential fish habitat; * derived from matrix analysis – see appendix. **Note that the information presented in columns 2-5 is derived from the EFH descriptions and may not completely agree with information provided in the rationale.**

Table 6.9 Monkfish EFH - Vulnerability to Effects of Bottom-Tending Fishing Gear

Life Stage	Geographic Area of EFH	Depth (m)	Seasonal Occurrence	EFH Description	EFH Vulnerability*				
					OT	SD	CD	PT	NL
Eggs	GOME, GB, southern NE, middle Atlantic south to Cape Hatteras, North Carolina	15-1000	March to September	Surface waters	NA	NA	NA	NA	NA
Larvae	GOME, GB, southern NE, middle Atlantic south to Cape Hatteras, North Carolina	25-1000	March to September	Pelagic waters	NA	NA	NA	NA	NA
Juveniles	Outer continental shelf in the middle Atlantic, mid-shelf off southern NE, all areas of GOME	25-200		Bottom habitats with substrates of a sand-shell mix, algae covered rocks, hard sand, pebbly gravel, or mud	L	L	L	L	L
Adults	Outer continental shelf in the middle Atlantic, mid-shelf off southern NE, outer perimeter of GB, all areas of GOME	25-200		Bottom habitats with substrates of a sand-shell mix, algae covered rocks, hard sand, pebbly gravel, or mud	L	L	L	L	L
Spawning Adults	Outer continental shelf in the middle Atlantic, mid-shelf off southern NE, outer perimeter of GB, all areas of GOME	25-200	February to August	Bottom habitats with substrates of a sand-shell mix, algae covered rocks, hard sand, pebbly gravel, or mud	L	L	L	L	L

Rationale: Monkfish (*Lophius americanus*), are demersal anglerfish found from Newfoundland south to Florida, but are common only north of Cape Hatteras (Steimle *et al.* 1999c). Juveniles are primarily found at depths between 40-75 m while adults are concentrated between 50-100 m. In the Gulf of Maine, adults occur primarily between the depths of 130 - 260 m. Occasionally, adults are seen at the surface. Both juveniles and adults (including spawning adults) occur on substrates ranging from mud to gravelly sand, algae and rocks. A monkfish has been observed digging depressions in the bottom substrate with its pectoral fins until its back was almost flush with the surrounding bottom (Caruso 2002).

The monkfish is a sight predator which uses its highly modified first dorsal fin as an angling apparatus to lure small fishes towards its mouth (Caruso 2002). Monkfish eat a wide array of prey items, but mainly fish and cephalopods. Monkfish have been reported to ingest a variety of seabirds. There are no indications in the literature that any monkfish life stage is habitat limited or that the functional value of its habitat could be adversely affected by fishing. Vulnerability of adult and juvenile EFH to mobile fishing gear was rated as low. Monkfish eggs and larvae are pelagic, and vulnerability to bottom-tending fishing gear is not applicable.

Definitions: GOME - Gulf of Maine; GB - Georges Bank; NE - New England; HAPC - Habitat Area of Particular Concern; YOY - Young-of-Year: OT - Otter Trawls; SD - New Bedford Scallop Dredge; CD - Hydraulic Clam Dredge; PT- Pots and Traps; NL - Gill Nets and Longlines. NA - not applicable; 0 - No vulnerability; L - Low vulnerability; M - moderate vulnerability; H - high vulnerability; EFH - essential fish habitat; * derived from matrix analysis – see appendix. **Note that the information presented in columns 2-5 is derived from the EFH descriptions and may not completely agree with information provided in the rationale.**

Table 6.10 Ocean Pout EFH - Vulnerability to Effects of Bottom-Tending Fishing Gear

Life Stage	Geographic Area of EFH	Depth (m)	Seasonal Occurrence	EFH Description	EFH Vulnerability*				
					OT	SD	CD	PT	NL
Eggs	GOME, GB, southern NE, middle Atlantic south to Delaware Bay and the following estuaries: Passamaquoddy Bay to Saco Bay; Mass Bay and Cape Cod Bay	<50	Late fall and winter	Bottom habitats, generally hard bottom sheltered nests, holes, or crevices where they are guarded by parents	H	H	H	L	L
Larvae	GOME, GB, southern NE, middle Atlantic south to Delaware Bay and the following estuaries: Passamaquoddy Bay to Saco Bay; Mass Bay and Cape Cod Bay	<50	Late fall to spring	Bottom habitats in close proximity to hard bottom nesting areas	H	H	H	L	L
Juveniles	GOME, GB, southern NE, middle Atlantic south to Delaware Bay and the following estuaries: Passamaquoddy Bay to Saco Bay; Mass Bay, Boston Harbor and Cape Cod Bay	<80		Bottom habitats, often smooth bottom near rocks or algae	H	H	H	L	L
Adults	GOME, GB, southern NE, middle Atlantic south to Delaware Bay and the following estuaries: Passamaquoddy Bay to Saco Bay; Mass Bay, Boston Harbor and Cape Cod Bay	<110		Bottom habitats, dig depressions in soft sediments which are then used by other species	H	H	H	L	L
Spawning Adults	GOME, GB, southern NE, middle Atlantic south to Delaware Bay and the following estuaries: Passamaquoddy Bay to Saco Bay; Mass Bay, and Cape Cod Bay	<50	Late summer to early winter, peaks in Sept. and October	Bottom habitats with a hard bottom substrate, including artificial reefs and shipwrecks	H	H	H	L	L

Rationale: Ocean pout (*Zoarces americanus***)** is a demersal species found in the western Atlantic from Labrador south to Cape Hatteras (Steimle *et al.* 1999e). It can occur in deeper waters south of Cape Hatteras, and has been found as deep as 363 m (Klein-MacPhee and Collette 2002a). It is found in most estuaries and embayments in the Gulf of Maine, and is caught in greatest abundance by the NEFSC trawl survey off southern New England (Steimle *et al.* 1999e).

Ocean pout eggs are laid in nests in crevices, on hard bottom or in holes and protected by the female parent for 2.5 to 3 months until they hatch (Klein-MacPhee and Collette 2002a). Potential impacts to habitat from otter trawls, scallop dredges and clam dredges include knocking down boulder piles, removing biogenic structure and filling in bottom depressions, which may disturb nests and/or leave these areas less suitable for nests. In addition, fishing may frighten parents from nests leaving eggs susceptible to predation. Egg EFH is therefore considered to have a high vulnerability to all bottom-tending mobile gear.

Ocean pout have a relatively short larval stage, and in fact some authors (Klein-MacPhee and Collette 2002a) suggest that there is no larval stage (Steimle *et al.* 1999e). Since the NEFMC designated EFH for this life stage, it is considered here. Larvae (hatchlings) remain near the nest site; however, there is little information on their use of habitats. Larvae do not appear to be as closely associated with the bottom as eggs or juveniles; however, it is anticipated that loss of structure may impact larvae to some degree. Larval EFH was determined to have high vulnerability to mobile bottom-tending gears.

Juvenile pout are found under rocks, shells and algae, in coastal waters and are closely associated with the bottom (Steimle *et al.* 1999e). They feed on benthic invertebrates such as gammarid amphipods and polychaetes. It is expected that loss of structure may be a fairly significant impact to juvenile EFH. Vulnerability of juvenile EFH to all mobile gear was considered to be high.

Adult pout are found in sand and gravel in winter and spring, and in rocky/hard substrate areas for spawning and nesting (Klein-MacPhee and Collette 2002a). They create burrows in soft sediments, and their diet consists mainly of benthic invertebrates including mollusks, crustaceans and echinoderms. Because of the strong benthic affinity of ocean pout, it is anticipated that vulnerability of adult EFH to all mobile gear is high.

Definitions: GOME - Gulf of Maine; GB - Georges Bank; NE - New England; HAPC - Habitat Area of Particular Concern; YOY - Young-of-Year: OT - Otter Trawls; SD - New Bedford Scallop Dredge; CD - Hydraulic Clam Dredge; PT- Pots and Traps; NL - Gill Nets and Longlines. NA - not applicable; 0 - No vulnerability; L - Low vulnerability; M - moderate vulnerability; H - high vulnerability; EFH - essential fish habitat; * derived from matrix analysis – see appendix. **Note that the information presented in columns 2-5 is derived from the EFH descriptions and may not completely agree with information provided in the rationale.**

Table 6.11 Offshore Hake EFH - Vulnerability to Effects of Bottom-Tending Fishing Gear

Life Stage	Geographic Area of EFH	Depth (m)	Seasonal Occurrence	EFH Description	EFH Vulnerability*				
					OT	SD	CD	PT	NL
Eggs	Outer continental shelf of GB and southern NE south to Cape Hatteras, North Carolina	<1250	Observed all year and primarily collected at depths from 110 - 270m	Pelagic waters	NA	NA	NA	NA	NA
Larvae	Outer continental shelf of GB and southern NE south to Chesapeake Bay	<1250	Observed all year and primarily collected at depths from 70 - 130m	Pelagic waters	NA	NA	NA	NA	NA
Juveniles	Outer continental shelf of GB and southern NE south to Cape Hatteras, NC	170-350		Bottom habitats	L	L	0	L	L
Adults	Outer continental shelf of GB and southern NE south to Cape Hatteras, NC	150 - 380		Bottom habitats	L	L	0	L	L
Spawning Adults	Outer continental shelf of GB and southern NE south to the Middle Atlantic Bight	330 - 550	Spawn throughout the year	Bottom habitats	L	L	0	L	L

Rationale: Offshore hake (*Merluccius albidus*)**,** are distributed over the continental shelf and slope of the northwest Atlantic, ranging from the Grand Banks south to the Caribbean and Gulf of Mexico (Chang *et al.* 1999a, Klein-MacPhee 2002c). Juveniles and adults are found in deeper waters, and are most abundant at depths between 150 - 380 m. They are an important component in the slope community off Florida, and are reportedly caught near the outer edge of the Scotian shelf, and on the slopes of deep basins in the Gulf of Maine and the continental slope from the southeastern edge of Georges Bank south. Because of their depth preference, very little is known about the offshore component of the stock. Moreover, offshore hake are similar in appearance to silver hake, and may have been misidentified in earlier studies. They are taken commercially as by-catch in the silver hake fishery. No information is available on substrate preferences for juveniles and adults. Eggs and larvae are pelagic, and EFH vulnerability to fishing gears is not applicable.

Juvenile and adult offshore hake appear to feed at or near the bottom, and are primarily piscivorous (feeding particularly on clupeids, anchovies, and lanternfishes) but they also eat crustaceans and squid (Klein-MacPhee 2002c) . There is evidence of adult diel vertical migration. Only limited information exists about this species, and none of it indicates that offshore hake have a very strong bottom affinity, or that impacts from fishing gear would affect the functional value of their habitat. Although spawning occurs near the bottom, the actual use of benthic habitat during spawning is unknown. The vulnerability of adult and juvenile EFH to otter trawls and scallop dredges is expected to be low. Vulnerability to clam dredges is rated as none since the gear does not operate in the EFH of this species.

Definitions: GOME - Gulf of Maine; GB - Georges Bank; NE - New England; HAPC - Habitat Area of Particular Concern; YOY - Young-of-Year: OT - Otter Trawls; SD - New Bedford Scallop Dredge; CD - Hydraulic Clam Dredge; PT- Pots and Traps; NL - Gill Nets and Longlines. NA - not applicable; 0 - No vulnerability; L - Low vulnerability; M - moderate vulnerability; H - high vulnerability; EFH - essential fish habitat; * derived from matrix analysis – see appendix. **Note that the information presented in columns 2-5 is derived from the EFH descriptions and may not completely agree with information provided in the rationale.**

Table 6.12 **Pollock EFH - Vulnerability to Effects of Bottom-Tending Fishing Gear**

Life Stage	Geographic Area of EFH	Depth (m)	Seasonal Occurrence	EFH Description	EFH Vulnerability*				
					OT	**SD**	**CD**	**PT**	**NL**
Eggs	GOME, GB and the following estuaries: Great Bay to Boston Harbor	30-270	October to June, peaks Nov. to Feb.	Pelagic waters	NA	NA	NA	NA	NA
Larvae	GOME, GB and the following estuaries: Passamaquoddy Bay, Sheepscot R., Great Bay to Cape Cod Bay	10-250	September to July, peaks Dec. to Feb.	Pelagic waters	NA	NA	NA	NA	NA
Juveniles	GOME, GB and the following estuaries: Passamaquoddy Bay to Saco Bay; Great Bay to Waquoit Bay; Long Island Sound, Great South Bay	0 - 250		Bottom habitats with aquatic vegetation or a substrate of sand, mud or rocks	L	L	L	L	L
Adults	GOME, GB, southern NE, and middle Atlantic south to New Jersey and the following estuaries: Passamaquoddy Bay, Damariscotta R., Mass Bay, Cape Cod Bay, Long Island Sound	15-365		Hard bottom habitats including artificial reefs	M	M	L	L	L
Spawning Adults	GOME, southern NE, and middle Atlantic south to New Jersey includes Mass Bay	15-365	September to April, peaks Dec. to Feb.	Bottom habitats with a substrate of hard, stony, or rocky bottom includes artificial reefs	M	M	L	L	L

Rationale: Pollock (*Pollachius virens*) range from the Hudson straits to North Carolina (Klein-MacPhee 2002b), and are most common on the Scotian Shelf, Georges Bank, the Great South Channel and Gulf of Maine (Cargnelli *et al.* 1999d). They segregate into schools by size, and avoid water warmer than about 15°C (Klein-MacPhee 2002b). They are active fish that live at any depth between the bottom and the surface, depending upon food supply. They are associated with coastal areas and offshore shoals, and are found from shore out to depths of about 325 m, but are most common from 75-175 m (Cargnelli *et al.* 1999d). Juveniles frequently occupy the rocky intertidal zone, which may serve as a nursery area (Klein-MacPhee 2002c). Neither adults nor juveniles are selective in substrate type.

Pollock are opportunistic, and the diet of both juveniles and adults consists mainly of euphausiid crustaceans, but fish, other crustaceans and squid are also eaten (Cargnelli *et al.* 1999d, Klein-MacPhee 2002c). Adults spawn over broken bottom and the slopes of offshore banks, and eggs are pelagic. Based on food habits, and the distribution and behavior of pollock, vulnerability of juvenile EFH to benthic mobile gear is characterized as low. Since pollock spawn on the bottom, the vulnerability of adult EFH to otter trawls and scallop dredges has been rated as moderate. EFH vulnerability from clam dredges has been rated as low for juveniles and adults since there is limited use of this gear in pollock EFH. Pollock eggs and larvae are pelagic, so EFH vulnerability to fishing gear is not applicable.

Definitions: GOME - Gulf of Maine; GB - Georges Bank; NE - New England; HAPC - Habitat Area of Particular Concern; YOY - Young-of-Year: OT - Otter Trawls; SD - New Bedford Scallop Dredge; CD - Hydraulic Clam Dredge; PT- Pots and Traps; NL - Gill Nets and Longlines. NA - not applicable; 0 - No vulnerability; L - Low vulnerability; M - moderate vulnerability; H - high vulnerability; EFH - essential fish habitat; * derived from matrix analysis – see appendix. **Note that the information presented in columns 2-5 is derived from the EFH descriptions and may not completely agree with information provided in the rationale.**

Table 6.13 Red Hake EFH - Vulnerability to Effects of Bottom-Tending Fishing Gear

Life Stage	Geographic Area of EFH	Depth (m)	Seasonal Occurrence	EFH Description	EFH Vulnerability*				
					OT	**SD**	**CD**	**PT**	**NL**
Eggs	GOME, GB, continental shelf off southern NE, and middle Atlantic south to Cape Hatteras		May to November, peaks in June and July	Surface waters of inner continental shelf	NA	NA	NA	NA	NA
Larvae	GOME, GB, continental shelf off southern NE, and middle Atlantic south to Cape Hatteras and following estuaries: Sheepscot R., Mass Bay to Cape Cod Bay; Buzzards Bay, Narragansett Bay & Hudson R./ Raritan Bay	<200	May to December, peaks in Sept. and Oct.	Surface waters	NA	NA	NA	NA	NA
Juveniles	GOME, GB, continental shelf off southern NE, and middle Atlantic south to Cape Hatteras and the following estuaries: Passamaquoddy Bay to Saco Bay; Great Bay, Mass Bay to Cape Cod Bay; Buzzards Bay to Conn. R.; Hudson R./ Raritan Bay, & Chesapeake Bay	<100		Bottom habitats with substrate of shell fragments, including areas with an abundance of live scallops	H	H	H	L	L
Adults	GOME, GB, continental shelf off southern NE, and middle Atlantic south to Cape Hatteras and the following estuaries: Passamaquoddy Bay to Saco Bay; Great Bay, Mass Bay to Cape Cod Bay; Buzzards Bay to Conn. R.; Hudson R./ Raritan, Delaware Bay, & Chesapeake Bay	10-130		Bottom habitats in depressions with a substrate of sand and mud	M	M	L	L	L
Spawning Adults	GOME, southern edge of GB, continental shelf off southern NE, and middle Atlantic south to Cape Hatteras and following estuaries: Sheepscott R., Mass Bay, Cape Cod Bay, Buzzards Bay, & Narragansett Bay	<100	May to November, peaks in June and July	Bottom habitats in depressions with a substrate of sand and mud	M	M	L	L	L

Rationale: Red hake (*Urophycis chuss***)** is a demersal species that ranges from southern Newfoundland to North Carolina, and is most abundant between Georges Bank and New Jersey (Steimle *et al.* 1999d). They occur at depths between 35 - 980 m, and are most common between 72 - 124 m (Klein-MacPhee 2002b). Larvae, juveniles, and adults have been found in estuaries from Maine south to Chesapeake Bay (NEFMC 1998). Eggs and larvae are pelagic, and EFH vulnerability to bottom-tending fishing gear is not applicable.

Juvenile red hake are found in live Atlantic sea scallops or empty scallop shells, and are also associated with other objects such as other shells, sponges, and rocks (Klein-MacPhee 2002b). Shelter appears to be a critical habitat requirement for this life stage (Able and Fahay 1998), and physical complexity, including biogenic structure other than scallop shells, may be important (Auster *et al.* 1991, 1995). Their diet consists mainly of amphipods and other infauna and epifauna. Juvenile hake EFH is considered to be highly vulnerable to all three mobile gear groups.

Adult red hake feed mainly on euphausiids, and also consume other invertebrates and fish (Klein-MacPhee 2002b). They are found mainly on soft bottoms (sand and mud) where they create depressions or use existing depressions. They are also found on shell beds, but not on open, sandy bottom. Otter trawls and scallop dredges operate in these soft bottom and shell bed areas and have been shown to affect the structural components of these habitats. Offshore in Maryland and northern Virginia, adult red hake are found on temperate reefs and hard bottom areas. There is a potential that otter trawls could operate in hard bottom areas and adversely affect the functional value of these reef habitats. Vulnerability of red hake EFH to otter trawls and scallop dredges is assessed as moderate. Clam dredges would not typically operate in these hard bottom areas, nor in the softer sediments with which red hake are usually associated in the northern extent of their range, but there is some overlap between adult EFH and clam dredge use in sandy habitats. EFH vulnerability to clam dredges is characterized as low.

Definitions: GOME - Gulf of Maine; GB - Georges Bank; NE - New England; HAPC - Habitat Area of Particular Concern; YOY - Young-of-Year: OT - Otter Trawls; SD - New Bedford Scallop Dredge; CD - Hydraulic Clam Dredge; PT- Pots and Traps; NL - Gill Nets and Longlines. NA - not applicable; 0 No vulnerability; L - Low vulnerability; M - moderate vulnerability; H - high vulnerability; EFH - essential fish habitat; * derived from matrix analysis – see appendix. **Note that the information presented in columns 2-5 is derived from the EFH descriptions and may not completely agree with information provided in the rationale.**

Table 6.14 **Redfish EFH - Vulnerability to Effects of Bottom-Tending Fishing Gear**

Life Stage	**Geographic Area of EFH**	**Depth (m)**	**Seasonal Occurrence**	**EFH Description**	**EFH Vulnerability***				
					OT	**SD**	**CD**	**PT**	**NL**
Eggs	Viviparous (eggs are retained in mother, released as larvae)				NA	NA	NA	NA	NA
Larvae	GOME, southern GB	50-270	March to October, peak in August	Pelagic waters	NA	NA	NA	NA	NA
Juveniles	GOME, southern edge of GB	25-400		Bottom habitats with a substrate of silt, mud, or hard bottom	H	H	0	L	L
Adults	GOME, southern edge of GB	50-350		Bottom habitats with a substrate of silt, mud, or hard bottom	M	M	0	L	L
Spawning Adults	GOME, southern edge of GB	5 -350	April to August	Bottom habitats with a substrate of silt, mud, or hard bottom	M	M	0	L	L

Rationale: Redfish *(Sebastes spp.)* include both the Acadian redfish (*Sebastes fasciatus*) and the deepwater redfish (*Sebastes mentella*). These two species are difficult to discriminate at all life stages, hence they are usually combined (Pikanowski *et al.* 1999). Acadian redfish range from Iceland to New Jersey, and deepwater redfish occur from the Gulf of Maine north. Where the species overlap, the deepwater redfish occurs in deeper water. They range in depth from 25 - 592 m (Klein-MacPhee and Collette 2002b), with adults most common from 125 - 200 m and juveniles between 75 and 175 m (Pikanowski *et al.* 1999). In general, information about redfish is very limited. Females bear live young and larvae are pelagic, so habitat vulnerability is not applicable to eggs or larvae.

Redfish are found chiefly on silt, mud or hard bottom and rarely over sand (Pikanowski *et al.* 1999). On the Scotian shelf they are strongly associated with fine-grained clay/silt bottom (Klein-MacPhee and Collette 2002b), as well as deposits of gravel and boulders (Pikanowski *et al.* 1999). It is hypothesized that redfish do not prefer a particular bottom type, but may be more exposed to predation over a featureless bottom due to their sedentary nature. There is limited evidence that juveniles use anemones and boulders for cover (Pikanowski *et al.* 1999). Early demersal phase Acadian redfish have been observed to occur primarily in piled boulder habitats while late-juvenile redfish occur in both piled boulder, gravel and dense cerianthid anemone habitats (Auster *et al.*, in prep.). Habitat vulnerability from otter trawls and scallop dredges in boulder habitats is high as gear can overturn boulders and reduce the number of crevices as well as dislodge cerianthid anemones from the bottom.

Redfish are benthic during the day, and become more active at night when they rise off the bottom, following the vertical migration of their primary euphausiid prey (Pikanowski *et al.* 1999). They also eat some benthic fish. Adult EFH was determined to be moderately vulnerable to impacts from otter trawls and scallop dredges. Clam dredges do not operate in areas of redfish EFH so vulnerability was rated as none.

Definitions: GOME - Gulf of Maine; GB - Georges Bank; NE - New England; HAPC - Habitat Area of Particular Concern; YOY - Young-of-Year: OT - Otter Trawls; SD - New Bedford Scallop Dredge; CD - Hydraulic Clam Dredge; PT- Pots and Traps; NL - Gill Nets and Longlines. NA - not applicable; 0 - No vulnerability; L - Low vulnerability; M - moderate vulnerability; H - high vulnerability; EFH - essential fish habitat; * derived from matrix analysis – see appendix. **Note that the information presented in columns 2-5 is derived from the EFH descriptions and may not completely agree with information provided in the rationale.**

Table 6.15 White Hake EFH - Vulnerability to Effects of Bottom-Tending Fishing Gear

Life Stage	Geographic Area of EFH	Depth (m)	Seasonal Occurrence	EFH Description	EFH Vulnerability*				
					OT	SD	CD	PT	NL
Eggs	GOME, GB, southern NE and the following estuaries: Great Bay to Cape Cod Bay		August to September	Surface waters	NA	NA	NA	NA	NA
Larvae	GOME, southern edge of GB, southern NE to middle Atlantic and the following estuaries: Mass Bay, to Cape Cod Bay		May in mid-Atlantic area, Aug. & Sept. in GOME, GB area	Pelagic waters	NA	NA	NA	NA	NA
Juveniles	GOME, southern edge of GB, southern NE to middle Atlantic and the following estuaries: Passamaquoddy Bay to Great Bay; Mass Bay to Cape Cod Bay	5 - 225	May-September	Pelagic stage - pelagic waters; Demersal stage - Bottom habitat with seagrass beds or substrate of mud or fine-grained sand	M	M	0	L	L
Adults	GOME, southern edge of GB, southern NE to middle Atlantic and the following estuaries: Passamaquoddy Bay to Great Bay; Mass Bay to Cape Cod Bay	5 - 325		Bottom habitats with substrate of mud or fine-grained sand	L	L	0	L	L
Spawning Adults	GOME, southern edge of GB, southern NE to middle Atlantic	5 - 325	April to May - southern part of range; August - Sept.- northern part of range	Bottom habitats with substrate of mud or fine-grained sand in deep water	L	L	0	L	L

Rationale: White hake *(Urophycis tenuis)* adults co-occur geographically with red hake, and their habits are similar, but white hake are distributed in a wider range of depths and temperatures (Chang *et al.* 1999c, Klein-MacPhee 2002b). They are found from Labrador south to North Carolina, and occasionally stray as far as Florida and Iceland. They inhabit coastal estuaries and occur across the continental shelf to the submarine canyons along the upper continental shelf, and in the basins of the Gulf of Maine. Adult distribution in the region is focused in the Gulf of Maine and along the southern slope of Georges Bank. All life stages are found in estuaries in the vicinity of the Gulf of Maine (NEFMC 1998).

Most pelagic juveniles cross the shelf and enter estuaries from Canada south to the Mid-Atlantic, although some may also settle to the bottom in as yet unknown shelf habitats (Klein-MacPhee 2002b). Demersal juveniles are found in nearshore waters out to a depth of about 225 m (Chang et al. 1999c). Eelgrass is an important habitat for juveniles, but its functional importance is unknown; this life stage is not necessarily dependent upon structure (Able and Fahay 1998). Young-of-the-year white hake feed mainly on shrimp, mysids and amphipods. Since otter trawls and scallop dredges can negatively impact eelgrass (Stephan et al. 2000) in estuaries, vulnerability of juvenile white hake EFH to these gears is characterized as moderate. Hydraulic clam dredges are not utilized in estuaries of the Gulf of Maine so vulnerability to this gear is rated as none.

Adults prefer benthic deposits of fine grained sediments (Chang *et al.* 1999c). They feed primarily on fish, cephalopods, and crustaceans. Since they are not benthivores and have not been documented to use benthic habitats for cover, EFH vulnerability to otter trawls and scallop dredges is characterized as low. Clam dredges are not operated in areas of adult EFH and vulnerability to this gear is rated as none.

Definitions: GOME - Gulf of Maine; GB - Georges Bank; NE - New England; HAPC - Habitat Area of Particular Concern; YOY - Young-of-Year: OT - Otter Trawls; SD - New Bedford Scallop Dredge; CD - Hydraulic Clam Dredge; PT- Pots and Traps; NL - Gill Nets and Longlines. NA - not applicable; 0 - No vulnerability; L - Low vulnerability; M - moderate vulnerability; H - high vulnerability; EFH - essential fish habitat; * derived from matrix analysis – see appendix. **Note that the information presented in columns 2-5 is derived from the EFH descriptions and may not completely agree with information provided in the rationale.**

Table 6.16 Silver Hake EFH - Vulnerability to Effects of Bottom-Tending Fishing Gear

Life Stage	Geographic Area of EFH	Depth (m)	Seasonal Occurrence	EFH Description	EFH Vulnerability*				
					OT	SD	CD	PT	NL
Eggs	GOME, GB, continental shelf off southern NE, middle Atlantic south to Cape Hatteras and the following estuaries: Merrimack R. to Cape Cod Bay	50-150	All year, peaks June to October	Surface waters	NA	NA	NA	NA	NA
Larvae	GOME, GB, continental shelf off southern NE, middle Atlantic south to Cape Hatteras and the following estuaries: Mass Bay to Cape Cod Bay	50-130	All year, peaks July to September	Surface waters	NA	NA	NA	NA	NA
Juveniles	GOME, GB, continental shelf off southern NE, middle Atlantic south to Cape Hatteras and the following estuaries: Passamaquoddy Bay to Casco Bay, Mass Bay to Cape Cod Bay	20-270		Bottom habitats of all substrate types	M	M	M	L	L
Adults	GOME, GB, continental shelf off southern NE, middle Atlantic south to Cape Hatteras and the following estuaries: Passamaquoddy Bay to Casco Bay, Mass Bay to Cape Cod Bay	30-325		Bottom habitats of all substrate types	L	L	L	L	L
Spawning Adults	GOME, GB, continental shelf off southern NE, middle Atlantic south to Cape Hatteras and the following estuaries: Mass Bay and Cape Cod Bay	30-325		Bottom habitats of all substrate types	L	L	L	L	L

Rationale: Whiting or silver hake *(Merluccius bilinearis)* range from Newfoundland south to Cape Fear, NC, and are most common from Nova Scotia to New Jersey (Morse *et al.* 1999). They are distributed broadly, and are found from nearshore shallows out to a depth of 400 m (Klein-MacPhee 2002c). All life stages have been found in estuaries from Maine to Cape Cod Bay (Morse *et al.* 1999). The vertical movement of offshore hake is governed chiefly by their pursuit of prey; both juveniles and adults show a vertical migration off the bottom at night when feeding activity is greatest.

In the Mid-Atlantic Bight, juvenile whiting have been found in greater densities in areas with greater amphipod tube cover (Auster *et al.* 1997). Further, silver hake size distributions in sand wave habitats are positively correlated with sand wave period (*i.e.*, the spacing between sand waves), suggesting energetic or prey capture benefits in particular sand wave environments (Auster *et al* in press). Juveniles are primarily found on silt or sand substrate and feed mainly on crustaceans, including copepods, amphipods, euphausiids, and decapods (Morse *et al.* 1999). The vulnerability of juvenile EFH to mobile gear was rated as moderate because of the potential connection between structure and habitat suitability for this life stage.

Adult whiting rest on the bottom in depressions by day, primarily over sand and pebble bottoms, and rarely in rockier areas. In the Mid-Atlantic, adults were found on flat sand, sand wave crests, shell, and biogenic depressions, but were most often found on flat sand. At night, adults feed on anchovies, herring, lanternfish, and other fishes (Klein-MacPhee 2002c). Piscivory increases with size for this species. Vulnerability of adult whiting EFH to the three mobile gear types was rated as low because of whiting's piscivorous food habits and preference for higher energy sand environments which recover quickly from fishing gear impacts (see Section 5). Eggs and larvae of this species are pelagic, so habitat vulnerability to fishing gear is not applicable.

Definitions: GOME - Gulf of Maine; GB - Georges Bank; NE - New England; HAPC - Habitat Area of Particular Concern; YOY - Young-of-Year: OT - Otter Trawls; SD - New Bedford Scallop Dredge; CD - Hydraulic Clam Dredge; PT- Pots and Traps; NL - Gill Nets and Longlines. NA - not applicable; 0 - No vulnerability; L - Low vulnerability; M - moderate vulnerability; H - high vulnerability; EFH - essential fish habitat; * derived from matrix analysis – see appendix. **Note that the information presented in columns 2-5 is derived from the EFH descriptions and may not completely agree with information provided in the rationale.**

Table 6.17 Windowpane Flounder EFH - Vulnerability to Effects of Bottom-Tending Fishing Gear

Life Stage	Geographic Area of EFH	Depth (m)	Seasonal Occurrence	EFH Description	EFH Vulnerability*				
					OT	**SD**	**CD**	**PT**	**NL**
Eggs	GOME, GB, southern NE, middle Atlantic south to Cape Hatteras and the following estuaries: Passamaquoddy Bay to Great Bay; Mass Bay to Delaware Inland Bays	<70	February to November, peaks May and October in middle Atlantic July - August on GB	Surface waters	NA	NA	NA	NA	NA
Larvae	GOME, GB, southern NE, middle Atlantic south to Cape Hatteras and the following estuaries: Passamaquoddy Bay to Great Bay; Mass Bay to Delaware Inland Bays	<70	February to November, peaks May and October in middle Atlantic July - August on GB	Pelagic waters	NA	NA	NA	NA	NA
Juveniles	GOME, GB, southern NE, middle Atlantic south to Cape Hatteras and the following estuaries: Passamaquoddy Bay to Great Bay; Mass Bay to Chesapeake Bay	1 - 100		Bottom habitats with substrate of mud or fine grained sand	L	L	L	L	L
Adults	GOME, GB, southern NE, middle Atlantic south to Virginia - NC border and the following estuaries: Passamaquoddy Bay to Great Bay; Mass Bay to Chesapeake Bay	1 - 75		Bottom habitats with substrate of mud or fine grained sand	L	L	L	L	L
Spawning Adults	GOME, GB, southern NE, middle Atlantic south to Virginia -NC border and the following estuaries: Passamaquoddy Bay to Great Bay; Mass Bay to Delaware Inland Bays	1 - 75	February - December, peak in May in middle Atlantic	Bottom habitats with substrate of mud or fine grained sand	L	L	L	L	L

Rationale: Windowpane flounder *(Scophthalmus aquosus)* is distributed in coastal waters from the Gulf of St. Lawrence to Florida, and are most abundant on Georges Bank and in the New York Bight (Klein-MacPhee 2002d). Windowpane are abundant in estuaries from Maine through the Chesapeake Bay (NEFMC 1998). They are a shoal-water fish, with a depth range of up to 200 m, but are most abundant in waters less than 50 m deep. Both juveniles and adults are found on muddy sediments in the Gulf of Maine, and fine, sandy sediments on Georges Bank and in New England and the Mid-Atlantic Bight.

Mysids are the main prey item of juveniles (Klein-MacPhee 2002d). Adults have been shown to feed exclusively on nekton and show little need for bottom structure (Chang *et al.* 1999b). EFH vulnerability to the three types of mobile gear was rated as low for both these life stages. Windowpane eggs and larvae are pelagic, so EFH vulnerability to fishing gear is not applicable.

Definitions: GOME - Gulf of Maine; GB - Georges Bank; NE - New England; HAPC - Habitat Area of Particular Concern; YOY - Young-of-Year: OT - Otter Trawls; SD - New Bedford Scallop Dredge; CD - Hydraulic Clam Dredge; PT- Pots and Traps; NL - Gill Nets and Longlines. NA - not applicable; 0 - No vulnerability; L - Low vulnerability; M - moderate vulnerability; H - high vulnerability; EFH - essential fish habitat; * derived from matrix analysis – see appendix. **Note that the information presented in columns 2-5 is derived from the EFH descriptions and may not completely agree with information provided in the rationale.**

Table 6.18 Winter Flounder EFH - Vulnerability to Effects of Bottom-Tending Fishing Gear

Life Stage	Geographic Area of EFH	Depth (m)	Seasonal Occurrence	EFH Description	EFH Vulnerability*				
					OT	SD	CD	PT	NL
Eggs	GB, inshore areas of GOME, southern NE, middle Atlantic south to Delaware Bay and the following estuaries: Passamaquoddy Bay to Delaware Inland Bays	<5	February to June, peak in April on GB	Bottom habitats with a substrate of sand, muddy sand, mud, and gravel	L	L	L	L	L
Larvae	GB, inshore areas of GOME, southern NE, middle Atlantic south to Delaware Bay and the following estuaries: Passamaquoddy Bay to Delaware Inland Bays	<6	March to July, peak in April and May on GB	Pelagic and bottom waters	L	L	L	L	L
Juveniles	GB, inshore areas of GOME, southern NE, middle Atlantic south to Delaware Bay and the following estuaries: Passamaquoddy Bay to Chincoteague Bay	0.1 - 10 (1 – 50, age 1+)		Bottom habitats with a substrate of mud or fine grained sand	L	L	L	L	L
Adults	GB, inshore areas of GOME, southern NE, middle Atlantic south to Delaware Bay and the following estuaries: Passamaquoddy Bay to Chincoteague Bay	1 - 100		Bottom habitats including estuaries with substrate of mud, sand, gravel	M	M	M	L	L
Spawning Adults	GB, inshore areas of GOME, southern NE, middle Atlantic south to Delaware Bay and the following estuaries: Passamaquoddy Bay to Delaware Inland Bays	<6	February to June	Bottom habitats including estuaries with substrate of mud, sand, gravel	M	M	M	L	L

Rationale: Winter flounder *(Pseudopleuronectes americanus)* range from Labrador to Georgia, and are most abundant from the Gulf of St. Lawrence to Chesapeake Bay (Klein-MacPhee 2002a). All lifestages are common in estuaries from Maine through Chesapeake Bay. Juveniles and adults are found in waters less than 100 m deep, and most are found from shore to 30 m. They range far upstream in estuaries, and have been found in freshwater.

Winter flounder lay demersal adhesive eggs in shallow water less than 5 m in depth, with the exception of spawning areas on Georges Bank and Nantucket shoals (Pereira *et al.* 1999). Substrates include sand, muddy sand, mud and gravel, with sand the most common. Although otter trawls, scallop dredges and clam dredges may affect the eggs directly, this was not considered a habitat impact. Since there is no indication that the eggs rely on any structure, egg EFH vulnerability to these three gears was rated as low. Since early stage larvae are associated with the bottom and are at times demersal (Able and Fahay 1998) larval EFH vulnerability to all gears were also rated as low instead of none.

Juvenile and adult winter flounder are found on mud and sand substrates, and adults are also seen on cobble, rocks and boulders (Pereira *et al.* 1999). Both life stages can be opportunistic feeders, however their main prey items are infaunal invertebrates. Because of their reliance on infauna and their ability to use alternative food supplies, EFH vulnerability to the three mobile gear types for these life stages was ranked as moderate.

Definitions: GOME - Gulf of Maine; GB - Georges Bank; NE - New England; HAPC - Habitat Area of Particular Concern; YOY - Young-of-Year: OT - Otter Trawls; SD - New Bedford Scallop Dredge; CD - Hydraulic Clam Dredge; PT- Pots and Traps; NL - Gill Nets and Longlines. NA - not applicable; 0 - No vulnerability; L - Low vulnerability; M - moderate vulnerability; H - high vulnerability; EFH - essential fish habitat; * derived from matrix analysis – see appendix. **Note that the information presented in columns 2-5 is derived from the EFH descriptions and may not completely agree with information provided in the rationale.**

Table 6.19 Witch Flounder EFH - Vulnerability to Effects of Bottom-Tending Fishing Gear

Life Stage	Geographic Area of EFH	Depth (m)	Seasonal Occurrence	EFH Description	EFH Vulnerability*				
					OT	**SD**	**CD**	**PT**	**NL**
Eggs	GOME, GB, continental shelf off southern NE, middle Atlantic south to Cape Hatteras	Deep	March to October	Surface waters	NA	NA	NA	NA	NA
Larvae	GOME, GB, continental shelf off southern NE, middle Atlantic south to Cape Hatteras	Deep	March to November, peaks in May - July	Surface waters	NA	NA	NA	NA	NA
Juveniles	GOME, outer continental shelf from GB south to Cape Hatteras	50-450 to 1500		Bottom habitats with fine-grained substrate	M	L	0	L	L
Adults	GOME, outer continental shelf from GB south to Chesapeake Bay	25-300		Bottom habitats with fine-grained substrate	M	L	L	L	L
Spawning Adults	GOME, outer continental shelf from GB south to Chesapeake Bay	25-360	March to November, peaks in May-August	Bottom habitats with fine-grained substrate	M	L	L	L	L

Rationale: Witch flounder (*Glyptocephalus cynoglossus*) range from Newfoundland south to Cape Hatteras. In U.S. waters, this species is common throughout the Gulf of Maine, and is found in deeper areas of and adjacent to Georges Bank and along the continental shelf edge and upper slope (Cargnelli et al 1999e, Klein-MacPhee 2002a).

Juvenile and adult witch flounder are found mainly over fine muddy sand, or mud. Their diet is comprised mainly of polychaetes, and they feed on other invertebrates as well (Cargnelli *et al.* 1999e). Since these life stages occur in areas of lower natural disturbance and rely on infauna, EFH vulnerability to impacts from otter trawls were rated as moderate. Impacts from scallop dredging may be less severe, since scallop dredges are not usually used in muddy habitat; however, vessel trip reports indicated scallop dredging in areas of witch flounder EFH (see Section 4), therefore, vulnerability to scallop dredges was rates as low. Juvenile EFH vulnerability to clam dredges was rated as none since clam dredges are not used in mud or in water depths where juvenile witch flounder are primarily found. However, EFH vulnerability to clam dredges for adults was rated as low since clam dredges do operate in adult EFH. Eggs and larvae of witch flounder are pelagic, so vulnerability of EFH to fishing gear impacts is not applicable.

Definitions: GOME - Gulf of Maine; GB - Georges Bank; NE - New England; HAPC - Habitat Area of Particular Concern; YOY - Young-of-Year: OT - Otter Trawls; SD - New Bedford Scallop Dredge; CD - Hydraulic Clam Dredge; PT- Pots and Traps; NL - Gill Nets and Longlines. NA - not applicable; 0 - No vulnerability; L - Low vulnerability; M - moderate vulnerability; H - high vulnerability; EFH - essential fish habitat; * derived from matrix analysis – see appendix. **Note that the information presented in columns 2-5 is derived from the EFH descriptions and may not completely agree with information provided in the rationale.**

Table 6.20 **Yellowtail Flounder EFH - Vulnerability to Effects of Bottom-Tending Fishing Gear**

Life Stage	Geographic Area of EFH	Depth (m)	Seasonal Occurrence	EFH Description	EFH Vulnerability*				
					OT	SD	CD	PT	NL
Eggs	GB, Mass Bay, Cape Cod Bay, southern NE continental shelf south to Delaware Bay and the following estuaries: Passamaquoddy Bay to Saco Bay; Great Bay to Cape Cod Bay	30 - 90	Mid-March to July, peaks in April to June in southern NE	Surface waters	NA	NA	NA	NA	NA
Larvae	GB, Mass Bay, Cape Cod Bay, southern NE continental shelf, middle Atlantic south to Chesapeake Bay and the following estuaries: Passamaquoddy Bay to Cape Cod Bay	10 - 90	March to April in New York bight; May to July in south NE and southeastern GB	Surface waters	NA	NA	NA	NA	NA
Juveniles	GB, GOME, southern NE continental shelf south to Delaware Bay and the following estuaries: Sheepscot R., Casco Bay, Mass Bay to Cape Cod Bay	20 - 50		Bottom habitats with substrate of sand or sand and mud	M	M	M	L	L
Adults	GB, GOME, southern NE continental shelf south to Delaware Bay and the following estuaries: Sheepscot R., Casco Bay, Mass Bay to Cape Cod Bay	20 - 50		Bottom habitats with substrate of sand or sand and mud	M	M	M	L	L
Spawning Adults	GB, GOME, southern NE continental shelf south to Delaware Bay and the following estuaries: Mass Bay to Cape Cod Bay	10-125		Bottom habitats with substrate of sand or sand and mud	M	M	M	L	L

Rationale: Yellowtail flounder (*Limanda ferruginea*) are found from the Gulf of St. Lawrence south to the Chesapeake Bay (Klein-MacPhee 2002a, Johnson *et al.* 1999). They are most abundant on the western half of Georges Bank, western Gulf of Maine, east of Cape Cod, and off southern New England (Johnson *et al.* 1999). Their usual depth range is from 10 - 100 m (Klein MacPhee 2002a). Juveniles and adults are found in some New England estuaries while eggs and larvae are found more frequently in these habitats (NEFMC 1998). Yellowtail eggs and larvae are pelagic, so EFH vulnerability is not applicable.

Yellowtail flounder feed mainly on benthic macrofauna, primarily amphipods and polychaetes (Johnson *et al.* 1999). Adults eat mostly crustaceans while juveniles focus on polychaetes. Both life stages are found on substrates of sand or sand and mud. Vulnerability of juvenile and adult EFH to the three types of mobile gear was rated as moderate because of the potential affect of these gears on infaunal yellowtail prey.

Definitions: GOME - Gulf of Maine; GB - Georges Bank; NE - New England; HAPC - Habitat Area of Particular Concern; YOY - Young-of-Year: OT - Otter Trawls; SD - New Bedford Scallop Dredge; CD - Hydraulic Clam Dredge; PT- Pots and Traps; NL - Gill Nets and Longlines. NA - not applicable; 0- No vulnerability; L - Low vulnerability; M - moderate vulnerability; H - high vulnerability; EFH - essential fish habitat; * derived from matrix analysis – see appendix. **Note that the information presented in columns 2-5 is derived from the EFH descriptions and may not completely agree with information provided in the rationale.**

Table 6.21 **Red Crab EFH - Vulnerability to Effects of Bottom-Tending Fishing Gear**

Life Stage	Geographic Area of EFH	Depth (m)	Seasonal Occurrence	EFH Description	EFH Vulnerability*				
					OT	SD	CD	PT	NL
Eggs	Southern flank of GB and south the Cape Hatteras, NC	200-400		Attached to the underside of the female crab until hatched - see spawning adults	NA	NA	NA	NA	NA
Larvae	Southern flank of GB and south the Cape Hatteras, NC	200-1800	January - June	Water column from surface to seafloor	NA	NA	NA	NA	NA
Juveniles	Southern flank of GB and south the Cape Hatteras, NC	700-1800		Bottom habitats of continental slope with a substrate of silts, clays, and all silt-clay-sand composites	L	0	0	L	L
Adults	Southern flank of GB and south the Cape Hatteras, NC	200-1300		Bottom habitats of continental slope with a substrate of silts, clays, and all silt-clay-sand composites	L	0	0	L	L
Spawning Adults	Southern flank of GB and south the Cape Hatteras, NC	200-1300		Bottom habitats of continental slope with a substrate of silts, clays, and all silt-clay-sand composites	L	0	0	L	L

Rationale: Red crab ***(Chaeceon (Geryon) quinquedens)*** are found on the outer continental shelf and slope of the western Atlantic from Nova Scotia into the Gulf of Mexico (Steimle *et al.* 2001). They are found on the bottom, chiefly between water depths of 200 and 1800. EFH depth range for juveniles is from 700 to 1800 m, and for adults EFH ranges from 200-1300 m. They are found on substrates ranging from silt and clay to hard substrates.

Red crab are opportunistic benthic feeders/scavengers, with a diet of epifauna and other opportunistically available items (Steimle *et al.* 2001). Post-larval juveniles feed on a wide variety of infaunal and epifaunal benthic invertebrates. Small crabs eat sponges, hydroids, gastropods and other organisms. Larger crabs eat similar small benthic fauna and larger prey including demersal and mid-water fishes.

The only fishery using mobile bottom gear which operates in red crab EFH is the monkfish trawl fishery (NEFMC 2002). The vulnerability of adult and juvenile red crab EFH to otter trawls was characterized as low because of their opportunistic feeding habits. Vulnerability to scallop dredges and clam dredges was rated as none since those gears do not operate in red crab EFH. Larval red crabs are pelagic and EFH vulnerability is not applicable. The “habitat” for eggs is the female carapace, therefore EFH vulnerability for this life stage is also not applicable.

Definitions: GOME - Gulf of Maine; GB - Georges Bank; NE - New England; HAPC - Habitat Area of Particular Concern; YOY - Young-of-Year: OT - Otter Trawls; SD - New Bedford Scallop Dredge; CD - Hydraulic Clam Dredge; PT- Pots and Traps; NL - Gill Nets and Longlines. NA - not applicable; 0 - No vulnerability; L - Low vulnerability; M - moderate vulnerability; H - high vulnerability; EFH - essential fish habitat; * derived from matrix analysis – see appendix. **Note that the information presented in columns 2-5 is derived from the EFH descriptions and may not completely agree with information provided in the rationale.**

Table 6.22 Atlantic Mackerel EFH - Vulnerability to Effects of Bottom-Tending Fishing Gear

Life Stage	Geographic Area of EFH	Depth (m)	Seasonal Occurrence	EFH Description	EFH Vulnerability*				
					OT	SD	CD	PT	NL
Eggs	Continental shelf from Maine through Cape Hatteras, NC also includes estuaries from Great Bay to Cape Cod Bay; Buzzards Bay to Long Island Sound; Gardiners Bay and Great South Bay	0 - 15		Pelagic waters	NA	NA	NA	NA	NA
Larvae	Continental shelf from GOME through Cape Hatteras, NC also includes estuaries from Great Bay to Cape Cod Bay; Narragansett Bay to Long Island Sound; Gardiners Bay and Great South Bay	10-130		Pelagic waters	NA	NA	NA	NA	NA
Juveniles	Continental shelf from GOME through Cape Hatteras, NC also includes estuaries from Passamaquoddy Bay; Penobscot Bay to Saco Bay; Great Bay; Mass Bay to Cape Cod Bay; Narragansett Bay, Long Island Bay; Gardiners Bay to Hudson R./ Raritan Bay	0 - 320		Pelagic waters	NA	NA	NA	NA	NA
Adults	Continental shelf from GOME through Cape Hatteras, NC also includes estuaries from Passamaquoddy Bay to Saco Bay; Mass Bay to Long Island Bay; Gardiners Bay to Hudson R./ Raritan Bay	0 - 380		Pelagic waters	NA	NA	NA	NA	NA

Rationale: All life stages of Atlantic mackerel *(Scomber scombrus)* are pelagic, so their EFH is not vulnerable to bottom tending fishing gear, and vulnerability was categorized as “not applicable.”

Definitions: GOME - Gulf of Maine; GB - Georges Bank; NE - New England; HAPC - Habitat Area of Particular Concern; YOY - Young-of-Year: OT - Otter Trawls; SD - New Bedford Scallop Dredge; CD - Hydraulic Clam Dredge; PT- Pots and Traps; NL - Gill Nets and Longlines. NA - not applicable; 0 - No vulnerability; L - Low vulnerability; M - moderate vulnerability; H - high vulnerability; EFH - essential fish habitat; * derived from matrix analysis – see appendix. **Note that the information presented in columns 2-5 is derived from the EFH descriptions and may not completely agree with information provided in the rationale.**

Table 6.23 **Black Sea Bass EFH - Vulnerability to Effects of Bottom-Tending Fishing Gear**

Life Stage	Geographic Area of EFH	Depth (m)	Seasonal Occurrence	EFH Description	EFH Vulnerability*				
					OT	SD	CD	PT	NL
Eggs	Continental shelf and estuaries from southern NE to North Carolina, also includes Buzzards Bay	0 - 200	May to October	Water column of coastal Mid-Atlantic Bight and Buzzards Bay	NA	NA	NA	NA	NA
Larvae	Pelagic waters over continental shelf from GOME to Cape Hatteras, NC, also includes Buzzards Bay	<100	May - November, peak June - July	Habitats for transforming (to juveniles) larvae are near coastal areas and into marine parts of estuaries between Virginia and NY; when larvae become demersal, found on structured inshore habitat such as sponge beds	H	H	H	L	L
Juveniles	Demersal waters over continental shelf from GOME to Cape Hatteras, NC, also includes estuaries from Buzzards Bay to Long Island Sound; Gardiners Bay, Barnegat Bay to Chesapeake Bay; Tangier/ Pocomoke Sound and James River	1 - 38	Found in coastal areas (April – Dec. , peak June – Nov.) between VA and MA, but winter offshore from NJ and south; estuaries in summer and spring	Rough bottom, shellfish and eelgrass beds, man-made structures in sandy-shelly areas, offshore clam beds and shell patches may be used during wintering	H	H	H	L	L
Adults	Demersal waters over continental shelf from GOME to Cape Hatteras, NC, also includes estuaries: Buzzards Bay, Narragansett Bay, Gardiners Bay, Great South Bay, Barnegat Bay to Chesapeake Bay; Tangier/ Pocomoke Sound and James River	20- 50	Wintering adults (Nov. to April) offshore, south of NY to NC; inshore, estuaries from May to October	Structured habitats (natural & man-made) sand and shell substrates preferred	H	H	H	L	L

Rationale: Black sea bass *(Centropristis striata)* are found in coastal waters of the northwest Atlantic, from Cape Cod south to Cape Canaveral (Klein-MacPhee 2002e). Occasionally they stray as far north as the Bay of Fundy (Gulf of Maine). Juveniles are common in high salinity estuaries. Adults and juveniles are found in estuaries from Massachusetts south to the James River, VA (Stone *et al.* 1994).

Black sea bass larvae are pelagic, but then become demersal and occupy structured inshore habitat such as sponge beds, eelgrass beds, shellfish beds, shell patches, and other rough bottoms (Steimle *et al.* 1999a) and offshore shell patches including clam beds (Able and Fahay 1998). The availability of structure limits successful postlarval and/or juvenile recruitment (Steimle *et al.* 1999a). Juveniles are diurnal visual predators that feed on benthic invertebrates and small fish. Adults are also structure oriented, and thought to use structure as shelter during day- time, but may stray off it to hunt at night.

Each of these life stages is associated with structure that may be vulnerable to fishing gear impacts, so vulnerability was rated as high for all mobile gear. It is important to note that structured habitats comprised of wrecks or other artificial reefs prone to damage by mobile gear may be avoided by fishermen. This is true of high relief natural areas as well. Black sea bass eggs are pelagic, so vulnerability to EFH is not applicable. Although larvae are pelagic, they do become demersal as they transition into juveniles. Therefore, larvae were rated the same as juveniles.

Definitions: GOME - Gulf of Maine; GB - Georges Bank; NE - New England; HAPC - Habitat Area of Particular Concern; YOY - Young-of-Year: OT - Otter Trawls; SD - New Bedford Scallop Dredge; CD - Hydraulic Clam Dredge; PT- Pots and Traps; NL - Gill Nets and Longlines. NA - not applicable; 0 - No vulnerability; L - Low vulnerability; M - moderate vulnerability; H - high vulnerability; EFH - essential fish habitat; * derived from matrix analysis – see appendix. **Note that the information presented in columns 2-5 is derived from the EFH descriptions and may not completely agree with information provided in the rationale.**

Table 6.24 Bluefish EFH - Vulnerability to Effects of Bottom-Tending Fishing Gear

Life Stage	Geographic Area of EFH	Depth (m)	Seasonal Occurrence	EFH Description	EFH Vulnerability*				
					OT	SD	CD	PT	NL
Eggs	North of Cape Hatteras, found over continental shelf from Montauk Point, NY south to Cape Hatteras, South of Cape Hatteras, found over Continental shelf through Key West, Florida	Mid-shelf depths	April to August	Pelagic waters	NA	NA	NA	NA	NA
Larvae	North of Cape Hatteras, found over continental shelf from Montauk Point, NY south to Cape Hatteras, South of Cape Hatteras, found over continental shelf through Key West, Florida, the slope sea and Gulf Stream between latitudes 29N and 40N; includes the following estuaries: Narragansett Bay	>15	April to September	Pelagic waters	NA	NA	NA	NA	NA
Juveniles	North of Cape Hatteras, found over continental shelf from Nantucket Island, MA south to Cape Hatteras, South of Cape Hatteras, found over Continental shelf through Key West, Florida, the slope sea and Gulf Stream between latitudes 29N and 40N also includes estuaries between Penobscot Bay to Great Bay; Mass Bay to James R.; Albemarle Sound to St. Johns River, FL		North Atlantic estuaries from June to October, Mid-Atlantic estuaries from May toOctober, South Atlantic estuaries from March to December	Pelagic waters	NA	NA	NA	NA	NA
Adults	North of Cape Hatteras, found over continental shelf from Cape Cod Bay, MA south to Cape Hatteras, South of Cape Hatteras, found over Continental shelf through Key West, Florida also includes estuaries between Penobscot Bay to Great Bay; Mass Bay to James R.; Albemarle Sound to Pamilco/ Pungo R., Bogue Sound, Cape Fear R., St. Helena Sound, Broad R., St. Johns R., & Indian R.		North Atlantic estuaries from June to October, Mid-Atlantic estuaries from April to October, South Atlantic estuaries from May to January	Pelagic waters	NA	NA	NA	NA	NA

Rationale: All life stages of bluefish *(Pomatomus saltatrix)* are pelagic, so their EFH is not vulnerable to bottom tending fishing gear, and vulnerability was not applicable.

Definitions: GOME - Gulf of Maine; GB - Georges Bank; NE - New England; HAPC - Habitat Area of Particular Concern; YOY - Young-of-Year: OT - Otter Trawls; SD - New Bedford Scallop Dredge; CD - Hydraulic Clam Dredge; PT- Pots and Traps; NL - Gill Nets and Longlines. NA - not applicable; 0 - No vulnerability; L - Low vulnerability; M - moderate vulnerability; H - high vulnerability; EFH - essential fish habitat; * derived from matrix analysis – see appendix. **Note that the information presented in columns 2-5 is derived from the EFH descriptions and may not completely agree with information provided in the rationale.**

Table 6.25 **Butterfish EFH - Vulnerability to Effects of Bottom-Tending Fishing Gear**

Life Stage	Geographic Area of EFH	Depth (m)	Seasonal Occurrence	EFH Description	EFH Vulnerability*				
					OT	**SD**	**CD**	**PT**	**NL**
Eggs	Over continental shelf from GOME through Cape Hatteras, NC, also in estuaries from Mass Bay to Long Island Sound; Gardiners Bay, Great South Bay, and Chesapeake Bay	0-1829	Spring and summer	Pelagic waters	NA	NA	NA	NA	NA
Larvae	Over continental shelf from GOME through Cape Hatteras, NC, also in estuaries from Boston Harbor, Waquoit Bay to Long Island Sound; Gardiners Bay to Hudson R./ Raritan Bay; Delaware Bay and Chesapeake Bay	10-1829	Summer and fall	Pelagic waters	NA	NA	NA	NA	NA
Juveniles	Over continental shelf from GOME through Cape Hatteras, NC also in estuaries from Mass Bay, Cape Cod Bay to Delaware Inland Bays; Chesapeake Bay, York R. and James R.	10-365 (most <120)	Winter – shelf, spring to fall - estuaries	Pelagic waters (larger individuals found over sandy and muddy substrates)	NA	NA	NA	NA	NA
Adults	Over continental shelf from GOME through Cape Hatteras, NC, also in estuaries from Mass Bay, Cape Cod Bay to Hudson R./ Raritan Bay; Delaware Bay and Inland Bays; York R. and James R.	10-365 (most <120)	Winter – shelf, summer to fall - estuaries	Pelagic waters (schools form over sandy, sandy-silt and muddy substrates)	NA	NA	NA	NA	NA

Rationale: All life stages of butterfish *(Peprilus triacanthus)* are pelagic, so their EFH is not vulnerable to bottom tending fishing gear, and vulnerability was not applicable.

Definitions: GOME - Gulf of Maine; GB - Georges Bank; NE - New England; HAPC - Habitat Area of Particular Concern; YOY - Young-of-Year: OT - Otter Trawls; SD - New Bedford Scallop Dredge; CD - Hydraulic Clam Dredge; PT- Pots and Traps; NL - Gill Nets and Longlines. NA - not applicable; 0- No vulnerability; L - Low vulnerability; M - moderate vulnerability; H - high vulnerability; EFH - essential fish habitat; * derived from matrix analysis – see appendix. **Note that the information presented in columns 2-5 is derived from the EFH descriptions and may not completely agree with information provided in the rationale.**

Table 6.26 Illex Squid EFH - Vulnerability to Effects of Bottom-Tending Fishing Gear

Life Stage	Geographic Area of EFH	Depth (m)	Seasonal Occurrence	EFH Description	EFH Vulnerability*				
					OT	SD	CD	PT	NL
Juveniles	Over continental shelf from GOME through Cape Hatteras, NC	0 - 182	Carried northward by Gulf Stream	Pelagic waters	NA	NA	NA	NA	NA
Adults	Over continental shelf from GOME through Cape Hatteras, NC	0 -182	Late fall - offshore, spawn Dec. - March	Pelagic waters	NA	NA	NA	NA	NA

Rationale: All stages of Ilex squid *(Illex illecebrosus)* are pelagic, so their EFH is not vulnerable to bottom tending fishing gear, and vulnerability was not applicable.

Definitions: GOME - Gulf of Maine; GB - Georges Bank; NE - New England; HAPC - Habitat Area of Particular Concern; YOY - Young-of-Year: OT - Otter Trawls; SD - New Bedford Scallop Dredge; CD - Hydraulic Clam Dredge; PT- Pots and Traps; NL - Gill Nets and Longlines. NA - not applicable; 0 - No vulnerability; L - Low vulnerability; M - moderate vulnerability; H - high vulnerability; EFH - essential fish habitat; * derived from matrix analysis – see appendix. **Note that the information presented in columns 2-5 is derived from the EFH descriptions and may not completely agree with information provided in the rationale.**

Table 6.27 Loligo Squid EFH - Vulnerability to Effects of Bottom-Tending Fishing Gear

Life Stage	Geographic Area of EFH	Depth (m)	Seasonal Occurrence	EFH Description	EFH Vulnerability*				
					OT	SD	CD	PT	NL
Eggs***	Over continental shelf from GOME through Cape Hatteras, NC	<50	Spawn in May, hatch in July	Demersal egg masses are commonly found on sandy/mud bottom, usually attached to rocks/boulders, pilings or algae such as Fucus, Ulva, Laminaria, and Porphyra	H	H	H	L	L
Juveniles	Over continental shelf from GOME through Cape Hatteras, NC	0 - 213	Spring - fall - inshore winter - offshore	Pelagic waters	NA	NA	NA	NA	NA
Adults	Over continental shelf from GOME through Cape Hatteras, NC	0 - 305	March – Oct. – inshore, winter - offshore	Pelagic waters	NA	NA	NA	NA	NA

Rationale: Loligo or longfin squid *(Loligo pealeii)* is a pelagic schooling species. It is distributed in continental shelf and slope waters from Newfoundland to the Gulf of Venezuela (Cargnelli *et al.* 1999a). Most life stages of loligo squid are pelagic; however, encapsulated eggs are laid in masses, called "mops" which are attached to structures such as rocks and algae on substrates of sand, mud, or hard bottom (Cargnelli *et al.* 1999a). ***As of this writing, EFH is not designated for Loligo eggs, however it will be designated in the near future. Once Loligo egg EFH is designated its EFH will be rated as highly vulnerable to otter trawls and scallop dredges, particularly since biogenic structures are used as attachment sites.

Definitions: GOME - Gulf of Maine; GB - Georges Bank; NE - New England; HAPC - Habitat Area of Particular Concern; YOY - Young-of-Year: OT - Otter Trawls; SD - New Bedford Scallop Dredge; CD - Hydraulic Clam Dredge; PT- Pots and Traps; NL - Gill Nets and Longlines. NA - not applicable; 0 - No vulnerability; L - Low vulnerability; M - moderate vulnerability; H - high vulnerability; EFH - essential fish habitat; * derived from matrix analysis – see appendix. **Note that the information presented in columns 2-5 is derived from the EFH descriptions and may not completely agree with information provided in the rationale.**

Table 6.28 Ocean Quahog EFH - Vulnerability to Effects of Bottom-Tending Fishing Gear

Life Stage	**Geographic Area of EFH**	**Depth (m)**	**Seasonal Occurrence**	**EFH Description**	**EFH Vulnerability***				
					OT	**SD**	**CD**	**PT**	**NL**
Juveniles	Eastern edge of GB and GOME throughout the Atlantic EEZ	8-245		Throughout substrate to a depth of 3ft within federal waters, occurs progressively further offshore between Cape Cod and Cape Hatteras	L	L	L	L	L
Adults	Eastern edge of GB and GOME throughout the Atlantic EEZ	8 -245	Spawn May-Dec. with several peaks	Throughout substrate to a depth of 3ft within federal waters, occurs progressively further offshore between Cape Cod and Cape Hatteras	L	L	L	L	L
Rationale: Ocean quahog *(Arctica islandica)* juveniles are found in offshore sandy substrate, and may survive in muddy intertidal areas (Cargnelli *et al.* 1999b). Adults are found in similar offshore habitats, just below the surface of the sediment, usually in medium to fine-grained sand. Although clam dredges remove clams from the sediment, the habitat's functional value is probably not affected. Juvenile and adult EFH vulnerability was therefore rated as low for all mobile gears. Ocean quahog eggs and larvae are pelagic, therefore EFH vulnerability is not applicable.									
Definitions: GOME - Gulf of Maine; GB - Georges Bank; NE - New England; HAPC - Habitat Area of Particular Concern; YOY - Young-of-Year: OT - Otter Trawls; SD - New Bedford Scallop Dredge; CD - Hydraulic Clam Dredge; PT- Pots and Traps; NL - Gill Nets and Longlines. NA - not applicable; 0- No vulnerability; L - Low vulnerability; M - moderate vulnerability; H - high vulnerability; EFH - essential fish habitat; * derived from matrix analysis – see appendix. **Note that the information presented in columns 2-5 is derived from the EFH descriptions and may not completely agree with information provided in the rationale.**									

Table 6.29 Atlantic Surfclam EFH - Vulnerability to Effects of Bottom-Tending Fishing Gear

Life Stage	**Geographic Area of EFH**	**Depth (m)**	**Seasonal Occurrence**	**EFH Description**	**EFH Vulnerability***				
					OT	**SD**	**CD**	**PT**	**NL**
Juveniles	Eastern edge of GB and the GOME throughout Atlantic EEZ	0 -60, low density beyond 38		Throughout substrate to a depth of 3 ft within federal waters, burrow in medium to coarse sand and gravel substrates, also found in silty to fine sand, but not in mud	L	L	L	L	L
Adults	Eastern edge of GB and the GOME throughout Atlantic EEZ	0 -60, low density beyond 38	Spawn-summer to fall	Throughout substrate to a depth of 3 ft within federal waters	L	L	L	L	L
Rationale: Atlantic surfclams *(Spisula solidissima)* are found in sandy continental shelf habitats from the southern Gulf of St. Lawrence to Cape Hatteras, North Carolina (Cargnelli *et al.* 1999c). They burrow into substrates from fine to coarse sandy gravel and are not found in mud. Although clam dredges remove clams from the sediment, the habitat's functional value is probably not affected. Juvenile and adult EFH vulnerability was therefore rated as low for all mobile gears. Surfclam eggs and larvae are pelagic, therefore EFH vulnerability is not applicable.									
Definitions: GOME - Gulf of Maine; GB - Georges Bank; NE - New England; HAPC - Habitat Area of Particular Concern; YOY - Young-of-Year: OT - Otter Trawls; SD - New Bedford Scallop Dredge; CD - Hydraulic Clam Dredge; PT- Pots and Traps; NL - Gill Nets and Longlines. NA - not applicable; 0 - No vulnerability; L - Low vulnerability; M - moderate vulnerability; H - high vulnerability; EFH - essential fish habitat; * derived from matrix analysis – see appendix. **Note that the information presented in columns 2-5 is derived from the EFH descriptions and may not completely agree with information provided in the rationale.**									

Table 6.30 **Scup EFH - Vulnerability to Effects of Bottom-Tending Fishing Gear**

Life Stage	Geographic Area of EFH	Depth (m)	Seasonal Occurrence	EFH Description	EFH Vulnerability*				
					OT	SD	CD	PT	NL
Eggs	Southern NE to coastal Virginia includes the following estuaries: Waquoit Bay to Long Island Sound; Gardiners Bay, Hudson R./ Raritan Bay	(<30)	May - August	Pelagic waters in estuaries	NA	NA	NA	NA	NA
Larvae	Southern NE to coastal Virginia includes the following estuaries: Waquoit Bay to Long Island Sound; Gardiners Bay, Hudson R./ Raritan Bay	(<20)	May - September	Pelagic waters in estuaries	NA	NA	NA	NA	NA
Juveniles	Continental shelf from GOME to Cape Hatteras, NC includes the following estuaries: Mass Bay, Cape Cod Bay to Long Island Sound; Gardiners Bay to Delaware Inland Bays; & Chesapeake Bay	(0 - 38)	Spring and summer in estuaries and bays	Demersal waters north of Cape Hatteras and Inshore on various sands, mud, mussel, and eelgrass bed type substrates	M	M	M	L	L
Adults	Continental shelf from GOME to Cape Hatteras, NC includes the following estuaries: Cape Cod Bay to Long Island Sound; Gardiners Bay to Hudson R./ Raritan Bay; Delaware Bay & Inland Bays; & Chesapeake Bay	(2 -185)	Wintering adults (November - April) are usually offshore, south of NY to NC	demersal waters north of Cape Hatteras and Inshore estuaries (various substrate types)	L	L	L	L	L

Rationale: Scup *(Stenotomus chrysops)* is a temperate species that occurs primarily from Massachusetts to South Carolina, although it has been reported as far north as the Bay of Fundy and Sable Island Bank, Canada (Steimle *et al.* 1999f). Scup are primarily benthic feeders that use a variety of habitat types. Juveniles forage on epibenthic amphipods, other small crustaceans, polychaetes, mollusks, fish eggs, and larvae. They occur over a variety of substrates, and are most abundant in areas without structure. Limited observations of scup have shown periodic use of seafloor depressions for cover (Auster *et al.* 1991, 1995).

Adults are found on soft bottoms or near structures. During the summer they are closer inshore and found on a wider range of habitats. In the winter they congregate offshore in areas that are expected to serve as a thermal refuge (Klein-McPhee 2002f), particularly deeper waters of the outer continental shelf and around canyon heads. Smaller adults feed on echinoderms, annelids, and small crustaceans. Larger scup consume more squids and fishes. Since juvenile scup are primarily benthic feeders, their EFH was rated as moderately vulnerable to impacts from mobile bottom gear. EFH for adults was rated as low since there is less of a reliance on benthic prey items.

Definitions: GOME - Gulf of Maine; GB - Georges Bank; NE - New England; HAPC - Habitat Area of Particular Concern; YOY - Young-of-Year: OT - Otter Trawls; SD - New Bedford Scallop Dredge; CD - Hydraulic Clam Dredge; PT- Pots and Traps; NL - Gill Nets and Longlines. NA - not applicable; 0 - No vulnerability; L - Low vulnerability; M - moderate vulnerability; H - high vulnerability; EFH - essential fish habitat; * derived from matrix analysis – see appendix. **Note that the information presented in columns 2-5 is derived from the EFH descriptions and may not completely agree with information provided in the rationale.**

Table 6.31 **Spiny Dogfish EFH - Vulnerability to Effects of Bottom-Tending Fishing Gear**

Life Stage	Geographic Area of EFH	Depth (m)	Seasonal Occurrence	EFH Description	EFH Vulnerability*				
					OT	SD	CD	PT	NL
Juveniles	GOME through Cape Hatteras, NC across the Continental shelf; Continental shelf waters South of Cape Hatteras, NC through Florida; also includes estuaries from Passamaquaddy Bay to Saco Bay; Mass Bay & Cape Cod Bay	10-390		Continental shelf waters and estuaries	L	L	L	L	L
Adults	GOME through Cape Hatteras, NC across the Continental shelf; Continental shelf waters South of Cape Hatteras, NC through Florida; also includes estuaries from Passamaquaddy Bay to Saco Bay; Mass Bay & Cape Cod Bay	10-450		Continental shelf waters and estuaries	L	L	L	L	L

Rationale: Spiny dogfish *(Squalus acanthias)* is a coastal shark with a circumboreal distribution and is one of the most abundant sharks in the western North Atlantic (McMillan and Morse 1999). Female dogfish are viviparous, so EFH designations were limited to juveniles and adults. Smaller dogfish have been reported to feed primarily on crustaceans, with an increase in piscivory in larger individuals (Burgess 2002). Fish, mainly schooling pelagic species, constitute 50% of their diet. Their voracious and opportunistic feeding behavior was emphasized by McMillan and Morse (1999). Since neither of these life stages appears to be closely tied to benthic organisms, the vulnerability of their EFH to mobile gears was rated as low.

Definitions: GOME - Gulf of Maine; GB - Georges Bank; NE - New England; HAPC - Habitat Area of Particular Concern; YOY - Young-of-Year: OT - Otter Trawls; SD - New Bedford Scallop Dredge; CD - Hydraulic Clam Dredge; PT- Pots and Traps; NL - Gill Nets and Longlines. NA - not applicable; 0 - No vulnerability; L - Low vulnerability; M - moderate vulnerability; H - high vulnerability; EFH - essential fish habitat; * derived from matrix analysis – see appendix. **Note that the information presented in columns 2-5 is derived from the EFH descriptions and may not completely agree with information provided in the rationale.**

Table 6.32 Summer Flounder EFH - Vulnerability to Effects of Bottom-Tending Fishing Gear

Life Stage	Geographic Area of EFH	Depth (m)	Seasonal Occurrence	EFH Description	EFH Vulnerability*				
					OT	SD	CD	PT	NL
Eggs	Over continental shelf from GOME to Cape Hatteras, NC; South of Cape Hatteras to Florida	30-70 fall; 110 winter; 9-30 spring	October to May	Pelagic waters, heaviest concentrations within 9 miles of shore off NJ and NY	NA	NA	NA	NA	NA
Larvae	Over continental shelf from GOME to Cape Hatteras, NC; South of Cape Hatteras to Florida; also includes estuaries from Waquoit Bay to Narragansett Bay; Hudson River/ Raritan Bay; Barnegat Bay, Chesapeake Bay, Rappahannock R., York R., James R., Albemarle Sound, Pamlico Sound, Neuse R. to Indian R.	10-70	Mid-Atlantic Bight from Sept. to Feb.; southern part from Nov. to May at depths of 9-30 m	Pelagic waters, larvae most abundant 19 - 83 km from shore, southern areas 12 - 52 miles from shore	NA	NA	NA	NA	NA
Juveniles	Over continental shelf from GOME to Cape Hatteras, NC; South of Cape Hatteras to Florida; also includes estuaries from Waquoit Bay to James R.; Albemarle Sound to Indian R.	0.5-5 in estuary		Demersal waters, on muddy substrate but prefer mostly sand; found in the lower estuaries in flats, channels, salt marsh creeks, and eelgrass beds	M* * L	L	L	0	0
Adults	Over continental shelf from GOME to Cape Hatteras, NC; South of Cape Hatteras to Florida; also includes estuaries from Buzzards Bay, Narragansett Bay, Conn. R. to James R.; Albemarle Sound to Broad R.; St. Johns R., & Indian R.	0 - 25	Shallow coastal and estuarine waters during warmer months, move offshore on outer continental shelf at depths of 150m in colder months	Demersal waters and estuaries	M** L	L	L	0	0

Rationale: Summer flounder *(Paralichthys dentatus)* occur in the shallow estuarine waters and outer continental shelf from Nova Scotia to Florida with the center of their range located in the Middle Atlantic Bight (Packer *et al.* 1999b). Juvenile summer flounder are opportunistic feeders, and their diet includes mysids, fish, and some crustaceans (Packer *et al.* 1999b). There are gradual changes in the diet of summer flounder, with fish becoming more important as a food source as individuals get older and larger. Adults are also opportunistic feeders, with fish and crustaceans making up a significant portion of their diet.

Eelgrass and macroalgae has been designated as a habitat area of particular concern (HAPC) for adult and juvenile summer flounder. Stephan *et al.* (2000) determined that otter trawls could result in below-ground impacts to submerged aquatic vegetation (SAV), which, of all the impacts to SAV possible from fishing gear, was ranked as the impact of greatest concern. This determination was qualified by an acknowledgment that factors relevant to trawl use and the type of SAV species present, must be considered for a more precise evaluation of the effects of this gear type in SAV habitat. * *Based on potential impacts to SAV, the vulnerability of the summer flounder HAPC to otter trawls is rated as moderate. Vulnerability to scallop or clam dredges was considered low since these gears are not typically used in estuaries where SAV is found.

Since adults and juveniles are both opportunistic feeders, their EFH vulnerability (aside from the HAPC) was rated as low for all bottom tending gear. Summer flounder eggs and larvae are pelagic so EFH vulnerability is not applicable.

Definitions: GOME - Gulf of Maine; GB - Georges Bank; NE - New England; HAPC - Habitat Area of Particular Concern; YOY - Young-of-Year: OT - Otter Trawls; SD - New Bedford Scallop Dredge; CD - Hydraulic Clam Dredge; PT- Pots and Traps; NL - Gill Nets and Longlines. NA - not applicable; 0 - No vulnerability; L - Low vulnerability; M - moderate vulnerability; H - high vulnerability; EFH - essential fish habitat; * derived from matrix analysis – see appendix. **Note that the information presented in columns 2-5 is derived from the EFH descriptions and may not completely agree with information provided in the rationale.**

Table 6.33 **Tilefish EFH - Vulnerability to Effects of Bottom-Tending Fishing Gear**

Life Stage	Geographic Area of EFH	Depth (m)	Seasonal Occurrence	EFH Description	EFH Vulnerability*				
					OT	SD	CD	PT	NL
Eggs	US-Canadian Boundary to VA/NC boundary (shelf break; GB to Cape Hatteras)	76-365	Serial spawning March - November; peaks April – October	Water column	NA	NA	NA	NA	NA
Larvae	US-Canadian Boundary to VA/NC boundary (outer continental shelf - GB to Cape Hatteras)	76-365	Feb. - Oct; peaks July – October	Water column	NA	NA	NA	NA	NA
Juveniles	US-Canadian Boundary to VA/NC boundary (shelf break, submarine canyon walls and flanks - GB to Cape Hatteras)	76-365	All year - may leave GB in winter	Rough bottom, small burrows, and sheltered areas – Substrate rocky, stiff clay, human debris	H	L	0	L	L
Adults	US-Canadian Boundary to VA/NC boundary (shelf break, submarine canyon walls and flanks - GB to Cape Hatteras)	76-365	All year - may leave GB in winter	Rough bottom, small burrows, and sheltered areas – Substrate rocky, stiff clay, human debris	H	L	0	L	L

Rationale: Tilefish *(Lopholatilus chamaeleontieps)* are restricted to the continental shelf break south of the Gulf of Maine (Steimle *et al.* 1999b). They occupy a number of habitats, including scour basins around rocks or other rough bottom areas that form burrow-like cavities, and pueblo habitats in clay substrate. The dominant habitat type is a vertical burrow in a substrate of semi-hard silt/clay, 2 - 3 m deep and 4 - 5 m in diameter with a funnel shape. These burrows are excavated by tilefish, and then secondary burrows are created by other organisms, including lobsters, conger eels, and galatheid crabs. Tilefish are visual daytime feeders on galatheid crabs, mollusks, shrimps, polychaetes and occasionally fish. Mollusks and echinoderms are more important to smaller tilefish. Little is known about juveniles of the species.

A report to the Mid-Atlantic Fishery Management Council (Able and Muzeni 2002) from a video survey in areas of tilefish habitat identified trawl tracks through these areas, and concluded that trawling caused a re-suspension of bottom sediments. The report noted that re-suspended sediments fill burrows in and/or cause physiological stress to tilefish that are present. No obvious structural impacts to the habitat were identified. However, due to the tilefish's reliance on structured shelter and the need for further study, the vulnerability of tilefish EFH to otter trawls was ranked as high. Clam dredges operate in shallow, sandy waters typically uninhabited by tilefish, so EFH vulnerability was rated as none for this gear. Scallop vessel monitoring data (Section 4) indicate that scallop dredges operate to a small extent in areas overlapping tilefish EFH, therefore EFH vulnerability to scallop dredges was ranked as low. Tilefish eggs and larvae are pelagic, therefore EFH vulnerability is not applicable.

Definitions: GOME - Gulf of Maine; GB - Georges Bank; NE - New England; HAPC - Habitat Area of Particular Concern; YOY - Young-of-Year: OT - Otter Trawls; SD - New Bedford Scallop Dredge; CD - Hydraulic Clam Dredge; PT- Pots and Traps; NL - Gill Nets and Longlines. NA - not applicable; 0 - No vulnerability; L - Low vulnerability; M - moderate vulnerability; H - high vulnerability; EFH - essential fish habitat; * derived from matrix analysis – see appendix. **Note that the information presented in columns 2-5 is derived from the EFH descriptions and may not completely agree with information provided in the rationale.**

Table 6.34 Red Drum EFH - Vulnerability to Effects of Bottom-Tending Fishing Gear

Life Stage	**Geographic Area of EFH**	**Depth (m)**	**Seasonal Occurrence**	**EFH Description**	**EFH Vulnerability***				
					OT	**SD**	**CD**	**PT**	**NL**
Larvae	Along the Atlantic coast from Virginia through the Florida Keys	<50		Estuarine wetlands especially important (flooded saltmarshes, brackish marsh, tidal creeks, mangrove fringe, seagrasses)	NA	NA	NA	NA	NA
Juveniles	Along the Atlantic coast from Virginia through the Florida Keys	<50	Found throughout Chesapeake Bay from Sept. - Nov.	Utilize shallow backwaters of estuaries as nursery areas and remain until they move to deeper water portions of the estuary associated with river mouths, oyster bars and front beaches	L	0	0	L	L
Adults	Along the Atlantic coast from Virginia through the Florida Keys	<50	Found in Chesapeake in spring and fall and also along eastern shore of VA	Concentrate around inlets, shoals, and capes along the Atlantic coast – shallow bay bottoms or oyster reef substrate preferred, also nearshore artificial reefs	L	L	L	L	L

Rationale: Red drum *(Sciaenops ocellatus)* are distributed in estuarine and coastal waters depending upon their stage of maturity (McGurrin 1994). Juvenile red drum are found in shallow estuarine backwaters and as they grow they move to deeper areas. Submerged aquatic vegetation is particularly important habitat for juvenile drum. Sub-adult and adult red drum are found on estuarine bay bottoms or oyster reefs, and in nearshore coastal waters including the beach zone out to several miles from shore.

Juvenile and adult red drum have a varied diet. Smaller juveniles eat copepods and mysids, while larger individuals eat decapods (crabs & shrimp), fish and plant material (McGurrin 1994). Although SAV is an important habitat for juvenile red drum, EFH vulnerability to otter trawls was rated as low since its use in SAV is limited. Scallop dredges and hydraulic clam dredges usually are not used in juvenile red drum EFH, therefore, EFH vulnerability for these gears was rated as none. Since red drum feed on a variety of organisms, and adults are found in many habitat types, vulnerability of adult EFH to mobile bottom gear was rated as low. Red drum eggs and larvae are pelagic therefore, EFH vulnerability is not applicable.

Definitions: GOME - Gulf of Maine; GB - Georges Bank; NE - New England; HAPC - Habitat Area of Particular Concern; YOY - Young-of-Year: OT - Otter Trawls; SD - New Bedford Scallop Dredge; CD - Hydraulic Clam Dredge; PT- Pots and Traps; NL - Gill Nets and Longlines. NA - not applicable; 0 - No vulnerability; L - Low vulnerability; M - moderate vulnerability; H - high vulnerability; EFH - essential fish habitat; * derived from matrix analysis – see appendix. **Note that the information presented in columns 2-5 is derived from the EFH descriptions and may not completely agree with information provided in the rationale.**

Table 6.35 Spanish Mackerel, Cobia, and King Mackerel EFH - Vulnerability to Effects of Bottom-Tending Fishing Gear

Life Stage	**Geographic Area of EFH**	**Depth (m)**	**Seasonal Occurrence**	**EFH Description**	**EFH Vulnerability***				
					OT	**SD**	**CD**	**PT**	**NL**
Spanish Mackerel All Life Stages	South Atlantic and Mid-Atlantic Bights			Sandy shoals of capes and offshore bars, high profile rock bottoms and barrier island ocean-side waters from surf zone to shelf break but from the Gulf Stream shoreward	NA	NA	NA	NA	NA
Cobia All Life Stages	South Atlantic and Mid-Atlantic Bights			Sandy shoals of capes and offshore bars, high profile rock bottoms and barrier island ocean side waters from surf zone to shelf break but from the Gulf Stream shoreward, also high salinity bays, estuaries, seagrass habitat	NA	NA	NA	NA	NA
King Mackerel All Life Stages	South Atlantic and Mid-Atlantic Bights			Sandy shoals of capes and offshore bars, high profile rock bottoms and barrier island ocean-side waters from surf zone to shelf break but from the Gulf Stream shoreward	NA	NA	NA	NA	NA

Rationale: All life stages of Spanish mackerel *(Scomberomorus maculatus)*, cobia *(Rachycentron canadum)* and King mackerel *(Scomberomorus cavalla)* are pelagic, so their EFH is not vulnerable to bottom tending fishing gear, and vulnerability was not applicable.

Definitions: GOME - Gulf of Maine; GB - Georges Bank; NE - New England; HAPC - Habitat Area of Particular Concern; YOY - Young-of-Year: OT - Otter Trawls; SD - New Bedford Scallop Dredge; CD - Hydraulic Clam Dredge; PT- Pots and Traps; NL - Gill Nets and Longlines. NA - not applicable; 0 - No vulnerability; L - Low vulnerability; M - moderate vulnerability; H - high vulnerability; EFH - essential fish habitat; * derived from matrix analysis – see appendix. **Note that the information presented in columns 2-5 is derived from the EFH descriptions and may not completely agree with information provided in the rationale.**

Table 6.36 Golden Crab EFH - Vulnerability to Effects of Bottom-Tending Fishing Gear

Life Stage	**Geographic Area**	**Depth (m)**	**Seasonal Occurrence**	**EFH Description**	**EFH Vulnerability***				
					OT	**SD**	**CD**	**PT**	**NL**
All Life Stages	Chesapeake Bay to the south through the Florida Straight (and into the Gulf of Mexico)	290-570		Continental slope in flat areas of foraminifera ooze, on distinct mounds of dead coral, ripple habitat, dunes, black pebble habitat, low outcrop, and soft bioturbated habitat	L	0	0	L	L

Rationale: Golden crab *(Chaceon fenneri)* inhabit the continental slope of Bermuda and the southeastern United States from Chesapeake Bay south through the Florida Straight and into the Gulf of Mexico (SAFMC 1998). Although similar to red crab, less is known about this species. They are categorized as opportunistic scavengers, and are found in depths from 290 - 570 m on substrates of foraminiferon ooze, dead coral mounds, and deep ripple habitat, dunes, and black pebble habitat. Scallop dredges and clam dredges do not operate in golden crab EFH due to depth so EFH vulnerability was rated as none. Most otter trawling operates in depths less than 200 m so EFH vulnerability was rated as low for this gear type.

Definitions: GOME - Gulf of Maine; GB - Georges Bank; NE - New England; HAPC - Habitat Area of Particular Concern; YOY - Young-of-Year: OT - Otter Trawls; SD - New Bedford Scallop Dredge; CD - Hydraulic Clam Dredge; PT- Pots and Traps; NL - Gill Nets and Longlines. NA - not applicable; 0 - No vulnerability; L - Low vulnerability; M - moderate vulnerability; H - high vulnerability; EFH - essential fish habitat; * derived from matrix analysis – see appendix. **Note that the information presented in columns 2-5 is derived from the EFH descriptions and may not completely agree with information provided in the rationale.**

Table 6.37 Barndoor Skate Pending EFH - Vulnerability to Effects of Bottom-Tending Fishing Gear

Life Stage	Geographic Area of	Depth (m)	Seasonal Occurrence	EFH Description	EFH Vulnerability*				
					OT	SD	CD	PT	NL
Juveniles	Eastern GOME, GB, SNE, MAB to Hudson Canyon	0-750 mostly <150		Bottom habitats with mud, gravel, and sand substrates	M	M	L	L	L
Adults	Eastern GOME, GB, SNE, MAB to Hudson Canyon	0-750 mostly <150		Bottom habitats with mud, gravel, and sand substrates	M	M	L	L	L

Rationale: Barndoor skate *(Dipturus laevis)* occur from Newfoundland south to Cape Hatteras, but are most abundant on Georges Bank and in the Gulf of Maine. They are found on soft mud, sand and gravel. (Packer *et al.* in press (a)). Barndoor skate feed on invertebrates usually associated with the bottom - including polychaetes, gastropods, and bivalves - squid and fish. Smaller individuals feed primarily on polychaetes, copepods and amphipods while larger individuals capture larger and more active prey (McEachran 2002, Packer *et al.* in press (a)). A single fertilized egg is encapsulated in a leathery capsule known as a "mermaids purse." The young hatch in late spring or early summer and are thought to be about 180-190 mm in length, although very little information is available on this life stage (Packer *et al.* in press(a)).

Juvenile EFH was considered to be moderately vulnerable to otter trawls and scallop dredges because of the closer association of juveniles to a benthic invertebrate diet. Adult EFH vulnerability to otter trawls and scallop dredges was rated as moderate due primarily to their reproductive habits. EFH vulnerability to clam dredges was rated as low for juveniles and adults because this gear is not extensively used in EFH.

Definitions: GOME - Gulf of Maine; GB - Georges Bank; NE - New England; HAPC - Habitat Area of Particular Concern; YOY - Young-of-Year: OT - Otter Trawls; SD - New Bedford Scallop Dredge; CD - Hydraulic Clam Dredge; PT- Pots and Traps; NL - Gill Nets and Longlines. NA - not applicable; 0 - No vulnerability; L - Low vulnerability; M - moderate vulnerability; H - high vulnerability; EFH - essential fish habitat; * derived from matrix analysis – see appendix. **Note that the information presented in columns 2-5 is derived from the EFH descriptions and may not completely agree with information provided in the rationale.**

Table 6.38 Clearnose Skate Pending EFH - Vulnerability to Effects of Bottom-Tending Fishing Gear

Life Stage	Geographic Area of EFH	Depth (m)	Seasonal Occurrence	EFH Description	EFH Vulnerability*				
					OT	SD	CD	PT	NL
Juveniles	GOME, along shelf to Cape Hatteras, NC; includes the estuaries from Hudson River/Raritan Bay south to the Chesapeake Bay mainstem	0 - 500 mostly <111		Bottom habitats with substrate of soft bottom along continental shelf and rocky or gravelly bottom	M	M	M	L	L
Adults	GOME, along shelf to Cape Hatteras, NC; includes the estuaries from Hudson River/Raritan Bay south to the Chesapeake Bay mainstem	0 - 500 mostly <111		Bottom habitats with substrate of soft bottom along continental shelf and rocky or gravelly bottom	M	M	M	L	L

Rationale: Clearnose skate *(Raja eglanteria)* occur in the Gulf of Maine, but are most abundant from Cape Hatteras north to Delaware Bay. They are found over soft bottoms of mud and sand, and also occur on rocky or gravelly bottoms. They have been captured from shore out to depths of 330 m, but are most abundant at depths less than 111 m. (Packer *et al.* in press (b)). Adults and juveniles feed on polychaetes, amphipods, decapod crustaceans, mollusks, and fish. Like barndoor skates, crabs and benthic invertebrates are more important for smaller, younger individuals, and the importance of fish in the diet increases with age (McEachran 2002; Packer *et al.* in press(b)). A single fertilized egg is encapsulated in a leathery case. Eggs are deposited in the spring or summer and hatch 3 months later.

Juvenile EFH was considered to be moderately vulnerable to otter trawls, scallop dredges and clam dredges because of the closer association of juveniles to a benthic invertebrate diet. Adult EFH vulnerability to otter trawls, scallop dredges and clam dredges was rated as moderate due primarily to their reproductive habits.

Definitions: GOME - Gulf of Maine; GB - Georges Bank; NE - New England; HAPC - Habitat Area of Particular Concern; YOY - Young-of-Year: OT - Otter Trawls; SD - New Bedford Scallop Dredge; CD - Hydraulic Clam Dredge; PT- Pots and Traps; NL - Gill Nets and Longlines. NA - not applicable; 0 - No vulnerability; L - Low vulnerability; M - moderate vulnerability; H - high vulnerability; EFH - essential fish habitat; * derived from matrix analysis – see appendix. **Note that the information presented in columns 2-5 is derived from the EFH descriptions and may not completely agree with information provided in the rationale.**

Table 6.39 Little Skate Pending EFH - Vulnerability to Effects of Bottom-Tending Fishing Gear

Life Stage	Geographic Area of EFH	Depth (m)	Seasonal Occurrence	EFH Description	EFH Vulnerability*				
					OT	SD	CD	PT	NL
Eggs	GB through MAB to Cape Hatteras, NC; includes the estuaries from Buzzards Bay south to the Chesapeake Bay mainstem	<27		Bottom habitats with sandy substrate	L	L	L	L	L
Juveniles	GB through MAB to Cape Hatteras, NC; includes the estuaries from Buzzards Bay south to the Chesapeake Bay mainstem	0-137 mostly 73-91		Bottom habitats with sandy or gravelly substrate or mud	M	M	M	L	L
Adults	GB through MAB to Cape Hatteras, NC; includes the estuaries from Buzzards Bay south to the Chesapeake Bay mainstem	0-137 mostly 73-91		Bottom habitats with sandy or gravelly substrate or mud	M	M	M	L	L

Rationale: Little skate *(Leucoraja erinacea)* range from Nova Scotia to Cape Hatteras, and are most abundant on Georges Bank and in coastal waters south to the mouth of Chesapeake Bay. They have been found at depths up to 500 m, but are most common at depths less than 111 m. In southern New England, juveniles and adults have been associated with microhabitat features including biogenic depressions and flat sand during the day (Auster *et al.* 1991, 1995). They are generally found on sandy or gravelly bottoms, but also occur on mud. They co-occur with winter skate, and are more active at night, although they appear to feed throughout the day and night. The most important prey are amphipods and decapod crustaceans, followed by polychaetes. Prey items of minor importance include bivalves, isopods, and fish. Similar to barndoor and clearnose skates, the use of fish as a food source increases with increasing size. Smaller skates eat more amphipods, and larger skate consume more decapod crustaceans (Packer *et al.* in press (c)).

A single fertilized egg is encapsulated in a leathery case which is deposited on sandy substrate. The cases have sticky filaments that adhere to bottom substrates. In one study, eggs deposited in the late spring and early summer required five to six months to hatch. Other studies have shown incubation to exceed one year. When the young hatch, they are considered juveniles and are fully developed, measuring from 93-102 mm in total length (Packer *et al.* in press (c)).

Vulnerability of juvenile EFH to mobile bottom gear was characterized as moderate because of the species dependence on benthic organisms in its diet. Vulnerability of adult EFH to mobile bottom gear was characterized as moderate due to its reproductive habits. Little skate is the only skate species in which EFH has been designated for eggs. Although bottom tending mobile gear may have adverse effects upon the eggs themselves, this was not considered to be a habitat impact. Since the bottom substrate appears to provide an attachment point for the eggs the EFH vulnerability to mobile gear was rated as low instead of none.

Definitions: GOME - Gulf of Maine; GB - Georges Bank; NE - New England; HAPC - Habitat Area of Particular Concern; YOY - Young-of-Year: OT - Otter Trawls; SD - New Bedford Scallop Dredge; CD - Hydraulic Clam Dredge; PT- Pots and Traps; NL - Gill Nets and Longlines. NA - not applicable; 0 - No vulnerability; L - Low vulnerability; M - moderate vulnerability; H - high vulnerability; EFH - essential fish habitat; * derived from matrix analysis – see appendix. **Note that the information presented in columns 2-5 is derived from the EFH descriptions and may not completely agree with information provided in the rationale.**

Table 6.40 Rosette Skate Pending EFH - Vulnerability to Effects of Bottom-Tending Fishing Gear

Life Stage	Geographic Area of EFH	Depth (m)	Seasonal Occurrence	EFH Description	EFH Vulnerability*				
					OT	**SD**	**CD**	**PT**	**NL**
Juveniles	Nantucket shoals and southern edge of GB to Cape Hatteras, NC	33-530 mostly 74-274		Bottom habitats with soft substrate, including sand/mud bottoms, mud with echinoid and ophiuroid fragments, and shell and pteropod ooze	M	M	M	L	L
Adults	Nantucket shoals and southern edge of GB to Cape Hatteras, NC	33-530 mostly 74-274		Bottom habitats with soft substrate, including sand/mud bottoms, mud with echinoid and ophiuroid fragments, and shell and pteropod ooze	M	M	M	L	L

Rationale: Rosette skate *(Leucoraja garmani virginica)* is a deeper water species that occurs along the outer shelf and continental slope from Nantucket Shoals to the Dry Tortugas, Florida. North of Cape Hatteras, it is most abundant in the southern section of the Chesapeake Bight. It occurs on soft bottoms, including sand and mud, at depths from 33-530 m, and is most common between 74 and 274 m. Juveniles tend to be found between 100 - 140 m. Major prey items include polychaetes, copepods, cumaceans, amphipods, *Crangon*, crabs, squid, octopods, and small fishes. A single fertilized egg is encapsulated in a leathery case. Egg cases are found in mature females most frequently in the summer (Packer *et al.* in press (d)).

Information on rosette skate is very limited. Because of the limited information available, the apparent dependence of the juveniles of this species on benthic organisms in its diet, and the reproductive habits of the adults, EFH vulnerability to mobile bottom gear was characterized as moderate.

Definitions: GOME - Gulf of Maine; GB - Georges Bank; NE - New England; HAPC - Habitat Area of Particular Concern; YOY - Young-of-Year: OT - Otter Trawls; SD - New Bedford Scallop Dredge; CD - Hydraulic Clam Dredge; PT- Pots and Traps; NL - Gill Nets and Longlines. NA - not applicable; 0 - No vulnerability; L - Low vulnerability; M - moderate vulnerability; H - high vulnerability; EFH - essential fish habitat; * derived from matrix analysis – see appendix. **Note that the information presented in columns 2-5 is derived from the EFH descriptions and may not completely agree with information provided in the rationale.**

Table 6.41 Smooth Skate Pending EFH - Vulnerability to Effects of Bottom-Tending Fishing Gear

Life Stage	Geographic Area of EFH	Depth (m)	Seasonal Occurrence	EFH Description	EFH Vulnerability*				
					OT	SD	CD	PT	NL
Juveniles	Offshore banks of GOME	31-874 mostly 110-457		Bottom habitats with a substrate of soft mud (silt and clay), sand, broken shells, gravel and pebbles	M	M	0	L	L
Adults	Offshore banks of GOME	31-874 mostly 110-457		Bottom habitats with a substrate of soft mud (silt and clay), sand, broken shells, gravel and pebbles	H	H	0	L	L

Rationale: Smooth skate *(Malacoraja senta)* center of abundance is the Gulf of Maine. It occurs along the Atlantic coast from the Gulf of St. Lawrence south to South Carolina, at depths between 31-874 m. It is most abundant between 110-457 m. Analysis of NEFSC trawl survey data found juvenile skate most abundant between depths of 100-300 m during the time period from 1963-69. Smooth skate are found mostly over soft mud and clay of the Gulf of Maine's deepwater basins, but also over the Gulf's off shore banks with substrates of sand, shell, and/or gravel (Packer *et al.* in press (e)).

The diet of smooth skate is generally limited to epifaunal crustaceans, with decapod shrimp and euphausids as the most common prey, followed by amphipods and mysids. The diet shifts from amphipods and mysids to decapods as smooth skate grow (Packer *et al.* in press (e)). The diet of smooth skate is more restricted than other skate species (McEachran 2002).

The vulnerability of juvenile smooth skate EFH to otter trawls and scallop dredges was characterized as moderate because of the dietary habits of this species. The vulnerability of adult EFH was rated as high for otter trawls and scallop dredges because of the benthic diet as well as the reproductive habits of the species. Vulnerability to clam dredges was considered to be none for juveniles and adults since this gear is not used in the Gulf of Maine.

Definitions: GOME - Gulf of Maine; GB - Georges Bank; NE - New England; HAPC - Habitat Area of Particular Concern; YOY - Young-of-Year: OT - Otter Trawls; SD - New Bedford Scallop Dredge; CD - Hydraulic Clam Dredge; PT- Pots and Traps; NL - Gill Nets and Longlines. NA - not applicable; 0 - No vulnerability; L - Low vulnerability; M - moderate vulnerability; H - high vulnerability; EFH - essential fish habitat; * derived from matrix analysis – see appendix. **Note that the information presented in columns 2-5 is derived from the EFH descriptions and may not completely agree with information provided in the rationale.**

Table 6.42 Thorny Skate Pending EFH - Vulnerability to Effects of Bottom-Tending Fishing Gear

Life Stage	Geographic Area of EFH	Depth (m)	Seasonal Occurrence	EFH Description	EFH Vulnerability*				
					OT	SD	CD	PT	NL
Juveniles	GOME and GB	18-2000 mostly 111-366		Bottom habitats with a substrate of sand gravel, broken shell, pebbles, and soft mud	M	M	0	L	L
Adults	GOME and GB	18-2000 mostly 111-366		Bottom habitats with a substrate of sand gravel, broken shell, pebbles, and soft mud	M	M	0	L	L

Rationale: Thorny skate *(Amblyraja radiata)* range from Greenland south to South Carolina. In the Northeast region, it is most commonly seen in the Gulf of Maine and on the Northeast Peak and northern Great South Channel of Georges Bank. It is one of the most common skates in the Gulf of Maine, and occurs over a wide variety of bottom substrates, from sand, gravel, and broken shell to mud. It is found at depths ranging from 18 - 1200 m, and is reported to be most common between 50-350 m. A single fertilized egg is encapsulated in an egg case. Females with fully formed egg cases have been captured year round, though the percentage of mature females with egg cases is higher in the summer (Packer *et al.* in press (f)).

The primary prey of thorny skates are polychaetes and decapods, followed by amphipods and euphausiids. Fish and mysids are also consumed in lesser quantities. According to a survey from Nova Scotia to Cape Hatteras, thorny skate prey varies with skate size. Skates less than 40 cm total length feed mostly on amphipods, skates greater than 40 cm fed on polychaetes and decapods, and fishes were a major dietary component for skates larger than 70 cm. In general, with increasing size, mysids decreased in the diet while fishes increased (Packer *et al.* in press (f)).

Since juvenile thorny skate appear to be more reliant on benthic invertebrates, vulnerability of EFH to otter trawls and scallop dredges for this life stage was characterized as moderate. For adults, EFH vulnerability to otter trawls and scallop dredges was characterized as moderate because of their reproductive habits. EFH vulnerability to clam dredges was rated as none for juveniles and adults since there is no overlap between thorny skate EFH and areas in which clam dredges are used.

Definitions: GOME - Gulf of Maine; GB - Georges Bank; NE - New England; HAPC - Habitat Area of Particular Concern; YOY - Young-of-Year: OT - Otter Trawls; SD - New Bedford Scallop Dredge; CD - Hydraulic Clam Dredge; PT- Pots and Traps; NL - Gill Nets and Longlines. NA - not applicable; 0 - No vulnerability; L - Low vulnerability; M - moderate vulnerability; H - high vulnerability; EFH - essential fish habitat; * derived from matrix analysis – see appendix. **Note that the information presented in columns 2-5 is derived from the EFH descriptions and may not completely agree with information provided in the rationale.**

Table 6.43 **Winter Skate Pending EFH - Vulnerability to Effects of Bottom-Tending Fishing Gear**

Life Stage	Geographic Area of EFH	Depth (m)	Seasonal Occurrence	EFH Description	EFH Vulnerability*				
					OT	SD	CD	PT	NL
Juveniles	Cape Cod Bay, GB, SNE shelf through MAB to North Carolina; includes the estuaries from Buzzards Bay south to the Chesapeake Bay mainstem	0-371 mostly <111		Bottom habitats with substrate of sand and gravel or mud	M	M	M	L	L
Adults	Cape Cod Bay, GB, SNE shelf through MAB to North Carolina; includes the estuaries from Buzzards Bay south to the Chesapeake Bay mainstem	0-371 mostly <111		Bottom habitats with substrate of sand and gravel or mud	M	M	M	L	L

Rationale: Winter skate *(Leucoraja ocellata)* are found from Newfoundland south to Cape Hatteras. They are most abundant on Georges Bank and in coastal waters south to the mouth of the Hudson River. They are found over substrates of sand, gravel, and mud, in depths from shore out to 371 m, and are most common in less than 111 m of water. A single fertilized egg is encapsulated in a leather case and deposited on the bottom during summer in the northern portion of the range. Deposition has been reported to extend through January off southern New England. Young are fully developed at hatching (Packer *et al.* 1999g).

Polychaetes and amphipods are the most important prey items, followed by decapods, isopods, bivalves, and fish. In general, crustaceans make up over 50% of the diet for skate smaller than 61 cm, and fish and bivalves are a major component of the diet for skates larger than 79 cm. Crustaceans declined in importance with increasing skate size while polychaetes increased, until skates reached 81 cm.

Since juvenile winter skate appear to be more reliant on benthic invertebrates, vulnerability of EFH to mobile gear for this life stage was characterized as moderate. For adults, EFH vulnerability to mobile gear was characterized as moderate because of their reproductive habits.

Definitions: GOME - Gulf of Maine; GB - Georges Bank; NE - New England; HAPC - Habitat Area of Particular Concern; YOY - Young-of-Year: OT - Otter Trawls; SD - New Bedford Scallop Dredge; CD - Hydraulic Clam Dredge; PT- Pots and Traps; NL - Gill Nets and Longlines. NA - not applicable; 0 - No vulnerability; L - Low vulnerability; M - moderate vulnerability; H - high vulnerability; EFH - essential fish habitat; * derived from matrix analysis – see appendix. **Note that the information presented in columns 2-5 is derived from the EFH descriptions and may not completely agree with information provided in the rationale.**

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Table 1.1. Percentage of Landings for Federally Managed Species by Fishing Gear Type Used in Northeast Region in 1999

	NORTHEAST SPECIES																														
GEAR	DOGFISH	BLUEFISH	BUTTERFISH	SURFCLAM	OCEAN QUAHOG	COD, ATLANTIC	RED CRAB	SUMMER FLNDR	WINDOWPANE FLNDR	WINTER FLNDR	WITCH FLNDR	YELLOWTAIL FLNDR	MONKFISH	HADDOCK	HAKE, RED	HAKE, SILVER	HAKE, WHITE	HALIBUT, ATLANTIC	HERRING, ATLANTIC	MACKEREL, ATLANT	PLAICE, AMERICAN	POLLOCK	OCEAN POUT	REDFISH	SCALLOP, SEA	SCUP	BLACK SEA BASS	SKATES	SQUID, LOLIGO	SQUID, ILLEX	TILEFISH
Bag Nets			-																											-	
Beam Trawls, Other		-	-		-					-	-	-	-		-	-									-	-			-		
Cast Nets		-						-																		-					
Combined Gears		-																									-				-
Diving Outfits, Other																									-	-					
Dredge Clam				92	10			-		-			-												-	-					
Dredge Conch								-																				-			
Dredge Scallop, Bay										-	-		-												-						
Dredge Scallop, Sea		-	-			-		2	-	-	-	1	16			-	-				-	-			90	-	-	-	-	-	-
Floating Traps (Shallow)		1	-			-		-		-			-			-			-	2		-				9	-	-	-		
Fyke And Hoop Nets, Fish		-	-					-	-	-	-	-	-															-			
Gill Nets, Drift, Other	-	9	-					-		-		-	-		-	-			-	-			-			-	-	-	-		
Gill Nets, Drift, Runaround		5	-																												
Gill Nets, Other		5	-					-					-							-							-	-			
Gill Nets, Sink/Anchor,	60	16	-			20		-	-	4	2	6	29	7	-	-	35	8	-	1	2	55	3	16	-	-	-	12	-	-	-
Gill Nets, Stake	-	-	-					-					-						-	-											
Haul Seines, Beach	-	1	-					-		-					-	-			-	-								-			
Haul Seines, Long		-	-																												
Haul Seines, Long(Danish)						-				-	-	-	-	-		-	-				-	-		-				-			
Lines Hand, Other	-	5	-			5		2	-	-	-	-	-	-	-	-	-		-	-	-	-	4	-		12	14	-	-		2
Lines Long Set With Hooks	-	-	-			17		-		-	-	-	-	2	-	-	5	-		-	-	2	7	-	-	-	-	-	-		61
Lines Long, Reef Fish																															32
Lines Troll, Other		-	-					-																			-				-
Lines Troll With Baits								-																							
Otter Trawl Bottom, Fish	38	20	93			57		92	98	95	97	92	53	91	98	99	58	89	2	93	97	42	77	83	-	66	25	86	99	10	4
Otter Trawl Bottom, Scallop		-				-		-		-	-	-	-	-							-	-			9		-	-	-		
Otter Trawl Midwater																			53	-											
Pots And Traps, Conch		-	-			-																	-				-				
Pots And Traps, Crab, Blue		-	-					-																			-				
Pots and Traps, Crab, Blue		-																													
Pots And Traps, Crab, Other		-					60	-																							
Pots And Traps, Fish		-	-			-		-		-			-		-	-	-		-	-		-	7	-		5	53	-	-		-
Pots And Traps, Lobster		-	-			-		-		-			-	-	-	-	-			-		-	-	-	-	-	-	-	-		
Pots And Traps, Lobster		-	-			-	40	-		-			-		-		-						-	-		-	-		-		-
Pots And Traps, Other		-						-																		-	3				
Pound Nets, Crab		-						-																							
Pound Nets, Fish		5	3			-		2	-	-		-	-		-	-			-	-						-	-	-	-		
Pound Nets, Other		-	-					-		-										2						2	-		-		
Purse Seines, Herring																			31												
Purse Seines, Other		3																													
Reel, Electric or Hydraulic																											-				
Rod and Reel																											-				
Scottish Seine		-	-			-		-	-	-	-	-	-	-	-	-	-			-	-	-	-			-	-	-	-		
Scrapes								-																							
Spears		-																									-				
Stop Seines																			-												
Trawl Midwater, Paired																			14												
Weirs																			-												

"-" Indicates there was less than 1% landings associated with this gear type for this species
"Blank" Indicates there were no landings recorded for this gear type for this species

Table 1.2. Principal Fishing Gears Used in Each State in the Northeast Region in 1999

	Percent of Landings (1% or more) for All Species by State											
Gear	**CT**	**DE**	**MA**	**MD**	**ME**	**NC**	**NH**	**NJ**	**NY**	**RI**	**VA**	**% Landings All States Combined**
By Hand, Other		18										
Diving Outfits, Other					5							1
Dredge Clam			9	10				39	1	1		6
Dredge Crab		11									1	
Dredge Mussel					1							
Dredge Other					3							
Dredge Scallop, Sea	7		10		1		1	2			1	2
Dredge Urchin, Sea					1							
Floating Traps (Shallow)										1		
Fyke And Hoop Nets, Fish				2								
Gill Nets, Drift, Other		4		3				2				1
Gill Nets, Drift, Runaround						1						
Gill Nets, Other						14						1
Gill Nets, Sink/Anchor,			12	5	1		42	5	5	4	3	4
Gill Nets, Stake		7										
Haul Seines, Beach				2							1	
Haul Seines, Long						1						
Hoes					1							
Lines Hand, Other		1	2	1		1	1		1			1
Lines Long Set With Hooks			4			1		1	4			1
Lines Long, Shark						1						
Lines Troll, Other						1						
Lines Trot With Baits				17								1
Not Coded	16				1			1	30			2
Otter Trawl Bottom, Shrimp					1	6	3					1
Otter Trawl Midwater			11		21		8			18		6
Pots And Traps, Conch		2										
Pots And Traps, Crab, Blue		51		36		36		3			6	8
Pots And Traps, Crab, Other			2							1		
Pots And Traps, Eel		2		1								
Pots And Traps, Fish		1		3								
Pots And Traps, Lobster Inshore	13		5		25		9			4		5
Pots And Traps, Lobster Offshore	2		4				9	1		2		1
Pots And Traps, Other			1		1							
Pound Nets, Crab				1								
Otter Trawl Bottom, Crab						1						
Otter Trawl Bottom, Fish	61		38	3	9	7	26	26	58	56	2	18
Pound Nets, Fish				14		1			1		4	2
Purse Seines, Herring			1		23							4
Purse Seines, Menhaden						27		18			74	28
Purse Seines, Other											7	2

Table 1.3. Fishing Gears Used in Estuaries and Bays, Coastal Waters, and Offshore Waters of the EEZ, from Maine to North Carolina.

GEAR	Estuary or Bay	Coastal 0-3 Miles	Offshore 3-200 Miles	Contacts Bottom	Federally Regulated
Bag Nets	X	X	X		X
Beam Trawls	X	X	X	X	X
By Hand	X	X			X
Cast Nets	X	X	X		
Clam Kicking	X			X	
Diving Outfits	X	X	X		
Dredge Clam	X	X	X	X	X
Dredge Conch	X			X	
Dredge Crab	X	X		X	
Dredge Mussel	X	X		X	
Dredge Oyster, Common	X			X	
Dredge Scallop, Bay	X			X	
Dredge Scallop, Sea		X	X	X	X
Dredge Urchin, Sea		X	X	X	
Floating Traps (Shallow)	X	X		X	X
Fyke And Hoop Nets, Fish	X	X		X	
Gill Nets, Drift, Other			X		X
Gill Nets, Drift, Runaround			X		X
Gill Nets, Sink/Anchor, Other	X	X	X	X	X
Gill Nets, Stake	X	X	X	X	X
Haul Seines, Beach	X	X		X	
Haul Seines, Long	X	X		X	
Haul Seines, Long(Danish)		X	X	X	X
Hoes	X			X	
Lines Hand, Other	X	X	X		X
Lines Long Set With Hooks		X	X	X	X
Lines Long, Reef Fish		X	X	X	X
Lines Long, Shark		X	X		X
Lines Troll, Other		X	X		X
Lines Trot With Baits		X	X		X
Otter Trawl Bottom, Crab	X	X	X	X	
Otter Trawl Bottom, Fish	X	X	X	X	X
Otter Trawl Bottom, Scallop		X	X	X	X
Otter Trawl Bottom, Shrimp	X	X	X	X	X
Otter Trawl Midwater		X	X		X
Pots And Traps, Conch	X	X		X	
Pots and Traps, Crab, Blue Peeler	X	X		X	
Pots And Traps, Crab, Blue	X	X		X	
Pots And Traps, Crab, Other	X	X	X	X	X
Pots And Traps, Eel	X	X		X	
Pots and Traps, Lobster Inshore	X	X		X	
Pots and Traps, Lobster Offshore			X	X	X
Pots and Traps, Fish	X	X	X	X	X
Pound Nets, Crab	X	X		X	
Pound Nets, Fish	X	X		X	
Purse Seines, Herring		X	X		X
Purse Seines, Menhaden		X	X		
Purse Seines, Tuna		X	X		X
Rakes	X			X	
Reel, Electric or Hydraulic		X	X		X
Rod and Reel	X	X	X		X
Scottish Seine		X	X	X	X
Scrapes	X			X	
Spears	X	X	X		
Stop Seines	X			X	
Tongs and Grabs, Oyster	X			X	
Tongs Patent, Clam Other	X			X	
Tongs Patent, Oyster	X			X	
Trawl Midwater, Paired		X	X		X
Weirs	X			X	

Includes all gears that accounted for 1% or more of any state's total landings and all gears that harvested any amount of any federally managed species, based upon 1999 NMFS landings data and ASMFC Gear Report (ASMFC 2000). Shaded rows represent gears that are federally managed and contact the bottom.

Table 2.1. Gulf of Maine Benthic Assemblages as Identified by Watling (1998).

Benthic Assemblage	Benthic Community Description
1	Comprises all sandy offshore banks, most prominently Jeffreys Ledge, Fippennies Ledge, and Platts Bank; depth on top of banks about 70 m; substrate usually coarse sand with some gravel; fauna characteristically sand dwellers with an abundant interstitial component.
2	Comprises the rocky offshore ledges, such as Cashes Ledge, Sigsbee Ridge and Three Dory Ridge; substrate either rock ridge outcrop or very large boulders, often with a covering of very fine sediment; fauna predominantly sponges, tunicates, bryozoans, hydroids, and other hard bottom dwellers; overlying water usually cold Gulf of Maine Intermediate Water.
3	Probably extends all along the coast of the Gulf of Maine in water depths less than 60 m; bottom waters warm in summer and cold in winter; fauna rich and diverse, primarily polychaetes and crustaceans; probably consists of several (sub-) assemblages due to heterogeneity of substrate and water conditions near shore and at mouths of bays.
4	Extends over the soft bottom at depths of 60 to 140 m, well within the cold Gulf of Maine Intermediate Water; bottom sediments primarily fine muds; fauna dominated by polychaetes, shrimp, and cerianthid anemones.
5	A mixed assemblage comprising elements from the cold water fauna as well as a few deeper water species with broader temperature tolerances; overlying water often a mixture of Intermediate Water and Bottom Water, but generally colder than 7° C most of the year; fauna sparse, diversity low, dominated by a few polychaetes, with brittle stars, sea pens, shrimp, and cerianthid also present.
6	Comprises the fauna of the deep basins; bottom sediments generally very fine muds, but may have a gravel component in the offshore morainal regions; overlying water usually 7 to 8° C, with little variation; fauna shows some bathyal affinities but densities are not high, dominated by brittle stars and sea pens, and sporadically by a tube-making amphipod.
7	The true upper slope fauna that extends into the Northeast Channel; water temperatures are always above 8° and salinities are at least 35 ppt; sediments may be either fine muds or a mixture of mud and gravel.

Geographical distribution of assemblages is shown in Figure 5.

Table 2.2. Comparison of Demersal Fish Assemblages of Georges Bank and Gulf of Maine Identified by Overholtz and Tyler (1985) and Gabriel (1992).

Overholtz & Tyler (1984)		**Gabriel (1992)**	
Assemblage	**Species**	**Species**	**Assemblage**
Slope & Canyon	offshore hake blackbelly rosefish Gulf stream flounder fourspot flounder monkfish, whiting white hake, red hake	offshore hake blackbelly rosefish Gulf stream flounder fawn cusk-eel, longfin hake, armored sea robin	**Deepwater**
Intermediate	whiting red hake monkfish Atlantic cod, haddock, ocean pout, yellowtail flounder, winter skate, little skate, sea raven, longhorn sculpin	whiting red hake monkfish short-finned squid, spiny dogfish, cusk	**Combination of Deepwater Gulf of Maine/Georges Bank & Gulf of Maine-Georges Bank Transition**
Shallow	Atlantic cod haddock pollock whiting white hake red hake monkfish ocean pout	Atlantic cod haddock pollock	**Gulf of Maine-Georges Bank Transition Zone** *(see below also)*
	yellowtail flounder windowpane winter flounder winter skate little skate longhorn sculpin summer flounder sea raven, sand lance	yellowtail flounder windowpane winter flounder winter skate little skate longhorn sculpin	**Shallow Water Georges Bank-Southern New England**
Gulf of Maine-Deep	white hake American plaice witch flounder thorny skate whiting, Atlantic cod, haddock, cusk Atlantic wolffish	white hake American plaice witch flounder thorny skate, redfish	**Deepwater Gulf of Maine-Georges Bank**
Northeast Peak	Atlantic cod haddock pollock ocean pout, winter flounder, white hake, thorny skate, longhorn sculpin	Atlantic cod haddock pollock	**Gulf of Maine-Georges Bank Transition Zone** *(see above also)*

Table 2.3. Ten Dominant Species and Mean Abundance/Tow from Each Cluster Species Group and Its Associated Substrate Type As Determined By Reflectance Value, from Stellwagen Bank, Gulf of Maine (Auster *et al.* in press).

SUBSTRATE TYPE									
Coarse		**Coarse**		**Wide Range**		**Fine**		**Fine**	
Species	**Mean**	**Species**	**Mean**	**Species**	**Mean**	**Species**	**Mean**	**Species**	**Mean**
Northern Sand Lance	1172.0	Haddock	13.1	American plaice	63.3	American plaice	152.0	Whiting	275.0
Atlantic herring	72.2	Atlantic cod	7.3	Northern sand lance	53.0	Acadian redfish	31.3	American plaice	97.1
Spiny dogfish	38.4	American plaice	5.3	Atlantic herring	28.5	Whiting	29.5	Atlantic mackerel	42.0
Atlantic cod	37.4	Whiting	3.3	Whiting	22.4	Atlantic herring	28.0	Pollock	41.1
Longhorn sculpin	29.7	Longhorn sculpin	2.0	Acadian redfish	16.0	Red hake	26.1	Alewife	37.2
American plaice	28.0	Yellowtail flounder	1.9	Atlantic cod	14.0	Witch flounder	23.8	Atlantic herring	32.0
Haddock	25.7	Spiny dogfish	1.6	Longhorn sculpin	9.5	Atlantic cod	13.1	Atlantic cod	18.1
Yellowtail flounder	20.2	Acadian redfish	1.6	Haddock	9.1	Haddock	12.7	Longhorn sculpin	16.8
Whiting	7.5	Ocean pout	1.3	Pollock	7.9	Longhorn sculpin	12.5	Red hake	15.2
Ocean pout	9.0	Alewife	1.1	Red hake	6.2	Daubed shanney	11.4	Haddock	13.2
No. tows = 83		**No. tows = 60**		**No. tows = 159**		**No. tows = 66**		**No. tows = 20**	

Table 2.4. Sedimentary Provinces of Georges Bank, As Defined by Valentine *et al.* (1993) and Valentine and Lough (1991) With Additional Comments by Valentine (personal communication) and Benthic Assemblages Assigned from Theroux and Grosslein (1987). (See text for further discussion on benthic assemblages).

Sedimentary Province	Depth (m)	Description	Benthic Assemblage
Northern Edge / Northeast Peak (1)	40-200	Dominated by gravel with portions of sand, common boulder areas, and tightly packed pebbles. Representative epifauna (bryozoa, hydrozoa, anemones,and calcareous worm tubes) are abundant in areas of boulders. Strong tidal and storm currents.	**Northeast Peak**
Northern Slope & Northeast Channel (2)	200-240	Variable sediment type (gravel, gravel-sand, and sand) scattered bedforms. This is a transition zone between the northern edge and southern slope. Strong tidal and storm currents.	**Northeast Peak**
North /Central Shelf (3)	60-120	Highly variable sediment type (ranging from gravel to sand) with rippled sand, large bedforms, and patchy gravel lag deposits. Minimal epifauna on gravel due to sand movement. Representative epifauna in sand areas include amphipods, sand dollars, and burrowing anemones.	**Central Georges**
Central & Southwestern Shelf - shoal ridges (4)	10-80	Dominated by sand (fine and medium grain) with large sand ridges, dunes, waves, and ripples. Small bedforms in southern part. Minimal epifauna on gravel due to sand movement. Representative epifauna in sand areas include amphipods, sand dollars, and burrowing anemones.	**Central Georges**
Central & Southwestern Shelf - shoal troughs (5)	40-60	Gravel (including gravel lag) and gravel-sand between large sand ridges. Patch large bedforms. Strong currents. (Few samples – submersible observation noted presence of gravel lag, rippled gravel-sand, and large bedforms.) Minimal epifauna on gravel due to sand movement. Representative epifauna in sand areas include amphipods, sand dollars, and burrowing anemones.	**Central Georges**
Southeastern Shelf (6)	80-200	Rippled gravel-sand (medium and fine-grained sand) with patchy large bedforms and gravel lag. Weaker currents; ripples are formed by intermittent storm currents. Representative epifauna include sponges attached to shell fragments and amphipods.	**Southern Georges**
Southeastern Slope (7)	400-2000	Dominated by silt and clay with portions of sand (medium and fine) with rippled sand on shallow slope and smooth silt-sand deeper.	**none**

Table 2.5. Mid-Atlantic Habitat Types as Described by Pratt (1973) and Boesch (1979) with Characteristic Macrofauna as Identified in Boesch 1979.

Habitat Type (after Boesch 1979)	**Description**		
	Depth (m)	Characterization (Pratt faunal zone)	Characteristic Benthic Macrofauna
Inner shelf	0-30	characterized by coarse sands with finer sands off MD and VA (sand zone)	Polychaetes: *Polygordius, Goniadella, Spiophanes*
Central shelf	30-50	(sand zone)	Polychaetes: *Spiophanes, Goniadella* Amphipod: *Pseudunciola*
Central and inner shelf swales	0-50	occurs in swales between sand ridges (sand zone)	*Polychaetes:* Spiophanes, Lumbrineris, Polygordius
Outer shelf	50-100	(silty sand zone)	Amphipods: *Ampelisca vadorum, Erichthonius* Polychaetes: *Spiophanes*
Outer shelf swales	50-100	occurs in swales between sand ridges (silty sand zone)	Amphipods: *Ampelisca agassizi, Unciola, Erichthonius*
Shelf break	100-200	(silt-clay zone)	not given
Continental slope	>200	(none)	not given

Table 2.6. Major Recurrent Demersal Finfish Assemblages of the Mid-Atlantic Bight During Spring and Fall as Determined by Colvocoresses and Musik (1983).

Season	**Species Assemblage**				
	Boreal	**Warm temperate**	**Inner shelf**	**Outer shelf**	**Slope**
Spring	Atlantic cod little skate sea raven monkfish winter flounder longhorn sculpin ocean pout whiting red hake white hake spiny dogfish	black sea bass summer flounder butterfish scup spotted hake northern searobin	windowpane	fourspot flounder	shortnose greeneye offshore hake blackbelly rosefish white hake
Fall	white hake whiting red hake monkfish longhorn sculpin winter flounder yellowtail flounder witch flounder little skate spiny dogfish	black sea bass summer flounder butterfish scup spotted hake northern searobin smooth dogfish	windowpane	fourspot flounder fawn cusk eel gulf stream flounder	shortnose greeneye offshore hake blackbelly rosefish white hake witch flounder

Table 2.7. Mid-Atlantic Reef Types, Location, and Representative Flora and Fauna, as Described in Steimle and Zetlin (2000).

Location (Type)	**Representative Flora & Fauna**		
	Epibenthic/Epibiotic	**Motile Epibenthic Invertebrates**	**Fish**
Estuarine (Oyster reefs, blue mussel beds,other hard surfaces, semi-hard clay and Spartina peat reefs)	Oyster, barnacles, ribbed mussel, blue mussel, algae, sponges, tube worms, anemones, hydroids, bryozoans, slipper shell, jingle shell, northern stone coral, sea whips, tunicates, caprellid amphipods, wood borers	Xanthid crabs, blue crab, rock crabs, spider crab, juvenile American lobsters, sea stars	Gobies, spot, striped bass, black sea bass, white perch, toadfish, scup, drum, croaker, spot, sheepshead porgy, pinfish, juvenile and adult tautog, pinfish, northern puffer, cunner, sculpins, juvenile and adult Atlantic cod, rock gunnel, conger eel, American eel, red hake, ocean pout, white hake, juvenile pollock
Coastal (exposed rock/soft marl, harder rock, wrecks & artificial reefs, kelp, other materials)	Boring mollusks (piddocks), red algae, sponges, anemones, hydroids, northern stone coral, soft coral, sea whips, barnacles, blue mussel, horse mussel, bryozoans, skeleton and tubiculous amphipods, polychaetes, jingle shell, sea stars	American lobster, Jonah crab, rock crabs, spider crab, sea stars, urchins, squid egg clusters	Black sea bass, pinfish, scup, cunner, red hake, gray triggerfish, black brouper, smooth dogfish, sumemr flounder, scad, bluefish amberjack, Atlantic cod, tautog, ocean pout, conger eel, sea raven, rock gunnel, radiated shanny
Shelf (rocks & boulders, wrecks & artificial reefs, other solid substrates)	Boring mollusks (piddocks) red algae, sponges, anemones, hydroids, stone coral, soft coral, sea whips, barnacles, blue mussels, horse mussels, bryozoans, amphipods, polychaetes	American lobster, Jonah crabs, rock crabs, spider crabs, sea stars, urchins, squid egg clusters (with addition of some deepwater taxa at shelf edge)	Black sea bass, scup, tautog, cunner, gag, sheepshead porgy, round herring, sardines, amberjack, spadefish, gray triggerfish, mackerels, small tunas, spottail pinfish, tautog, Atlantic cod, ocean pout, red hake, conger eel, cunner, sea raven, rock gunnel, pollock, white hake
Outer shelf (reefs and clay burrows including “pueblo village community”)			Tilefish, white hake, conger eel

Table 2.8. Faunal Zones of the Continental Slope of Georges Bank and Southern New England (from Hecker 1990).

Zone	Approximate Depth (m)	Gradient	Current	Fauna
Upper Slope	300-700	Low	strong	Dense filter feeders; Scleratinians (*Dasmosmilia lymani*, *Flabellum alabastrum*), quill worm (*Hyalinoecia*)
Upper Middle Slope	500-1300	High	moderate	Sparse scavengers; red crab (*Geryon quinqueidens*), long-nosed eel (*Synaphobranchus*), common grenadier (*Nezumia*). Alcyonarians (*Acanella arbuscula*, *Eunephthya florida*) in areas of hard substrate
Lower Middle Slope/Transition	1200-1700	High	moderate	Sparse suspension feeders; cerianthids, sea pen (*Distichoptilum gracile*)
Lower Slope	>1600	Low	strong	Dense suspension & deposit feeders; ophiurid (*Ophiomusium lymani*), cerianthid, sea pen

Table 2.9. Habitat Types for the Canyons of Georges Bank Described by Geologic Attributes and Characteristic Fauna (from Cooper *et al.* 1987).

Habitat Type	Geologic Description	Canyon Locations	Most Commonly Observed Fauna
I	Sand or semiconsolidated silt substrate (claylike consistency) with less than 5% overlay of gravel. Relatively featureless except for conical sediment mounds.	Walls & axis	Cerianthid, pandalid shrimp, white colonial anemone, Jonah crab, starfishes, portunid crab, greeneye, brittle stars, mosaic worm, red hake, four spot flounder, shell-less hermit crab, silver hake, gulf stream flounder
II	Sand or semiconsolidated silt substrate (claylike consistency) with more than 5% overlay of gravel. Relatively featureless.	Walls	Cerianthid, galatheid crab, squirrel hake, white colonial anemone, Jonah crab, silver hake, starfishes, ocean pout, brittle stars, shell-less hermit crab, greeneye
III	Sand or semiconsolidated silt (claylike consistency) overlain by siltstone outcrops and talus up to boulder size. Featured bottom with erosion by animals and scouring.	Walls	White colonial anemone, pandalid shrimp, cleaner shrimp, rock anemone, white hake, starfishes, ocean pout, conger eel, brittle star, Jonah crab, lobster, black-bellied rose fish, galatheid crab, mosaic worm, tilefish
IV	Consolidated silt substrate, heavily burrowed/excavated. Slope generally more than 5º and less than 50º Termed “pueblo village” habitat.	Walls	Starfishes, black-bellied rosefish, Jonah crab, lobster, white hake, cusk, ocean pout, cleaner shrimp, conger eel, tilefish, galatheid crab, shell-less hermit crab
V	Sand dune substrate.	Axis	Starfishes, white hake, Jonah crab, and monkfish

Faunal characterization is for depths < 230 m only

Table 5.1. Number of Studies Included In This Review, By Gear and Substrate Type

GEAR	**SUBSTRATE**	**1990-2002**			**Pre-1990**			**TOTAL**
		PR	**NPR**	**Total**	**PR**	**NPR**	**Total**	
Otter Trawls	Mud	9	2	11	0	0	0	11
	Sand	10	2	12	1	0	1	13
	Gravel/Rock	2	0	2	1	0	1	3
	Mixed	1	1	2	0	1	1	3
	All	22	5	27	2	1	3	30
NB Scallop Dredges	Sand	3	0	3	0	0	0	3
	Mixed	1	0	1	2	0	2	3
	All	4	0	4	2	0	2	6
Toothed Scallop Dredges	Sand	6	0	6	0	1	1	7
	Biogenic	1	0	1	0	0	0	1
	Mixed	6	1	7	1	0	1	8
	All	13	1	14	1	1	2	16
Hydraulic Clam Dredges	Mud	1	0	1	0	0	0	1
	Sand	4	1	5	2	1	3	8
	Biogenic	0	1	1	0	1	1	2
	Mixed	0	0	0	0	1	1	1
	All	5	2	7	2	3	5	12
Other Dredge	Biogenic	2	1	3	1	0	1	4
Multiple Gears	Sand	2	1	3	0	0	0	3
	Gravel/Rock	2	0	2	0	0	0	2
	Mixed	2	1	3	3	0	3	6
	All	7	1	8	3	0	3	11
Lobster Pots	Mixed	1	0	1	0	0	0	1
TOTAL	**All**	**53**	**11**	**64**	**11**	**5**	**16**	**80**

PR = peer-reviewed
NPR = non-peer-reviewed

Table 5.2. Number of Studies Included In This Review, By Substrate Type

SUBSTRATE	1990-2002			Pre-1990			TOTAL
	PR	NPR	Total	PR	NPR	Total	
Mud	10	2	12	0	0	0	12
Sand	25	4	29	3	2	5	34
Gravel/Rock	4	0	4	1	0	1	5
Biogenic	3	2	5	1	1	2	7
Mixed Substrate	11	3	14	6	2	8	22
TOTAL	53	11	64	11	7	18	80

Table 5.3. Number of Studies Included in This Review, By Geographical Area

GEAR	Northeast U.S.	Other North America	Europe and Scandinavia	Australia and New Zealand	Total
Otter Trawls	7	10	8	5	30
NB Scallop Dredge	4	2	0	0	6
Toothed Scallop Dredge	0	2	8	6	16
Hydraulic Clam Dredge	2	5	5	0	12
Other Dredge	3	0	1	0	4
Multiple Gears	5	0	5	1	11
Lobster Pots	0	0	1	0	1
TOTAL	21	19	28	12	80

Table 5.4. Effects of Otter Trawls on Mud Substrate Habitat: Summary of Published Studies

No.	Reference	Location	Depth	Sediment	Effects	Recovery	Approach
1	Ball *et al.* 2000	Irish Sea	75 m	Sandy silt	Reduced infaunal and epifaunal richness, diversity, number of species and individuals in fishing ground compared to wreck site.		Experimental trawling in heavily fished prawn fishing ground, unfished area near a shipwreck used as control.
2	**Brylinsky *et al*. 1994**	Bay of Fundy, , Nova Scotia, Canada	Inter-tidal	Silt and coarse sand overlain with silty layer	Door tracks in sediment, rollers compressed sediment; S decrease in nematodes and benthic diatoms in door tracks, no effects on larger infaunal organisms (mostly polychaetes).	Furrows visible 2-7 months; nematodes recovered in 1-1.5 mos, diatoms in about 1-3 mos.	Four trawling experiments (repeated tows during a single day) at two locations in a trawled area, effects evaluated for 1.5-4 mos.
3	DeAlteris *et al*. 1999	Narragansett Bay, Rhode Island, USA	14 m	Mud	Doors produced tracks 5-10 cm deep and adjacent berm 10-20 cm high.	No changes in hand dug trenches for > 60 days.	Diver observations
4	**Drabsch *et al.* 2001**	Gulf of St. Vincent, South Australia	20 m	Fine silt	Trawl door tracks, smoothing of topographic features, S decrease in total infaunal abundance and one group of polychaetes, damaged epifauna.		Experimental trawling (2 tows per unit area in 1 day) in area with no trawling for 15 years (1 site), effects evaluated after 1 week.
5	**Frid *et al.* 1999**	NE England (North Sea)	80 m	Silt/clay	S increase in total number of individuals in taxa predicted to increase at high fishing effort and number of errant polychaetes, no effect of increasing effort on total number of individuals expected to decrease, but S decline in sea urchins.		Related changes in benthic fauna in a heavily trawled location to low, high, and moderate fishing activity and changes in phytoplankton production over 27 yrs.
6	**Hansson *et al.* 2000**	Fjord on the west coast of Sweden	75-90 m	Clay	61% infaunal species negatively affected and S reductions in brittlestars during last 6 mos of disturbance period, S reductions in total biomass and number of individuals in trawled and control sites, abundance of polychaetes, amphipods and molluscs not affected.		Experimental trawling for 1 year (2 tows per wk, 24 tows per unit area) in area closed to fishing for 6 yrs (3 treatment and 3 control sites), effects evaluated during last 5 mos of experiment.
7	**Mayer *et al.* 1991**	Maine coast, USA	20 m	Mud	Dispersal of fine surface sediment, doors made furrows several cm deep, some planing of surface features, but no plowing of bottom or burial of surface sediments.		Experimental trawling (single tow), examined immediate effects on sediment composition and food value to sediment depth of 18 cm.
8	**Pilskaln *et al*. 1998**	Gulf of Maine (USA)	250 m	Mud	Greater abundance of suspended infaunal polychaetes in more heavily-trawled area.		Deployed sediment traps in fishing grounds 25-35 m above substrate.
9	**Sanchez *et al.* 2000**	Coast of Spain, Mediterranean Sea	30-40 m	Mud	Door tracks in sediment, no change in number of infaunal individuals or taxa or abundance of individual taxa, no changes in community structure.	Door tracks still clearly visible after 150 hrs.	Experimental trawling in trawled area at 2 sites swept once and twice in a single day, effects evaluated after 24, 72, 102, and 150 hrs.
10	**Sparks-McConkey & Watling 2001**	Penobscot Bay, Maine (USA)	60 m	Mud	S decline in porosity, increased food value, and increased chlorophyll production of surface sediments, S reductions in number of infaunal individuals and species, species diversity, and abundances of 6 polychaete and bivalve species, S increase in nemerteans.	All geochemical sediment properties and all but one polychaete/bivalve species recovered within 3.5 mos, nemerteans still more abundant after 5 mos.	Experimental trawling (4 tows in 1 day) in untrawled area, pre-trawl sampling of sediments and infauna for a year, recovery monitored for 5 mos.

11	**Tuck *et al.* 1998**	West coast of Scotland	30-35 m	Fine silt	Tracks in sediment, increased bottom roughness, no effect on sediment characteristics; S increase in number of infaunal species after 16 mos and during 18 mo recovery period, no change in biomass or number of individuals; S increase in polychaetes, decrease in bivalves; S alteration in community structure after 5 mos, S reduction in diversity during first 22 mos.	Door tracks still evident after 18 months, bottom roughness recovered after 6 mos; nearly complete recovery of infaunal community within 12 mos, complete after 18 mos	Experimental trawling for 1 day/mo (1.5 tows per unit area) for 16 mos in area closed to fishing for >25 years, recovery monitored after 6, 12, and 18 mos

Citations in bold print are peer-reviewed publications.

Table 5.5. Effects of Otter Trawls on Sand Substrate Habitat: Summary of Published Studies

No.	Reference	Location	Depth	Sediment	Effects	Recovery	Approach
1	Ball *et al.* 2000	Irish Sea	35 m	Muddy sand	Lower number of infaunal and epifaunal species and individuals, species diversity and richness compared to wreck site.		Experimental trawling in heavily fished prawn fishing ground, unfished area near a shipwreck used as control.
2	Bergman and Santbrink 2000	Southern North Sea (Dutch coast)	<30-50 m	Silty sand and sand	High (20-50%) mortalities for 6 sedentary and/or immobile megafaunal (>1 cm) species, <20% for 10 others, from a single pass of the trawl, S effects on 11 of 54 occasions.		Experimental trawling (1.5 tows per unit area) in commercially trawled area, effects assessed after 24-48 hrs.
3	**DeAlteris *et al.* 1999**	Narragansett Bay, Rhode Island (USA)	7 m	Sand	No tracks.	Hand dug trenches not visible after 1-4 days.	Diver observations.
4	**Drabsch *et al.* 2001**	Gulf of St. Vincent, South Australia	20 m	Coarse sand with shells.	Trawl door tracks, smoothing of topographic features, removal of and damage to epifauna, no S effects on total infaunal abundance, S reduction in density for one family of polychaetes after 1 week.		Experimental trawling (2 tows per unit area) in area with no trawling for 15 years, effects assessed after 1 week (site 1) and 3 mos (site 2).
5	**Frid *et al.* 1999**	NE England (North Sea)	55 m	Sand	Total abundance of benthic macrofauna increased as phytoplankton abundance increased, no correlation with fishing effort.		Related changes in benthic fauna in a lightly trawled location to low, high, and moderate fishing activity and changes in phytoplankton production over 27 yrs.
6	**Gibbs *et al.* 1980**	Botany Bay, New South Wales, Australia	Shallow estuary	Sand with 0-30% silt/clay	Sediment plume, no consistent effects on benthic community diversity, very little disturbance of seafloor.		Sampling before, immediately after, and 6 mos after 1 week of experimental trawling in fished location, control area located 200 km away.
7	**Gilkinson *et al.* 1998**	Test tank to simulate Grand Banks of Newfoundland		Sand	Trawl door created 5.5 cm berm adjacent to 2 cm furrow, bivalves displaced.		Observed effects of commercial otter door model in test tank.
8	**Hall *et al.* 1993**	North Sea	80 m	Coarse sand	Abundance of infauna related to changes in sediment type and organic content, not distance from shipwreck.		Sampled infauna at increasing distance from a shipwreck (proxy for increasing fishing effort).
9	**Kenchington *et al.* 2001**	Grand Banks, Newfoundland	120-146 m	Fine to medium grain sand	S short-term reductions in total abundance and abundance of 15 infaunal taxa (mostly polychaetes) in only 1 of 3 years , no short-term effects on biomass or taxonomic diversity, no long-term effects.	Infaunal organisms that were reduced in abundance in 1994 had recovered a year later.	Experimental trawling (3-6 tows per unit area) in closed area 1, 2 and 3 years after closure, lightly exploited for >10 yrs, effects evaluated within several hrs or days after trawling and after one year.
10	**McConnaughey *et al.* 2000**	Eastern Bering Sea, Alaska	44-52 m	Sand with ripples	Reduced abundance (S for sponges and anemones), more patchy distribution, and S decrease in species diversity of sedentary epifauna, mixed responses of motile taxa and bivalves.		Compared abundance of epifauna caught in small-mesh trawl inside and outside an area closed to trawling for almost 40 years.

11	**Moran & Stephenson 2000**	Northwest Australia	50-55 m	Not given, presumed to be sand	Single tow reduced density of macrobenthos (>20 cm) by 15%, 4 tows by 50%.		Video surveys before and after 4 experimental trawling events (1 tow per unit area) at 2-day intervals in unexploited area.
12	**Prena *et al.* 1999**	Grand Banks, Newfoundland	120-146 m	Fine to medium grain sand	24% average decrease in epibenthic biomass, S reductions in total and mean individual epifaunal biomass and biomass of 5 of 9 dominant species, damage to echinoderms.		Experimental trawling (3-6 tows per unit area) in closed area 1, 2 and 3 years after closure, lightly exploited for >10 yrs.
13	**Sainsbury 1997**	Northwest Australia	< 200 m	Calcareous sands	Decreased abundance of benthic organisms and fish associated with large epifauna, removal of attached epifauna (single tow removed 89% of sponges >15 cm).	Increased catch rates of fish associated with large epifauna and small (<25 cm) benthos within 5 yrs, recovery of large epifauna takes >5 yrs.	Compared historical survey data (before and after fishing started) to data collected in area that remained open to commercial trawlers and area closed for 5 years.
14	**Schwinghamer *et al.* 1998**	Grand Banks, Newfoundland	120-146 m	Fine and medium grain sand	Tracks in sediment, increased bottom roughness, sediment re-suspension and dispersal, smoothing of seafloor and removal of flocculated organic material, organisms and shells organized into linear features.	Tracks last up to 1 year, recovery of seafloor topography within 1 year.	Experimental trawling (3-6 tows per unit area) in closed area 1, 2 and 3 years after closure, lightly exploited for >10 yrs.

Citations in bold print are peer-reviewed publications.

Table 5.6. Effects of Otter Trawls on Gravel/Rock Substrate Habitat: Summary of Published Studies

No.	Reference	Location	Depth	Sediment	Effects	Recovery	Approach
1	**Auster *et al.* 1996**	Gulf of Maine (Jeffreys Bank)	94 m	Gravel/boulder with thin mud veneer.	Gravel base exposed, boulders moved, reduced abundance of erect sponges and associated epifaunal species.		Submersible and video observations in same location in 1987 and 1993, changes attributed to trawling.
2	**Freese *et al.* 1999**	Gulf of Alaska	206-274 m	93% pebble, 5% cobble, 2% boulder.	Boulders displaced, groundgear left furrows 1-8 cm deep in less compact sediment, layer of silt removed, S reductions in abundance of sponges, anemones, and sea whips, damage to sponges, sea whips and brittle stars.		Video observations from a submersible 2-5 hr after single trawl tows in area exposed to little or no commercial trawling for about 20 years.
3	**Van Dolah *et al.* 1987**	Georgia, SE U.S. coast	20 m	Smooth rock with thin layer of sand and attached epifauna.	Reduced abundance of and damage to large sponges and soft corals, esp barrel sponges and stick corals; no S effects on abundance of vase/finger sponges, or stony corals.	Full recovery of damaged organisms and abundance within 12 mos.	Experimental study using diver counts of large sponges and corals before, immediately after, and 12 mos after a single trawl tow in an un-exploited area.

Citations in bold print are peer-reviewed publications.

Table 5.7. Effects of Otter Trawls on Mixed Substrate Habitat: Summary of Published Studies

No.	Reference	Location	Depth	Sediment	Effects	Recovery	Approach
1	Canadian DFO 1993	Bras d'Or Lakes, Nova Scotia (Canada)	10-500 m	Mud, sand, gravel, and boulders	Trawl doors left parallel marks (furrows and berms), fainter marks from footgear , primarily in mud.		Side scan sonar survey after area was closed to mobile gear for 1 yr.
2	**Engel and Kvitek 1998**	California (USA)	180 m	Gravel, sand, silt, and clay	S fewer rocks, shell fragments, rocks and mounds in HT area; lower densities of large epibenthic taxa in HT area (S for seapens, seastars, anemones, and sea slugs), higher densities of nematodes, oligochaetes, brittlestars and one species of polychaete in HT area, no differences between areas for crustaceans, molluscs, or nemerteans.		Used a submersible and grab samples (3 yrs) to compare lightly trawled (LT) and heavily trawled (HT) commercial fishing sites with same sediments and depth.
3	Smith *et al.* 1985	Long Island Sound, New York (USA)	Not given	Sand and mud	Tracks in sediment (<5 cm in sand, 5-15 cm in mud), attraction of predators, suspension of epibenthic organisms.	Tracks "naturalized" by tidal currents.	Video and diver observations.

Citations in bold print are peer-reviewed publications.

Table 5.8. Effects of New Bedford Scallop Dredges on Sand Habitat: Summary of Published Studies

No.	Reference	Location	Depth	Sediment	Effects	Recovery	Approach
1	**Auster *et al.* 1996**	Stellwagen Bank, Gulf of Maine (USA)	20-55 m	Coarse sand	Disturbance of storm sand ripples and low sand waves, dispersal of shell deposits in wave troughs.		Examined gear tracks in side-scan sonar images.
2	**Langton & Robinson 1990**	Fippennies Ledge, Gulf of Maine (USA)	80-100 m	Gravelly sand with some gravel, shell hash, and small rocks	Coarser substrate, disruption of amphipod tube mats, piles of small rocks and scallop shells dropped from surface, S reductions in densities of tube dwelling polychaete and burrowing anemone.	.	Submersible observations made two years apart, before and after commercial dredging of area.
3	**Watling *et al.* 2001**	Damariscotta River, Maine (USA)	15 m	Silty sand	Loss of fine surficial sediments, lowered food quality of sediment, reduced abundance of some taxa, no changes in number of taxa, S reductions in total number of individuals 4 mos after dredging.	No recovery of fine sediments, full recovery of benthic fauna and food value within 6 mos.	Experimental study (23 tows in one day), effects on macrofauna (mostly infauna) evaluated 1 day and 4 and 6 mos after dredging in an un-exploited area.

Citations in bold print are peer-reviewed publications.

Table 5.9. Effects of New Bedford Scallop Dredges on Mixed Substrate Habitat: Summary of Published Studies

No.	Reference	Location	Depth	Sediment	Effects	Recovery	Approach
1	**Caddy 1968**	Northumberland Strait, Gulf of St. Lawrence, Canada	20 m	Mud and sand	Drag tracks (3 cm deep) produced by skids, smooth ridges between them produced by rings in drag belly, dislodged shells in dredge tracks.		Diver observations of physical effects of two tows.
2	**Caddy 1973**	Chaleur Bay, Gulf of St. Lawrence, Canada	40-50 m	Gravel over sand, with occasional boulders	Suspended sediment, flat track, marks left by skids, rings and tow bar, gravel fragments less frequent (many overturned), rocks dislodged or plowed along bottom.		Submersible observations of tow tracks made less than 1 hr after single dredge tows.
3	**Mayer *et al.* 1991**	Coastal Gulf of Maine (USA)	8 m	Mud, sand and shell hash	Lowered sediment surface by 2 cm, injection of organic matter and finer sediment into lower 5-9 cm, increased mean grain size in upper 5 cm, disruption of surface diatom mat, increased microbial biomass at sediment surface.		Experimental study, compared dredged and undredged sites before and 1day after a single dredge tow.

Citations in bold print are peer-reviewed publications.

Table 5.10. Effects of Toothed Scallop Dredges on Sand Substrate Habitat: Summary of Published Studies

No.	Reference	Location	Depth	Sediment	Effects	Recovery	Approach
1,2	**Black & Parry 1994, 1999**	Port Phillip Bay, SE Australia (3 sites)	15 m	Sand (7-30% mud)	Sediment plume, maximum depth of disturbance 4-6 cm into bottom; cutterbar trims off high regions of seafloor.	Turbidity returned to normal storm levels within 9 minutes.	Experimental dredging for 2-4 days (2-4 tows per unit area) in 3 areas with no commercial dredging for 4 yrs.
3	Butcher *et al.* 1981	Jervis Bay, New South Wales, Australia	> 13 m	Sand	Sediment plume up to 5 m off bottom, flattening of sand ridges.	Sediment plume settled out within 15 mins.	Diver observations.
4,5	**Currie & Parry 1996, 1999**	Port Phillip Bay, SE Australia (St. Leonards)	15 m	Fine/very fine sand	Flattening of low relief biogenic mounds, depressions filled in, parallel tracks produced by skids; most species 20-30% less abundant, S fewer species after 3 wks and S reduced abundance of 6 of 10 most common infaunal species within first 3.5 months (S increase in abundance for one species), no effect on total number of individuals; surface-dwelling organisms released into water column right away, burrowing organisms as dredging continued; increased abundance of more mobile, opportunistic species within first 3.5 mos.	Mounds re-formed after 6 mos, tracks visible after 1 mo, but not after 6 mos; most species recovered within 8 mos, but some had not after 14 mos.	Experimental dredging for 3 days (2 tows per unit area) in an area (St. Leonards) with no commercial dredging for 4 yrs, recovery of infauna monitored at 5 intervals during 14 mos, seafloor changes at 8 days, 6 and 11 mos.
5	**Currie & Parry 1999**	Port Phillip Bay, SE Australia (Dromana)	15 m	Medium-fine sand	Removal of small, parallel sand ripples, S reductions in abundance of 3 of 10 most common infaunal species within 2 days.	Ripples re-formed after 5 days following storm	Experimental dredging for 2 days (2 tows per unit area) in an area (Dromana) with no commercial dredging for 4 yrseffects on infauna evaluated after 2 days, seafloor changes after 5 days.
		Port Phillip Bay, SE Australia (Portarlington)	15 m	Muddy sand with shell fragments	Flattening of biogenic mounds, S reductions in abundance of 2 of 10 most common infaunal species within 1 day.	Mounds re-formed 7 mos after dredging, but were still smaller than in undredged area.	Experimental dredging for 4 days (4 tows per unit area) in an area (Portarlington) with no commercial dredging for 4 yrs, effects on infauna evaluated after 1 day, seafloor changes after 7 mos.
6	**Eleftheriou & Robertson 1992**	Firemore Bay, Loch Ewe, Scotland	5 m	Sand	Dredge eliminated natural bottom features, teeth created 3-4 cm deep furrows, no effect on sediment characteristics; damage or mortality of larger epifauna, razor clams, and sand eels, attraction of predators, increase in small infaunal crustaceans and sedentary polychaetes, no effect on taxa adapted to dynamic environment (*e.g.* amphipods, bivalves).	Grooves and furrows no longer visible shortly after dredging, duration depended on wave and current action.	Evaluation of incremental effects of dredging (25 tows in one week) at a single site (no control).

7	**Thrush *et al.* 1995**	Mercury Bay, New Zealand	24 m	Coarse sand	Breaking down of surface sediment features, grooves 2-3 cm deep created by teeth; S declines in abundance of 6 of 13 most common taxa at unexploited site, 4 of 13 most common taxa at exploited site; S reductions in total number of individuals and taxa at both sites.	Complete recovery of macrobenthic abundance at previously exploited site after 3 mos, but not at unexploited site.	Experimental dredging (5 parallel tows in one day) at a previously exploited and an unexploited site with different benthic communities; biological effects evaluated within 2 hrs and 3 mos after dredging.

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Table 5.11. Effects of Toothed Scallop Dredges on Biogenic Substrate Habitat: Summary of Published Studies

Reference	**Location**	**Depth**	**Sediment**	**Effects**	**Recovery**	**Approach**
Hall-Spencer & Moore 2000a	Clyde Sea, Scotland	10-15 m	Live bottom (maerl) with some cobble and boulders	Disturbance of seafloor to 10 cm, overturned boulders, suspended sediment, erasure of bottom features and burial of living maerl in dredge tracks; most megafauna in top 10 cm either caught in dredge or left damaged in dredge track (large, fragile organisms more vulnerable), rapid aggregation of predatory species in track.	Dredge tracks remained visible for 0.5-2.5 yrs, recovery rates of large epibenthic species variable; some species recovered quickly, but others were still depleted at unexploited site 4 yrs after dredging; macrobenthic community at previously exploited site recovered within 2 yrs.	Observations of the effects of single dredge tows at a previously dredged and an undredged site, immediate effects and recovery (4 yrs) evaluated by divers using video cameras.

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Table 5.12. Effects of Toothed Scallop Dredges on Mixed Substrate Habitat: Summary of Published Studies

No.	Reference	Location	Depth	Sediment	Effects	Recovery	Approach
1	**Bradshaw *et al.* 2002**	Isle of Man, Irish Sea	Not given	Sand and gravel	More vulnerable taxa less abundant in recent samples, less vulnerable taxa more abundant; faunal differences and proportion of species "lost" between time periods increased significantly as number of years since fishing began increased, no effect of increases in total effort; no clear evidence over all sites for reduced species diversity.		Recent benthic sample data collected at 7 sites exposed to varying amounts of fishing effort compared with data collected 50-60 years ago, when scallop fishing was very limited.
2,3	**Bradshaw *et al.* 2000, 2001**	Isle of Man, Irish Sea	25-40 m	Gravel, sand, and mud	6 mos of experimental dredging in closed area altered community structure, no trends in abundance of individual species; no S effects on number of species, but community heterogeneity was reduced; encrusting species were more abundant and upright species less abundant in dredged plots than in control plots after 3 yrs.	S increases in abundance of several epifaunal species in undredged portion of closed area 5-9 years after closure.	Continuous experimental dredging (10 tows with 8 dredges every 2 mos for 3 yrs) in an area closed to commercial fishing for 6 yrs, semi-annual grab sampling inside and outside closed area and bi-annual diver surveys of epibenthic animals in closed area.
4	**Caddy 1973**	Chaleur Bay, Gulf of St. Lawrence (Canada)	40-50 m	Gravel over sand, with occasional cobble and boulders.	Shallow, flat tracks, tooth marks in sand, boulders dislodged and small rocks "plowed" by dredge, spoil ridges at edges of track.		Submersible observations and photographs of tow tracks made less than 1 hr after dredging.
5	Canadian DFO 1993	Bras d'Or Lakes, Nova Scotia (Canada)	10-500m	Gravel and mud	Furrows left by dredge teeth, berms at outer edges of dredge track.		Side-scan sonar survey 1 yr after area was closed to mobile gear.
6	**Kaiser *et al.* 1996a**	Irish Sea, southwest of Isle of Man	Not given	Not given, assume mixed substrates	Reduced abundance of most large epibenthic species, same effects on community structure as beam trawls, but lower by-catch.		Experimental study of effects of dredging (10 tows with 8 dredges) and beam trawling on large epifauna, sampling with small mesh (40 mm) beam trawl 24 hrs after fishing.
7	**Kaiser** *et al.* **2000a**	Irish Sea	Not given	Coarse sand and gravel	S more epifaunal organisms in areas exposed to high fishing effort , no effects on infauna or on diversity or number of epifaunal species, shift from communities dominated by more larger-bodied to fewer smaller-bodied organisms.		Compared benthic communities in areas exposed to 10 yrs of low and high fishing effort.
8	**Veale *et al.* 2000**	Irish Sea	20-67 m	Coarse sand or gravel, often overlain with pebbles, cobbles and dead shell.	S decreases in epibenthic species diversity and total number of species and individuals with increasing fishing effort; total abundance, biomass, and production and production of most taxa S decreased with increasing effort..		Compared dredge by-catch from fishing grounds exposed to varying amounts of fishing effort during last 60 yrs.

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Table 5.13. Effects of Other Non-Hydraulic Dredges on Biogenic Substrate Habitat: Summary of Published Studies

No.	Reference	Location	Depth	Sediment	Effects	Recovery	Comments
1	**Fonseca *et al.* 1984**	Beaufort, North Carolina (USA)	Very shallow, subtidal	Silty sand with eelgrass	S reduction in number of eelgrass shoots and biomass with increased dredging intensity at both sites.		Experimental study with two levels of disturbance.
2	Langan 1998	Piscataqua River (USA)	Not given	Oyster bed	No detectable differences in the number of benthic invertebrates, species richness or diversity; turbidity of near-bottom water doubled 10 m behind dredge.	Turbidity returned to normal 110 m behind dredge.	Limited sampling of benthic invertebrates in dredged and undredged sides of the river, turbidity measured during a single dredge tow.
3	**Lenihan & Peterson 1998**	Neuse River, North Carolina (USA)	3 and 6 m	Oyster reefs	Dredging lowered mean height of 1-m reefs by about 30%.		Reefs dredged for 1 week to remove all marketable-sized oysters.
4	**Riemann & Hoffmann 1991**	Limfjord, Denmark	Mean depth 7 m, maximum 15 m	Not given (presumed mussel bed)	S increase in suspended particulate matter, slight reduction in oxygen, especially near the bottom.	Turbidity returned to normal within 1 hr.	Water column sampling before and after dredging (maximum 1 hr) at an experimental and a control site.

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Table 5.14. Effects of Hydraulic Clam Dredges on Mud Substrate Habitat: Summary of Published Studies

Reference	Location	Depth	Sediment	Effects	Recovery	Approach
Hall & Harding 1997	Scotland	Intertidal	Mud	Dredge tracks, S reductions in number of infaunal species and individuals persisted for 4 weeks; 3 of 5 dominant species reduced in abundance throughout experiment (8 weeks).	Nearly complete recovery of infaunal community after 8 weeks, but some effects remained; dredge tracks not seen after first day.	Experimental study of the effects of single suction dredge passes in a commercially harvested area; recovery monitored 1, 4, and 8 weeks after dredging.

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Table 5.15. Effects of Hydraulic Clam Dredges on Sand Substrate Habitat: Summary of Published Studies

No.	Reference	Location	Depth	Sediment	Effects	Recovery	Approach
1	**Hall *et al.* (1990)**	Scotland	7 m	Fine sand	Shallow trenches (25 cm deep) and large holes, sediment "almost fluidized," S increase in median grain size in trenches, S reductions in numbers of infaunal organisms, no effect on abundance of individual species, some mortality (not assessed) of large polychaetes and crustacea retained on conveyor belt or returned to sea surface.	Complete recovery of physical features and benthic community after 40 days, filling of trenches and holes accelerated by winter storms.	Experimental study in unexploited area to evaluate effects of simulated commercial escalator dredging activity (5 hrs dredging in __m^2 plot), recovery evaluated after 40 days.
2	**Kaiser *et al.* (1996b)**	SE England	Intertidal	Fine sand	Re-suspension and loss of fine sand from sediment surface, S reductions in total number of infaunal species and individuals.	Complete recovery of sediments and benthic community within 7 months.	Experimental study, effects of suction dredging for cultivated clams evaluated after 3 hrs and 7 months.
3	**MacKenzie, 1982**	Southern New Jersey (USA)	37 m	Very fine to medium sand	Re-sorting of sediments, no effect on number of infaunal individuals or species, or on species composition.		Comparison of actively fished, recently fished and never fished areas on the continental shelf; dredging conducted with hydraulic cage dredges.
4	Maier *et al.* 1995	South Carolina (USA)	Tidal creeks	Muddy sand	Turbidity plumes, no S effects on abundance of dominant infaunal taxa or total number of individuals.	Turbidity plumes persisted for a few hours.	Before and after study of commercial escalator dredging effects in four tidal creeks, **one of which had never been dredged before and one 5 yrs previously?**
5	Medcof & Caddy 1971	Southern Nova Scotia (Canada)	7-12 m	Sand and sand-mud	Smooth tracks with steep walls, 20 cm deep; sediment cloud.	Sediment plume lasted 1 minute; dredge tracks still clearly visible after 2-3 days.	SCUBA & submersible observations of the effects of individual tows with a cage dredge.
6	**Meyer *et al.* 1981**	Long Island, New York (USA)	11 m	Very fine to medium sand	>20 cm deep trench, mounds on either side of trench, silt cloud, attraction of predators.	Trench nearly indistinct, predator abundance normal after 24 hours; silt settled in 4 minutes.	SCUBA observations following a single tow with a cage dredge in a closed area, effects evaluated after 24 hrs.
7	**Pranovi & Giovanardi 1994**	Adriatic Sea (Italy)	1.5-2 m	Sand	8-10 cm deep trench; S decrease in total abundance, biomass, and diversity of benthic macrofauna in fishing ground; no S effects outside fishing ground.	After 2 mos, dredge tracks still visible, densities (especially of small species and epibenthic species) in fishing ground recovered, biomass did not.	Experimental dredging with a cage dredge (single tows) in previously dredged and undredged areas in coastal lagoon, recovery monitored every 3 weeks for 2 mos.

8	**Tuck *et al.* 2000**	Outer Hebrides, Scotland	2-5 m	Medium to fine sand	Steep-sided trenches (30 cm deep), sediments fluidized up to 30 cm, S decrease in total abundance and number of infaunal species, polychaetes most affected.	Trenches no longer visible but sand still fluidized after 11 weeks, species diversity and total abundance recovered within 5 days, abundance of some species recovered after 11 weeks.	Experimental dredging with cage dredge (individual tows at 6 sites) in area closed to commercial dredging, recovery evaluated after 5 days and 11 weeks.

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Table 5.16. Effects of Hydraulic Clam Dredges on Mixed Substrate Habitat: Summary of Published Studies

Reference	**Location**	**Depth**	**Sediment**	**Effects**	**Recovery**	**Approach**
Murawski & Serchuk 1989	Mid-Atlantic Bight, USA	Not given	Sand, mud and coarse gravel	Trench cut, temporary increase in turbidity, disruption of benthic organisms in dredge path, attraction of predators.	Trenches filled quickly in coarse gravel, but took several days in fine sediments.	Submersible observations following hydraulic cage dredge tows.

Citations in bold print are peer-reviewed publications.

Table 5.17. Effects of Hydraulic Clam Dredges on Biogenic Substrate Habitat: Summary of Published Studies

No.	**Reference**	**Location**	**Depth**	**Sediment**	**Effects**	**Recovery**	**Approach**
1	Godcharles 1971	Tampa Bay, Florida (USA)	Not given	Open sand, sand with seagrass, and sand with algae	Water jets penetrate to 45 cm, create trenches 15-45 cm deep; uprooted vegetation, increased silt/clay content in some dredge tracks.	Trenches lasted longer (up to 86 days) in grass beds, filled in immediately in open sand; most sediments hardened within 1 mo, some spots still soft 500 days after dredging, sediment composition returned to normal after 1 year, but seagrass still had not recovered; new algal growth after 86 days, complete after a year.	SCUBA observations and sediment sampling before and after experimental escalator dredging in undisturbed sand, seagrass, and algae bottom habitats, recovery monitored for 16+ months.
2	Orth *et al.* 1998	Chincoteague Bay, Virginia (USA)	Not given	Seagrass beds	Circular “scars” left by dredges, loss of grass and large holes in dredge track.	No re-vegetation 3 yrs after disturbance, estimated to take at least 5 yrs in lightly disturbed areas, longer in heavily disturbed areas.	Field observations of commercial escalator dredging effects over a 3-yr period.

Citations in bold print are peer-reviewed publications.

Table 5.18. Effects of Pots and Traps on Mixed Substrate Habitat: Summary of Published Studies

Reference	Location	Depth	Sediment	Effects	Recovery	Approach
Eno *et al.* 2001	West coast of Scotland	Not given	Mud	Bending and smothering of sea pens underneath pots, uprooting of some sea pens when pots are dragged over bottom.	Sea pens recover from effects of pot dragging within 24-72 hrs, re-assume upright posture within 72-144 hours of pot removal, and re-root as long as "foot" remains in contact with bottom.	Diver observations and experiments to assess effects on and recovery of sea pens following dragging, uprooting, and smothering by lobster pots left on bottom for 24 or 48 hrs.
Eno *et al.* 2001	Wales, south coast of England	14-20 m	Rocky, sometimes covered by sediment, and coarse sediment.	Pots leave tracks in bottom when hauled, increased abundance of sponges in experimental plots after 4 weeks, no changes in abundance of other epibenthic species.		Diver observations and experiments to assess effects of 4 weeks of simulated commercial pot fishing on attached megafauna at two study sites.

Citations in bold print are peer-reviewed publications.

Table 5.19. Effects of Multiple Gears on Sand Substrate Habitat: Summary of Published Studies

No.	Reference	Location	Depth	Sediment	Effects	Recovery	Approach
1	Almeida *et al.* 2000	Georges Bank (USA)	<50 - >90 m	Sandy	Two species of sponges more abundant inside closed area, no S differences for six other microhabitat types.		Analysis of still photos and video imagery inside and outside area closed to trawls, dredges, longlines, and gill nets 4.5 yrs after it was closed.
2	**Kaiser *et al.* 2000b**	England (South Devon Coast)	15-70 m	Fine, medium, and coarse sand	No S effect of high fishing effort on numbers of infaunal or epifaunal species or individuals; reduced abundance of larger, less mobile, and emergent epifauna, higher abundance of more mobile species, fewer high-biomass organisms and more smaller-bodied species in high effort areas, infauna in deeper coarse-medium sand habitat most affected by fishing.		Compared benthic communities in areas of high, medium and low fishing intensity by fixed and mobile gears.

Citations in bold print are peer-reviewed publications.

Table 5.20. Effects of Multiple Gears on Gravel/Rock Substrate Habitat: Summary of Published Studies

No.	Reference	Location	Depth	Sediment	Effects	Recovery	Approach
1,2	**Collie *et al.* 1997, 2000**	Eastern Georges Bank (U.S. and Canada)	42-90 m	Pebble/cobble "pavement" with some overlying sand	S higher total densities, biomass, and species diversity in undisturbed sites, but also in deeper water (ie effects of fishing could not be distinguished from depth effects), 6 species abundant at U sites, rare or absent at D sites; sediments in U sites slightly coarser with more sand and cobble; percent cover of tube-dwelling polychaetes, hydroids, and bryozoans S higher in deep water, but no disturbance effect.		Benthic sampling, video and still photos in two shallow (42-47 m) and four deep (80-90 m) sites disturbed (D) and undisturbed (U) by trawls and scallop dredges.

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Table 5.21. Effects of Multiple Gears on Mixed Substrate Habitat: Summary of Published Studies

No.	Reference	Location	Depth	Sediment	Effects	Recovery	Approach
1	**Auster *et al.* 1996**	Coastal Gulf of Maine (USA)	30-40 m	Sand-shell	S more sea cucumbers and bottom depressions inside closed area.		ROV and video observations inside and outside an area closed to mobile gear for 10 years.
1	**Auster *et al.* 1996**	Coastal Gulf of Maine (USA)	30-40 m	Cobble-shell	S more emergent epifauna inside closed area.		ROV and video observations inside and outside an area closed to mobile gear for 10 years.
1	**Auster *et al.* 1996**	Stellwagen Bank (Gulf of Maine, USA)	20-55 m	Sand with gravel and shell	Disturbed sand ripples and sand waves, dispersed shell deposits, absence of epifauna and reduced microalgal cover in trawl and dredge tracks.		Side-scan sonar survey and ROV observations.
2,3,4	**Reise and Schubert, 1987; Riesen and Reise 1982; Reise 1982**	Wadden Sea (Netherlands)	<23 m	Mud, coarse sand and some pebbles	Loss of oyster and *Sabelleria* reefs, decrease in abundance of 28 species (molluscs and amphipods), 23 "new" species (mostly polychaetes).		Compared benthic surveys conducted during time period when oysters were over-exploited and trawl fishery developed on *Sabellaria* reefs (1869-1986)..
5	**Thrush *et al.* 1998**	Hauraki Gulf, New Zealand	17-35 m	Mud and sand	S reductions in density of large epifauna, echinoderms, and long-lived surface dwellers; S increases in density of small, opportunistic species; 15-20% variability in macrofaunal community composition attributed to fishing pressure.		Tested ten predictions of the effects of increasing fishing intensity on benthic community structure by comparing samples and video images from 18 stations exposed to varying degrees of commercial fishing pressure by bottom trawls, Danish seines, and scallop dredges.
6	Valentine and Lough 1991	Eastern Georges Bank		Sand and gravel	Trawl and dredge tracks in sediments, sparse epifauna, gravel mounds and smoother bottom in disturbed areas.		Side scan sonar and submersible observations of area presumed to be disturbed by trawls and scallop dredges.

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Figure 2.1

U.S. Atlantic Coast
Northeast Shelf Ecosystem

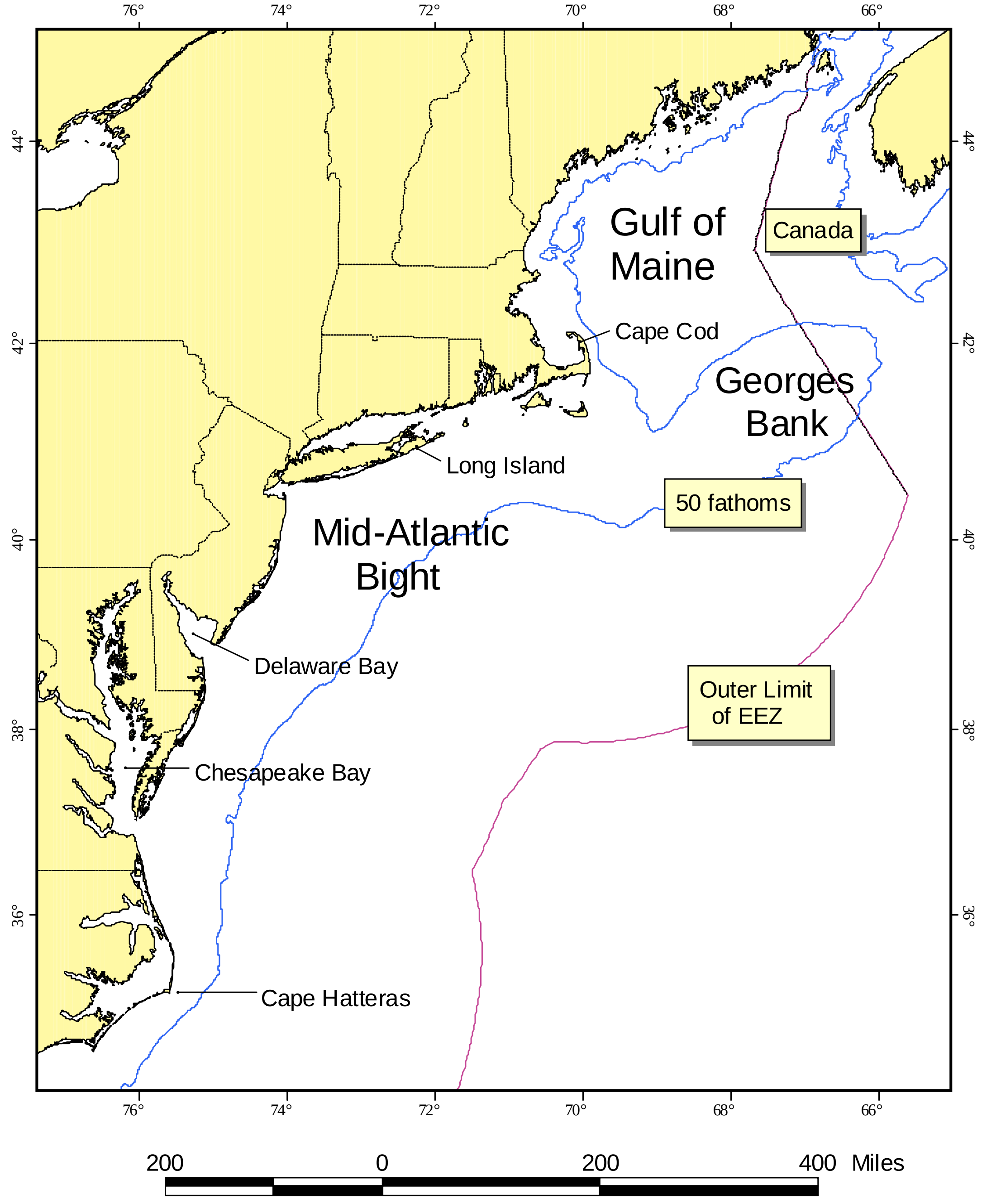


Figure 2.2

Gulf of Maine

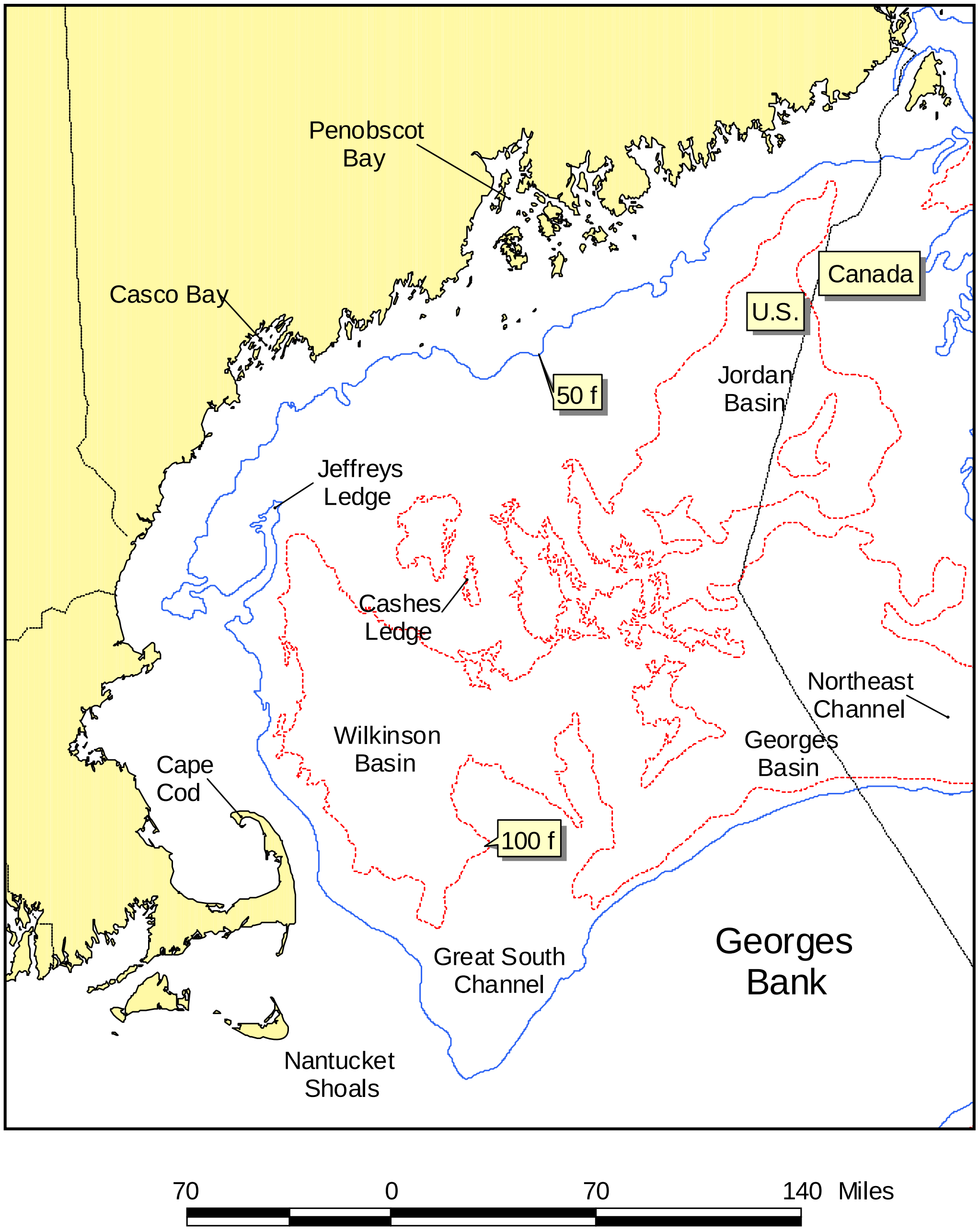


Figure 2.3

Northeast Region Sediments
(Modified from Poppe et al. 1989)

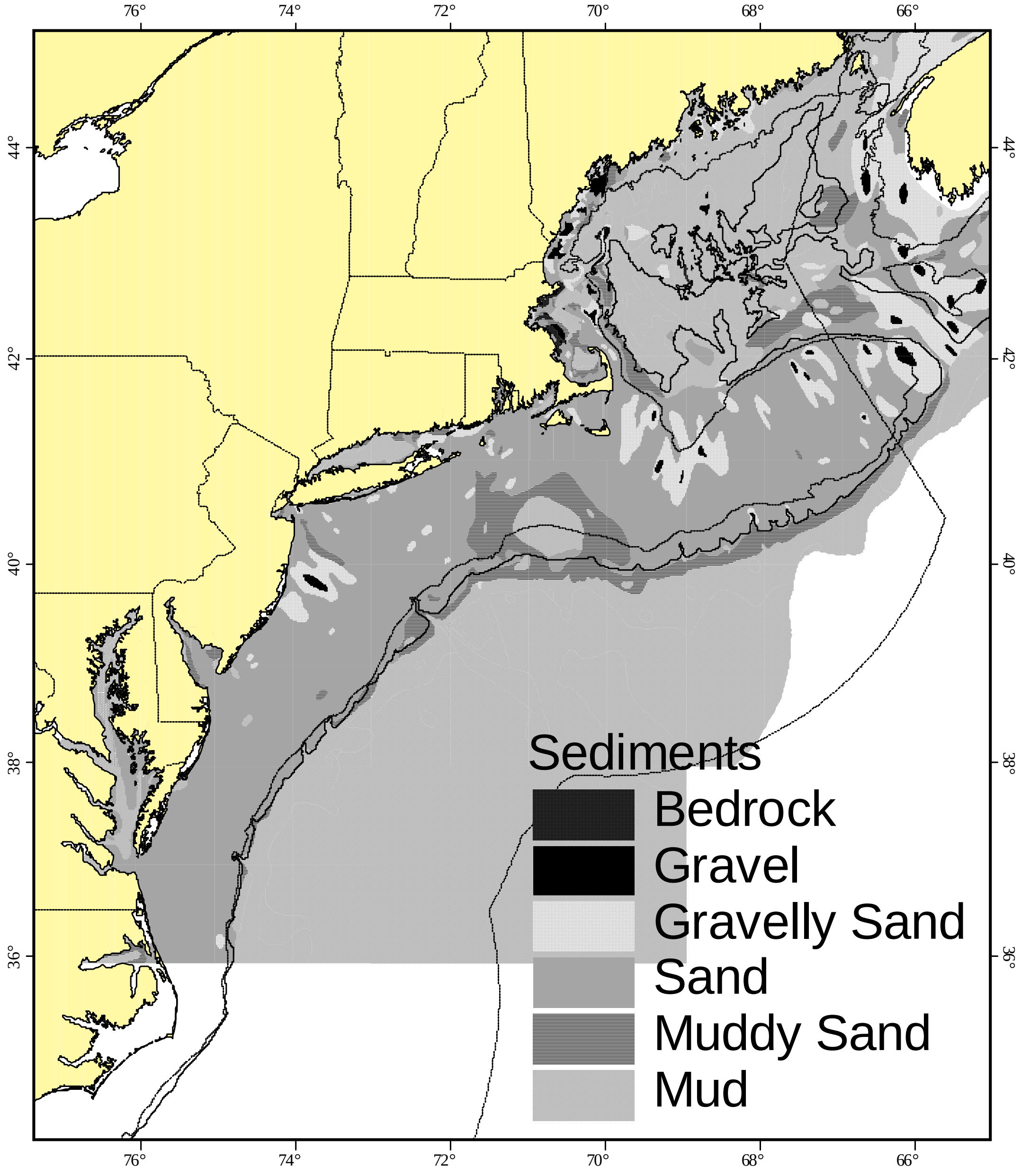


Figure 2.4. Water mass circulation patterns in the Georges Bank - Gulf of Maine region. Depth in meters. Scale 1:3,600,000 (1 inch = 57 miles). Source: Valentine and Lough (1991).

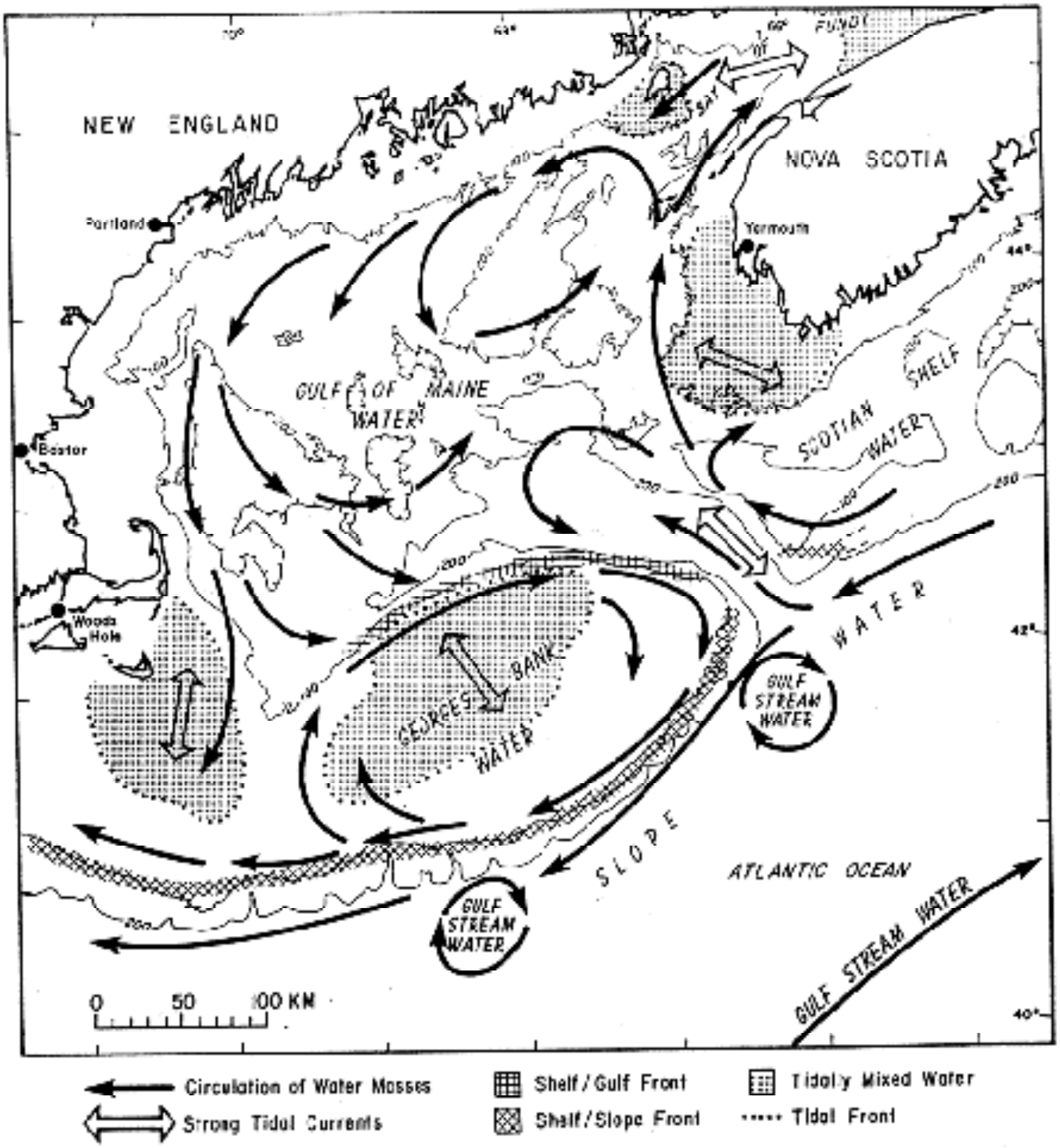


Figure 2.5. Distribution of the seven major benthic assemblages in the Gulf of Maine as determined from both soft bottom quantitative sampling and qualitative hard bottom sampling. The assemblages are characterized as follows: 1. Sandy offshore banks; 2. Rocky offshore ledges; 3. Shallow (<50 m) temperate bottoms with mixed substrate; 4. Boreal muddy bottom, overlain by Maine Intermediate Water, 50 – 160 m (approx.); 5. Cold deep water, species with broad tolerances, muddy bottom; 6. Deep basin warm water, muddy bottom; 7. Upper slope water, mixed sediment. Source: Watling 1998.

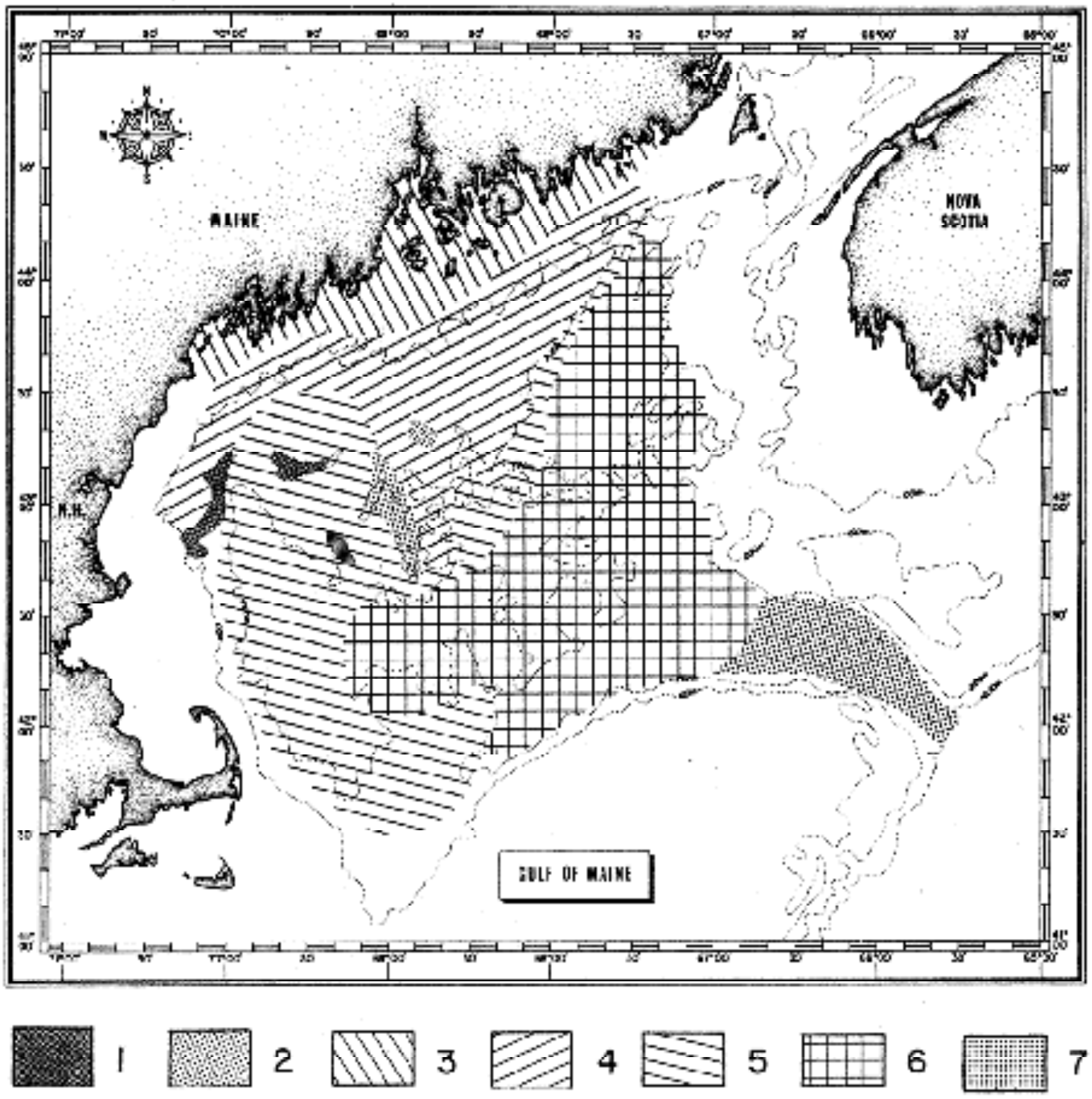


Figure 2.6. Sedimentary provinces of eastern Georges Bank based on criteria of sea floor morphology, texture, sediment movement and bedforms, and mean tidal bottom current speed (cm/sec). Relict moraines (bouldery sea floor) are enclosed by dashed lines. See Table 2.4 for descriptions of provinces. Scale 1:1,000,000 (1 inch = 16 miles). Source: Valentine and Lough (1991).

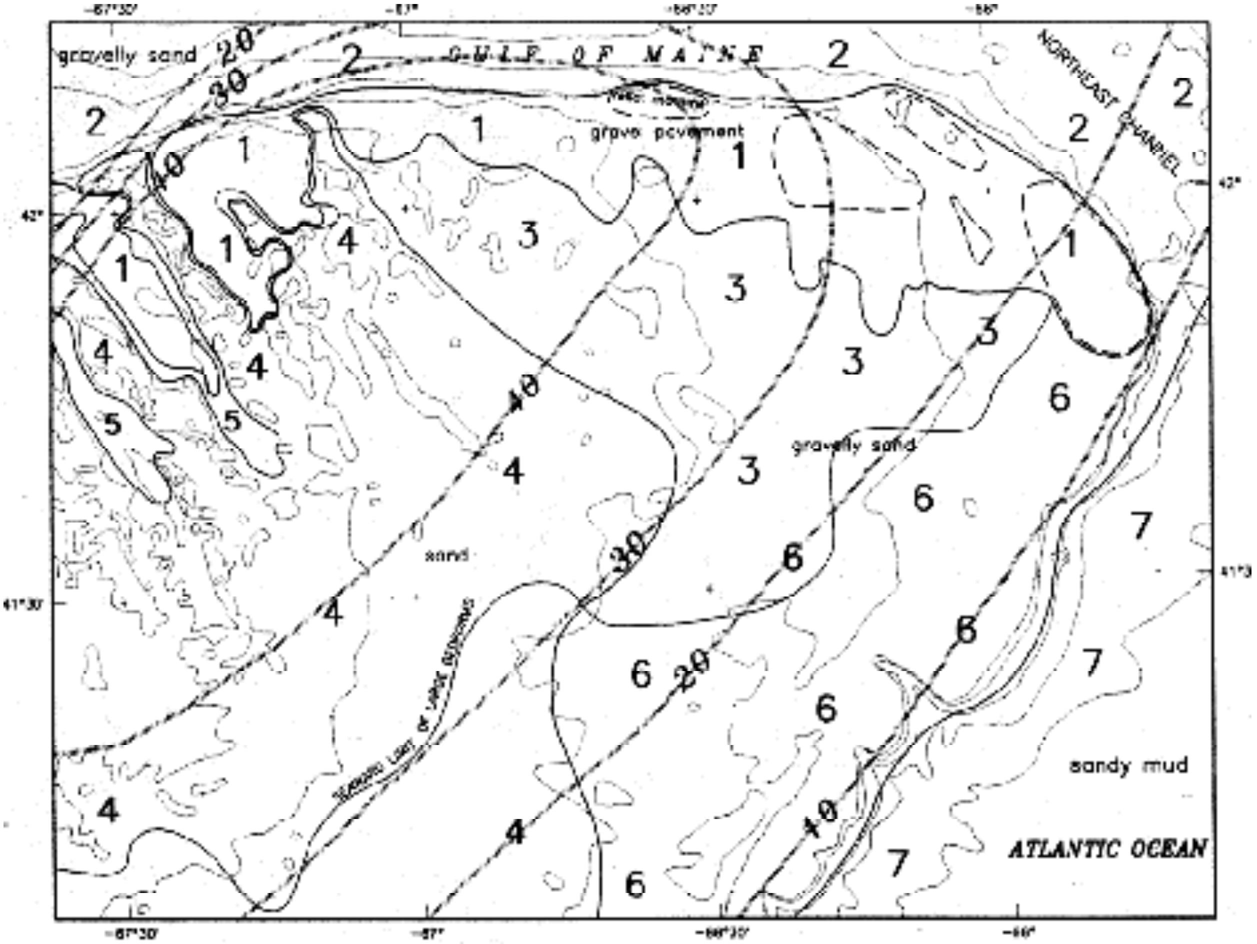


Figure 2.7. Mid-Atlantic Bight submarine morphology. Source: Stumpf and Biggs (1988).

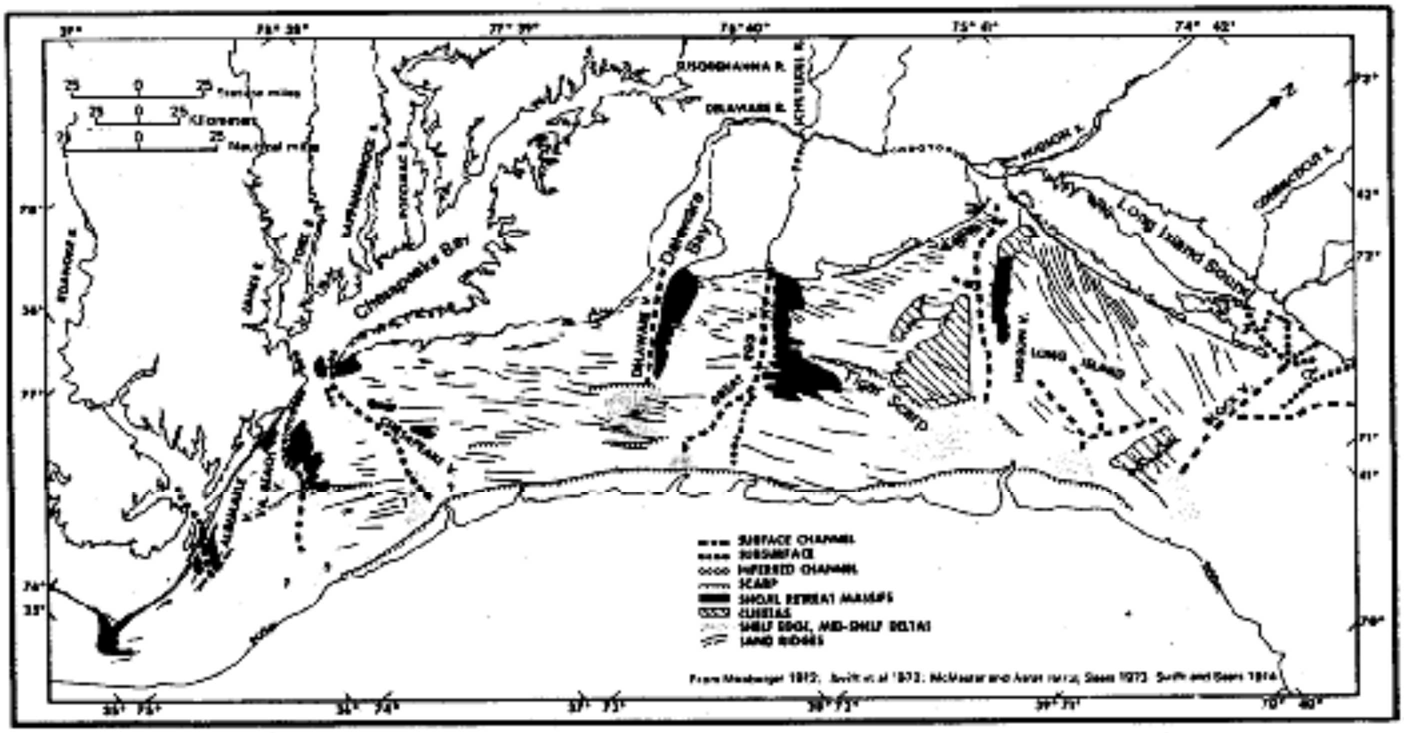


Figure 2.8. Major features of the Mid-Atlantic and Southern New England continental shelf. Source: Stumpf and Biggs (1988).

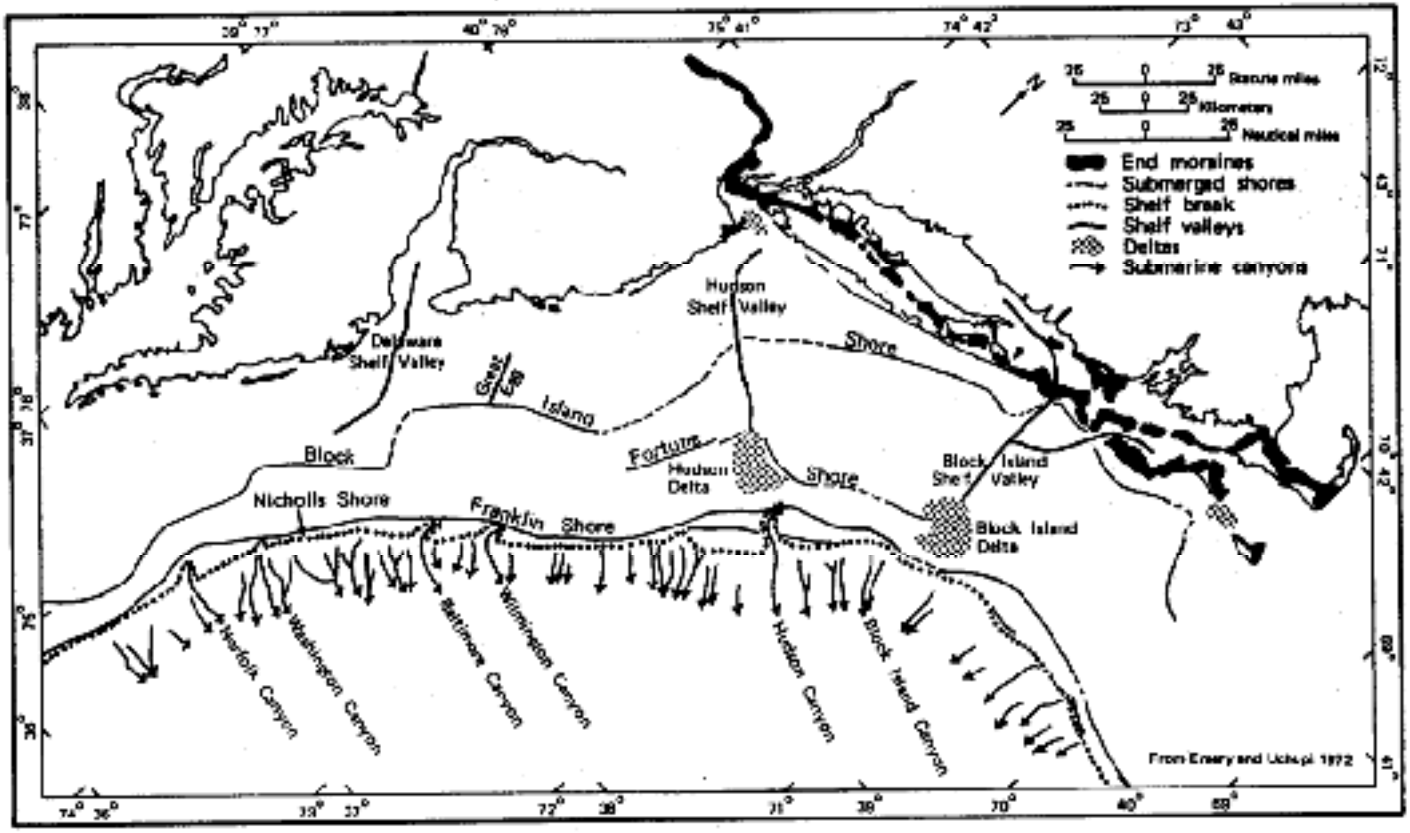


Figure 2.9. Schematic representation of major macrofaunal zones on the Mid-Atlantic shelf. Approximate location of ridge fields indicated. Source: Reid and Steimle (1988).

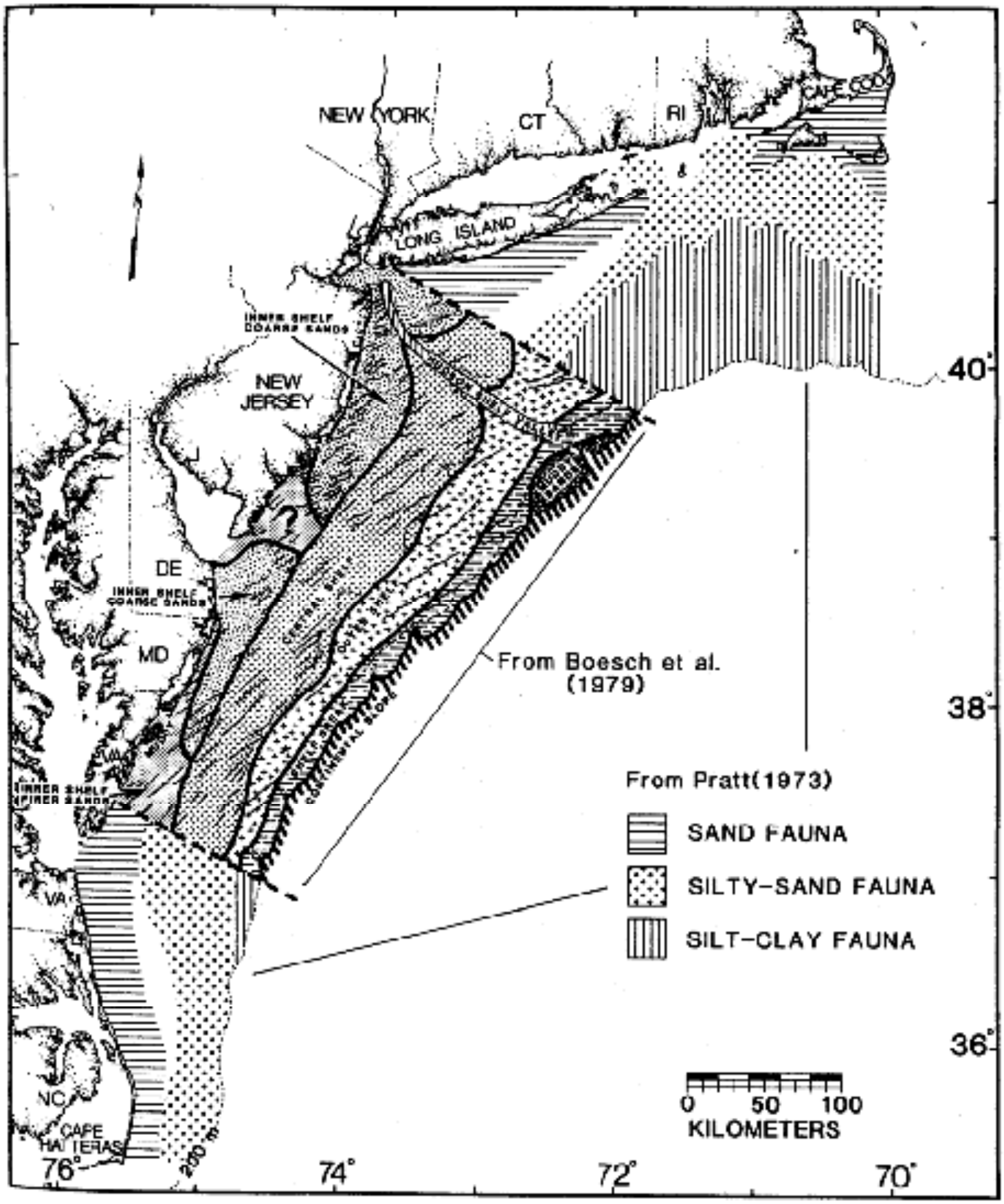


Figure 2.10. Summary of all reef habitats (except biogenic, such as mussel or oyster beds) in the Mid-Atlantic Bight. Source: Steimle and Zetlin (2000).

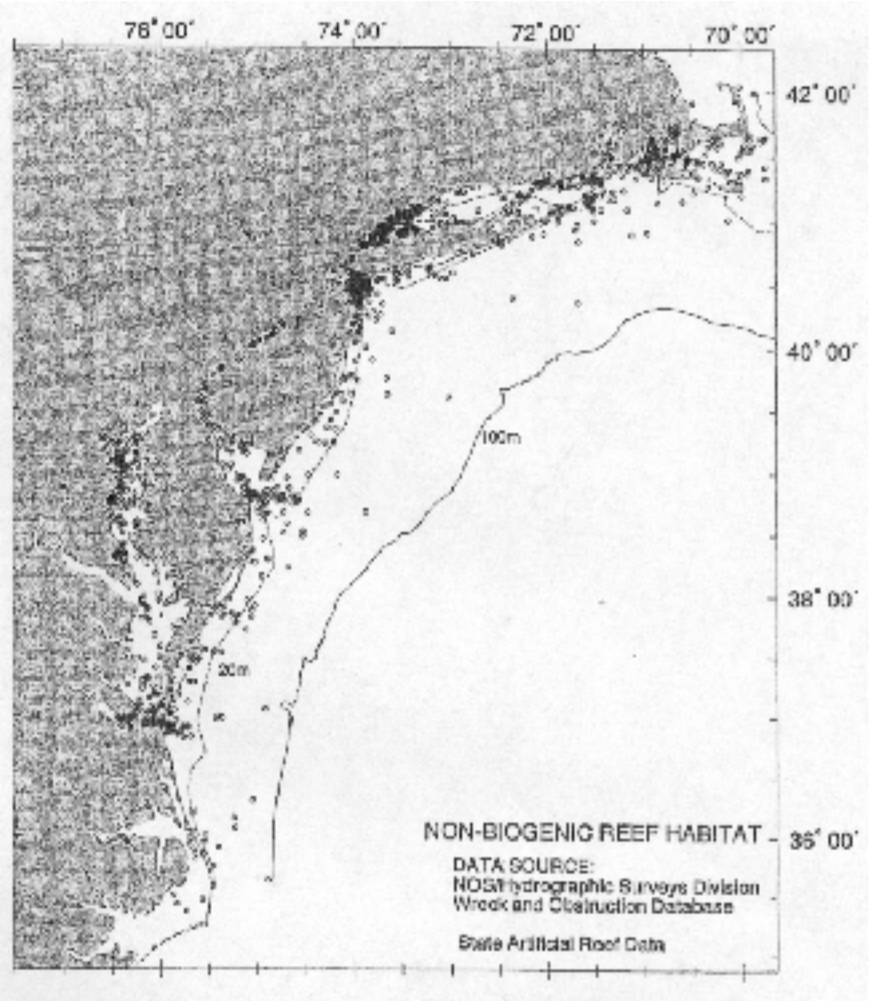
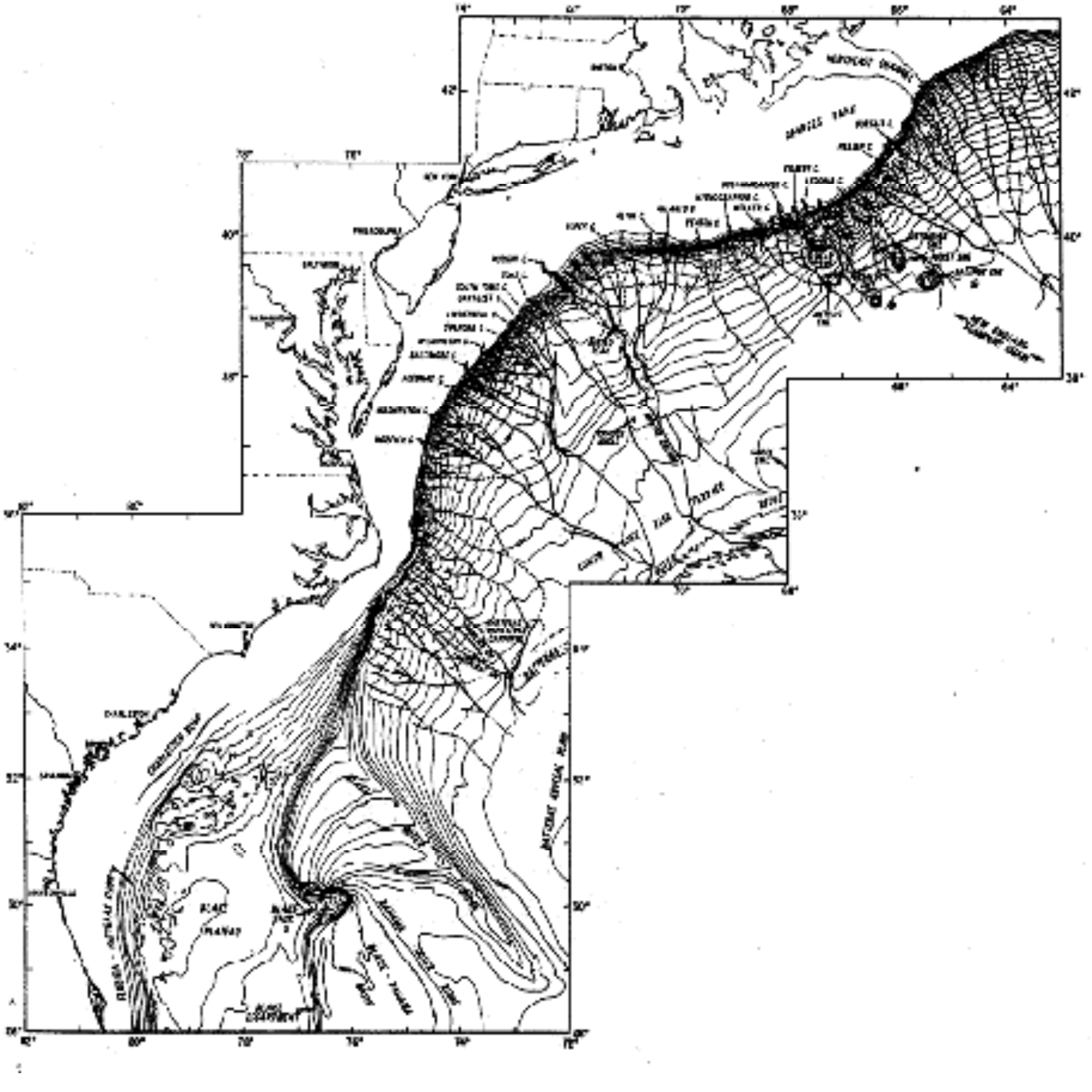


Figure 2.11. Bathymetry of the U.S. Atlantic continental margin. Contour interval is 200 m below 1000 m water depth and 100 m above 1000 m. Axes of principal canyons and channels are shown by solid lines (dashed where uncertain or approximate). Source: Tucholke (1987).



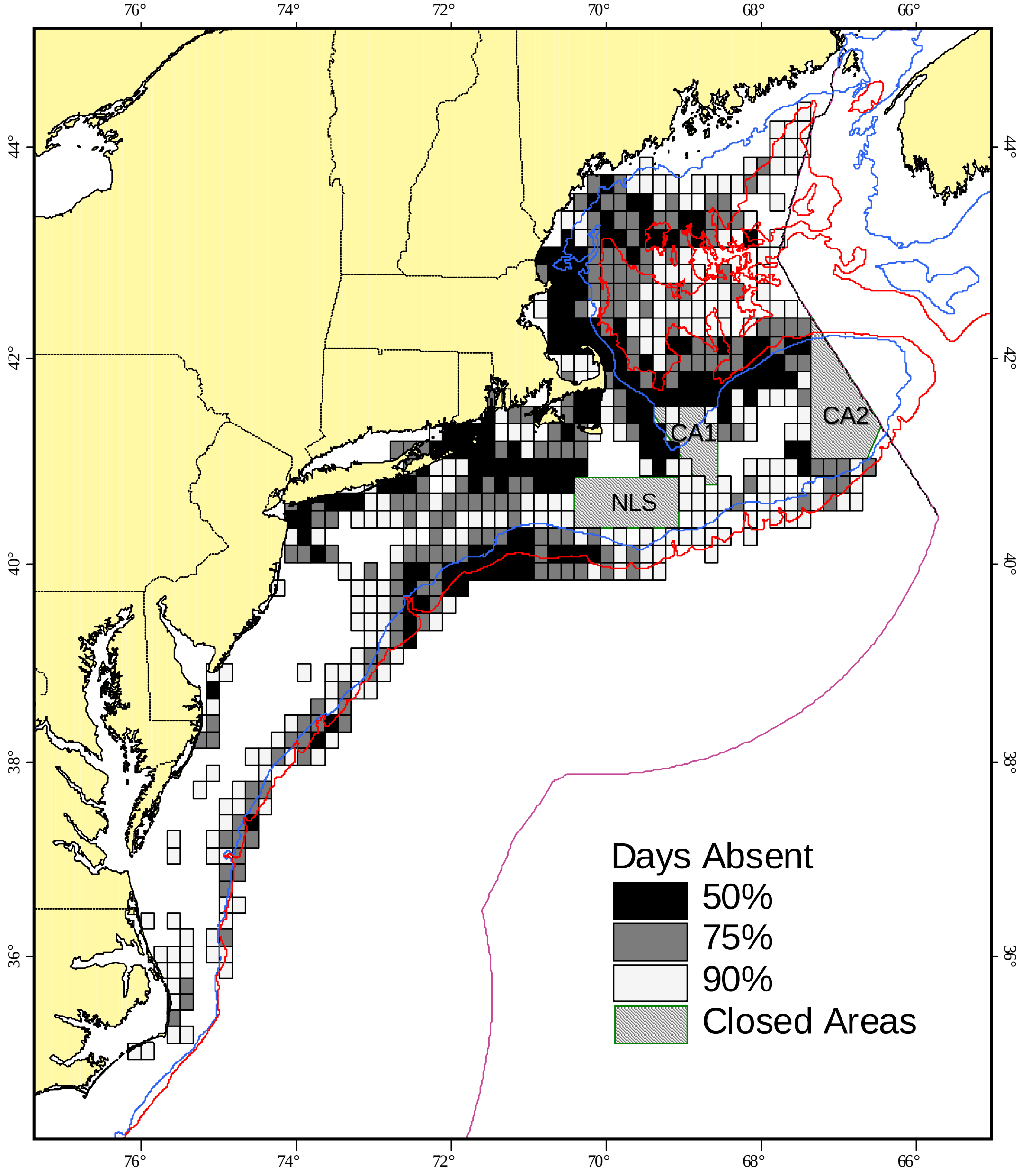
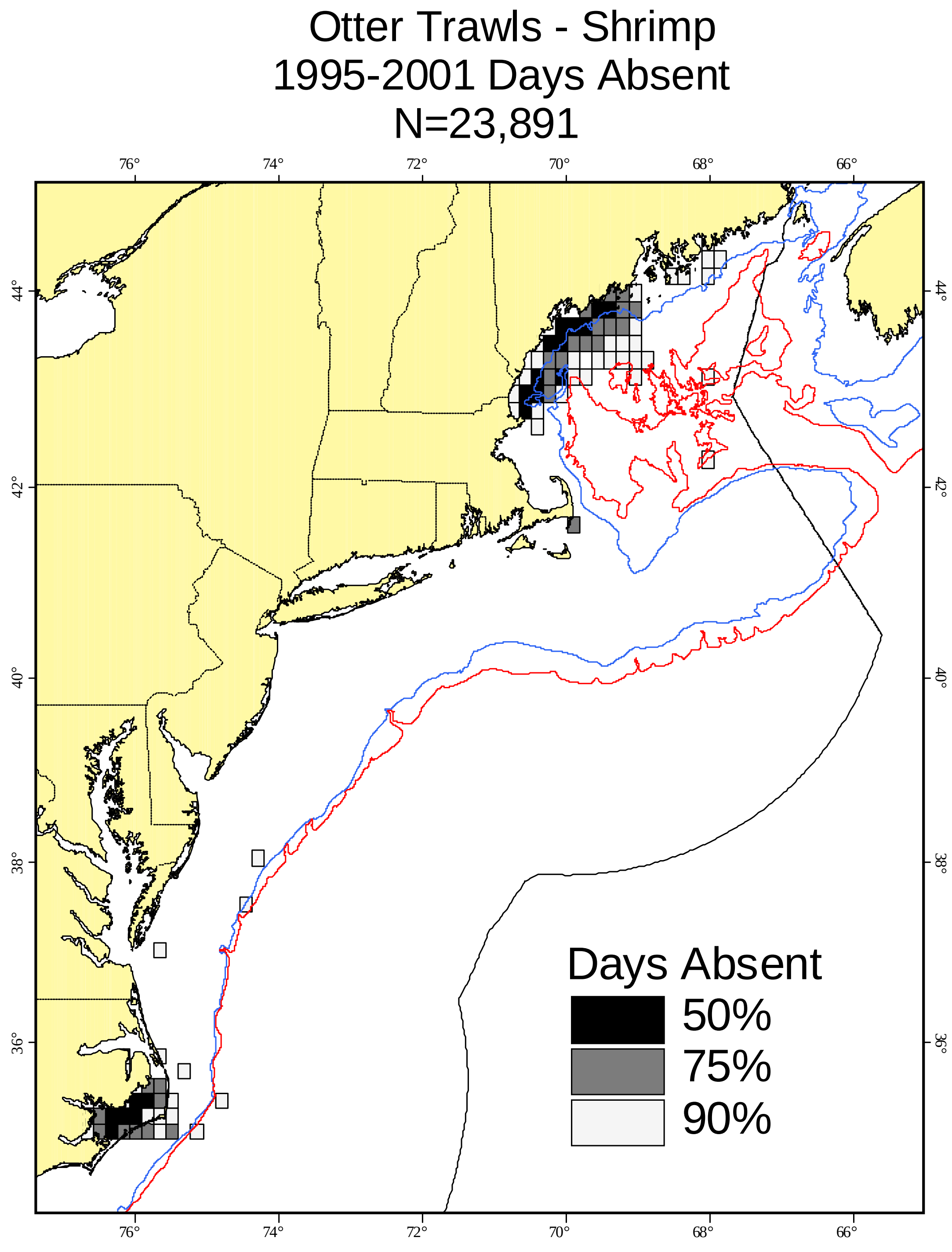


Figure 4.1

Bottom Otter Trawl (Fish)
1995-2001 Days Absent
N=348,841

Figure 4.2



Otter Trawls - Shrimp
1995-2001 Days Absent
N=23,891

Figure 4.3

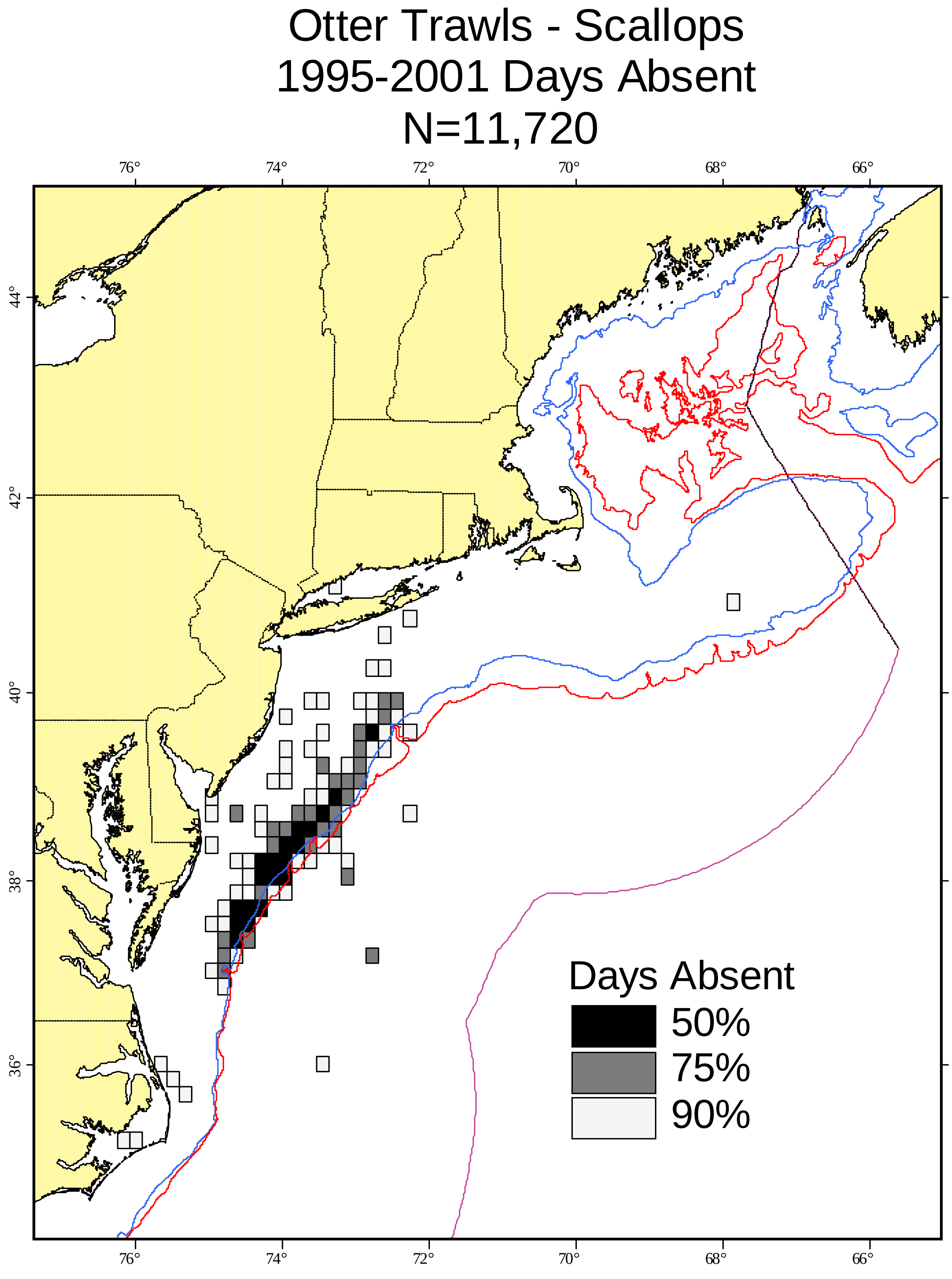

Otter Trawls - Scallops
1995-2001 Days Absent
N=11,720
76°
74°
72°
70°
68°
66°
44°
42°
40°
38°
36°
Days Absent
50%
75%
90%

Figure 4.4

Scallop Dredges
1995-2001
N=145,748

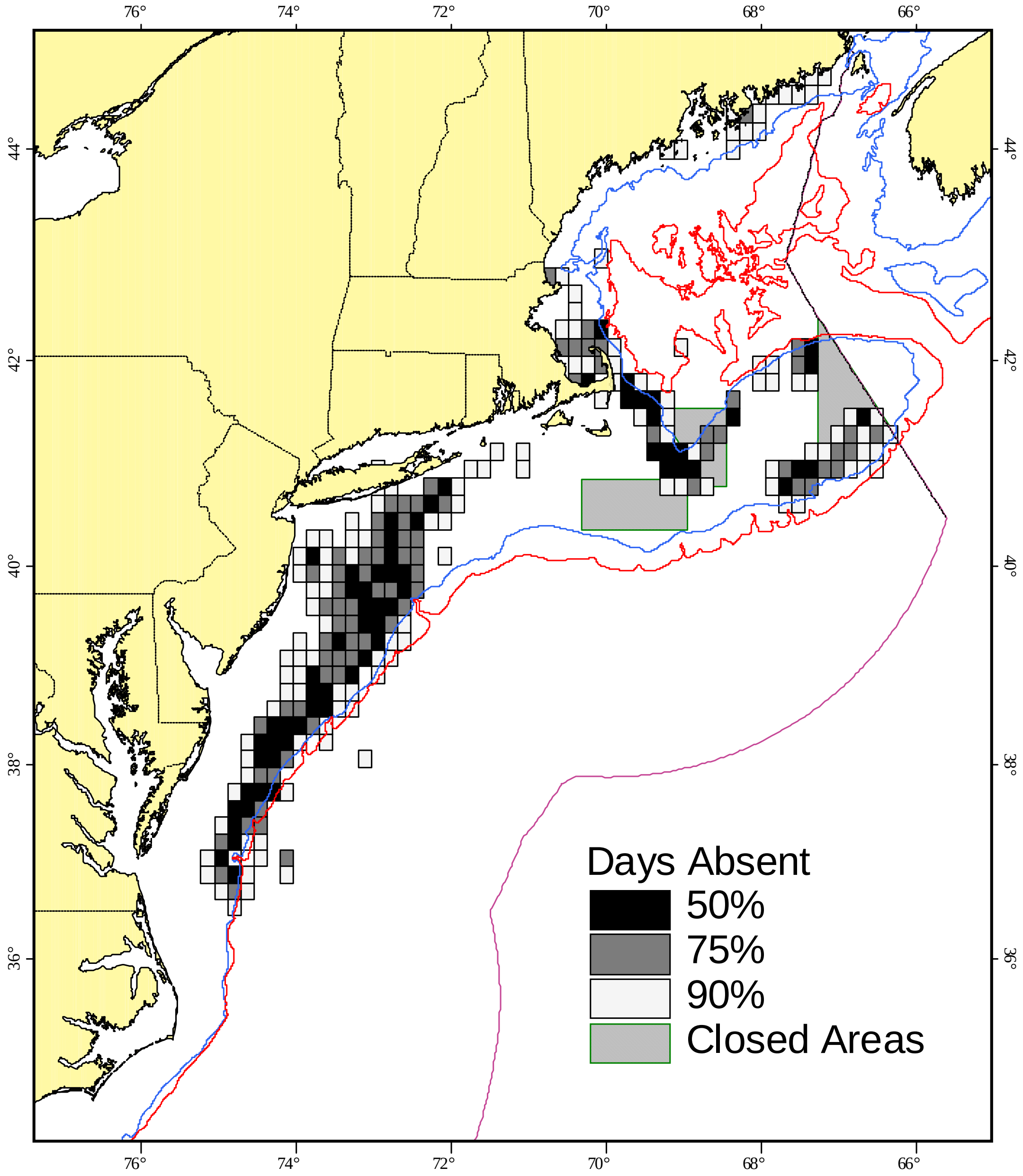


Figure 4.5

Hydraulic Clam Dredges
1995-2001
N=14,503

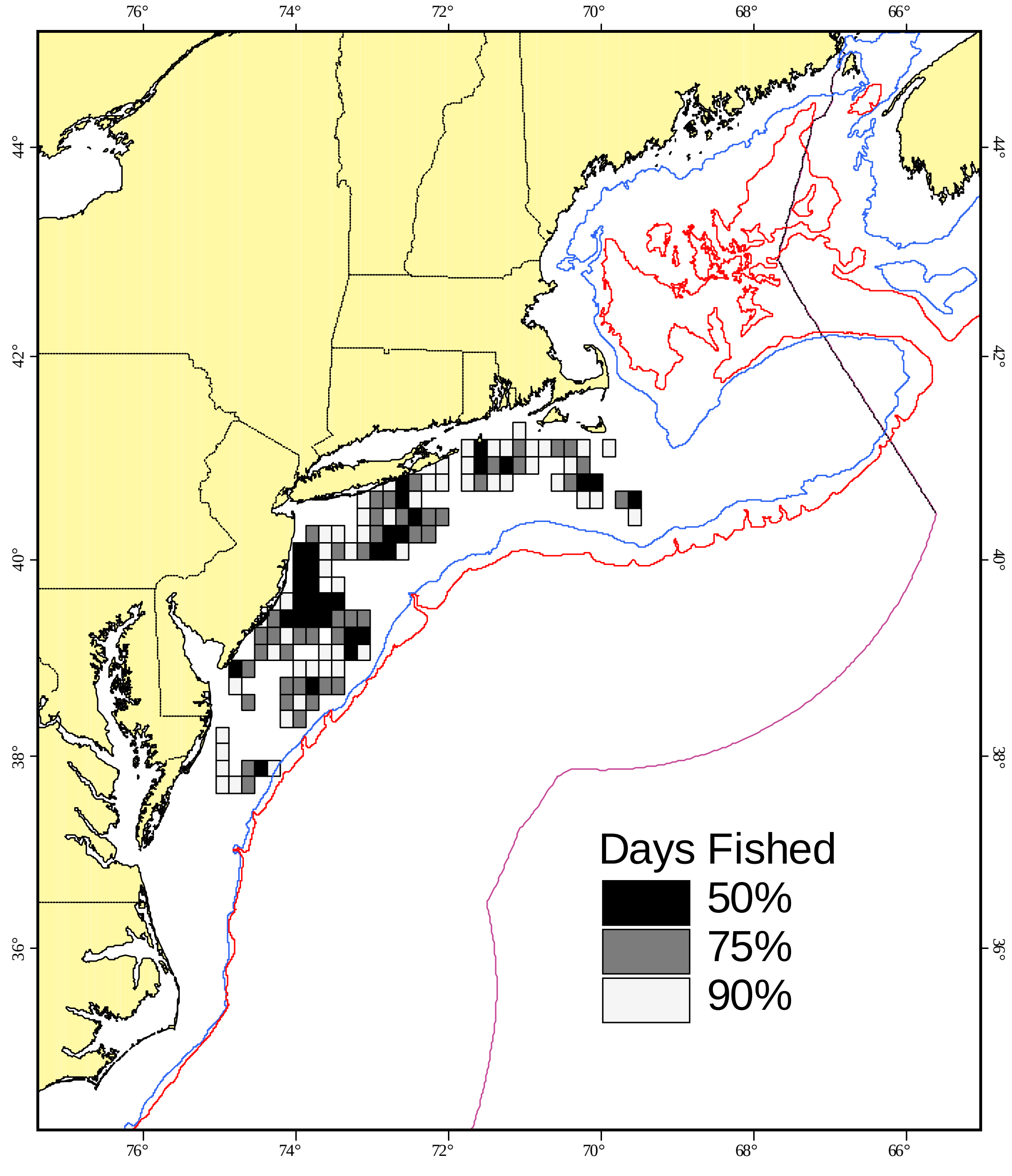


Figure 4.6

Bottom Longlines
1995-2001
N=14,914

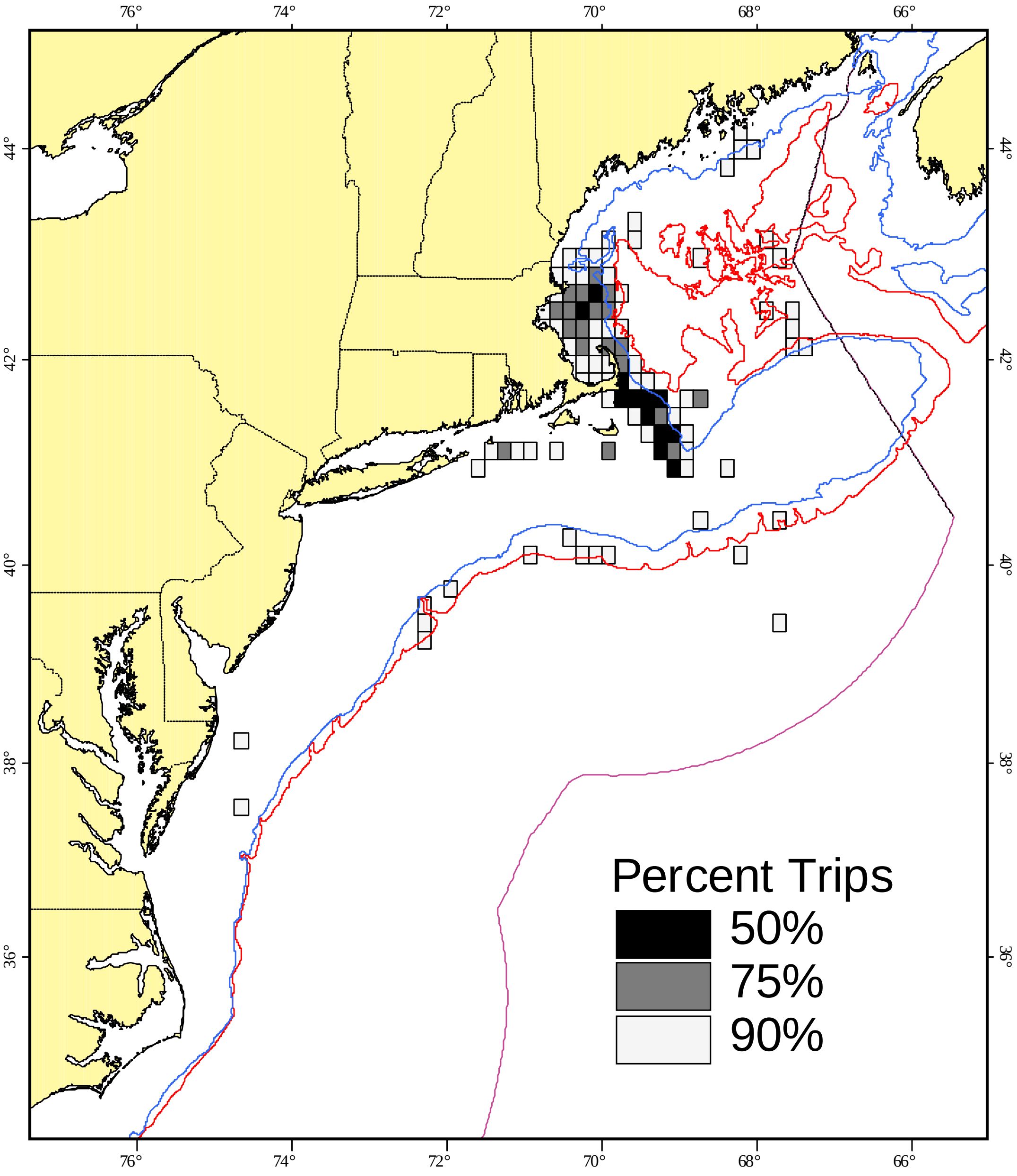


Figure 4.7

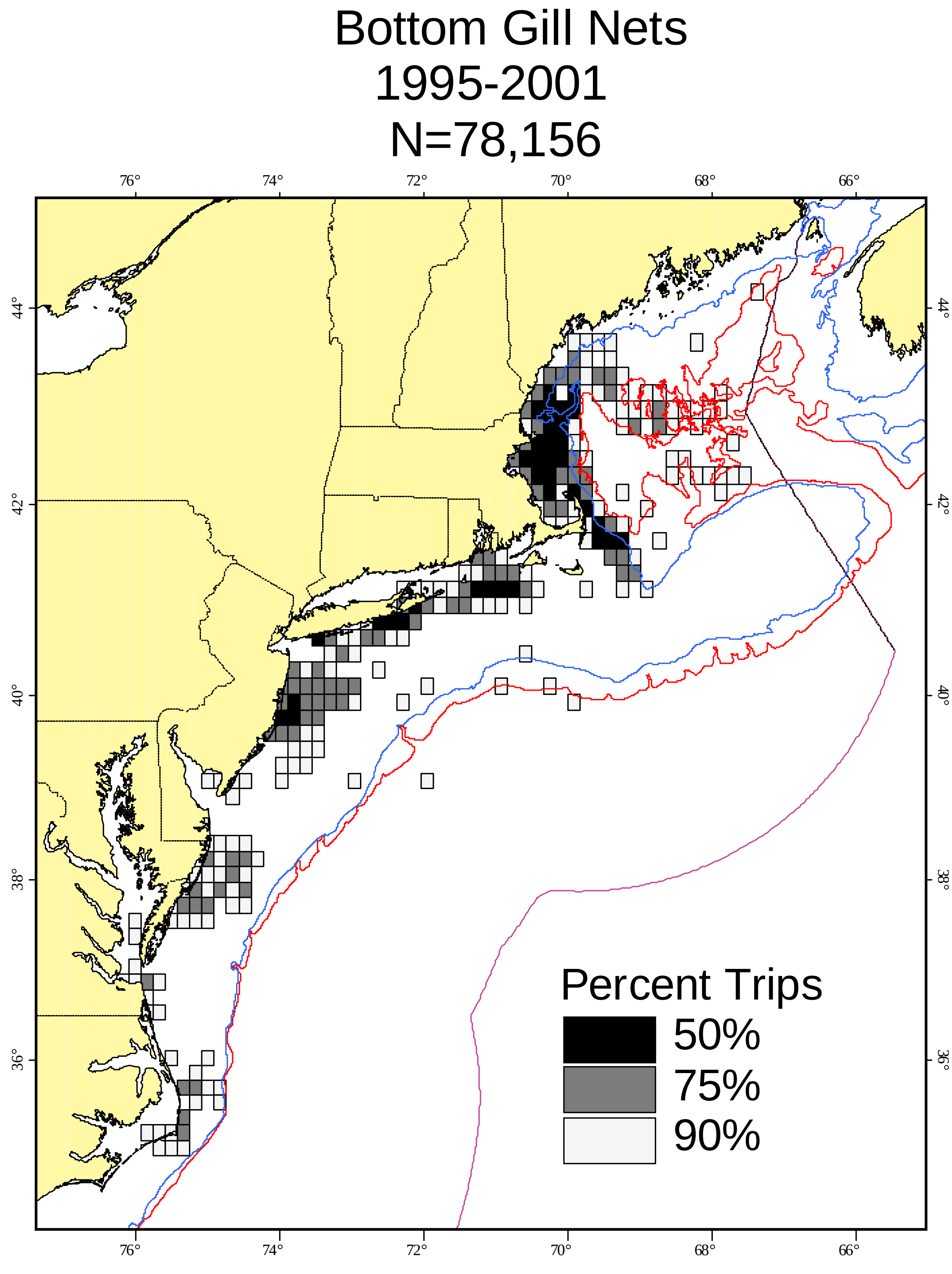

Bottom Gill Nets
1995-2001
N=78,156
76°
74°
72°
70°
68°
66°
44°
42°
40°
38°
36°
Percent Trips
50%
75%
90%

Figure 4.8

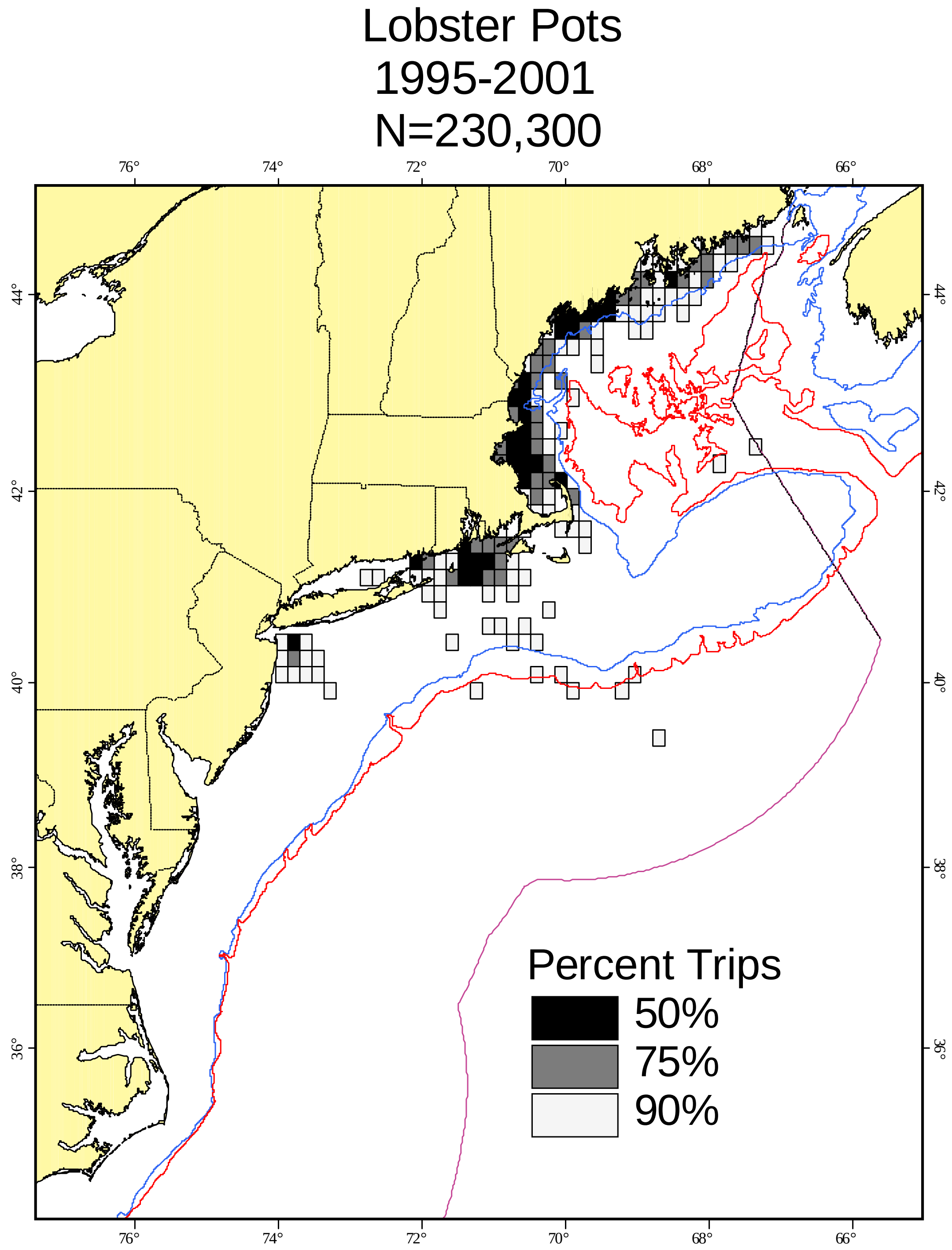

Lobster Pots
1995-2001
N=230,300
76°
74°
72°
70°
68°
66°
44°
42°
40°
38°
36°
Percent Trips
50%
75%
90%

Figure 4.9

Fish Pots
1995-2001
N=8,523

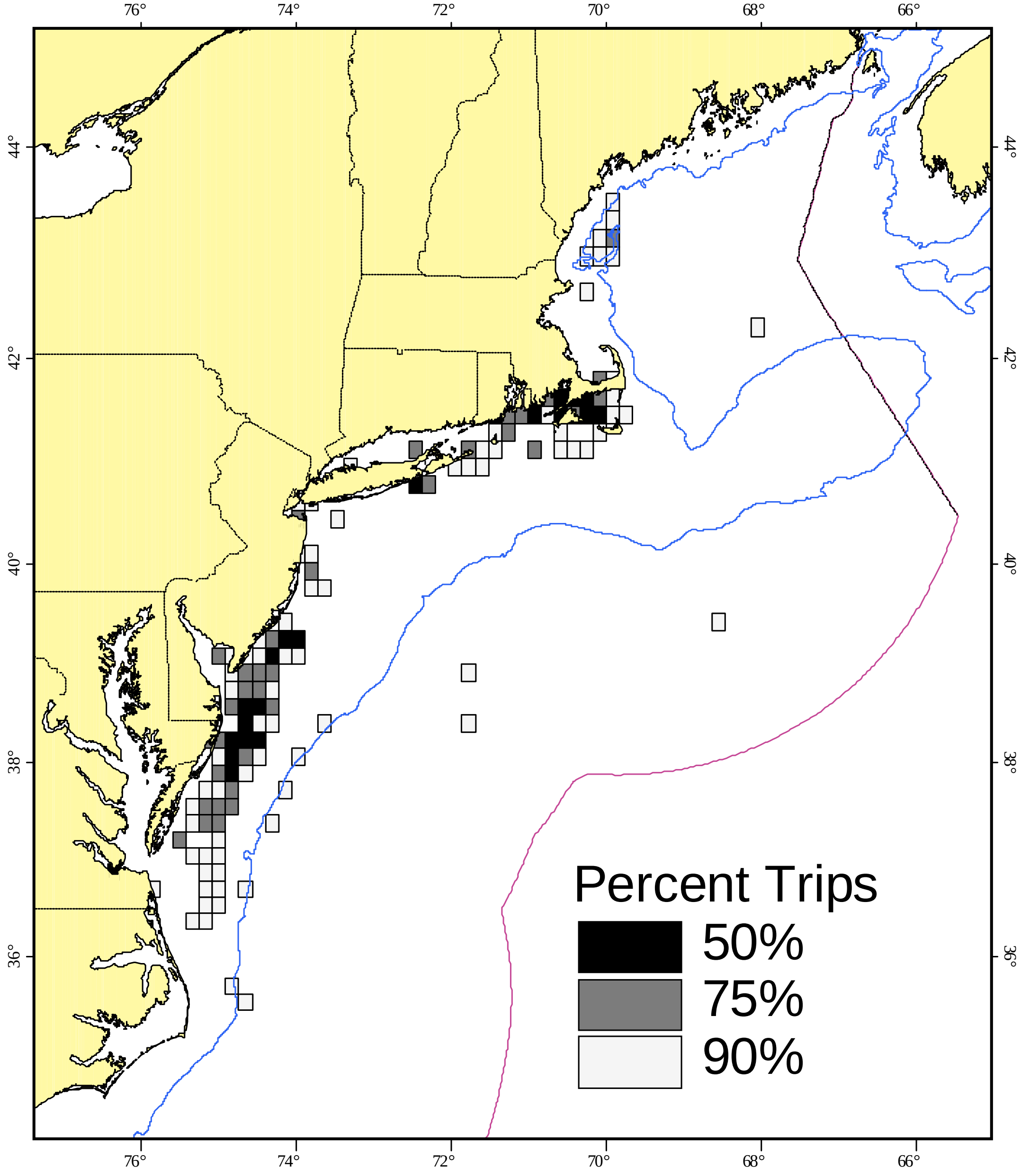


Figure 4.10

Conch/Whelk Pots
1995-2001
N=2,471

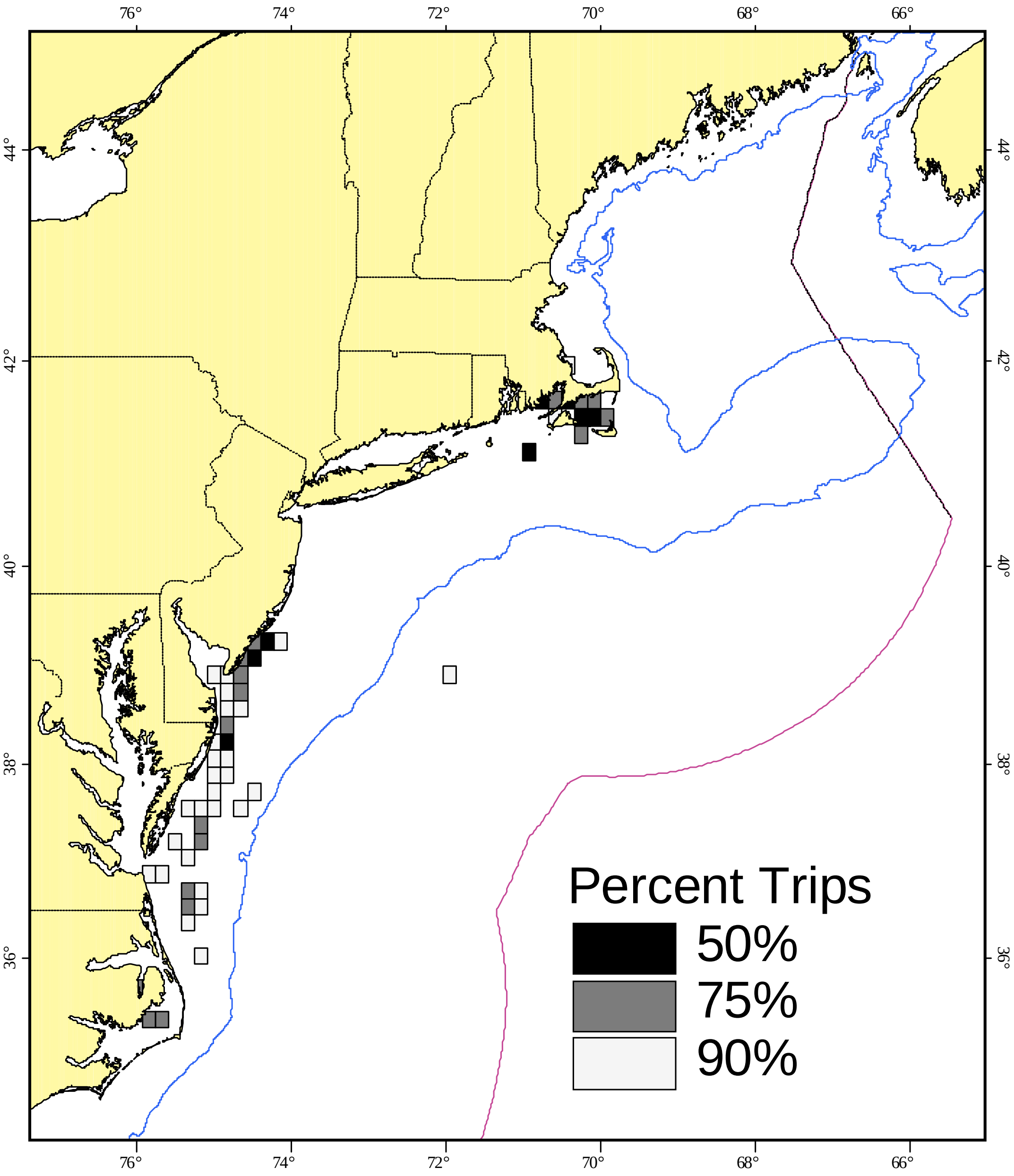
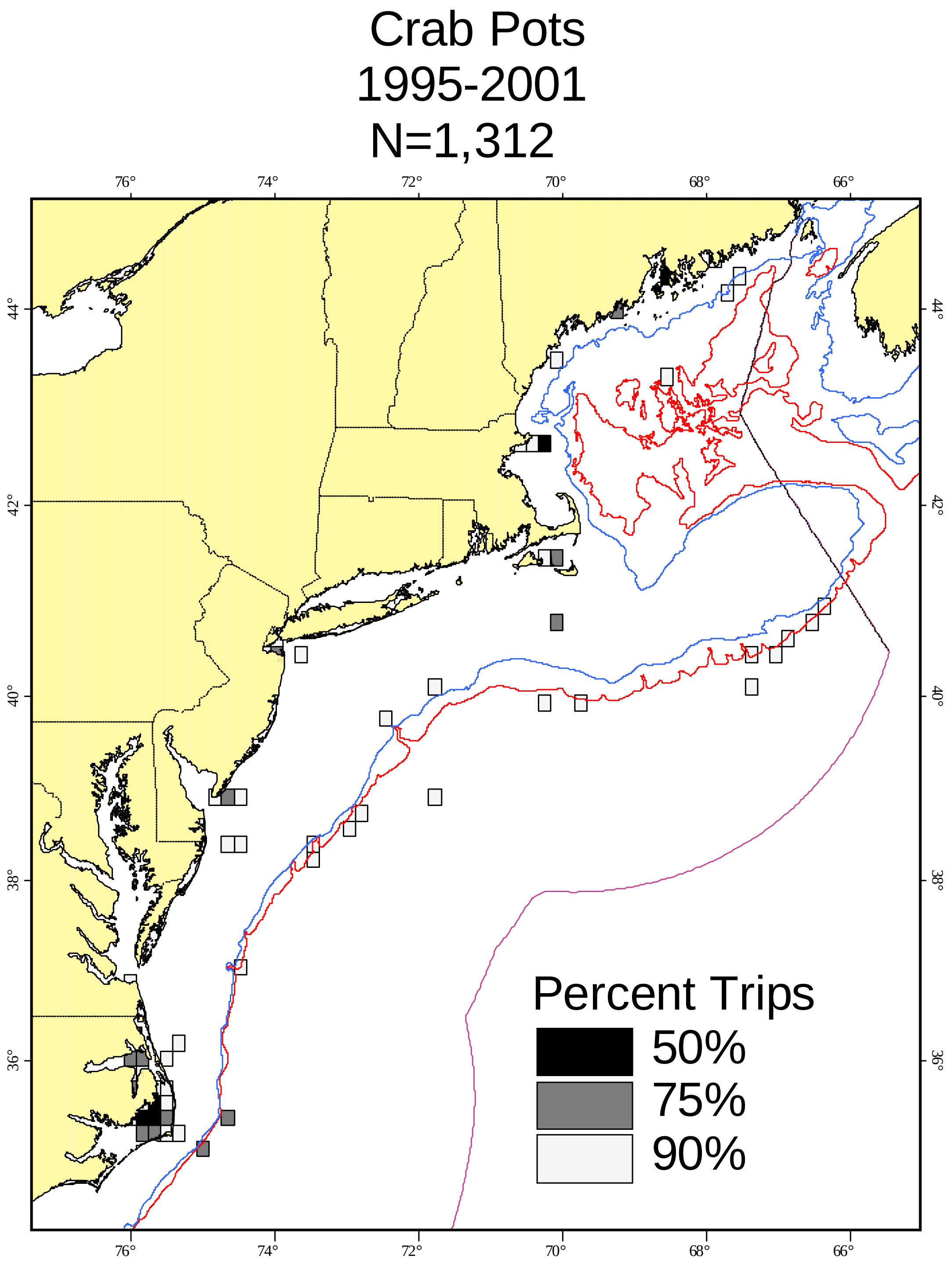


Figure 4.11


Crab Pots
1995-2001
N=1,312
76°
74°
72°
70°
68°
66°
44°
42°
40°
38°
36°
Percent Trips
50%
75%
90%

Appendix 5

Atlantic mackerel EFH Source Document

NOAA Technical Memorandum NMFS-NE-141

Essential Fish Habitat Source Document:

Atlantic Mackerel, *Scomber scombrus*, Life History and Habitat Characteristics

U. S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
National Marine Fisheries Service
Northeast Region
Northeast Fisheries Science Center
Woods Hole, Massachusetts

September 1999

Recent Issues

105. **Review of American Lobster (*Homarus americanus*) Habitat Requirements and Responses to Contaminant Exposures.** By Renee Mercaldo-Allen and Catherine A. Kuropat. July 1994. v + 52 p., 29 tables. NTIS Access. No. PB96-115555.

106. **Selected Living Resources, Habitat Conditions, and Human Perturbations of the Gulf of Maine: Environmental and Ecological Considerations for Fishery Management.** By Richard W. Langton, John B. Pearce, and Jon A. Gibson, eds. August 1994. iv + 70 p., 2 figs., 6 tables. NTIS Access. No. PB95-270906.

107. **Invertebrate Neoplasia: Initiation and Promotion Mechanisms -- Proceedings of an International Workshop, 23 June 1992, Washington, D.C.** By A. Rosenfield, F.G. Kern, and B.J. Keller, comps. & eds. September 1994. v + 31 p., 8 figs., 3 tables. NTIS Access. No. PB96-164801.

108. **Status of Fishery Resources off the Northeastern United States for 1994.** By Conservation and Utilization Division, Northeast Fisheries Science Center. January 1995. iv + 140 p., 71 figs., 75 tables. NTIS Access. No. PB95-263414.

109. **Proceedings of the Symposium on the Potential for Development of Aquaculture in Massachusetts: 15-17 February 1995, Chatham/Edgartown/Dartmouth, Massachusetts.** By Carlos A. Castro and Scott J. Soares, comps. & eds. January 1996. v + 26 p., 1 fig., 2 tables. NTIS Access. No. PB97-103782.

110. **Length-Length and Length-Weight Relationships for 13 Shark Species from the Western North Atlantic.** By Nancy E. Kohler, John G. Casey, Patricia A. Turner. May 1996. iv + 22 p., 4 figs., 15 tables. NTIS Access. No. PB97-135032.

111. **Review and Evaluation of the 1994 Experimental Fishery in Closed Area II on Georges Bank.** By Patricia A. Gerrior, Fredric M. Serchuk, Kathleen C. Mays, John F. Kenney, and Peter D. Colosi. October 1996. v + 52 p., 24 figs., 20 tables. NTIS Access. No. PB98-119159.

112. **Data Description and Statistical Summary of the 1983-92 Cost-Earnings Data Base for Northeast U.S. Commercial Fishing Vessels: A Guide to Understanding and Use of the Data Base.** By Amy B. Gautam and Andrew W. Kitts. December 1996. v + 21 p., 11 figs., 14 tables. NTIS Access. No. PB97-169320.

113. **Individual Vessel Behavior in the Northeast Otter Trawl Fleet during 1982-92.** By Barbara Pollard Rountree. August 1997. v + 50 p., 1 fig., 40 tables. NTIS Access. No. PB99-169997.

114. **U.S. Atlantic and Gulf of Mexico Marine Mammal Stock Assessments -- 1996.** By Gordon T. Waring, Debra L. Palka, Keith D. Mullin, James H.W. Hain, Larry J. Hansen, and Kathryn D. Bisack. October 1997. viii + 250 p., 42 figs., 47 tables. NTIS Access. No. PB98-112345.

115. **Status of Fishery Resources off the Northeastern United States for 1998.** By Stephen H. Clark, ed. September 1998. vi + 149 p., 70 figs., 80 tables. NTIS Access. No. PB99-129694.

116. **U.S. Atlantic Marine Mammal Stock Assessments -- 1998.** By Gordon T. Waring, Debra L. Palka, Phillip J. Clapham, Steven Swartz, Marjorie C. Rossman, Timothy V.N. Cole, Kathryn D. Bisack, and Larry J. Hansen. February 1999. vii + 182 p., 16 figs., 56 tables. NTIS Access. No. PB99-134140.

117. **Review of Distribution of the Long-finned Pilot Whale (*Globicephala melas*) in the North Atlantic and Mediterranean.** By Alan A. Abend and Tim D. Smith. April 1999. vi + 22 p., 14 figs., 3 tables. NTIS Access. No. PB99-165029.

118. **Tautog (*Tautoga onitis*) Life History and Habitat Requirements.** By Frank W. Steimle and Patricia A. Shaheen. May 1999. vi + 23 p., 1 fig., 1 table. NTIS Access. No. PB99-165011.

119. **Data Needs for Economic Analysis of Fishery Management Regulations.** By Andrew W. Kitts and Scott R. Steinback. August 1999. iv + 48 p., 10 figs., 22 tables. NTIS Access. No. PB99-171456.

120. **Marine Mammal Research Program of the Northeast Fisheries Science Center during 1990-95.** By Janeen M. Quintal and Tim D. Smith. September 1999. v + 28 p., 4 tables, 4 app. NTIS Access. No. PB2000-100809.

NOAA Technical Memorandum NMFS-NE-141

This series represents a secondary level of scientifiic publishing. All issues employ thorough internal scientific review; some issues employ external scientific review. Reviews are -- by design -- transparent collegial reviews, not anonymous peer reviews. All issues may be cited in formal scientific communications.

Essential Fish Habitat Source Document:

Atlantic Mackerel, *Scomber scombrus*, Life History and Habitat Characteristics

Anne L. Studholme, David B. Packer, Peter L. Berrien,
Donna L. Johnson, Christine A. Zetlin, and Wallace W. Morse

National Marine Fisheries Serv., James J. Howard Marine Sciences Lab., 74 Magruder Rd., Highlands, NJ 07732

U. S. DEPARTMENT OF COMMERCE
William Daley, Secretary
National Oceanic and Atmospheric Administration
D. James Baker, Administrator
National Marine Fisheries Service
Penelope D. Dalton, Assistant Administrator for Fisheries
Northeast Region
Northeast Fisheries Science Center
Woods Hole, Massachusetts

September 1999

Editorial Notes on Issues 122-152
in the
NOAA Technical Memorandum NMFS-NE Series

Editorial Production

For Issues 122-152, staff of the Northeast Fisheries Science Center's (NEFSC's) Ecosystems Processes Division have largely assumed the role of staff of the NEFSC's Editorial Office for technical and copy editing, type composition, and page layout. Other than the four covers (inside and outside, front and back) and first two preliminary pages, all preprinting editorial production has been performed by, and all credit for such production rightfully belongs to, the authors and acknowledgees of each issue, as well as those noted below in "Special Acknowledgments."

Special Acknowledgments

David B. Packer, Sara J. Griesbach, and Luca M. Cargnelli coordinated virtually all aspects of the preprinting editorial production, as well as performed virtually all technical and copy editing, type composition, and page layout, of Issues 122-152. Rande R. Cross, Claire L. Steimle, and Judy D. Berrien conducted the literature searching, citation checking, and bibliographic styling for Issues 122-152. Joseph J. Vitaliano produced all of the food habits figures in Issues 122-152.

Internet Availability

Issues 122-152 are being copublished, *i.e.*, both as paper copies and as web postings. All web postings are, or will soon be, available at: *www.nefsc.nmfs.gov/nefsc/habitat/efh*. Also, all web postings will be in "PDF" format.

Information Updating

By federal regulation, all information specific to Issues 122-152 must be updated at least every five years. All official updates will appear in the web postings. Paper copies will be reissued only when and if new information associated with Issues 122-152 is significant enough to warrant a reprinting of a given issue. All updated and/or reprinted issues will retain the original issue number, but bear a "Revised (Month Year)" label.

Species Names

The NMFS Northeast Region's policy on the use of species names in all technical communications is generally to follow the American Fisheries Society's lists of scientific and common names for fishes (*i.e.*, Robins *et al.* 1991[a]), mollusks (*i.e.*, Turgeon *et al.* 1998[b]), and decapod crustaceans (*i.e.*, Williams *et al.* 1989[c]), and to follow the Society for Marine Mammalogy's guidance on scientific and common names for marine mammals (*i.e.*, Rice 1998[d]). Exceptions to this policy occur when there are subsequent compelling revisions in the classifications of species, resulting in changes in the names of species (*e.g.*, Cooper and Chapleau 1998[e]).

---

[a] Robins, C.R. (chair); Bailey, R.M.; Bond, C.E.; Brooker, J.R.; Lachner, E.A.; Lea, R.N.; Scott, W.B. 1991. Common and scientific names of fishes from the United States and Canada. 5th ed. *Amer. Fish. Soc. Spec. Publ.* 20; 183 p.

[b] Turgeon, D.D. (chair); Quinn, J.F., Jr.; Bogan, A.E.; Coan, E.V.; Hochberg, F.G.; Lyons, W.G.; Mikkelsen, P.M.; Neves, R.J.; Roper, C.F.E.; Rosenberg, G.; Roth, B.; Scheltema, A.; Thompson, F.G.; Vecchione, M.; Williams, J.D. 1998. Common and scientific names of aquatic invertebrates from the United States and Canada: mollusks. 2nd ed. *Amer. Fish. Soc. Spec. Publ.* 26; 526 p.

[c] Williams, A.B. (chair); Abele, L.G.; Felder, D.L.; Hobbs, H.H., Jr.; Manning, R.B.; McLaughlin, P.A.; Pérez Farfante, I. 1989. Common and scientific names of aquatic invertebrates from the United States and Canada: decapod crustaceans. *Amer. Fish. Soc. Spec. Publ.* 17; 77 p.

[d] Rice, D.W. 1998. Marine mammals of the world: systematics and distribution. *Soc. Mar. Mammal. Spec. Publ.* 4; 231 p.

[e] Cooper, J.A.; Chapleau, F. 1998. Monophyly and interrelationships of the family Pleuronectidae (Pleuronectiformes), with a revised classification. *Fish. Bull. (U.S.)* 96:686-726.

FOREWORD

One of the greatest long-term threats to the viability of commercial and recreational fisheries is the continuing loss of marine, estuarine, and other aquatic habitats.

Magnuson-Stevens Fishery Conservation and
Management Act (October 11, 1996)

The long-term viability of living marine resources depends on protection of their habitat.

NMFS Strategic Plan for Fisheries
Research (February 1998)

The Magnuson-Stevens Fishery Conservation and Management Act (MSFCMA), which was reauthorized and amended by the Sustainable Fisheries Act (1996), requires the eight regional fishery management councils to describe and identify essential fish habitat (EFH) in their respective regions, to specify actions to conserve and enhance that EFH, and to minimize the adverse effects of fishing on EFH. Congress defined EFH as "those waters and substrate necessary to fish for spawning, breeding, feeding or growth to maturity." The MSFCMA requires NMFS to assist the regional fishery management councils in the implementation of EFH in their respective fishery management plans.

NMFS has taken a broad view of habitat as the area used by fish throughout their life cycle. Fish use habitat for spawning, feeding, nursery, migration, and shelter, but most habitats provide only a subset of these functions. Fish may change habitats with changes in life history stage, seasonal and geographic distributions, abundance, and interactions with other species. The type of habitat, as well as its attributes and functions, are important for sustaining the production of managed species.

The Northeast Fisheries Science Center compiled the available information on the distribution, abundance, and habitat requirements for each of the species managed by the New England and Mid-Atlantic Fishery Management Councils. That information is presented in this series of 30 EFH species reports (plus one consolidated methods report). The EFH species reports comprise a survey of the important literature as well as original analyses of fishery-independent data sets from NMFS and several coastal states. The species reports are also the source for the current EFH designations by the New England and Mid-Atlantic Fishery Management Councils, and have understandably begun to be referred to as the "EFH source documents."

NMFS provided guidance to the regional fishery management councils for identifying and describing EFH of their managed species. Consistent with this guidance, the species reports present information on current and historic stock sizes, geographic range, and the period and location of major life history stages. The habitats of managed species are described by the physical, chemical, and biological components of the ecosystem where the species occur. Information on the habitat requirements is provided for each life history stage, and it includes, where available, habitat and environmental variables that control or limit distribution, abundance, growth, reproduction, mortality, and productivity.

Identifying and describing EFH are the first steps in the process of protecting, conserving, and enhancing essential habitats of the managed species. Ultimately, NMFS, the regional fishery management councils, fishing participants, Federal and state agencies, and other organizations will have to cooperate to achieve the habitat goals established by the MSFCMA.

A historical note: the EFH species reports effectively recommence a series of reports published by the NMFS Sandy Hook (New Jersey) Laboratory (now formally known as the James J. Howard Marine Sciences Laboratory) from 1977 to 1982. These reports, which were formally labeled as *Sandy Hook Laboratory Technical Series Reports*, but informally known as "Sandy Hook Bluebooks," summarized biological and fisheries data for 18 economically important species. The fact that the bluebooks continue to be used two decades after their publication persuaded us to make their successors – the 30 EFH source documents – available to the public through publication in the *NOAA Technical Memorandum NMFS-NE* series.

JAMES J. HOWARD MARINE SCIENCES LABORATORY
HIGHLANDS, NEW JERSEY
SEPTEMBER 1999

JEFFREY N. CROSS, CHIEF
ECOSYSTEMS PROCESSES DIVISION
NORTHEAST FISHERIES SCIENCE CENTER

Contents

Tables

Figures

INTRODUCTION

Atlantic mackerel, *Scomber scombrus* L. (Figure 1), is a fast swimming, pelagic schooling species distributed in the northwest Atlantic from the Gulf of St. Lawrence to Cape Lookout, North Carolina (Sette 1943, 1950; Anderson 1976; MAFMC 1994). While there are two separate spawning contingents in the northwest Atlantic (Sette 1950), since 1975 all mackerel in this area have been assessed as a unit stock (Anderson 1982) and are considered one stock for management purposes (MAFMC 1994). Atlantic mackerel are managed under the Mid-Atlantic Fishery Management Plan for Atlantic mackerel, squid and butterfish (MAFMC 1994). This EFH source document provides information on the distribution, life history and habitat characteristics of Atlantic mackerel in the northwest Atlantic extending from Cape Hatteras to Georges Bank and the Gulf of Maine.

LIFE HISTORY

A brief synopsis of the life history of Atlantic mackerel is provided in Amendment #5 to the Fishery Management Plan for Atlantic Mackerel, Squid and Butterfish Fisheries (MAFMC 1994). More specific information is provided here and in other reviews (see Sette 1943, 1950; Bigelow and Schroeder 1953; Collette, in prep.). Since there is an important winter fishery on Atlantic mackerel on the eastern continental shelf where they occur (Maguire *et al*. 1987), the two major spawning contingents (see below) are managed as a single transboundary stock. Thus, where appropriate, information will be provided on both northern and southern groups.

EGGS

The eggs of Atlantic mackerel are pelagic and spherical, ranging in size from 1.01-1.28 mm (avg. = 1.3 mm) in diameter, and have one oil globule ranging from 0.22-0.38 mm (avg. = 0.29 mm) in diameter (Berrien 1975). Sampling in the Gulf of St. Lawrence indicates that egg size decreased over time and in relation to ambient temperatures (Ware 1977).

LARVAE

Larvae average about 3.1-3.3 mm standard length (SL) at hatching and have a large yolk sac; the eyes are large and unpigmented (Sette 1943; Bigelow and Schroeder 1953; Colton and Marak 1969; Berrien 1975; Ware and Lambert 1985; Scott and Scott 1988). Hatching occurs at 90-120 h post-fertilization at an average temperature of 13.8°C (Berrien 1975). The 50% threshold for the onset of feeding is 3.8 mm (Ware and Lambert 1985). At about 4-6 mm the yolk sac is absorbed by which time there is a considerable change in body pigmentation and by 192 h, teeth are present (Berrien 1975). Larvae undergo major changes in body form and Sette (1943) describes a transition stage between the larval and post-larval stages (~ 9-10 mm) where fins are in various stages of development. This probably enhances successful prey capture as well as predator avoidance (Ware and Lambert 1985). To maintain rapid growth rates, with average digestive times of 1-2 h, Peterson and Ausubel (1984) concluded that the larvae must feed constantly.

JUVENILES

Post-larvae gradually transform from planktonic to swimming and schooling behavior at about 30-50 mm (Sette 1943). Fish reach a length of about 50 mm in approximately two months at which time they closely resemble adults and reach 20 cm in December after about one year of growth (Sette 1943; Bigelow and Schroeder 1953; Anderson and Paciorkowski 1980; Berrien 1982; Collette, in prep.). Kendall and Gordon (1981) show somewhat faster larval and juvenile growth rates based on daily growth increments from otoliths taken from fish collected in the Middle Atlantic Bight; i.e., approximately 70-80 mm in two months; however, these were not verified by comparison with fish of known age. Ware and Lambert (1985) found that in St. Georges Bay, Nova Scotia, at 15-17°C, growth rates of juveniles (> 15 mm) averaged 0.73 mm/d from birth to metamorphosis, similar to the estimates by Kendall and Gordon (1981). Using daily growth rings, D'Amours *et al*. (1990) estimated that young mackerel from the northern contingent would grow faster earlier in their first growing season which would be consistent with Sette's (1950) conclusions. However, Simard *et al*. (1992) calculated that growth curves of juvenile Atlantic mackerel, based on otolith samples from the northern and southern spawning groups were not significantly different at least up to 90 days in age.

ADULTS

By the end of their second year, Atlantic mackerel attain a size of about 26 cm and after five years about 33 cm (Anderson 1973; Isakov 1973; Stobo and Hunt 1974). Fish that are 6 years old can reach a length of 39-40 cm. Based on studies of Canadian mackerel, MacKay (1967) theorized that growth is population density dependent; i.e., that abundant year classes grow more slowly than less abundant year classes, although Moores *et al*. (1975) did not find this to be true for Newfoundland fish. Overholtz (1989) found the 1982 cohort to be one of the slowest growing on record; it is one of the largest recruiting year-classes recorded. Large differences in mackerel growth suggest that year-class size partially influences the initial pattern of growth during a cohort's first years (Overholtz *et al*. 1991b). Thus, early growth may be related to year-class size, while stock size may be more influential after the juveniles join the offshore adults (Overholtz *et al*. 1991b; Collette, in prep.).

The adults are highly mobile and school. They are obligate swimmers due to the absence of a swimbladder and the necessity for ram gill ventilation to meet blood oxygenation demands (Roberts 1975). Nevertheless this species exhibits diurnal changes in activity, swimming faster during the day than at night (Olla *et al*. 1975, 1976). Under laboratory conditions, at temperatures ranging from 7.3-15.8°C (within their preferred range), swimming speed of adults averaged 36 cm/s during the day and 29 cm/s at night (Olla *et al*. 1975, 1976). The fish continued to school both day and night although there were diurnal changes in cohesiveness of the group.

REPRODUCTION

There is some variation in estimates of size and age at maturity. Based on samples of Atlantic mackerel collected from 1987-1989 by the Northeast Fisheries Science Center (NEFSC) groundfish surveys, median length at maturity (L_{50}) was 25.7 cm for females and 26.0 cm for males; median age (A_{50}) was 1.9 years for both (O'Brien *et al*. 1993). By age 3, 99% of the females and 97% of the males were mature (O'Brien *et al*. 1993). Fish collected in Newfoundland waters from June-September 1970-1973 had higher values for L_{50} of 34 cm and 35 cm for females and males respectively (Moores *et al*. 1975). MacKay (1967) reported first spawning for mackerel occurred at age 2 and at lengths > 30 cm for fish collected in May-July 1965-1966 from the Gulf of St Lawrence and coastal Nova Scotia and Massachusetts. These differences in median maturity may be due to the slower growth of larger year classes that may delay spawning from one to three years (MacKay 1973; Overholtz 1989). Consequently, both year-class size and adult stock size may be important factors regulating growth in Atlantic mackerel (Overholtz 1989; Overholtz *et al*. 1991b).

Spawning occurs during spring and summer and progresses from south to north as the surface waters warm and fish migrate (Sette 1943). There are two spawning contingents; a southern group that spawns primarily in the Mid-Atlantic Bight and Gulf of Maine from mid-April to June and a northern contingent that spawns in the southern Gulf of St. Lawrence from the end of May to mid-August (Berrien 1982). The southern contingent begins the spring spawning migration by moving inshore between Delaware Bay and Cape Hatteras, usually between mid-March and mid-April depending to some extent on water temperature (Berrien 1982). The northern contingent begins to move inshore off southern New England usually in late May, mixing temporarily with part of the southern contingent before migrating eastward along the coast of Nova Scotia. Here other mackerel schools from offshore join the fish before moving into the Gulf of St. Lawrence to spawn (Berrien 1982). Small fish (< 30 cm) lag behind larger fish and spawn later (Berrien 1982).

Most of the spawning occurs in the shoreward half of continental shelf waters, although there is some spawning on the shelf edge and beyond (Berrien 1982; Collette, in prep.). Sette (1943) described the area bordered by southern New England and the Middle Atlantic states as the most important spawning grounds for mackerel. Current information indicates that the oceanic bight between Chesapeake Bay and southern New England is the most productive area. The Gulf of St. Lawrence is somewhat less so although the southern side is considered extremely productive for the northern contingent (MacKay 1973) while the Gulf of Maine and coast of outer Nova Scotia are the least (Sette 1950; Collette, in prep.). Some open bays; i.e., Cape Cod Bay and Massachusetts Bay, are sites of some importance with spawning fish abundant or common from May to July and August (Table 1). While according to Wheatland (1956), spawning occurs rarely in Gardiner's Bay and Long Island Sound, recent assessments of relative abundance of eggs and larvae in these areas show that both life stages are highly abundant and abundant in April and May (Table 2). Well-enclosed bays, especially those receiving considerable river inflow such as Chesapeake Bay and Delaware Bay show little evidence of spawning (Table 2).

Atlantic mackerel are serial, or batch spawners, with estimates of total fecundity ranging from 285,000 to 1.98 million eggs for southern contingent mackerel between 31 and 44 cm fork length (FL) (Morse 1980). Based on a very limited sample of northern contingent mackerel, fecundity estimates ranged from 211,000 to 397,000 eggs for 35 and 40 cm females respectively (MacKay 1973). Analysis of egg diameter frequencies indicate that five to seven egg batches are spawned by each female (Morse 1980).

FOOD HABITS

Atlantic mackerel are opportunistic feeders that can ingest prey either by individual selection of organisms or by passive filter feeding (Pepin *et al*. 1988). Filter feeding occurs when small plankton are abundant and mackerel swim through patches with mouth slightly agape, filtering food through their gill rakers (MacKay 1979). According to MacKay (1979), particulate feeding is the principal feeding mode in the spring and fall, while filter feeding predominates in the summer in the Gulf of St. Lawrence. Moores *et al*. (1975) maintain that the diet of fish from Newfoundland suggests that particulate feeding occurs there throughout the season.

Larvae feed primarily on zooplankton (Collette, in prep.). First-feeding larvae (3.5 mm) collected from Long Island Sound were found to be phytophagous while slightly larger individuals (> 4.4 mm) fed on copepod nauplii (Peterson and Ausubel 1984; Ware and Lambert 1985). Fish > 5 mm fed on copepodites of *Acartia* and *Temora* while diets of fish > 6 mm contained adult copepods (Peterson and Ausubel 1984). Larvae > 6.4 mm were also cannibalistic, feeding on 3.5-4.5 mm conspecifics (Peterson and Ausubel 1984; Fortier and Villeneuve 1996). Consumption rates of larvae average between 25 and 75% body weight per day and they probably feed continuously. Larvae feed selectively, primarily on the basis of prey visibility (Peterson and Ausubel 1984). Fortier and Villeneuve (1996), studying larval mackerel from the Scotian Shelf, found that with increasing larval length, the diet shifted from copepod nauplii to copepod and fish larvae; the fish larvae included yellowtail flounder, silver hake, redfish and a large proportion of conspecifics. Predation was stage-specific; only the newly hatched larvae of a given species were ingested. However, piscivory was limited at densities of fish larvae < 0.1/m^3 and declined with increasing density of nauplii and with increasing number of alternative copepod prey ingested.

Juveniles eat mostly small crustaceans such as copepods, amphipods, mysid shrimp and decapod larvae (Collette, in prep.). They also feed on small pelagic mollusks (*Spiratella* and *Clione*) when available (Collette, in prep.). Adults feed on the same food as juveniles but diets also include a wider assortment of organisms and larger prey items. For example, euphausiid, pandalid and crangonid shrimp are common prey; chaetognaths, larvaceans, pelagic polychaetes and larvae of many marine species have been identified in mackerel stomachs (Collette, in prep.). Bigelow and Schroeder (1953) found many Gulf of Maine mackerel feeding on *Calanus* as well as other copepods. Larger prey such as squids (*Loligo*) and fishes (silver and other hakes, sand lance, herring, and sculpins) are not uncommon, especially for large mackerel (Bowman *et al*. 1984). Under laboratory conditions, mackerel also fed on *Aglantha digitale*, a small transparent medusa common in temperate and boreal waters (Runge *et al*. 1987). The 1973 -1990 NEFSC bottom trawl survey data on food habits for two size classes of mackerel (11-30 cm; 30-50 cm) for 1973-1980 and 1981-1990 reflects this diversity (Figure 2). While there is variability between the two size classes and between the two survey periods, copepods, euphausiids and various crustaceans could be considered relative staples in the diet.

Immature mackerel begin feeding in the spring; older fish feed until gonadal development begins, stop feeding until spent and then resume prey consumption (Berrien 1982; Collette, in prep.). Under experimental conditions in which larval fish (3-10 mm in length) were presented as part of natural zooplankton assemblages, prey preference by mackerel was positively size selective and predation rates were not influenced by larval fish density (Pepin *et al*. 1987). Subsequent studies indicated that mackerel may achieve a higher rate of energy intake by switching to larger prey and increasing search rate as prey size and total abundance increase (Pepin *et al*. 1988). Filter feeding activity also increased with increasing prey density and Pepin *et al*. (1988) suggest that feeding rates under natural conditions of prey abundance (0.1 g wet weight/m^3) indicate that mackerel would not be satiated if foraging were restricted only to daylight.

PREDATION

Predation has a major influence on the dynamics of northwest Atlantic mackerel (Overholtz *et al*. 1991b). In fact, predation mortality is probably the largest component of natural mortality on this stock, and based on model predictions, may be higher than previously thought (Overholtz *et al*. 1991b). Atlantic mackerel serve as prey for a wide variety of predators including other mackerel, dogfish, tunas, bonito, and striped bass (Collette, in prep.). Small mackerel are prey for Atlantic cod and squid, which feed on fish < 10 to 13 cm in length (Collette, in prep.). Pilot whales, common dolphins, harbor seals, porpoises and seabirds are also significant predators (Smith and Gaskin 1974; Payne and Selzer 1983; Overholtz and Waring 1991; Montevecchi and Myers 1995). Other predators include swordfish, bigeye thresher, thresher, shortfin mako, tiger shark, blue shark, spiny dogfish, dusky shark, king mackerel, thorny skate, silver hake, red hake, bluefish, pollock, white hake, goosefish and weakfish (Scott and Tibbo 1968; Maurer and Bowman 1975; Stillwell and Kohler 1982, 1985; Bowman and Michaels 1984; Collette, in prep.).

MIGRATION/STOCK STRUCTURE

As stated previously, the two major spawning contingents are managed as a single transboundary stock. Sette (1950) described northern and southern population contingents of Atlantic mackerel in the northwest Atlantic with different spring and autumn migration patterns and summer distributions. Various methods have attempted to discriminate the two contingents in the northwest Atlantic, including meristic analyses (MacKay and Garside 1969), comparison of parasitic fauna (Isakov 1976), genetic variability (Maguire *et al*. 1987) and differences in otoliths (Gregoire and Castonguay 1989; Castonguay *et al*. 1991). While there were some significant differences, overlaps in character distributions have prevented the development of a useful discrimination method.

During the winter, Atlantic mackerel apparently overwinter in deep water of the continental shelf from Sable Island Bank, off Nova Scotia to the Chesapeake Bay region and in spring move inshore and northeast; this pattern is reversed in the fall (Sette 1950; Leim and Scott 1966; MacKay 1967; Berrien 1982). In April and early May the fish form the two spawning aggregations; i.e., a southern contingent that spawns off New Jersey and New York, and a northern contingent that spawns in the Gulf of St. Lawrence.

As fish from the southern contingent move northeast along the coast, they are joined by the schools from the northern contingent which are also moving inshore. The overwintering area and timing of migration varies annually, probably influenced by meteorological events or regional conditions with low spring temperatures significantly delaying the timing, extent and duration (Murray *et al*. 1983; Murray 1984). In fact, the seasonal cycle in temperature in the waters of the Mid-Atlantic and southern New England [well-mixed water column in winter with temperatures < 4°C near the coast to > 8°C near the shelf edge; warming surface layers in spring and gradual warming from south (to 25°C) to north (to about 18°C) and subsequent fall cooling] is certainly an important environmental factor influencing migration and distribution (Overholtz *et al*. 1991a). This is supported by field studies that have shown that mackerel are intolerant of temperatures < 5-6°C or > 15-16°C (Overholtz and Anderson 1976) and laboratory studies that have confirmed that as temperatures departed from preferred ranges (7.3-15.8°C) swimming speeds of adult mackerel increased, reflecting thermal avoidance (Olla *et al*. 1975, 1976). By late April and May, the southern contingent is distributed off New Jersey and Long Island moving into the western side of the Gulf of Maine by June and July, and returning to the shelf edge probably between Long Island and Chesapeake Bay by October (Sette 1950; Berrien 1982).

The northern contingent, by late spring, has moved inshore off southern New England, mixing temporarily with the southern contingent before migrating eastward along the coast of Nova Scotia, and moving into the Gulf of St. Lawrence where they spawn in June and July. Some fish however, remain along the coasts of Maine and Nova Scotia throughout the summer. These fish again mix with fish from the southern group in late fall in the Gulf of Maine before moving to the outer shelf between Sable Island Bank and Long Island to overwinter (Sette 1950; Parsons and Moores 1974; Moores *et al*. 1975). Temperature may not be as limiting for this contingent since D'Amours and Castonguay (1992) found that mackerel occurred in June in the Cabot Strait off of eastern Cape Breton Island at 2.8°C, 4°C colder than the 7°C isotherm proposed by Sette (1950) as the thermal barrier to northern migration.

HABITAT CHARACTERISTICS

An extensive literature review and synthesis has provided detailed information on the life history and habitat requirements of Atlantic mackerel (Table 3). The review is primarily limited to U.S. waters; however, due to the intermixing of the two contingents, some information also relates to fish in Canadian waters.

EGGS

The eggs are pelagic in water over 34 ppt (Fritzsche 1978), floating in surface waters above the thermocline or in the upper 10-15 m (Sette 1943; Berrien 1982). Incubation time depends primarily on temperature: at 11°C, 7.5 days; at 13°C, 5.5 days and at 16°C, 3.6 days (Worley 1933). Lanctot (1980) had similar results: at 11°C, 8 days; at 13°C, 5.8 days and at 16°C, 3.9 days.

Based on the NEFSC Marine Resources Monitoring, Assessment, and Prediction (MARMAP) offshore ichthyoplankton surveys, eggs were collected at near surface temperatures ranging from 5-23°C with the largest proportion between ~ 7°C and 16°C (Figure 3). In April, the highest abundances were collected from 7-9°C; in May, from 9-12°C; in June, from 10-12°C; while the few collected in July and August were at a wide range of temperatures (11-23°C) (Figure 3). This is consistent with findings by Berrien (1978) who reported that for May 1966, the weighted mean surface temperature for all eggs collected from Martha's Vineyard to Chesapeake Bay was 11.0°C (range 6.3-16.9°C) with 97% collected at 8.7-13.8°C. Sette (1943), for eggs collected in 1932, reported a weighted mean of 10.9°C surface temperature with 98% occurring from 9.0-13.5°C.

Mortality may be influenced by acclimation temperatures of adult fish (Lanctot 1980). Worley (1933) found minimal mortality at 16°C which corresponded to capture temperature of the adults. Lockwood *et al*. (1977) found mortalities < 20% between 9.4 and 15.1°C. Ware and Lambert (1985) also found that egg mortality rates of mackerel from St. Georges Bay, Nova Scotia were highly correlated with the rate of warming during the spawning season.

Salinities may also affect survival. Peterson and Ausubel (1984) attributed high egg mortality to unusually low salinities (23 ppt) in Long Island Sound as compared with usual values of 25-27 ppt.

Eggs were collected at depths in the water column ranging from 10-325 m; the majority were collected from 30-70 m (Figure 3). In April, the highest numbers of eggs were collected at depths of 10-30 m; in May from 30-50 m; in June, July and August, at depths of 30-70 m (Figure 3). Ware and Lambert (1985) found that mackerel eggs in St. Georges Bay tended to concentrate near the surface, particularly under light winds and declined exponentially with depth with the rate of decline a function of egg diameter and temperature gradient in the top 5 m.

LARVAE

Based on the NEFSC MARMAP ichthyoplankton surveys, larvae are found at water column temperatures ranging from 6-22°C with the largest proportion between about 8°C and 13°C (Figure 4). In May, the majority of larvae were found at 8-10°C; in June at 8-11°C; in July at 8°C and 10-11°C; and in August at 9°C and 12-13°C (Figure 4). For larvae collected during May, June and August 1966, Berrien (1978) indicated that surface water temperatures ranged from 12.3-20.7°C with 96% occurring from 13.7-16.8°C. Ware and Lambert (1985) found that larval mortality rates (~ 42 %/d) were positively correlated with temperature.

Larvae were collected at depths ranging from 10-130 m (Figure 4). With the exception of July when 50% were collected at a depth of 70 m, larvae were primarily distributed at depths ≤ 50 m (Figure 4). Sette (1943) reports that larvae vertically migrate diurnally from the surface at night to the thermocline during the day. Ware and Lambert (1985) found that in St. Georges Bay, recently-hatched larvae were collected at depths of 5-10 m and as they grew, moved progressively closer to the surface during the day; at sizes ranging from 3-8 mm, median depth increased at a rate of 0.7 m/d.

JUVENILES

Based on the 1963-1997 NEFSC bottom trawl surveys, juveniles in the fall were caught at temperatures ranging from 4-22^{o}C, with the majority (> 55%) occurring at 10^{o}C. In the winter 90% were collected at 5-6^{o}C (range: 3-12°C) (Figure 5). The temperatures at which juveniles were found were a little broader in spring (4-17^{o}C) and summer (4-19^{o}C). Although the majority of juveniles (> 60%) were still found at 5-6^{o}C in the spring, by summer they wee found at higher temperatures with > 40% collected at 8^{o}C and 40% at 13^{o}C (Figure 5).

In the fall, the majority of juveniles (> 77%) were at depths of 20-40 m (range: surface to 320 m); in the winter > 60% were at slightly deeper depths (50-70 m) while by spring they were widely dispersed through the water column (surface to 340 m) but concentrated (> 75%) at depths ranging from 30-90 m (Figure 5). By summer, fish were higher in the water column (surface to 210 m) with ~ 94% distributed from 20-50 m in two peaks (Figure 5).

Based on collections from the 1978-1996 Massachusetts inshore bottom trawl surveys, juveniles were most abundant at 11^{o}C in spring and 9 and 13^{o}C in autumn, and at depths of 10 and 50 m in the spring and 25 and 60 m in the autumn (Figure 6).

Based on collections from the 1990-1996 Rhode Island Narragansett Bay bottom trawl surveys, juveniles were captured in summer at bottom depths between 6.1-15.2 m (20-50 ft) and were most abundant at 12.2-15.2 m (40-50 ft) (Figure 7). They were caught at bottom temperatures of 19^{o}C in summer and at 11 and 15^{o}C in autumn (Figure 7).

Juveniles collected in otter trawl surveys in the Hudson-Raritan estuary (New York and New Jersey) during July 1997 were found at depths ranging from 4.9-9.8 m. Salinities ranged from 26.1-28.9 ppt, dissolved oxygen from 7.3-8.0 mg/l and temperatures from 17.6-21.7^{o}C (S. Wilk, NMFS, NEFSC, James J. Howard Marine Sciences Laboratory, Highlands, NJ, personal communication).

ADULTS

Based on the NEFSC bottom trawl surveys, adults in the fall were found at a slightly narrower range of temperatures (4-16^{o}C) with > 80% caught from 9-12°C (Figure 8). Winter distribution was similar to that of the juveniles with nearly 70% at 5-6^{o}C (range: 3-13^{o}C) (Figure 8). In the spring, temperature ranges were similar (2-14^{o}C), but adults were distributed more evenly through a temperature band of 5-13^{o}C with > 25% at 13^{o}C (Figure 8). By summer, fish were found at temperatures ranging from 4-14^{o}C with > 30% at 10-11^{o}C and > 35% at 14^{o}C (Figure 8). These temperatures are within the ranges previously reported for mackerel. In addition, Bigelow and Schroeder (1953) indicate that the highest temperature at which mackerel are commonly found is 20^{o}C while commercial catches are sometimes taken at 7^{o}C. In the northern Gulf of St. Lawrence, concentrations of mackerel were found at 4^{o}C; however, the overall probability of occurrence inshore was higher when near-bottom temperatures were ≥ 7^{o}C (Castonguay *et al*. 1992).

As stated previously in the migration section, field studies have shown that mackerel are intolerant of temperatures < 5-6^{o}C or > 15-16^{o}C (Overholtz and Anderson 1976) and laboratory studies have confirmed that as temperatures departed from preferred ranges (7.3-15.8^{o}C), swimming speeds of adult mackerel increased, reflecting thermal avoidance (Olla *et al*.1975, 1976). Again, temperature may not be as limiting for the northern contingent since D'Amours and Castonguay (1992) found that mackerel occurred in June off of eastern Cape Breton Island at 2.8^{o}C, 4^{o}C colder than the 7^{o}C isotherm proposed by Sette (1950) as the thermal barrier to northern migration.

Based on the NEFSC bottom trawl surveys, adults in the fall were spread from 10-340 m; however > 50% were caught at 60-80 m (Figure 8). By winter, while fish were still found at depths of 10-270 m, ~ 50% were found at depths of 20-30 m (Figure 8). By spring fish were broadly dispersed from the surface to as deep as 380 m; however, around 25% were at depths of 160-170 m (Figure 8). By summer, schools had again moved upward in the water column, swimming at depths of 10-180 m with > 60% at depths of 50-70 m (Figure 8). This depth range is broader than reported by Bigelow and Schroeder (1953) who stated that while mackerel can swim as deep as 183 m, in spring, summer and into fall they swim at depths of 46-55 m or less. According to Sette (1950) larger fish tend to swim deeper than smaller ones.

In the northern Gulf of St. Lawrence, vertical distribution was greatest at 15 and 35 m with mackerel occurrences positively correlated with downwelling events and the onshore advection of warm surface waters (Castonguay *et al*. 1992).

Based on Massachusetts inshore bottom trawl surveys, adults were most abundant at 14°C in spring with the few found in autumn at 10 and 15^{o}C. They were also found at depths of 10 m in the spring while the few found in the autumn were at 50 m (Figure 6).

Based on Rhode Island Narragansett Bay bottom trawl surveys, a single adult was caught in winter at a depth of

30.5 m and at a bottom temperature of 5°C.

Factors controlling spawning time are unclear. Morse (1980) indicated that the regularity in spawning shown by Ware (1977) points to an internal control or constant external stimulus; e.g., photoperiod changes, which ensures that peak hatching occurs at the time of maximum zooplankton abundance. Based on field investigations (Nichols and Warnes 1993) and laboratory observations (Walsh and Johnstone 1992), there appears to be no diel periodicity in spawning and no significant peaks either during the day or night. Sette (1943) noted that temperature < 7°C is a limiting factor in migration which subsequently affects timing of spawning in specific locations. Based on the NEFSC MARMAP ichthyoplankton surveys, spawning does not begin until temperatures reach ~ 7-8°C, with most occurring between 9 and 14°C (Berrien 1982; Collette, in prep.). Sette (1943) stated that peak spawning occurs within that range at around 10-12°C at salinities > 30 ppt. These temperatures were in the preferred range (7-16°C) determined for adult mackerel in the laboratory (Olla *et al*. 1975, 1976). Thus the spawning season is progressively later as water temperatures warm and fish migrate from south to north.

GEOGRAPHICAL DISTRIBUTION

Northwest Atlantic mackerel are primarily found in the open sea (although rarely beyond the continental shelf) from Black Island, Labrador (Parsons 1970) to Cape Lookout, North Carolina (Collette and Nauen 1983). Eggs, larvae and juveniles also found at varying levels of abundance in bays and estuarine areas from New Jersey north through New England and into Canadian waters (see also Sette 1950; Tables 1, 2).

EGGS

The NEFSC MARMAP ichthyoplankton surveys found eggs from offshore waters off Chesapeake Bay to Georges Bank and the Gulf of Maine (Figure 9). Egg production progressed northward from April through May, June and July as would be expected based on the spawning/migratory patterns of adults. For example, egg production in April extended from Chesapeake Bay to coastal New Jersey and along the south shore of Long Island. In May, egg production extended from the shelf waters off New Jersey to Nantucket, the southern edge of Georges Bank and the western Gulf of Maine; in June production extended off southern Rhode Island, in the region of Massachusetts Bay and the western Gulf of Maine (Figure 9). By July, some eggs were collected along Georges Bank, while by August, few, if any, eggs were found. Highest densities (eggs/10 m^2) were in May (> 39,000) and June (> 53,000). This pattern of production and distribution is consistent with previous reports (Sette 1943; Bigelow and Schroeder 1953; Collette, in prep.). Eggs have been collected from early June to mid-August on the southern side of the Gulf of St. Lawrence (Sette 1943) and this area is considered an extremely productive spawning ground (Collette, in prep.).

LARVAE

The NEFSC MARMAP ichthyoplankton surveys also found larvae (< 13 mm) from waters off Chesapeake Bay to the Gulf of Maine, although more were concentrated offshore of Delaware Bay to Massachusetts Bay from inshore waters to the seaward limits of the survey (Figure 10). Larvae were collected from May through August with the highest average mean density (> 10,000/10 m^2) occurring in June and ranging from inshore to offshore from southern New England to the Hudson Canyon with considerable numbers collected north of Cape Cod. This was north of where larvae were most abundant (> 2000/10 m^2) in May. Mean densities were low in July (≤ 102/10 m^2) with few, if any, (≤ 32/10 m^2) collected in August (Figure 10). Berrien (1978) reported that in May 1966, larvae were caught between Chesapeake Bay and Oregon Inlet, North Carolina across the continental shelf, while by June larvae had spread from Martha's Vineyard to Currituck Beach, North Carolina. The highest abundance was off Montauk Point, New York. By June, most larvae occurred to the north, while in August few were caught. This pattern also corresponds with previous reports by Sette (1943).

JUVENILES AND ADULTS

Collections of Atlantic mackerel from the NEFSC bottom trawl surveys show that the distributions of juveniles (≤ 25 cm) and adults (≥ 26 cm) ranged from Cape Hatteras to Georges Bank, and southwestern Nova Scotia and the Gulf of Maine (Figure 11). The distribution of both life stages was generally similar although in spring adults tended to be distributed further offshore than the juveniles, along the outer edge of the Continental Shelf. In the fall, a few juveniles were collected in the near coastal waters of the Mid-Atlantic Bight and southern New England, particularly eastern Long Island, while adults were absent. The mean number of fish caught was highest in winter for adults (106/station) and in summer for juveniles (351/station), with more collected in the spring than in the fall reflecting the movements of the southern spawning contingent inshore. The highest abundance in spring occurs in the oceanic waters between Chesapeake Bay and southern New England, as the fish move north. Winter and summer distributions are presented as presence/absence data, precluding a discussion of abundances.

Based on the Massachusetts inshore bottom trawl surveys, occurrences of Atlantic mackerel were higher for juveniles in the autumn and for adults in the spring (Figure 12). In the autumn, most juveniles (10 to < 1391 fish/tow) were caught in and around the waters off Cape Ann although small numbers (1 to < 500 fish/tow) were collected in Cape Cod Bay, primarily off Race Point. In the spring, the catch was highest (100 to < 101 fish/tow) along Vineyard Sound. In the fall, only two adults were collected (one in Cape Cod Bay, one off Cape Ann). In spring, the greatest numbers of fish (25 to < 37 fish/tow) were found in Nantucket Sound with lesser numbers (5 to < 25 fish /tow) also collected there and south of Cape Ann in the northern end of Massachusetts Bay. From 1 to < 5 fish/tow were also caught at several stations in and around Cape Cod in the spring. This would correspond with the spawning and migration patterns described above.

From 1960-1970, 112 species of fishes were collected in coastal Massachusetts waters as part of the Massachusetts coastal zone survey (Clayton *et al*. 1978). Indices were prepared on percent frequency of occurrence of various life stages with the term “random” used to designate marine species which may randomly occur in the estuary and percentages based on the total number of fish (all species) collected in the whole survey. The following list indicates areas where Atlantic mackerel were recorded, the life stage, and relative frequency.

Location	**Life stage**	**Frequency of Occurrence**
Annisquam/ Gloucester	Adults	Random; < 1% of collection
Salem Harbor	Eggs	Random; < 1% of collection
Lynn/Saugus	Adults	Random; < 1% of collection
Rocky Point/ Plymouth	Eggs/larvae	Common; 1-4.99% of collection
Cape Cod Canal	Eggs/larvae	No information
Taunton River/ Mount Hope Bay	Adults	Random; < 1% of collection

A total of 92 Atlantic mackerel were caught during the Rhode Island Narragansett Bay bottom trawl surveys. They were captured in low numbers at all but four stations and in all years except 1990 and 1995. Juveniles were present in summer and autumn and a single adult was caught in winter. The length frequencies by season show juveniles from 7-17 cm total length (TL) occurred in summer and from 18-23 cm TL occurred in winter. Juveniles were caught throughout much of the Bay but the highest catch was made at the ocean station in autumn (2.3 fish/tow; Figure 13). The single adult was caught farther up the Bay near Newport.

Survey data from the Connecticut bottom trawl surveys in Long Island Sound indicated that although few Atlantic mackerel were collected, analysis of length-frequency data indicated that both juveniles and adults were present at different times and distributed differently (Gottschall *et al*., in review). This is confirmed by recent analysis of the 1992-1997 survey results (Figure 14). Adults (> 28 cm; range 36-49 cm) were present in the spring and according to Gottschall *et al*. (in review) into midsummer and distributed throughout the sound. In contrast, juveniles ranging from 12-24 cm were collected in the autumn (primarily September and October) at depths < 18 m from Norwalk to the Housatonic River along the Connecticut shore (Gottschall *et al*., in review).

Few (n=12) Atlantic mackerel were collected in otter trawl surveys in the Hudson-Raritan estuary from 1992 to 1997. All were juveniles ranging from 7-8 cm and were collected during one survey in July 1997; most were collected on the eastern edge of Staten Island (S. Wilk, personal communication).

Estuarine Distribution (ELMR)

The NOAA/National Ocean Service (NOS) Estuarine Living Marine Resources (ELMR) program reviewed the distribution and relative abundances of mackerel in estuaries from Waquoit Bay, Massachusetts to the Cape Fear River, North Carolina. The data were based on three salinity zones, i.e., tidal (0.0-0.5 ppt), mixed (0.5-25 ppt) and seawater (> 25 ppt). Summaries of these distributions are presented in Table 1 for northwestern Atlantic estuaries (Jury *et al*. 1994) and in Table 2 for southern New England and Mid-Atlantic estuaries (Stone *et al*. 1994).

STATUS OF THE STOCKS

Total domestic landings, including commercial and recreational, of Atlantic mackerel in the northwest Atlantic were 32,100 metric tons (mt) in 1993, 16% less than 1992 landings (Anderson 1995; Figure 15). Canadian landings totaled 26,900 mt in 1993, a record since 1986, whereas United States commercial and recreational landings in 1993 were only 4,500 and 500 mt, respectively (Anderson 1995). Recent improvements in recruitment and reduced average annual landings enabled the Atlantic mackerel stock to recover from low biomass levels in the late 1970's (Anderson 1995; Figure 15).

From 1973-1977, Total Allowable Catches (TAC) were set for the southern spawning contingent in Northwest Atlantic Fisheries Organization (NAFO) Subareas 5 and 6 and for the northern contingent. However, there is no evidence for genetic differences between the contingents (MacKay 1967) and distinctions have not been made to determine individual contingent contributions to the total population (Garrod 1975). As a result, Atlantic mackerel have been managed as a unit stock since 1975 (Anderson 1982).

Atlantic mackerel landings reached a peak in the early 1970s of approximately 400,000 mt but were drastically reduced to 30,000 mt in the late 1970s (Anderson 1995;

Figure 15). Throughout 1980-1988, landings increased to an average 82,700 mt until Total Allowable Level of Foreign Fishing (TALFF) regulations for distant water fleet fishing activities in the northwest Atlantic were eliminated in 1992 and landings subsequently decreased to 32,000 mt in 1993 (Anderson 1995).

Northeast Fisheries Science Center fall and spring trawl survey data and assessment analyses indicate Atlantic mackerel stock biomass levels increased from 300,000 mt to 1.6 million mt in the years 1962-1969; however, levels decreased to an average 776,000 mt during 1977-1981 (Anderson 1995; Figure 15). Stock biomass increased steadily throughout the 1980s and in 1990 to approximately 3 million mt, which is the current estimated biomass level (Anderson 1995; Figure 15). Spawning stock biomass (50% of age 2 and 100% of age 3 and older mackerel) increased from 600,000 mt in 1982 to more than 2 million mt in 1990, and has remained at or above that level since that time.

Regulations on landings of Atlantic mackerel were enforced in 1976 in hopes of reducing fishing effort so as to ensure reproductive success in the population by keeping spawning stock levels above devastating levels. Recruitment has increased since 1976-1980 and strong year classes were evident in 1982, 1987, 1988, and 1990-1993 (Northeast Fisheries Science Center 1996). The northwest Atlantic mackerel stock is currently at a high level of biomass and is underexploited (Northeast Fisheries Science Center 1996).

RESEARCH NEEDS

As stated by Overholtz *et al*. (1991b) and based on the results of model projections, unless the impacts of compensatory mechanisms are accounted for, evaluations of current stock status using the current standard assessment methodology may in fact be optimistic and risky if catches are increased to high levels. These authors indicate that two advances would help to improve assessments: (1) an MSVPA to provide correctly scaled estimates of recruitment, and (2) a general prediction mortality model that would provide useful estimates of M2's for forecasting purposes. Other data that will be important include monitoring weights of individual fish to assess future changes, annual tracking of sexual maturity of age 2 and age 3 fish, additional food habits sampling at critical times and places and information on predation mortality of age-0 mackerel. Improved predation models that account for predator preference and prey abundance would allow for more accurate predictions of the impacts of these factors.

In addition, even though Atlantic mackerel is managed and assessed as one stock throughout the U.S. EEZ, the question of multiple stocks still needs to be settled from a scientific standpoint. This could be addressed via new technologies such as microconstituent analysis of otoliths using inductively coupled plasma mass-spectrometry (ICPMS).

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Table 1. Summary of the distribution and abundance of Atlantic mackerel in northwestern Atlantic estuaries based on Jury *et al*. (1994). Data reliability: *** = Highly Certain, ** = Moderately Certain, * = Reasonable Inference. Relative abundance: H = highly abundant, A = abundant, C = common, R = rare, 0 = not present, N = no data presented, NI = no data available, NZ = zone not present.

Estuaries and Rivers	**Life Stage**	**Relative Abundance and Distribution (months)** months shown as (1)-(12); i.e., January = (1)			**Data Reliability**
		Tidal Fresh 0.0-0.5 ppt	**Mixing Zone 0.5-25 ppt**	**Seawater Zone > 25 ppt**	
Passamaquoddy Bay	**A**dults (A)	0	C(6-9), R(10)	C(6-9), R(10)	**
	Spawning adults (S)	0	0	0	**
	Eggs (E)	0	0	NI	*
	Larvae (L)	0	0	NI	*
	Juveniles (J)	0	C(6-9), R(10)	C(6-9), R(10)	**
Englishman/Machias Bay	**A**	0	C(6-9), R(10)	C(6-9), R(10)	*
	S	0	0	0	*
	E	0	0	NI	*
	L	0	0	NI	*
	J	0	R(6-10)	R(6-10)	*
Narraguagus Bay	**A**	0	C(6-9), R(10)	C(6-9), R(10)	*
	S	0	0	0	*
	E	0	0	NI	*
	L	0	0	NI	*
	J	0	R(6-10)	R(6-10)	*
Blue Hill Bay	**A**	0	C(6-9), R(10)	C(6-9), R(10)	*
	S	0	0	0	*
	E	0	0	NI	*
	L	0	0	NI	*
	J	0	R(6-10)	R(6-10)	*
Penobscot Bay	**A**	0	C(6-9), R(10)	C(6-9), R(10)	**
	S	0	0	0	**
	E	0	0	R(6-7)	**
	L	0	0	R(6-7)	**
	J	0	C(6-9), R(10)	C(6-9), R(10)	**
Muscongus Bay	**A**	0	C(6-9), R(10)	C(6, 8-9), A(7), R(10)	*
	S	0	0	0	**
	E	0	0	0	**
	L	0	0	0	**
	J	0	C(6-9), R(10)	C(6, 8-9), A(7), R(10)	*
Damariscotta River	**A**	0	C(6-9), R(10)	C(6, 8-9), A(7), R(10)	**
	S	0	0	0	**
	E	0	0	0	**
	L	0	0	0	**
	J	0	C(6-9), R(10)	C(6, 8-9), A(7), R(10)	**
Sheepscot River	**A**	0	C(6-9), R(10)	C(6, 8-9), A(7), R(10)	***
	S	0	0	0	**
	E	0	0	0	**
	L	0	0	0	**
	J	0	C(6-9), R(10)	C(6, 8-9), A(7), R(10)	***
Kennebec/Androscoggin Rivers	**A**	0	C(6-9), R(10)	C(6, 8-9), A(7), R(10)	**
	S	0	0	0	**
	E	0	0	0	**
	L	0	0	0	**
	J	0	C(6-9), R(10)	C(6, 8-9), A(7), R(10)	**

Table 1. cont’d.

Estuaries and Rivers	**Life Stage**	**Relative Abundance and Distribution (months)** months shown as (1)-(12); i.e., January = (1)			**Data Reliability**
		Tidal Fresh 0.0-0.5 ppt	**Mixing Zone 0.5-25 ppt**	**Seawater Zone > 25 ppt**	
Casco Bay	**A**	0	C(6-9), R(10)	C(6-9), R(10)	*
	S	0	0	0	**
	E	0	0	NI	*
	L	0	0	NI	*
	J	0	C(6-9), R(10)	C(6-9), R(10)	*
Saco Bay	**A**	0	C(6-9), R(10)	C(6-9), R(10)	*
	S	0	0	0	**
	E	0	0	0	*
	L	0	0	0	*
	J	0	C(6-9), R(10)	C(6-9), R(10)	*
Wells Harbor	**A**	NZ	R(6-10)	R(6-10)	*
	S	NZ	0	0	**
	E	NZ	0	0	*
	L	NZ	0	0	*
	J	NZ	R(6-10)	R(6-10)	*
Great Bay	**A**	0	0	R(5-11)	*
	S	0	0	0	***
	E	0	C(5-7)	C(5), A(6-7)	*
	L	0	C(5-7), R(8)	C(5-7), R(8)	*
	J	0	0	C(5-11)	*
Merrimack River	**A**	0	R(5-10)	NZ	**
	S	0	0	NZ	**
	E	0	H(5-6), C(7)	NZ	**
	L	0	C(5-8)	NZ	**
	J	0	R(5-10)	NZ	**
Massachusetts Bay	**A**	NZ	NZ	C(5-10), R(11)	***
	S	NZ	NZ	C(5-8)	*
	E	NZ	NZ	C(5), A(6,7), R(8)	*
	L	NZ	NZ	C(5), A(6,7), R(8)	*
	J	NZ	NZ	C(5-10)	***
Boston Harbor	**A**	NZ	R(5), C(6-9)	R(5), C(6-9)	**
	S	NZ	0	0	*
	E	NZ	R(5, 8), C(6,7)	C(5,8), A(6,7)	*
	L	NZ	R(5), C(6-8)	C(5), A(6,7) R(8)	*
	J	NZ	R(5), C(6-10)	R(5), C(6-10)	**
Cape Cod Bay	**A**	NZ	C(5-8), R(9)	A(5-7), C(8-11)	**
	S	NZ	0	A(5-7)	*
	E	NZ	C(5-8)	H(5,6), A(7), C(8)	**
	L	NZ	C(5-8)	H(5,6), A(7), C(8)	**
	J	NZ	C(5-10)	A(5-8), C(9-11)	**

Table 2. Summary of the distribution and abundance of Atlantic mackerel in southern New England and Mid-Atlantic estuaries based on Stone *et al*. (1994). Data reliability: *** = Highly Certain, ** = Moderately Certain, * = Reasonable Inference. Relative abundance: H = highly abundant, A = abundant, C = common, R = rare, 0 = not present, N = no data presented, NI = no data available, NZ = zone not present.

Estuaries and Rivers	**Life Stage**	**Relative Abundance and Distribution (months)** months shown as (1)-(12); i.e., January = (1)			**Data Reliability**
		Tidal Fresh 0.0-0.5 ppt	**Mixing Zone 0.5-25 ppt**	**Seawater Zone > 25 ppt**	
Waquoit Bay	**A**dults (A)	NZ	0	R(5,6), C(7-9)	*
	Spawning adults (S)	NZ	0	0	**
	Eggs (E)	NZ	0	R(5-8)	*
	Larvae (L)	NZ	0	R(5-8)	*
	Juveniles (J)	NZ	0	R(5-9)	*
Buzzards Bay	**A**	NZ	0	C(3,4,11,12), R(5-9)	**
	S	NZ	0	0	**
	E	NZ	R(5-8)	A(5,6), C(7), R(8)	*
	L	NZ	R(6-8)	R(5-8)	*
	J	NZ	R(5-9)	R(5-9)	*
Narragansett Bay	**A**	0	0	C(5-9)	*
	S	0	0	0	**
	E	0	R(5-7)	A(5,6), C(7)	**
	L	0	R(5-7)	C(5,6), R(7)	*
	J	0	R(5-9)	C(5-9)	*
Long Island Sound	**A**	0	0	C(4-11)	*
	S	0	0	R(4-6)	***
	E	0	0	C(4,6), A(5)	***
	L	0	0	C(5), R(6)	***
	J	0	R(4,5)	C(4-11)	*
Connecticut River	**A**	0	0	NZ	**
	S	0	0	NZ	***
	E	0	0	NZ	**
	L	0	0	NZ	**
	J	0	0	NZ	**
Gardiners Bay	**A**	NZ	0	C(4,5), R(6-11)	*
	S	NZ	0	R(4-6)	*
	E	NZ	0	H(4), A(5), C(6)	**
	L	NZ	0	H(4), A(5), C(6)	**
	J	NZ	0	C(4-11)	**
Great South Bay	**A**	NZ	0	C(4,5), R(6-11)	*
	S	NZ	0	0	**
	E	NZ	0	C(4)	**
	L	NZ	0	C(5)	**
	J	NZ	0	C(4-11)	*
Hudson/Raritan River	**A**	0	0	C(4,5,10,11), R(6,9,12)	*
	S	0	0	0	*
	E	0	0	0	*
	L	0	0	0	*
	J	0	R(4-6,10-12)	C(4-6,10,11), R(7-9,12)	*
Barnegat Bay	**A**	0	0	0	***
	S	0	0	0	***
	E	0	0	R(4-6)	**
	L	0	0	R(4-6)	**
	J	0	0	R(5-9)	**
NJ Inland Bays	**A**	0	0	0	***
	S	0	0	0	***
	E	0	0	R(4-6)	**
	L	0	0	R(4-6)	**
	J	0	0	R(5-9)	**
Delaware Bay	**A**	0	0	R(3-5)	**
	S	0	0	0	***
	E	0	0	0	***
	L	0	0	0	***
	J	0	0	0	***

Table 2. cont'd.

Estuaries and Rivers	**Life Stage**	**Relative Abundance and Distribution (months)** months shown as (1)-(12); i.e., January = (1)			**Data Reliability**
		Tidal Fresh 0.0-0.5 ppt	**Mixing Zone 0.5-25 ppt**	**Seawater Zone > 25 ppt**	
Delaware Inland Bays	**A**	NZ	0	R(3-5)	**
	S	NZ	0	0	***
	E	NZ	0	0	***
	L	NZ	0	0	**
	J	NZ	0	0	**
Chincoteague	**A**	NZ	NZ	0	***
	S	NZ	NZ	0	***
	E	NZ	NZ	0	***
	L	NZ	NZ	0	***
	J	NZ	NZ	0	***
Chesapeake Bay	**A**	0	R(1-3)	R(1-3)	**
	S	0	0	0	***
	E	0	0	0/NI(4-5)	**
	L	0	0	R(5)	**
	J	0	R(1-4,11,12)	R(1-4,11,12)	**
Chester River	**A**	0	0	NZ	***
	S	0	0	NZ	***
	E	0	0	NZ	***
	L	0	0	NZ	***
	J	0	0	NZ	***
Choptank River	**A**	0	0	NZ	***
	S	0	0	NZ	***
	E	0	0	NZ	***
	L	0	0	NZ	***
	J	0	0	NZ	***
Patuxent River	**A**	0	0	NZ	***
	S	0	0	NZ	***
	E	0	0	NZ	***
	L	0	0	NZ	***
	J	0	0	NZ	***
Potomac River	**A**	0	0	NZ	***
	S	0	0	NZ	***
	E	0	0	NZ	***
	L	0	0	NZ	***
	J	0	0	NZ	***
Tangier/Pocomoke	**A**	NZ	0	NZ	***
	S	NZ	0	NZ	***
	E	NZ	0	NZ	***
	L	NZ	0	NZ	***
	J	NZ	0	NZ	***
Rappahannock River	**A**	0	R(1-3)	NZ	**
	S	0	0	NZ	***
	E	0	0	NZ	***
	L	0	0	NZ	***
	J	0	R(1-4,11,12)	NZ	**
York River	**A**	0	R(1-3)	NZ	**
	S	0	0	NZ	***
	E	0	0	NZ	***
	L	0	0	NZ	***
	J	0	R(1-4,11,12)	NZ	**
James River	**A**	0	R(1-3)	NZ	**
	S	0	0	NZ	***
	E	0	0	NZ	***
	L	0	0	NZ	***
	J	0	R(1-4,11,12)	NZ	**

Table 3. Summary of life history and habitat parameters for Atlantic mackerel, *Scomber scombrus*.

Life Stage	Size and Growth	Geographic Location	Habitat	Temperature
Eggs [1]	Diameter: 1-1.3 mm, avg. = 1.1 mm. 1 oil globule, avg. 0.3 mm diameter. In Gulf of St. Lawrence egg size decreased over time and in relation to ambient temperature (avg. diam. = 1.3 mm in June, 1.1 mm in August).	Offshore waters of Chesapeake Bay to southern side of Gulf of St. Lawrence with majority on shoreward side of continental shelf. Varying abundances in bays and estuaries from New Jersey to Canada. Highest abundances in May, June in southern New England - Mid-Atlantic region.	Eggs pelagic, distributed at depths ranging from 10-325 m, majority from 30-70 m; depth varies with season, egg diameter, thermocline.	Eggs collected at 5-23°C, highest abundance from ~ 7-16°C with range related to season. In May, weighted mean surface temperature = 11°C for eggs from Martha's Vineyard. Egg mortality rates (~ 41%/d) correlated with rate of warming during spawning season since acclimation temperature of adults related to egg mortality. Mortality < 20% from 9.4-15.1°C. Incubation temperature dependent: 7.5 d at 11°C to ~ 3 d at 20°C. Temperatures must be > ~ 7°C for development.
Larvae [2]	Larvae average 3.1-3.3 mm SL with large yolk sac. Postlarvae are 11-50 mm. Teeth present at 192 h after hatching.	Larvae (< 13 mm) occur primarily in offshore waters from Chesapeake Bay to southern Gulf of St. Lawrence. Similar to distribution of eggs, some larvae also collected in open bays and estuaries. Highest abundances in May offshore from Delaware Bay to Hudson Canyon; by June, highest abundance ranges from Hudson Canyon north to southern New England and north of Cape Cod.	Most distributed at depths from 10-130 m, usually at < 50 m. Depth varies diurnally, also with age and with thermocline; i.e., newly hatched larvae found between 5-10 m during the day, however, as they grow they're at depths closer to the surface.	Hatching occurs ~ 90-120 h at average temperature of 13.8°C. Yolk sac stage complete by 137 h at this temperature. Larvae collected at 6-22°C; highest abundance at 8-13°C. Changes in abundance at different temperature ranges related to season; i.e., increasing from May through August. Larval mortality rates (~ 35-42%/d) may be partially correlated with temperature.
Juveniles [3]	Postlarvae transform from planktonic to swimming and schooling behavior at ~ 30-50 mm; reach 50 mm in ~ 2 months; 20 cm after 1 y (rates may be faster in mid-Atlantic: ~ 70-80 mm in 2 months). Northern contingent fish may grow faster in 1st year than southern contingent, but may not be significantly different for first 90 days.	Southwestern Nova Scotia, Gulf of Maine, Georges Bank to Cape Hatteras - distribution changes seasonally. Late summer/fall primarily along western shores of Gulf of Maine, around Cape Ann, inshore areas of New England (includes estuaries in Rhode Island, Connecticut), eastern Long Island. In spring, although common offshore, some are further inshore than adults and found in some Mid-Atlantic estuaries until fall.	Depth varies seasonally. Offshore in fall, most abundant at ~ 20-40 m, range from 0-320 m. In winter, 50-70 m. Spring, although dispersed through water column, concentrated 30-90 m. Move higher in summer to 20-50 m, range from 0-210 m.	At 15-17°C growth rates of fish > 15 mm averaged 0.73 mm/d. Juveniles found from 4-22°C, most at 10°C. Temperature distribution offshore changes seasonally as average temperature ranges increase: in winter/spring, most found 5-6°, in summer at 8-13°C. Similar associations inshore: Massachusetts, 11° in spring, 9 and 13° in fall; Rhode Island, 19° in summer, 11 and 15°C in fall.
Adults [4]	Males/females grow at same rate, reaching maximum age of ~ 20 y, with maximum fork length of ~ 47 cm. Reach 26 cm by second year, 33 cm by fifth year. By age 6, may be 39-40 cm. Spring weight for 35 cm fish is ~ 0.5 kg; fall is 0.6 kg. Growth may be population density dependent; year class size partially influences initial growth during cohort's first years.	Two major contingents in NW Atlantic. Fish overwinter in deep water of shelf from Nova Scotia to Cape Hatteras. In spring, two groups formed: fish from southern group move inshore and northward along coast, joined by northern group moving inshore. By late Apr./May southern group found off New Jersey, Long Island, moving to western Gulf of Maine by summer, returns to shelf edge between Long Island - Chesapeake Bay in Oct. Northern group mixes briefly with southern group late spring off New England, migrates east along Nova Scotia into Gulf of St. Lawrence; some fish remain along Maine/Nova Scotia coast. By late fall, this contingent mixes with southern group in Gulf of Maine before returning to outer shelf.	Depth changes seasonally, perhaps influenced by prey availability. Fall: 10-340 m, > 50% at 60-80 m. Winter: ~ 50% at 20-30 m. Spring: down to 380 m, ~ 25% at 60-170 m. Summer: > 60% at 50-70 m. Larger fish deeper than smaller ones. Distribution may also be correlated with downwelling events and onshore advection of warm surface water.	Seasonal temperature cycles influence migration/distribution. Field studies: intolerant of temperatures < 5-6°C or > 15-16°C. Lab: prefer 7-16°, lethal at < 2° or > 28.5°. Offshore distribution varies with seasonal temperature changes. Fall: > 80% at 9-12°. Winter: ~ 70% at 5-6°. Spring > 25% at 13°. Summer: > 30% at 10-11°, > 35% at 14°. Massachusetts: spring most at 14°, fall at 10° and 15°. In northern Gulf of St. Lawrence, adults in colder temperatures (4°); however, probability of occurrence higher when temperatures ≥ 7°C.
Spawning Adults [5]	L_{50} for females = 25.7 cm, males = 26.0; A_{50} for both = 1.9 y. By age 3, 99% of females, 97% of males mature. Newfoundland fish have higher L_{50} values: females = 34 cm, males = 35 cm. Gulf of St. Lawrence, coastal Nova Scotia, Massachusetts fish spawn first at age 2, lengths > 30 cm. Differences in median maturity may be due to slower growth of larger year classes that may delay spawning from one to three years.	Spawning progresses from south to north. Southern contingent spawns in Mid-Atlantic Bight and Gulf of Maine mid-Apr.-June, northern in southern Gulf of St. Lawrence May-Aug. Most spawning in shoreward half of continental shelf, some on shelf edge and beyond. Most productive between Chesapeake Bay/southern New England, less in Gulf of St. Lawrence, Gulf of Maine, Nova Scotia coast. Some spawning in open bays; e.g., Cape Cod, Massachusetts Bays. Less in enclosed bays; e.g., Chesapeake, Delaware Bays.		Spawning begins when temperatures are ≥ 7°C (peak 9-14°C) and progresses from southern to northern waters during adult migration.

References on next page

Table 3. cont’d.

Life Stage	Salinity	Prey	Predators	Notes
Eggs[1]	Although eggs are collected in waters ranging from estuaries (18-25 ppt) to full seawater (> 30 ppt), mortality is higher at lower salinities (< 25 ppt).			
Larvae[2]	Although larvae are occasionally collected in open bays and estuaries at salinities < 25 ppt, the largest abundances are found in higher salinities of > 30 ppt in offshore waters. Mortality may be related to salinities of ≤ 23 ppt.	50% threshold for first feeding is 3.8 mm, all larvae feeding by 4.5 mm. Diet related to larval size: first feeding larvae may be phytophagous; individuals > 4.4 mm feed on copepod nauplii; > 5 mm, copepodites; > 6 mm adult copepods. Diets of larger larvae shift to include fish larvae: yellowtail flounder, silver hake, redfish; > 6 mm are cannibalistic on smaller conspecifics which may make up as much as 20% of larval fish consumed. However, piscivory is density dependent; i.e., limited at densities of fish larvae < 0.1 m^3 and declines with increasing density of nauplii, switching to copepods.	Mackerel > 6 mm are cannibalistic on smaller conspecifics of 3.5-4.5 mm.	Calculated mean digestive times ~ 1-2 h; to maintain rapid growth rates larvae must feed continually for about 15 h/d. Diet may reflect most abundant food items capable of being ingested due to width of mouth gape. Factors influencing mortality include zooplankton abundance, wind driven surface currents, epizootics in addition to temperature and appropriate food supply.
Juveniles[3]	Juveniles found in some inshore bays and estuaries as well as offshore at salinities > 25 ppt.	Principal prey include small crustaceans, such as copepods, euphausiids, amphipods, mysid shrimp, decapod larvae. Also small pelagic mollusks, chaetognaths, nematodes, ammodytes, other larval fish.	Same as for adults, but for juveniles specifically: Atlantic cod, squid, seabirds.	Atlantic mackerel are opportunistic feeders that can ingest prey either by individual selection of organisms or by filter feeding (see adults, below).
Adults[4]	Found in open sea although occasionally in open bays with lower salinity limits of ~ 25 ppt.	Opportunist feeders. Filter feeding or individual selection. Diet similar to juveniles, but wider range and larger prey items. Includes euphausid, pandalid, and crangonid shrimps; chaetognaths, larvaceans, pelagic polychaetes, squids. Calanus and other copepods, amphipods, other planktonic organisms. Fishes: sand lances, herring, silver and other hakes, sculpins. Lab studies: small medusae common to temperate waters; also, where prey abundance is only 0.1 g wet weight/m^3, mackerel may not be satiated if feeding was restricted to daylight.	Mortality from predation may be the most important source of natural mortality. Predators include conspecifics, tunas, bonito, striped bass, pilot whales, common dolphins, harbor seals, porpoises, seabirds, swordfish. Sharks: shortfin mako, tiger, blue, bigeye thresher, spiny dogfish. Other predators: king mackerel, thorny skate, silver hake, red hake, bluefish, pollock, white hake, goosefish, weakfish.	Although there are two major contingents of the population they are managed as a single transboundary stock. Shifts in feeding mode may be related to season for fish in the Gulf of St. Lawrence while diet of fish in Newfoundland indicates that particulate feeding may occur throughout the season.
Spawning Adults[5]	Peak spawning occurs at salinities > 30 ppt.	Fish feed until gonadal development begins, then stop feeding until spent, feeding then resumes.	Same as for adults in general.	Mackerel are serial, or batch, spawners. Fecundity of southern contingent: 285,000-1.98 million eggs for 31-44 cm fish. Northern contingent: 211,000 to 397,000 eggs for 35 and 40 cm females, respectively, with 5-7 batches. Control of spawning time is unclear although there may be both endogenous and exogenous factors which ensures peak hatching at the time of maximum zooplankton abundance. No evidence of diel periodicity in spawning.

[1] Worley (1933), Jury *et al.* (1994), Sette (1943), Berrien (1975, 1978), Ware (1977), Fritzsche (1978), Lanctot (1980), Peterson and Ausubel (1984), Ware and Lambert (1985), Stone *et al.* (1994), Collette (in prep.)

[2] Sette (1943), Bigelow and Schroeder (1953), Colton and Marak (1969), Berrien (1975, 1978, 1982), Peterson and Ausubel (1984), Ware and Lambert (1985), Scott and Scott (1988), Jury *et al.* (1994), Stone *et al.* (1994), Fortier and Villeneuve (1996), Collette (in prep.)

[3] Sette (1943, 1950), Bigelow and Schroeder (1953), Anderson and Paciorkwski (1980), Kendall and Gordon (1981), Berrien (1982), Ware and Lambert (1985), Pepin *et al.* (1988), D’Amours *et al.* (1990), Simard *et al.* (1992), Jury *et al.* (1994), Stone *et al.* (1994), Collette (in prep.)

[4] Sette (1950), Leim and Scott (1966), MacKay (1967), Scott and Tibbo (1968), Anderson (1973), Isakov (1973), Parsons and Moores (1974), Stobo and Hunt (1974), Maurer and Bowman (1975), Moores *et al.* (1975), Olla *et al.* (1975), Overholtz and Anderson (1976), MacKay (1979), Berrien (1982), Stillwell and Kohler (1982, 1985), Murray *et al.* (1983), Bowman and Michaels (1984), Bowman *et al.* (1984), Murray (1984), Runge *et al.* (1987), Dery (1988), Pepin *et al.* (1988), Overholtz *et al.* (1991b), Castonguay *et al.* (1992), Collette (in prep.)

[5] Sette (1943), MacKay (1967, 1973), Ware (1977), Morse (1980), Berrien (1982), Overholtz (1989), Overholtz *et al.* (1991b), Walsh and Johnstone (1992), Nichols and Warne (1993), O’Brien *et al.* (1993), Jury *et al.* (1994), Stone *et al.* (1994), Collette (in prep.)

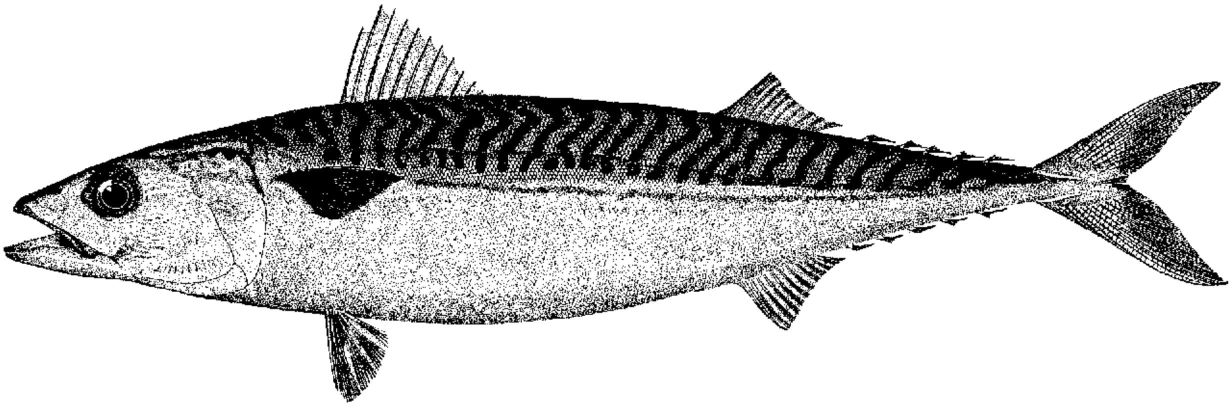
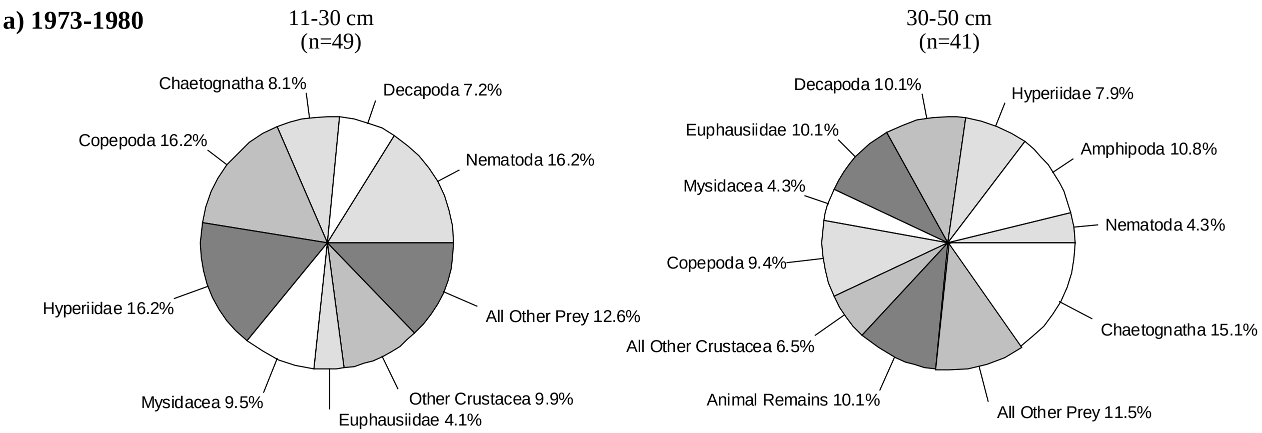


Figure 1. The Atlantic mackerel, *Scomber scombrus* (from Goode 1884).



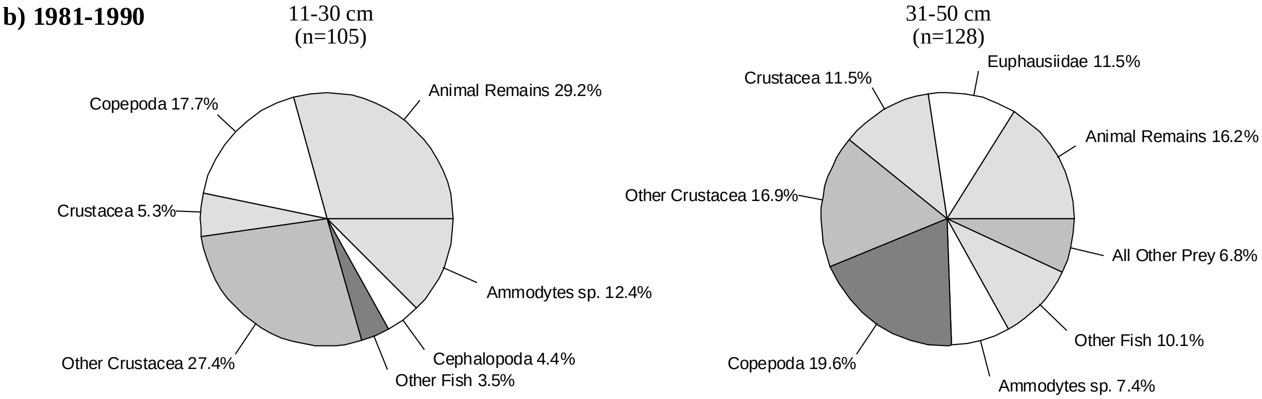


Figure 2. Abundance (percent occurrence) of the major prey items in the diet of Atlantic mackerel collected during NEFSC bottom trawl surveys from 1973-1980 and 1981-1990. The 11-30 cm size range corresponds, at least roughly, to juveniles, and the 30-50 cm size class corresponds to adults. The category “animal remains” refers to unidentifiable animal matter. Methods for sampling, processing, and analysis of samples differed between the time periods [see Reid *et al.* (1999) for details].

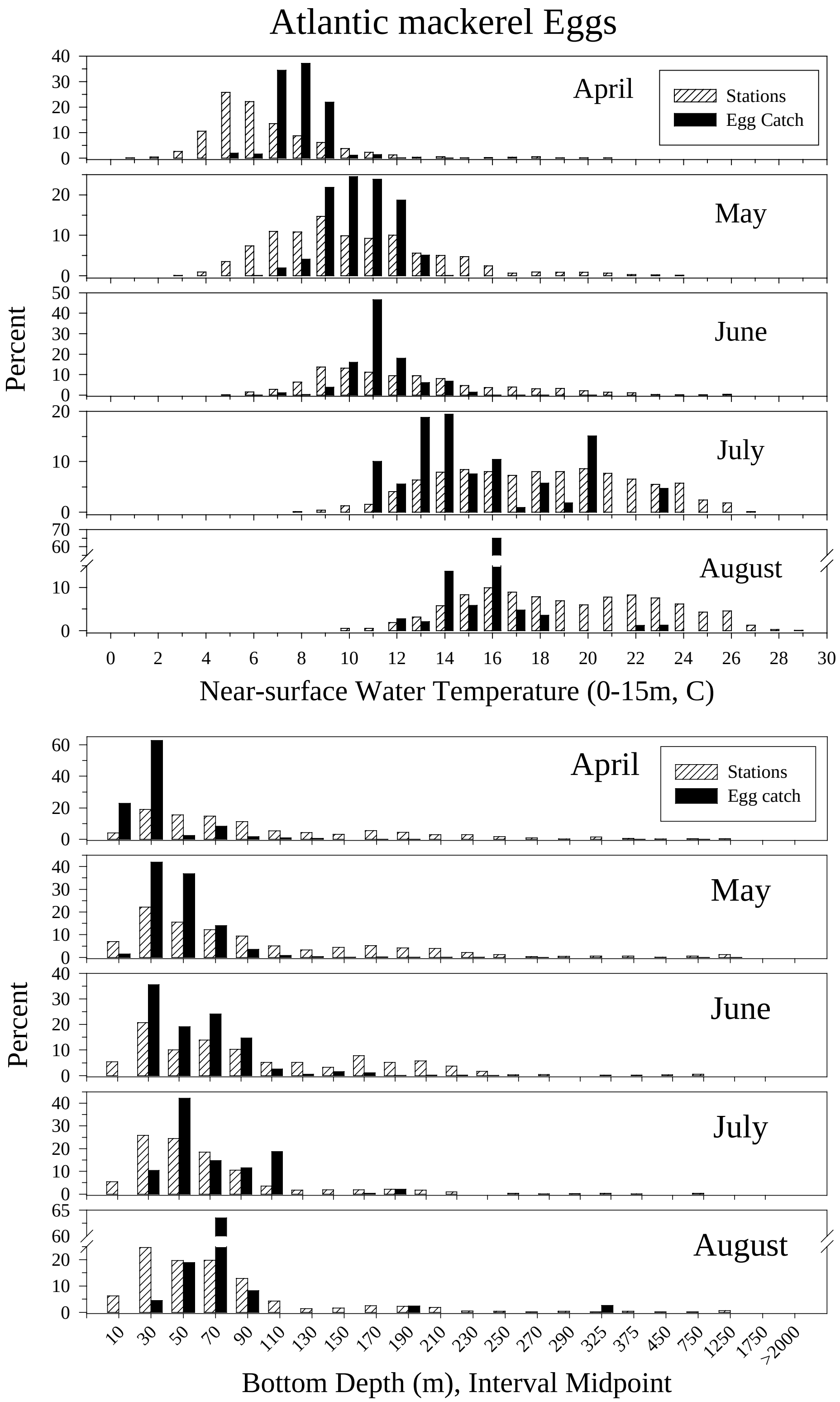


Figure 3. Abundance of Atlantic mackerel eggs relative to surface water temperature (0-15 m) and bottom depth based on NEFSC MARMAP ichthyoplankton surveys (April to August 1978-1987; all years combined). Open bars represent the proportion of all stations surveyed, while solid bars represent the proportion of the sum of all standardized catches (number/10 m^2).

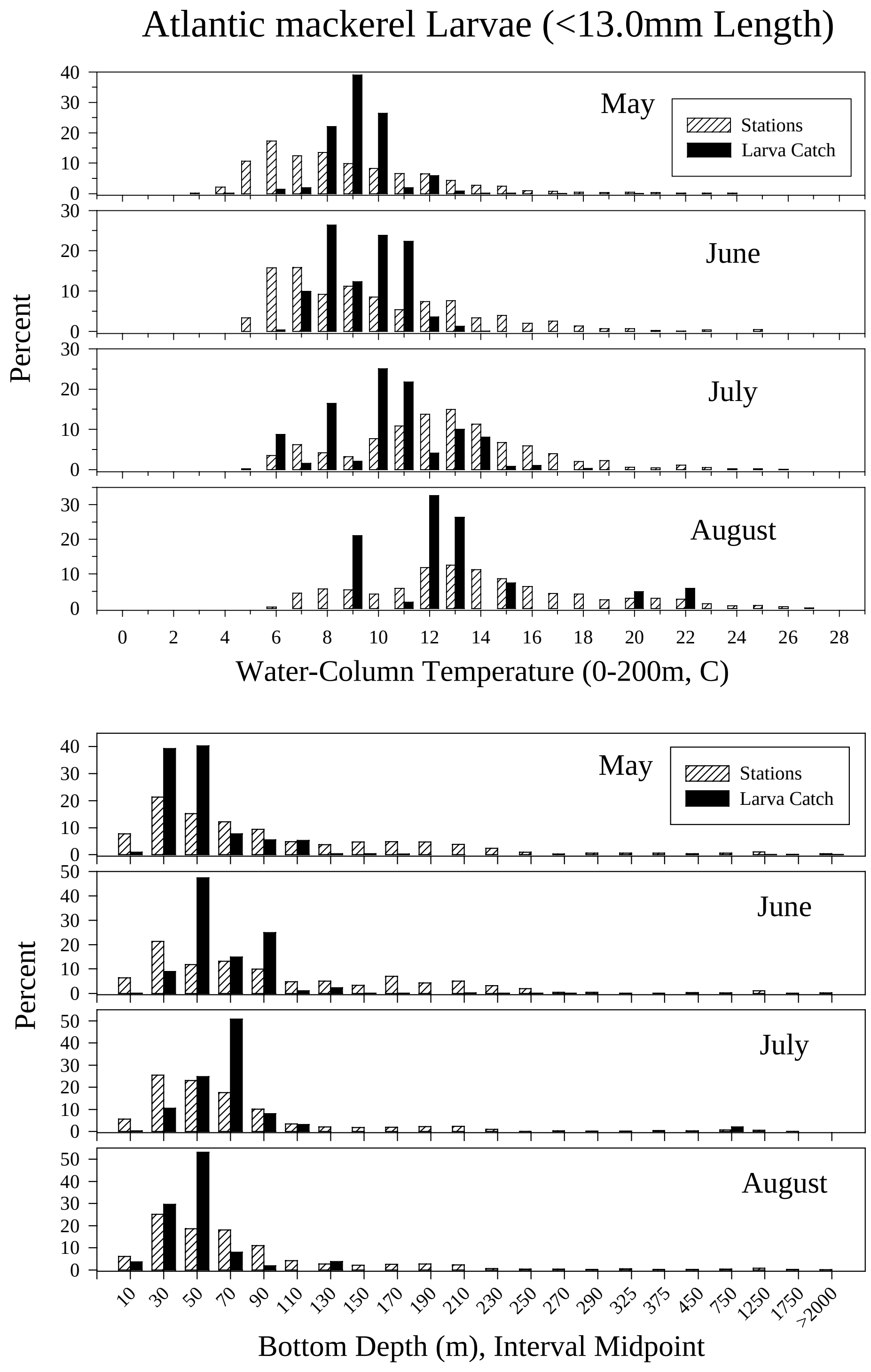


Figure 4. Abundance of Atlantic mackerel larvae (< 13 mm) relative to water column temperature (to a maximum of 200 m) and bottom depth based on NEFSC MARMAP ichthyoplankton surveys (May to August 1977-1987; all years combined). Open bars represent the proportion of all stations surveyed, while solid bars represent the proportion of the sum of all standardized catches (number/10 m^2).

Juveniles: < 26 cm TL

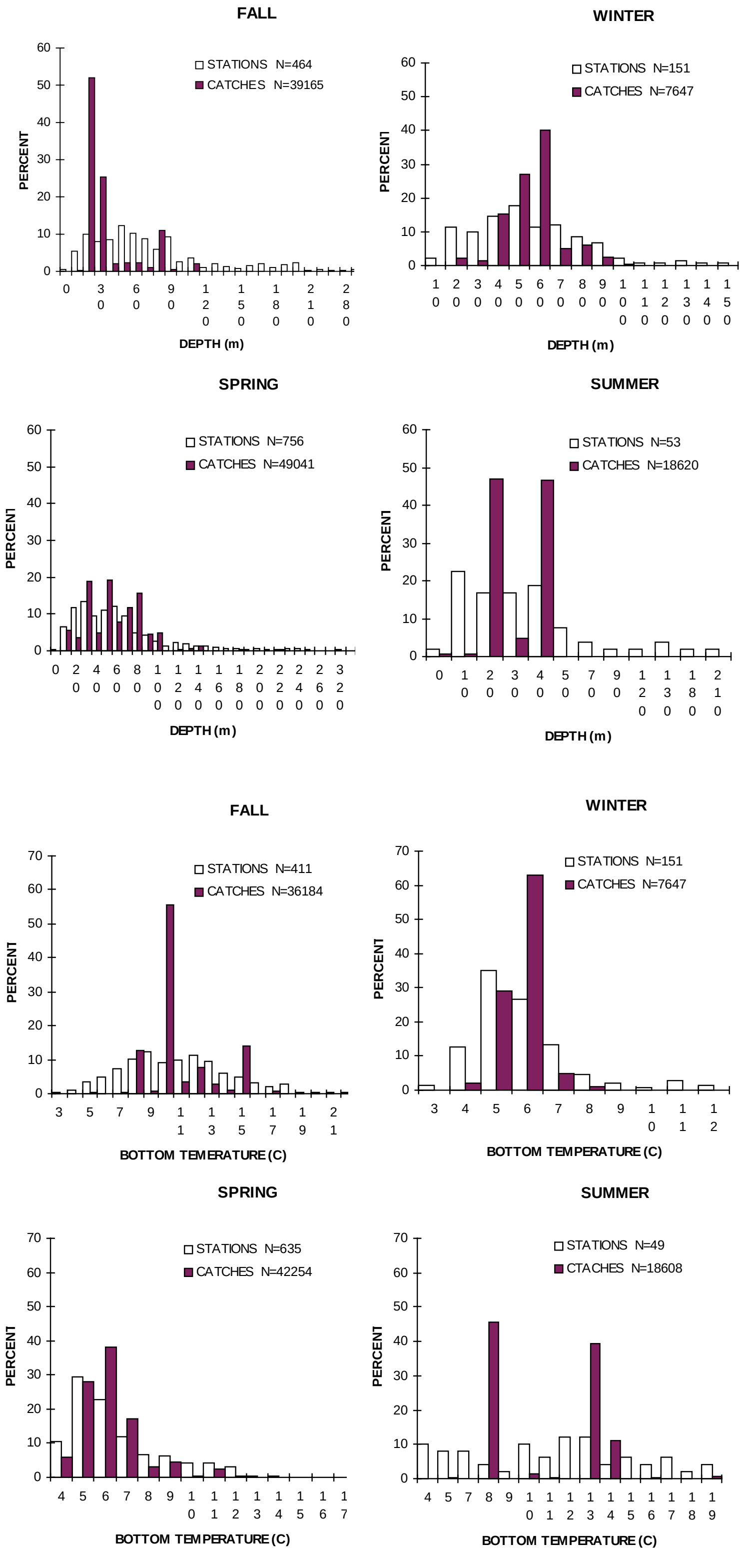


Figure 5. Seasonal abundance of juvenile Atlantic mackerel relative to bottom water temperature and depth based on NEFSC bottom trawl surveys (1963-1997; all years combined). Open bars represent the proportion of all stations surveyed, while solid bars represent the proportion of the sum of all standardized catches (number/10 m^2).

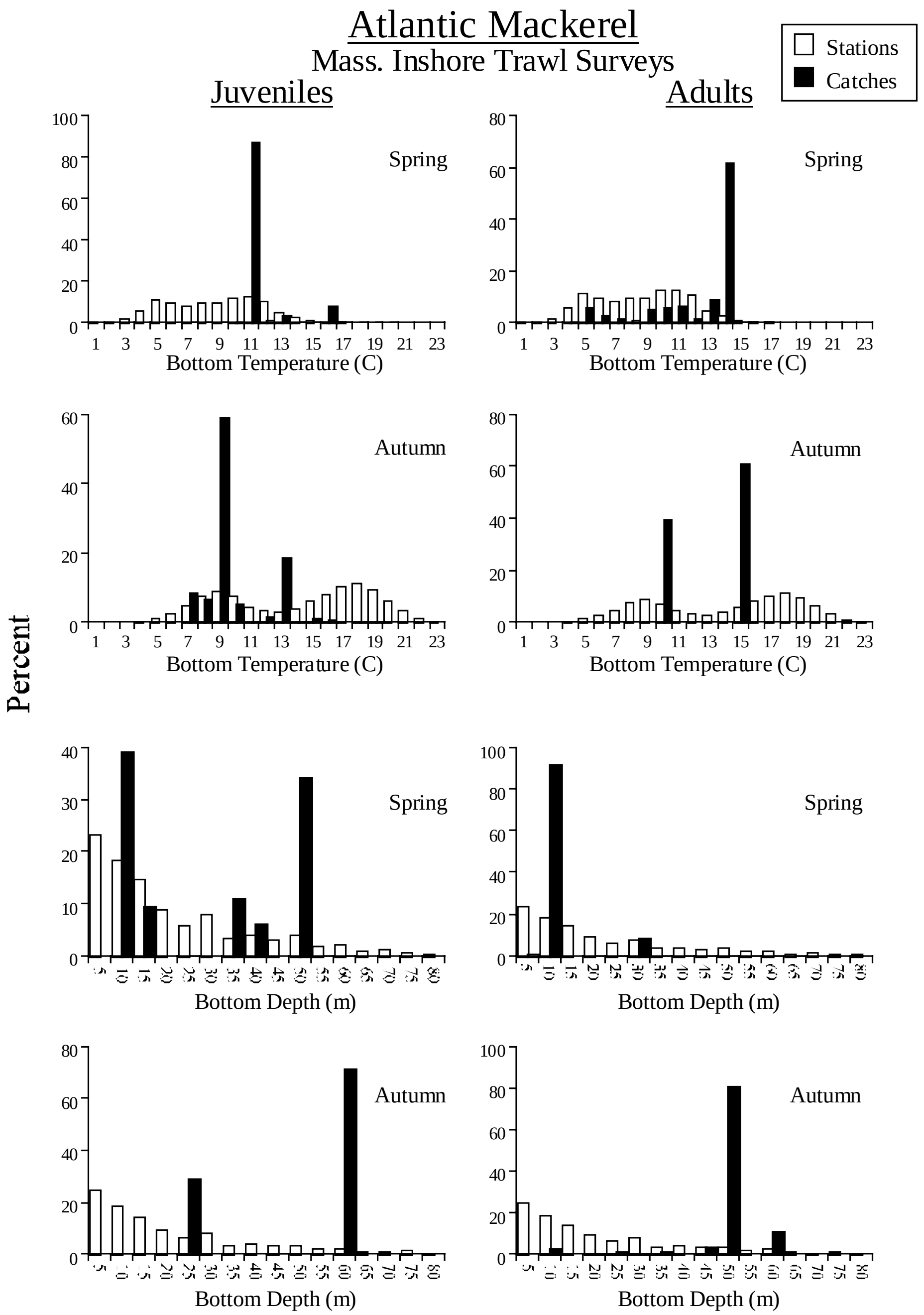


Figure 6. Abundance of juvenile (≤ 25 cm) and adult (≥ 26 cm) Atlantic mackerel relative to bottom water temperature and depth based on spring and autumn Massachusetts inshore bottom trawl surveys (1978-1996; all years combined). Open bars represent the proportion of all stations surveyed, while solid bars represent the proportion of the sum of all standardized catches (number/10 m^2).

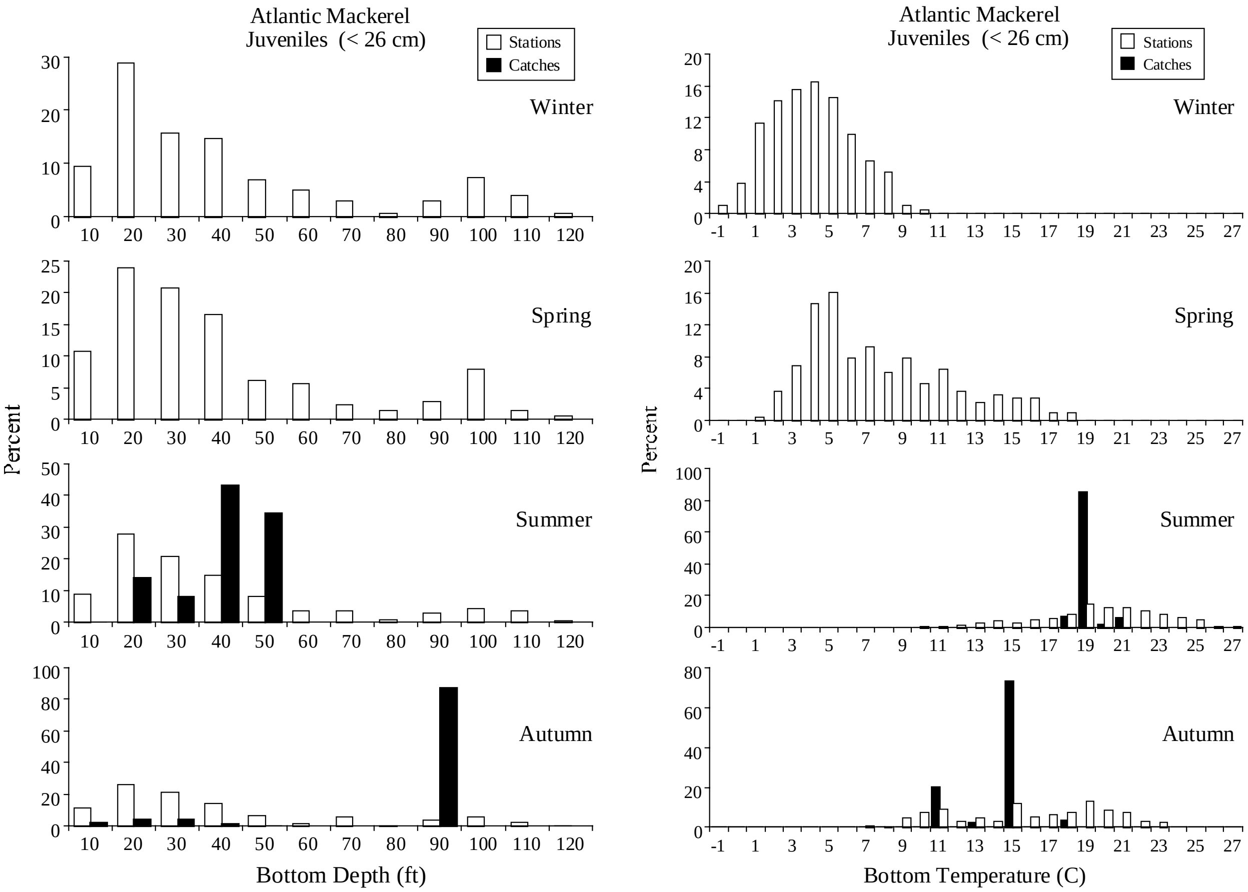


Figure 7. Seasonal abundance of juvenile Atlantic mackerel (< 26 cm) relative to bottom depth and bottom water temperature based on Rhode Island Narragansett Bay trawl surveys (1990-1996; all years combined). Open bars represent the proportion of all stations surveyed, while solid bars represent the proportion of the sum of all catches.

Adults: ≥ 26 cm TL

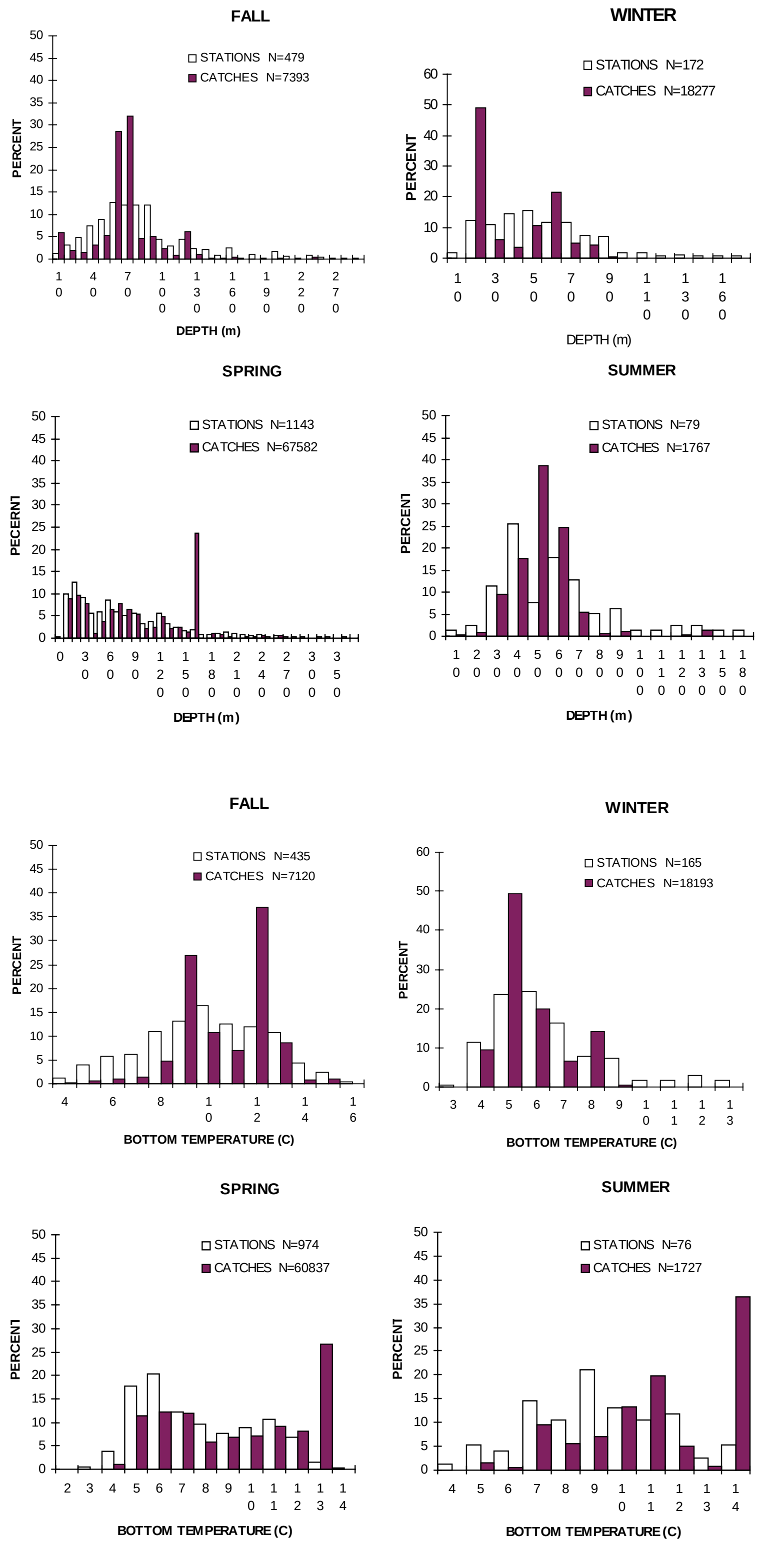


Figure 8. Seasonal abundance of adult Atlantic mackerel relative to bottom water temperature and depth based on NEFSC bottom trawl surveys (1963-1997; all years combined). Open bars represent the proportion of all stations surveyed, while solid bars represent the proportion of the sum of all standardized catches (number/10 m^2).

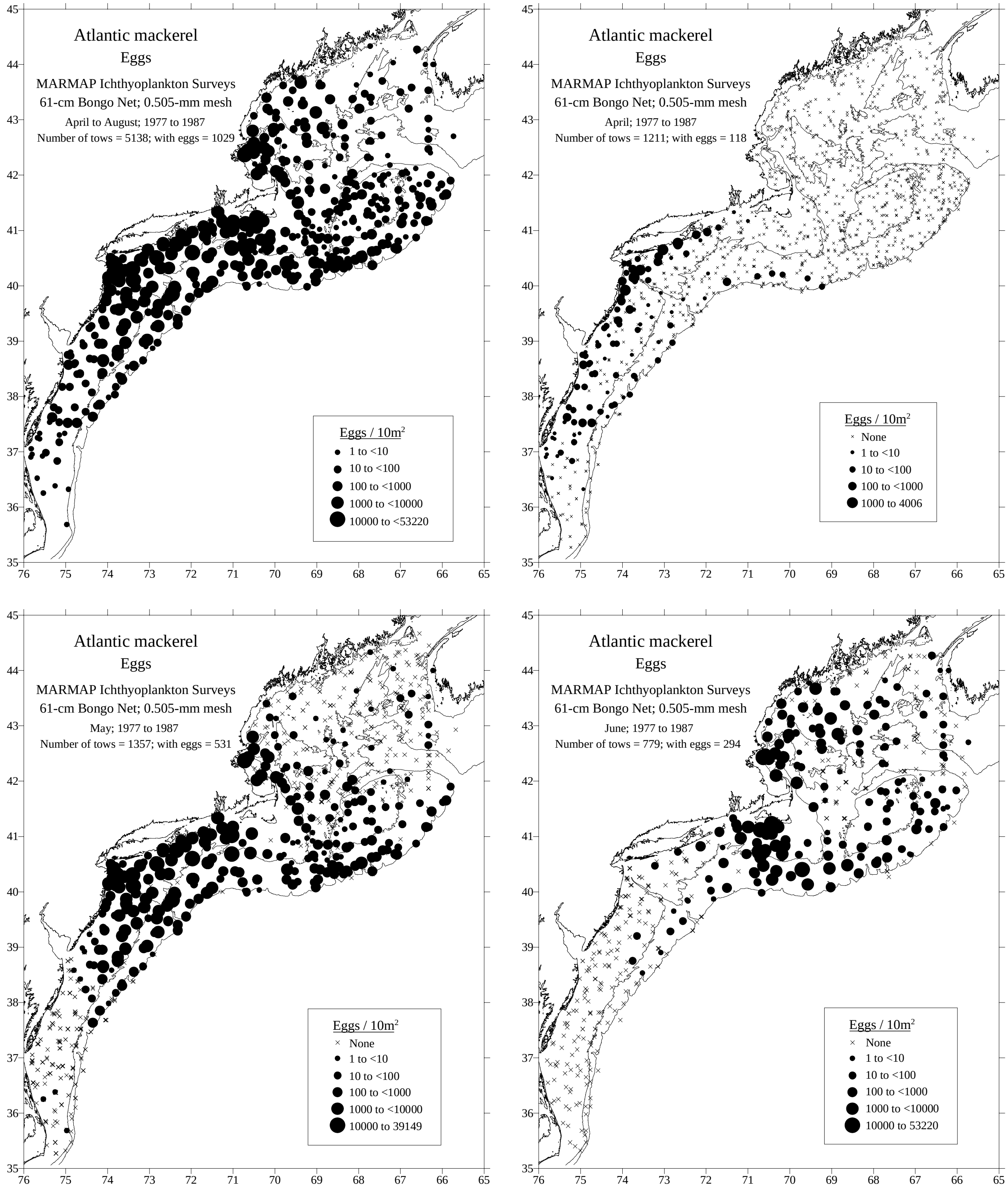
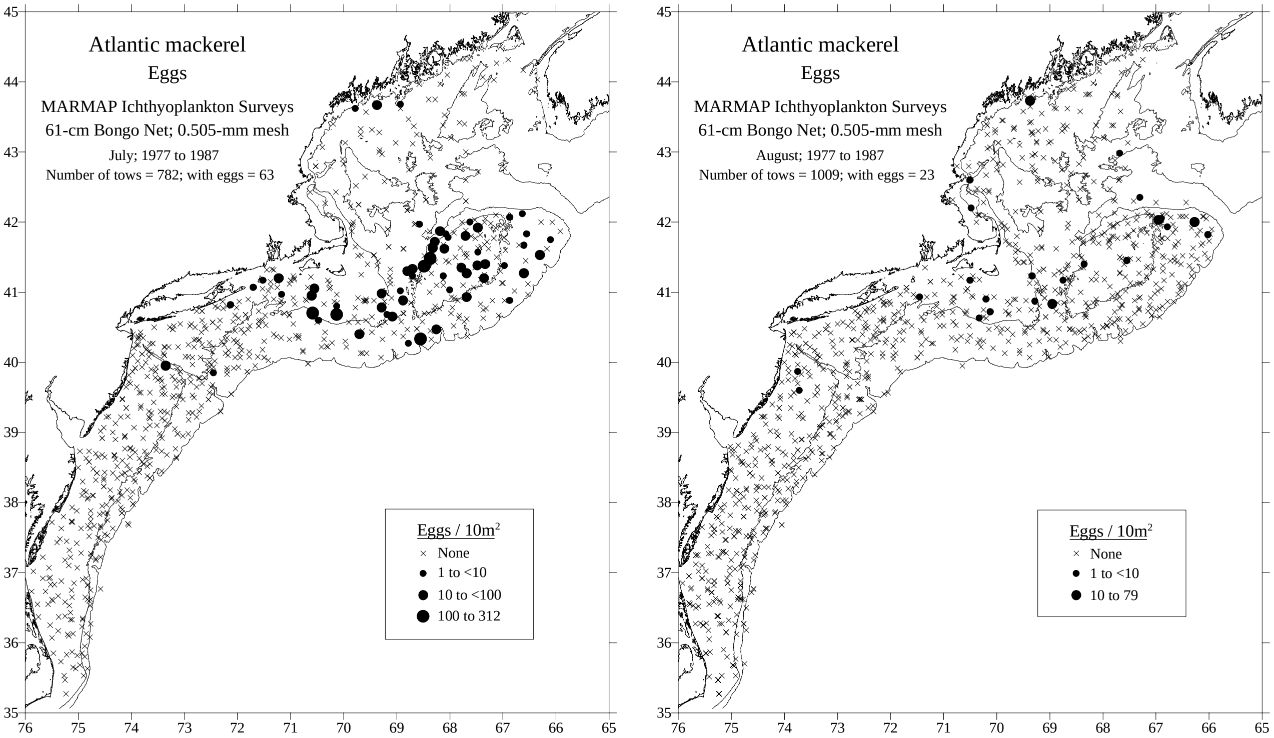


Figure 9. Distribution and abundance of Atlantic mackerel eggs collected during NEFSC MARMAP ichthyoplankton surveys from April to August, 1977-1987 [all years combined; see Reid *et al.* (1999) for details]. Egg densities are represented by dot size.



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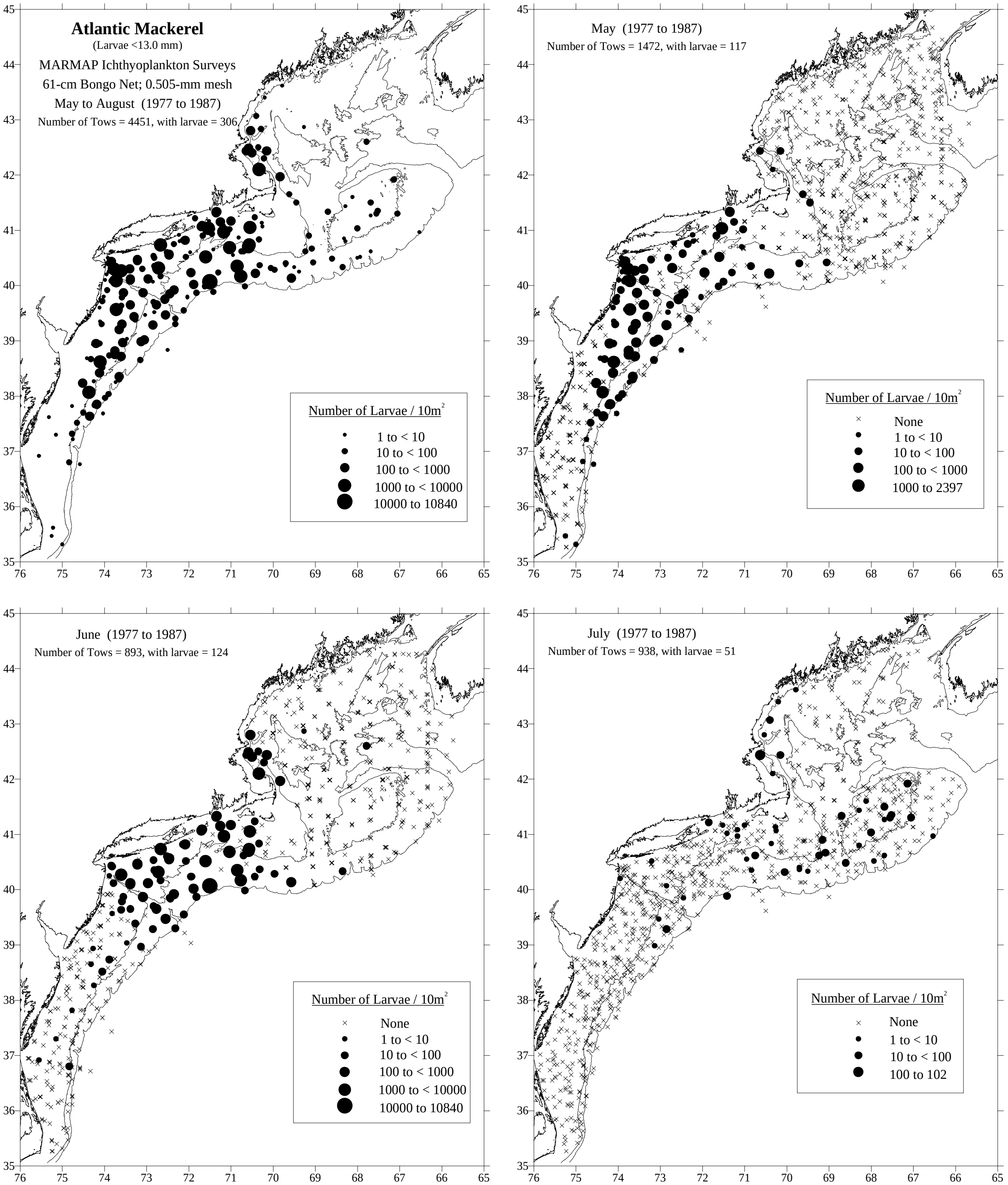
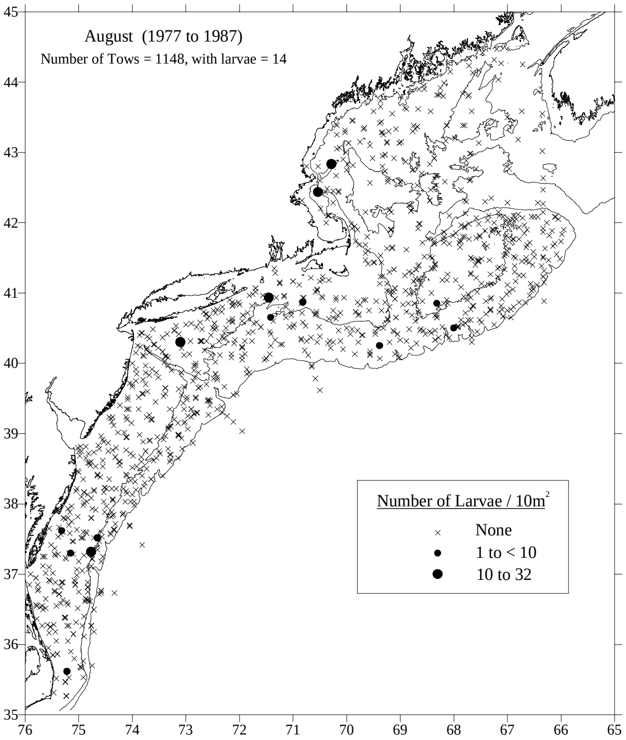


Figure 10. Distribution and abundance of Atlantic mackerel larvae collected during NEFSC MARMAP ichthyoplankton surveys from May to August, 1977-1987 [all years combined; see Reid *et al.* (1999) for details]. Larval densities are represented by dot size.



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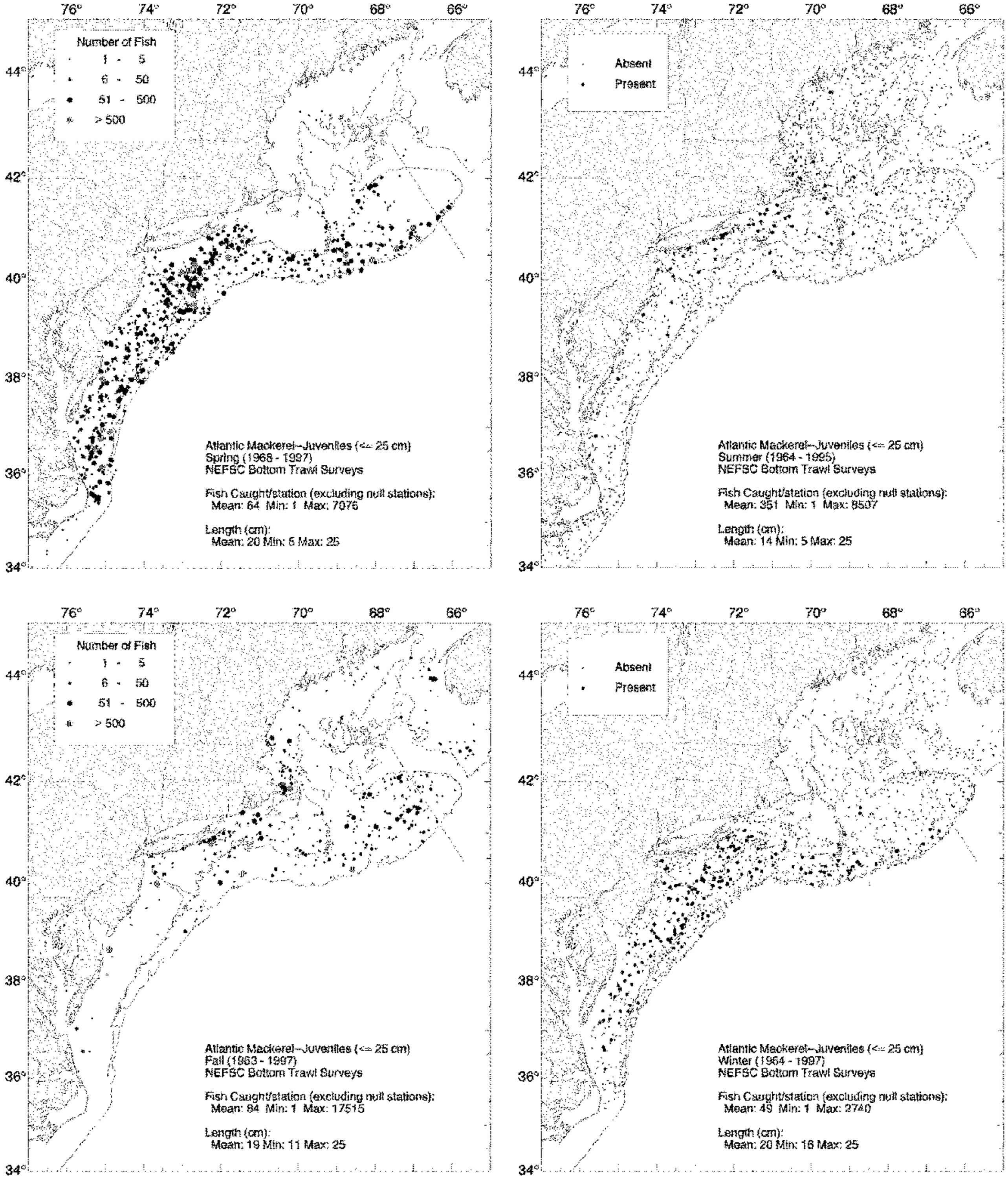

Figure 11. Seasonal distribution and abundance of juvenile (≤ 25 cm) and adult (≥ 26 cm) Atlantic mackerel collected during NEFSC bottom trawl surveys, 1963-1997 (all years combined). Densities are represented by dot size in spring and fall plots, while only presence and absence are represented in summer and winter plots [see Reid *et al.* (1999) for details].

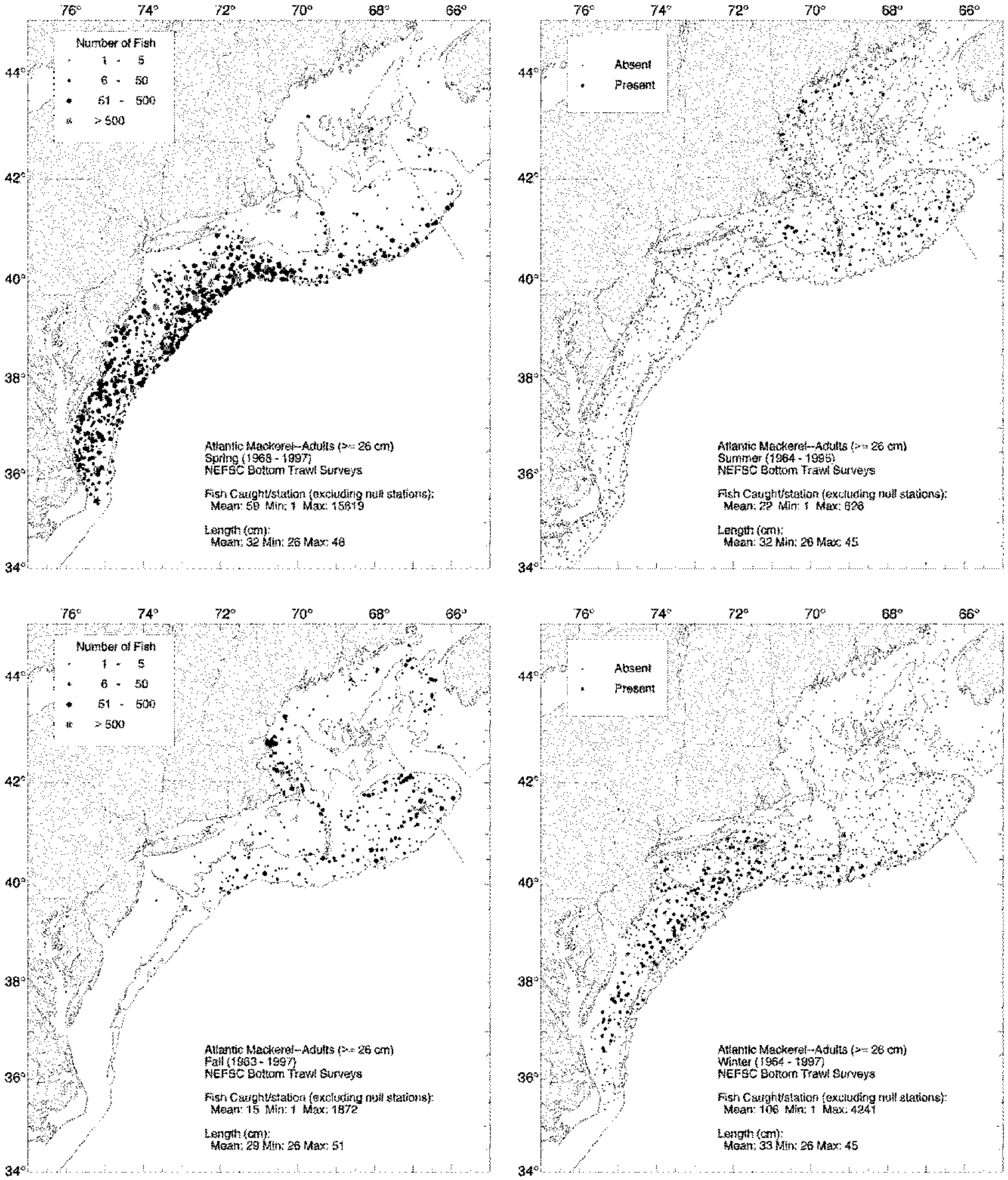

Figure 11. cont'd.

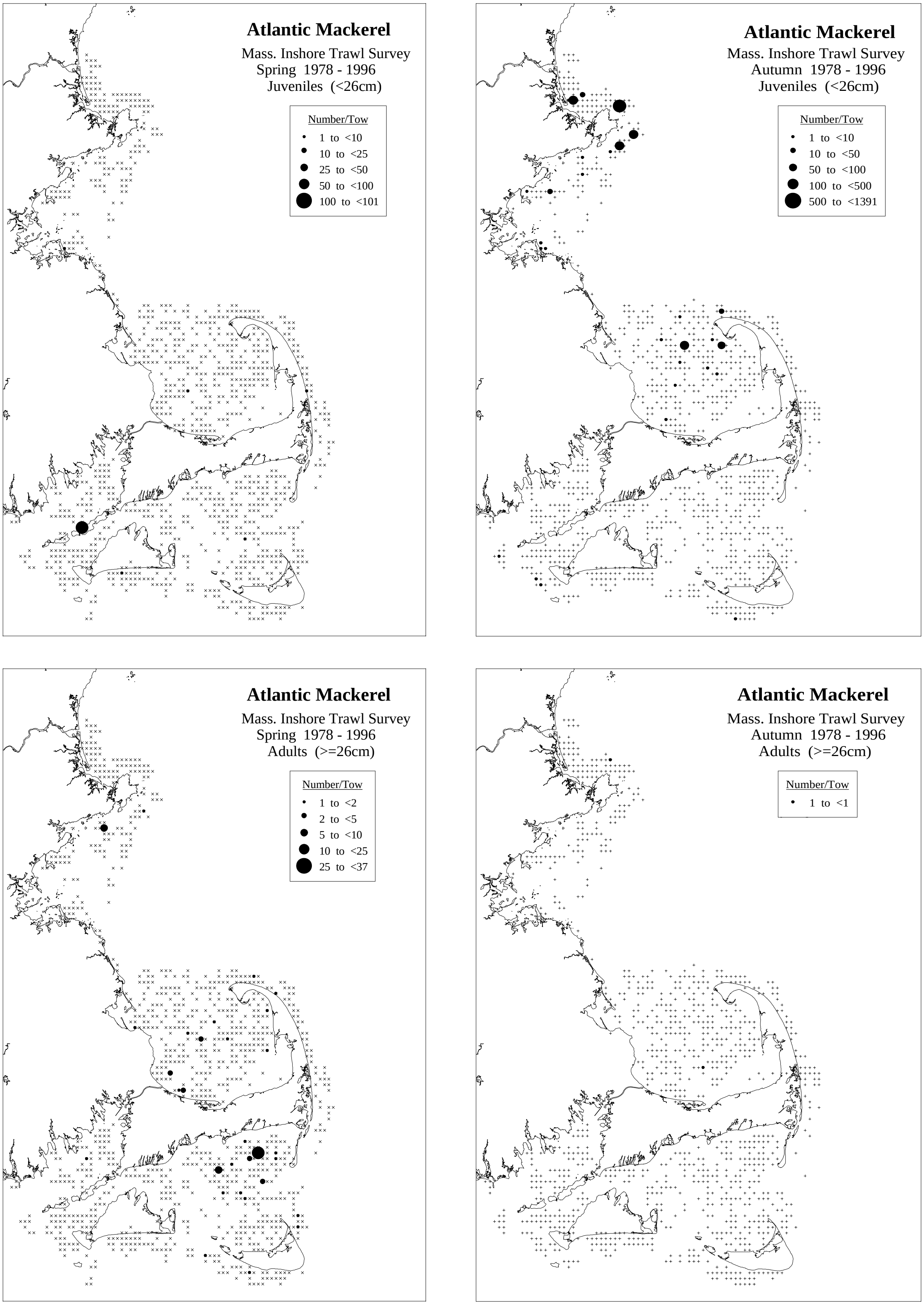

Figure 12. Distribution and abundance of juvenile (< 26 cm) and adult (≥ 26 cm) Atlantic mackerel in Massachusetts coastal waters collected during the spring and autumn Massachusetts inshore trawl surveys [1978-1996, all years combined; see Reid *et al.* (1999) for details].

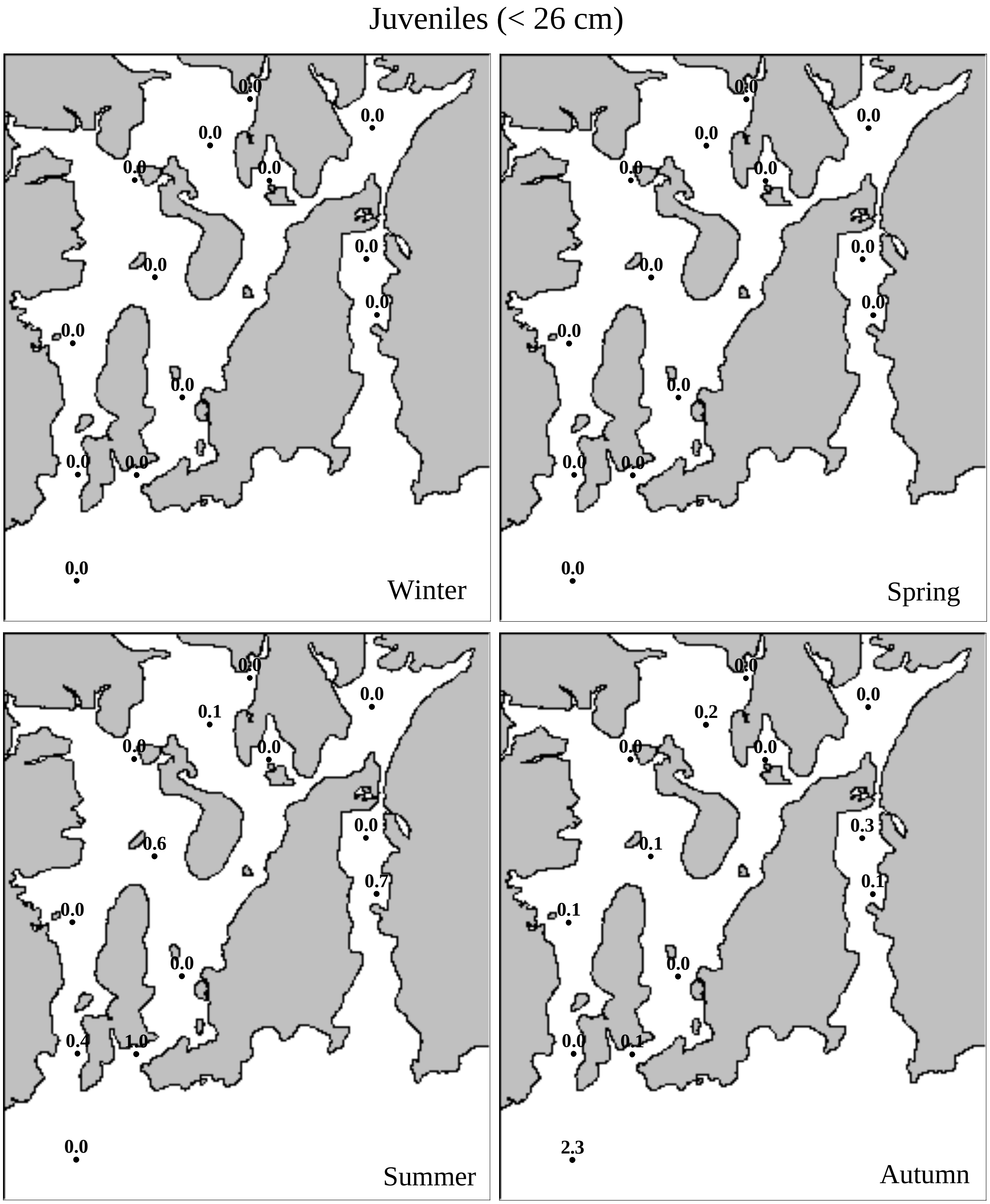

Figure 13. Seasonal distribution and relative abundance of juvenile (< 26 cm) Atlantic mackerel collected in Narragansett Bay during Rhode Island bottom trawl surveys (1990-1996; all years combined). The numbers shown at each station are the average catch per tow rounded to one decimal place [see Reid *et al.* (1999) for details].

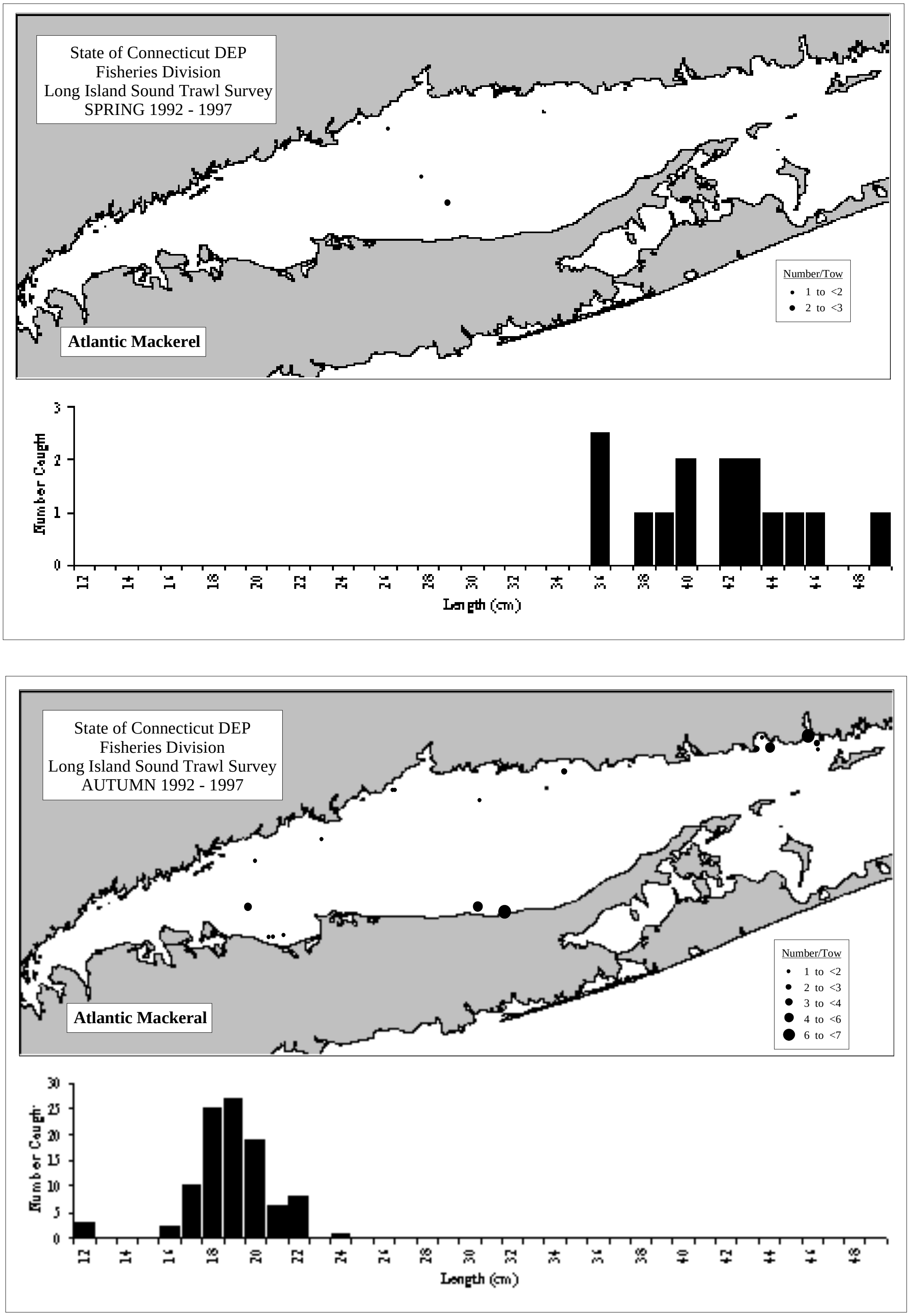

Figure 14. Distribution, abundance, and length frequency distribution of juvenile and adult Atlantic mackerel collected in Long Island Sound during spring and autumn Connecticut bottom trawl surveys [1992-1997, all years combined; see Reid *et al.* (1999) for details].

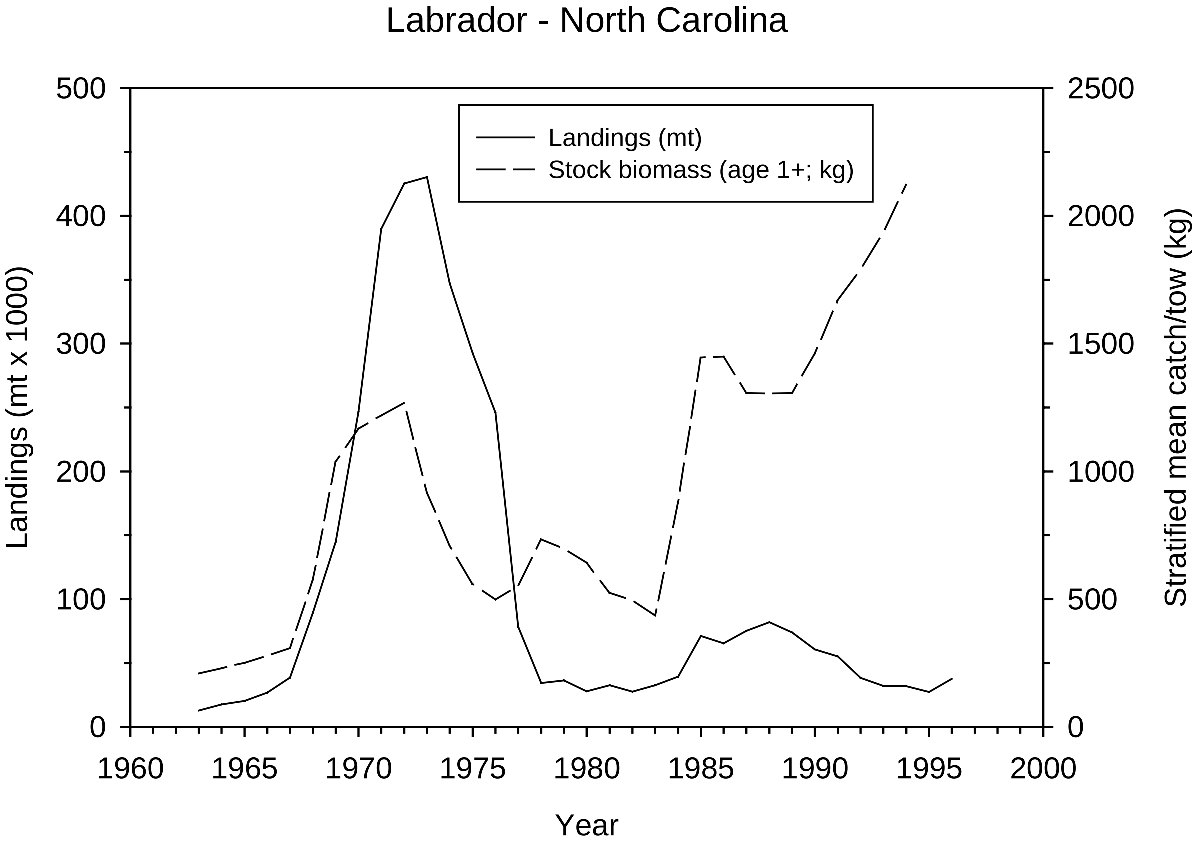

Figure 15. Commercial landings and stock biomass for Atlantic mackerel from Labrador to North Carolina.

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Style: All NEFSC publication and report series are obligated to conform to the style contained in the most recent edition of the *United States Government Printing Office Style Manual*. That style manual is silent on many aspects of scientific manuscripts. NEFSC publication and report series rely more on the *CBE Style Manual,* fifth edition.

For in-text citations, use the name-date system. A special effort should be made to ensure that the list of cited works contains all necessary bibliographic information. For abbreviating serial titles in such lists, use the most recent edition of the *Serial Sources for the BIOSIS Previews Database* (Philadelphia, PA: Biosciences Information Service). Personal communications must include date of contact and full name and mailing address of source.

For spelling of scientific and common names of fishes, mollusks, and decapod crustaceans from the United States and Canada, use *Special Publications* No. 20 (fishes), 26 (mollusks), and 17 (decapod crustaceans) of the American Fisheries Society (Bethesda, MD). For spelling of scientific and common names of marine mammals, use *Special Publication* No. 4 of the Society for Marine Mammalogy (Lawrence, KS). For spelling in general, use the most recent edition of *Webster's Third New International Dictionary of the English Language Unabridged* (Springfield, MA: G.&C. Merriam).

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Tables should be prepared using all tabs or all spaces between columnar data, but not a combination of the two. Figures must be original (even if oversized) and on paper; they cannot be photocopies (*e.g.,* Xerox) unless that is all that is available, nor be on disk. Except under extraordinary circumstances, color will not be used in illustrations.

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Authors must submit one paper copy of the double-spaced manuscript, one magnetic copy on a disk, and original figures (if applicable). NEFSC authors must include a completely signed-off "NEFSC Manuscript/Abstract/Webpage Review Form." Non-NEFSC authors who are not federal employees will be required to sign a "Release of Copyright" form.

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STANDARD
MAIL A

Publications and Reports of the Northeast Fisheries Science Center

The mission of NOAA's National Marine Fisheries Service (NMFS) is "stewardship of living marine resources for the benefit of the nation through their science-based conservation and management and promotion of the health of their environment." As the research arm of the NMFS's Northeast Region, the Northeast Fisheries Science Center (NEFSC) supports the NMFS mission by "planning, developing, and managing multidisciplinary programs of basic and applied research to: 1) better understand the living marine resources (including marine mammals) of the Northwest Atlantic, and the environmental quality essential for their existence and continued productivity; and 2) describe and provide to management, industry, and the public, options for the utilization and conservation of living marine resources and maintenance of environmental quality which are consistent with national and regional goals and needs, and with international commitments." Results of NEFSC research are largely reported in primary scientific media (*e.g.*, anonymously-peer-reviewed scientific journals). However, to assist itself in providing data, information, and advice to its constituents, the NEFSC occasionally releases its results in its own media. Those media are in three categories:

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Fishermen's Report* and *The Shark Tagger -- The ***Fishermen's Report*** (FR) is a quick-turnaround report on the distribution and relative abundance of commercial fisheries resources as derived from each of the NEFSC's periodic research vessel surveys of the Northeast's continental shelf. There is no scientific review, nor any technical or copy editing, of the FR; copies are available through free subscription. ***The Shark Tagger***(TST) is an annual summary of tagging and recapture data on large pelagic sharks as derived from the NMFS's Cooperative Shark Tagging Program; it also presents information on the biology (movement, growth, reproduction, etc.) of these sharks as subsequently derived from the tagging and recapture data. There is internal scientific review, but no technical or copy editing, of the TST; copies are available only to participants in the tagging program.

To obtain a copy of a technical memorandum or a reference document, or to subscribe to the fishermen's report, write: Research Communications Unit, Northeast Fisheries Science Center, 166 Water St., Woods Hole, MA 02543-1026. An annual list of NEFSC publications and reports is available upon request at the above address. Any use of trade names in any NEFSC publication or report does not imply endorsement.

Appendix 6

Illex EFH Source Document

NOAA Technical Memorandum NMFS-NE-191

Essential Fish Habitat Source Document:

Northern Shortfin Squid, *Illex illecebrosus*, Life History and Habitat Characteristics

Second Edition

U. S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
National Marine Fisheries Service
Northeast Fisheries Science Center
Woods Hole, Massachusetts

November 2004

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174. **Essential Fish Habitat Source Document: Clearnose Skate, *Raja eglanteria*, Life History and Habitat Characteristics**. By David B. Packer, Christine A. Zetlin, and Joseph J. Vitaliano. March 2003. v + 50 p., 25 figs., 2 tables. NTIS Access. No. PB2003-104260.

175. **Essential Fish Habitat Source Document: Little Skate, *Leucoraja erinacea*, Life History and Habitat Characteristics**. By David B. Packer, Christine A. Zetlin, and Joseph J. Vitaliano. March 2003. v + 66 p., 27 figs., 2 tables. NTIS Access. No. PB2003-104259.

176. **Essential Fish Habitat Source Document: Rosette Skate, *Leucoraja garmani virginica*, Life History and Habitat Characteristics**. By David B. Packer, Christine A. Zetlin, and Joseph J. Vitaliano. March 2003. v + 17 p., 11 figs., 1 table. NTIS Access. No. PB2003-104258.

177. **Essential Fish Habitat Source Document: Smooth Skate, *Malacoraja senta*, Life History and Habitat Characteristics**. By David B. Packer, Christine A. Zetlin, and Joseph J. Vitaliano. March 2003. v + 26 p., 15 figs., 1 table. NTIS Access. No. PB2003-104256.

178. **Essential Fish Habitat Source Document: Thorny Skate, *Amblyraja radiata*, Life History and Habitat Characteristics**. By David B. Packer, Christine A. Zetlin, and Joseph J. Vitaliano. March 2003. v + 39 p., 18 figs., 2 tables. NTIS Access. No. PB2003-104255.

179. **Essential Fish Habitat Source Document: Winter Skate, *Leucoraja ocellata*, Life History and Habitat Characteristics**. By David B. Packer, Christine A. Zetlin, and Joseph J. Vitaliano. March 2003. v + 57 p., 25 figs., 2 tables. NTIS Access. No. PB2003-104254.

180. **Variability in Blood Chemistry of Yellowtail Flounder, *Limanda ferruginea*, with Regard to Sex, Season, and Geographic Location**. By Renee Mercaldo-Allen, Margaret A. Dawson, Catherine A. Kuropat, and Diane Kapareiko. September 2003. vi + 20 p., 1 fig., 10 tables. NTIS Access. No. PB2004-107074.

181. In press.

182. **U.S. Atlantic and Gulf of Mexico Marine Mammal Stock Assessments – 2003.** By Gordon T. Waring, Richard M. Pace, Janeen M. Quintal, Carol P. Fairfield, and Katherine Maze-Foley, eds., Nicole Cabana, Phillip J. Clapham, Timothy V.N. Cole, Gregory L. Fulling, Lance P. Garrison, Aleta A. Hohn, Blair G. Maise, Wayne E. McFee, Keith D. Mullin, Debra L. Palka, Patricia E. Rosel, Marjorie C. Rossman, Frederick W. Wenzel, and Amy L. Whitingham, contribs. May 2004. vii + 287 p., 47 figs., 58 tables, 4 app., index. NTIS Access. No. PB2004-106431.

NOAA Technical Memorandum NMFS-NE-191

This series represents a secondary level of scientific publishing. All issues employ thorough internal scientific review; some issues employ external scientific review. Reviews are -- by design -- transparent collegial reviews, not anonymous peer reviews. All issues may be cited in formal scientific communications.

Essential Fish Habitat Source Document:

Northern Shortfin Squid, *Illex illecebrosus*, Life History and Habitat Characteristics

Second Edition

Lisa C. Hendrickson and Elizabeth M. Holmes

National Marine Fisheries Serv., 166 Water St., Woods Hole, MA 02543

U. S. DEPARTMENT OF COMMERCE
Donald L. Evans, Secretary
National Oceanic and Atmospheric Administration
Vice Admiral Conrad C. Lautenbacher, Jr., USN (ret.), Administrator
National Marine Fisheries Service
William T. Hogarth, Assistant Administrator for Fisheries
Northeast Fisheries Science Center
Woods Hole, Massachusetts

November 2004

Editorial Notes on "Essential Fish Habitat Source Documents" Issued in the *NOAA Technical Memorandum NMFS-NE* Series

Editorial Production

For "Essential Fish Habitat Source Documents" issued in the *NOAA Technical Memorandum NMFS-NE* series, staff of the Northeast Fisheries Science Center's (NEFSC's) Ecosystems Processes Division largely assume the role of staff of the NEFSC's Editorial Office for technical and copy editing, type composition, and page layout. Other than the four covers (inside and outside, front and back) and first two preliminary pages, all preprinting editorial production is performed by, and all credit for such production rightfully belongs to, the staff of the Ecosystems Processes Division.

Internet Availability and Information Updating

Each original issue of an "Essential Fish Habitat Source Document" is published both as a paper copy and as a Web posting. The Web posting, which is in "PDF" format, is available at: *http://www.nefsc.noaa.gov/nefsc/habitat/efh*.

Each issue is updated at least every five years. The updated edition will be published as a Web posting only; the replaced edition(s) will be maintained in an online archive for reference purposes.

Species Names

The NMFS Northeast Region's policy on the use of species names in all technical communications is generally to follow the American Fisheries Society's lists of scientific and common names for fishes (*i.e.*, Robins *et al.* 1991a[a],b[b]), mollusks (*i.e.*, Turgeon *et al.* 1998[c]), and decapod crustaceans (*i.e.*, Williams *et al.* 1989[d]), and to follow the Society for Marine Mammalogy's guidance on scientific and common names for marine mammals (*i.e.*, Rice 1998[e]). Exceptions to this policy occur when there are subsequent compelling revisions in the classifications of species, resulting in changes in the names of species (*e.g.*, Cooper and Chapleau 1998[f]; McEachran and Dunn 1998[g]).

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[a] Robins, C.R. (chair); Bailey, R.M.; Bond, C.E.; Brooker, J.R.; Lachner, E.A.; Lea, R.N.; Scott, W.B. 1991a. Common and scientific names of fishes from the United States and Canada. 5th ed. *Amer. Fish. Soc. Spec. Publ.* 20; 183 p.

[b] Robins, C.R. (chair); Bailey, R.M.; Bond, C.E.; Brooker, J.R.; Lachner, E.A.; Lea, R.N.; Scott, W.B. 1991b. World fishes important to North Americans. *Amer. Fish. Soc. Spec. Publ.* 21; 243 p.

[c] Turgeon, D.D. (chair); Quinn, J.F., Jr.; Bogan, A.E.; Coan, E.V.; Hochberg, F.G.; Lyons, W.G.; Mikkelsen, P.M.; Neves, R.J.; Roper, C.F.E.; Rosenberg, G.; Roth, B.; Scheltema, A.; Thompson, F.G.; Vecchione, M.; Williams, J.D. 1998. Common and scientific names of aquatic invertebrates from the United States and Canada: mollusks. 2nd ed. *Amer. Fish. Soc. Spec. Publ.* 26; 526 p.

[d] Williams, A.B. (chair); Abele, L.G.; Felder, D.L.; Hobbs, H.H., Jr.; Manning, R.B.; McLaughlin, P.A.; Pérez Farfante, I. 1989. Common and scientific names of aquatic invertebrates from the United States and Canada: decapod crustaceans. *Amer. Fish. Soc. Spec. Publ.* 17; 77 p.

[e] Rice, D.W. 1998. Marine mammals of the world: systematics and distribution. *Soc. Mar. Mammal. Spec. Publ.* 4; 231 p.

[f] Cooper, J.A.; Chapleau, F. 1998. Monophyly and interrelationships of the family Pleuronectidae (Pleuronectiformes), with a revised classification. *Fish. Bull. (Washington, DC)* 96:686-726.

[g] McEachran, J.D.; Dunn, K.A. 1998. Phylogenetic analysis of skates, a morphologically conservative clade of elasmobranchs (Chondrichthyes: Rajidae). *Copeia* 1998(2):271-290.

PREFACE TO SECOND EDITION

One of the greatest long-term threats to the viability of commercial and recreational fisheries is the continuing loss of marine, estuarine, and other aquatic habitats.

Magnuson-Stevens Fishery Conservation and Management Act (October 11, 1996)

The long-term viability of living marine resources depends on protection of their habitat.

NMFS Strategic Plan for Fisheries Research (February 1998)

The Magnuson-Stevens Fishery Conservation and Management Act (MSFCMA), which was reauthorized and amended by the Sustainable Fisheries Act (1996), requires the eight regional fishery management councils to describe and identify essential fish habitat (EFH) in their respective regions, to specify actions to conserve and enhance that EFH, and to minimize the adverse effects of fishing on EFH. Congress defined EFH as "those waters and substrate necessary to fish for spawning, breeding, feeding or growth to maturity." The MSFCMA requires NOAA Fisheries to assist the regional fishery management councils in the implementation of EFH in their respective fishery management plans.

NOAA Fisheries has taken a broad view of habitat as the area used by fish throughout their life cycle. Fish use habitat for spawning, feeding, nursery, migration, and shelter, but most habitats provide only a subset of these functions. Fish may change habitats with changes in life history stage, seasonal and geographic distributions, abundance, and interactions with other species. The type of habitat, as well as its attributes and functions, are important for sustaining the production of managed species.

The Northeast Fisheries Science Center compiled the available information on the distribution, abundance, and habitat requirements for each of the species managed by the New England and Mid-Atlantic Fishery Management Councils. That information is presented in a series EFH species reports (plus one consolidated methods report). The EFH species reports are a survey of the important literature as well as original analyses of fishery-independent data sets from NOAA Fisheries and several coastal states. The species reports are also the source for the current EFH designations by the New England and Mid-Atlantic Fishery Management Councils, and understandably have begun to be referred to as the "EFH source documents."

NOAA Fisheries provided guidance to the regional fishery management councils for identifying and describing EFH of their managed species. Consistent with this guidance, the species reports present information on current and historic stock sizes, geographic range, and the period and location of major life history stages. The habitats of managed species are described by the physical, chemical, and biological components of the ecosystem where the species occur. Information on the habitat requirements is provided for each life history stage, and it includes, where available, habitat and environmental variables that control or limit distribution, abundance, growth, reproduction, mortality, and productivity.

The initial series of EFH species source documents were published in 1999 in the *NOAA Technical Memorandum NMFS-NE* series. Updating and review of the EFH components of the councils' Fishery Management Plans is required at least every 5 years by the NOAA Fisheries Guidelines for meeting the Sustainable Fisheries Act/EFH Final Rule. The second editions of these species source documents were written to provide the updated information needed to meet these requirements. The second editions provide new information on life history, geographic distribution, and habitat requirements via recent literature, research, and fishery surveys, and incorporate updated and revised maps and graphs. This second edition of the northern shortfin squid EFH source document is based on the original by Luca M. Cargnelli, Sara J. Griesbach, and Christine A. Zetlin, with a foreword by Jeffrey N. Cross (Cargnelli *et al*. 1999).

Identifying and describing EFH are the first steps in the process of protecting, conserving, and enhancing essential habitats of the managed species. Ultimately, NOAA Fisheries, the regional fishery management councils, fishing participants, Federal and state agencies, and other organizations will have to cooperate to achieve the habitat goals established by the MSFCMA.

Contents

Tables

Figures

INTRODUCTION

The northern shortfin squid, *Illex illecebrosus* (Figure 1), is a highly migratory species of the family Ommastrephidae. Distributed across a broad geographic area, *I. illecebrosus* is found in the northwest Atlantic Ocean between the Sea of Labrador and the Florida Straits (66ºN to 29º30'N; Roper *et al.* 1998). Throughout its range of commercial exploitation, from Newfoundland to Cape Hatteras, North Carolina, the population is considered to constitute a single stock (Dawe and Hendrickson 1998). The southern stock component (inhabiting U.S. waters) is managed by the Mid-Atlantic Fishery Management Council, in accordance with the Atlantic Mackerel, Squid and Butterfish Fishery Management Plan (MAFMC 1998), and the northern stock component (inhabiting waters between Newfoundland and Nova Scotia) is assessed and managed by the Northwest Atlantic Fisheries Organization (Hendrickson *et al.* 2002). Both stock components are managed based on an annual quota.

This Essential Fish Habitat Source Document provides information on the life history and habitat characteristics of northern shortfin squid. Data sources and methodologies used to prepare this document are described in Reid *et al.* (1999).

LIFE HISTORY

The life history characteristics of northern shortfin squid have been reviewed by Black *et al.* (1987), Perez (1994), and O'Dor and Dawe (1998). Most of the supporting studies have been based on the northern component of the stock. Like many squid species, *I. illecebrosus* lives for less than one year, has a high natural mortality rate, and exhibits a protracted spawning season whereby overlapping "microcohorts" enter the population throughout the year and exhibit variable growth rates (Caddy 1991; Jackson 1994). The life cycle is comprised of oceanic and neritic components. During spring, squid migrate onto the continental shelf between Newfoundland and Cape Hatteras. During late autumn, squid migrate off the continental shelf, presumably to a winter spawning site (Black *et al.* 1987). The seasonal proportion of squid residing beyond the continental shelf is unknown because this habitat is not sampled during seasonal U.S. and Canadian bottom trawl surveys. Little is known about either the habitat of mature individuals (particularly females) or the winter habitat of the species.

The life cycle (Figure 2) proposed by Black *et al.* (1987) remains hypothetical because several aspects remain unknown. These include the location of the winter spawning site, migration patterns between northern and southern stock components, the autumn spawning migration route, and what fraction of the stock inhabits waters beyond the continental shelf.

New life history information regarding population structure, spawning location, lifespan, and age and size at maturity are described herein. This new information is based on data collected on the U.S. shelf during a stratified, random bottom trawl survey of the population (Hendrickson 2004).

EGGS AND PARALARVAE

Illex illecebrosus egg masses have never been collected in the wild (O'Dor and Dawe 1998) but have been described from laboratory spawning events. The gelatinous egg balloons are 0.5 to 1.0 m in diameter and contain between 10,000 and 100,000 eggs (Durward *et al.* 1980). Females can produce multiple egg masses (Durward *et al.* 1978). Mature eggs are ovoid, ranging from 0.9 x 0.6 to 1.0 to 0.8 mm in size, and weigh between 200 and 250 µg (Durward *et al.* 1980).

Laboratory studies indicate that hatching occurs in 16 days at 13°C, 12 days at 16°C, and 8 days at 21°C; normal embryonic development requires water temperatures of at least 12.5°C (O'Dor *et al.* 1982b). Paralarvae may remain within the remnants of the egg mass to utilize the nutrients as a food source (Durward *et al.* 1980). In the laboratory, paralarvae hatch at approximately 1.1 mm mantle length (ML) (Durward *et al.* 1980), then enter a transitional stage at approximately 5.0 mm ML, followed by a juvenile stage at about 7.0 mm ML (Hatanaka 1986).

Based on the distribution of paralarvae, it is hypothesized that the Gulf Stream serves as the primary transport mechanism for egg masses and paralarvae (O'Dor 1983; Rowell *et al.* 1985a). Paralarvae have been collected during all seasons (Roper and Lu 1979), from south of Cape Hatteras to as far north as the tail of the Grand Bank (Dawe and Beck 1985; Hatanaka *et al.* 1985). Paralarvae are most abundant in February and March, in the nutrient-rich waters of the Gulf Stream/Slope Water convergence zone; above the thermocline at temperatures greater than 13°C (Hatanaka *et al.* 1985).

I. illecebrosus paralarvae hatched in the laboratory were 1.10 to 1.25 mm ML (O'Dor *et al.* 1986). *Illex* sp. hatchlings have only been collected in waters south of Cape Hatteras (35.5ºN) and during February through March (Dawe and Beck 1985; Rowell *et al.* 1985a). However, species identification of *Illex* paralarvae is problematic, particularly if caught south of New Jersey, due to the difficulty in distinguishing between paralarvae of *I. illecebrosus* and two sympatric *Illex* species (Vecchione and Roper 1986).

JUVENILES AND ADULTS

Onset of the juvenile stage at 8 to 10 mm ML is indicated by a separation of the proboscis into a pair of tentacles (Roper and Lu 1979). Juveniles collected in surveys conducted in the Gulf Stream and continental slope waters during February through May ranged in size from 10 to 94 mm ML (O'Dor 1983). During late spring, juveniles migrate onto the continental shelf between Nova Scotia and Cape Hatteras (O'Dor 1983; Black *et al*. 1987).

Juveniles caught on the continental shelf in late May ranged in size from 34 to 68 mm ML. Gonadal development began at about 64 mm ML in males and at 74 mm ML in females. Males attained 50% maturity at a smaller size and older age than females, but these differences were not statistically significant. Size- and age-at-maturity increased with latitude and were correlated with decreases in water temperature (Hendrickson 2004). Mean size at maturity may also vary inter-annually (Coelho and O'Dor 1993). In inshore Newfoundland waters, the percentage of mature males and male gonadosomatic indices were significantly higher for squid hatched in May than during March or April. Although females do not become mature in inshore Newfoundland waters, those hatched in May were more mature than those hatched in March or April (Dawe and Beck 1997). Captive females matured within 40 to 60 days (O'Dor *et al*. 1977).

In Nova Scotian and Newfoundland waters, males mature at a faster rate than females and are believed to emigrate during autumn from continental shelf fishing areas before females (Black *et al.* 1987). Evidence for this phenomenon is a seasonal decline in the percentage of males collected on the Scotian Shelf during some years (Amaratunga 1980a). However, a reduction in the proportion of males, which tend to be small individuals, can also result from cannibalism by larger females (O'Dor and Dawe 1998). During late autumn, nearly-mature squid migrate from all continental shelf fishing areas (Hurley 1980; Black *et al.* 1987), presumably to spawn. Most mature females have been collected from the U.S. shelf (Hendrickson 2004), but four have also been recorded from waters off the coast of Newfoundland and Nova Scotia (Dawe and Drew 1981).

Age estimation, accomplished by counting daily growth increments in the statoliths, has been validated for *I. illecebrosus* (Dawe *et al*. 1985; Hurley *et al*. 1985). Increment counts of statoliths from mated females caught in the Mid-Atlantic Bight indicate a lifespan of about 115 to 215 days (Hendrickson 2004). Squid inhabiting warmer waters of the Mid-Atlantic Bight exhibit faster rates of growth and maturation, and possibly a shorter lifespan, than squid from the northern stock component (Hendrickson 2004). The species may achieve a maximum size of 35 cm ML and 700 g, with females achieving larger sizes than males (Hendrickson 1998; O'Dor and Dawe 1998).

The terms recruit and pre-recruit are used herein to describe geographical distributions and habitat characteristics for the exploited and unexploited portions of the stock, respectively. Exploitation occurs at a minimum mantle length of 10 cm ML, the approximate length at which individuals migrate onto the continental shelf (O'Dor 1983; Hendrickson *et al*. 1996). Pre-recruits and recruits are thus defined as individuals ≤ 10 cm ML and ≥ 11 cm ML, respectively.

REPRODUCTION

Mating and spawning have only been observed in captivity. *I. illecebrosus* is a semelparous, terminal spawner whereby spawning and death occur within several days of mating (O'Dor 1983). Mature females collected on the U.S. continental shelf had mated with as many as four males (Hendrickson 2004).

Until recently, few mature females and only two mated individuals have been recorded (Dawe and Drew 1981). However, back-calculations of hatch dates based on statolith age analyses indicate that spawning occurs during October through June (Dawe and Beck 1997; Hendrickson 2004).

A winter spawning area, located off the east coast of Florida in the vicinity of the Blake Plateau (Figure 2; Black *et al*. 1987), has been inferred based on: the presence of *Illex* sp. hatchlings along the north wall of the Gulf Stream during January and February (Dawe and Beck 1985; Rowell *et al*. 1985a; Vecchione and Roper 1986; Coelho and O'Dor 1993); the offshore migration of adults in late autumn (Black *et al*. 1987); and the presence of minimum water temperatures required for hatching (O'Dor *et al*. 1982b; Trites 1983; Rowell and Trites 1985).

The only confirmed spawning area is located in the Mid-Atlantic Bight, at depths of 113 to 377 m, where a large number of mated females were collected between 39º10´N and 35º50´N during late May (Figure 3; Hendrickson 2004). This spawning area overlaps spatially with the fishing grounds of the directed fishery (Hendrickson *et al*. 1996). Spawning may also occur offshore in the Gulf Stream/Slope Water frontal zone, where paralarvae have been collected (O'Dor and Balch 1985; Rowell *et al*. 1985a), or south of Cape Hatteras during winter where *Illex* sp. hatchlings have been collected (Dawe and Beck 1985). Previous reports of mated females consist of three individuals that were caught south of Georges Bank (Dawe and Drew 1981).

DIET

Trophic relationships between *I. illecebrosus* and other marine species are described by Dawe and Brodziak (1998). Northern shortfin squid feed primarily on fish and crustaceans, but cannibalism of small individuals (most likely males) by larger females also occurs, particularly during autumn (Squires 1957; Froerman 1984; Maurer and Bowman 1985; Dawe 1988). An ontogenetic shift in diet from a predominance of crustaceans to a predominance of fish and squid is evident in squid from both stock components (Maurer and Bowman 1985; Dawe 1988).

Fish prey consists of the early life history stages of Atlantic cod, Arctic cod and redfish (Squires 1957, Dawe *et al*. 1997), sand lance (Dawe *et al*. 1997), mackerel and Atlantic herring (O'Dor *et al*. 1980a; Dawe *et al*. 1997), and haddock and sculpin (Squires 1957). *Illex* also feed on adult capelin (Squires 1957; O'Dor *et al*. 1980a; Dawe *et al*. 1997) and longfin inshore squid, *Loligo pealeii* (Vinogradov 1984).

Illex exhibit diel vertical migrations (Roper and Young 1975; Brodziak and Hendrickson 1999) and both juveniles (Arkhipkin and Fedulov 1986) and adults feed primarily at night in the upper layers of the water column (Maurer and Bowman 1985). On the U.S. shelf in the spring, *I. illecebrosus* primarily consume euphausiids, whereas fish and squid were the dominant prey in the summer and fall. *I. illecebrosus* 6-10 cm and 26-30 cm in size eat mostly squid, while 11-15 cm *Illex* eat mostly crustaceans and fish, and individuals 16-20 cm eat mostly crustaceans (Maurer and Bowman 1985).

Illex gut content data collected during Northeast Fisheries Science Center (NEFSC) bottom trawl surveys (Link and Almeida 2000) were combined across seasons to compute the percent composition of major prey categories (Figure 4). For both pre-recruits (92%) and recruits (57%), a majority of the gut contents consisted of well-digested prey. Pre-recruit prey types that could be identified consisted of crustaceans (3%) and fish (3%). The diet of recruits consisted of cephalopods (30%), crustaceans (including euphausiids, 7%), and fish (6%).

PREDATION AND MORTALITY

Numerous species of pelagic and benthic fishes prey on *Illex*, including bluefin tuna (Butler 1971), silver hake and red hake (Vinogradov 1972). Other fish predators include bluefish (Maurer 1975; Buckel 1997), goosefish (Maurer 1975; Langton and Bowman 1977), fourspot flounder (Langton and Bowman 1977), Atlantic cod (Lilly and Osborne 1984), sea raven (Maurer 1975), spiny dogfish (Templeman 1944; Maurer 1975), and swordfish (Langton and Bowman 1977; Stillwell and Kohler 1985; Scott and Scott 1988). Mammalian predators include pilot whales (Squires 1957; Wigley 1982) and the common dolphin (Major 1986). Seabird predators include shearwaters, gannets, and fulmars (Brown *et al*. 1981). Northern shortfin squid are known to exhibit a variety of defense mechanisms that may reduce predation, such as camouflage coloration (O'Dor 1983), schooling behavior, jetting, and ink release (Major 1986).

MIGRATION

Northern shortfin squid are highly migratory. An individual tagged off Newfoundland was recaptured off the coast of Maryland, more than 1,000 miles away (Dawe *et al*. 1981b). A hypothetical, annual migration route (Figure 2, from Black *et al*. 1987) has been constructed based on seasonal squid distribution patterns observed in bottom trawl surveys of the U.S. and Canadian continental shelves, concentrations of hatchlings in offshore waters south of Cape Hatteras during winter (Dawe and Beck 1985; Hatanaka *et al*. 1985; Rowell *et al*. 1985a), and suggestions that the neutrally-buoyant egg masses and paralarvae are rapidly transported northeastward by the Gulf Stream current (Trites 1983).

Seasonal distribution patterns in *Illex* abundance suggest that annual migrations off the U.S. shelf in autumn and onto the shelf in spring occur simultaneously along the entire length of the shelf edge rather than over the shelf in a gauntlet pattern (Hendrickson 2004; also see Geographical Distribution below). Tagging studies have demonstrated a southeastward migration of individuals from Newfoundland during autumn (Dawe *et al*. 1981b). However, the migration patterns between northern and southern stock components remain unknown and the offshore fraction of the population is not well understood because NEFSC surveys do not extend beyond the edge of the continental shelf and few stations are sampled in the deepest survey strata (185 to 366 m).

GEOGRAPHICAL DISTRIBUTION

Illex illecebrosus utilizes oceanic and neritic habitats and adults are believed to undergo long-distance migrations between boreal, temperate and sub-tropical waters. Data from U.S. and Canadian seasonal bottom trawl surveys (1975 to 1994) indicate that northern shortfin squid are distributed on the continental shelf of the U.S. and Canada, between Newfoundland and Cape Hatteras, North Carolina (Figure 5). The species is present in the Gulf of St.

Lawrence, along the western edge of the Grand Bank, and along the western shore of Newfoundland, but are most abundant on the U.S. and Scotian Shelf. Paralarvae and juveniles inhabit the Gulf Stream-slope water interface, located off the continental shelf of the U.S. and Canada, and juveniles also occur on the U.S. continental shelf. Adults have primarily been collected on the shelf due to sampling depth limitations of U.S. and Canadian bottom trawl surveys.

The southernmost limit of the range of *I. illecebrosus* is difficult to identify because of its co-occurrence with *I. coindetii* and *I. oxygonius*. Distinguishing between the three species is difficult given the high degree of interspecific and intraspecific variability in morphological characters (Roper and Mangold 1998; Roper *et al*. 1998).

EGGS AND PARALARVAE

Egg masses have never been collected in nature (O'Dor and Dawe 1998). Paralarvae have been collected during all seasons (Roper and Lu 1979), but predominately during January and February in the nutrient-rich waters of the Slope Water-Gulf Stream frontal zone, from south of Cape Hatteras to as far north as the Grand Bank (Dawe and Beck 1985; Hatanaka *et al*. 1985). The Gulf Stream has been hypothesized as the primary mechanism for the transport of egg balloons and paralarvae toward the Grand Bank (Trites 1983) based on its northeastern trajectory and rapid current (about 100 km/day).

PRE-RECRUITS

NEFSC bottom trawl surveys [see Reid et al. (1999) for details] have captured pre-recruits during all seasons (Figure 6; note that winter and summer distributions are presented as presence/absence data, precluding a discussion of abundances). In winter, the occurrence of pre-recruits is very low and distributed along the shelf edge between Cape Hatteras and Georges Bank. In the spring, pre-recruits are concentrated in low densities along the shelf edge, including the southern Scotian Shelf; the highest densities are found off of Cape Hatteras. By summer, pre-recruits have migrated onto the continental shelf and are distributed throughout all depths, primarily in the Mid-Atlantic Bight and along the coast of Maine. In autumn, pre-recruits begin their return migration to waters off the shelf. During fall, pre-recruits are present at depths greater than 60 m, between Georges Bank and Cape Hatteras, and are most abundant along the shelf edge. Low densities are also present in the Gulf of Maine.

The autumn distribution and abundance of pre-recruits around coastal Massachusetts, based on Massachusetts inshore bottom trawl surveys [see Reid et al. (1999) for details], is shown in Figure 7. During all of the spring surveys conducted between 1978 and 2003, only 16 individuals were collected at five stations in Massachusetts coastal waters. During the fall surveys, pre-recruits were present at very low densities at 28 stations located primarily off Cape Ann and northern Cape Cod Bay (at depths of 20 to 60 m); a few higher concentrations were found east of Cape Cod and near Nantucket Island.

Few (N=30) northern shortfin squid were caught during seasonal surveys of Narragansett Bay between 1990 and 1996. *Illex* were captured only during the summer and at three stations. Individuals ranged in size from 4 to 11 cm ML.

ADULTS

NEFSC bottom trawl surveys indicate similar seasonal distributions of recruits and pre-recruits. (See Figure 8 for recruits; again note that winter and summer distributions are presented as presence/absence data, precluding a discussion of abundances). Recruit abundance during spring and autumn appears to be greater than that of pre-recruits, but this is partially due to differences in catchability between the two size groups. The occurrence of recruits on the U.S. continental shelf is lowest during winter and concentrated along the shelf edge (at depths around 366 m) between Georges Bank and Cape Hatteras. By spring, recruits are still only present at low densities and concentrated near the shelf edge, extending to south of Cape Hatteras, where some of the highest densities are found. Recruits occur both inshore and throughout the continental shelf during the summer between the Gulf of Maine and Cape Hatteras. During autumn, recruits begin to migrate back offshore and south, as indicated by their high concentrations at depths between 60 and 366 m.

Recruit abundance was low in Massachusetts coastal waters during 1978-2003, particularly during the spring, when only a few recruits were collected at four stations. During the fall, recruits were collected at more stations and at higher densities. Abundance was highest in the waters off Cape Ann and the northern portion of Cape Cod Bay (Figure 9).

HABITAT CHARACTERISTICS

Habitat characteristics of northern shortfin squid are summarized by life history stage in Table 1.

EGGS AND PARALARVAE

Based on lab studies, egg balloons probably occur at water temperatures between 12.5°C, the minimum temperature required for successful embryonic development (O'Dor *et al*. 1982b), and 26°C (Balch *et al*. 1985). Egg masses are neutrally-buoyant and probably occur in midwater near the pycnocline (O'Dor and Balch 1985).

Illex sp. paralarvae have been collected at water temperatures from 5 to 20°C (Vecchione 1979; O'Dor 1983; Dawe and Beck 1985; Hatanaka *et al*. 1985; Vecchione and Roper 1986), with maximum abundance, in the Gulf Stream, at temperatures greater than 16.5°C (Hatanaka *et al*. 1985) and salinities ranging from 35 to 37 ppt (Vecchione 1979; O'Dor 1983; Dawe and Beck 1985; Vecchione and Roper 1986). Paralarvae exhibit diel vertical migrations and are more abundant in the upper layer of the water at night and in deeper water during the day (Hatanaka *et al*. 1985).

JUVENILES

During the spring, epipelagic juveniles migrate from oceanic to neritic waters as they grow. Juveniles have been collected from continental slope waters at temperatures from 14.3 to 16.3°C (Fedulov and Froerman 1980; Perez 1994), at temperatures above 16°C in the Gulf Stream (Perez 1994), and at temperatures from 5 to 6°C on the Scotian Shelf in spring (Perez 1994). During late May, juveniles (34 to 68 mm ML) were collected along the southeast flank of Georges Bank, at depths of 140 to 260 m, where surface and bottom temperatures were 10.6°C and 9.9°C, respectively (Hendrickson 2004). Juveniles have been collected at salinities of 34 to 37 ppt (Vecchione 1979; Amaratunga *et al*. 1980b; Fedulov and Froerman 1980; Rowell *et al*. 1985a). South of Cape Hatteras, squid 7 to 10 cm ML are most abundant during spring (Whitaker 1980).

Distributions of pre-recruits relative to bottom water temperature, depth, and salinity based on spring and fall NEFSC bottom trawl surveys from the Gulf of Maine to Cape Hatteras are shown in Figure 10. During the spring surveys, pre-recruits occur in deep water and are most abundant at depths ranging from 101 to 300 m, bottom temperatures of 11 to 14ºC and at salinities of 35 to 36 ppt. During the fall surveys, pre-recruits occur in greater abundance across a broader depth range, and in a wider range of temperatures and salinities. During autumn, juveniles are most abundant at bottom temperatures of 10 to 13ºC and salinities of 32 to 35 ppt.

The spring and autumn distributions of pre-recruits in Massachusetts coastal waters relative to bottom water temperature and depth based on Massachusetts inshore bottom trawl surveys are shown in Figure 11. As observed in the NEFSC spring surveys, pre-recruits are distributed offshore during spring; only 16 individuals were collected at five stations in Massachusetts coastal waters (< 80 m deep), most at temperatures of 11ºC and at a depth of 11 to 15 m. During the fall, pre-recruits were present at very low densities at only 28 stations and were most abundant at depths of 31 to 55 m, and were found over at bottom temperatures of 6 to 10ºC.

ADULTS

Adults have been captured at temperatures ranging from -0.5 to 27.3°C (Whitaker 1980), salinities of 30 to 36.5 ppt (Palmer and O'Dor 1978), and at depths ranging from the surface to 1000 m or more (Whitaker 1980), depending on the time of year (see Migrations above). In summer, on the eastern U.S. continental shelf, adults are most abundant at depths of 100 to 200 m (Bowman 1977; Grinkov and Rikhter 1981) and are not generally found in waters shallower than 18 m. In the fall and winter, adults migrate offshore, and have been found at 100 to 945 m (Amaratunga *et al*. 1980a; Felley and Vecchione 1995). However, there is little information on the offshore component of the population, which may be found at depths greater than 1000 m (O'Dor and Dawe 1998).

Distributions of recruits relative to bottom water temperature, depth, and salinity based on NEFSC spring and fall bottom trawl surveys are shown in Figure 12. During the spring, recruits are found over a temperature range of 4 to 20°C, but are most abundant at 10 to 14°C. Recruits are found over a depth range of 11 to 500 m, but are most abundant at 121 to 400 m. The majority of recruits occur at a salinity of 35 ppt in the spring. In the autumn, recruits were found over a bottom temperature range of 4 to about 21°C, and are most abundant at 8 to 13°C. Recruit abundance increased with depth between 31 and 140 m and reached a secondary peak at 201 to 300 m. During autumn, recruits occur over a salinity range from 31 to 36 ppt.

The spring and autumn distributions of recruits in Massachusetts coastal waters relative to bottom water temperature and depth based on Massachusetts inshore bottom trawl surveys are shown in Figure 13. The few adults caught in the spring occurred at temperatures of 10 to 13°C and at depths of 11 to 15 m, 26 to 30 m, and 41 to 45 m. Recruits were caught at higher densities in the fall and were found over a temperature range of 4 to 15°C, with most recruits found between 7 and 9°C.

Recruits were caught over a depth range of 11 to 85 m, with most found between 41 and 75 m.

RESEARCH NEEDS

Additional research is needed to better understand the life cycle of this species. In particular, recruitment patterns and the exchange of squid between the northern and southern stock components remain unknown, along with the migration routes from fishing areas during autumn. U.S. research surveys do not include waters deeper than 366 m, so it remains unknown what fraction of the stock resides offshore and whether spawning occurs there. In addition, the location of the winter spawning area has not been confirmed.

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Table 1. Summary of life history and habitat parameters for northern shortfin squid *Illex illecebrosus*.

Life Stage	Size and Growth	Habitat	Substrate	Temperature	Salinity
Eggs [1]	Eggs protected in gelatinous masses ranging in diameter from 30 - 100 cm. In lab studies, females produced 10,000 - 400,000 eggs.	Egg masses have not been collected in the wild. It is hypothesized that egg masses are transported northeasterly in the Gulf Stream current based on distribution of paralarvae and temperatures required for hatching.	Egg masses are pelagic; do not attach to substrate (based on lab-induced spawning events).	Egg incubation lasts 16 days at 13°C, 12 days at 16°C and 8 days at 21°C; normal development requires at least 13°C.	Egg masses have greater density than seawater; possibly become neutrally - buoyant in colder, higher-density water (shown in lab studies).
Paralarvae [2] Hatchling: 1.0-1.1 mm Paralarvae: 1.2-5.0 mm Transitional: 5.1-6.9 mm	Size at hatch: 1.0-1.1 mm ML. Paralarvae have non-functional tentacles; body not yet elongated. Rhynchoteuthion (Type C[1]) larval stage ends when proboscis splits into 2 tentacles. Mantle length increases during migration from Gulf Stream to continental shelf. Only find hatchlings south of Cape Hatteras.	Offshore, along continental shelf edge from surface waters to 360 m. Hatching occurs at inshore boundary of Gulf Stream, 9 to 16 days after spawning. Paralarvae have been found during winter and spring off tail of Grand Bank. Abundant in late February-March in Gulf Stream/slope waters above the thermocline. The convergence of Gulf Stream and slope water creates an area of high productivity that is beneficial to young for feeding and growth. Undergo diel vertical migrations; greater abundance during the day at 50-100 m.		Found from 5-20°C; maximum abundance at temperatures > 16.5°C.	Found at salinities ranging from 35-37 ppt.
Pre-recruits [3] ≤ 10.0 cm	Separation of proboscis into tentacles indicates onset of juvenile stage. Larger juveniles found from east to west, indicating westward movement on continental shelf with growth. Growth is approximately 1.5 mm/day.	Winter: in Gulf Stream/slope water interface. Spring: begin migration onto U.S. continental shelf (Georges Bank to south of Cape Hatteras). Summer: occur throughout U.S. shelf (Georges Bank to Cape Hatteras). Fall: migrate off U.S. shelf (Georges Bank to south of Cape Hatteras). Undergo diel vertical migrations; greater abundance near the bottom during the day.		Gulf Stream: > 16°C; slope water: < 16°C; surface: 14-21°C; continental shelf: 5-6°C in spring. Pre-recruits on U.S. shelf most abundant at bottom temperatures > 10°C and surface temperatures 14.6-20.5°C.	Found at salinities ranging from 34-37 ppt.
Recruits [4] ≥ 11 cm	Can reach size of 35 cm ML. Life span less than a year; (215 days for squid in U.S. shelf waters). Males and females grow about 1 mm/day. Females generally larger than males.	Range from Labrador to south of Cape Hatteras; most abundant at depths of 100-150m. Winter: low abundance along edge of U.S. shelf; presumably in warmer waters offshore and south of Cape Hatteras. Spring: begin migration onto U.S. shelf (Georges Bank to south of Cape Hatteras) and Scotian Shelf. Summer: occur throughout U.S. shelf (Gulf of Maine to Cape Hatteras), Scotian Shelf and inshore Newfoundland waters. Fall: migrate off continental shelf of U.S. and Canada; presumably to spawn. Increase in squid size with depth in autumn.	Over various sediment types, including sand-silt or "Sambro sand" (sediment between banks and edges of basins on Scotian Shelf, as well as along edge of continental shelf, 100-300m). Avoid areas inhabited by anemones.	*Illex* ≥ 11 cm found at bottom temperatures ranging from 3.5-15.0°C (surface > 20°C), most abundant at bottom temperatures of 5-10.0°C. Maturation may be enhanced by high temperatures but not initiated by it.	Generally found at 30-36.5 ppt.

[1] Durward *et al.* (1978); O'Dor and Durward (1979); Durward *et al.* (1980); O'Dor *et al.* (1980b, 1982b, 1986); O'Dor (1983); O'Dor and Balch (1985); Rowell *et al.* (1985a); Perez (1994).

[2] Vecchione (1979); Amaratunga (1980a); Durward *et al.* (1980); O'Dor (1983); Trites (1983); Dawe and Beck (1985); Hatanaka *et al.* (1985); Rowell and Trites (1985); Rowell *et al.* (1985a); Vecchione and Roper (1986); Young and Harman (1988); Mann and Lazier (1991); Perez (1994).

[3] Squires (1957); Vecchione (1979); Amaratunga (1980a); Amaratunga *et al.* (1980b); Fedulov and Froerman (1980); Dawe *et al.* (1981a); Coelho (1985); Rowell *et al.* (1985a); Black *et al.* (1987); Nigmatullin (1987); Perez (1994); Dawe and Beck (1997); Brodziak and Hendrickson (1999).

[4] Frost and Thompson (1933); McLellan *et al.* (1953); Squires (1957, 1967); Templeman (1966); Mercer (1973a, b); Mercer and Paulmier (1974); Bowman (1977); Mesnil (1977); O'Dor *et al.* (1977, 1980a); Amaratunga *et al.* (1978, 1980a); Lange (1978); Lux *et al.* (1978); Palmer and O'Dor (1978); Amaratunga and McQuinn 1979; Fedulov and Froerman (1980); Hurley (1980); Whitaker (1980); Dawe and Drew (1981); Dawe *et al.* (1981b); Grinkov and Rikhter (1981); Lange and Johnson (1981); Scott (1982); Wigley (1982); Amaratunga 1983; Waldron (1983); Roper *et al.* (1984); Coelho (1985); Dawe and Beck (1985, 1997); Rowell *et al.* (1985b); Vecchione *et al.* (1989); Laptikhovsky and Nigmatullin (1993); Perez (1994); Felley and Vecchione (1995); Brodziak and Hendrickson (1999); Hendrickson (2004).

Table 1. Cont'd.

Life Stage	Prey	Predators	Spawning	Notes
Eggs [1]			Spawning has bee induced in the lab, but not observed in the wild. Lab studies indicate that egg masses are spawned pelagically.	Eggs that are presumably spawned in Gulf Stream waters can hatch in northern shelf waters > 12.5ºC (transported by Gulf Stream at rate of 7 km/hr); can also hatch in warm Gulf Stream waters.
Paralarvae [2] Hatchling: 1.0-1.1 mm Paralarvae: 1.2-5.0 mm Transitional: 5.1-6.9 mm	Hatchlings may spend early life in remains of egg mass to utilize the nutrients for food. Yolk-sac not especially large; food must be adequate to sustain hatchling during this stage of rapid growth and increased metabolism.			Gulf Stream may be important mode of transportation for paralarvae throughout range in NW Atlantic; initially flows northeastward along shelf, off Cape Hatteras, then flows easterly and creates eddies in which young are transported westward into slope waters.
Pre-recruits [3] ≤ 10.0 cm	Primarily feed on crustaceans (euphausiids) at night near the surface; also consume nematodes and fish.			Gulf Stream presumably transports juveniles northward; hydrographic variability in this system may explain annual abundance differences.
Recruits [4] ≥ 11 cm	Visual predators; feeding rate reduced in highly turbid waters. Feed primarily on fish and are cannibalistic (larger females cannibalize smaller males, increased in autumn). Fish prey includes juvenile Atlantic cod, mackerel, redfish, sand lance, Atlantic herring, and adult capelin. Seasonal/ontogenetic diet shifts, during spring (offshore): euphausiids; during summer-fall (inshore): fish and squid.	Many pelagic and benthic fishes feed heavily on *Illex*, including bluefin tuna and silver and red hakes. Other fish predators include shark and dogfish species, fourspot flounder, Atlantic cod, swordfish, bluefish, goosefish, and sea raven. Mammalian predators include common dolphin and pilot whales. Avian predators include shearwaters, gannets, and fulmars.	Spawning likely pelagic and occurs during October-July. Late May: mated females indicate spawning area (113-377 m) in Mid-Atlantic Bight; overlaps with fishing grounds. Winter: presumably spawn during December-March in the Gulf Stream and/or south of Cape Hatteras where *Illex* sp. hatchlings were collected. Lab studies indicate females mate, spawn once (may release multiple egg masses), then die within a week. Mated females collected in Mid-Atlantic Bight indicate females may mate with as many as four males.	Diel vertical migrations: more abundant on bottom at dawn/dusk and day than at night; feed primarily at night before sunrise near surface or mid-water. Migrate to bottom or deeper waters during daytime. Change color to camouflaged pattern when resting on bottom to reduce risk of predation by benthic species.

[1] O'Dor *et al*. (1980b, 1982a, 1986); O'Dor (1983); Rowell *et al*. (1985a); Perez (1994).

[2] Durward *et al*. (1980); Trites (1983); Rowell and Trites (1985); O'Dor *et al*. (1986); Vecchione and Roper (1986); Csanady and Hamilton (1988); Mann and Lazier (1991); Perez (1994).

[3] Amaratunga *et al*. (1980b); Dawe *et al*. (1981a); Coelho (1985); Arkhipkin and Fedulov (1986).

[4] Templeman (1944); Squires (1957, 1966, 1967); Vinogradov (1970, 1972, 1984); Butler (1971); Mercer and Paulmier (1974); Maurer (1975); Langton and Bowman (1977); Bennett (1978); Durward *et al*. (1978); Hirtle (1978); Ennis and Collins (1979); Froerman (1979); Vinogradov and Noskov (1979); Amaratunga (1980b, 1983); Amaratunga *et al*. (1980a); Fedulov and Froerman (1980); Hurley (1980); Lange and Sissenwine (1980); O'Dor *et al*. (1980a, b); Brown *et al*. (1981); DeMont (1981); Hirtle *et al.* (1981); Wigley (1982); O'Dor (1983); Lily and Osborne (1984); Dawe and Beck (1985, 1997); Maurer and Bowman (1985); Nicol and O'Dor (1985); O'Dor and Balch (1985); Rowell *et al*. (1985a); Stillwell and Kohler (1985); Major (1986); Scott and Scott (1988); Vecchione *et al*. (1989); Laptikhovsky and Nigmatullin (1993); Perez (1994); Dawe *et al*. (1997); Brodziak and Hendrickson (1999); Hendrickson (2004).

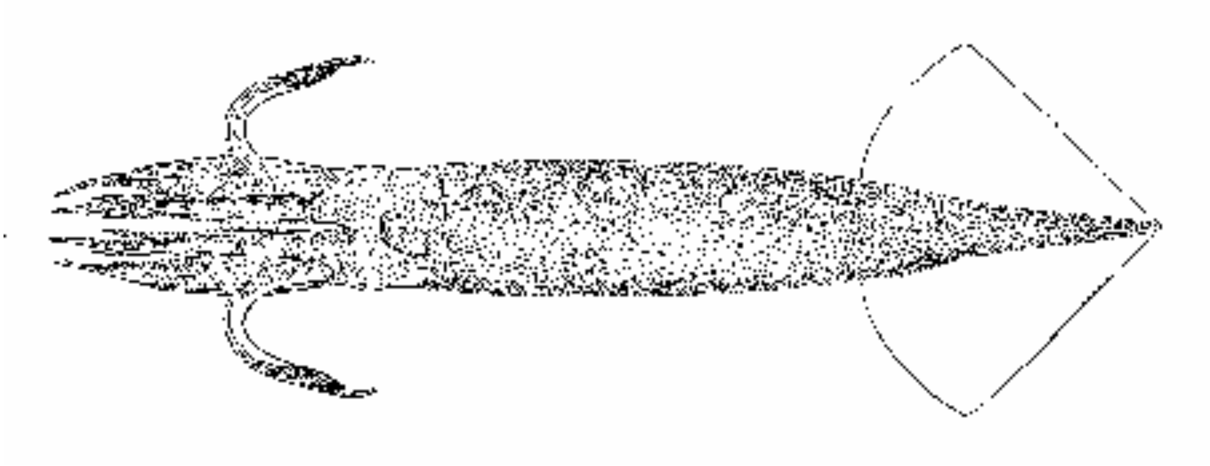


Figure 1. The northern shortfin squid, *Illex illecebrosus* (from Goode 1884).

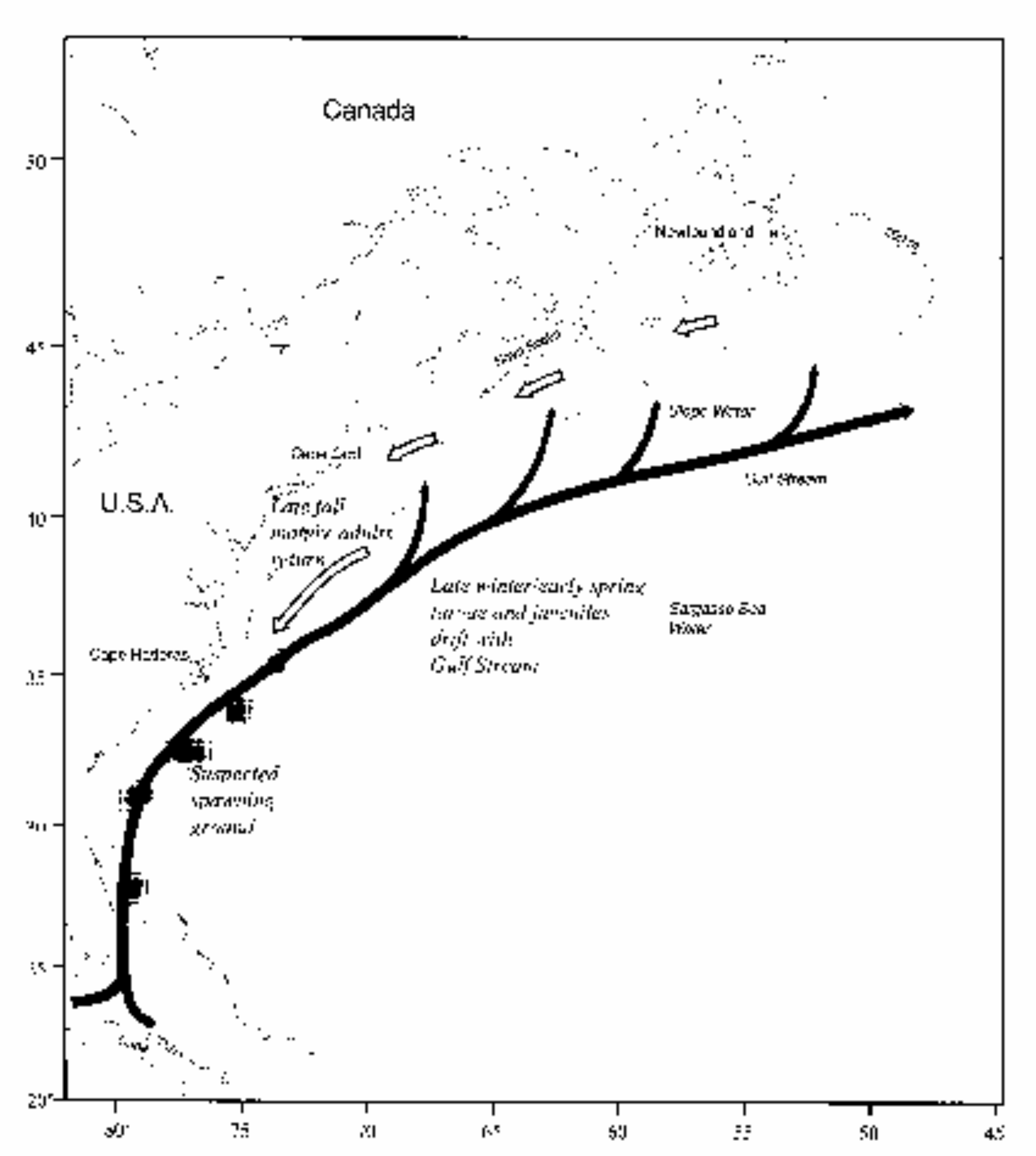


Figure 2. Hypothetical migration path of the northern shortfin squid, *Illex illecebrosus*. From Black *et al*. (1987).

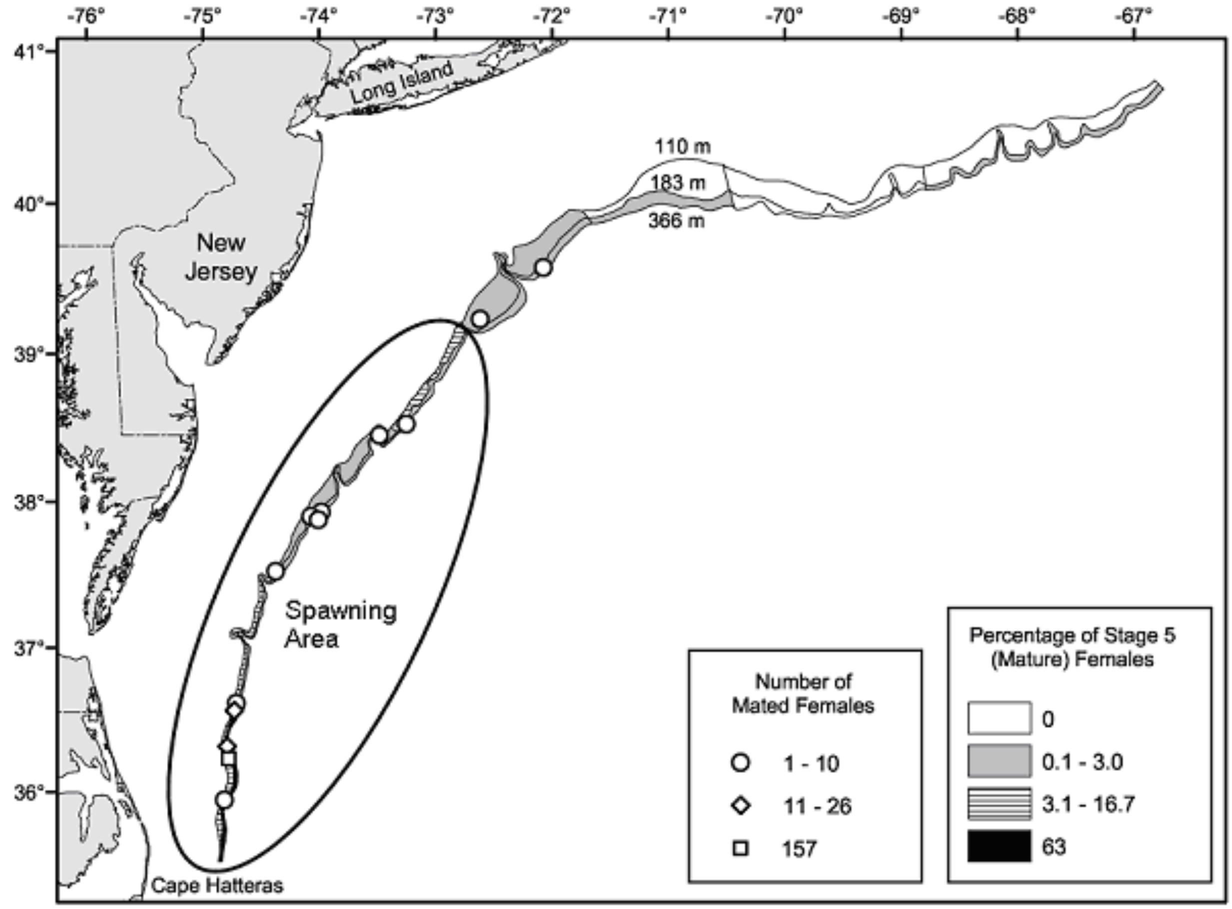


Figure 3. Spawning area of northern shortfin squid (encircled) during late May. Based on the distribution of mated females (Hendrickson 2004).

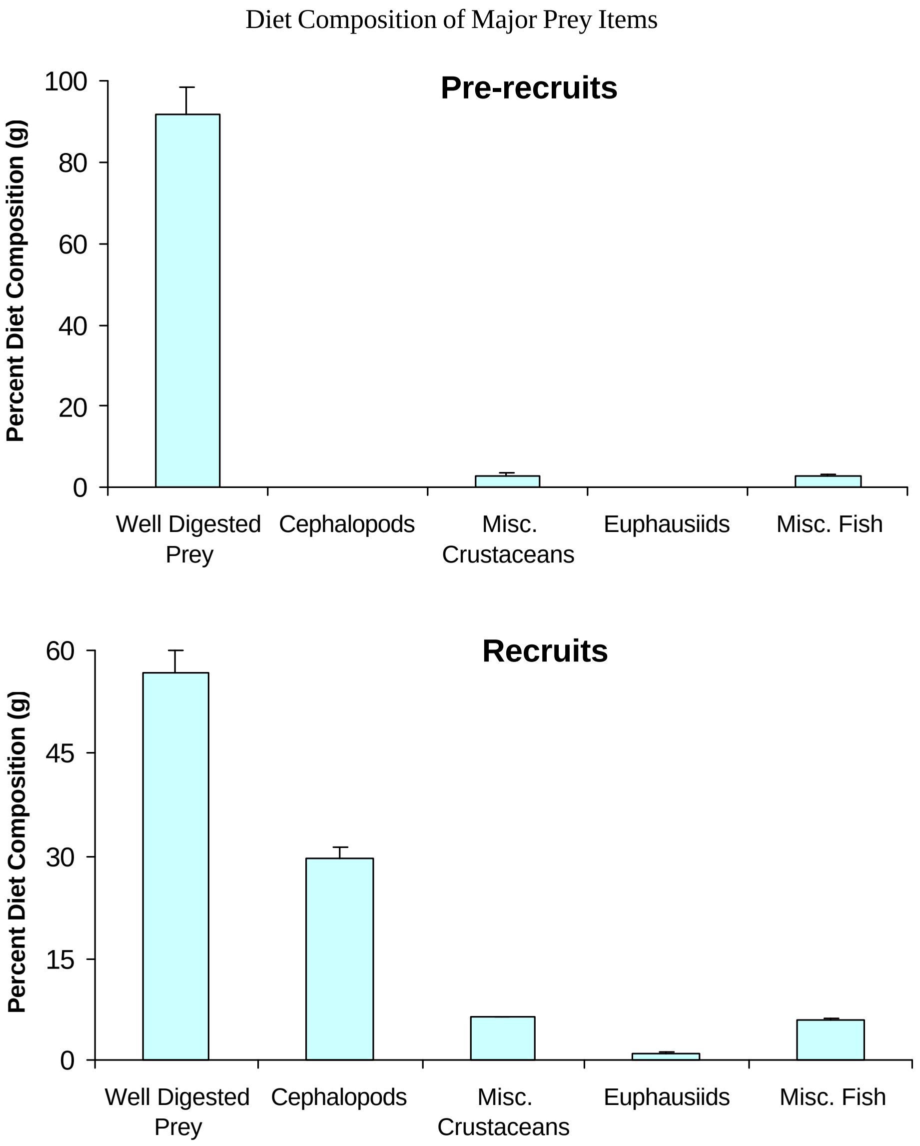


Figure 4. Percent by weight (g) of the major prey items in the diet of northern shortfin squid. From specimens collected during NEFSC bottom trawl surveys from 1973-2001 (all seasons). For details on NEFSC diet analysis, see Link and Almeida (2000).

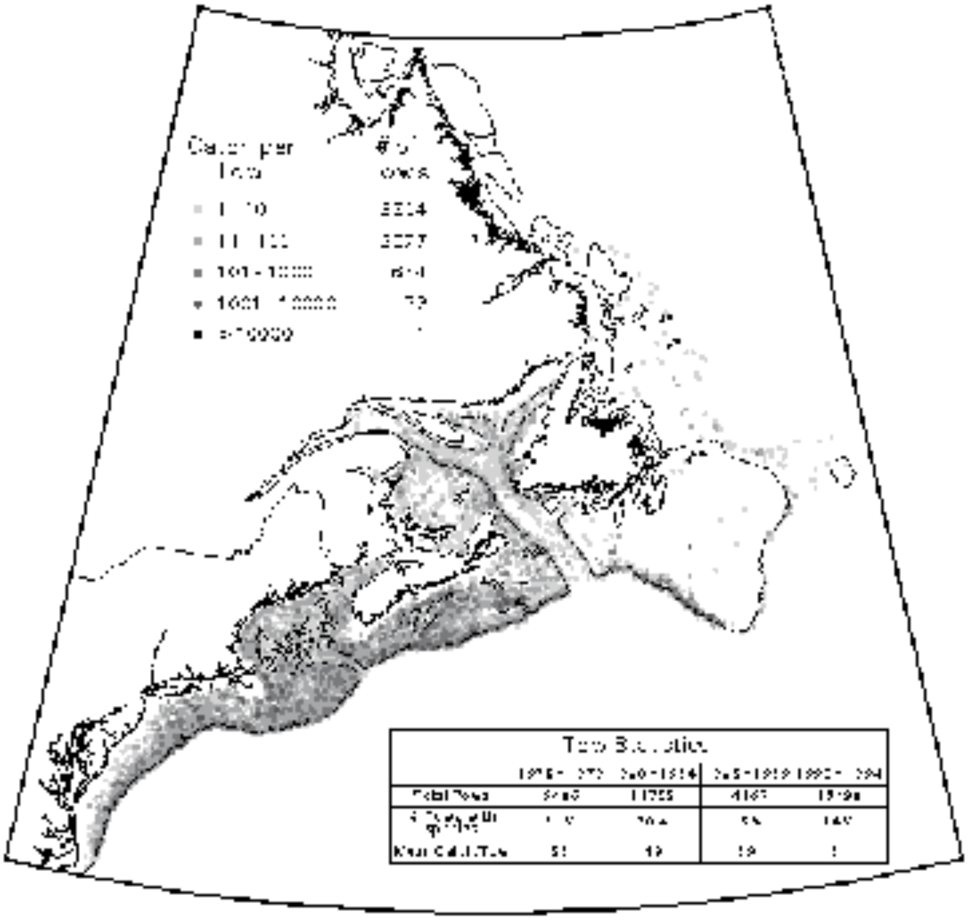


Figure 5. Distribution and abundance of northern shortfin squid from Newfoundland to Cape Hatteras. Based on research trawl surveys conducted by Canada (DFO) and the United States (NMFS) from 1975-1994 (http://www-orca.nos.noaa.gov/projects/ecnasap/ecnasap_table1.html).

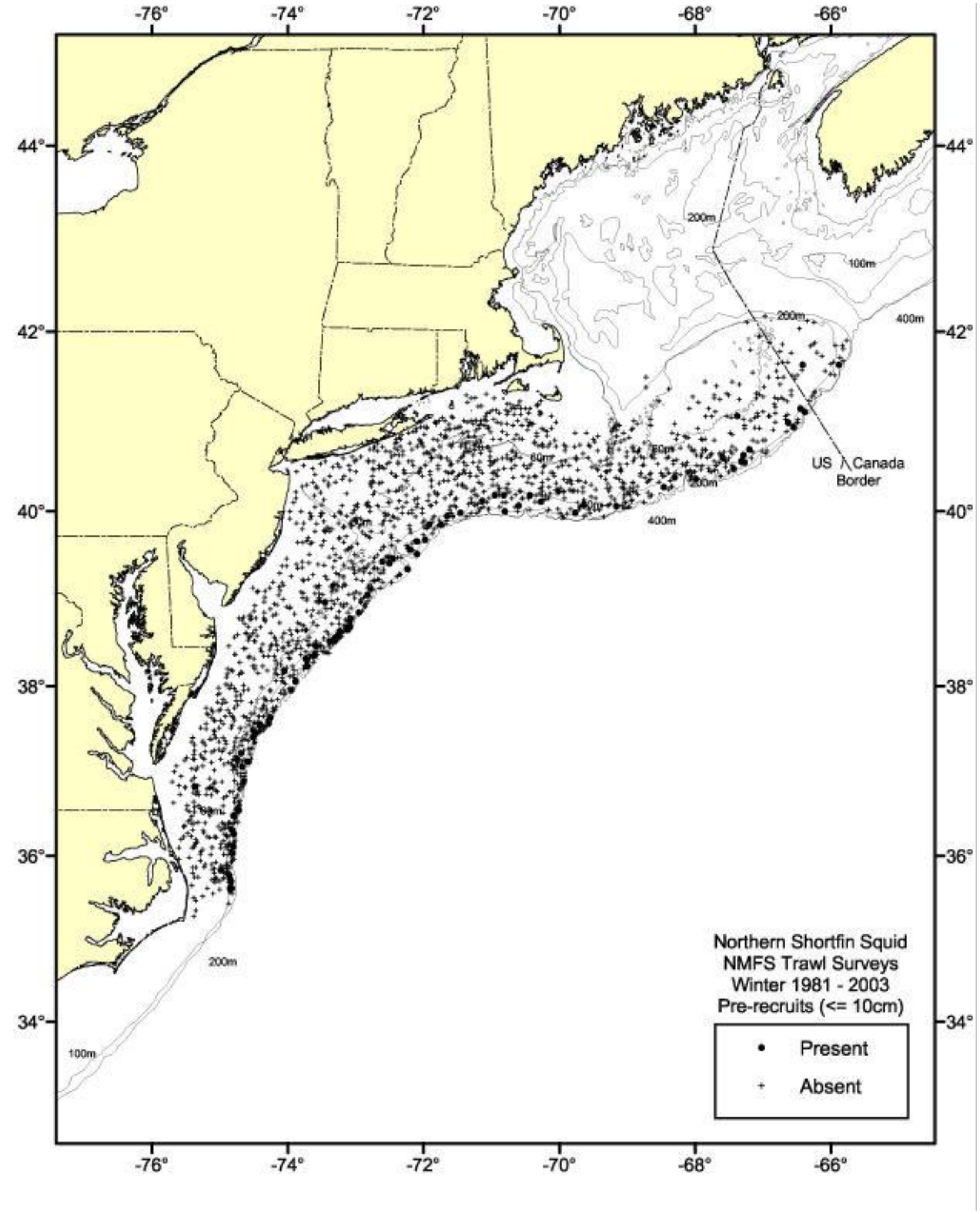


Figure 6. Seasonal distributions and abundances of pre-recruit northern shortfin squid collected during NEFSC bottom trawl surveys.
From NEFSC winter bottom trawl surveys (1981-2003, all years combined). Distributions are displayed as presence/absence only.

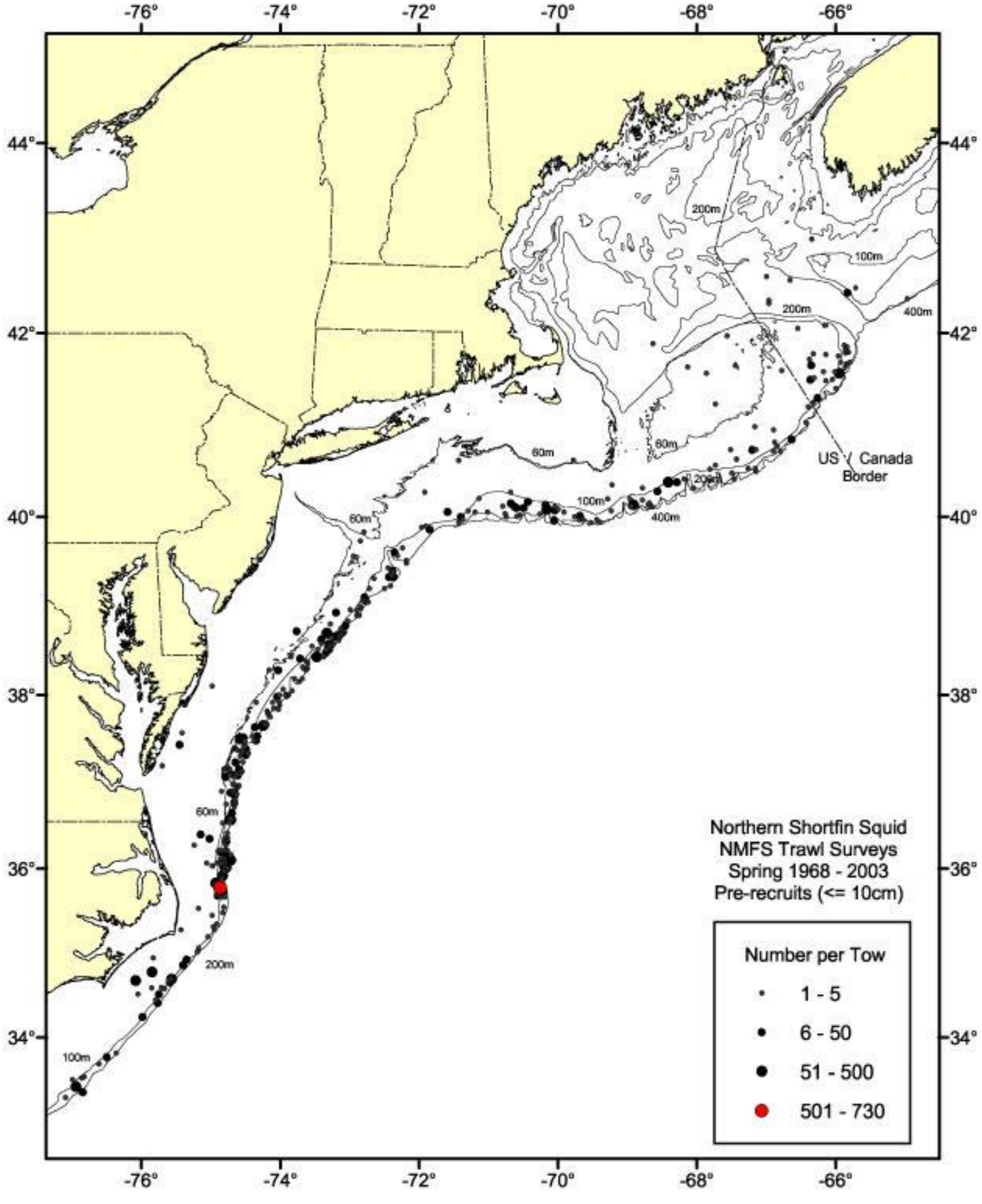


Figure 6. Cont'd.
From NEFSC spring bottom trawl surveys (1968-2003, all years combined). Survey stations where pre-recruits were not found are not shown.

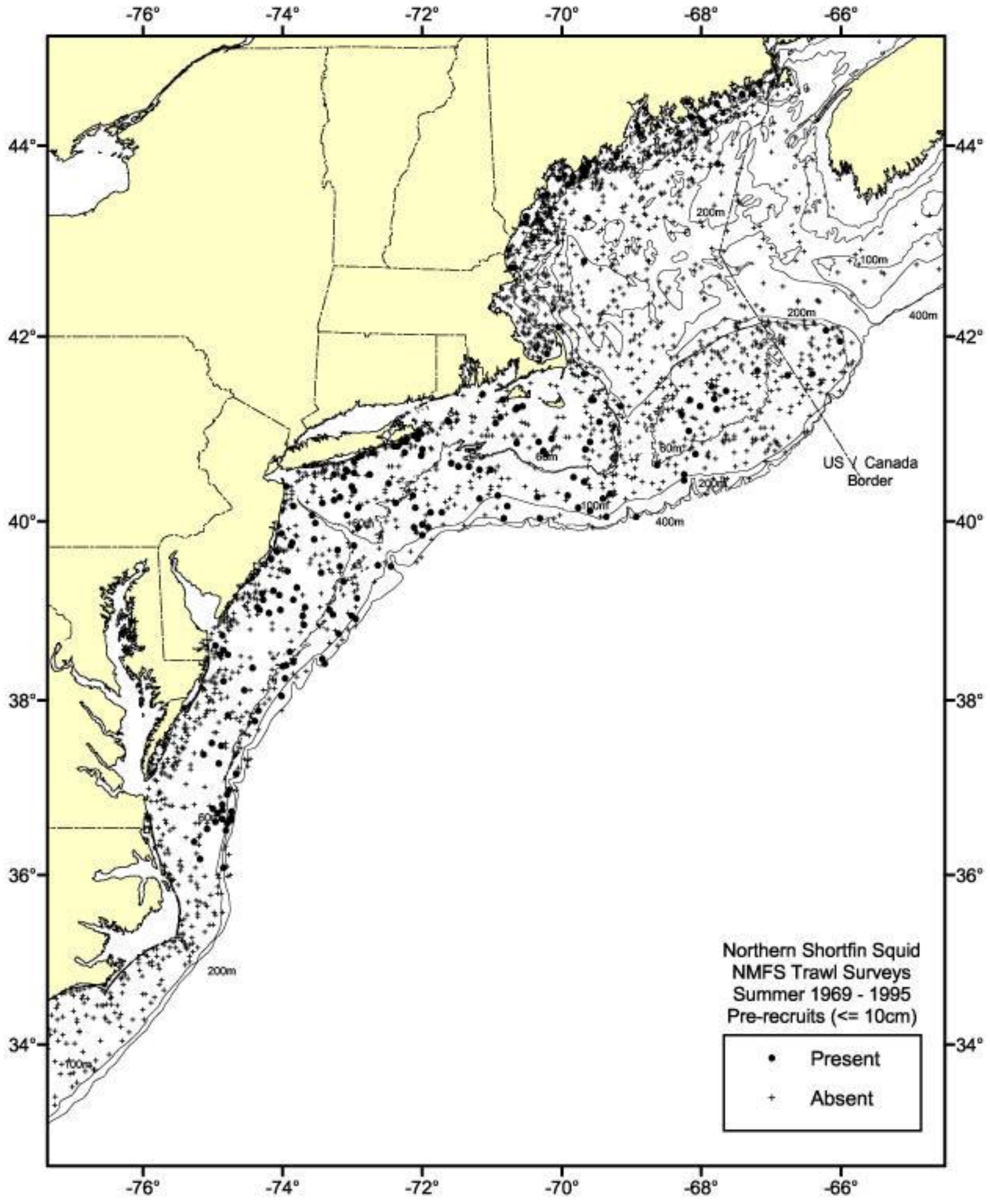


Figure 6. Cont'd.
From NEFSC summer bottom trawl surveys (1969-1995, all years combined). Distributions are displayed as presence/absence only.

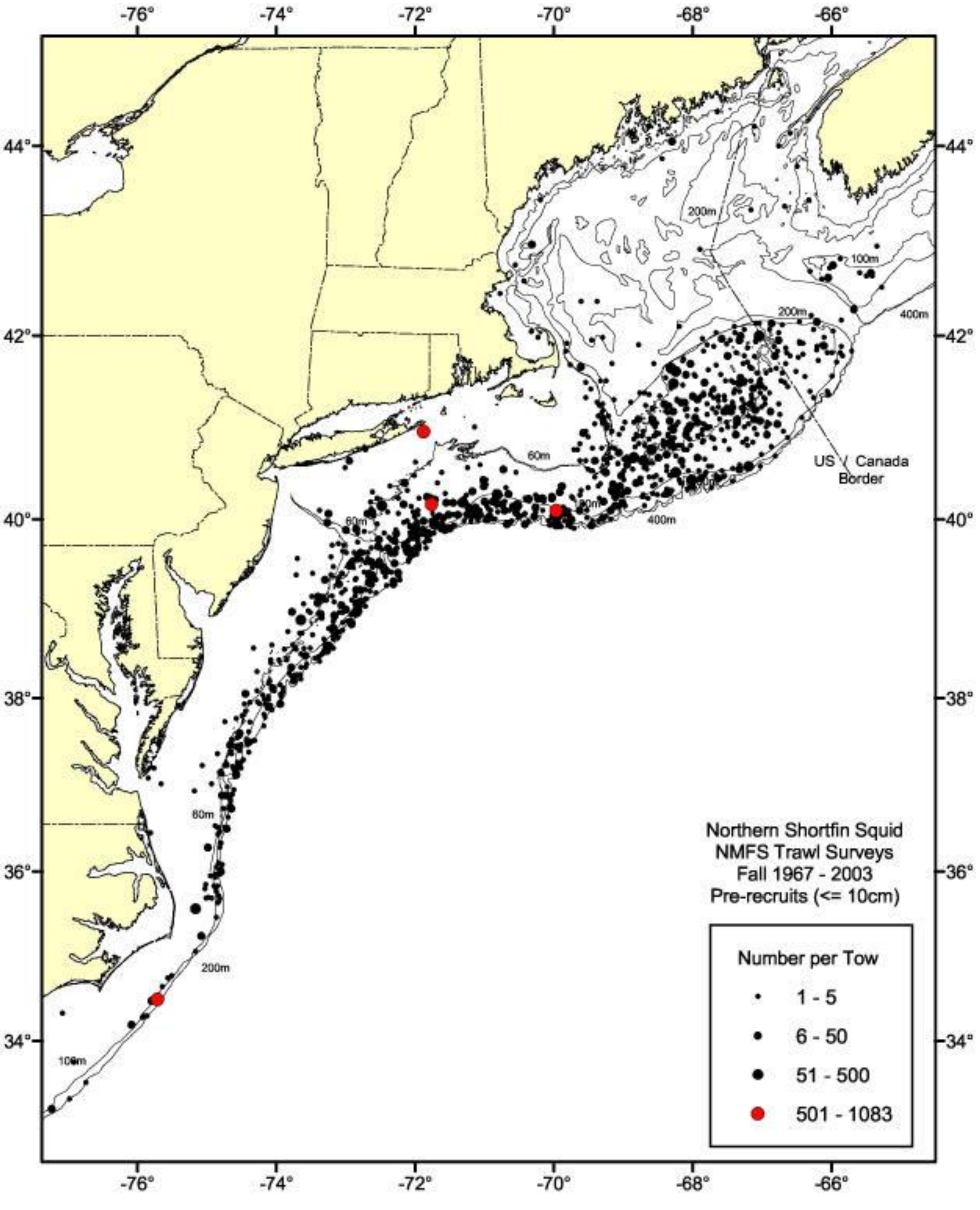


Figure 6. Cont'd.
From NEFSC fall bottom trawl surveys (1967-2003, all years combined). Survey stations where pre-recruits were not found are not shown.

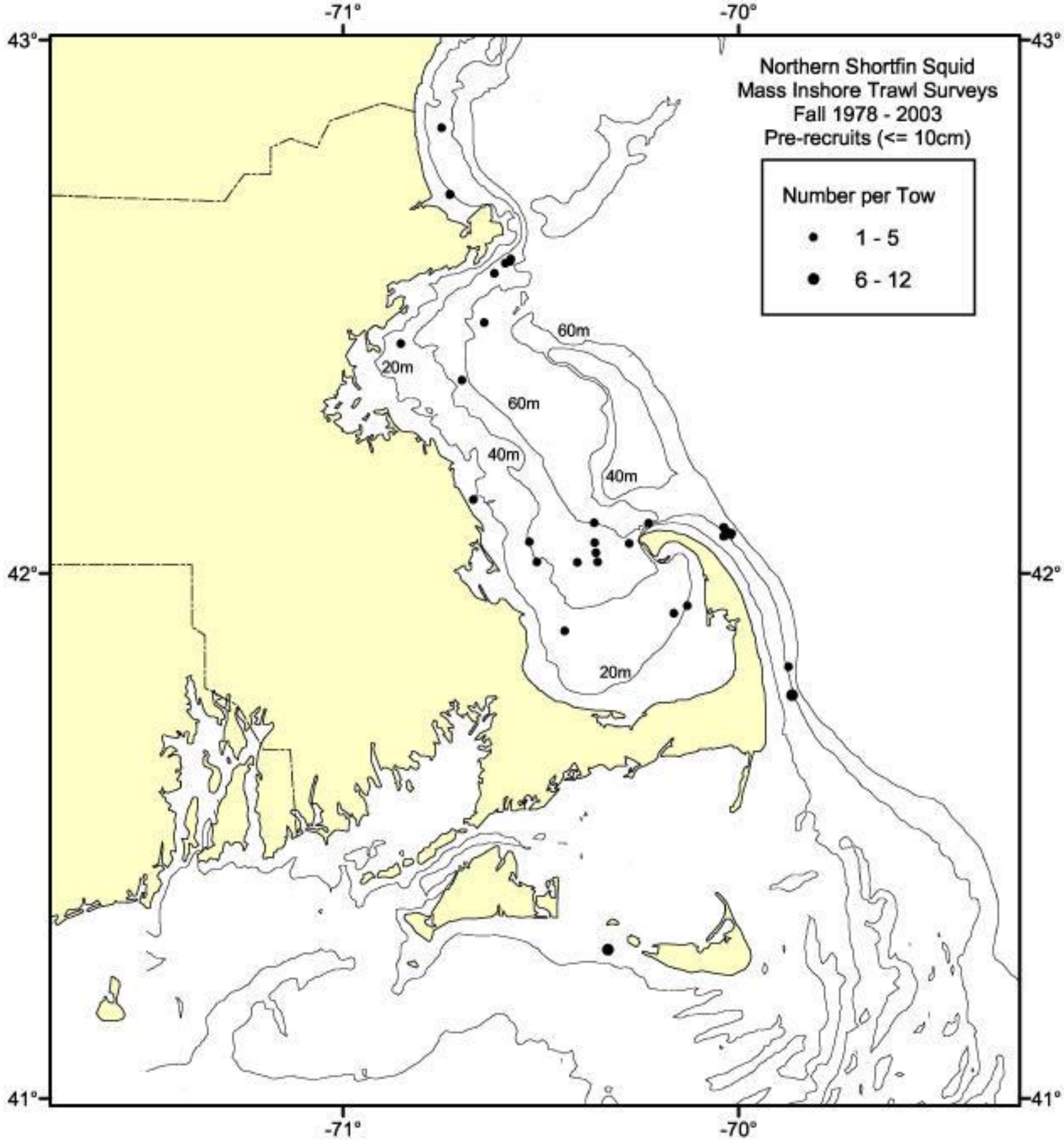


Figure 7. Distribution and abundance of pre-recruit northern shortfin squid in Massachusetts coastal waters. From fall Massachusetts inshore bottom trawl surveys (1978-2003, all years combined). Survey stations where pre-recruits were not found are not shown.

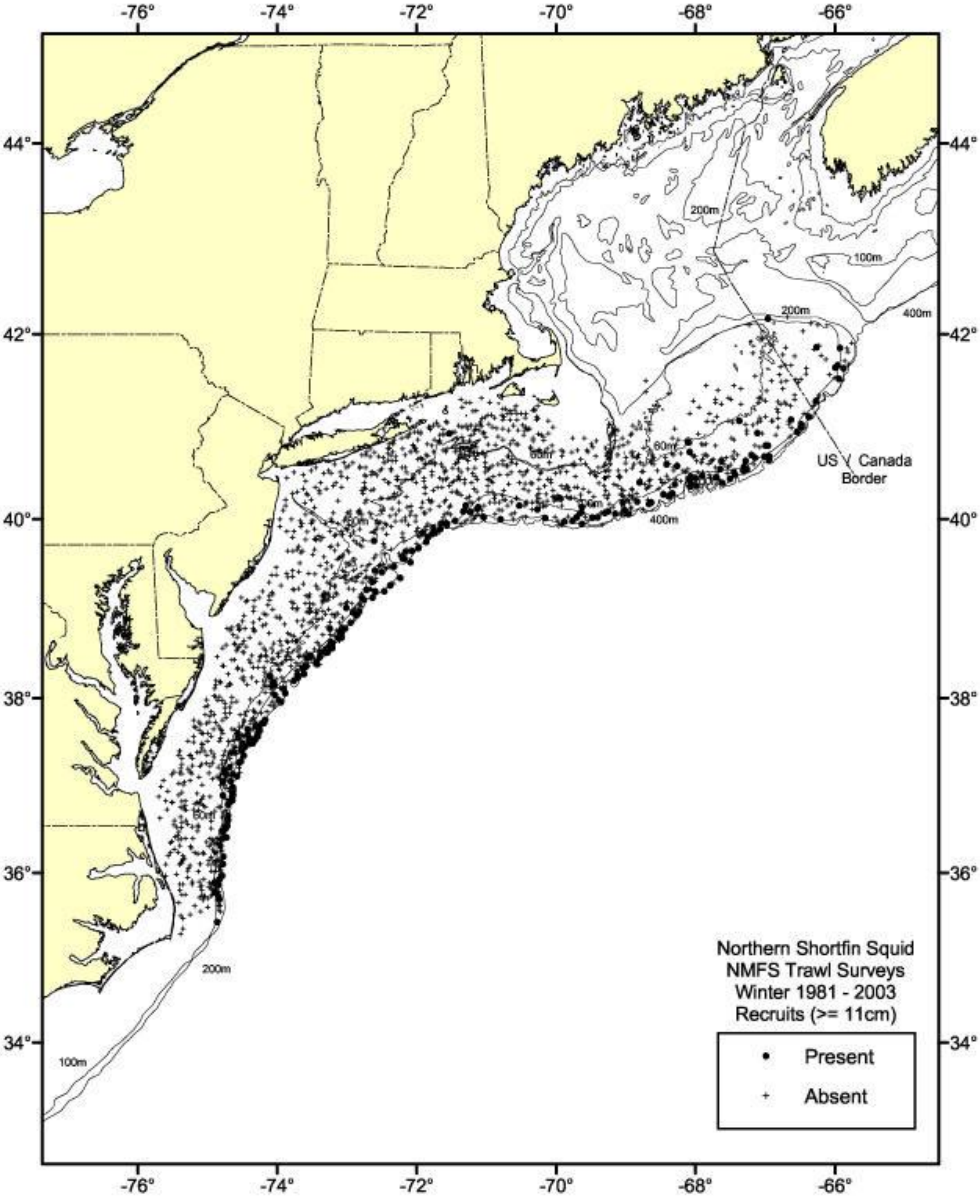


Figure 8. Seasonal distributions and abundances of recruit northern shortfin squid collected during NEFSC bottom trawl surveys.

From NEFSC winter bottom trawl surveys (1981-2003, all years combined). Distributions are displayed as presence/absence only.

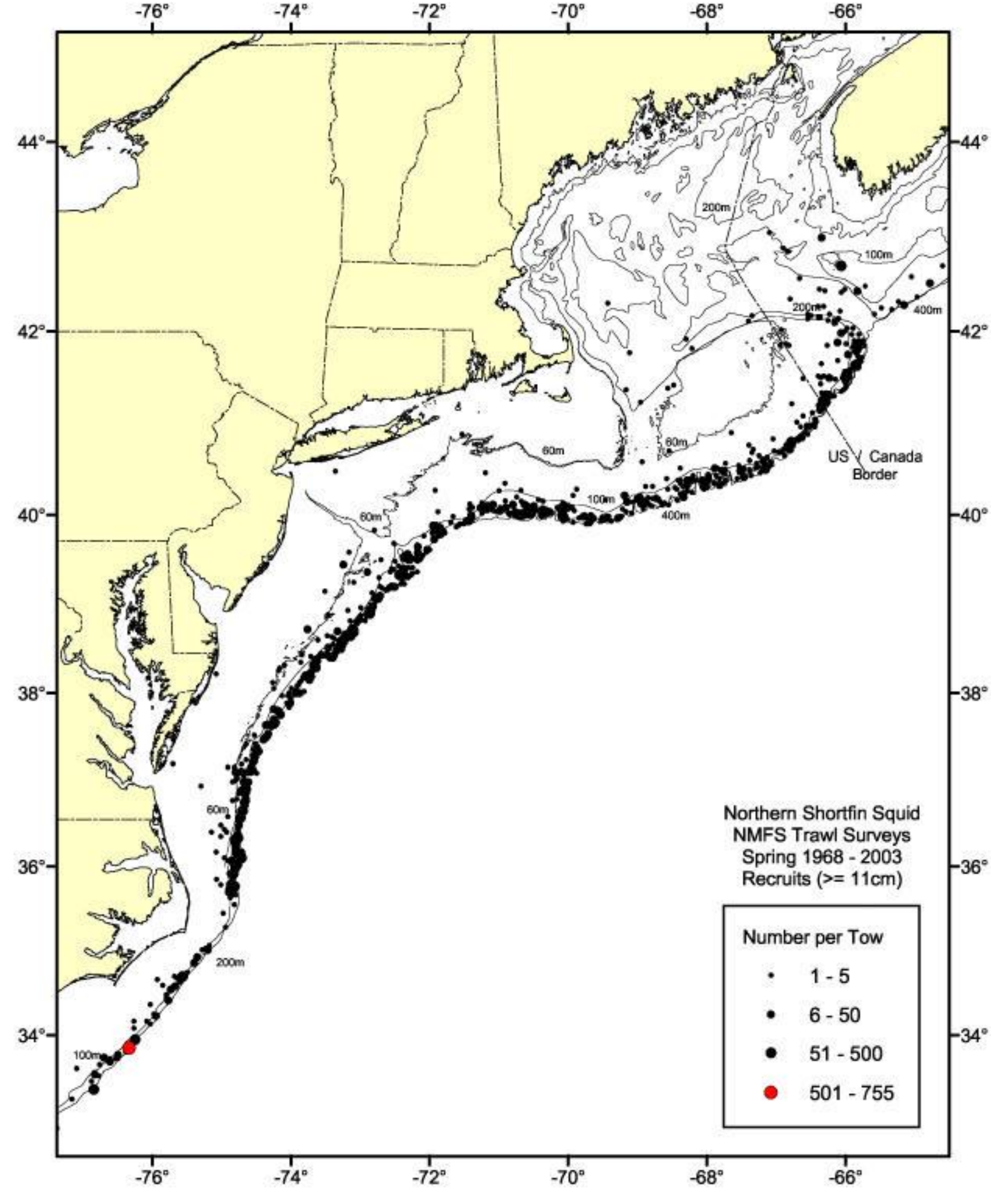


Figure 8. Cont'd.
From NEFSC spring bottom trawl surveys (1968-2003, all years combined). Survey stations where recruits were not found are not shown.

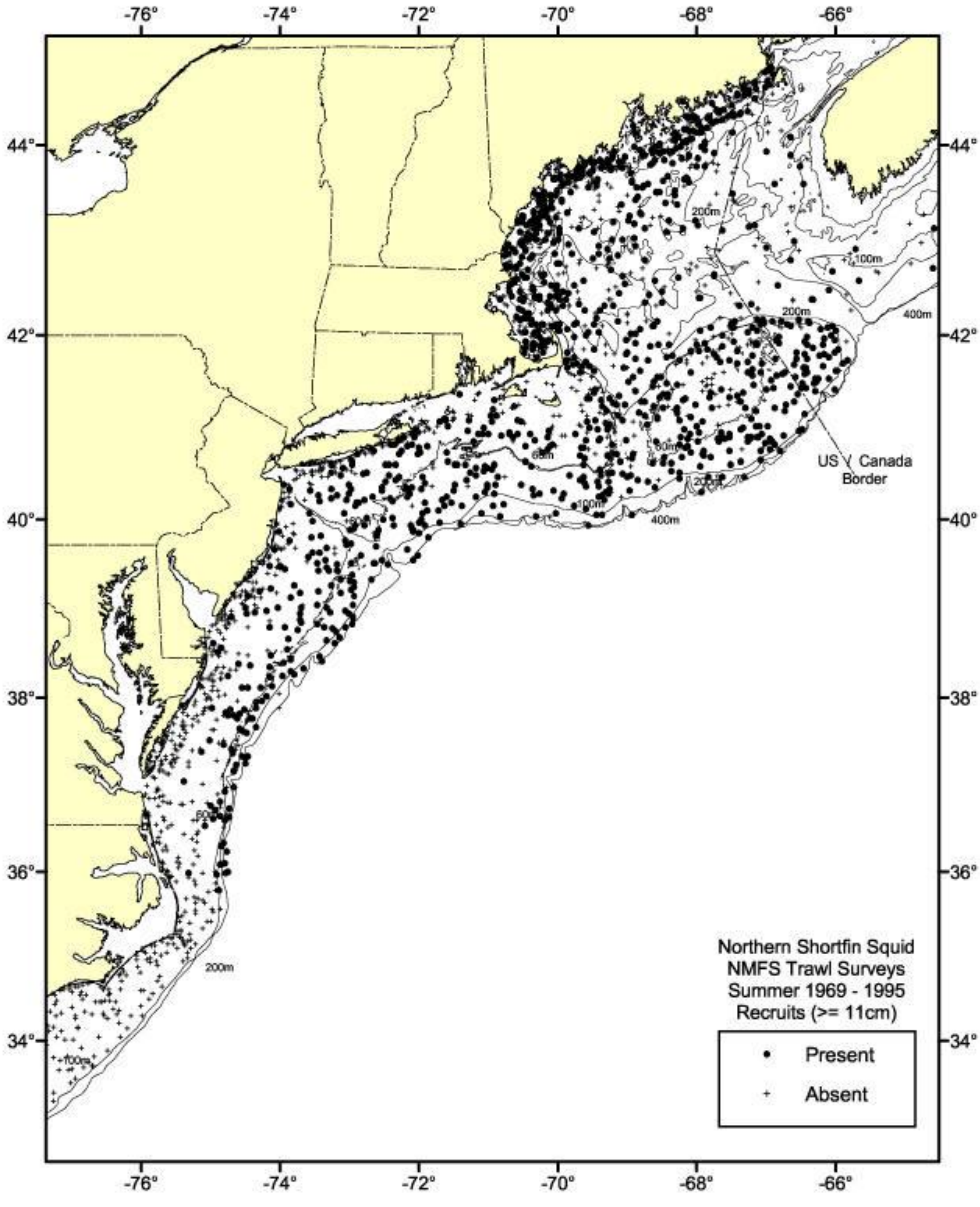


Figure 8. Cont'd.
From NEFSC summer bottom trawl surveys (1969-1995, all years combined). Distributions are displayed as presence absence only.

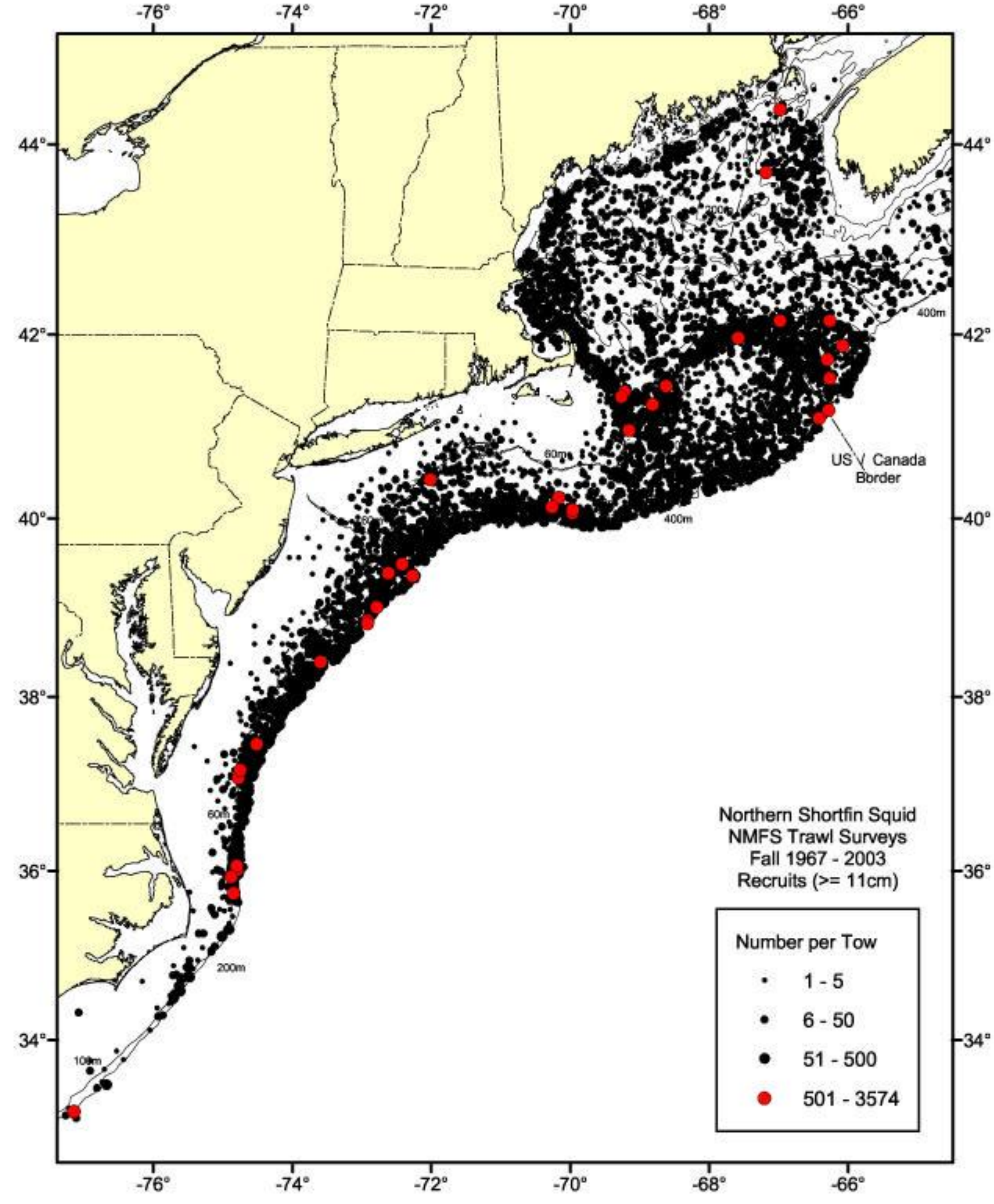


Figure 8. Cont'd.
From NEFSC fall bottom trawl surveys (1967-2003, all years combined). Survey stations where recruits were not found are not shown.

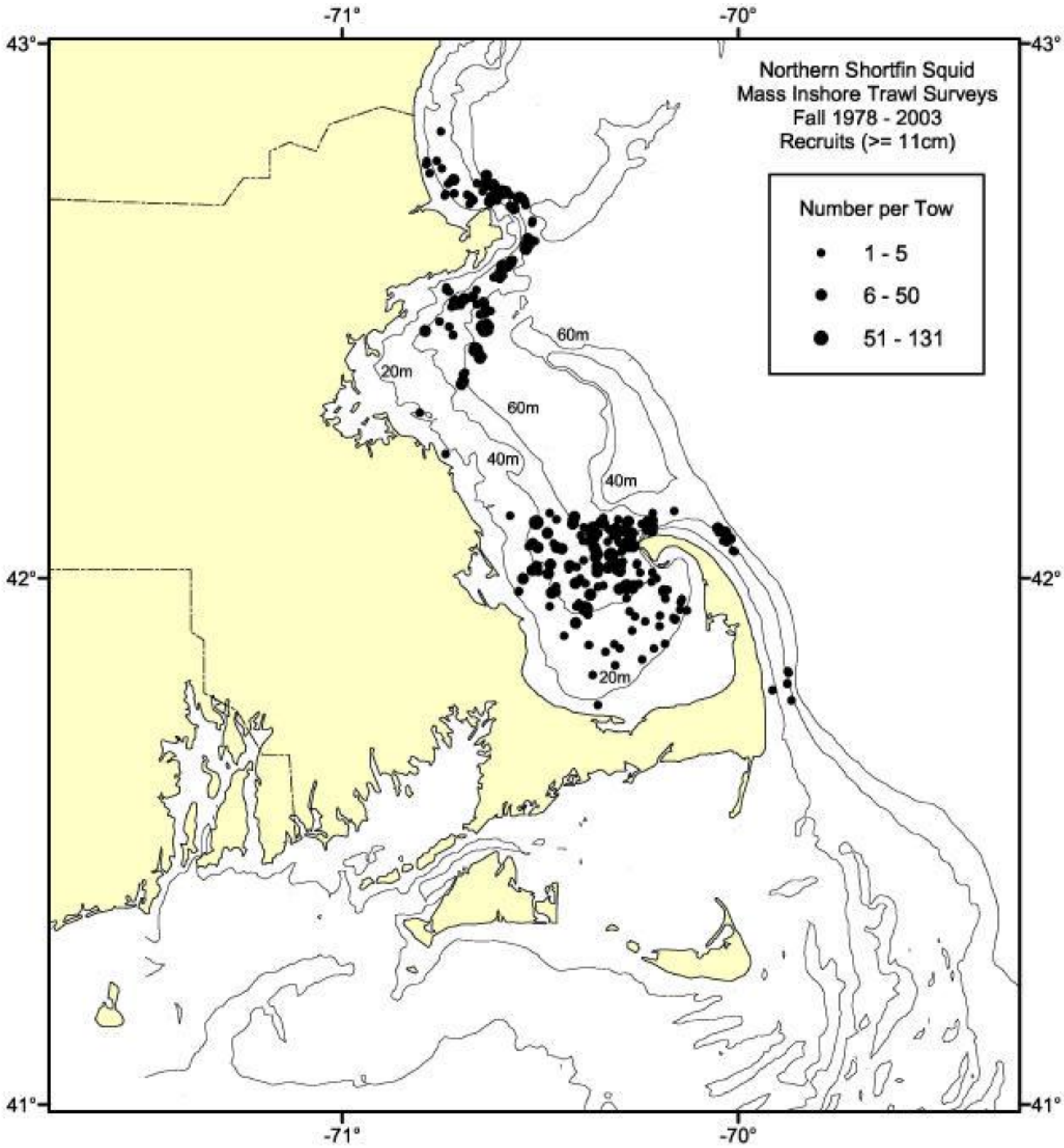


Figure 9. Distribution and abundance of recruit northern shortfin squid in Massachusetts coastal waters. From fall Massachusetts inshore bottom trawl surveys (1978-2003, all years combined). Survey stations where recruits were not found are not shown.

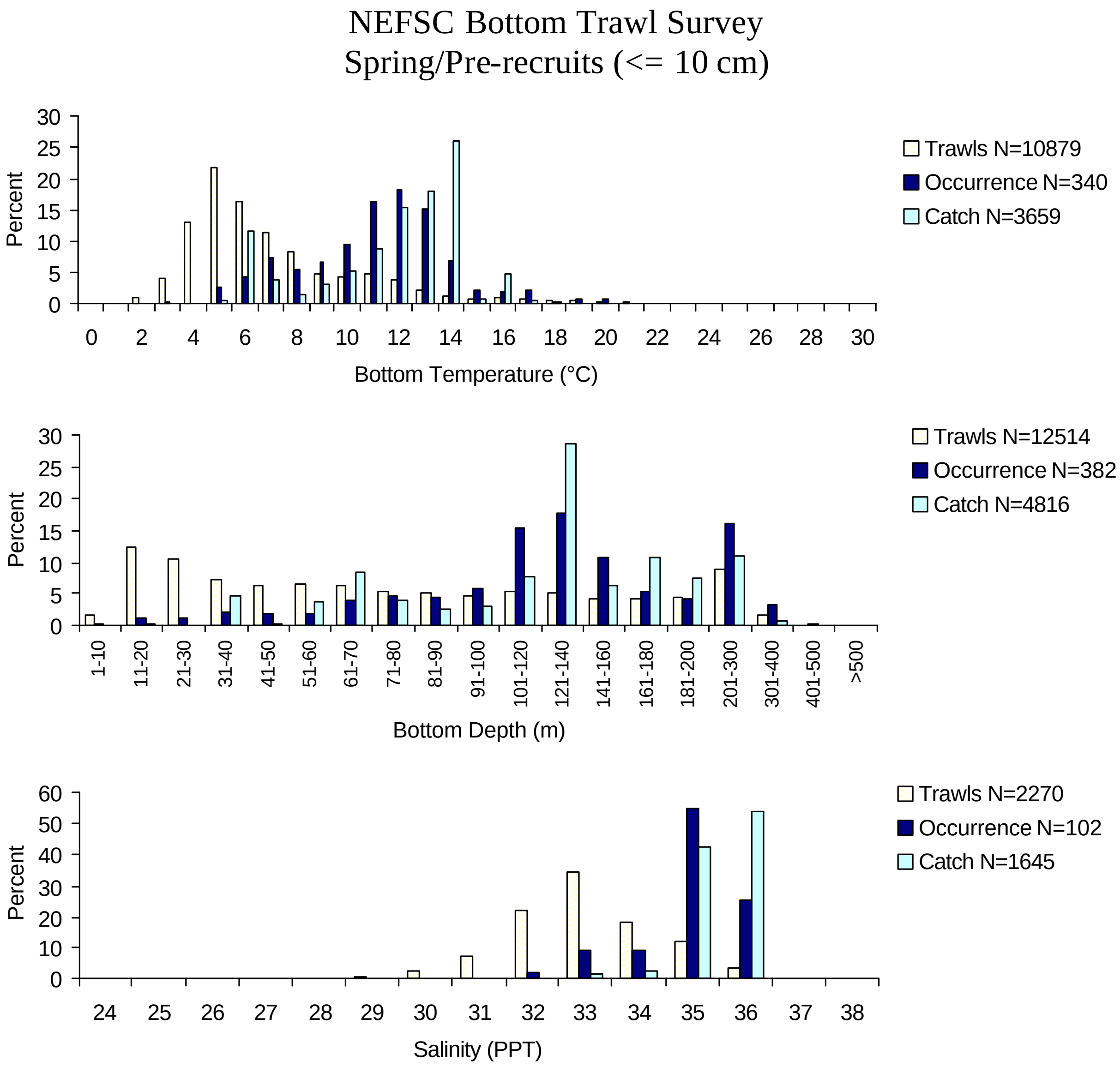


Figure 10. Distributions of pre-recruit northern shortfin squid and trawls from NEFSC bottom trawl surveys relative to bottom water temperature, depth, and salinity.
Based on NEFSC spring bottom trawl surveys (temperature and depth: 1968-2003, all years combined; salinity: 1991-2003, all years combined). Light bars show the distribution of all the trawls, dark bars show the distribution of all trawls in which northern shortfin squid occurred and medium bars show, within each interval, the percentage of the total number of northern shortfin squid caught. Note that the bottom depth interval changes with increasing depth.

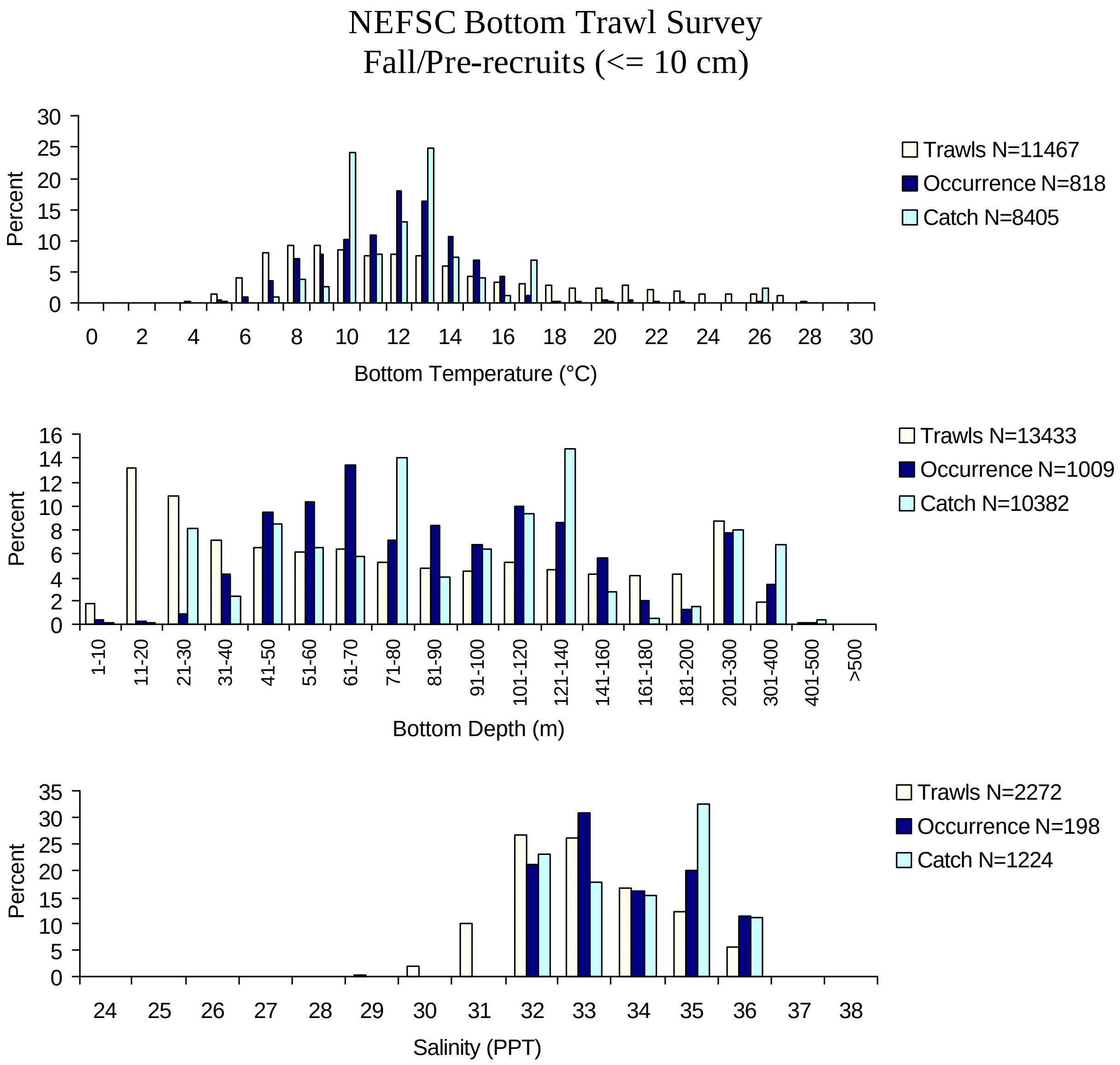


Figure 10. Cont'd.
Based on NEFSC fall bottom trawl surveys (temperature and depth: 1967-2003, all years combined; salinity: 1991-2003, all years combined). Light bars show the distribution of all the trawls, dark bars show the distribution of all trawls in which northern shortfin squid occurred and medium bars show, within each interval, the percentage of the total number of northern shortfin squid caught. Note that the bottom depth interval changes with increasing depth.

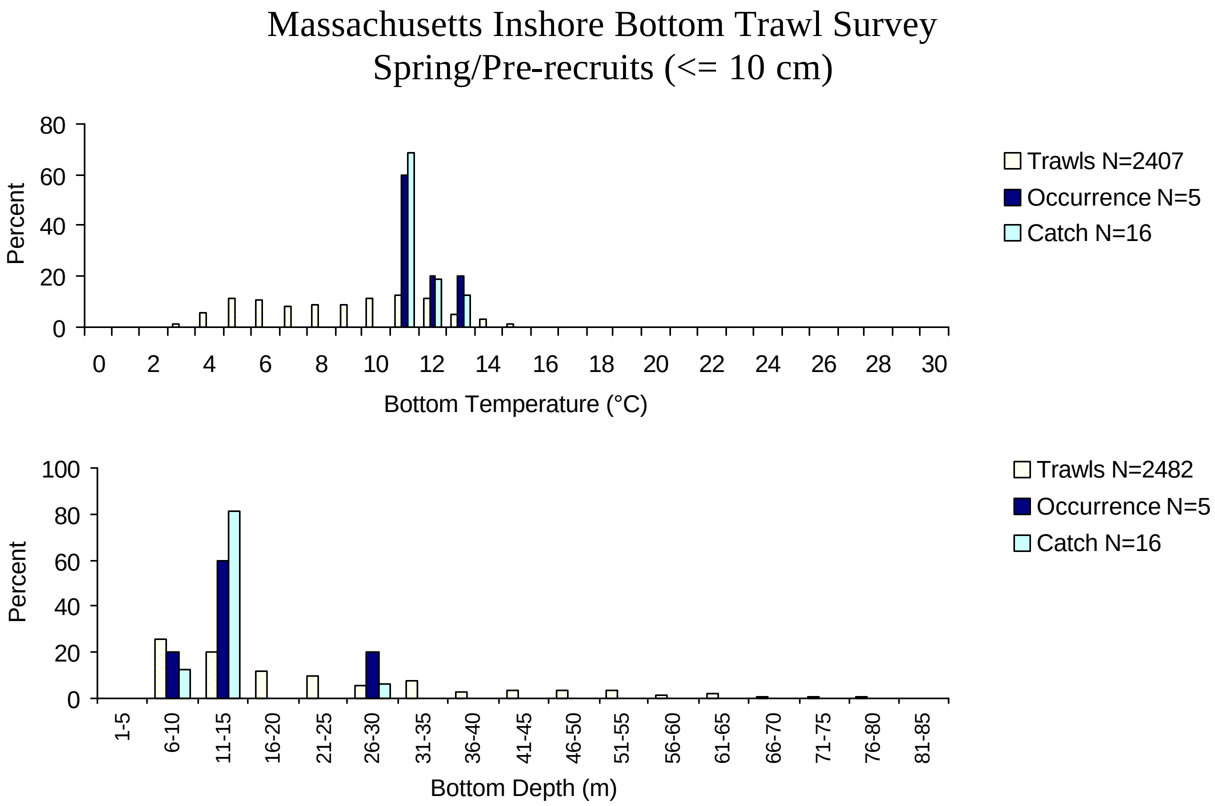


Figure 11. Distributions of pre-recruit northern shortfin squid and trawls in Massachusetts coastal waters relative to bottom water temperature and depth.
Based on spring Massachusetts inshore bottom trawl surveys (1978-2003, all years combined). Light bars show the distribution of all the trawls, dark bars show the distribution of all trawls in which northern shortfin squid occurred and medium bars show, within each interval, the percentage of the total number of northern shortfin squid caught.

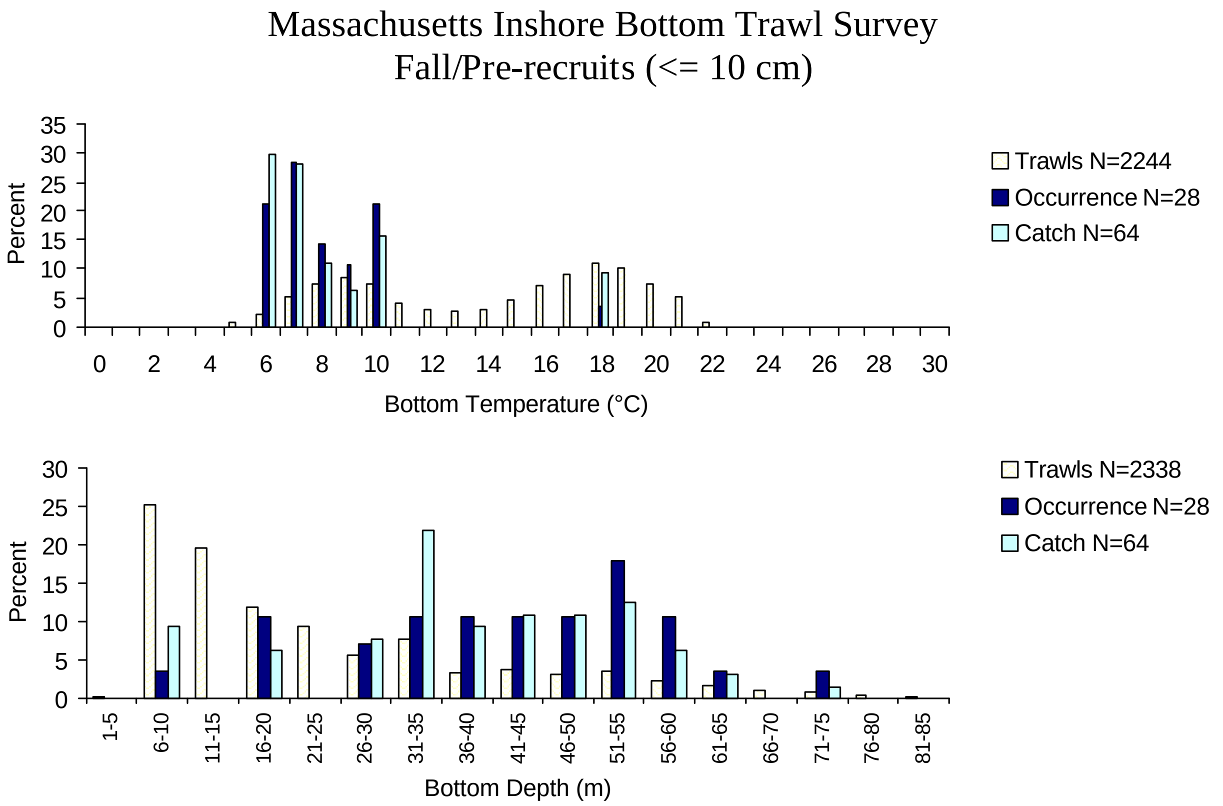


Figure 11. Cont'd.
Based on fall Massachusetts inshore bottom trawl surveys (1978-2003, all years combined). Light bars show the distribution of all the trawls, dark bars show the distribution of all trawls in which northern shortfin squid occurred and medium bars show, within each interval, the percentage of the total number of northern shortfin squid caught.

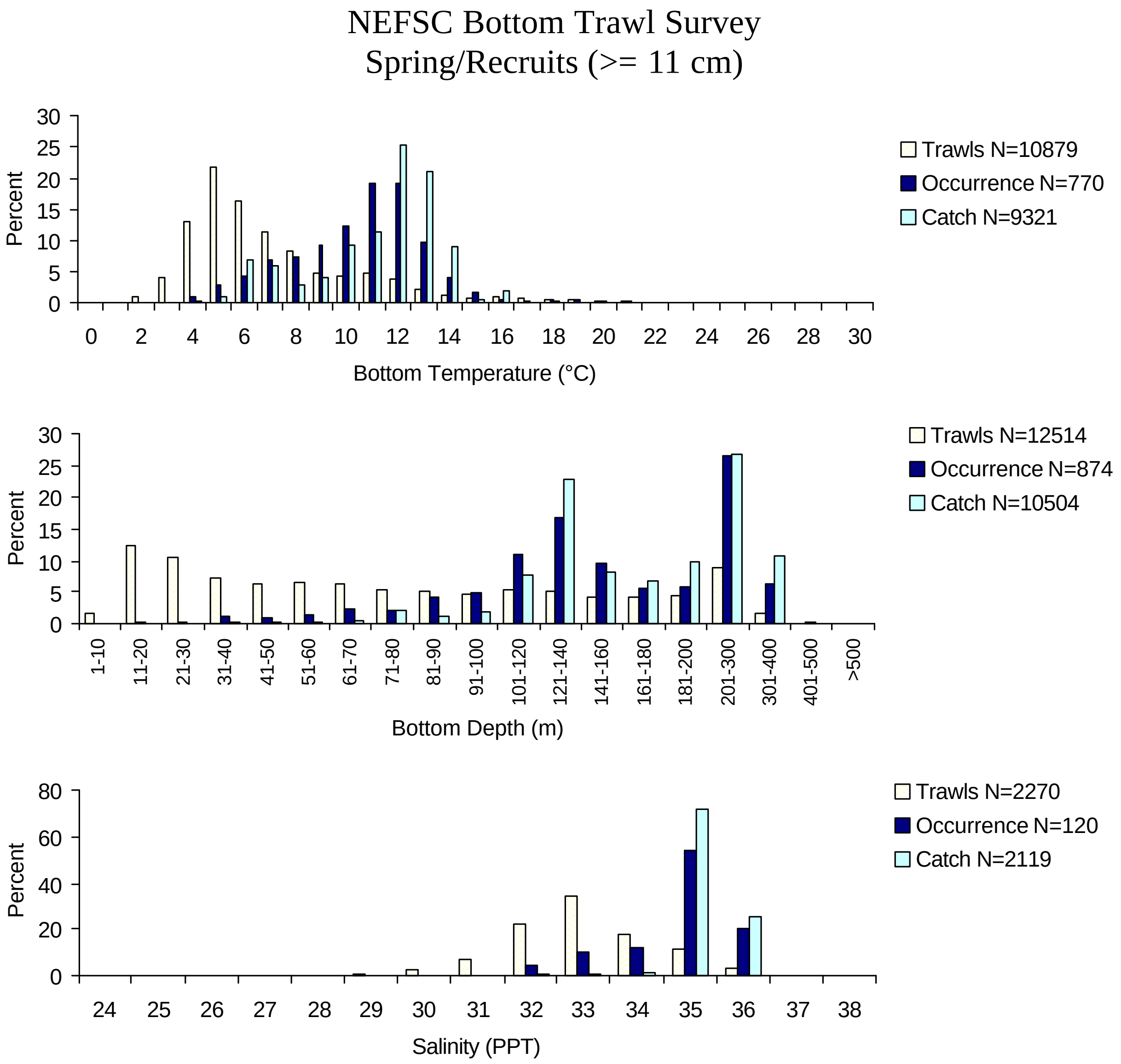


Figure 12. Distributions of recruit northern shortfin squid and trawls from NEFSC bottom trawl surveys relative to bottom water temperature, depth, and salinity.
Based on NEFSC spring bottom trawl surveys (temperature and depth: 1968-2003, all years combined; salinity: 1991-2003, all years combined). Light bars show the distribution of all the trawls, dark bars show the distribution of all trawls in which northern shortfin squid occurred and medium bars show, within each interval, the percentage of the total number of northern shortfin squid caught. Note that the bottom depth interval changes with increasing depth.

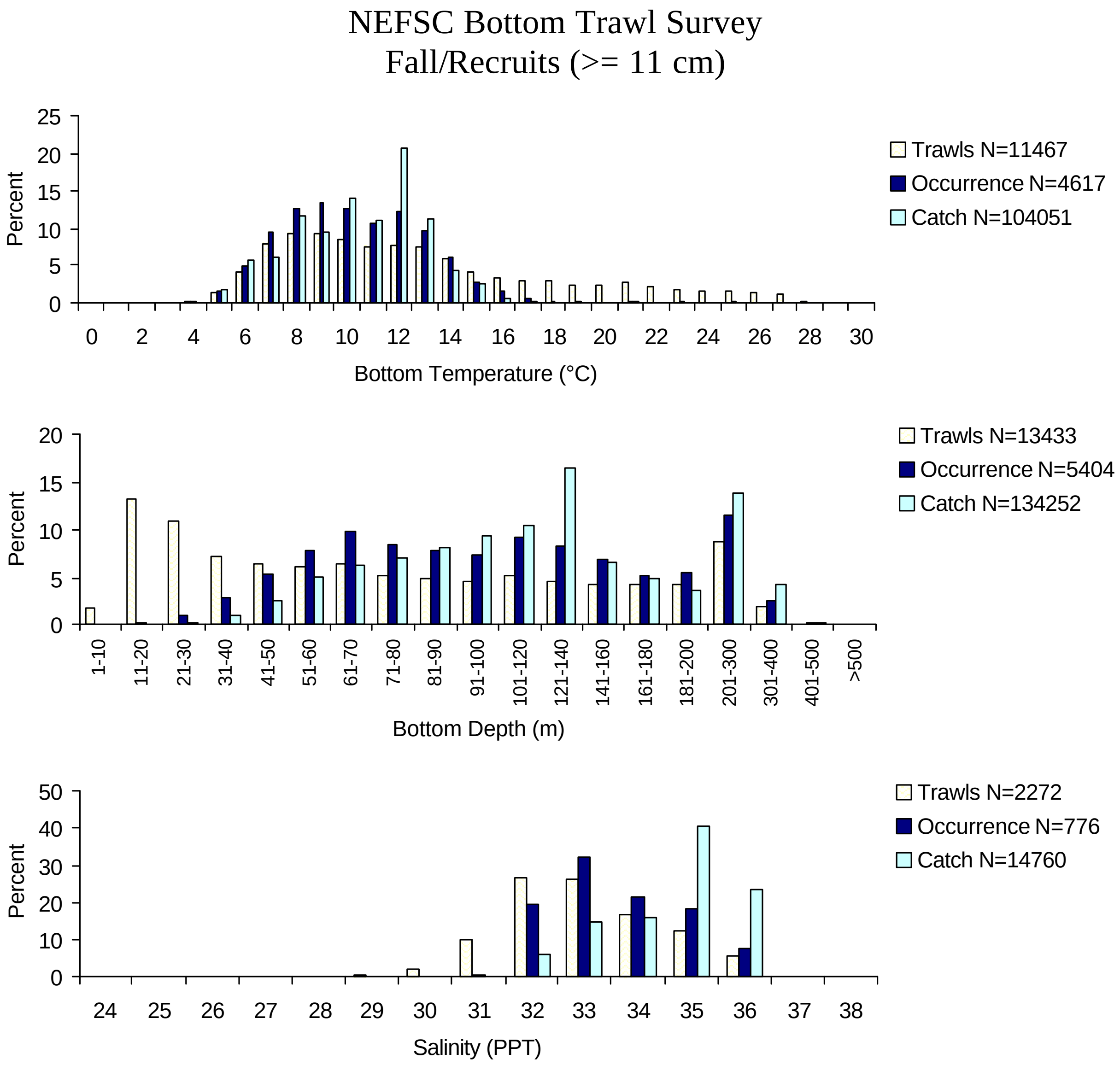
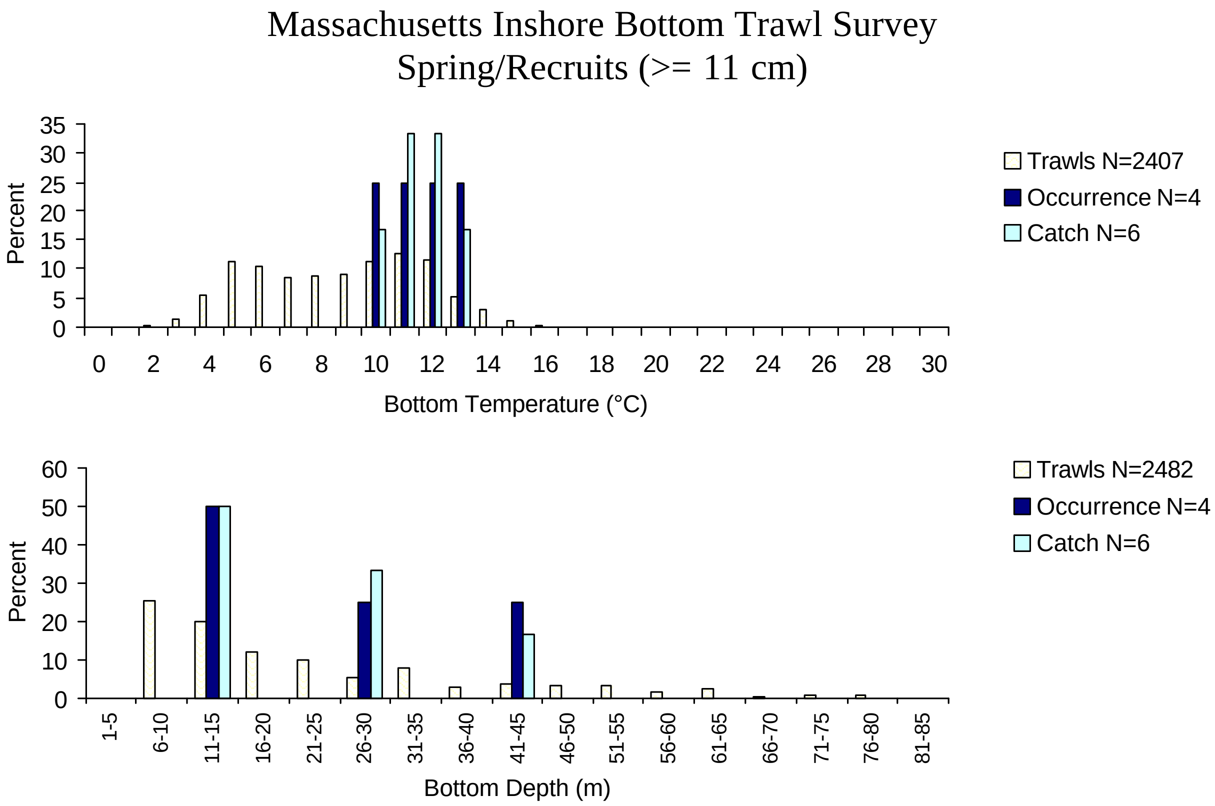


Figure 12. Cont'd.
Based on NEFSC fall bottom trawl surveys (temperature and depth: 1967-2003, all years combined; salinity: 1991-2003, all years combined). Light bars show the distribution of all the trawls, dark bars show the distribution of all trawls in which northern shortfin squid occurred and medium bars show, within each interval, the percentage of the total number of northern shortfin squid caught. Note that the bottom depth interval changes with increasing depth.



Massachusetts Inshore Bottom Trawl Survey
Spring/Recruits (>= 11 cm)

Figure 13. Distributions of recruit northern shortfin squid and trawls in Massachusetts coastal waters relative to bottom water temperature and depth.
Based on spring Massachusetts inshore bottom trawl surveys (1978-2003, all years combined). Light bars show the distribution of all the trawls, dark bars show the distribution of all trawls in which northern shortfin squid occurred and medium bars show, within each interval, the percentage of the total number of northern shortfin squid caught.

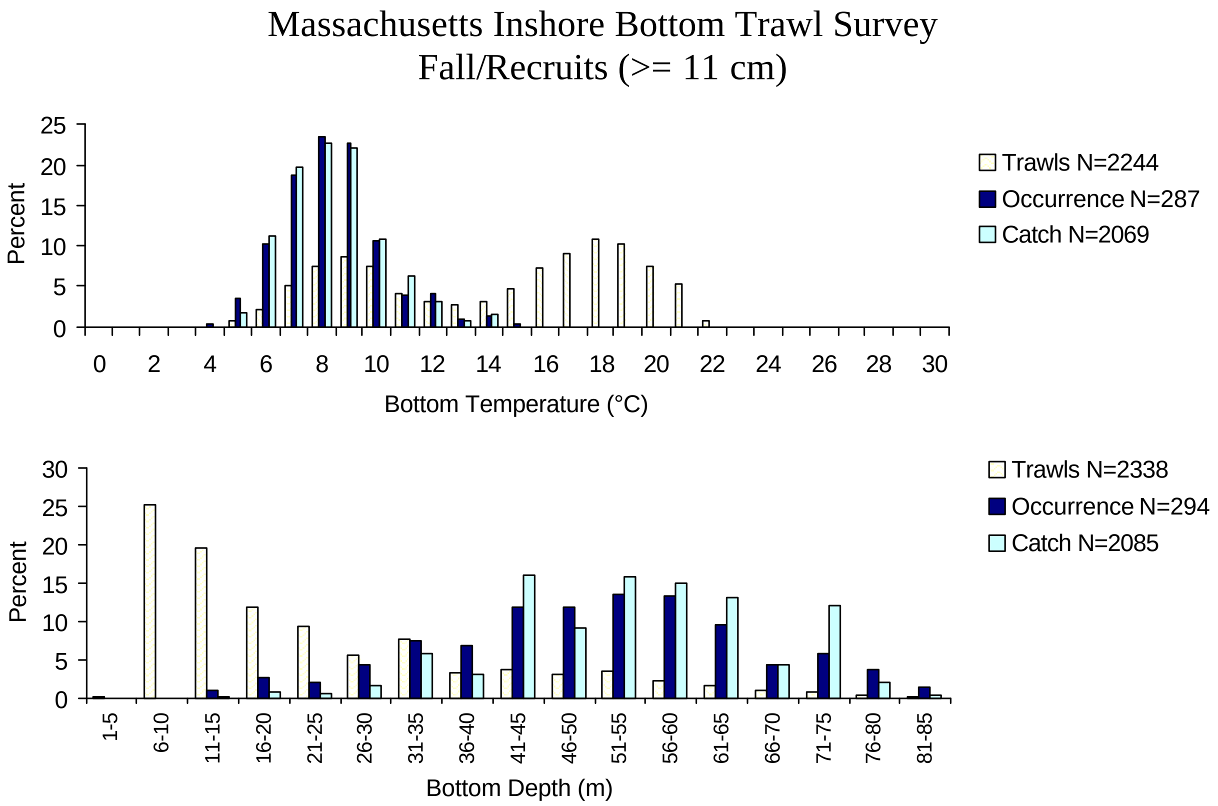


Figure 13. Cont'd.
Based on fall Massachusetts inshore bottom trawl surveys (1978-2003, all years combined). Light bars show the distribution of all the trawls, dark bars show the distribution of all trawls in which northern shortfin squid occurred and medium bars show, within each interval, the percentage of the total number of northern shortfin squid caught.

Publishing in *NOAA Technical Memorandum NMFS-NE*

Manuscript Qualification

This series represents a secondary level of scientific publishing in the National Marine Fisheries Service (NMFS). For all issues, the series employs thorough internal scientific review, but not necessarily external scientific review. For most issues, the series employs rigorous technical and copy editing. Manuscripts that may warrant a primary level of scientific publishing should be initially submitted to one of NMFS's primary series (*i.e., Fishery Bulletin, NOAA Technical Report NMFS,* or *Marine Fisheries Review*).

Identical, or fundamentally identical, manuscripts should not be concurrently submitted to this and any other publication series. Manuscripts which have been rejected by any primary series strictly because of geographic or temporal limitations may be submitted to this series.

Manuscripts by Northeast Fisheries Science Center (NEFSC) authors will be published in this series upon approval by the NEFSC's Deputy Science & Research Director. Manuscripts by non-NEFSC authors may be published in this series if: 1) the manuscript serves the NEFSC's mission; 2) the manuscript meets the Deputy Science & Research Director's approval; and 3) the author arranges for the printing and binding funds to be transferred to the NEFSC's Research Communications Unit account from another federal account. For all manuscripts submitted by non-NEFSC authors and published in this series, the NEFSC will disavow all responsibility for the manuscripts' contents; authors must accept such responsibility.

The ethics of scientific research and scientific publishing are a serious matter. All manuscripts submitted to this series are expected to adhere -- at a minimum -- to the ethical guidelines contained in Chapter 1 ("Ethical Conduct in Authorship and Publication") of the *CBE Style Manual*, fifth edition (Chicago, IL: Council of Biology Editors). Copies of the manual are available at virtually all scientific libraries.

Manuscript Preparation

Organization: Manuscripts must have an abstract, table of contents, and -- if applicable -- lists of tables, figures, and acronyms. As much as possible, use traditional scientific manuscript organization for sections: "Introduction," "Study Area," "Methods & Materials," "Results," "Discussion" and/or "Conclusions," "Acknowledgments," and "References Cited."

Style: All NEFSC publication and report series are obligated to conform to the style contained in the most recent edition of the *United States Government Printing Office Style Manual.* That style manual is silent on many aspects of scientific manuscripts. NEFSC publication and report series rely more on the *CBE Style Manual,* fifth edition.

For in-text citations, use the name-date system. A special effort should be made to ensure that the list of cited works contains all necessary bibliographic information. For abbreviating serial titles in such lists, use the guidance of the International Standards Organization; such guidance is easily accessed through the various Cambridge Scientific Abstracts' serials source lists (see *http://www.public.iastate.edu/~CYBERSTACKS/JAS.htm*). Personal communications must include date of contact and full name and mailing address of source.

For spelling of scientific and common names of fishes, mollusks, and decapod crustaceans from the United States and Canada, use *Special Publications* No. 20 (fishes), 26 (mollusks), and 17 (decapod crustaceans) of the American Fisheries Society (Bethesda, MD). For spelling of scientific and common names of marine mammals, use *Special Publication* No. 4 of the Society for Marine Mammalogy (Lawrence, KS). For spelling in general, use the most recent edition of *Webster's Third New International Dictionary of the English Language Unabridged* (Springfield, MA: G.&C. Merriam).

Typing text, tables, and figure captions: Text, tables, and figure captions should be converted to WordPerfect. In general, keep text simple (*e.g.,* don't switch fonts and type sizes, don't use hard returns within paragraphs, don't indent except to begin paragraphs). Also, don't use an automatic footnoting function; all notes should be indicated in the text by simple numerical superscripts, and listed together in an "Endnotes" section prior to the "References Cited" section. Especially, don't use a graphics function for embedding tables and figures in text.

Tables should be prepared with a table formatting function. Each figure should be supplied both on paper and on disk, unless there is no digital file of a given figure. Except under extraordinary circumstances, color will not be used in illustrations.

Manuscript Submission

Authors must submit one paper copy of the double-spaced manuscript, one disk copy, and original figures (if applicable). NEFSC authors must include a completely signed-off "NEFSC Manuscript/Abstract/Webpage Review Form." Non-NEFSC authors who are not federal employees will be required to sign a "Release of Copyright" form.

Send all materials and address all correspondence to: Jon A. Gibson (Biological Sciences Editor), NMFS Northeast Fisheries Science Center, 166 Water Street, Woods Hole, MA 02543-1026.

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Operations, Management & Information Services Staff
Research Communications Branch
Editorial Office

National Marine Fisheries Service, NOAA
166 Water St.
Woods Hole, MA 02543-1026

MEDIA
MAIL

Publications and Reports of the Northeast Fisheries Science Center

The mission of NOAA's National Marine Fisheries Service (NMFS) is "stewardship of living marine resources for the benefit of the nation through their science-based conservation and management and promotion of the health of their environment." As the research arm of the NMFS's Northeast Region, the Northeast Fisheries Science Center (NEFSC) supports the NMFS mission by "conducting ecosystem-based research and assessments of living marine resources, with a focus on the Northeast Shelf, to promote the recovery and long-term sustainability of these resources and to generate social and economic opportunities and benefits from their use." Results of NEFSC research are largely reported in primary scientific media (*e.g.*, anonymously-peer-reviewed scientific journals). However, to assist itself in providing data, information, and advice to its constituents, the NEFSC occasionally releases its results in its own media. Currently, there are three such media:

NOAA Technical Memorandum NMFS-NE -- This series is issued irregularly. The series typically includes: data reports of long-term field or lab studies of important species or habitats; synthesis reports for important species or habitats; annual reports of overall assessment or monitoring programs; manuals describing program-wide surveying or experimental techniques; literature surveys of important species or habitat topics; proceedings and collected papers of scientific meetings; and indexed and/or annotated bibliographies. All issues receive internal scientific review and most issues receive technical and copy editing.

Northeast Fisheries Science Center Reference Document -- This series is issued irregularly. The series typically includes: data reports on field and lab studies; progress reports on experiments, monitoring, and assessments; background papers for, collected abstracts of, and/or summary reports of scientific meetings; and simple bibliographies. Issues receive internal scientific review, but no technical or copy editing.

Resource Survey Report (formerly *Fishermen's Report*) -- This information report is a quick-turnaround report on the distribution and relative abundance of selected living marine resources as derived from each of the NEFSC's periodic research vessel surveys of the Northeast's continental shelf. There is no scientific review, nor any technical or copy editing, of this report.

OBTAINING A COPY: To obtain a copy of a *NOAA Technical Memorandum NMFS-NE* or a *Northeast Fisheries Science Center Reference Document*, or to subscribe to the *Resource Survey Report*, either contact the NEFSC Editorial Office (166 Water St., Woods Hole, MA 02543-1026; 508-495-2228) or consult the NEFSC webpage on "Reports and Publications" (*http://www.nefsc.noaa.gov/nefsc/publications/*).

Appendix 7

Loligo EFH Source Document

NOAA Technical Memorandum NMFS-NE-193

Essential Fish Habitat Source Document:

Longfin Inshore Squid, *Loligo pealeii*, Life History and Habitat Characteristics

Second Edition

U. S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
National Marine Fisheries Service
Northeast Fisheries Science Center
Woods Hole, Massachusetts

August 2005

Recent Issues in This Series:

174. **Essential Fish Habitat Source Document: Clearnose Skate, *Raja eglanteria*, Life History and Habitat Characteristics**. By David B. Packer, Christine A. Zetlin, and Joseph J. Vitaliano. March 2003. v + 50 p., 25 figs., 2 tables. NTIS Access. No. PB2003-104260.

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181. In press.

182. **U.S. Atlantic and Gulf of Mexico Marine Mammal Stock Assessments – 2003.** By Gordon T. Waring, Richard M. Pace, Janeen M. Quintal, Carol P. Fairfield, and Katherine Maze-Foley, eds., Nicole Cabana, Phillip J. Clapham, Timothy V.N. Cole, Gregory L. Fulling, Lance P. Garrison, Aleta A. Hohn, Blair G. Maise, Wayne E. McFee, Keith D. Mullin, Debra L. Palka, Patricia E. Rosel, Marjorie C. Rossman, Frederick W. Wenzel, and Amy L. Whitingham, contribs. May 2004. vii + 287 p., 47 figs., 58 tables, 4 app., index. NTIS Access. No. PB2004-106431.

183. In press.

184. **A Large Marine Ecosystem Approach to Fisheries Management and Sustainability.** By Frank J. Gable. August 2004. v + 84 p., 38 figs., 10 tables. NTIS Access. No. PB2005-101435.

185. **Revised and Updated Edition of F. Bruce Sanford's 1957 "Planning Your Scientific Research Paper."** By Jon A. Gibson. August 2004. x + 36 p., 5 figs., 12 tables.

186. **Essential Fish Habitat Source Document: Silver Hake, *Merluccius bilinearis*, Life History and Habitat Characteristics. 2nd ed.** By Meredith C. Lock and David B. Packer. August 2004. v + 68 p., 28 figs., 6 tables. NTIS Access. No. PB2005-101436.

187. In preparation by authors.

188. In preparation by authors.

189. **Essential Fish Habitat Source Document: Sea Scallop, *Placopecten magellanicus*, Life History and Habitat Characteristics. 2nd ed.** By Deborah R. Hart and Antonie S. Chute. September 2004. v + 21 p., 6 figs., 2 tables. NTIS Access. No. PB2005-104079.

190. In preparation by authors.

191. **Essential Fish Habitat Source Document: Northern Shortfin Squid, *Illex illecebrosus*, Life History and Habitat Characteristics. 2nd ed.** By Lisa C. Hendrickson and Elizabeth M. Holmes. November 2004. v + 36 p., 13 figs., 1 table. NTIS Access. No. PB2005-101437.

192. **Essential Fish Habitat Source Document: Atlantic Herring, *Clupea harengus*, Life History and Habitat Characteristics. 2nd ed.** By David K. Stevenson and Marcy L. Scott. July 2005. vi + 84 p., 40 figs., 7 tables. NTIS Access. No. PB2005-107567.

NOAA Technical Memorandum NMFS-NE-193

Essential Fish Habitat Source Document:

Longfin Inshore Squid, *Loligo pealeii*, Life History and Habitat Characteristics

Second Edition

Larry D. Jacobson

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U. S. DEPARTMENT OF COMMERCE
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William T. Hogarth, Assistant Administrator for Fisheries
Northeast Fisheries Science Center
Woods Hole, Massachusetts

August 2005

Editorial Notes on "Essential Fish Habitat Source Documents" Issued in the *NOAA Technical Memorandum NMFS-NE* Series

Editorial Production

For "Essential Fish Habitat Source Documents" issued in the *NOAA Technical Memorandum NMFS-NE* series, staff of the Northeast Fisheries Science Center's (NEFSC's) Ecosystems Processes Division largely assume the role of staff of the NEFSC's Editorial Office for technical and copy editing, type composition, and page layout. Other than the four covers (inside and outside, front and back) and first two preliminary pages, all preprinting editorial production is performed by, and all credit for such production rightfully belongs to, the staff of the Ecosystems Processes Division.

Internet Availability and Information Updating

Each original issue of an "Essential Fish Habitat Source Document" is published both as a paper copy and as a Web posting. The Web posting, which is in "PDF" format, is available at: *http://www.nefsc.noaa.gov/nefsc/habitat/efh*.

Each issue is updated at least every five years. The updated edition will be published as a Web posting only; the replaced edition(s) will be maintained in an online archive for reference purposes.

Species Names

The NMFS Northeast Region's policy on the use of species names in all technical communications is generally to follow the American Fisheries Society's lists of scientific and common names for fishes (*i.e.*, Nelson *et al.* 2004[a]; Robins *et al.* 1991[b]), mollusks (*i.e.*, Turgeon *et al.* 1998[c]), and decapod crustaceans (*i.e.*, Williams *et al.* 1989[d]), and to follow the Society for Marine Mammalogy's guidance on scientific and common names for marine mammals (*i.e.*, Rice 1998[e]). Exceptions to this policy occur when there are subsequent compelling revisions in the classifications of species, resulting in changes in the names of species.

---

[a] Nelson, J.S.; Crossman, E.J.; Espinosa-Pérez, H.; Findley, L.T.; Gilbert, C.R.; Lea, R.N.; Williams, J.D. 2004. Common and scientific names of fishes from the United States, Canada, and Mexico. 6th ed. *Amer. Fish. Soc. Spec. Publ.* 29; 386 p.

[b] Robins, C.R. (chair); Bailey, R.M.; Bond, C.E.; Brooker, J.R.; Lachner, E.A.; Lea, R.N.; Scott, W.B. 1991. World fishes important to North Americans. *Amer. Fish. Soc. Spec. Publ.* 21; 243 p.

[c] Turgeon, D.D. (chair); Quinn, J.F., Jr.; Bogan, A.E.; Coan, E.V.; Hochberg, F.G.; Lyons, W.G.; Mikkelsen, P.M.; Neves, R.J.; Roper, C.F.E.; Rosenberg, G.; Roth, B.; Scheltema, A.; Thompson, F.G.; Vecchione, M.; Williams, J.D. 1998. Common and scientific names of aquatic invertebrates from the United States and Canada: mollusks. 2nd ed. *Amer. Fish. Soc. Spec. Publ.* 26; 526 p.

[d] Williams, A.B. (chair); Abele, L.G.; Felder, D.L.; Hobbs, H.H., Jr.; Manning, R.B.; McLaughlin, P.A.; Pérez Farfante, I. 1989. Common and scientific names of aquatic invertebrates from the United States and Canada: decapod crustaceans. *Amer. Fish. Soc. Spec. Publ.* 17; 77 p.

[e] Rice, D.W. 1998. Marine mammals of the world: systematics and distribution. *Soc. Mar. Mammal. Spec. Publ.* 4; 231 p.

PREFACE TO SECOND EDITION

One of the greatest long-term threats to the viability of commercial and recreational fisheries is the continuing loss of marine, estuarine, and other aquatic habitats.

Magnuson-Stevens Fishery Conservation and Management Act (October 11, 1996)

The long-term viability of living marine resources depends on protection of their habitat.

NMFS Strategic Plan for Fisheries Research (February 1998)

The Magnuson-Stevens Fishery Conservation and Management Act (MSFCMA), which was reauthorized and amended by the Sustainable Fisheries Act (1996), requires the eight regional fishery management councils to describe and identify essential fish habitat (EFH) in their respective regions, to specify actions to conserve and enhance that EFH, and to minimize the adverse effects of fishing on EFH. Congress defined EFH as "those waters and substrate necessary to fish for spawning, breeding, feeding or growth to maturity." The MSFCMA requires NOAA Fisheries to assist the regional fishery management councils in the implementation of EFH in their respective fishery management plans.

NOAA Fisheries has taken a broad view of habitat as the area used by fish throughout their life cycle. Fish use habitat for spawning, feeding, nursery, migration, and shelter, but most habitats provide only a subset of these functions. Fish may change habitats with changes in life history stage, seasonal and geographic distributions, abundance, and interactions with other species. The type of habitat, as well as its attributes and functions, are important for sustaining the production of managed species.

The Northeast Fisheries Science Center compiled the available information on the distribution, abundance, and habitat requirements for each of the species managed by the New England and Mid-Atlantic Fishery Management Councils. That information is presented in a series of EFH species reports (plus one consolidated methods report). The EFH species reports are a survey of the important literature as well as original analyses of fishery-independent data sets from NOAA Fisheries and several coastal states. The species reports are also the source for the current EFH designations by the New England and Mid-Atlantic Fishery Management Councils, and understandably are referred to as the "EFH source documents."

NOAA Fisheries provided guidance to the regional fishery management councils for identifying and describing EFH of their managed species. Consistent with this guidance, the species reports present information on current and historic stock sizes, geographic range, and the period and location of major life history stages. The habitats of managed species are described by the physical, chemical, and biological components of the ecosystem where the species occur. Information on the habitat requirements is provided for each life history stage, and it includes, where available, habitat and environmental variables that control or limit distribution, abundance, growth, reproduction, mortality, and productivity.

The initial series of EFH species source documents were published in 1999 in the *NOAA Technical Memorandum NMFS-NE* series. Updating and review of the EFH components of the councils' Fishery Management Plans is required at least every 5 years by the NOAA Fisheries Guidelines for meeting the Sustainable Fisheries Act/EFH Final Rule. The second editions of these species source documents were written to provide the updated information needed to meet these requirements. The second editions provide new information on life history, geographic distribution, and habitat requirements via recent literature, research, and fishery surveys, and incorporate updated and revised maps and graphs. This second edition of the longfin inshore squid EFH source document is based on the original by Luca M. Cargnelli, Sara J. Griesbach, Cathy McBride, Christine A. Zetlin, and Wallace W. Morse, with a foreword by Jeffrey N. Cross (Cargnelli *et al.* 1999).

Identifying and describing EFH are the first steps in the process of protecting, conserving, and enhancing essential habitats of the managed species. Ultimately, NOAA Fisheries, the regional fishery management councils, fishing participants, Federal and state agencies, and other organizations will have to cooperate to achieve the habitat goals established by the MSFCMA.

Contents

Tables

Figures

INTRODUCTION

The longfin inshore squid, *Loligo pealeii*, is a schooling species of the molluscan family Loliginidae (Figure 1). It is distributed in continental shelf and slope waters from Newfoundland to the Gulf of Venezuela, and occurs in commercial abundance from southern Georges Bank to Cape Hatteras. The fishery for longfin inshore squid is managed by the Mid-Atlantic Fishery Management Council under the Atlantic Mackerel, Squid and Butterfish Fishery Management Plan, Amendment 8 (MAFMC 1998). Within the range of commercial exploitation, the population is considered to be a single stock unit. This Essential Fish Habitat Source Document provides information on the life history and habitat characteristics of longfin inshore squid inhabiting the Gulf of Maine, Georges Bank, and the Middle Atlantic Bight.

LIFE HISTORY

See Brodziak (1995) for a brief synopsis of life history. More detailed information is provided here.

EGGS AND LARVAE

The 1 mm x 1.6 mm eggs are encased in a gelatinous capsule as they pass through the female oviduct during mating. Each capsule contains 150-200 eggs (Arnold *et al.* 1974; Gosner 1978; MAFMC 1998) and is about 50-80 mm long and 1 cm in diameter (Gosner 1978; Lange 1982; MAFMC 1998). During spawning, the male cements bundles of spermatophores into the mantle cavity of the female. The jelly is penetrated by sperm as the egg capsules pass through the oviduct (Black *et al.* 1987). The egg capsules are laid on the bottom in clusters 50-60 cm wide composed of hundreds of capsules (Gosner 1978; Griswold and Prezioso 1981). Each female lays 20-30 capsules (Lange 1982). The number of eggs spawned per female has been reported as 950-8,500 (Haefner 1959), 3,500-6,000 (Summers 1971), 2,500-15,900 (Vovk 1972b), and 3,000-6,000 (MAFMC 1998). Development time varies from 257 to 642 hrs depending on water temperature; 26.7 days to hatching at 12-18^{o}C, 18.5 days at 15.5-21.3^{o}C, and 10.7 days at 15.5-23.0^{o}C (Summers 1971).

Larvae of the longfin inshore squid are referred to as paralarvae (Young and Harman 1988). Little is known about them because they are planktonic, being found in the water column near the surface (McMahon and Summers 1971), and require special sampling techniques. Larvae 2-4 mm in length have been caught in the Gulf of Maine (Bigelow 1924).

JUVENILES AND SUBADULTS

There are two juvenile stages. 'Juvenile' is the stage after the paralarval stage and before the 'subadult' stage. The subadult stage is before maturity, when morphological characteristics of adults are attained (Young and Harman 1988). The shift from inhabiting surface waters to a demersal lifestyle occurs at 45 mm (Vecchione 1981). Off Martha's Vineyard, the juvenile life stage lasts about 1 month. Subadults migrate by November to the outer shelf areas where they remain until March (Summers 1968a, b). Subadults are thought to overwinter in deeper waters along the edge of the continental shelf (Black *et al.* 1987). Young-of-the-year (subadults) are found with adults in mid-summer bottom trawl catches (Summers 1968a, b). Juveniles and subadults grow quickly, with growth rates dependent on temperature (Hatfield *et al.* 2001).

Sexual maturity is first reached at about 8-12 cm (Macy 1980; Brodziak and Hendrickson 1999). The length at which 50% of individuals are sexually mature (L_{50}) is 16-20 cm, depending on season and location (Brodziak 1995; Macy and Brodziak 2001; Hatfield and Cadrin 2002).

ADULTS

Historically, the lifespan of longfin inshore squid was believed to be 1-2 years (Summers 1971; Lange 1982). However, Brodziak and Macy (1996), using statolith aging, demonstrated exponential growth and a lifespan of less than 1 year.

Longfin inshore squid reach sizes greater than 40-50 cm mantle length (ML), although most are less than 30 cm (Vecchione *et al.* 1989; Brodziak 1995). They are sexually dimorphic – males grow more rapidly and reach larger size at age than females (Brodziak 1995). Growth depends on temperature (Hatfield *et al.* 2001) and is highest for individuals hatched during winter (Macy and Brodziak 2001). Longfin inshore squid migrate offshore during late autumn and overwinter in warmer waters along the edge of the continental shelf; they return inshore during the spring and early summer (MAFMC 1998). Mature individuals enter inshore waters before immature ones (Macy 1982). Off Massachusetts, larger individuals migrate inshore in April-May while smaller individuals move inshore in the summer (Lange 1982). Longfin inshore squid form large schools based on size prior to feeding (Macy 1980) and make diurnal vertical migrations up into the water column at night (MAFMC 1998). This movement may be associated with the pursuit of food organisms such as euphausiids.

REPRODUCTION

Brodziak and Macy (1996), Macy and Brodziak (2001), and Hatfield and Cadrin (2002) show that longfin inshore squid spawn year round with seasonal and geographic peaks that vary among years and geographic areas (Lange and Sissenwine 1980). Most eggs are spawned in May and hatching occurs in July (Summers 1971). Spawning has been reported from August to September in the Bay of Fundy (Stevenson 1934), from May to August in New England waters (Summers 1971; Macy 1980), and from late spring to early summer in the Middle Atlantic (Lange and Sissenwine 1983; Black *et al.* 1987). Mesnil (1977) reported that spawning on the Scotian Shelf and Georges Bank occurs during early spring and late summer. Spawning south of Cape Hatteras may also be important (Hatfield and Cadrin 2002).

Spawning has been reported in the Gulf of Maine in Cobequid Bay and Massachusetts Bay (Bigelow 1924), the Bay of Fundy (Stevenson 1934), Minas Basin (Cohen 1976), along the eastern coast of Nova Scotia in St. Margaret's and Terrence bays (Dawe *et al.* 1990), on Georges Bank (Mesnil 1977), and in the Middle Atlantic in Narragansett and Delaware bays (Haefner 1959; Griswold and Prezioso 1981).

Based on recent research, reproductive biology and behavior is complicated for longfin inshore squid. Visual and chemical cues regulate competition among males for females on spawning grounds (Buresch *et al.* 2003). Females may lay multiple clutches over periods of up to several weeks (Maxwell and Hanlon 2000; King *et al.* 2003). Eggs in the same capsule from a single female may have multiple fathers from multiple spawning events and females appear to store sperm from spawning events for later use (Buresch *et al.* 2001).

FOOD HABITS

The diet of the longfin inshore squid changes with size; small immature individuals feed on planktonic organisms (Vovk 1972b; Tibbetts 1977) while larger individuals feed on crustaceans and small fish (Vinogradov and Noskov 1979). Cannibalism is observed in individuals larger than 5 cm (Whitacker 1978). Studies by Vovk and Khvichiya (1980) and Vovk (1985) showed that juveniles 4.1-6 cm long fed on euphausiids and arrow worms, while those 6.1-10 cm fed mostly on small crabs, but also on polychaetes and shrimp. Adults 12.1-16 cm long fed on fish (clupeids, myctophids) and squid larvae/juveniles, and those > 16 cm fed on fish and squid (Vovk and Khvichiya 1980; Vovk 1985). Fish species preyed on by longfin inshore squid include silver hake, mackerel, herring, menhaden (Langton and Bowman 1977), sand lance, bay anchovy, menhaden, weakfish, and silversides (Kier 1982). Maurer and Bowman (1985) demonstrated the following seasonal and inshore/offshore differences in diet: in offshore waters in the spring, the diet is composed of crustaceans (mainly euphausiids) and fish; in inshore waters in the fall, the diet is composed almost exclusively of fish; and in offshore waters in the fall, the diet is composed of fish and squid.

PREDATION

Many pelagic and demersal fish species, as well as marine mammals and diving birds, prey upon juvenile and adult longfin inshore squid (Lange and Sissenwine 1980; Vovk and Khvichiya 1980; Summers 1983). Marine mammal predators include longfin pilot whale, *Globicephala melas*, and common dolphin, *Delphinus delphis* (Waring *et al.* 1990; Overholtz and Waring 1991; Gannon *et al.* 1997). Fish predators include bluefish, sea bass, mackerel, cod, haddock, pollock, silver hake, red hake, sea raven, spiny dogfish, angel shark, goosefish, dogfish, and flounder (Maurer 1975; Langton and Bowman 1977; Gosner 1978; Lange 1980).

GEOGRAPHICAL DISTRIBUTION

Longfin inshore squid occur from Newfoundland to the Gulf of Venezuela, however, the principal concentrations exploited in the United States occur from Georges Bank to Cape Hatteras (Brodziak 1995). Longfin inshore squid are generally found at water temperatures of at least 9°C (Lange and Sissenwine 1980). The population makes seasonal migrations that appear to be related to bottom water temperatures; they move offshore during late autumn to overwinter along the edge of the continental shelf and return inshore during the spring and early summer (MAFMC 1998). When inshore waters are coldest during winter and early spring, the population concentrates along the outer edge of the continental shelf. The inshore movement to the shelf areas takes place when water temperatures are rising (Black *et al.* 1987) and begins in the south and proceeds north along the coast (MAFMC 1998). A northerly extension of the range has been noted in summer (Black *et al.* 1987).

The terms 'pre-recruit' (unexploited sizes) and 'recruit' (exploited sizes) are often used in reference to longfin inshore squid. Exploitation begins at a minimum mantle length of about 9 cm. Thus, pre-recruits are ≤ 8 cm and recruits are ≥ 9 cm.

EGGS AND LARVAE

The egg and larval stages of longfin inshore squid were not sampled by the Northeast Fisheries Science Center (NEFSC) Marine Resources Monitoring, Assessment and Prediction program (MARMAP) offshore ichthyoplankton surveys.

PRE-RECRUITS

The NEFSC bottom trawl surveys [see Reid *et al.* (1999) for details] captured longfin inshore squid pre-recruits during all seasons (Figure 2; note that winter and summer distributions are presented as presence only data, precluding a discussion of abundances.). In winter, pre-recruits were captured from Cape Hatteras to Nantucket Shoals, although most were found south of Long Island. They were generally found offshore and concentrated toward the 200 m isobath. They were distributed a little farther inshore in the southern part of the range, presumably due to warmer water temperatures. In the spring, the distribution extended farther to the south, with high concentrations south of Cape Hatteras, and farther to the north, with high numbers in southern New England and some catches on Georges Bank and the Scotian Shelf. Higher concentrations were found near the 200 m isobath. In summer, they were concentrated nearshore, with a few found on central Georges Bank. In autumn, longfin inshore squid were distributed along the coast of Maine, in Massachusetts Bay, and from Georges Bank to south of Cape Hatteras from nearshore to the 200 m isobath, with some of the highest concentrations found nearshore. This presumably indicates the beginning of the offshore migration.

The spring and fall distributions and abundances of pre-recruits around coastal Massachusetts, based on Massachusetts inshore bottom trawl surveys [see Reid et al. (1999) for details], are shown in Figure 3. In the spring, high concentrations occurred south of Cape Cod and around Martha's Vineyard and Nantucket Island. Low numbers were found in and around Cape Cod Bay, and none were captured north of Cape Cod. Much higher numbers of pre-recruits were found in the fall. High concentrations were found in Buzzards Bay, around Martha's Vineyard and Nantucket Island, throughout Cape Cod Bay, in Massachusetts Bay, and north and south of Cape Ann. The lower numbers of pre-recruits in inshore waters in the spring was most likely due to the survey occurring prior to the main part of the inshore migration.

The seasonal distributions and abundances of prerecruits in Narragansett Bay, based upon the 1990-1996 Rhode Island bottom trawl surveys, are shown in Figure 4. In winter, very few were caught, and they were only found at one station near the entrance to the Bay. Catches increased slightly in spring, and were highest during summer and autumn. This pattern corresponds to inshore migrations beginning in early spring.

The distributions and abundances of both pre-recruit and recruit longfin inshore squid in Long Island Sound from April to November 1986-1994, based on the Connecticut Fisheries Division bottom trawl surveys, are shown in Figure 5, Figure 6, and Figure 7. The following description of their distributions relative to depth and bottom type is taken almost verbatim from Gottschall *et al.* (2000).

Longfin inshore squid taken in the survey ranged from 2-40 cm mantle length (Figure 5), with the largest squid present in May and June. Squid were rarely observed in April (4% occurrence), but from May through November they were commonly taken throughout the Sound. The percent occurrence varied little during these months, ranging from 63% in July to 81% in September (Figure 6D). Abundance remained stable through late spring and summer (Figure 6A), and then increased dramatically in fall when squid ranging in size from 2-12 cm recruited to the trawl.

Although squid were commonly encountered throughout Long Island Sound in late spring, they were most abundant east of Stratford Shoal, particularly in depths > 18 m on the transitional and sand bottom (Figure 6B and C) of the Mattituck Sill and the adjacent portion of the Central Basin (Figure 7). In addition, they were concentrated in Niantic Bay. In contrast, longfin inshore squid appeared to be more dispersed in summer. In fall, when small squid were abundant, they were distributed throughout the Sound, but were more abundant in the Central and Western Basins. During the fall generally, abundance tended to increase with depth and was highest over mud bottom, with abundance over transitional and sand bottoms ranking second and third respectively. Although the abundance of squid was very low in November, they were still commonly encountered throughout the Sound (65% occurrence). Abundance was similar over all bottom types but, as in the fall period, abundance tended to increase with depth (Gottschall *et al.* 2000).

Longfin inshore squid pre-recruits were captured in the Hudson-Raritan estuary during spring, summer, and fall (Figure 8). They were found almost exclusively in the eastern portion of the bay and were collected in the highest numbers in the summer and autumn.

RECRUITS

NEFSC bottom trawl surveys captured longfin inshore squid recruits during all seasons (Figure 9; again note that winter and summer distributions are presented as presence data, precluding a discussion of abundances.). Their seasonal distributions are nearly identical to that of pre-recruits and illustrate the spring and summer inshore and the autumn offshore migrations.

The distribution of longfin inshore squid recruits in waters off Massachusetts was almost identical to that of pre-recruits, although the overall number of recruits was much lower (Figure 10).

Recruits were caught during all seasons in Narragansett Bay (Figure 11). Catches were low in winter, increased somewhat in spring, and were highest during summer and autumn. This pattern corresponds to inshore migrations beginning in spring.

The distributions and abundances of both pre-recruits and recruits in Long Island Sound were discussed previously.

Longfin inshore squid recruits were captured in the Hudson-Raritan estuary during spring, summer, and fall (Figure 12). They were found mostly in the eastern portion of the bay; the highest catches occurred in summer and autumn.

The 1988-1999 Virginia Institute of Marine Science (VIMS) trawl surveys of Chesapeake Bay suggests that recruit longfin inshore squid (> 12 cm) appeared in their catches primarily in April, with a few in May, and most likely were limited to sites around the Bay mouth and eastward (Geer 2002).

HABITAT CHARACTERISTICS

Information on the habitat characteristics and preferences of the longfin inshore squid are summarized in Table 1.

EGGS AND LARVAE

Egg masses are commonly found attached to rocks and small boulders on sandy/muddy bottom and on aquatic vegetation, such as *Fucus* sp., *Ulva lactuca*, *Laminaria* sp. and *Porphyra* sp. (Arnold *et al.* 1974; Griswold and Prezioso, 1981; Summers 1983). The eggs are demersal, are generally laid in waters < 50 m deep (Bigelow 1924; Griswold and Prezioso 1981; Lange 1982), and are found at temperatures of 10-23^{o}C (McMahon and Summers 1971) and salinities of 30-32 ppt (McMahon and Summers 1971).

The larvae are pelagic near the surface (McMahon and Summers 1971; McConathy *et al.* 1980) and occur at temperatures of 10-26^{o}C and salinities of 31.5-34.0 ppt (Vecchione 1981). Surface waters are important to hatchlings and larvae and individuals move deeper as they grow older (Vecchione 1981). Longfin inshore squid larvae were common in ichthyoplankton samples across a wide range of depths and areas (Vecchione *et al.* 2001).

PRE-RECRUITS

Juveniles inhabit the upper 10 m of the water column over water 50-150 m deep (Mercer 1969; Vovk and Khvichiya 1980; Brodziak and Hendrickson 1999). They are found at surface water temperatures of 10-26^{o}C (Vecchione 1981; Brodziak and Hendrickson 1999) and salinities of 31.5-34.0 ppt (Vecchione 1981). Longfin inshore squid move up (nighttime) and down (daytime) in the water column on a daily (diel) basis (Hatfield and Cadrin 2002) but the importance of off-bottom habitat is unknown because sampling has been primarily with bottom trawls. Diel migration patterns depend on squid size and season (Hatfield and Cadrin 2002).

Distributions of pre-recruits relative to bottom water temperature, depth, and salinity based on spring and fall NEFSC bottom trawl surveys are shown in Figure 13. During the spring surveys, pre-recruits were found in a temperature range of 4-21ºC, with the majority at about 8-14ºC. They were found over a depth range of 1-400 m, and a salinity range of 31-36, with most found at 34-36 ppt. During the fall the pre-recruits were found over a wider temperature range of 6-28ºC, with peaks in abundance between roughly 10-19ºC. Their depth range during that season was between 1-400 m, with the majority found above about 60 m. Their salinity range was between 29-36 ppt, with the majority at 32-33 ppt.

The spring and autumn distributions of pre-recruits in Massachusetts coastal waters relative to bottom water temperature and depth based on Massachusetts inshore bottom trawl surveys are shown in Figure 14. In the spring, the pre-recruits were found at a temperature range of 5-17ºC, with most at 10-14ºC. Their depth range was from 6 m to a depth of approximately 65 m; the majority were found between 6-25 m. In the fall they were found over a wider temperature range of 5-22ºC, with bimodal peaks at about 8-10ºC and a larger one 16-20ºC. Their depth range during fall was between 1-85 m, with the majority found between about 6-35 m.

In the Narragansett Bay bottom trawl survey, pre-recruits were found at depths ranging from 10-110 feet (3-367 m) (Figure 15). In winter the few pre-recruits caught were taken at 90 feet (27 m), in summer and spring most were caught at 20-40 feet (6-12 m) and

100-110 feet (30-34 m), and in autumn most were caught at 100 feet (30 m). Pre-recruits were collected at temperatures ranging from 9-25°C. They were collected at temperatures of 10°C in winter, from 9-16°C in spring, from 11-25°C with most at 19°C in summer, and from 13-23°C with most at 20°C in autumn.

In the Hudson-Raritan estuary, pre-recruits were collected at temperatures ranging from 11-24°C, but most were taken at 16-21°C. They were also collected at depths of 15-75 ft (~5-23 m), with most at 30 ft (9 m) and 45-50 ft (14-15 m), and salinities of 20-33 ppt, with the highest catch at 30 ppt. They were found at dissolved oxygen levels of 5-10 mg/L, with most at 7-8 mg/L (Figure 16). Longfin inshore squid require oxygen concentrations greater than 4 mg/L (Howell and Simpson 1994).

The distributions and abundances of both pre-recruit and recruit squid in Long Island Sound relative to depth and bottom type, based on surveys by Gottschall *et al.* (2000), were discussed previously in Geographic Distribution: Pre-recruits.

RECRUITS

Adult longfin inshore squid inhabit the continental shelf and upper continental slope to depths of 400 m (Vecchione *et al.* 1989), but depth varies seasonally. In spring they occur at depths of 110-200 m (Serchuk and Rathjen 1974; Lange and Sissenwine 1980), in summer and autumn they inhabit inshore waters as shallow as 6-28 m (Summers 1968a, b; Serchuk and Rathjen 1974; Gosner 1978; Howell and Simpson 1994), and in winter they inhabit offshore waters to depths of 365 m (Lange 1982). They are found on mud or sand/mud substrate (Howell and Simpson 1994), at surface temperatures ranging from 9-21°C, and bottom temperatures ranging from 8-16°C (Summers 1969; Lux *et al.* 1974; Serchuck and Rathjen 1974; Lange and Sissenwine 1980; Macy 1980; Brodziak and Hendrickson 1999). Adults, like juveniles, migrate up and down in the water column in response to light conditions and the importance of off-bottom habitat is unknown.

Distributions of recruits relative to bottom water temperature, depth, and salinity based on spring and fall NEFSC bottom trawl surveys are shown in Figure 17. During the spring, recruits were found in a temperature range of 4-21ºC, with the majority at about 7-13ºC. They were found over a depth range of 1-400 m, and a salinity range of about 30-36, with most found at 34-35 ppt. During the fall the pre-recruits were found over a wider temperature range of 6-28ºC, with a peak between about 10-15ºC. Their depth range during that season was between 1-400 m, with the majority found above about 70 m. Their salinity range was between 30-37 ppt, with most at 32-33 ppt.

Around Massachusetts in the spring, the recruits were found at a temperature range of 6-17ºC, with most at 10-13ºC (Figure 18). Their depth range was from about 1 m to approximately 50 m, with the majority found between 6-20 m. As with the pre-recruits, the recruits in the fall were found over a wider temperature range of 5-22ºC, with bimodal peaks at about 8-10ºC and a larger one 16-20ºC. Their depth distribution during fall was similar to that of the pre-recruits (range of 1-85 m, with the majority found between about 6-35 m).

In Narragansett Bay, recruits were found at depths ranging from 10 to 120 ft (3-37 m) (Figure 19). In winter the few recruits caught were taken at 90-100 ft (27-30 m). In summer and spring they were taken at depths ranging from 10-120 ft (3-37 m). In spring, about 40% were caught at 100-110 feet (30-34 m), with another 20% found at 70 ft (21 m), while in summer, the majority were caught at 100-110 ft. In autumn, most were caught at 90-100 feet (27-30 m). Recruits were taken at temperatures ranging from 7-25°C (Figure 19). Seasonally they were collected at 7-10°C in winter, with almost all caught at 10°C; at 9-16°C in spring, with most at 9-13°C; at 9-25°C in summer, with most at 18-21°C; and at 11-23°C in autumn, with a peak at 15°C.

In the Hudson-Raritan estuary, recruits were collected at temperatures ranging from 9-24°C, but most were at 16-17°C (Figure 20). They were also collected at depths of 10-75 ft (~5-23 m), with most at 50 and 60 ft (~15-18 m), and salinities of 20-33 ppt, with the highest catch at 30 ppt. They were found at dissolved oxygen levels of 5-11 mg/L, with most at 7-8 mg/L. Longfin inshore squid require oxygen concentrations greater than 4 mg/L (Howell and Simpson 1994).

RESEARCH NEEDS

- Human impacts may be significant on sandy bottom habitats used by inshore longfin squid for their eggs. However, little information is available on egg habitat locations, seasonal occurrence, sediment characteristics, and depth or water chemistry. This type of information might be useful for designating marine reserves, seasonal closed areas, and other measures.
- Additional information about use of off-bottom habitat and vertical distribution of inshore longfin squid in the water column is needed for stock assessment and management. This is because a substantial portion of the inshore longfin squid stock may be unavailable to bottom trawl surveys that are used to track abundance.
- Information about distribution of inshore longfin squid in deepwater off the continental shelf and south of Cape Hatteras would be useful because

bottom trawl surveys do not reach these areas and an unknown portion of the stock is resident there (NEFSC 2002).

- More information on growth rates and maturity are needed from geographically and temporally diverse studies.
- The commercially exploited population from Cape Hatteras to Georges Bank, inshore and offshore and in all seasons, is considered a single stock unit. More information is needed on stock structure, including gene flow and levels of genetic differentiation among geographic areas.

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Table 1. Summary of life history and habitat characteristics for longfin inshore squid, based on the pertinent literature. This table is essentially the same as that used in the first longfin inshore squid EFH source document (Cargnelli *et al*. 1999); more recent studies have not been added.

Life Stage	Size and Growth	Habitat	Substrate	Temperature	Salinity
Eggs [1]	Incubation time varies with temperature: 26.7 d at 12-18°C, 18.5 d at 15.5-21.3°C, and 10.7 d at 15.5-23.0°C.	Eggs generally in shallow waters, < 50 m and near shore.	Egg masses are commonly found on sandy/mud bottom; usually attached to rocks/boulders, pilings, or algae such as *Fucus*, *Ulva lactuca*, *Laminaria* and *Porphyra* sp.	Eggs found in waters 10-23°C; usually > 8°C. Optimal development at 12°C.	Found at 30-32 ppt.
Larvae [2]	Paralarvae range in size from 1.4-15 mm ML (mantle length). Growth rates slower for winter-hatched animals than spring-hatched.	Found in coastal, surface waters in spring, summer, and fall. Hatchlings found in surface waters day and night. Move deeper in water column as they grow larger.		Found at 10-26°C (at lower temperatures found at higher salinities).	Found at 31.5-34.0 ppt.
Juveniles [3]	Size ranges from approximately 15 mm - 8 cm. At 6-8 cm sexual size dimorphism is evident, before offshore migrations occur. Growth rates of young-of-the-year are 12-38 mm/month.	Inhabit upper 10 m at depths of 50-100 m on continental shelf. Found in coastal inshore waters in spring/fall, offshore in winter. Migrate to surface at night. Ontogenetic descent: at 45 mm, chromatophores are concentrated on dorsal rather than ventral surface, indicating a change from inhabiting surface waters to demersal lifestyle.		Found at 10-26°C (at lower temperatures found at higher salinities). Juveniles prefer warmer bottom temperatures and shallower depths in fall than adults.	Found at 31.5-34.0 ppt.
Adults [4]	Smallest size at maturity 8 cm ML; most are > 10 cm ML. Males grow faster than females and attain larger sizes; larger sizes at higher latitudes. Growth is rapid, faster in warm months (1.5-2.0 cm/month) than in cold months (0.4-0.6 cm/month). Life span is < 1 year. Maximum size and age are ~50 cm ML, 3 yrs.	Range from Newfoundland south to Cape Hatteras, on continental shelf and upper slope. Most abundant from Gulf of Maine to Hatteras. March-October: inshore, shallow waters up to 180 m. Winter: offshore deeper waters, up to 400 m on shelf edge. Most abundant at bottom during the day; move upwards at night. Generally found at greater depths and cooler bottom temperatures in the fall than juveniles. Importance of off-bottom habitat poorly understood.	Mud or sandy mud.	Found at surface temperatures ranging from 9-21°C and bottom temperatures ranging from 8-16°C.	

[1] Bigelow (1924); McMahon and Summers (1971); Arnold *et al.* (1974); Griswold and Prezioso (1981); Lange (1982); Summers (1983); Dawe *et al.* (1990).

[2] McMahon and Summers (1971); McConathy *et al.* (1980); Vecchione (1981); Nesis (1982); Vovk (1983); Young and Harman (1988).

[3] Summers (1968a, b); Mercer (1969); Macy (1980); Vovk and Khvichiya (1980); Vecchione (1981); Young and Harman (1988); Brodziak and Henderson (1999).

[4] Haefner (1964); Summers (1968a, b, 1969, 1971, 1983); Rathjen (1973); Lux *et al.* (1974); Serchuk and Rathjen (1974); Cohen (1976); Mesnil (1977); Gosner (1978); Sissenwine and Bowman (1978); Lange (1980, 1982); Lange and Sissenwine (1980); Macy (1980); Nesis (1982); Vecchione *et al.* (1989); Dawe *et al*. (1990); Howell and Simpson (1994); Brodziak and Macy (1996); Brodziak and Henderson (1999).

Table 1. Cont'd.

Life Stage	Prey	Predators	Spawning	Notes
Eggs [1]	N/A		Most eggs are spawned in May, hatching occurs in July. Fecundity ranges from 950-15,900 eggs per female.	Eggs are demersal. Enclosed in a gelatinous capsule containing up to 200 eggs. Each female lays 20-30 capsules. Laid in masses made up of hundreds of egg capsules from different females.
Larvae [2]	Primary prey are copepods.			"Paralarvae" defined as stage after hatching when cephalopods are pelagic. Tentacles are non-functional at ≤ 15 mm.
Juveniles [3]	Primary prey varies with size: < 4.0 cm: plankton, copepods; 4.1-6.0 cm: euphausiids, arrow worms; 6.1-10.0 cm: crabs, polychaetes, shrimp. Cannibalism observed in specimens larger than 5 cm ML (small *Illex illecebrosus* were found in 49 of 322 *Loligo* stomachs).	Many pelagic and demersal fish species as well as marine mammals and birds.		Changes in habitat as the squid grows are indicated by changes in the diet.
Adults [4]	Fish prey includes silver hake, mackerel, herring, menhaden, sand lance, bay anchovy, menhaden, weakfish, and silversides. Invertebrate prey includes crustaceans (*Crangon, Palaeomonetes* sp.) and squid. 15 cm adults can eat fish up to half their mantle length. At 16-25 cm, consume more fish and less crustaceans as growth increases; > 25 cm, more squid than fish eaten; and > 30 cm, almost exclusively squid.	Predators include many fishes (bluefish, sea bass, mackerel, cod, haddock, pollock, hakes, sea raven, goosefish, flounder, dogfish, angel sharks, skates), pilot whale (*Globicephala melas*) and common dolphin (*Delphinus delphis*), and diving birds.	Spawning occurs on Scotian Shelf, Georges Bank, Gulf of Maine, and from Nantucket Shoals to Cape Hatteras in shallow waters, 10-90 m, from April-November (New England: May-August; Bay of Fundy: Aug-September). Georges Bank: two broods - early spring and late summer. Spring spawn: hatch in June, mature over winter. Summer spawn: hatch in fall, mature in 2nd winter. Mating occurs during inshore migration in spring. Mortality occurs after first spawning.	*Loligo* form schools according to size class prior to feeding. Oxygen requirement > 4 ml/l. Larger individuals migrate earlier (April-May) than smaller ones.

[1] Haefner (1959); Summers (1971); Vovk (1972b), Arnold *et al.* (1974); Gosner (1978); Griswold and Prezioso (1981); Lange (1982); Nesis (1982); Lange and Sissenwine (1983).

[2] Vecchione (1981); Vovk (1983); Young and Harman (1988).

[3] Vovk (1972b, 1985); Tibbetts (1977); Whitaker (1978); Vinogradov and Noskov (1979); Vovk and Khvichiya (1980); Vecchione (1981).

[4] Stevenson (1934); Summers (1969, 1971); Vovk (1972a, 1985); Rathjen (1973); Maurer (1975); Cohen (1976); Langton and Bowman (1977); Mesnil (1977); Tibbetts (1977); Gosner (1978); Vinogradov and Noskov (1979); Lange (1980, 1982); Lange and Sissenwine (1980, 1983); Macy (1980); Griswold and Prezioso (1981); Kier (1982); Summers (1983); Maurer and Bowman (1985); Dawe *et al.* (1990); Waring *et al.* (1990); Overholtz and Waring (1991); Howell and Simpson (1994); Brodziak and Macy (1996); Gannon *et al.* (1997).

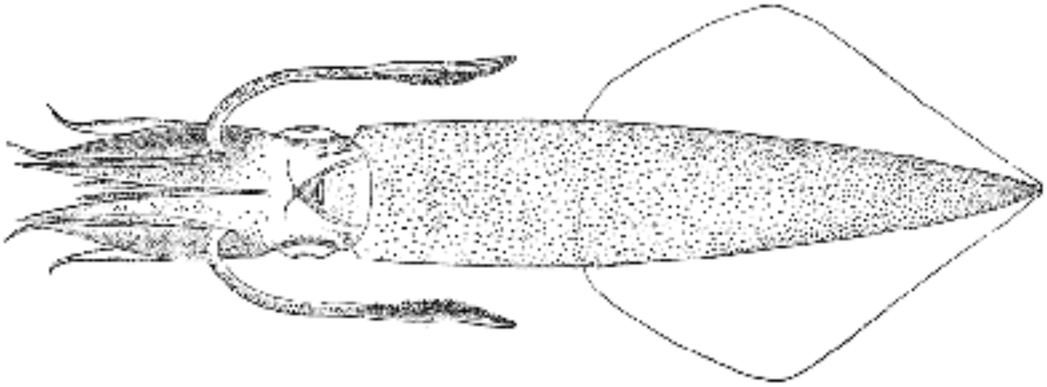

Figure 1. The longfin inshore squid, *Loligo pealeii* (from Goode 1884).

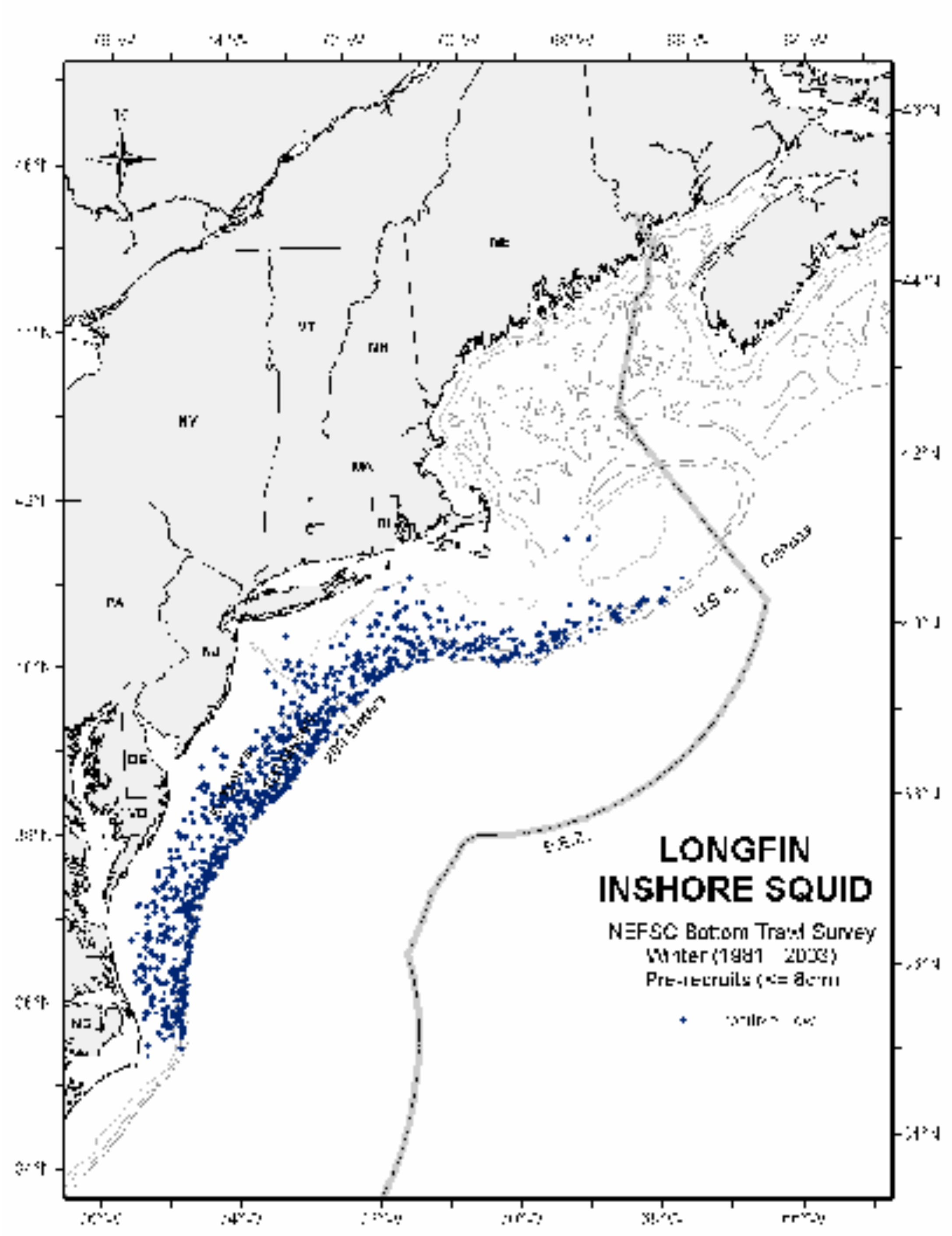

Figure 2. Seasonal distributions and abundances of pre-recruit longfin inshore squid collected during NEFSC bottom trawl surveys.
Based on NEFSC winter bottom trawl surveys (1981-2003, all years combined). Distributions are displayed as presence only.

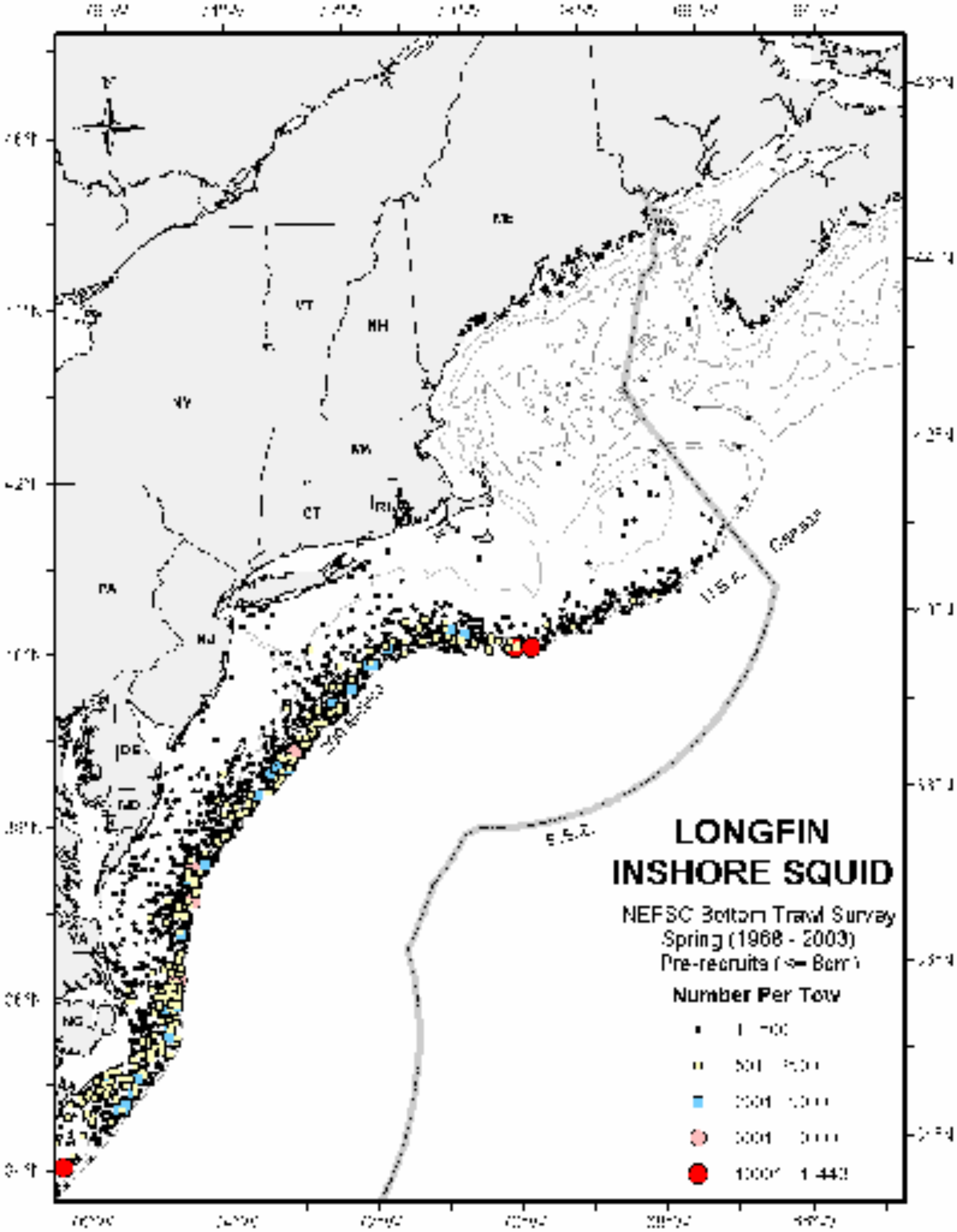

Figure 2. Cont’d.
Based on NEFSC spring bottom trawl surveys (1968-2003, all years combined). Survey stations where pre-recruits were not found are not shown.

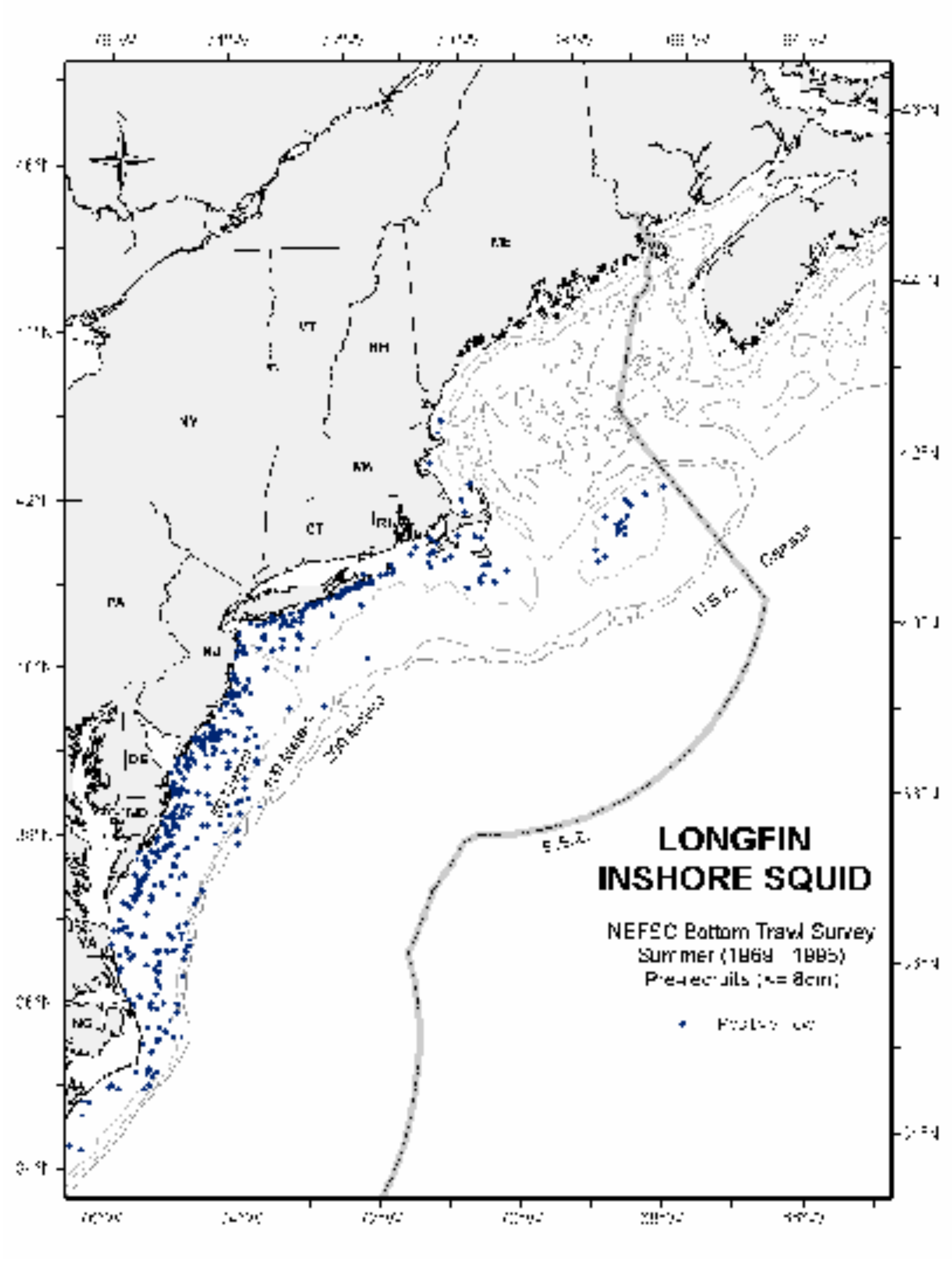

Figure 2. Cont'd.
Based on NEFSC summer bottom trawl surveys (1969-1995, all years combined). Distributions are displayed as presence only.

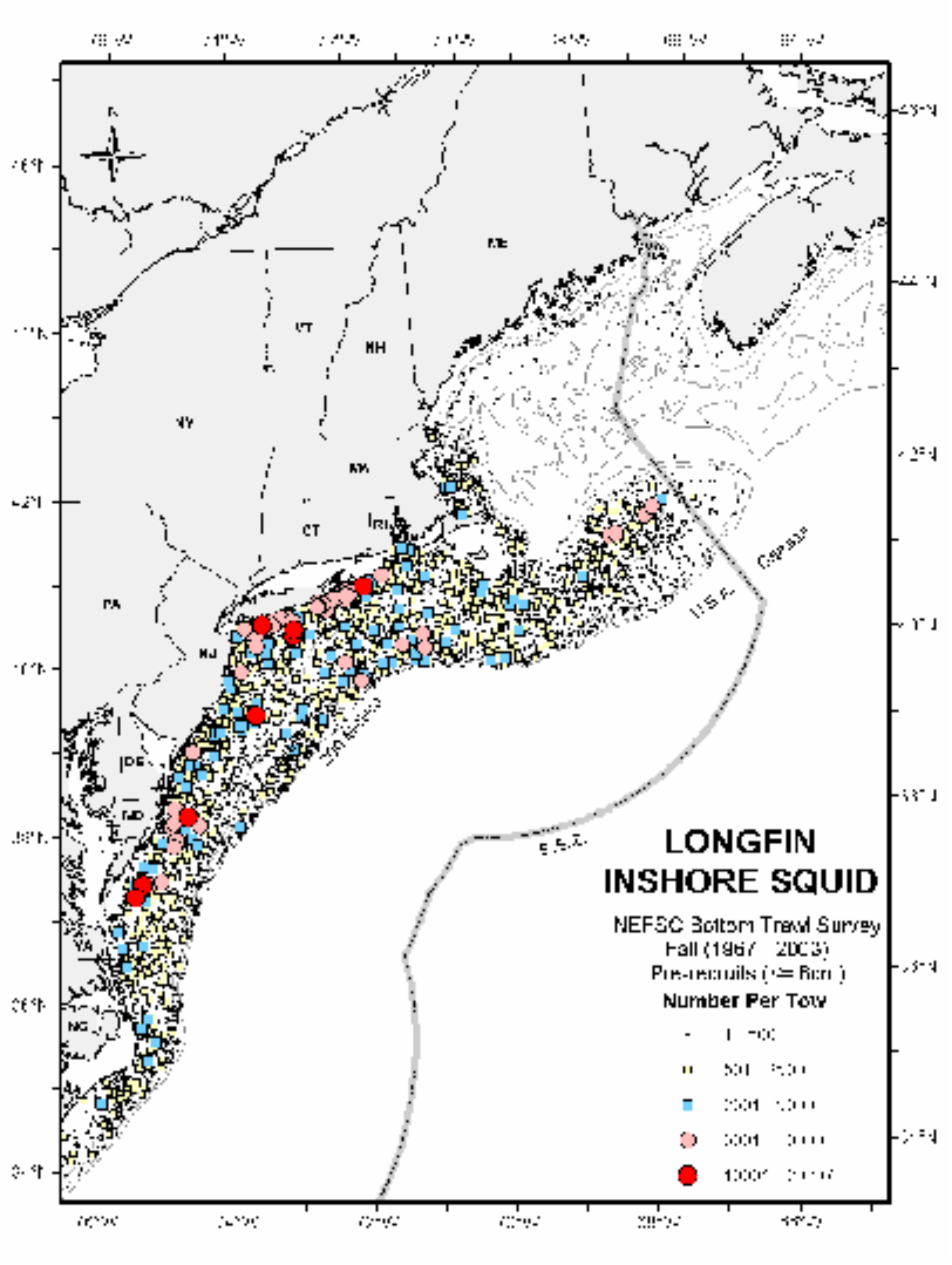

Figure 2. Cont'd.
Based on NEFSC fall bottom trawl surveys (1967-2003, all years combined). Survey stations where pre-recruits were not found are not shown.

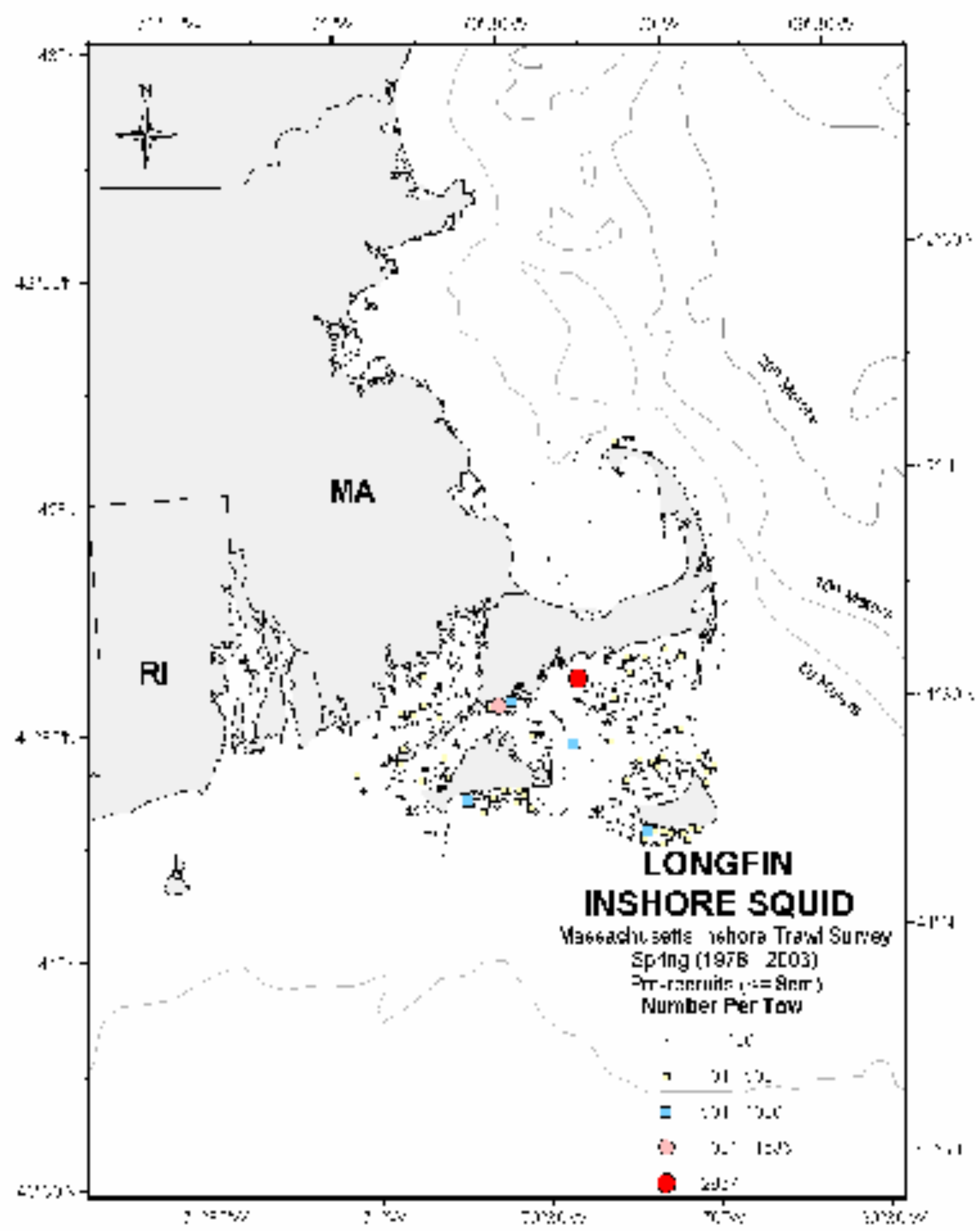

Figure 3. Distribution and abundance of pre-recruit longfin inshore squid in Massachusetts coastal waters. Based on spring Massachusetts inshore bottom trawl surveys (1978-2003, all years combined). Survey stations where pre-recruits were not found are not shown.

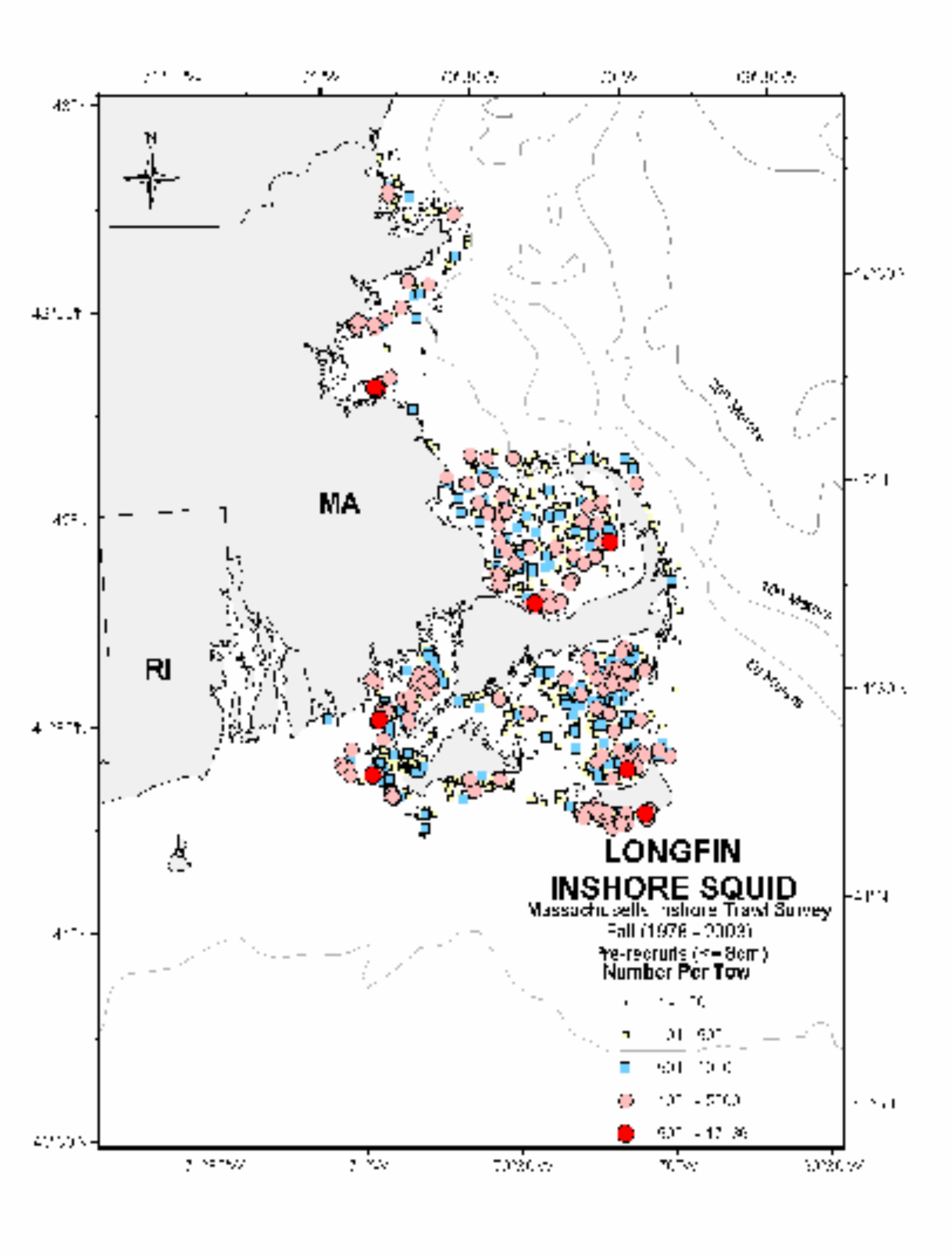

Figure 3. Cont'd.
Based on fall Massachusetts inshore bottom trawl surveys (1978-2003, all years combined). Survey stations where pre-recruits were not found are not shown.

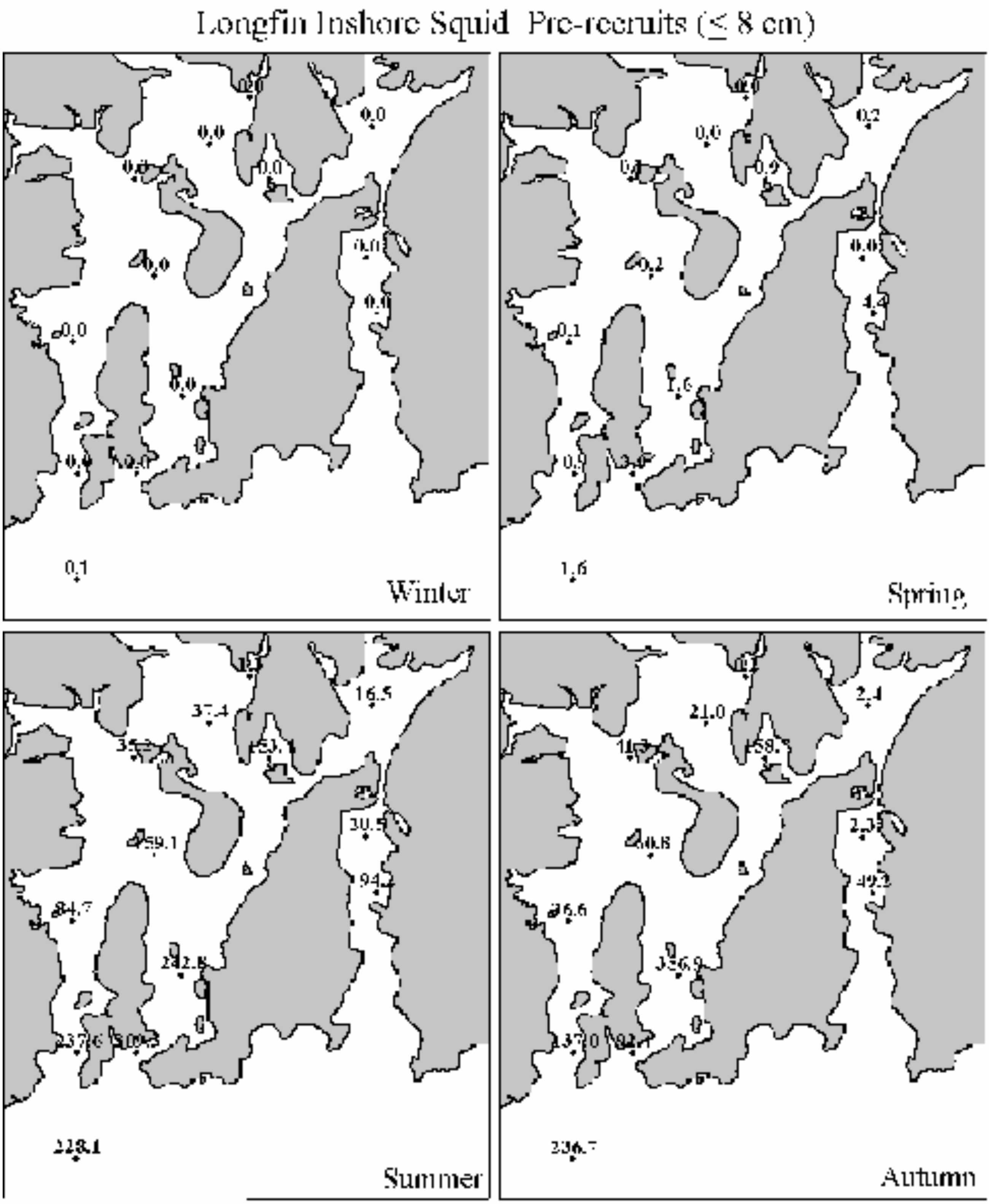

Figure 4. Seasonal distribution and abundance of longfin inshore squid pre-recruits in Narragansett Bay. Based upon the 1990-1996 Rhode Island bottom trawl surveys. The numbers shown at each station are the average catch per tow rounded to one decimal place [see Reid *et al.* (1999) for details].

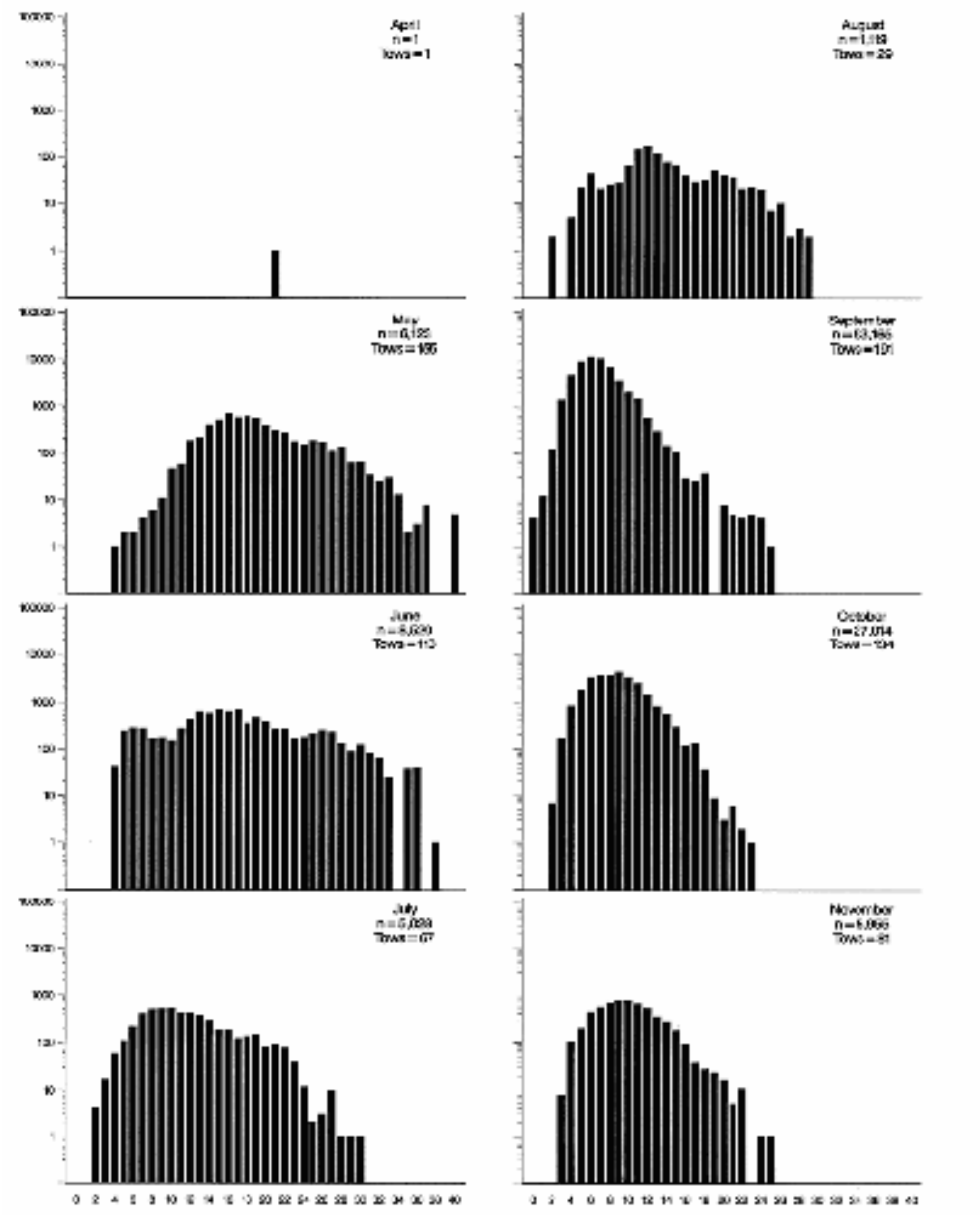

Figure 5. Monthly $\log_{10}$ length frequencies (cm) of longfin inshore squid collected in Long Island Sound, based on 106,925 squid taken in 771 tows between 1987 and 1994. Source: Gottschall *et al.* (2000).

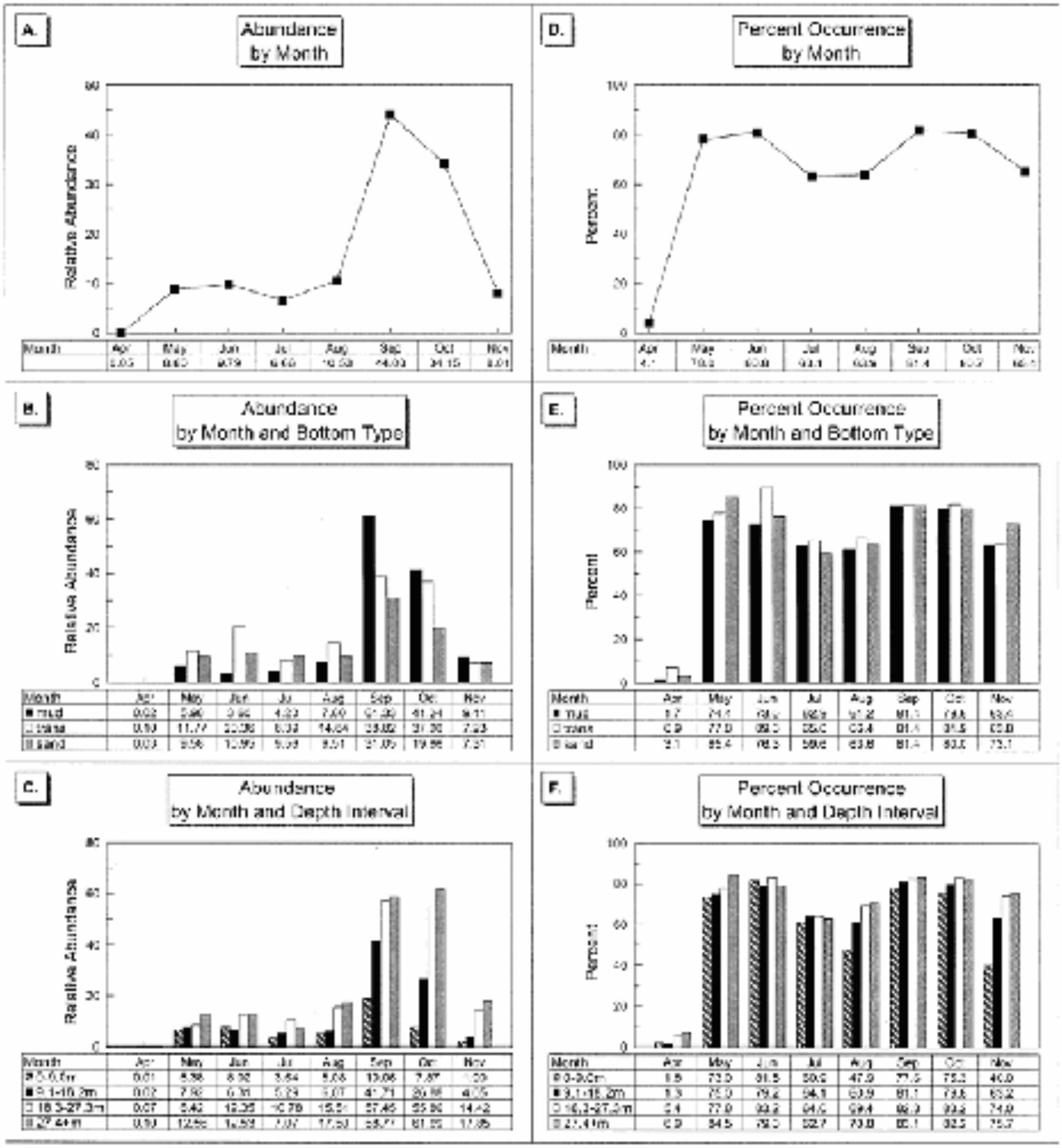

Figure 6. Relative abundance (geometric mean catch/tow) catch/tow and percent occurrence (proportion of samples in which at least one individual was observed) for longfin inshore squid in Long Island Sound, by month, month and bottom type, and month and depth interval. Source: Gottschall *et al.* (2000).

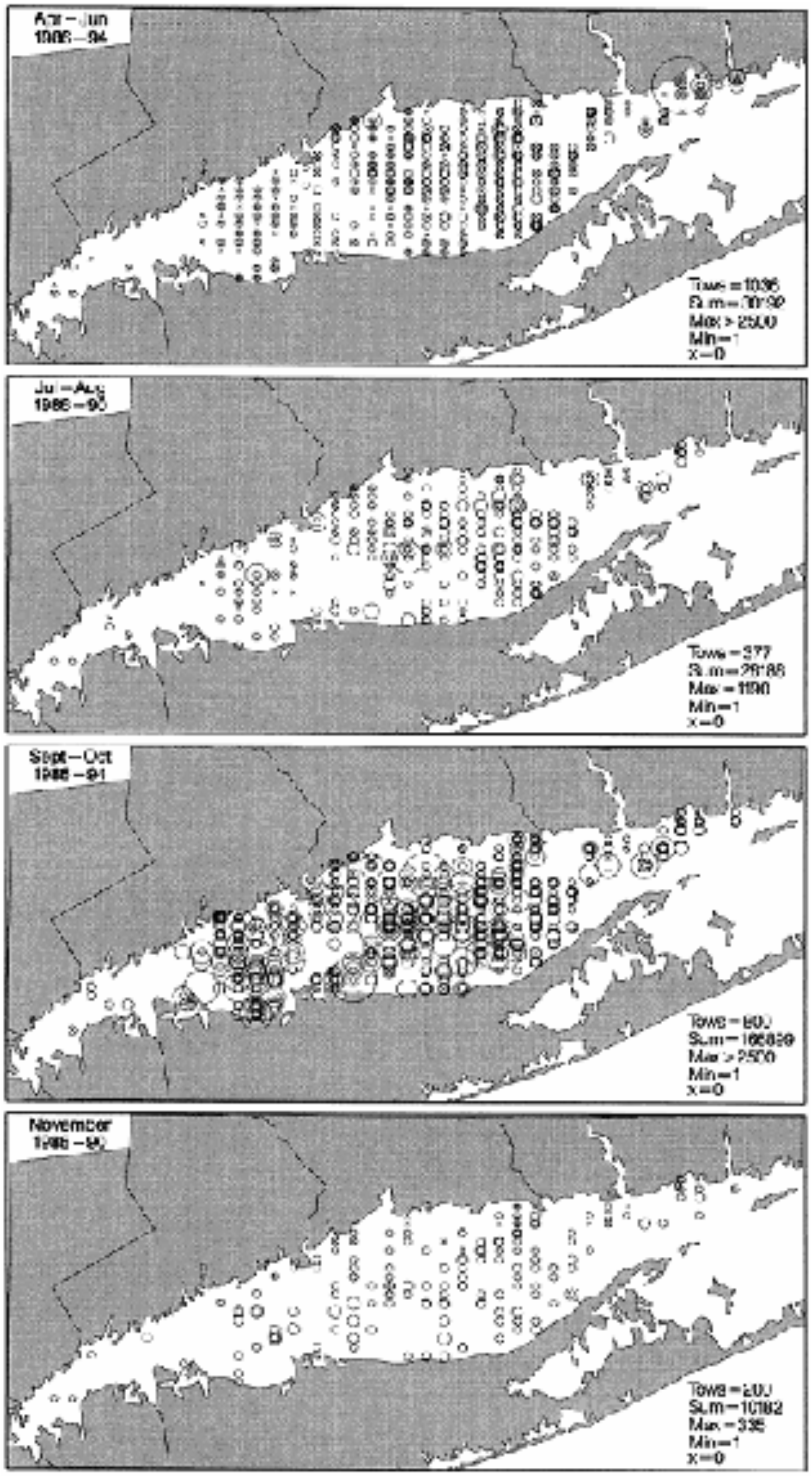

Figure 7. Distribution and abundances of longfin inshore squid in Long Island Sound, based on the finfish surveys of the Connecticut Fisheries Division, 1986-1994. Source: Gottschall *et al.* (2000). Circle diameter is proportional to the number of squid caught, and is scaled to the maximum catch (indicated by “max=” or “max>”); the largest circle represents a tow with a catch of > 2,500 squid. Collections were made with a 14 m otter trawl at about 40 stations chosen by stratified random design.

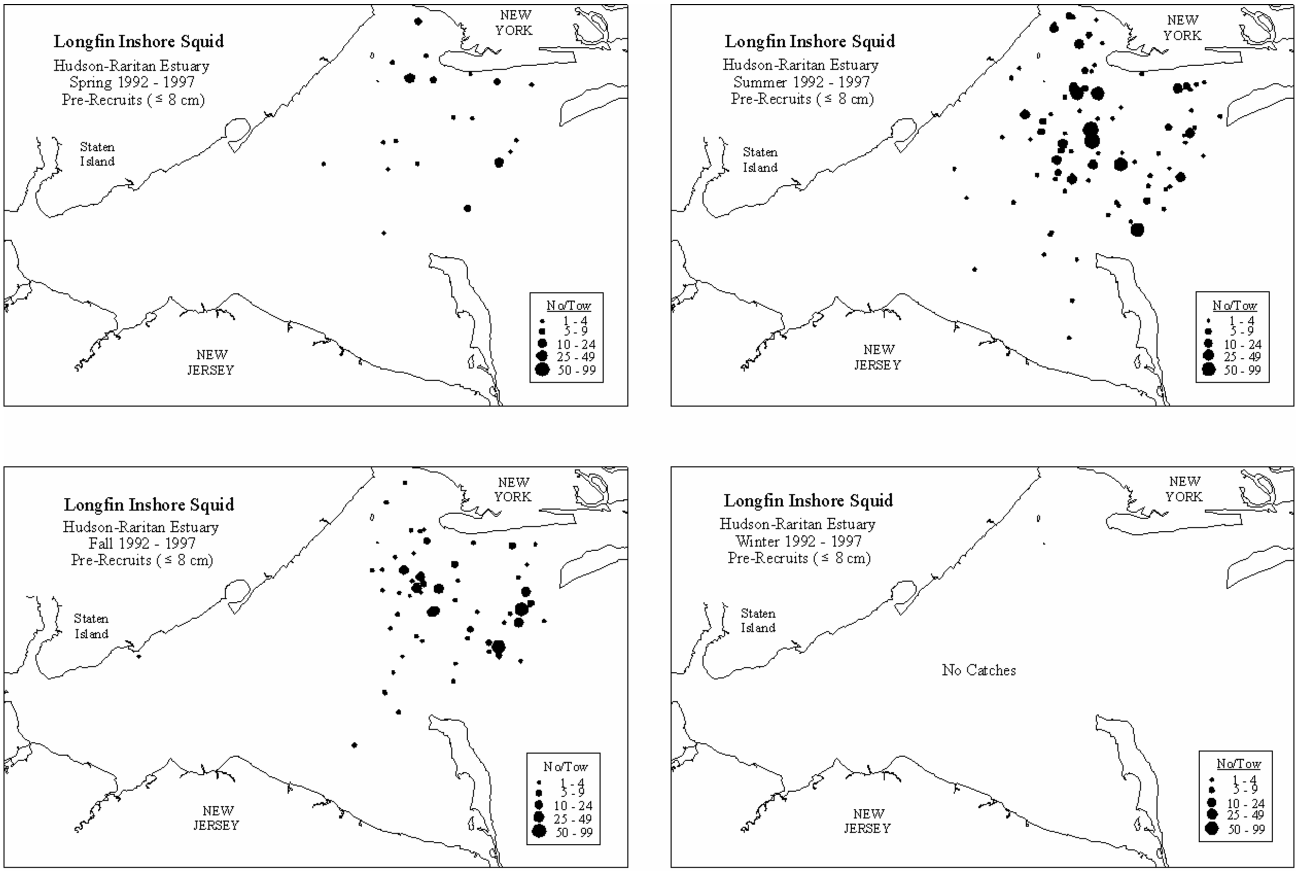

Figure 8. Seasonal distribution and abundance of longfin inshore squid pre-recruits collected in the Hudson-Raritan estuary.
Based on NEFSC Hudson-Raritan trawl surveys, January 1992 – June 1997 [see Reid *et al.* (1999) for details].

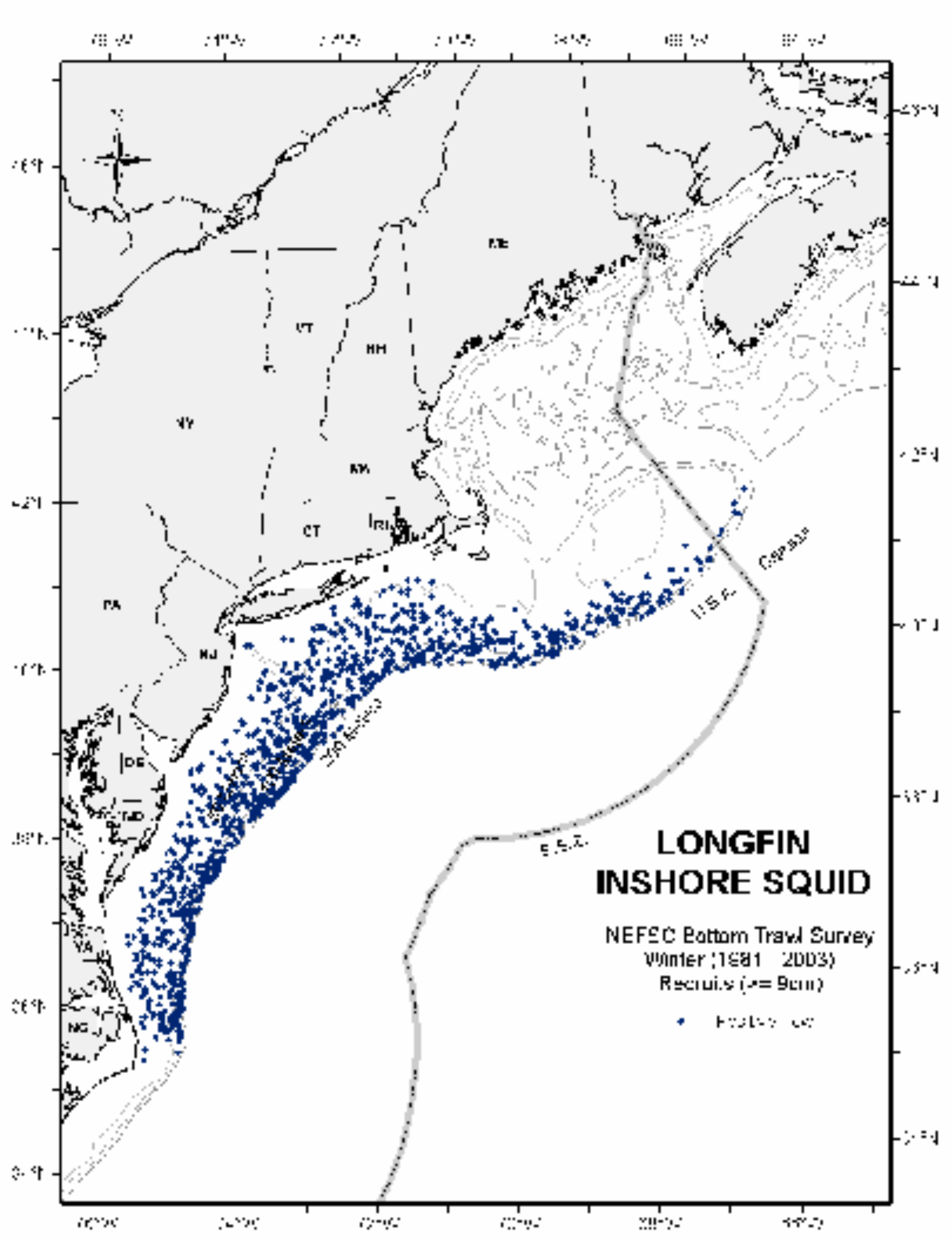

Figure 9. Seasonal distributions and abundances of recruit longfin inshore squid collected during NEFSC bottom trawl surveys.
Based on NEFSC winter bottom trawl surveys (1981-2003, all years combined). Distributions are displayed as presence only.

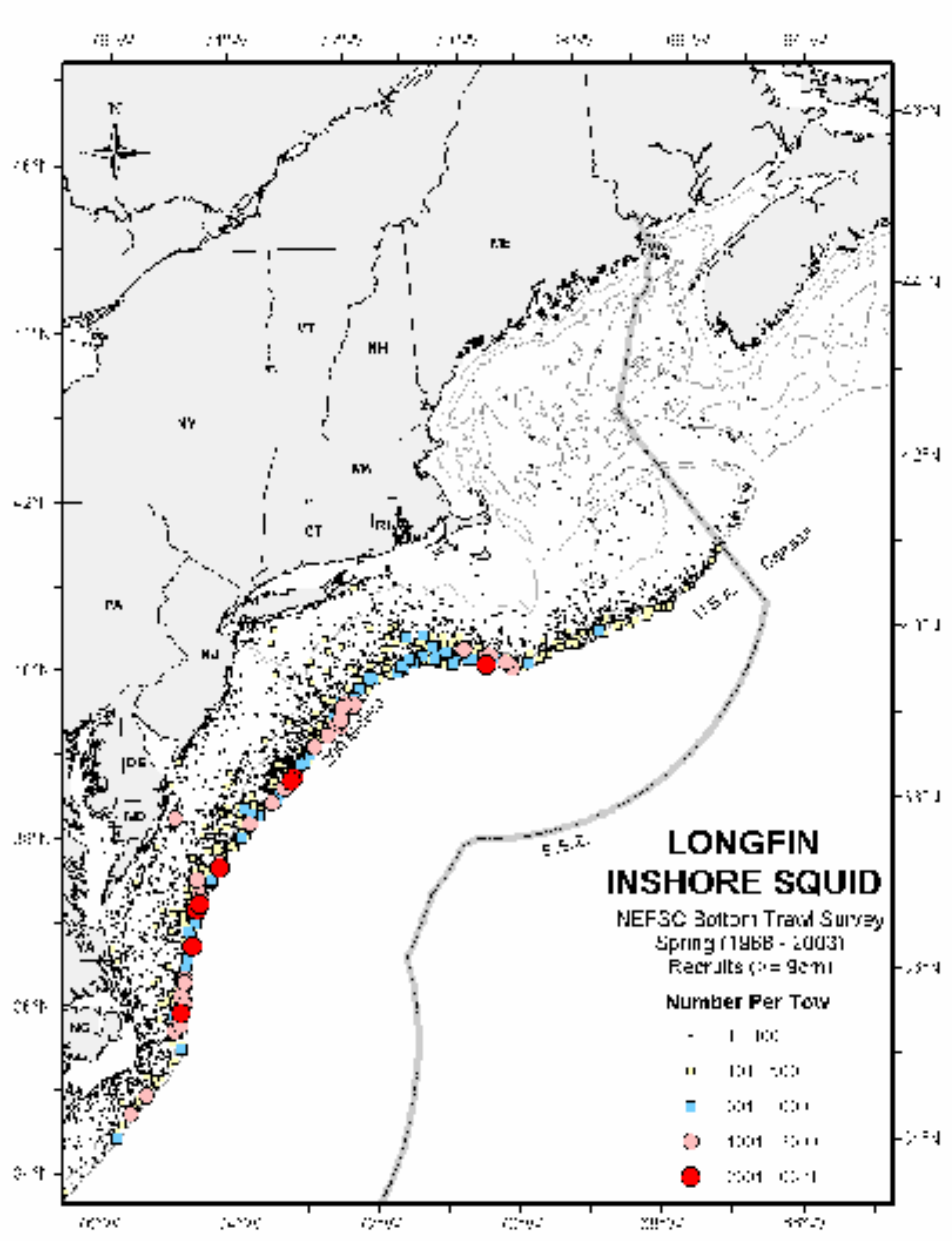

Figure . Cont'd.
Based on NEFSC spring bottom trawl surveys (1968-2003, all years combined). Survey stations where recruits were not found are not shown.

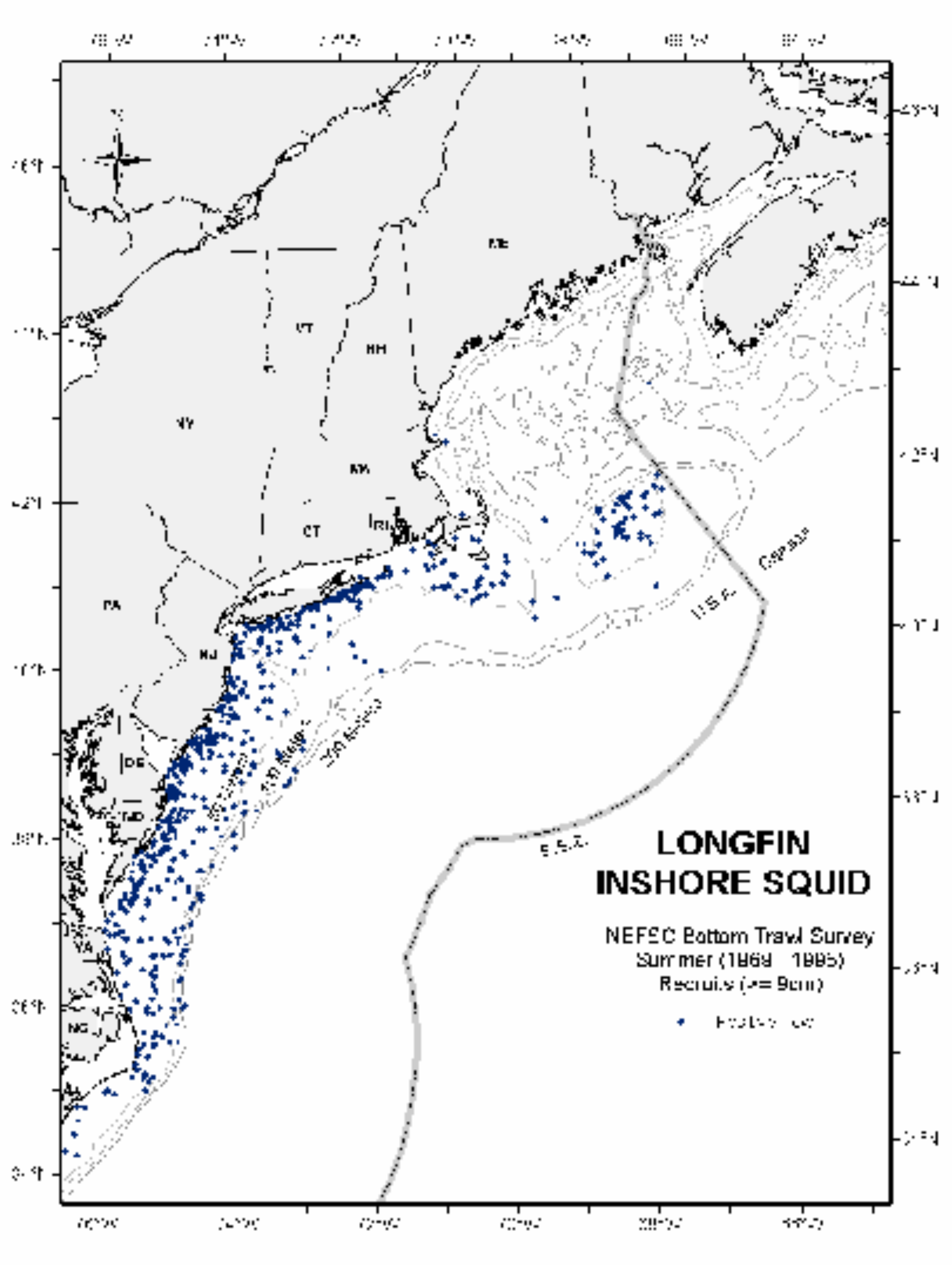

Figure 9. Cont'd.
Based on NEFSC summer bottom trawl surveys (1969-1995, all years combined). Distributions are displayed as presence only.

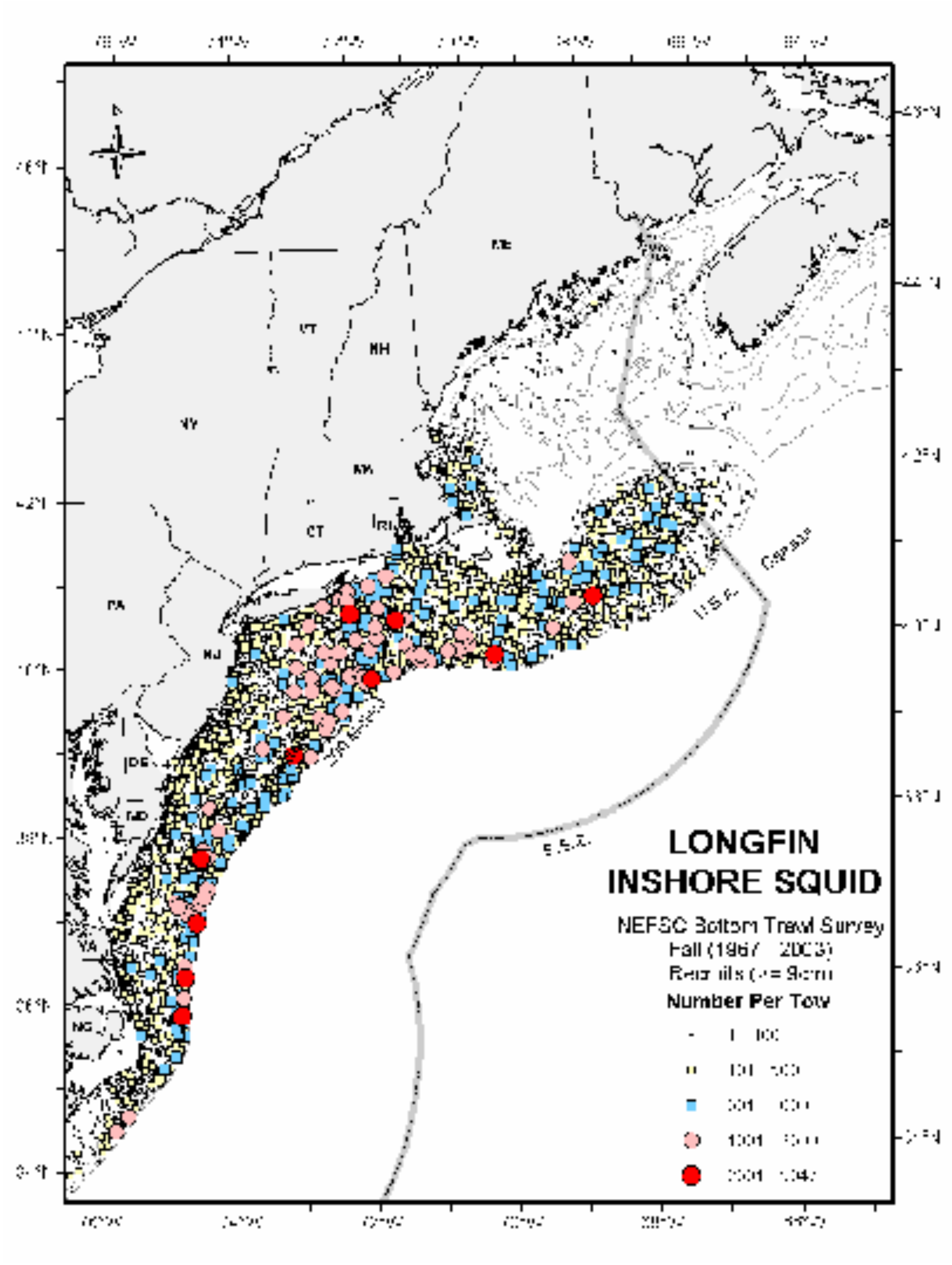

Figure 9. Cont'd.
Based on NEFSC fall bottom trawl surveys (1967-2003, all years combined). Survey stations where recruits were not found are not shown.

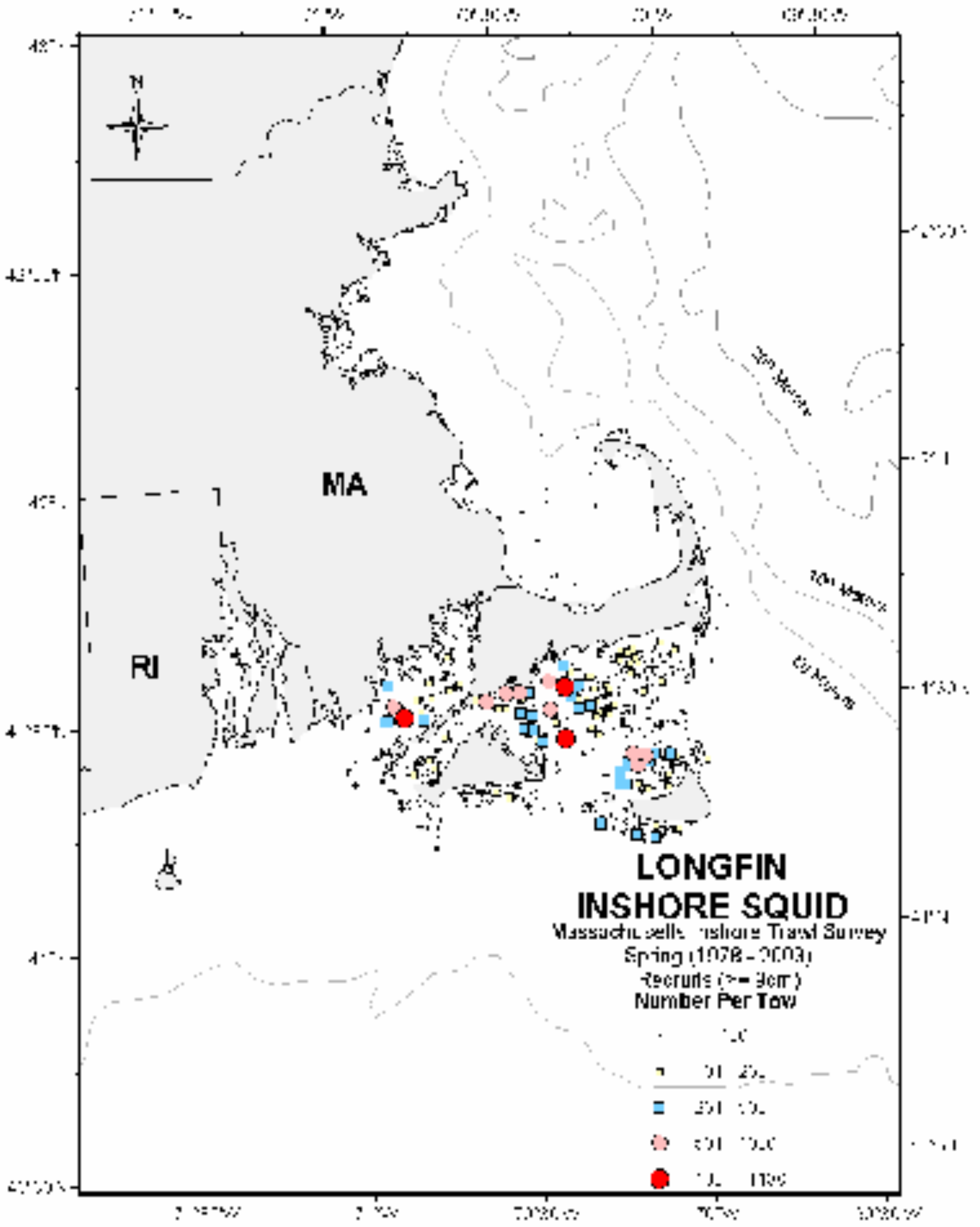

Figure 10. Seasonal distributions and abundances of recruit longfin inshore squid in Massachusetts coastal waters. Based spring Massachusetts inshore bottom trawl surveys (1978-2003, all years combined). Survey stations where recruits were not found are not shown.

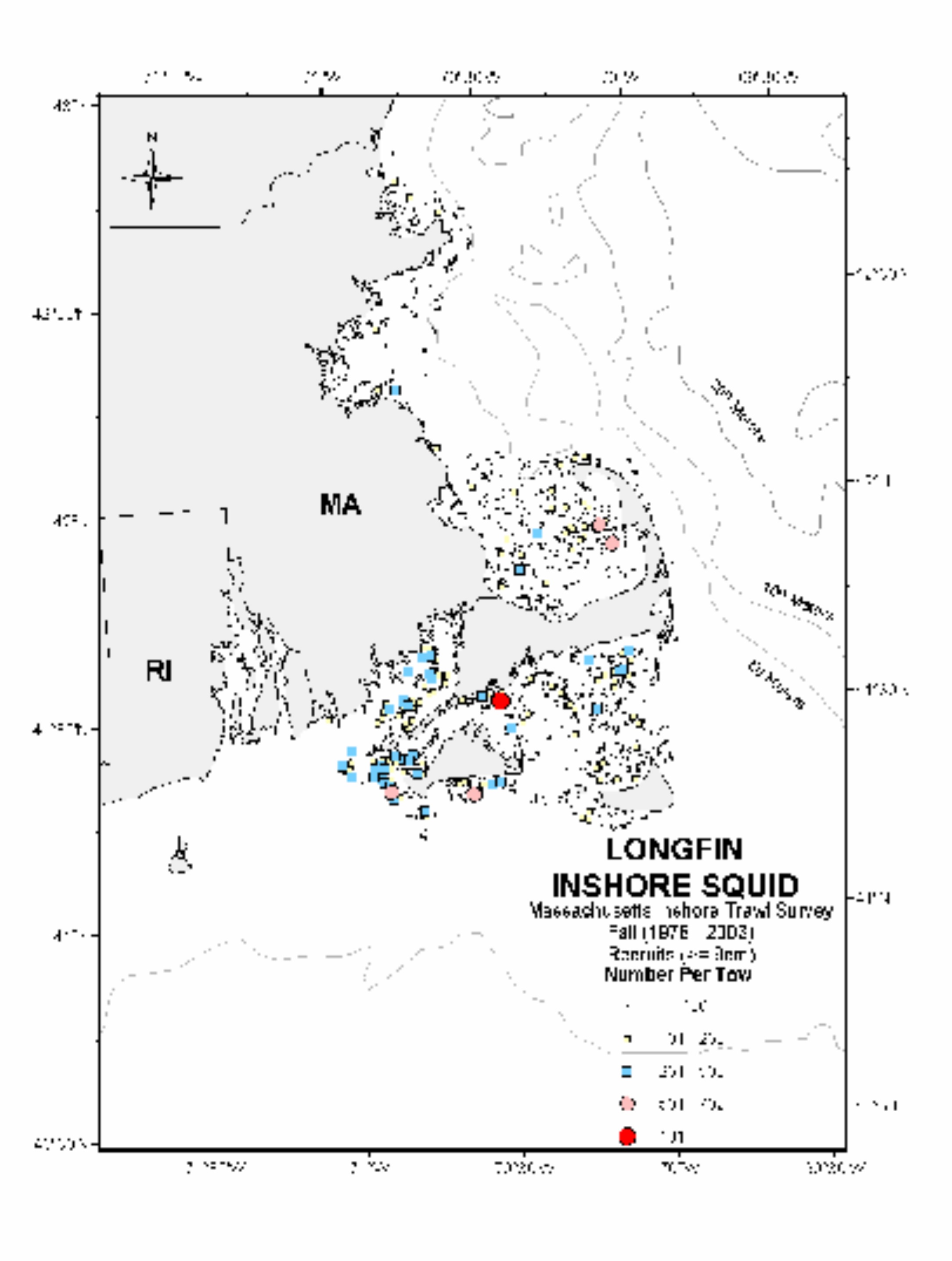

Figure 10. Cont'd.
Based on fall Massachusetts inshore bottom trawl surveys (1978-2003, all years combined). Survey stations where recruits were not found are not shown.

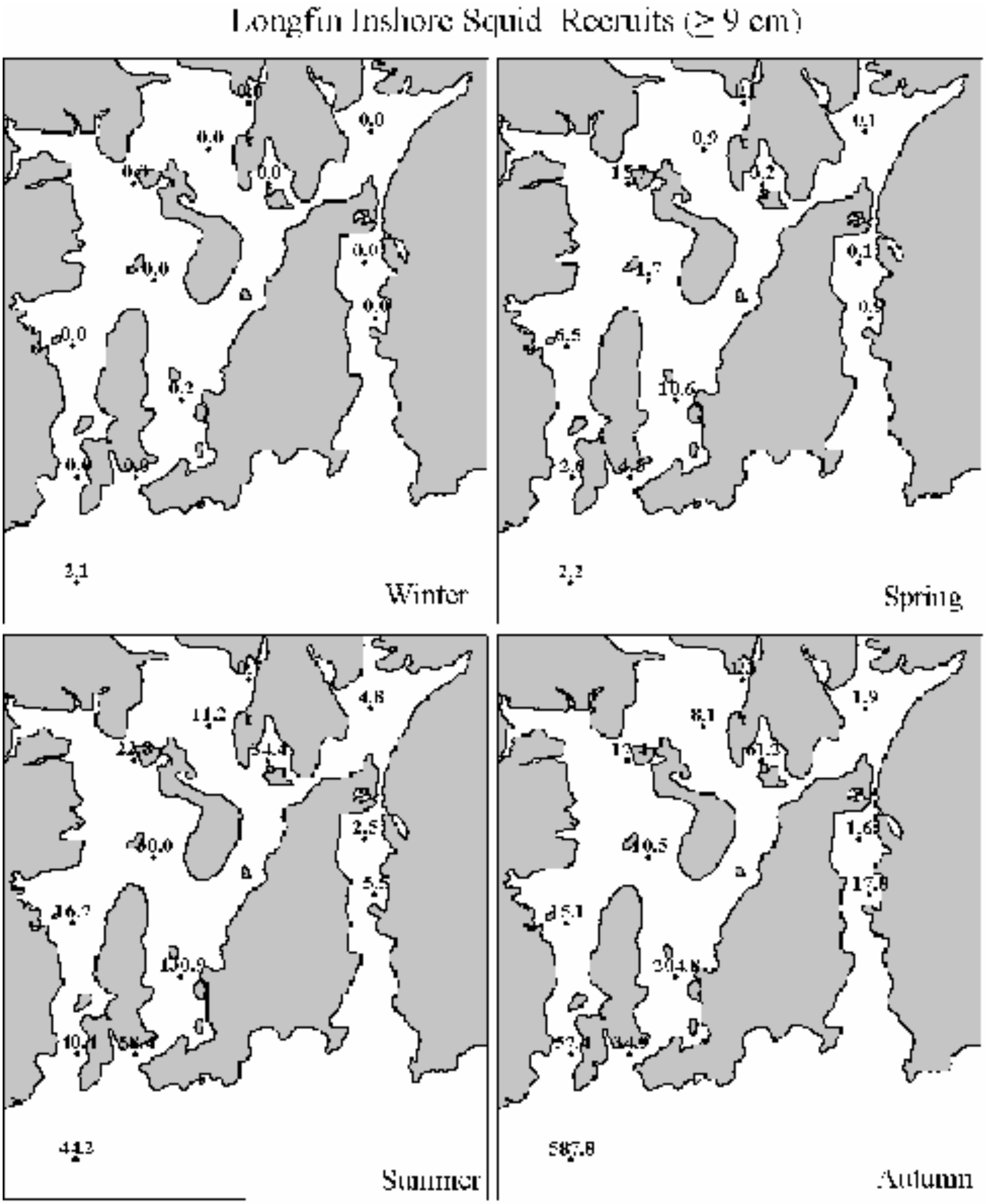

Figure 11. Seasonal distribution and abundance of longfin inshore squid recruits in Narragansett Bay.
Based upon the 1990-1996 Rhode Island bottom trawl surveys. The numbers shown at each station are the average catch per tow rounded to one decimal place.

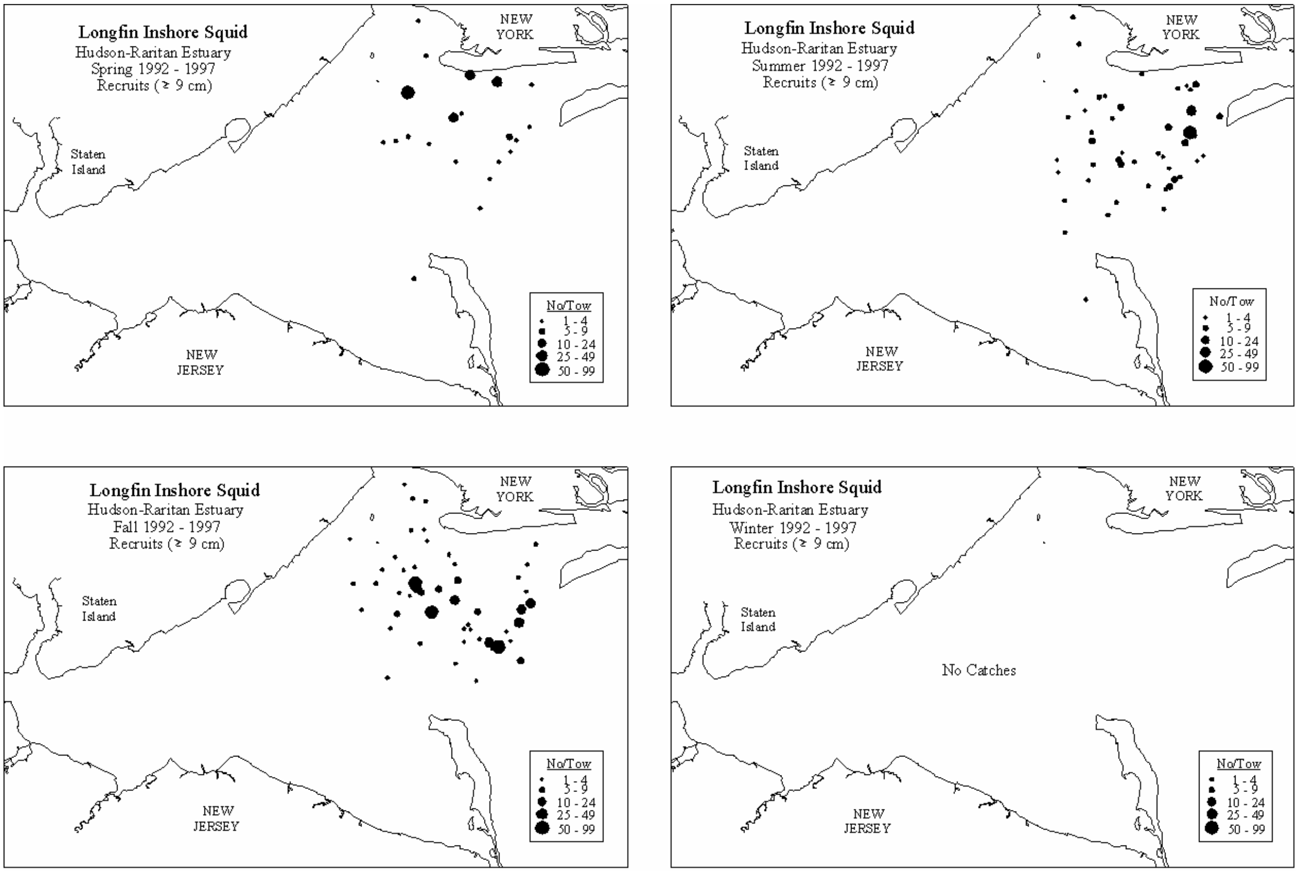

Figure 12. Seasonal distribution and abundance of longfin inshore squid recruits collected in the Hudson-Raritan estuary.
Based on NEFSC Hudson-Raritan trawl surveys, January 1992 – June 1997.

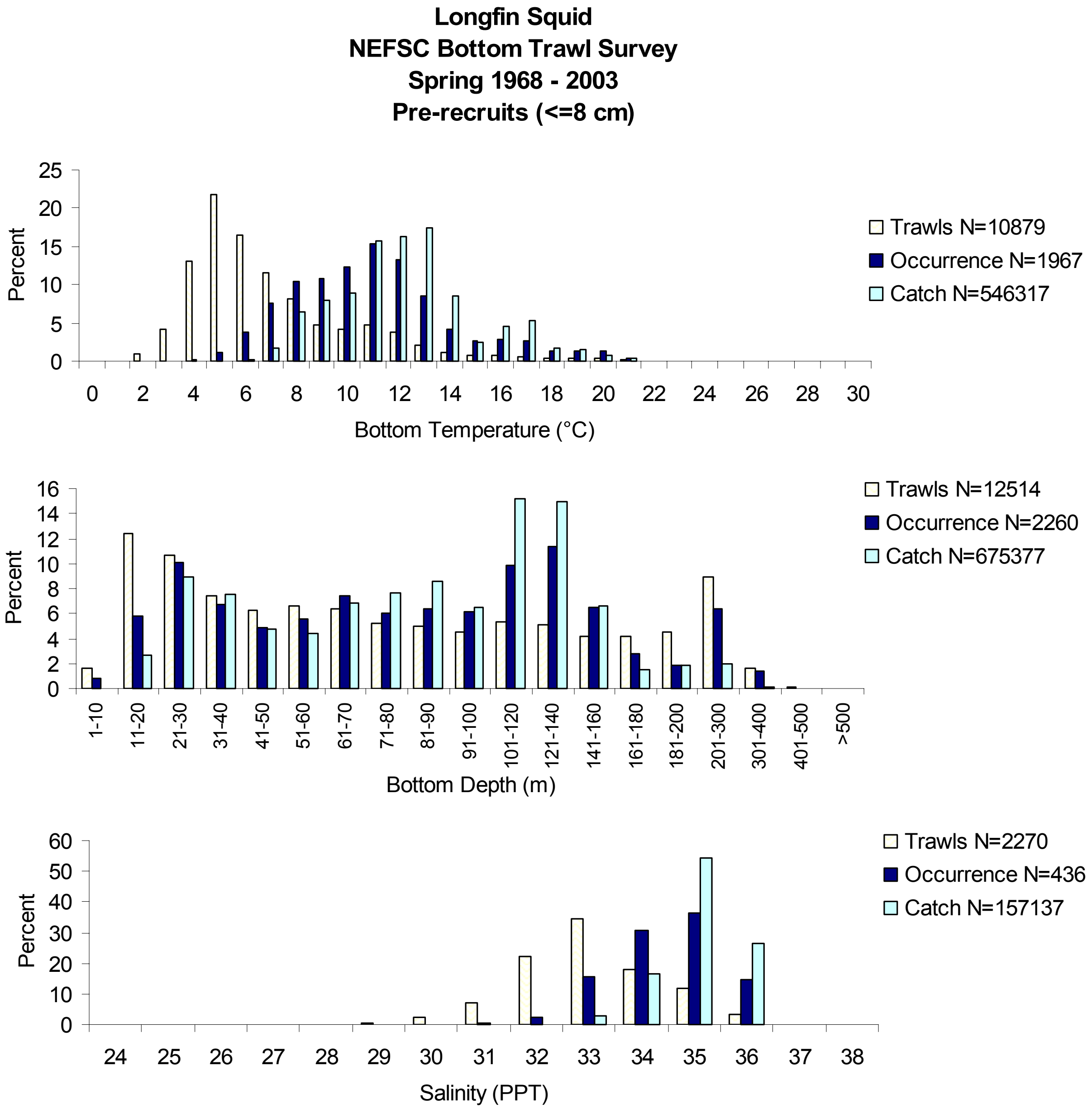

Figure 13. Distributions of pre-recruit longfin inshore squid and trawls from NEFSC bottom trawl surveys relative to bottom water temperature, depth, and salinity.
Based on NEFSC spring bottom trawl surveys (temperature and depth: 1968-2003, all years combined; salinity: 1991-2003, all years combined). Light bars show the distribution of all the trawls, dark bars show the distribution of all trawls in which longfin inshore squid occurred and medium bars show, within each interval, the percentage of the total number of longfin inshore squid caught. Note that the bottom depth interval changes with increasing depth.

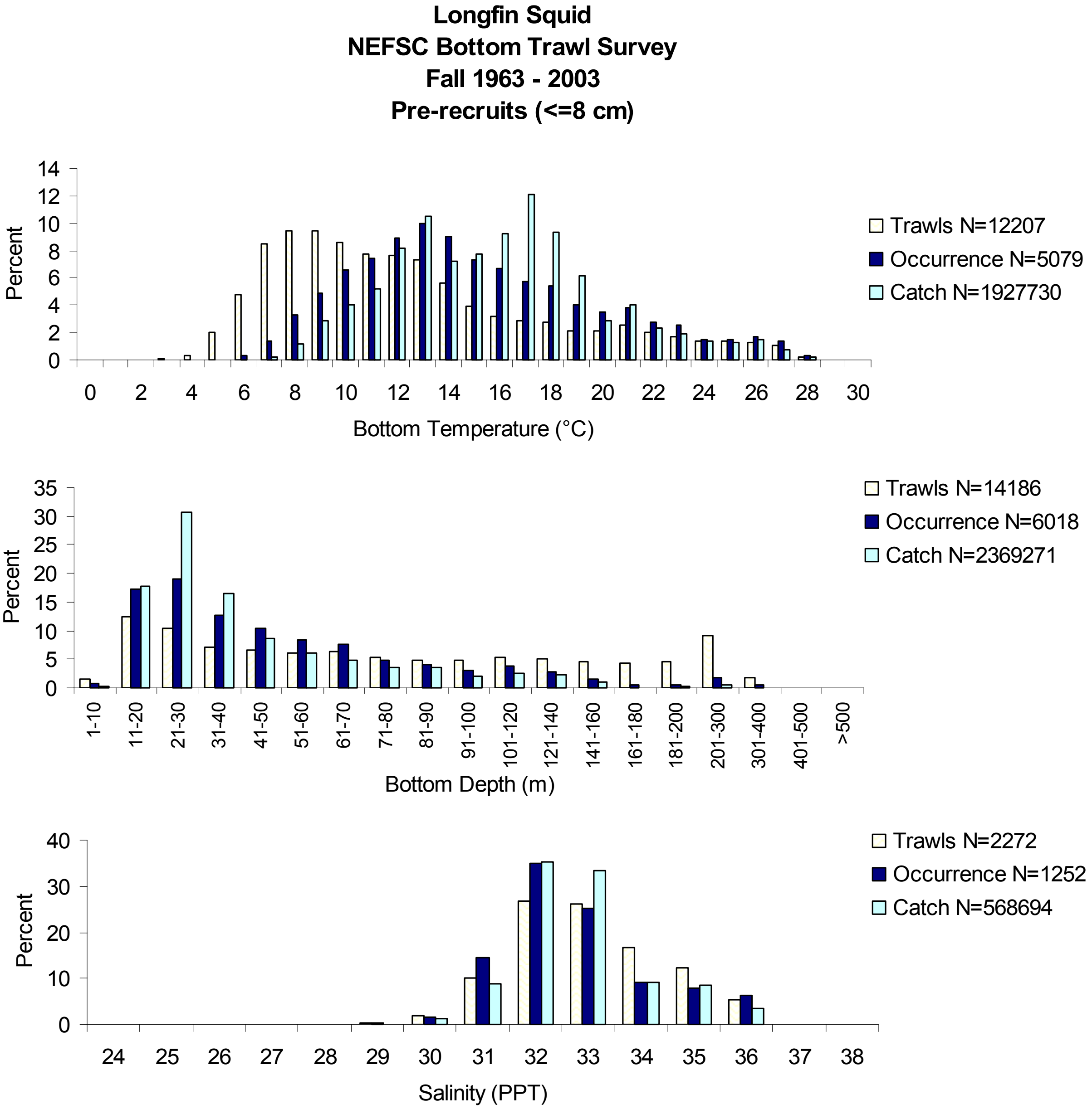

Figure 13. Cont'd.
Based on NEFSC fall bottom trawl surveys (temperature and depth: 1967-2003, all years combined; salinity: 1991-2003, all years combined). Light bars show the distribution of all the trawls, dark bars show the distribution of all trawls in which longfin inshore squid occurred and medium bars show, within each interval, the percentage of the total number of longfin inshore squid caught. Note that the bottom depth interval changes with increasing depth.

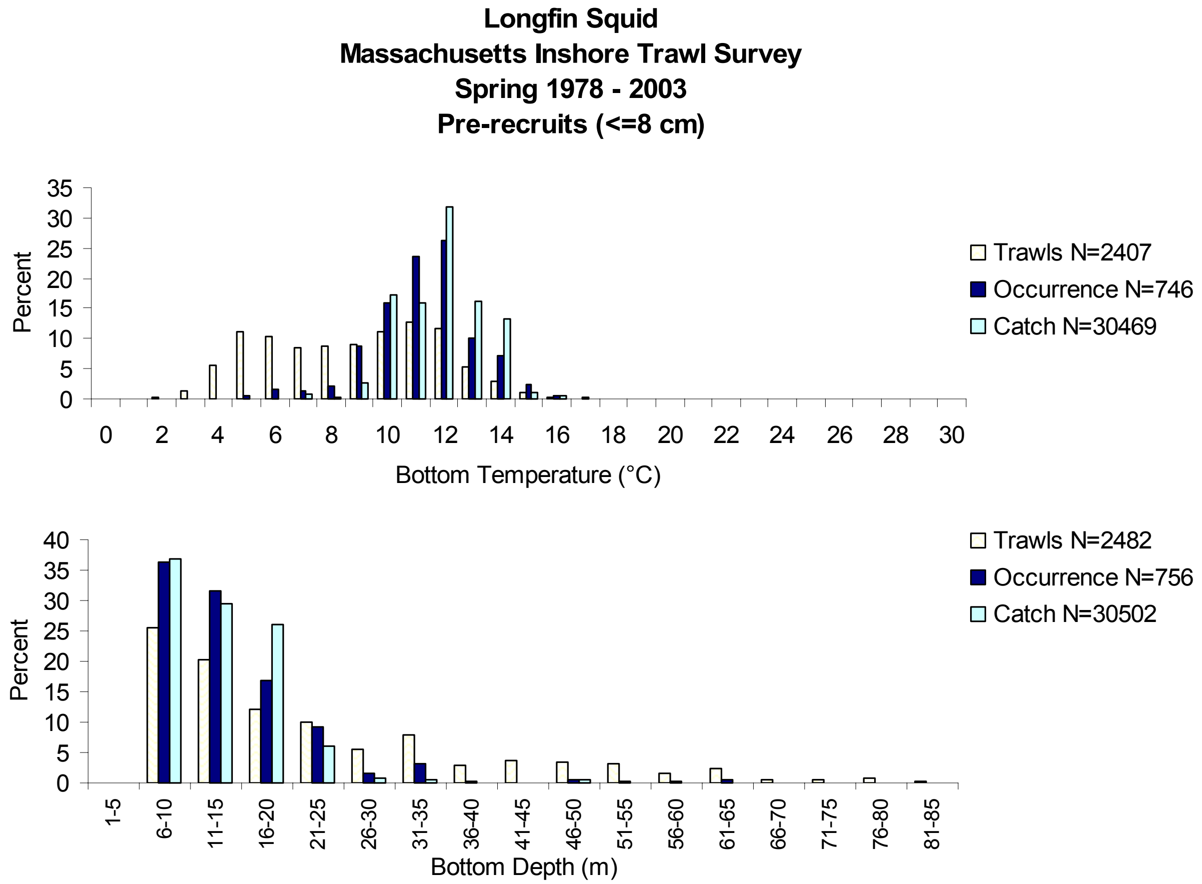

Figure 14. Distributions of pre-recruit longfin inshore squid and trawls in Massachusetts coastal waters relative to bottom water temperature and depth.
Based on spring Massachusetts inshore bottom trawl surveys (1978-2003, all years combined). Light bars show the distribution of all the trawls, dark bars show the distribution of all trawls in which longfin inshore squid occurred and medium bars show, within each interval, the percentage of the total number of longfin inshore squid caught.

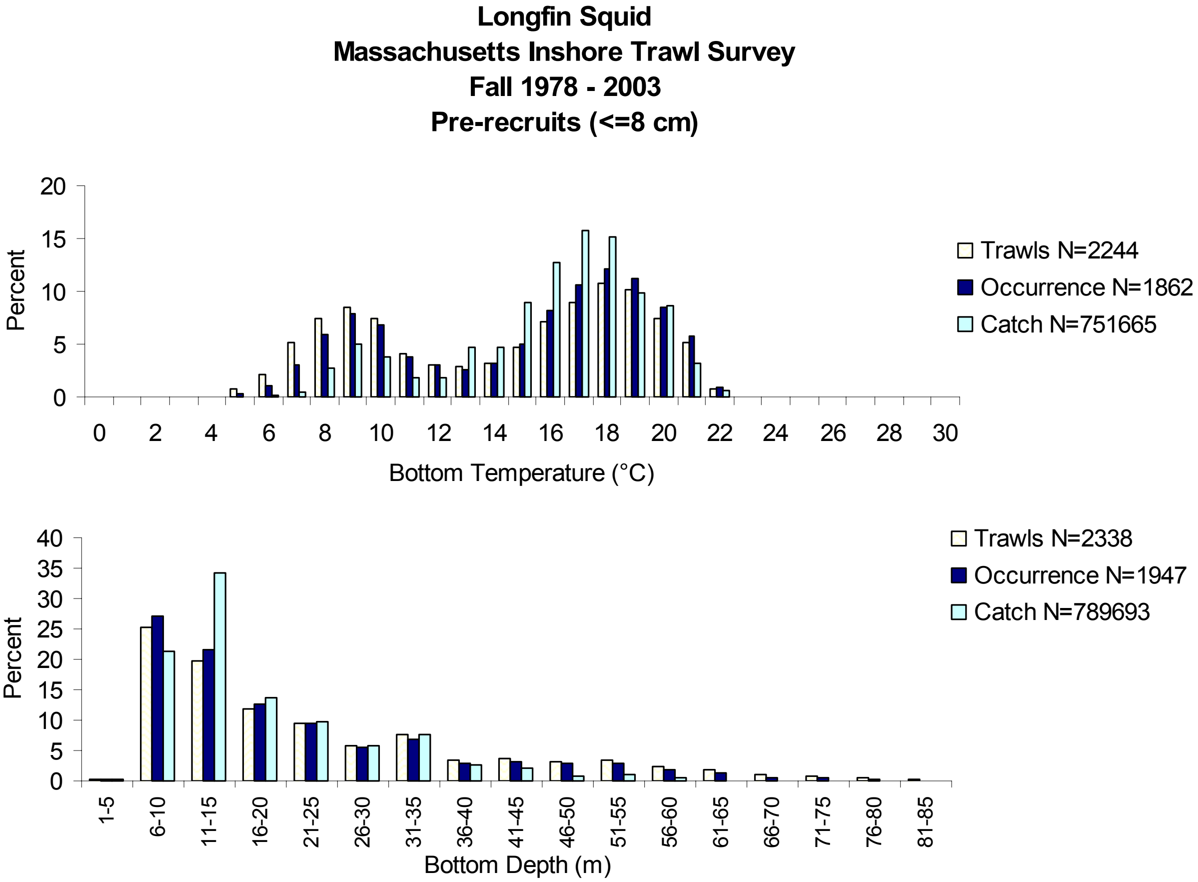

Figure 14. Cont'd.
Based on fall Massachusetts inshore bottom trawl surveys (1978-2003, all years combined). Light bars show the distribution of all the trawls, dark bars show the distribution of all trawls in which longfin inshore squid occurred and medium bars show, within each interval, the percentage of the total number of longfin inshore squid caught.

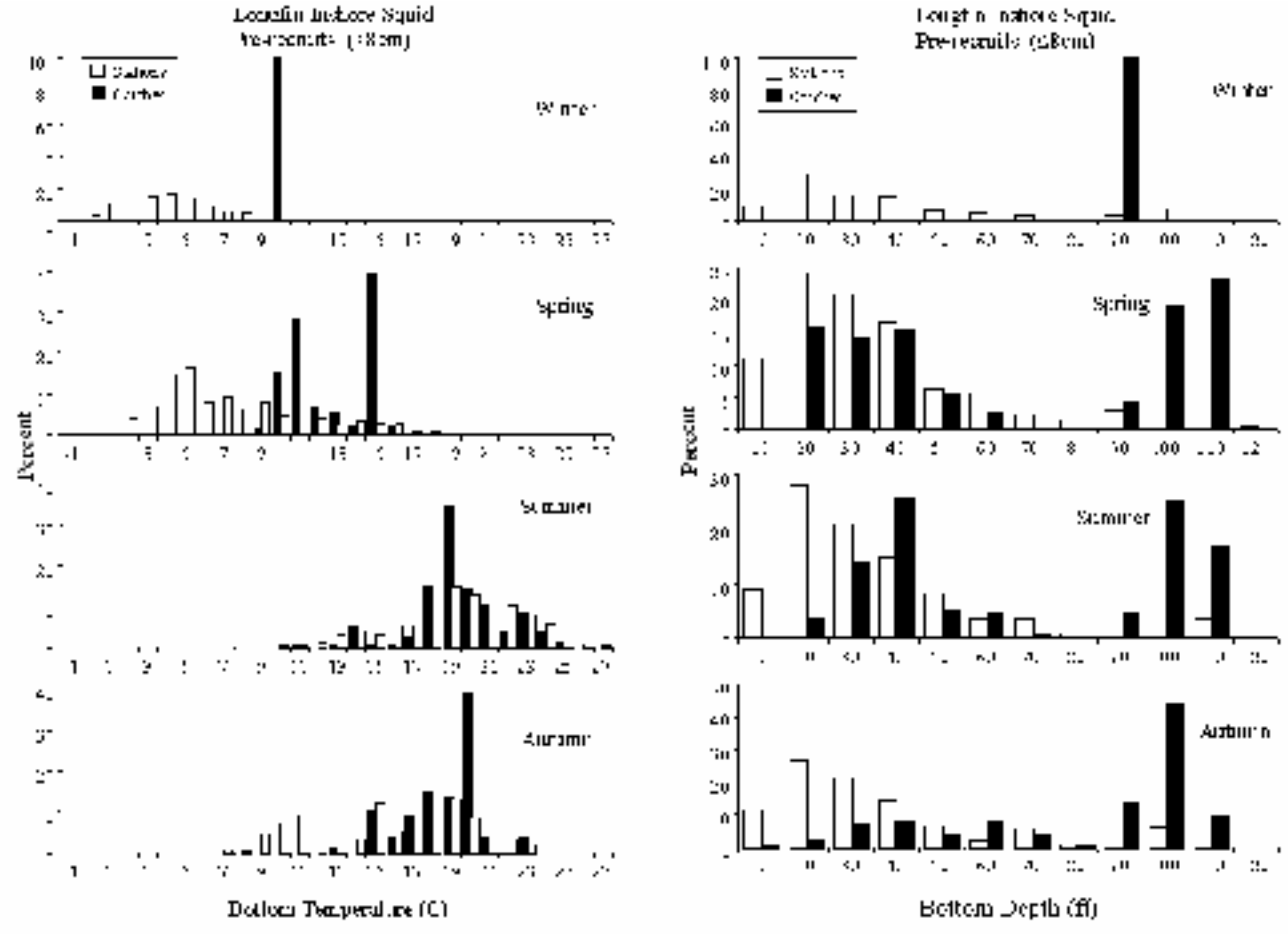

Figure 15. Distributions of longfin inshore squid pre-recruits in Narragansett Bay relative to mean bottom water temperature and bottom depth.
Based on Rhode Island trawl surveys, 1990-1996. Open bars represent the proportion of all stations surveyed, while solid bars represent the proportion of the sum of all catches.

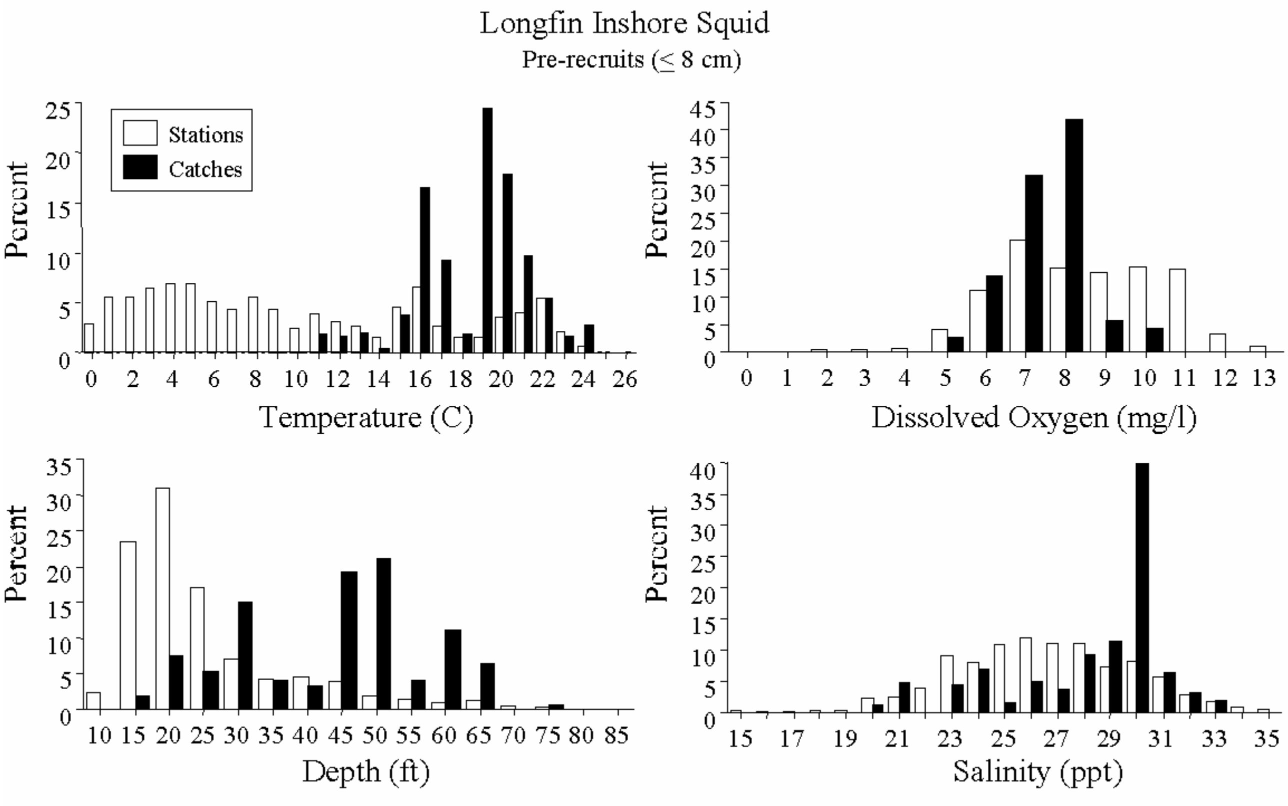

Figure 16. Distributions of longfin inshore squid pre-recruits in the Hudson-Raritan estuary relative to bottom water temperature, depth, dissolved oxygen, and salinity.

Based on NEFSC Hudson-Raritan estuary trawl surveys, 1992-1997, all seasons and years combined. Open bars represent the proportion of all stations surveyed, solid bars represent the proportion of the sum of all standardized catches.

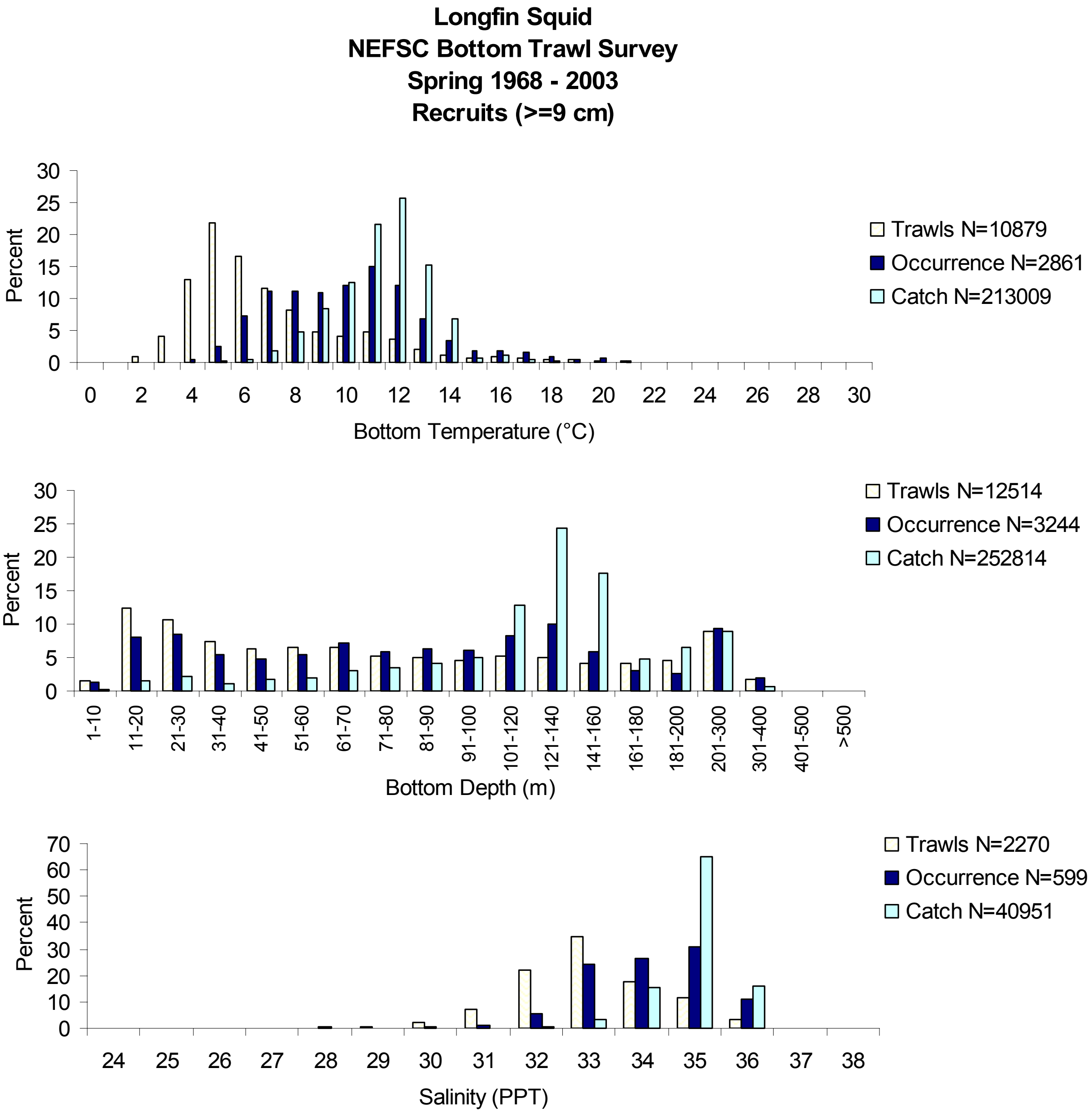

Figure 17. Distributions of recruit longfin inshore squid and trawls from NEFSC bottom trawl surveys relative to bottom water temperature, depth, and salinity.
Based on NEFSC spring bottom trawl surveys (temperature and depth: 1968-2003, all years combined; salinity: 1991-2003, all years combined). Light bars show the distribution of all the trawls, dark bars show the distribution of all trawls in which longfin inshore squid occurred and medium bars show, within each interval, the percentage of the total number of longfin inshore squid caught. Note that the bottom depth interval changes with increasing depth.

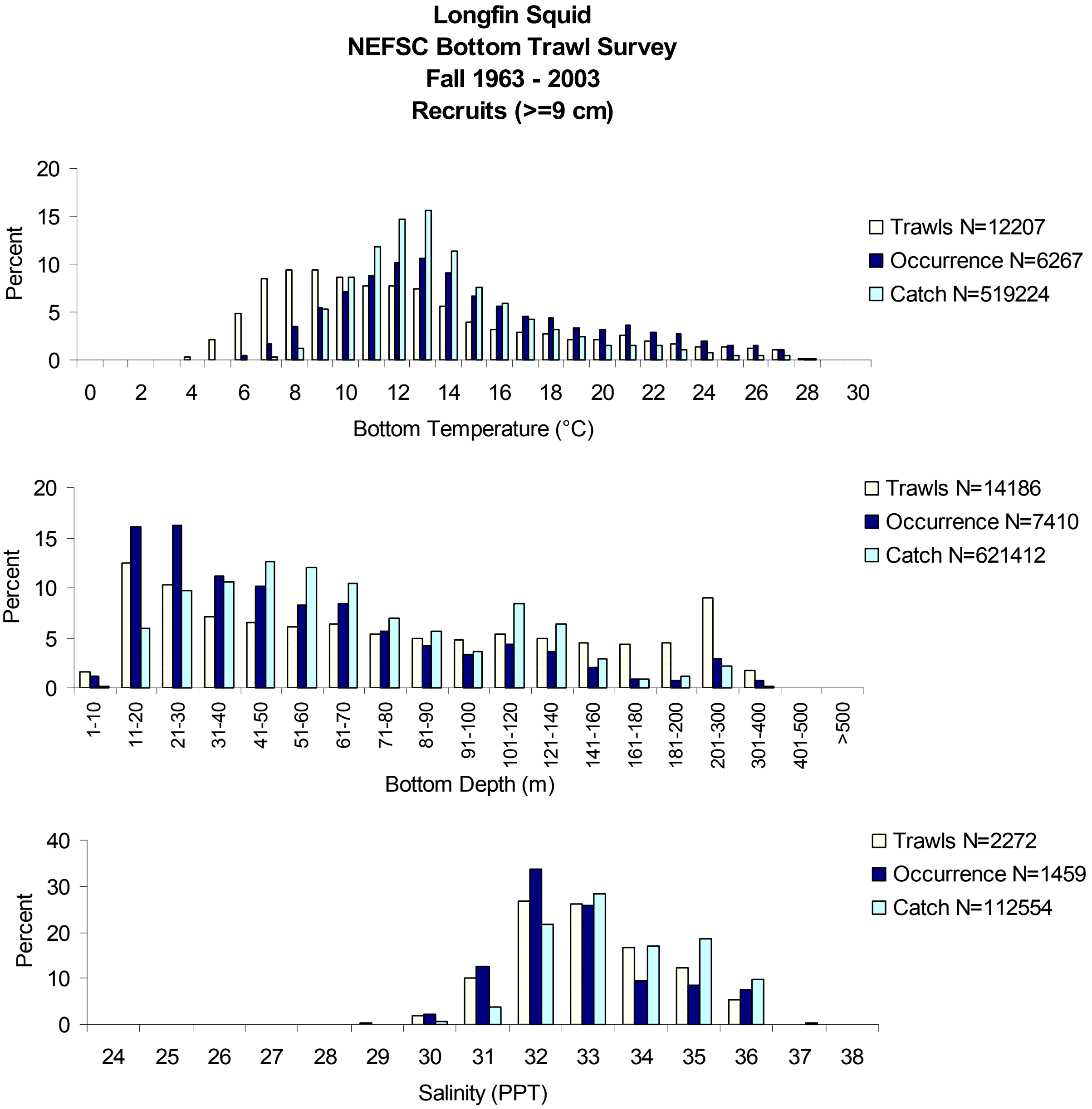

Figure 17. Cont'd.
Based on NEFSC fall bottom trawl surveys (temperature and depth: 1967-2003, all years combined; salinity: 1991-2003, all years combined). Light bars show the distribution of all the trawls, dark bars show the distribution of all trawls in which longfin inshore squid occurred and medium bars show, within each interval, the percentage of the total number of longfin inshore squid caught. Note that the bottom depth interval changes with increasing depth.

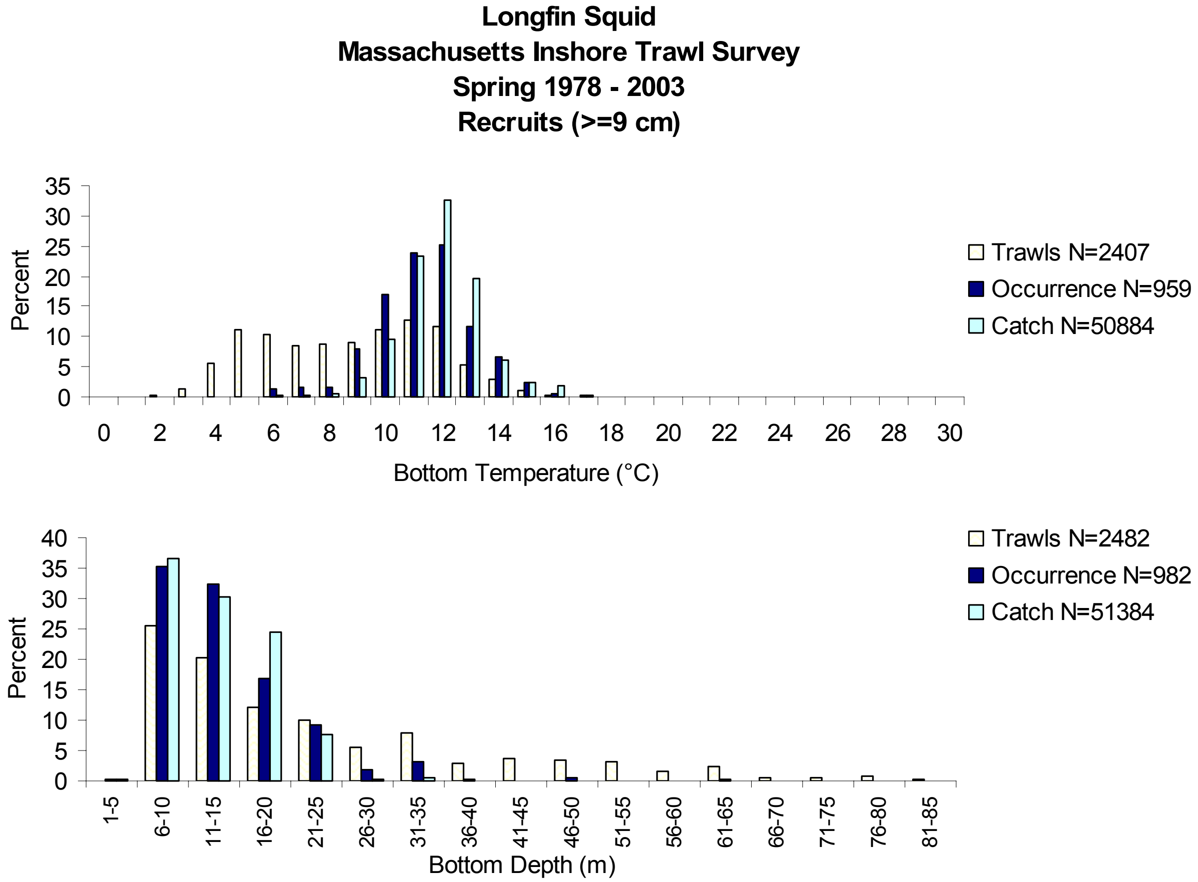

Figure 18. Distributions of recruit longfin inshore squid and trawls in Massachusetts coastal waters relative to bottom water temperature and depth.
Based on spring Massachusetts inshore bottom trawl surveys (1978-2003, all years combined). Light bars show the distribution of all the trawls, dark bars show the distribution of all trawls in which longfin inshore squid occurred and medium bars show, within each interval, the percentage of the total number of longfin inshore squid caught.

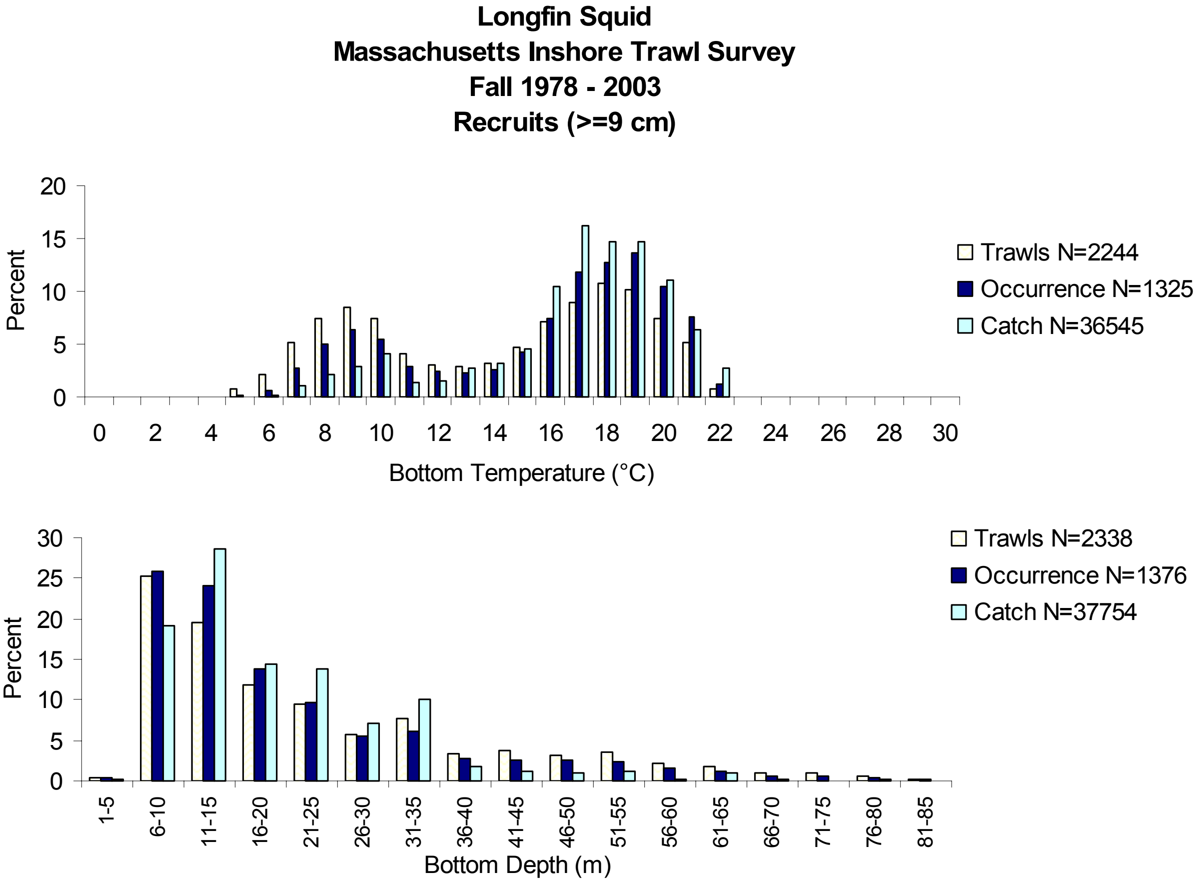

Figure 18. Cont'd.
Based on fall Massachusetts inshore bottom trawl surveys (1978-2003, all years combined). Light bars show the distribution of all the trawls, dark bars show the distribution of all trawls in which longfin inshore squid occurred and medium bars show, within each interval, the percentage of the total number of longfin inshore squid caught.

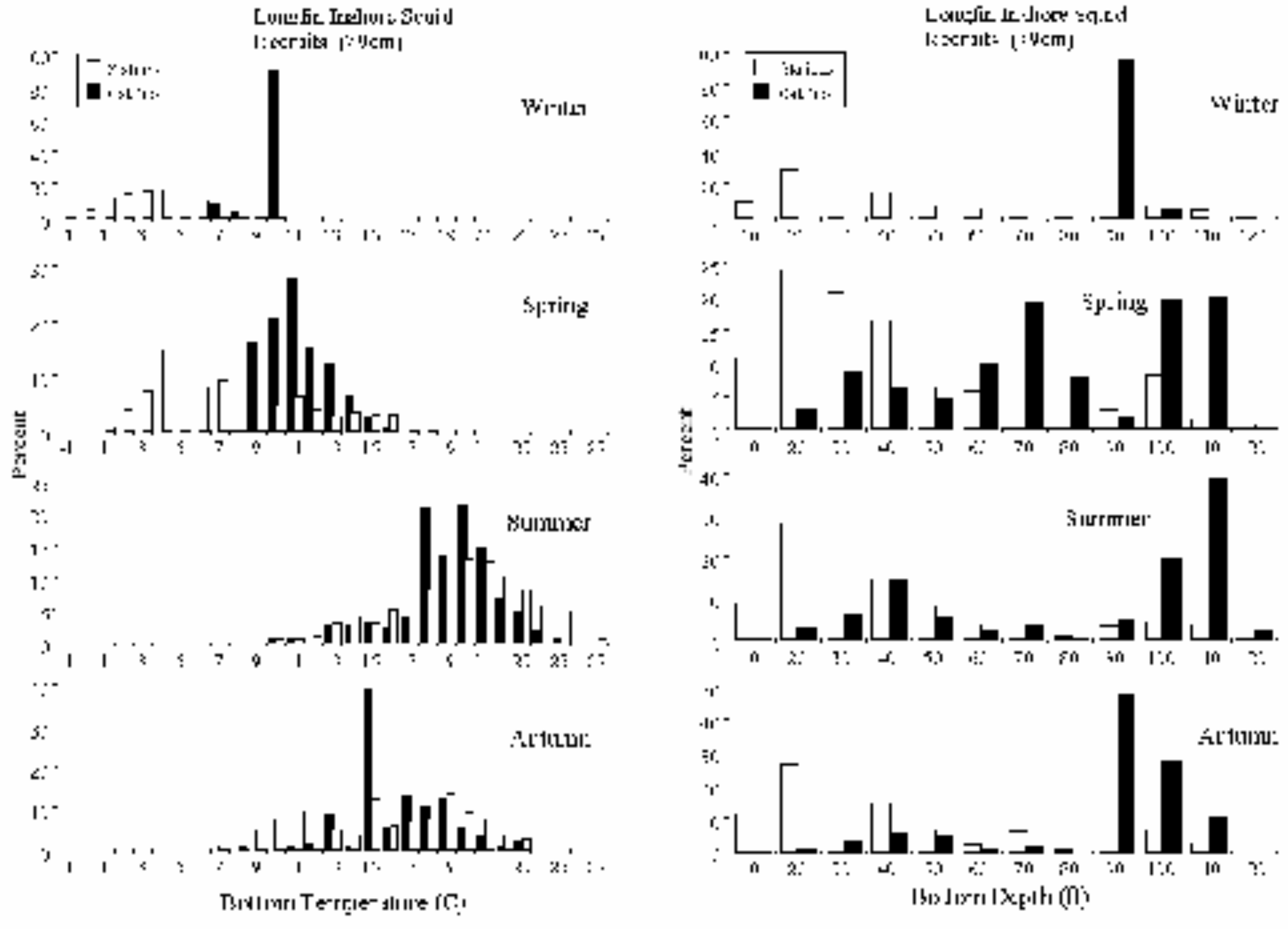

Figure 19. Distributions of longfin inshore squid recruits in Narragansett Bay relative to mean bottom water temperature and bottom depth.
Based on Rhode Island trawl surveys, 1990-1996. Open bars represent the proportion of all stations surveyed, while solid bars represent the proportion of the sum of all catches.

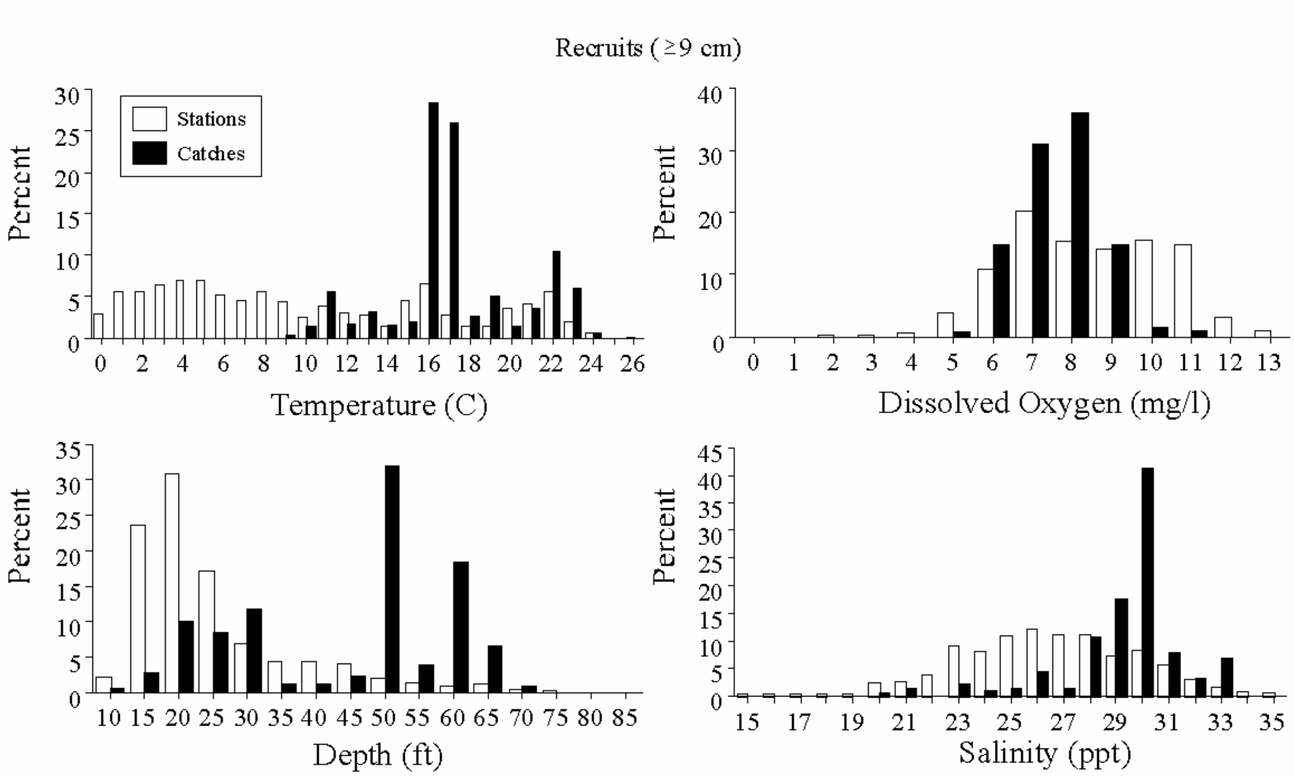

Figure 20. Distributions of longfin inshore squid recruits in the Hudson-Raritan estuary relative to bottom water temperature, depth, dissolved oxygen, and salinity.
Based on NEFSC Hudson-Raritan estuary trawl surveys, 1992-1997, all seasons and years combined. Open bars represent the proportion of all stations surveyed, solid bars represent the proportion of the sum of all standardized catches.

Publishing in *NOAA Technical Memorandum NMFS-NE*

Manuscript Qualification

This series represents a secondary level of scientific publishing in the National Marine Fisheries Service (NMFS). For all issues, the series employs thorough internal scientific review, but not necessarily external scientific review. For most issues, the series employs rigorous technical and copy editing. Manuscripts that may warrant a primary level of scientific publishing should be initially submitted to one of NMFS's primary series (*i.e., Fishery Bulletin, NOAA Professional Paper NMFS,* or *Marine Fisheries Review*).

Identical, or fundamentally identical, manuscripts should not be concurrently submitted to this and any other publication series. Manuscripts which have been rejected by any primary series strictly because of geographic or temporal limitations may be submitted to this series.

Manuscripts by Northeast Fisheries Science Center (NEFSC) authors will be published in this series upon approval by the NEFSC's Deputy Science & Research Director. Manuscripts by non-NEFSC authors may be published in this series if: 1) the manuscript serves the NEFSC's mission; 2) the manuscript meets the Deputy Science & Research Director's approval; and 3) the author arranges for the printing and binding funds to be transferred to the NEFSC's Research Communications Branch account from another federal account. For all manuscripts submitted by non-NEFSC authors and published in this series, the NEFSC will disavow all responsibility for the manuscripts' contents; authors must accept such responsibility.

The ethics of scientific research and scientific publishing are a serious matter. All manuscripts submitted to this series are expected to adhere -- at a minimum -- to the ethical guidelines contained in Chapter 1 ("Ethical Conduct in Authorship and Publication") of the *CBE Style Manual*, fifth edition (Chicago, IL: Council of Biology Editors). Copies of the manual are available at virtually all scientific libraries.

Manuscript Preparation

Organization: Manuscripts must have an abstract, table of contents, and -- if applicable -- lists of tables, figures, and acronyms. As much as possible, use traditional scientific manuscript organization for sections: "Introduction," "Study Area," "Methods & Materials," "Results," "Discussion" and/or "Conclusions," "Acknowledgments," and "References Cited."

Style: All NEFSC publication and report series are obligated to conform to the style contained in the most recent edition of the *United States Government Printing Office Style Manual*. That style manual is silent on many aspects of scientific manuscripts. NEFSC publication and report series rely more on the *CBE Style Manual,* fifth edition.

For in-text citations, use the name-date system. A special effort should be made to ensure that the list of cited works contains all necessary bibliographic information. For abbreviating serial titles in such lists, use the guidance of the International Standards Organization; such guidance is easily accessed through the various Cambridge Scientific Abstracts' serials source lists (see *http://www.public.iastate.edu/~CYBERSTACKS/JAS.htm*). Personal communications must include date of contact and full name and mailing address of source.

For spelling of scientific and common names of fishes, mollusks, and decapod crustaceans from the United States and Canada, use *Special Publications* No. 29 (fishes), 26 (mollusks), and 17 (decapod crustaceans) of the American Fisheries Society (Bethesda, MD). For spelling of scientific and common names of marine mammals, use *Special Publication* No. 4 of the Society for Marine Mammalogy (Lawrence, KS). For spelling in general, use the most recent edition of *Webster's Third New International Dictionary of the English Language Unabridged* (Springfield, MA: G.&C. Merriam).

Typing text, tables, and figure captions: Text, tables, and figure captions should be converted to WordPerfect. In general, keep text simple (*e.g.*, don't switch fonts and type sizes, don't use hard returns within paragraphs, don't indent except to begin paragraphs). Also, don't use an automatic footnoting function; all notes should be indicated in the text by simple numerical superscripts, and listed together in an "Endnotes" section prior to the "References Cited" section. Especially, don't use a graphics function for embedding tables and figures in text.

Tables should be prepared with a table formatting function. Each figure should be supplied both on paper and on disk, unless there is no digital file of a given figure. Except under extraordinary circumstances, color will not be used in illustrations.

Manuscript Submission

Authors must submit one paper copy of the double-spaced manuscript, one disk copy, and original figures (if applicable). NEFSC authors must include a completely signed-off "NEFSC Manuscript/Abstract/Webpage Review Form." Non-NEFSC authors who are not federal employees will be required to sign a "Release of Copyright" form.

Send all materials and address all correspondence to: Jon A. Gibson (Biological Sciences Editor), NMFS Northeast Fisheries Science Center, 166 Water Street, Woods Hole, MA 02543-1026.

Northeast Fisheries Science Center
Operations, Management & Information Division
Research Communications Branch
Editorial Office

National Marine Fisheries Service, NOAA
166 Water St.
Woods Hole, MA 02543-1026

**MEDIA
MAIL**

Publications and Reports of the Northeast Fisheries Science Center

The mission of NOAA's National Marine Fisheries Service (NMFS) is "stewardship of living marine resources for the benefit of the nation through their science-based conservation and management and promotion of the health of their environment." As the research arm of the NMFS's Northeast Region, the Northeast Fisheries Science Center (NEFSC) supports the NMFS mission by "conducting ecosystem-based research and assessments of living marine resources, with a focus on the Northeast Shelf, to promote the recovery and long-term sustainability of these resources and to generate social and economic opportunities and benefits from their use." Results of NEFSC research are largely reported in primary scientific media (*e.g.*, anonymously-peer-reviewed scientific journals). However, to assist itself in providing data, information, and advice to its constituents, the NEFSC occasionally releases its results in its own media. Currently, there are three such media:

NOAA Technical Memorandum NMFS-NE -- This series is issued irregularly. The series typically includes: data reports of long-term field or lab studies of important species or habitats; synthesis reports for important species or habitats; annual reports of overall assessment or monitoring programs; manuals describing program-wide surveying or experimental techniques; literature surveys of important species or habitat topics; proceedings and collected papers of scientific meetings; and indexed and/or annotated bibliographies. All issues receive internal scientific review and most issues receive technical and copy editing.

Northeast Fisheries Science Center Reference Document -- This series is issued irregularly. The series typically includes: data reports on field and lab studies; progress reports on experiments, monitoring, and assessments; background papers for, collected abstracts of, and/or summary reports of scientific meetings; and simple bibliographies. Issues receive internal scientific review, but no technical or copy editing.

Resource Survey Report (formerly *Fishermen's Report*) -- This information report is a quick-turnaround report on the distribution and relative abundance of selected living marine resources as derived from each of the NEFSC's periodic research vessel surveys of the Northeast's continental shelf. There is no scientific review, nor any technical or copy editing, of this report.

OBTAINING A COPY: To obtain a copy of a *NOAA Technical Memorandum NMFS-NE* or a *Northeast Fisheries Science Center Reference Document*, or to subscribe to the *Resource Survey Report*, either contact the NEFSC Editorial Office (166 Water St., Woods Hole, MA 02543-1026; 508-495-2228) or consult the NEFSC webpage on "Reports and Publications" (*http://www.nefsc.noaa.gov/nefsc/publications/*).

Appendix 8

Butterfish EFH Source Document

NOAA Technical Memorandum NMFS-NE-145

Essential Fish Habitat Source Document:

Butterfish, *Peprilus triacanthus*, Life History and Habitat Characteristics

U. S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
National Marine Fisheries Service
Northeast Region
Northeast Fisheries Science Center
Woods Hole, Massachusetts

September 1999

Recent Issues

105. **Review of American Lobster (*Homarus americanus*) Habitat Requirements and Responses to Contaminant Exposures.** By Renee Mercaldo-Allen and Catherine A. Kuropat. July 1994. v + 52 p., 29 tables. NTIS Access. No. PB96-115555.

106. **Selected Living Resources, Habitat Conditions, and Human Perturbations of the Gulf of Maine: Environmental and Ecological Considerations for Fishery Management.** By Richard W. Langton, John B. Pearce, and Jon A. Gibson, eds. August 1994. iv + 70 p., 2 figs., 6 tables. NTIS Access. No. PB95-270906.

107. **Invertebrate Neoplasia: Initiation and Promotion Mechanisms -- Proceedings of an International Workshop, 23 June 1992, Washington, D.C.** By A. Rosenfield, F.G. Kern, and B.J. Keller, comps. & eds. September 1994. v + 31 p., 8 figs., 3 tables. NTIS Access. No. PB96-164801.

108. **Status of Fishery Resources off the Northeastern United States for 1994.** By Conservation and Utilization Division, Northeast Fisheries Science Center. January 1995. iv + 140 p., 71 figs., 75 tables. NTIS Access. No. PB95-263414.

109. **Proceedings of the Symposium on the Potential for Development of Aquaculture in Massachusetts: 15-17 February 1995, Chatham/Edgartown/Dartmouth, Massachusetts.** By Carlos A. Castro and Scott J. Soares, comps. & eds. January 1996. v + 26 p., 1 fig., 2 tables. NTIS Access. No. PB97-103782.

110. **Length-Length and Length-Weight Relationships for 13 Shark Species from the Western North Atlantic.** By Nancy E. Kohler, John G. Casey, Patricia A. Turner. May 1996. iv + 22 p., 4 figs., 15 tables. NTIS Access. No. PB97-135032.

111. **Review and Evaluation of the 1994 Experimental Fishery in Closed Area II on Georges Bank.** By Patricia A. Gerrior, Fredric M. Serchuk, Kathleen C. Mays, John F. Kenney, and Peter D. Colosi. October 1996. v + 52 p., 24 figs., 20 tables. NTIS Access. No. PB98-119159.

112. **Data Description and Statistical Summary of the 1983-92 Cost-Earnings Data Base for Northeast U.S. Commercial Fishing Vessels: A Guide to Understanding and Use of the Data Base.** By Amy B. Gautam and Andrew W. Kitts. December 1996. v + 21 p., 11 figs., 14 tables. NTIS Access. No. PB97-169320.

113. **Individual Vessel Behavior in the Northeast Otter Trawl Fleet during 1982-92.** By Barbara Pollard Rountree. August 1997. v + 50 p., 1 fig., 40 tables. NTIS Access. No. PB99-169997.

114. **U.S. Atlantic and Gulf of Mexico Marine Mammal Stock Assessments -- 1996.** By Gordon T. Waring, Debra L. Palka, Keith D. Mullin, James H.W. Hain, Larry J. Hansen, and Kathryn D. Bisack. October 1997. viii + 250 p., 42 figs., 47 tables. NTIS Access. No. PB98-112345.

115. **Status of Fishery Resources off the Northeastern United States for 1998.** By Stephen H. Clark, ed. September 1998. vi + 149 p., 70 figs., 80 tables. NTIS Access. No. PB99-129694.

116. **U.S. Atlantic Marine Mammal Stock Assessments -- 1998.** By Gordon T. Waring, Debra L. Palka, Phillip J. Clapham, Steven Swartz, Marjorie C. Rossman, Timothy V.N. Cole, Kathryn D. Bisack, and Larry J. Hansen. February 1999. vii + 182 p., 16 figs., 56 tables. NTIS Access. No. PB99-134140.

117. **Review of Distribution of the Long-finned Pilot Whale (*Globicephala melas*) in the North Atlantic and Mediterranean.** By Alan A. Abend and Tim D. Smith. April 1999. vi + 22 p., 14 figs., 3 tables. NTIS Access. No. PB99-165029.

118. **Tautog (*Tautoga onitis*) Life History and Habitat Requirements.** By Frank W. Steimle and Patricia A. Shaheen. May 1999. vi + 23 p., 1 fig., 1 table. NTIS Access. No. PB99-165011.

119. **Data Needs for Economic Analysis of Fishery Management Regulations.** By Andrew W. Kitts and Scott R. Steinback. August 1999. iv + 48 p., 10 figs., 22 tables. NTIS Access. No. PB99-171456.

120. **Marine Mammal Research Program of the Northeast Fisheries Science Center during 1990-95.** By Janeen M. Quintal and Tim D. Smith. September 1999. v + 28 p., 4 tables, 4 app. NTIS Access. No. PB2000-100809.

NOAA Technical Memorandum NMFS-NE-145

This series represents a secondary level of scientifiic publishing. All issues employ thorough internal scientific review; some issues employ external scientific review. Reviews are -- by design -- transparent collegial reviews, not anonymous peer reviews. All issues may be cited in formal scientific communications.

Essential Fish Habitat Source Document:

Butterfish, *Peprilus triacanthus*, Life History and Habitat Characteristics

Jeffrey N. Cross[1], Christine A. Zetlin[1], Peter L. Berrien[1],
Donna L. Johnson[1], and Cathy McBride[2]

[1]*National Marine Fisheries Serv., James J. Howard Marine Sciences Lab., 74 Magruder Rd., Highlands, NJ 07732*
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U. S. DEPARTMENT OF COMMERCE
William Daley, Secretary
National Oceanic and Atmospheric Administration
D. James Baker, Administrator
National Marine Fisheries Service
Penelope D. Dalton, Assistant Administrator for Fisheries
Northeast Region
Northeast Fisheries Science Center
Woods Hole, Massachusetts

September 1999

Editorial Notes on Issues 122-152 in the *NOAA Technical Memorandum NMFS-NE* Series

Editorial Production

For Issues 122-152, staff of the Northeast Fisheries Science Center's (NEFSC's) Ecosystems Processes Division have largely assumed the role of staff of the NEFSC's Editorial Office for technical and copy editing, type composition, and page layout. Other than the four covers (inside and outside, front and back) and first two preliminary pages, all preprinting editorial production has been performed by, and all credit for such production rightfully belongs to, the authors and acknowledgees of each issue, as well as those noted below in "Special Acknowledgments."

Special Acknowledgments

David B. Packer, Sara J. Griesbach, and Luca M. Cargnelli coordinated virtually all aspects of the preprinting editorial production, as well as performed virtually all technical and copy editing, type composition, and page layout, of Issues 122-152. Rande R. Cross, Claire L. Steimle, and Judy D. Berrien conducted the literature searching, citation checking, and bibliographic styling for Issues 122-152. Joseph J. Vitaliano produced all of the food habits figures in Issues 122-152.

Internet Availability

Issues 122-152 are being copublished, *i.e.*, both as paper copies and as web postings. All web postings are, or will soon be, available at: *www.nefsc.nmfs.gov/nefsc/habitat/efh*. Also, all web postings will be in "PDF" format.

Information Updating

By federal regulation, all information specific to Issues 122-152 must be updated at least every five years. All official updates will appear in the web postings. Paper copies will be reissued only when and if new information associated with Issues 122-152 is significant enough to warrant a reprinting of a given issue. All updated and/or reprinted issues will retain the original issue number, but bear a "Revised (Month Year)" label.

Species Names

The NMFS Northeast Region's policy on the use of species names in all technical communications is generally to follow the American Fisheries Society's lists of scientific and common names for fishes (*i.e.*, Robins *et al.* 1991[a]), mollusks (*i.e.*, Turgeon *et al.* 1998[b]), and decapod crustaceans (*i.e.*, Williams *et al.* 1989[c]), and to follow the Society for Marine Mammalogy's guidance on scientific and common names for marine mammals (*i.e.*, Rice 1998[d]). Exceptions to this policy occur when there are subsequent compelling revisions in the classifications of species, resulting in changes in the names of species (*e.g.*, Cooper and Chapleau 1998[e]).

---

[a] Robins, C.R. (chair); Bailey, R.M.; Bond, C.E.; Brooker, J.R.; Lachner, E.A.; Lea, R.N.; Scott, W.B. 1991. Common and scientific names of fishes from the United States and Canada. 5th ed. *Amer. Fish. Soc. Spec. Publ.* 20; 183 p.

[b] Turgeon, D.D. (chair); Quinn, J.F., Jr.; Bogan, A.E.; Coan, E.V.; Hochberg, F.G.; Lyons, W.G.; Mikkelsen, P.M.; Neves, R.J.; Roper, C.F.E.; Rosenberg, G.; Roth, B.; Scheltema, A.; Thompson, F.G.; Vecchione, M.; Williams, J.D. 1998. Common and scientific names of aquatic invertebrates from the United States and Canada: mollusks. 2nd ed. *Amer. Fish. Soc. Spec. Publ.* 26; 526 p.

[c] Williams, A.B. (chair); Abele, L.G.; Felder, D.L.; Hobbs, H.H., Jr.; Manning, R.B.; McLaughlin, P.A.; Pérez Farfante, I. 1989. Common and scientific names of aquatic invertebrates from the United States and Canada: decapod crustaceans. *Amer. Fish. Soc. Spec. Publ.* 17; 77 p.

[d] Rice, D.W. 1998. Marine mammals of the world: systematics and distribution. *Soc. Mar. Mammal. Spec. Publ.* 4; 231 p.

[e] Cooper, J.A.; Chapleau, F. 1998. Monophyly and interrelationships of the family Pleuronectidae (Pleuronectiformes), with a revised classification. *Fish. Bull. (U.S.)* 96:686-726.

FOREWORD

One of the greatest long-term threats to the viability of commercial and recreational fisheries is the continuing loss of marine, estuarine, and other aquatic habitats.

Magnuson-Stevens Fishery Conservation and
Management Act (October 11, 1996)

The long-term viability of living marine resources depends on protection of their habitat.

NMFS Strategic Plan for Fisheries
Research (February 1998)

The Magnuson-Stevens Fishery Conservation and Management Act (MSFCMA), which was reauthorized and amended by the Sustainable Fisheries Act (1996), requires the eight regional fishery management councils to describe and identify essential fish habitat (EFH) in their respective regions, to specify actions to conserve and enhance that EFH, and to minimize the adverse effects of fishing on EFH. Congress defined EFH as "those waters and substrate necessary to fish for spawning, breeding, feeding or growth to maturity." The MSFCMA requires NMFS to assist the regional fishery management councils in the implementation of EFH in their respective fishery management plans.

NMFS has taken a broad view of habitat as the area used by fish throughout their life cycle. Fish use habitat for spawning, feeding, nursery, migration, and shelter, but most habitats provide only a subset of these functions. Fish may change habitats with changes in life history stage, seasonal and geographic distributions, abundance, and interactions with other species. The type of habitat, as well as its attributes and functions, are important for sustaining the production of managed species.

The Northeast Fisheries Science Center compiled the available information on the distribution, abundance, and habitat requirements for each of the species managed by the New England and Mid-Atlantic Fishery Management Councils. That information is presented in this series of 30 EFH species reports (plus one consolidated methods report). The EFH species reports comprise a survey of the important literature as well as original analyses of fishery-independent data sets from NMFS and several coastal states. The species reports are also the source for the current EFH designations by the New England and Mid-Atlantic Fishery Management Councils, and have understandably begun to be referred to as the "EFH source documents."

NMFS provided guidance to the regional fishery management councils for identifying and describing EFH of their managed species. Consistent with this guidance, the species reports present information on current and historic stock sizes, geographic range, and the period and location of major life history stages. The habitats of managed species are described by the physical, chemical, and biological components of the ecosystem where the species occur. Information on the habitat requirements is provided for each life history stage, and it includes, where available, habitat and environmental variables that control or limit distribution, abundance, growth, reproduction, mortality, and productivity.

Identifying and describing EFH are the first steps in the process of protecting, conserving, and enhancing essential habitats of the managed species. Ultimately, NMFS, the regional fishery management councils, fishing participants, Federal and state agencies, and other organizations will have to cooperate to achieve the habitat goals established by the MSFCMA.

A historical note: the EFH species reports effectively recommence a series of reports published by the NMFS Sandy Hook (New Jersey) Laboratory (now formally known as the James J. Howard Marine Sciences Laboratory) from 1977 to 1982. These reports, which were formally labeled as *Sandy Hook Laboratory Technical Series Reports*, but informally known as "Sandy Hook Bluebooks," summarized biological and fisheries data for 18 economically important species. The fact that the bluebooks continue to be used two decades after their publication persuaded us to make their successors – the 30 EFH source documents – available to the public through publication in the *NOAA Technical Memorandum NMFS-NE* series.

JAMES J. HOWARD MARINE SCIENCES LABORATORY
HIGHLANDS, NEW JERSEY
SEPTEMBER 1999

JEFFREY N. CROSS, CHIEF
ECOSYSTEMS PROCESSES DIVISION
NORTHEAST FISHERIES SCIENCE CENTER

Contents

Tables

Figures

INTRODUCTION

Butterfish, *Peprilus triacanthus* (Figure 1), range from Newfoundland and the Gulf of St. Lawrence to the Atlantic and Gulf coasts of Florida (Figure 2), but they are most abundant from the Gulf of Maine to Cape Hatteras (Bigelow and Schroeder 1953; Haedrich 1967; Horn 1970a; Powell *et al*. 1972; Cooley 1978; Scott and Scott 1988; Brodziak 1995; Klein-MacPhee, in review). Butterfish are fast-growing, short-lived, pelagic fishes that form loose schools, often near the surface (Schreiber 1973; Dery 1988; Brodziak 1995). They winter near the edge of the continental shelf in the Middle Atlantic Bight and migrate inshore in the spring into southern New England and Gulf of Maine waters. During the summer, butterfish occur over the entire mid-Atlantic shelf from sheltered bays and estuaries out to about 200 m. In late fall, butterfish move southward and offshore in response to falling water temperatures (Fritz 1965; Horn 1970a; Schreiber 1973; Waring 1975; Azarovitz *et al*. 1980; Klein-MacPhee, in review).

LIFE HISTORY

Butterfish are short-lived and grow rapidly; few individuals live beyond 3 years and most are sexually mature at 1-2 years of age. The maximum age reported is 3+ years (DuPaul and McEachran 1973; Waring 1975; Kawahara 1977a) and 6 years (Draganik and Zukowski 1966). Butterfish are eurythermal (4.4-21.6ºC; Fritz 1965; Schaefer 1967; Horn 1970a) and euryhaline (5-32 ppt; Musick 1972).

EGGS

Butterfish eggs are buoyant, transparent, and spherical (0.68-0.82 mm diameter; Wheatland 1956; Colton and Marak 1969; Martin and Drewry 1978; Elliott and Jiminez 1981). The incubation period is about 48 hrs at 18ºC; 50% of eggs hatched at 72 hrs at about 15ºC (Martin and Drewry 1978; Colton and Honey 1963). Eggs have been collected between 12.8-22.5ºC and 78-100% seawater (Martin and Drewry 1978). At hatching, butterfish are 1.68-1.75 mm; yolk absorption is complete by 2.48-2.64 mm (Colton and Honey 1963; Colton and Marak 1969).

LARVAE

Butterfish larvae range from 2.6 to 16 mm standard length (SL) (Martin and Drewry 1978). By 6 mm they have the thin, deep body that is characteristic of adults and by 15-16 mm they have a forked tail (Horn 1970a; Ditty and Truesdale 1983). At 10-15 mm, larvae are more nektonic than planktonic (Martin and Drewry 1978) and are caught in neuston nets (Powles and Stender 1976; Lux and Wheeler 1992). They begin to associate with jellyfish, *Sargassum*, and other flotsam at this size (Mansueti 1963; Haedrich 1967; Horn 1970b; Thomas and Milstein 1973; Lippson and Lippson 1984). Larvae may undertake diel vertical migrations; more butterfish larvae were collected between 0-4 m at night than during the day (Kendall and Naplin 1981). Metamorphosis is gradual as the larvae progressively assume juvenile characters (Able and Fahay 1998). Rotunno (1992) reported growth rates of 0.227 mm/day for fish 6.0-28.0 mm SL based on otolith analyses.

JUVENILES

Juvenile butterfish range from 16 mm to about 120 mm SL (Martin and Drewry 1978). During their first year, they grow to 76-127 mm, or about half their adult size (Hildebrand and Schroeder 1928; Klein-MacPhee, in review). Early-spawned individuals are 76-102 mm in the fall; late-spawned individuals are 51-76 mm in the fall and 76-127 mm the following spring (Martin and Drewry 1978). Young butterfish (< 30 mm) often live in the shelter of large jellyfishes during their first summer. Although this commensal association is not essential, it is a source of food and provides young butterfish some protection from their predators (Mansueti 1963; Horn 1970b, 1975).

ADULTS

Adult butterfish range from about 120 mm to 305 mm SL (Hildebrand and Schroeder 1928) with an average length of 150-230 mm (Klein-MacPhee, in review). The median length at maturity (L_{50}) for butterfish collected on the northeast shelf (1986-1989) was 12.0 cm total length (TL) for females and 11.4 cm TL for males (O'Brien *et al*. 1993), which corresponds to an age of about 1 year (Horn 1970a; DuPaul and McEachran 1973). In Chesapeake Bay, butterfish begin to mature during their second summer (age 1) and most individuals are mature by their third summer (DuPaul and McEachran 1973). In the New York Bight, ripe females 124-242 mm FL were collected in 3-145 m of water from May through August; less than 5% of the ripe females were collected in the Hudson-Raritan estuary (Wilk *et al.* 1990). At 2+ years of age, butterfish are about 17 cm and at 3+, they are about 19 cm (Waring and Murawski 1982).

REPRODUCTION

Butterfish are broadcast spawners (Horn 1970a) and spawn primarily in the evening or at night (Ferraro 1980;

Kendall and Naplin 1981), but no direct observations have been made (Klein-MacPhee, in review). Butterfish may spawn in the upper part of the water column during the evening; more eggs were collected between 0-4 m at night in the Middle Atlantic Bight than during the day (Kendall and Naplin 1981).

Butterfish are usually reported to spawn offshore (e.g., Wang and Kernehan 1979). Butterfish may spawn a few miles out to sea off Woods Hole, MA and return inshore when they are spent (Klein-MacPhee, in review). However, eggs and larvae have been collected in coastal waters and most estuaries in the northern part of the Middle Atlantic Bight (Hildebrand and Schroeder 1928; Herman 1963; Martin and Drewry 1978; Lux and Wheeler 1992; Able and Fahay 1998). Early stage eggs have been collected in Narragansett Bay and Salem Harbor (Herman 1963; Bourne and Govoni 1988; Elliott and Jiminez 1981), Raritan Bay, NJ (Croker 1965), and in the lower portions of Chesapeake Bay (Lippson and Moran 1974), but not in Delaware Bay (Wang and Kernehan 1979).

Water temperatures appear to regulate butterfish reproduction as spawning dates are progressively later in the year in the northern part of its range (Murawski *et al.* 1978; Rotunno and Cowen 1997; Able and Fahay 1998). Spawning may occur year round in the South Atlantic Bight with a peak in spring (Fahay 1975; Able and Fahay 1998). Spawning probably does not occur below 15ºC (Colton 1972).

Butterfish begin spawning in Chesapeake Bay as early as late May with a peak in activity in June and July (Hildebrand and Schroeder 1928; Pearson 1941). Spawning in the Middle Atlantic Bight occurs from May through October (Smith *et al.* 1980); the gonad weight of fish > 15 cm increases in March and April, reaches its maximum during June and July, and decreases in the fall (Kawahara 1977b). In Long Island Sound, spawning occurs from June through late August with a peak in late July; the principal spawning areas are in the eastern part of the sound (Perlmutter 1939). In Narragansett Bay, butterfish eggs are found from June to August (Herman 1963). In Massachusetts Bay, butterfish spawn from June to August (Bigelow and Schroeder 1953). In the Gulf of Maine, spawning begins in May-June, peaks in July, and ends in August (Bigelow and Schroeder 1953; Smith *et al.* 1980). On the Scotian Shelf, spawning occurs from July to October (Markle and Frost 1985).

The spawning period may be more protracted in the Middle Atlantic Bight than previously thought. Rotunno (1992) and Rotunno and Cowen (1997) estimated spawning times from a birthdate analysis of otoliths from butterfish up to about 50 mm SL collected in the Middle Atlantic and South Atlantic bights. Spawning began in February and continued through at least late July. It began in the south and progressed northward over time, which is consistent with the temporal and spatial distribution of larvae, and suggests that butterfish spawn as they migrate north and inshore on their annual migration in association with seasonal warming of waters on the northeast shelf.

FOOD HABITS

Butterfish feed mainly on planktonic prey including thaliaceans (primarily Larvacea and Hemimyaria), mollusks (primarily squids), crustaceans (copepods, amphipods, and decapods), coelenterates (primarily hydrozoans), polychaetes (primarily Tomopteridae and Goniadidae), small fishes, and ctenophores (Fritz 1965; Leim and Scott 1966; Haedrich 1967; Horn 1970a, b; Schreiber 1973; Mauer and Bowman 1975; Oviatt and Kremer 1977; Tibbets 1977; Murawski *et al.* 1978; Bowman and Michaels 1984; Klein-MacPhee, in review).

The food habits of butterfish collected during the northeast shelf during Northeast Fisheries Science Center (NEFSC) bottom trawl surveys [see Reid *et al.* (1999) for details] were similar to diets reported in the literature (Figure 3). The stomach contents were dominated by unidentifiable animal remains. Arthropods dominated the identifiable items, followed by urochordates (thaliaceans and larvaceans), unidentified plankton, annelids (probably polychaetes), chaetognaths (arrowworms), mollusks (probably squids), cnidarians (coelenterates, probably jellyfish), and fishes.

PREDATION

Butterfish are preyed on by many species including haddock, silver hake, goosefish, weakfish, bluefish, swordfish, sharks (hammerhead), and longfin inshore squid (Bigelow and Schroeder 1953; Scott and Tibbo 1968; Horn 1970a; Maurer and Bowman 1975; Tibbets 1977; Stillwell and Kohler 1985; Brodziak 1995; Klein-MacPhee, in review).

MIGRATION

North of Cape Hatteras, butterfish have a seasonal inshore-offshore north-south migration in response to changing water temperatures. There is a limited seasonal inshore-offshore migration south of Cape Hatteras (Caldwell 1961; Fritz 1965; Horn 1970a; Klein-MacPhee, in review). During the summer, butterfish move north and inshore to feed on planktonic fish, squid, crustaceans, and jellyfish, and to reproduce. They remain near the surface at depths of 22-55 m and often come close inshore; schools are frequently seen on shallow flats and in sheltered bays and estuaries (Bigelow and Schroeder 1953; Klein-MacPhee, in review).

Butterfish are common in the lower Chesapeake Bay from March through November (Geer and Austin 1997;

Murdy *et al.* 1997). They occur in Great Bay, NJ and nearby coastal waters from June through November (Able and Fahay 1998) and in the surf zone off Long Island from June through October (Schaefer 1967). They appear off Rhode Island by the last half of April and off Woods Hole, MA by mid-May, although they are not abundant there until June. Butterfish appear on Georges Bank in early June, but are not abundant until late June or early July. They occur in the Gulf of Maine from late June-early July through the fall (Bigelow and Schroeder 1953; Overholtz and Tyler 1985; Klein-MacPhee, in review). They are found in New Hampshire waters from July to October with a peak in abundance in September (MAFMC 1995). Butterfish are common along the coast of Maine and, in some years, they are common along the coast of Nova Scotia bordering the Gulf of Maine (Bigelow and Schroeder 1953).

During the winter, the stock moves south and offshore. Butterfish are found near the bottom over sand, mud, and rock bottoms. They have been caught to about 200 m deep in the northwest Atlantic (Bigelow and Schroeder 1953; Klein-MacPhee, in review) and over 350 m in the South Atlantic Bight (Barans and Burrell 1976). Butterfish are absent from nearshore waters off New Jersey from January through late April (Milstein 1974; Milstein and Hamer 1976). South of Delaware Bay, the winter offshore movement is not so extensive and some individuals move south in shallow water (Waring and Murawski 1982).

STOCK STRUCTURE

Butterfish range from Newfoundland to Florida and are considered a unit stock (Brodziak 1995; Klein-MacPhee, in review). There may be two stocks south of Cape Hatteras that are isolated by depth, although the shallow stock (< 20 m) may be a *Peprilus triacanthus-Peprilus burti* hybrid (Caldwell 1961; Horn 1970a; Klein-MacPhee, in review) or *P. burti*, a Gulf of Mexico species (Pershbacher *et al*. 1979).

HABITAT CHARACTERISTICS

Butterfish are pelagic fishes that form loose schools, often near the surface (Schreiber 1973; Dery 1988; Brodziak 1995). They winter near the edge of the continental shelf in the Middle Atlantic Bight and migrate inshore in the spring into southern New England and Gulf of Maine waters. During the summer, butterfish occur over the entire Mid-Atlantic shelf from sheltered bays and estuaries out to about 200 m. In late fall, butterfish move southward and offshore in response to falling water temperatures (Fritz 1965; Horn 1970a; Schreiber 1973; Waring 1975; Azarovitz *et al*. 1980; Klein-MacPhee, in review).

Table 1 summarizes the environmental conditions where butterfish eggs, larvae, juveniles, and adults have been collected based on a literature survey and analyses of several fishery-independent databases [see Reid *et al.* (1999) for survey methods and location maps].

EGGS AND LARVAE

Butterfish eggs and larvae are pelagic and occur from the outer continental shelf to the lower, high salinity parts of estuaries in Middle Atlantic Bight. Eggs have been collected between 12-23ºC and larvae have been collected between 4-28ºC; eggs and larvae occur at salinities that range from estuarine to full strength seawater (Table 1). Larvae may undertake diel vertical migrations (Kendall and Naplin 1981). Larger larvae (10-15 mm) are more nektonic than planktonic; larger larvae and pelagic juveniles (< 30 mm) often associate with jellyfish, *Sargassum*, and other flotsam (Mansueti 1963; Haedrich 1967; Horn 1970b; Thomas and Milstein 1973; Lippson and Lippson 1984).

Eggs were collected during the NEFSC Marine Resources Monitoring, Assessment and Prediction program (MARMAP) ichthyoplankton survey at water temperatures ranging from 6º to 26ºC; most eggs were collected between 11-17ºC (Figure 4). Eggs were collected in surface waters (upper 200 m or within 5 m of bottom where station depths were < 200 m) in depths ranging from 10 to 1250 m (Figure 4). Most eggs were collected in water depths < 200 m.

Larvae were collected during the MARMAP ichthyoplankton survey at water temperatures ranging from 7-26ºC; most larvae were collected at 9-19ºC (Figure 5). Larvae were collected in surface waters in depths ranging from 10 to 1750 m; most larvae were collected in water depths < 120 m (Figure 5).

Eggs and larvae are common in the high salinity zones of some estuaries in southern New England and the Middle Atlantic Bight and in the mixing zone in Chesapeake Bay (Table 2a).

JUVENILES AND ADULTS

Juvenile and adult butterfish are pelagic fishes that form loose schools, often near the surface (Schreiber 1973; Dery 1988; Brodziak 1995). They are eurythermal (4.4-21.6ºC) and euryhaline (5-32 ppt) and are frequently found over sand, mud, and mixed substrates (Table 1). In Long Island Sound, butterfish were collected less frequently at low dissolved oxygen levels (2.0-2.9ml/l) (Howell and Simpson 1994).

During the summer, butterfish occur inshore where they remain near the surface; schools are frequently seen on shallow flats and in sheltered bays, estuaries, and the surf zone (Bigelow and Schroeder 1953; Leim and Scott

1966; Schaefer 1967; Klein-MacPhee, in review). Smaller juveniles often aggregate under floating objects including the bells of coelenterates (Pearson 1941; Bigelow and Schroeder 1953; Mansueti 1963; Haedrich 1967; Horn 1970b, 1975; Lippson and Moran 1974; Milstein 1974; Scott and Scott 1988). Larger juveniles are pelagic schooling fishes that may congregate near the bottom during the day and disperse upwards at night (Waring 1975).

Juvenile and adult butterfish are common to abundant in the high salinity and mixing zones of estuaries from Massachusetts Bay to the mid-Atlantic; they are rare to uncommon in the high salinity and mixing zones of estuaries in the central and northern Gulf of Maine and in the South Atlantic Bight (Tables 2a, b). In the Gulf of Maine and Middle Atlantic Bight, butterfish move offshore during the winter; fish are found near the bottom over sand, mud, and rock substrates (Bigelow and Schroeder 1953; Klein-MacPhee, in review). The offshore migration is not as pronounced south of Delaware Bay where winter water temperatures are warmer (Waring and Murawski 1982). In the South Atlantic Bight, butterfish are present throughout most of the year in nearshore waters (Keiser 1976).

In the NEFSC bottom trawl survey (1963-1997), juvenile and adult butterfish were collected on the continental shelf from 10 m of water nearshore out to about 360 m of water offshore; most juveniles and adults were collected in water depths < 180 m (Figure 6). Adults were distributed somewhat deeper than juveniles in all seasons. Bottom-water temperatures where juveniles and adults were captured ranged from 3º to 28ºC; most fish were collected between 7-20ºC (Figure 6). Modal water temperatures during spring and fall surveys were 10-14ºC for juveniles and adults.

In the Massachusetts trawl survey (1978-1996), juvenile and adult butterfish were collected at depths ranging from 5 to 80 m; most juveniles were collected between 10-35 m and most adults between 10-50 m (Figure 7). Bottom water temperatures ranged from 9-15ºC in the spring and 7-22ºC in the fall (Figure 7). Adults were caught deeper than juveniles in the fall when water temperatures were lower.

In the Rhode Island Narragansett Bay/Coastal trawl survey, juvenile and adult butterfish were collected at depths between 10-120 ft (3-37 m); most juveniles and adults were collected between 30-110 ft (10-34 m). Bottom water temperatures for juveniles and adults at the time of collection ranged from 9-24ºC in the summer and fall and 5-15ºC in the winter and spring.

In the Connecticut Long Island Sound trawl survey, juvenile and adult butterfish were collected at depths between 6-60 m; most fish were collected between 10-30 m. Bottom water temperatures for juveniles and adults at the time of collection ranged from 7-18ºC in the spring and 8-23ºC in the fall; most fish were captured at 9-15ºC in the spring and 16-21ºC in the fall. Bottom water salinities at the time of collection ranged from 18-32 ppt; most fish were captured at 26-29 ppt.

In the Hudson-Raritan trawl survey, juvenile and adult butterfish were collected at depths ranging from 10-75 ft (3-23 m) (Figure 8). Bottom water temperatures ranged from 8-26ºC, salinities ranged from 19-32 ppt, and dissolved oxygen ranged from 3-10 mg/l (Figure 8).

GEOGRAPHICAL DISTRIBUTION

Butterfish range from Newfoundland and the Gulf of St. Lawrence to the Atlantic and Gulf coasts of Florida (Figure 2), but they are most abundant from the Gulf of Maine to Cape Hatteras (Haedrich 1967; Horn 1970a; Powell *et al.* 1972; Cooley 1978; Scott and Scott 1988; Brodziak 1995; Klein-MacPhee, in review). Butterfish spend the winter near the edge of the continental shelf in the Middle Atlantic Bight and migrate inshore in spring to waters off southern New England and into the Gulf of Maine. During the summer, butterfish range from the Gulf of Maine to the South Atlantic Bight where they are found from sheltered bays and estuaries (Table 3) across the shelf to depths of 200 m and greater. In late fall, butterfish move southward and offshore in response to falling water temperatures (Fritz 1965; Horn 1970a; Schreiber 1973; Waring 1975; Azarovitz *et al.* 1980; Klein-MacPhee, in review). During the winter, they are largely absent from bays and estuaries in the Middle Atlantic Bight and Gulf of Maine (Table 3).

EGGS

Butterfish eggs have been reported in the Gulf of Maine, on Georges Bank, in the Middle Atlantic Bight, and off North Carolina (Smith *et al.* 1980; Rotunno 1992; MAFMC 1995; Rotunno and Cowen 1997). They have also been collected in Salem Harbor, MA and Narragansett Bay, RI (Herman 1963; Bourne and Govoni 1988; Elliott and Jiminez 1981), Block Island Sound (Merriman and Sclar 1952), Long Island Sound (Wheatland 1956), Peconic Bay, NY (Ferraro 1980), Raritan Bay, NJ (Croker 1965), and Chesapeake Bay (Lippson and Moran 1974).

During the MARMAP ichthyoplankton survey, butterfish eggs were collected from Cape Hatteras to the northern Gulf of Maine from April through September (Figure 9). Eggs first appeared in ichthyoplankton collections in April; by May, eggs were distributed along the edge of the continental shelf between Cape Hatteras and Georges Bank and inshore in the southern and middle Mid-Atlantic Bight. As water temperatures increased on the shelf, eggs were found progressively closer to the coast from south to north. Eggs were most abundant and most frequently encountered in July; they were most abundant in the Gulf of Maine in August. By September, egg abundance declined dramatically; no eggs were collected from October to March.

In coastal bays and estuaries, butterfish eggs were recorded as far north as Penobscot Bay and as far south as Chesapeake Bay (Stone *et al.* 1994). Eggs were abundant in Narragansett Bay and common in Massachusetts Bay, Cape Cod Bay, Waquoit Bay, Buzzards Bay, Long Island Sound, Gardiners Bay, Great South Bay, and Chesapeake Bay (Table 2a).

LARVAE

Butterfish larvae have been reported from the New York Bight and Georges Bank (Smith *et al*. 1980; Wilk *et al*. 1990; Rotunno 1992; MAFMC 1995; Rotunno and Cowen 1997), in Buzzards Bay, MA (Lux and Wheeler 1992), Narragansett Bay, RI (Herman 1963; Bourne and Govoni 1988; Elliott and Jiminez 1981), Raritan Bay, NJ (Croker 1965), Great Bay, NJ (Able and Fahay 1998), Chesapeake Bay (Lippson and Moran 1974), and in the South Atlantic Bight as far south as Cape Kennedy, FL (Fahay 1975; Powles and Stender 1976; Rotunno 1992; Rotunno and Cowen 1997). Larvae were not abundant in the South Atlantic Bight (< 0.5% of total ichthyoplankton) and did not occur frequently (< 10% of stations in a survey of 73 coastal stations) (Fahay 1975).

During the MARMAP ichthyoplankton survey, butterfish larvae were collected from Cape Hatteras into the Gulf of Maine in every month except December (Figure 10). Larvae first appeared in ichthyoplankton collections in January. From January through April, larvae were collected primarily off Cape Hatteras. In May and June, larvae began to appear along the edge of the continental shelf between Cape Hatteras and Georges Bank and inshore in the southern portion of the Middle Atlantic Bight. As water temperatures increased on the shelf, larvae were found progressively closer to the coast from south to north. Larvae were most abundant and most frequently encountered in July and August across the continental shelf in the Middle Atlantic Bight northward to Georges Bank. The abundance of larvae declined sharply from September through November.

In the coastal bays and estuaries of New England and the mid-Atlantic, butterfish larvae were recorded as far north as Penobscot Bay and as far south as Chesapeake Bay (Stone *et al.* 1994). Larvae were common in Boston Harbor, Waquoit Bay, Buzzards Bay, Narragansett Bay, Long Island Sound, Gardiners Bay, Great South Bay, Great South Bay, and Chesapeake Bay (Table 2a).

JUVENILES

Juvenile butterfish occur from Nova Scotia to the Atlantic and Gulf coasts of Florida, but they are most abundant from the Gulf of Maine to Cape Hatteras (Bigelow and Schroeder 1953; Haedrich 1967; Horn 1970a; Powell *et al*. 1972; Cooley 1978; Scott and Scott 1988; Brodziak 1995; Klein-MacPhee, in review). They occur in the high salinity and mixed salinity zones of most estuaries from the Gulf of Maine to Florida (Table 2a) (Jury *et al.* 1994; Stone *et al.* 1994; Geer and Austin 1997; Murdy *et al*. 1997).

During the NEFSC Bottom trawl survey, juvenile butterfish were collected from the northern Gulf of Maine south to Cape Lookout, South Carolina (Figure 11). During the winter and spring, juveniles were collected along the outer continental shelf from southern New England to Cape Hatteras and along the coast near Cape Hatteras. During the summer, juvenile butterfish were collected near the coast throughout the Middle Atlantic Bight and on Georges Bank. During the fall, they were abundant across the shelf throughout the Middle Atlantic Bight and on Georges Bank.

Juvenile butterfish were collected in spring and fall by the Massachusetts Trawl Survey, but catches were 1-2 orders of magnitude greater in the fall (Figure 12). During the Southeast Area Monitoring and Assessment Program-South Atlantic (SEAMAP-SA) bottom trawl survey, juvenile butterfish were collected from Cape Lookout, South Carolina to Cape Kennedy, Florida (Figure 13). Catches were smallest during the winter and largest during the summer.

In the coastal bays and estuaries of New England and the mid-Atlantic, juvenile butterfish were recorded from Passamaquoddy Bay, Maine south to the James River in Virginia (Table 2a) (Stone *et al.* 1994). South of Cape Hatteras, juveniles occurred in bays and estuaries in South Carolina, Georgia, and Florida (Table 2a). Juveniles were abundant in Buzzards Bay, Narragansett Bay, and Long Island Sound, and common in most of the remaining bays and estuaries between Massachusetts Bay and Chesapeake Bay.

In Narragansett Bay, juvenile butterfish were collected in all seasons, but they were rare in winter and spring; they were most abundant in summer when they occurred throughout the bay (Figure 14). In Long Island Sound, butterfish appeared in May; abundance peaked in September-October and declined in November (Figure 15). Juveniles composed 17% of all butterfish caught in May, 91% in September-October, and 73% in November. Juveniles appear in surf zone off Long Island in July and are common from August through October (Schaefer 1967). In the Hudson-Raritan estuary, juveniles were caught in trawls from spring through fall (Figure 16).

ADULTS

Adult butterfish have been reported from Newfoundland to the Atlantic and Gulf coasts of Florida, but they are most abundant from the Gulf of Maine to Cape Hatteras (Bigelow and Schroeder 1953; Haedrich

1967; Horn 1970a; Powell *et al.* 1972; Cooley 1978; Scott and Scott 1988; Brodziak 1995; Klein-MacPhee, in review). They have been collected in high salinity and mixed salinity zones of most estuaries from the Gulf of Maine to Florida (Tables 2a, b) (Hildebrand and Schroeder 1928; DuPaul and McEachran 1973; Wilk and Silverman 1976b; Jury *et al.* 1994; Stone *et al.* 1994; Geer and Austin 1997; Murdy *et al.* 1997).

During the NEFSC bottom trawl survey, adult butterfish were collected from the northern Gulf of Maine south to below Cape Lookout, South Carolina (Figure 11). During the winter and spring, they were distributed along the outer continental shelf from southern New England to Cape Hatteras; they occurred along the coast from Cape Hatteras to Maryland. During the summer, adult butterfish were collected across the shelf throughout the Middle Atlantic Bight, on Georges Bank, and in the coastal Gulf of Maine. During the fall, they were abundant on the shelf throughout the Middle Atlantic Bight, on Georges Bank, and in Massachusetts Bay.

In the Massachusetts Trawl Survey, adult butterfish were collected in the spring primarily south of Cape Cod and in Buzzards Bay, and in the fall primarily in Buzzards Bay, Massachusetts Bay, and around Cape Ann (Figure 12). During the SEAMAP-SA bottom trawl survey, adult butterfish were collected from Cape Lookout, South Carolina to Cape Kennedy, Florida (Figure 13). The size of the catches was similar throughout the year. Butterfish are present in nearshore waters off South Carolina throughout most of the year (Keiser 1976).

In the coastal bays and estuaries of New England and the mid-Atlantic, adult butterfish were recorded from Passamaquoddy Bay in Maine south to the James River in Virginia (Jury *et al.* 1994; Stone *et al.* 1994). South of Cape Hatteras, adults occurred in bays and estuaries in South Carolina, Georgia, and Florida (Table 2a, b). Adults were abundant in Buzzards Bay, Narragansett Bay, and Long Island Sound, and common in most of the remaining bays and estuaries between Massachusetts Bay and Chesapeake Bay (Table 2b). Spawning adults were recorded from Massachusetts Bay south to the Chesapeake Bay, but were common only in Long Island Sound, Gardiners Bay, Great South Bay, and Chesapeake Bay (Table 2b).

In Narragansett Bay, adult butterfish were collected in all seasons, but they were rare in winter and spring; they were most abundant in summer when they occurred throughout the bay (Figure 14). In Long Island Sound, butterfish appeared in May; abundance peaked in September-October and declined in November (Figure 15; Wheatland 1956). Adults composed 83% of all butterfish caught in May, 9% in September-October, and 27% in November. Adults appear in the surf zone off Long Island in May and are common from June through October (Schaefer 1967). Butterfish were among the most abundant species in both of these Long Island surveys. In the Hudson-Raritan estuary, adults were caught from spring through fall (Figure 16).

STATUS OF THE STOCKS

A fishery for butterfish has existed since the late 1800s (Murawski and Waring 1979); from 1920 to 1962, the average annual landings in US waters were 3,000 mt (Waring 1975). In 1963, distant water fleets from Japan, Poland, and the USSR began targeting butterfish from late autumn through early spring when the fish were concentrated offshore (Murawski and Waring 1979; MAFMC 1995). Annual landings increased to a record 19,500 mt in 1973 (Figure 17) (Brodziak 1995). Restrictions were placed on the foreign fisheries and landings subsequently decreased to an average of 6,100 mt from 1977 to 1987. Directed foreign fishing was halted in 1987 and landings continued to decline to an average 2,500 mt in the domestic fishery from 1987 to 1992 (Brodziak 1995; MAFMC 1995). The domestic fishery targeted butterfish from late spring through fall in inshore areas (Murawski and Waring 1979). Butterfish landings totaled 4,500 mt in 1993 and came primarily from southern New England (79% in Rhode Island ports) and the New York Bight. These landings were 60% higher than landings in 1992 and were comparable with record domestic catches in 1987 (Brodziak 1995).

Butterfish biomass estimated from the Northeast Fisheries Science Center bottom trawl surveys has made several record lows and near record highs in the last decade (Figure 17). Despite seasonal increases in biomass and pre-recruit indices, butterfish stock size has decreased and commercial landings remain low (Northeast Fisheries Science Center 1994). Although the demand for butterfish has declined in recent years, the capacity for increased landings remains in an under-exploited fishery (Brodziak 1995). The butterfish stock is not overfished nor approaching an overfished condition (National Marine Fisheries Service 1997).

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Table 1. Summary of life history and habitat characteristics for butterfish, *Peprilus triacanthus.* *

Life Stage	Geographic Location	Habitat	Substrate	Temperature	Salinity
Eggs (0.68-0.82 mm diameter)	Cape Sable, Nova Scotia to Florida; in spring along edge of continental shelf from Georges Bank to Cape Hatteras; found progressively closer to coast from south to north as water temperatures increase. Commonly occur in the saline parts of bays and estuaries from MA to NY and Chesapeake Bay in spring and summer.	Surface waters from continental shelf into estuaries and bays; collected to about 60 m deep in shelf waters. Common in high salinity zone of estuaries and bays from MA through VA. MARMAP Survey: collected in surface waters in 10-1250 m of water.		Literature: 12.8-22.5ºC; MARMAP Survey: 6-26ºC; most eggs collected between 11-17ºC	Estuarine to full seawater; about 25-33 ppt
Larvae (2.6-16 mm SL)	Cape Sable, Nova Scotia to Cape Kennedy, FL; most abundant in central Middle Atlantic Bight in summer, but absent in the winter. Commonly occur in bays and estuaries from MA to NY and Chesapeake Bay in summer and fall.	Surface waters from continental shelf into estuaries and bays; collected to about 60 m deep in shelf waters; common in high salinity zone of estuaries and bays; may spend day deeper in the water column and migrate to the surface at night. MARMAP Survey: collected in surface waters in water 10-1750 m deep.		Literature: 4.4-27.9ºC. MARMAP Survey: 7-26ºC; most eggs collected between 9-19ºC	6.4-37.4 ppt
Juveniles (16 mm SL-120 mm FL)	Cape Sable, Nova Scotia to Florida; most abundant in Middle Atlantic Bight in summer and near the edge of continental shelf in winter. Commonly occur in bays and estuaries from MA to VA from spring through fall; less abundant in bays and estuaries in the Gulf of Maine and in the South Atlantic Bight.	From surface waters to depth on continental shelf; into coastal bays and estuaries; common in inshore areas, including the surf zone, and in high salinity and mixed salinity zones of bays and estuaries. NEFSC Trawl Survey: collected on continental shelf in 10-330 m of water; most collected in < 120 m	Larger individuals found over sandy and muddy substrates.	4.4-29.7ºC; survival reduced below 10ºC	3.0-37.4 ppt
Adults (> 120 mm FL)	Cape Sable, Nova Scotia to Florida; most abundant inshore in Middle Atlantic Bight in summer and near the edge of continental shelf in winter; most abundant north of Cape Cod in summer and fall; commonly occur in bays and estuaries from MA to VA from spring through fall; less abundant in bays and estuaries in the Gulf of Maine and in the South Atlantic Bight; do not migrate far offshore in South Atlantic Bight.	From surface waters to depths of 270-420 m on continental shelf; into coastal bays and estuaries; common in inshore areas, including the surf zone, and in high salinity and mixed salinity zones of bays and estuaries. NEFSC Trawl Survey: collected on continental shelf in 10-360 m of water; most collected in < 180 m.	Schools found over sandy, sandy-silt, and muddy substrates.	4.4-26.0ºC; survival reduced below 10ºC	3.8-33.0 ppt
Spawning Adults	At least the Gulf of Maine to the South Atlantic Bight (SAB); most abundant in Middle Atlantic Bight; in SAB between Cape Hatteras and Cape Kennedy. Common in Long Island Sound, some Long Island bays, and Chesapeake Bay in spring and summer. In NY Bight, caught from May-August.	Spawning occurs on continental shelf, inshore areas, and in bays and estuaries (rarely in bays and estuaries north of Cape Cod). Spawning adults common in Long Island Sound and bays and estuaries of Long Island. In NY Bight, caught between 3-145 m.		Spawning does not occur at < 15ºC	

Table 1. cont'd.

Life Stage	Dissolved Oxygen	Light	Currents	Prey	Predators	Notes
Eggs (0.68-0.82 mm diameter)						Incubation period 2-3 days. Salinity range based on 78-100% seawater (Martin and Drewry, 1978) assuming seawater at 33 ppt.
Larvae (2.6-16 mm SL)						More nektonic than planktonic by 10-15 mm.
Juveniles (16 mm SL-120 mm FL)	Hudson-Raritan Bay: 3-9 mg/l; most 5-8 mg/l	Larger juveniles are pelagic schoolers; may congregate near bottom during day and disperse upward at night.		Feed mainly on planktonic prey, including thaliaceans, squids, copepods, amphipods, decapods, coelenterates, polychaetes, small fishes, and ctenophores.	Preyed on by haddock, silver hake, bluefish, swordfish, weakfish, goosefish, sharks, and long-finned squid	Smaller juveniles may associate with floating objects including jellyfish and inanimate objects.
Adults (> 120 mm FL)	Abundance declines in Long Island Sound at 2.0-2.9 mg/l. Hudson-Raritan Bay: 3-10 mg/l; most 6-9 mg/l.			Feed mainly on planktonic prey, including thaliaceans, squids, copepods, amphipods, decapods, coelenterates, polychaetes, small fishes, and ctenophores.	Preyed on by haddock, silver hake, bluefish, swordfish, weakfish, goosefish, sharks, skates, and long-finned squid	Median size of sexual maturity 120 mm FL based on O'Brien *et al.* (1993).
Spawning Adults						Spawning occurs July-October on Scotian Shelf, May-August in Gulf of Maine, May-October in Middle Atlantic Bight (peak June-August), January-April off Cape Hatteras (peak in March), and year round in South Atlantic Bight (peak in spring).

*In addition to the citations mentioned in the text, the following references were used to compile Table 1: Austin 1973, 1976; Berrien *et al*. 1978; Colton *et al*. 1979; Edwards *et al*. 1962; Lang 1974; Lessard 1974; Obenchain 1981; Wilk and Silverman 1976a; Wilk *et al*. 1977.

Table 2a. Relative abundance of eggs, larvae, and juvenile butterfish (*Peprilus triacanthus*) in New England and Mid-Atlantic estuaries by salinity zone [based on Estuarine Living Marine Resources (ELMR) data in Stone *et al.* 1994]. Salinity zone: T = tidal fresh, M = mixing zone, S = seawater, • = salinity zone not present. Relative abundance: H = highly abundant, A = abundant, C = common, R = rare, blank = not present, na = no data available.

	Eggs			**Larvae**			**Juveniles**		
	T	**M**	**S**	**T**	**M**	**S**	**T**	**M**	**S**
Passamaquoddy Bay		na	na		na	na		R	R
Englishman/Machias Bays								R	R
Narraguagus Bay								R	R
Blue Hill Bay								R	R
Penobscot Bay		R	R		R	R		R	R
Muscongus Bay								R	R
Damariscotta River								R	R
Sheepscot River								R	R
Kennebec/Androscoggin Rivers								R	R
Casco Bay								R	R
Saco Bay								R	R
Wells Harbor	•			•			•		
Great Bay		R	R		R	R		R	R
Merrimack River		R	•		R	•		R	•
Massachusetts Bay	•	•	C	•	•	R	•	•	C
Boston Harbor	•		C	•		C	•		R
Cape Cod Bay	•		C	•		R	•	C	C
Waquoit Bay		R	C		R	C		R	C
Buzzards Bay		R	C		R	C		C	H
Narragansett Bay		R	H		R	C		C	H
Long Island Sound			C			C	R	H	A
Connecticut River								C	
Gardiners Bay			C			C			C
Great South Bay, NY			C			C		R	C
Hudson River/Raritan Bay			R	R	C	R	R	C	C
Barnegat Bay, NJ						R		C	C
New Jersey Inland Bays						R		C	C

Table 2a cont’d.

	Eggs			**Larvae**			**Juveniles**		
	T	**M**	**S**	**T**	**M**	**S**	**T**	**M**	**S**
Delaware Bay			R			C		C	C
Delaware Inland Bays									C
Chincoteague Bay									
Chesapeake Bay Mainstream		C	C		C	C		C	C
Chester River									
Coptank River								R	
Patuxent River								R	
Potomac River								R	
Tangier/Pocomoke Sound								R	
Rappahannock River								R	
York River, VA								C	
James River, VA								C	
South Atlantic estuaries – see below									

Butterfish occur in estuaries between North Carolina and Florida, but this species was not included in the ELMR survey of the southeast estuaries (Nelson *et al.* 1991). Information on their occurrence in South Atlantic estuaries is presented below.

North Carolina

- Cape Fear River estuary: butterfish < 0.05% of all fishes caught (Schwartz *et al.* 1979)

South Carolina

- Winyah Bay estuary: butterfish (50-110 mm TL) collected in lower and middle estuary; < 1% of all fishes caught (Wenner *et al*. 1981)
- Charleston Harbor estuary system: occur in Charleston Harbor and lower reaches of Ashley, Cooper, and Wando rivers; < 0.05% of all fishes collected (Stender and Martore 1990)

Georgia

- Sapelo Sound: butterfish collected “occasionally” on ocean beaches and in the lower and middle reaches of estuary; did not occur at salinities < 19.5 ppt (Dahlberg 1972).

Florida

- Pensacola Bay: juveniles present in winter, spring, summer; rare to uncommon (Cooley 1978).
- Santa Rosa Sound: juveniles collected in winter, spring, summer; rare to uncommon (Cooley 1978).
- Escambia Bay: juveniles collected in winter, spring, fall; rare to uncommon (Cooley 1978).
- Butterfish recorded from ocean beaches on Atlantic and Gulf coasts (to Mississippi) and in Tampa Bay (Powell *et al*. 1972).

Table 2b. Relative abundance of spawning adult and adult butterfish (*Peprilus triacanthus*) in New England and Mid-Atlantic estuaries by salinity zone [based on Estuarine Living Marine Resources (ELMR) data in Stone *et al.* 1994]. Salinity zone: T = tidal fresh, M = mixing zone, S = seawater, • = salinity zone not present. Relative abundance: H = highly abundant, A = abundant, C = common, R = rare, blank = not present, na = no data available.

	Spawning Adults			**Adults**		
	T	**M**	**S**	**T**	**M**	**S**
Passamaquoddy Bay					R	R
Englishman/Machias Bays					R	R
Narraguagus Bay					R	R
Blue Hill Bay					R	R
Penobscot Bay					R	R
Muscongus Bay					R	R
Damariscotta River					R	R
Sheepscot River					R	R
Kennebec/Androscoggin Rivers					R	R
Casco Bay					R	R
Saco Bay					R	R
Wells Harbor	•			•		
Great Bay					R	R
Merrimack River	•			•	R	
Massachusetts Bay	•	•	R	•	•	C
Boston Harbor	•			•	R	R
Cape Cod Bay	•			•	C	C
Waquoit Bay	•		R	•	R	C
Buzzards Bay	•		R	•	C	H
Narragansett Bay			R		C	A
Long Island Sound			C		A	H
Connecticut River			•		C	•
Gardiners Bay	•		C	•	C	C
Great South Bay, NY	•		C	•	R	C
Hudson River/Raritan Bay					C	C
Barnegat Bay, NJ					R	R
New Jersey Inland Bays						R

Table 2b cont'd.

	Spawning Adults			**Adults**		
	T	**M**	**S**	**T**	**M**	**S**
Delaware Bay			R		R	C
Delaware Inland Bays	●			●		C
Chincoteague Bay	●	●		●	●	
Chesapeake Bay Mainstream		C	C		C	C
Chester River			●			●
Coptank River			●		R	●
Patuxent River			●		R	●
Potomac River			●		R	●
Tangier/Pocomoke Sound	●		●	●	R	●
Rappahannock River			●		R	●
York River, VA			●		C	●
James River, VA			●		C	●
South Atlantic estuaries[1]						

[1] See note at bottom of Table 2a.

Table 3. Abundance of butterfish eggs, larvae, juveniles, adults, and spawning adults in New England and Mid-Atlantic estuaries by month summarized across salinity zones [based on Estuarine Living Marine Resources (ELMR) data in Stone *et al*. 1994]. Maximum abundance: A = abundant, C = common, R = rare, blank = not present.

	Eggs		**Larvae**		**Juveniles**		**Adults**		**Spawning Adults**	
Estuary	months present	max. abun.	months present	max. abun.	months present	max. abun.	months present	max. abun.	months present	max. abun.
Passamaquoddy Bay	------------		------------		-----JJASO--	R	-----JJASO--	R	------------	
Englishman/Machias Bays	------------		------------		-----JJASO--	R	-----JJASO--	R	------------	
Narraguagus Bay	------------		------------		-----JJASO--	R	-----JJASO--	R	------------	
Blue Hill Bay	------------		------------		-----JJASO--	R	-----JJASO--	R	------------	
Penobscot Bay	------JAS---	R	------JAS---	R	-----JJASO--	R	-----JJASO--	R	------------	
Muscongus Bay	------------		------------		-----JJASO--	R	-----JJASO--	R	------------	
Damariscotta River	------------		------------		-----JJASO--	R	-----JJASO--	R	------------	
Sheepscot River	------------		------------		-----JJASO--	R	-----JJASO--	R	------------	
Kennebec/Androscoggin Rivers	------------		------------		-----JJASO--	R	-----JJASO--	R	------------	
Casco Bay	------------		------------		-----JJASO--	R	-----JJASO--	R	------------	
Saco Bay	------------		------------		-----JJASO--	R	-----JJASO--	R	------------	
Wells Harbor	------------		------------		------------		------------		------------	
Great Bay	-----JJAS---	R	-----JJAS---	R	-----JJASO--	R	-----JJASO--	R	------------	
Merrimack River	-----JJA----	R	-----JJA----	R	-----JJAS---	R	-----JJAS---	R	------------	
Massachusetts Bay	-----JJAS---	C	-----JJAS---	R	-----JJASO--	C	-----JJASO--	C	-----JJAS---	R
Boston Harbor	-----JJAS---	C	------JAS---	C	-----JJASO--	R	-----JJASO--	R	------------	
Cape Cod Bay	-----JJASO--	C	------JASO--	R	-----JJASO--	C	-----JJASO--	C	------------	
Waquoit Bay	----MJJA----	C	-----JJASO--	C	----MJJASO--	C	----MJJASO--	C	----MJJAS---	R
Buzzards Bay	----MJJAS---	C	-----JJASO--	C	---AMJJASOND	A	---AMJJASOND	A	-----JJAS---	R
Narragansett Bay	----MJJA----	A	-----JJASO--	C	---AMJJASOND	A	---AMJJASOND	A	----MJJA----	R
Gardiners Bay	----MJJ-----	C	----MJJ-----	C	----MJJASOND	C	----MJJASOND	C	----MJJ-----	C
Long Island Sound	-----JJAS---	C	-----JJASON-	C	----MJJASOND	A	----MJJASOND	A	-----JJAS---	C
Connecticut River	------------		------------		----MJJASOND	C	----MJJASOND	C	------------	
Great South Bay	----MJJ-----	C	----MJJA----	C	----MJJASOND	C	----MJJASOND	C	----MJJ-----	C
Hudson River/Raritan Bay	-----JJA----	R	----MJJASON-	C	---AMJJASON-	C	---AMJJASON-	C	------------	
Barnegat Bay	------------		-----JJA----	R	-----JJASO--	C	----MJJASO--	R	------------	
New Jersey Inland Bays	------------		-----JJA----	R	-----JJASO--	C	------JAS---	R	------------	
Delaware Bay	----MJJ-----	R	----MJJ-----	C	------JASOND	C	----MJJASO--	C	----MJJ-----	R
Delaware Inland Bays	------------		------------		----MJJASON-	C	----MJJASON-	C	------------	
Chincoteague Bay	------------		------------		------------		------------		------------	
Chesapeake Bay	----MJJ-----	C	-----JJA----	C	------JASO--	C	---AMJJASON-	C	----MJJ-----	C
Potomac River	------------		------------		-----JJASO--	R	----MJJASO--	R	------------	
Rappahannock River	------------		------------		------JASON-	R	---AMJJASON-	R	------------	
York River	------------		------------		------JASON-	C	---AMJJASON-	C	------------	
James River	------------		------------		------JASON-	C	---AMJJASON-	C	------------	
Patuxent River	------------		------------		------JAS---	R	-----JJAS---	R	------------	
Chester River	------------		------------		------------		------------		------------	
Choptank River	------------		------------		------JAS---	R	-----JJAS---	R	------------	
Tangier/Pocomoke Sound	------------		------------		------JASO--	R	----MJJASO--	R	------------	

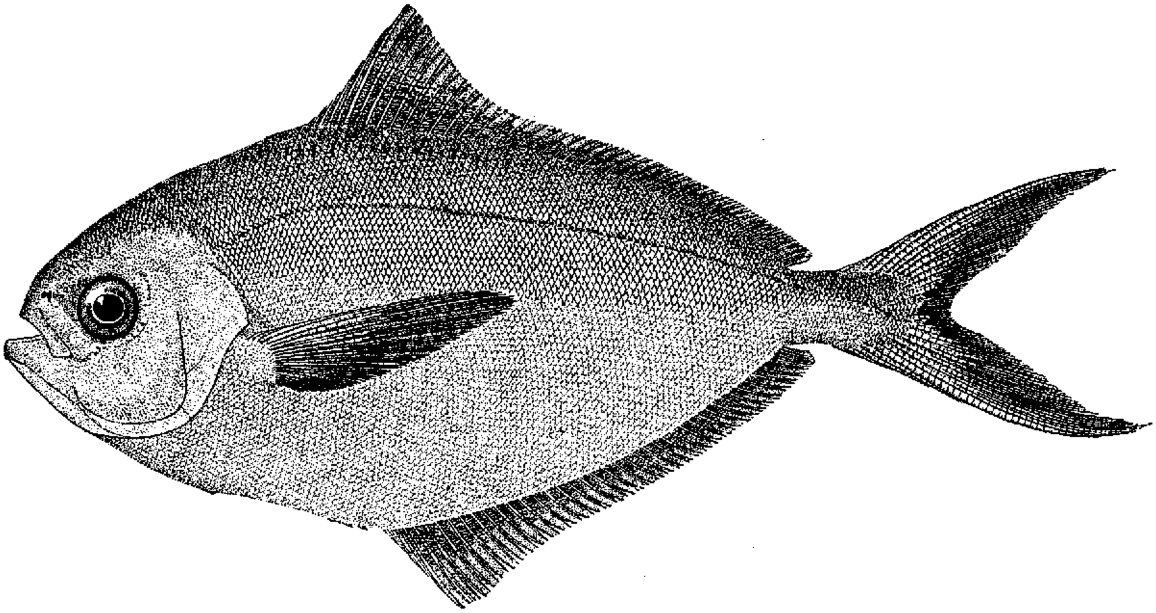


Figure 1. The adult butterfish, *Peprilus triacanthus* (from Goode 1884).

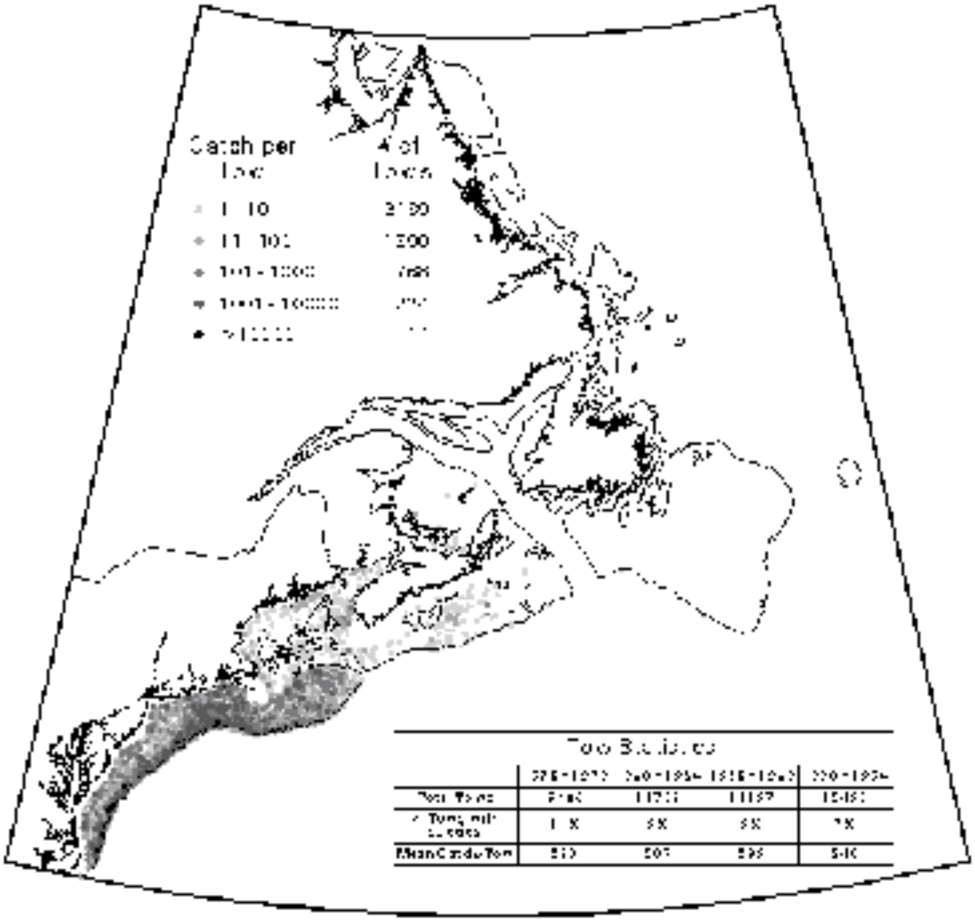


Figure 2. The distribution of butterfish from Newfoundland to Cape Hatteras. Data are from the U.S. NOAA/Canada DFO East Coast of North America Strategic Assessment Project (http://www-orca.nos.noaa.gov/projects/ecnasap/ecnasap_table1.html).

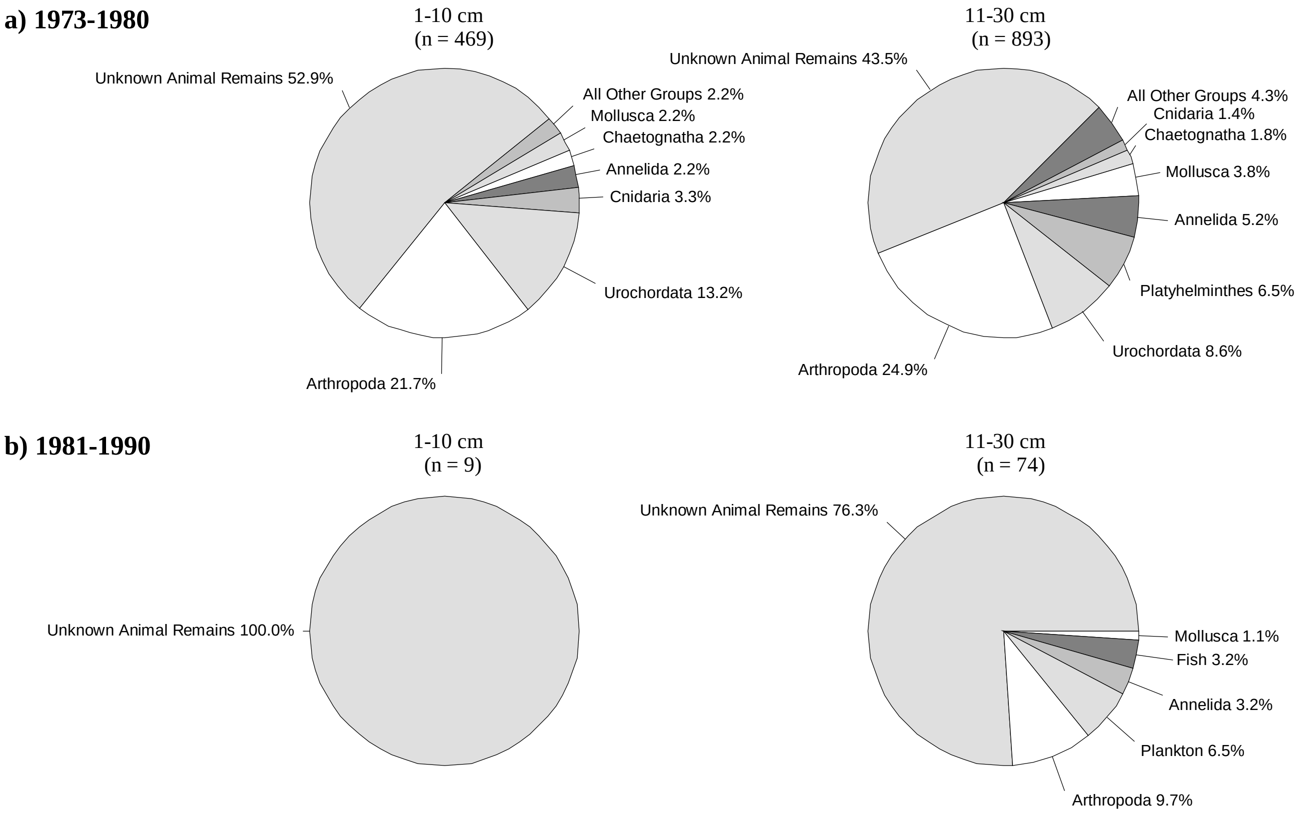


Figure 3. Abundance (percent occurrence) of the major prey items of butterfish collected during NEFSC bottom trawl surveys from 1973-1980 and 1981-1990. The 1-10 cm size range corresponds, at least roughly, to juveniles, and the 11-30 cm size class corresponds to adults. The category “animal remains” refers to unidentifiable animal matter. Methods for sampling, processing, and analysis of samples differed between the time periods [see Reid *et al.* (1999) for details].

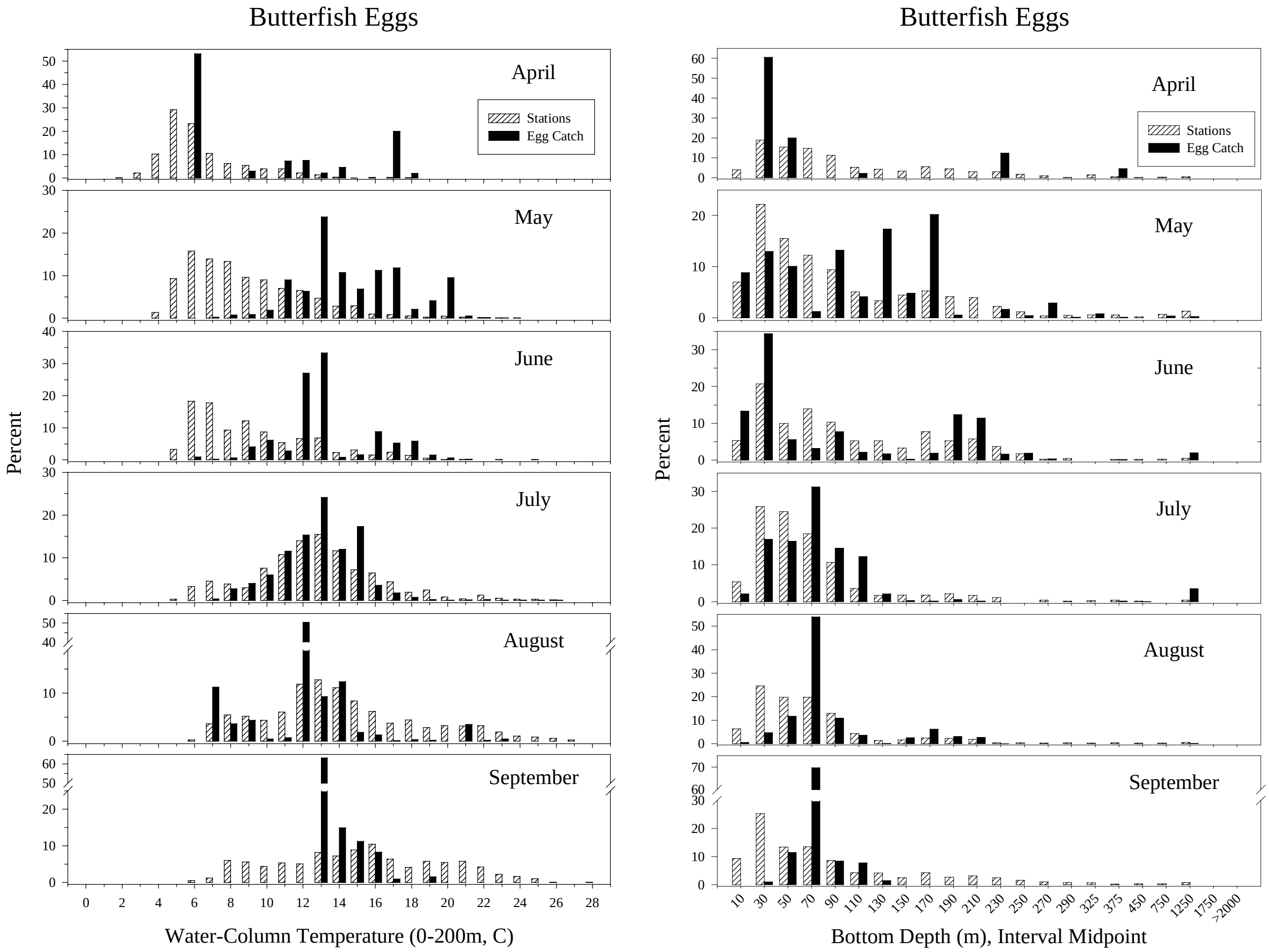


Figure 4. Abundance of butterfish eggs relative to water column temperature (to a maximum of 200 m) and bottom depth from NEFSC MARMAP ichthyoplankton surveys (1978-1987) by month for all years combined. Open bars represent the proportion of all stations surveyed, while solid bars represent the proportion of the sum of all standardized catches (number/10 m^2).

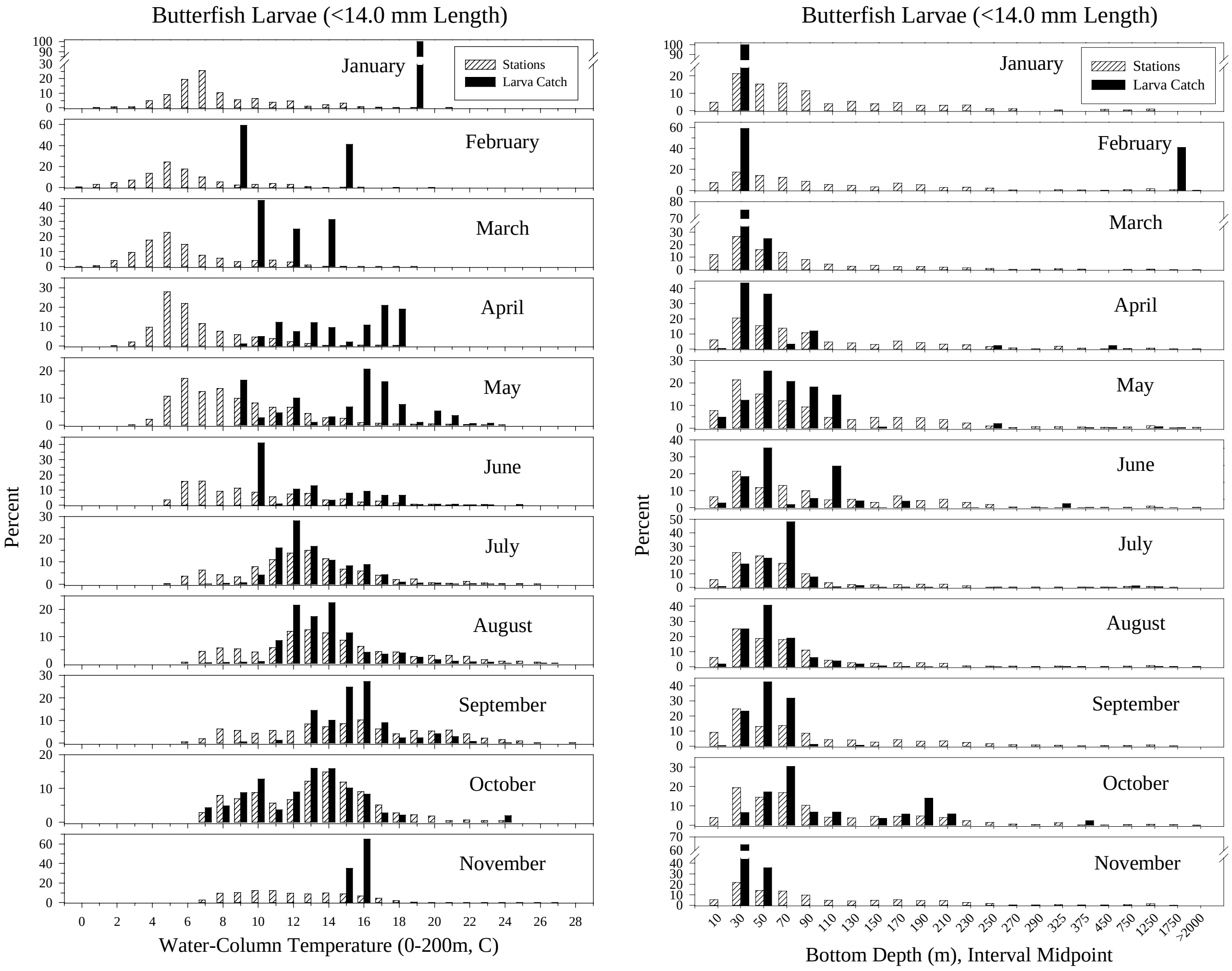


Figure 5. Abundance of butterfish larvae (< 14 mm) relative to water column temperature (to a maximum of 200 m) and bottom depth from NEFSC MARMAP ichthyoplankton surveys (1977-1987) by month for all years combined. Open bars represent the proportion of all stations surveyed, while solid bars represent the proportion of the sum of all standardized catches (number/10 m^2).

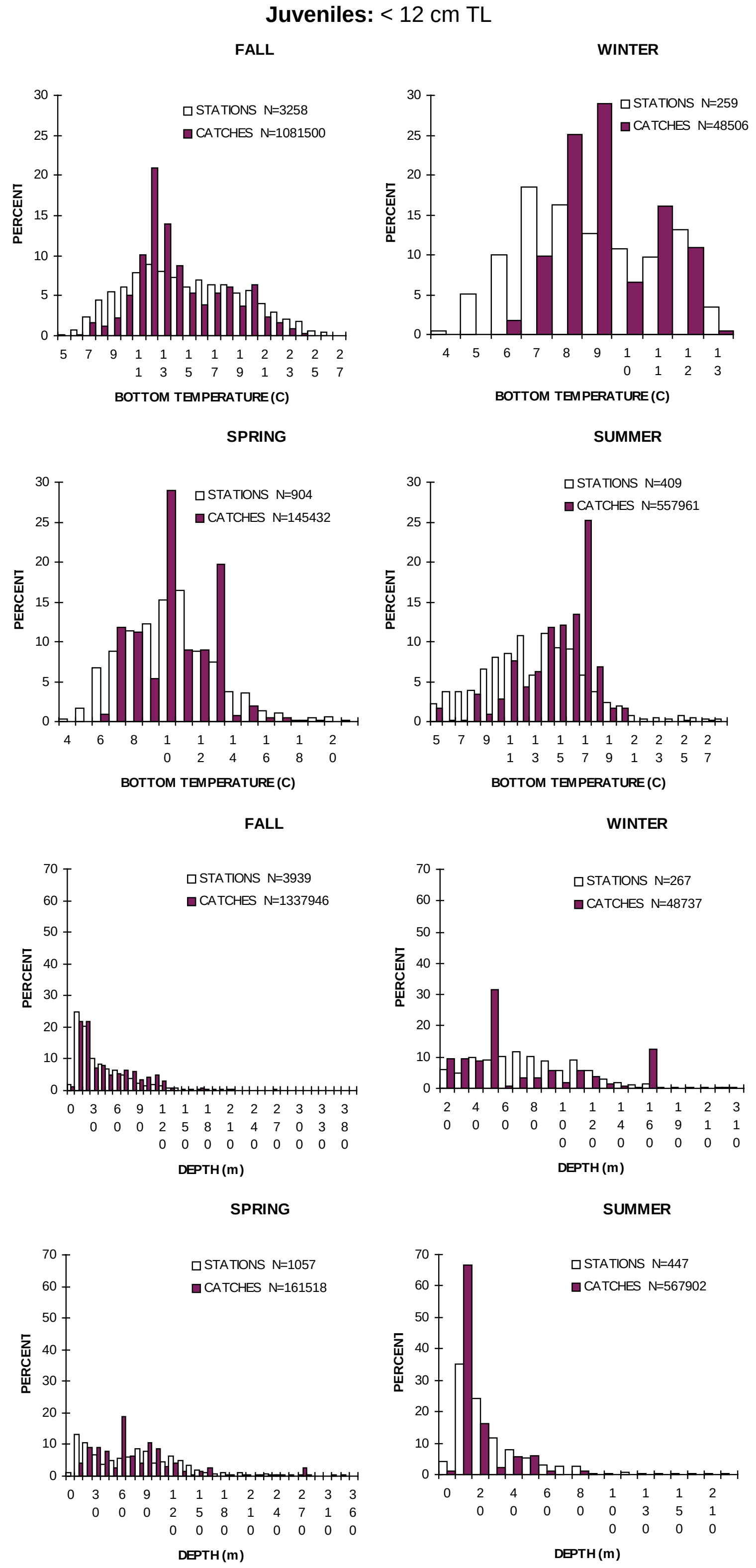


Figure 6. Abundance of juvenile (< 12 cm) and adult (≥ 12 cm) butterfish relative to bottom water temperature and depth based on NEFSC bottom trawl surveys (1963-1997) by season for all years combined. Open bars represent the proportion of all stations surveyed, while solid bars represent the proportion of the sum of all standardized catches (number/10 m^2).

Adults: ≥ 12 cm TL

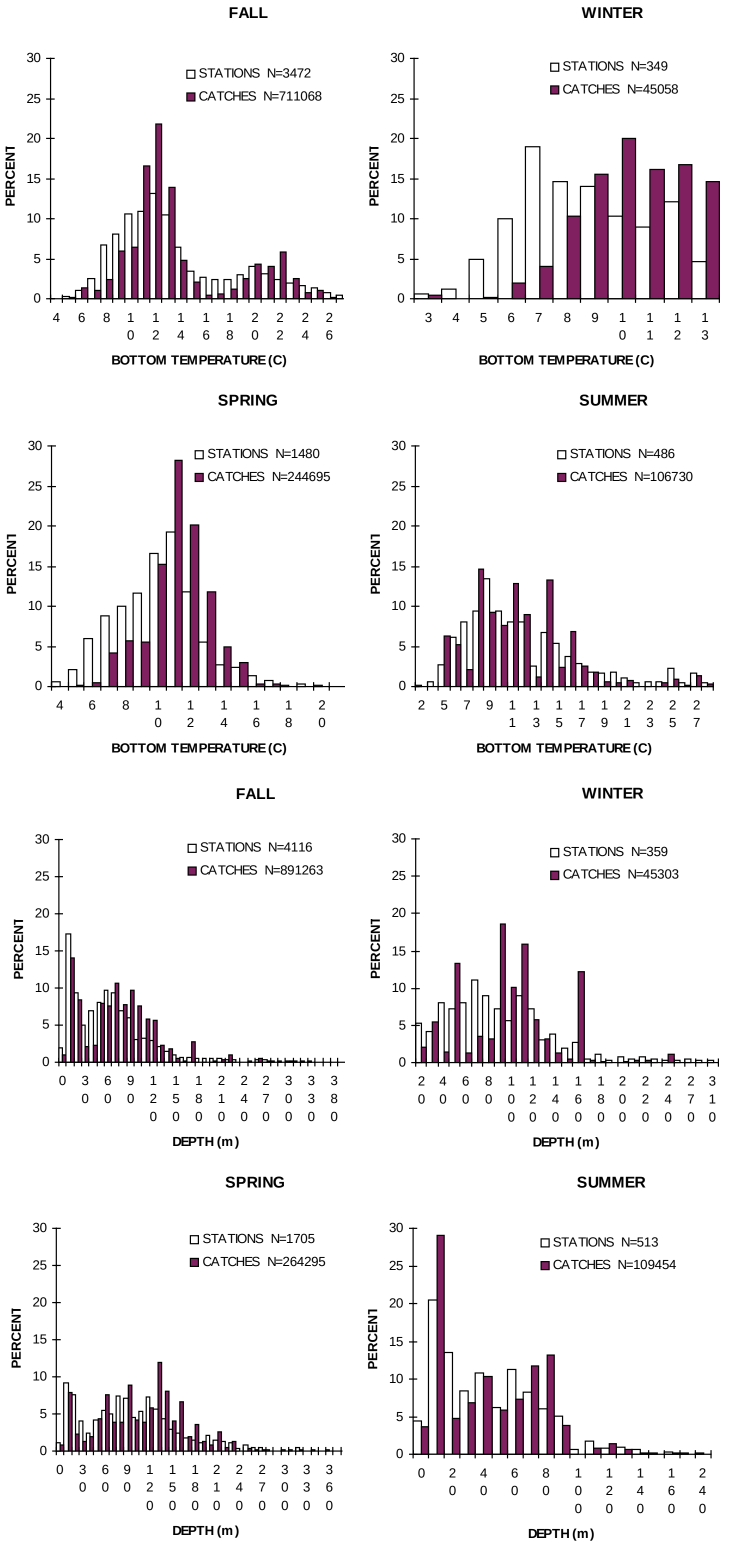


Figure 6. cont'd.

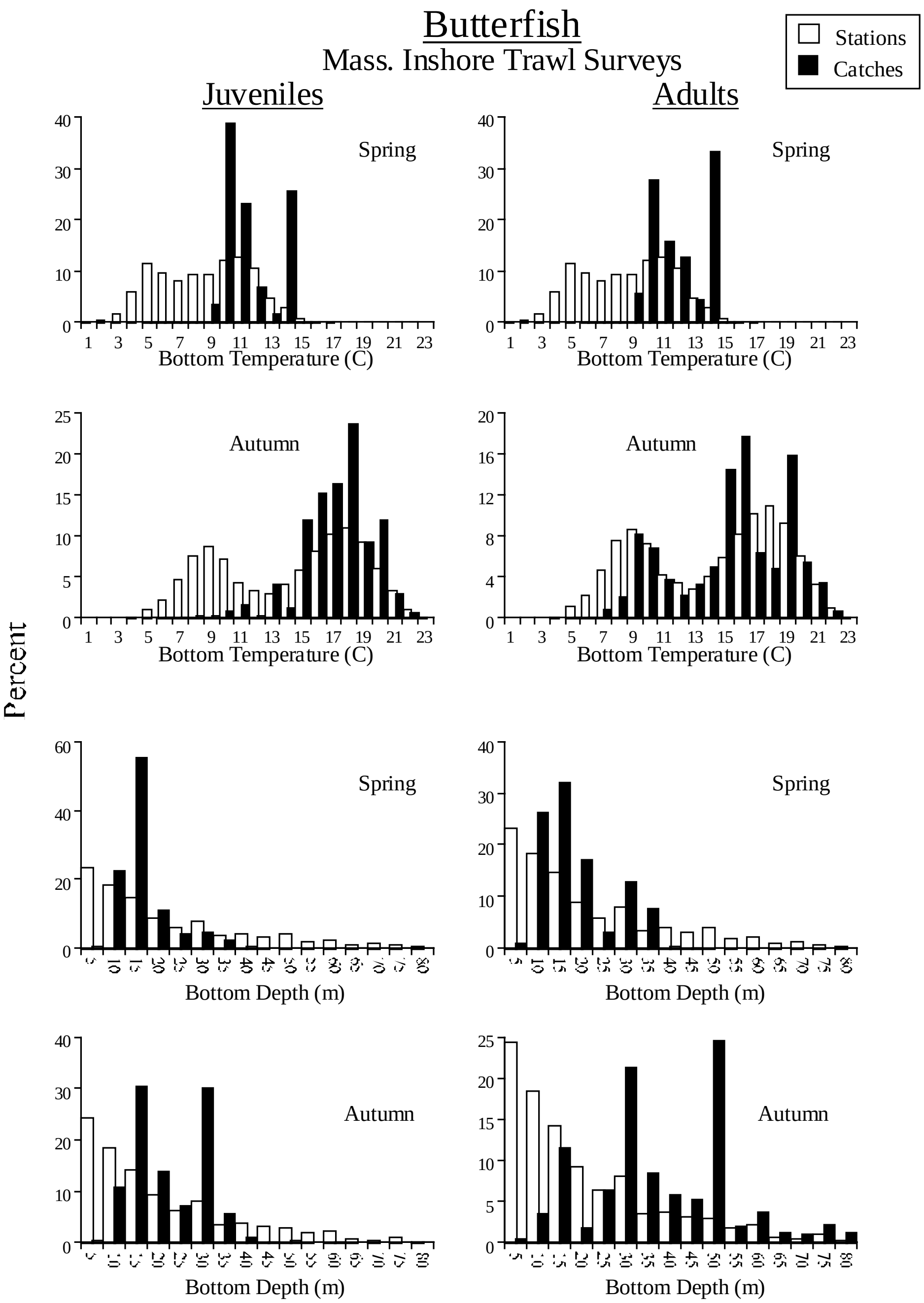
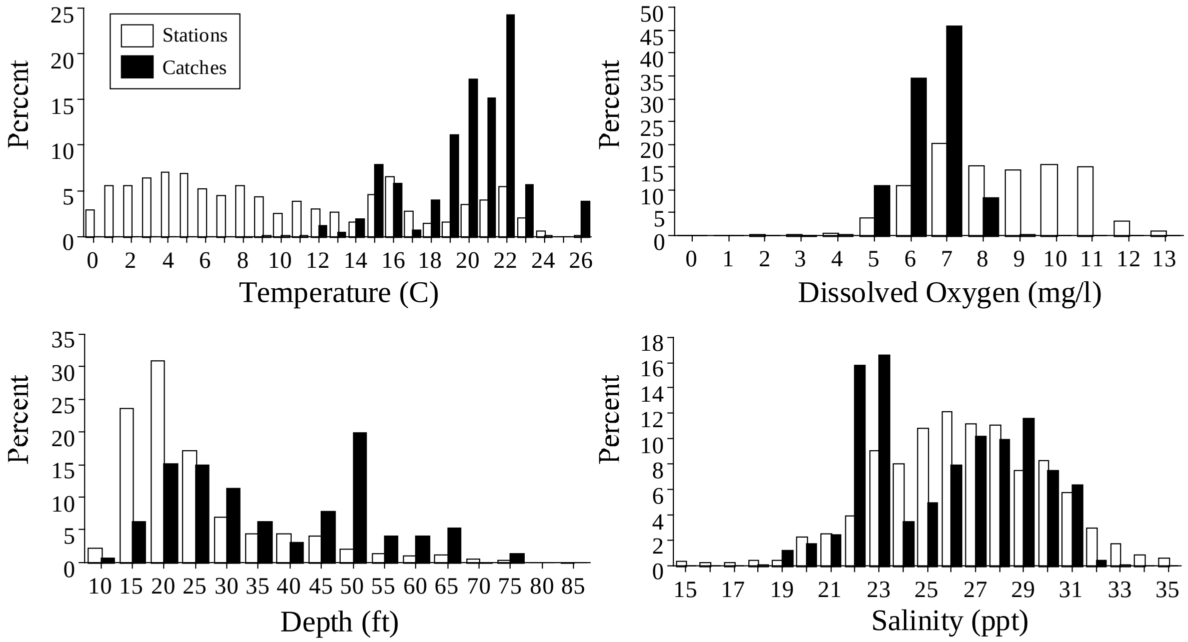


Figure 7. Abundance of juvenile and adult butterfish relative to bottom water temperature and depth based on Massachusetts inshore bottom trawl surveys (spring and autumn 1978-1996, all years combined). Open bars represent the proportion of all stations surveyed, while solid bars represent the proportion of the sum of all standardized catches (number/10 m^2).

Juveniles (<12 cm)



Adults (≥12 cm)

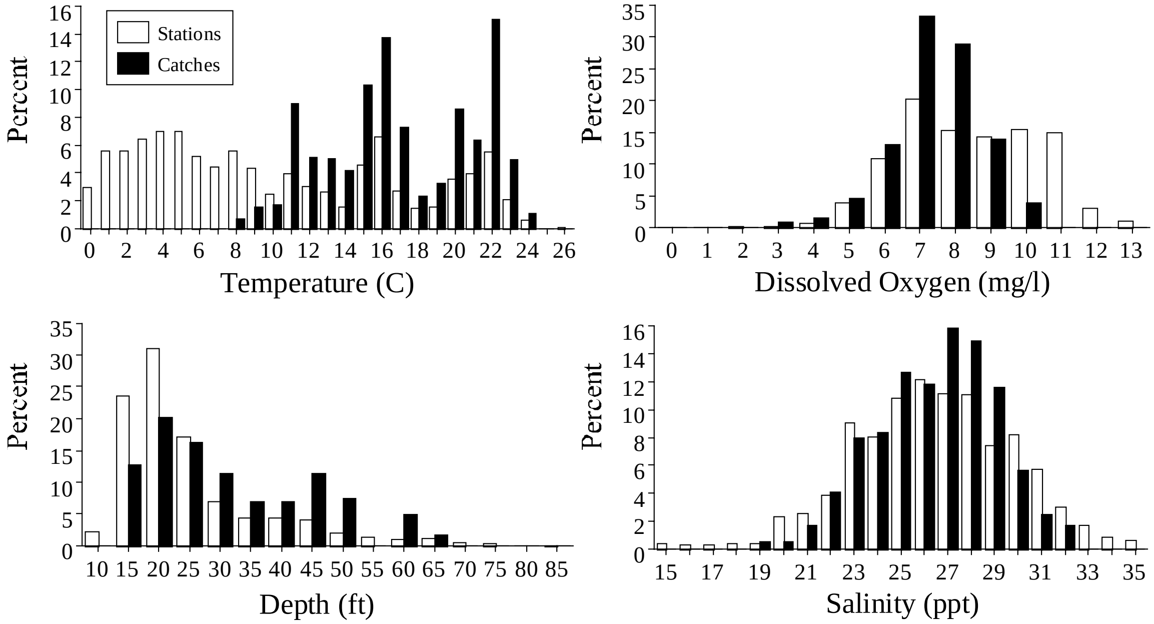


Figure 8. Abundance of juvenile and adult butterfish relative to bottom water temperature, depth, dissolved oxygen and salinity from Hudson-Raritan estuary trawl surveys (1992-1997) for all years combined.

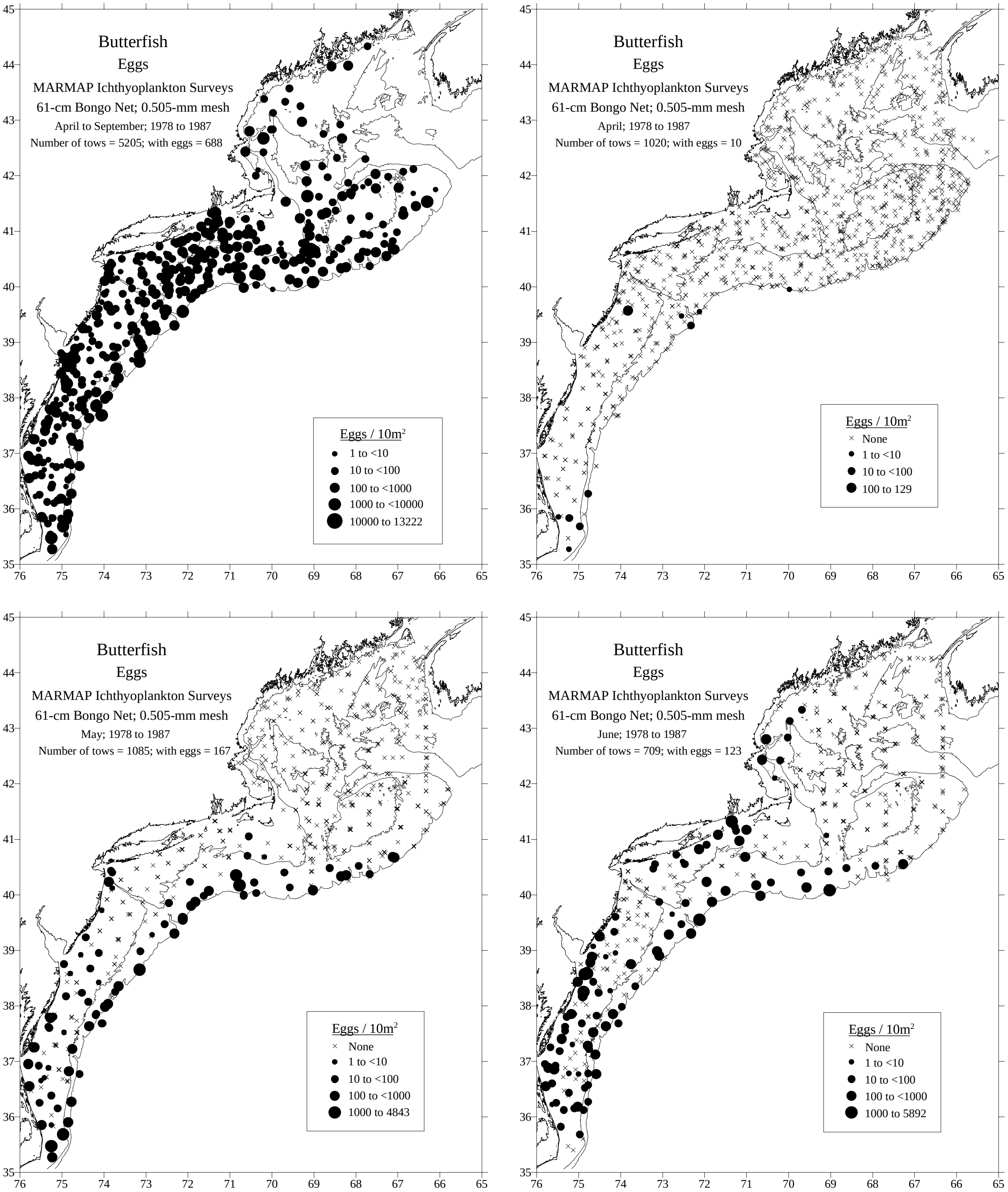
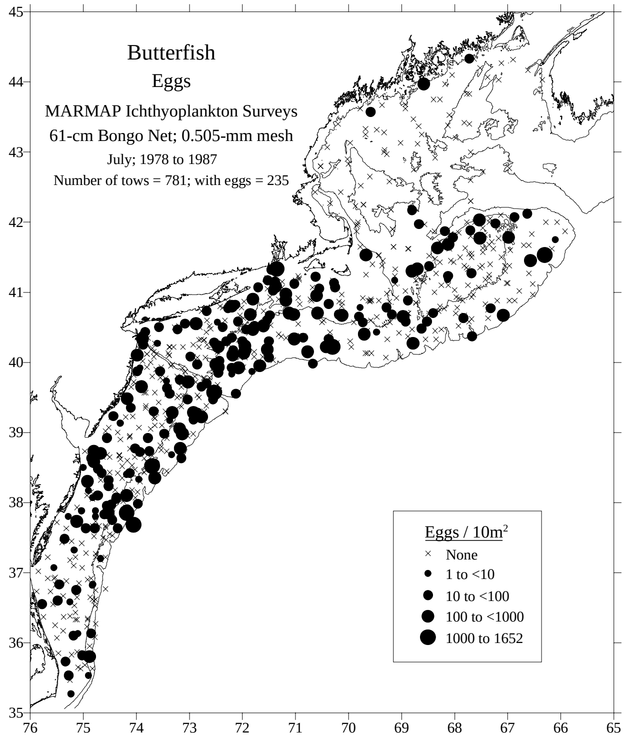
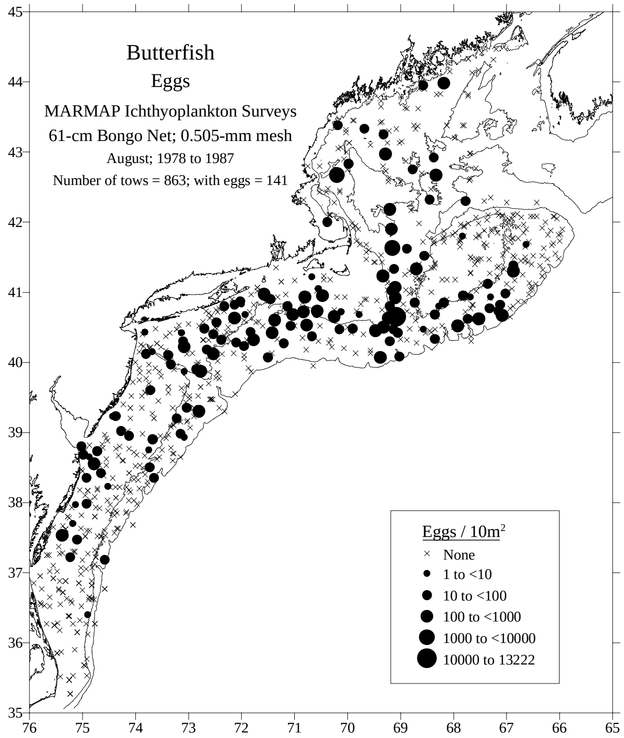
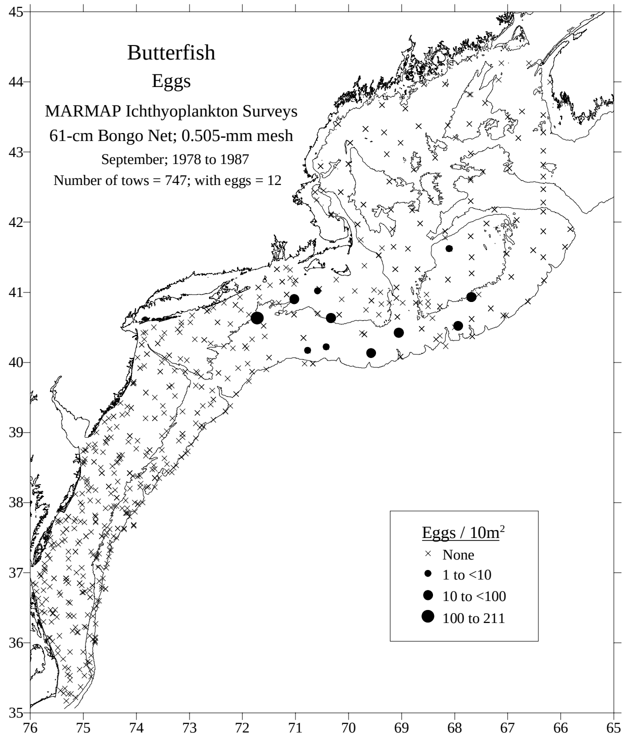


Figure 9. Distribution of butterfish eggs based on NEFSC MARMAP ichthyoplankton surveys from April to September, 1978-1987 [see Reid *et al.* (1999) for details].







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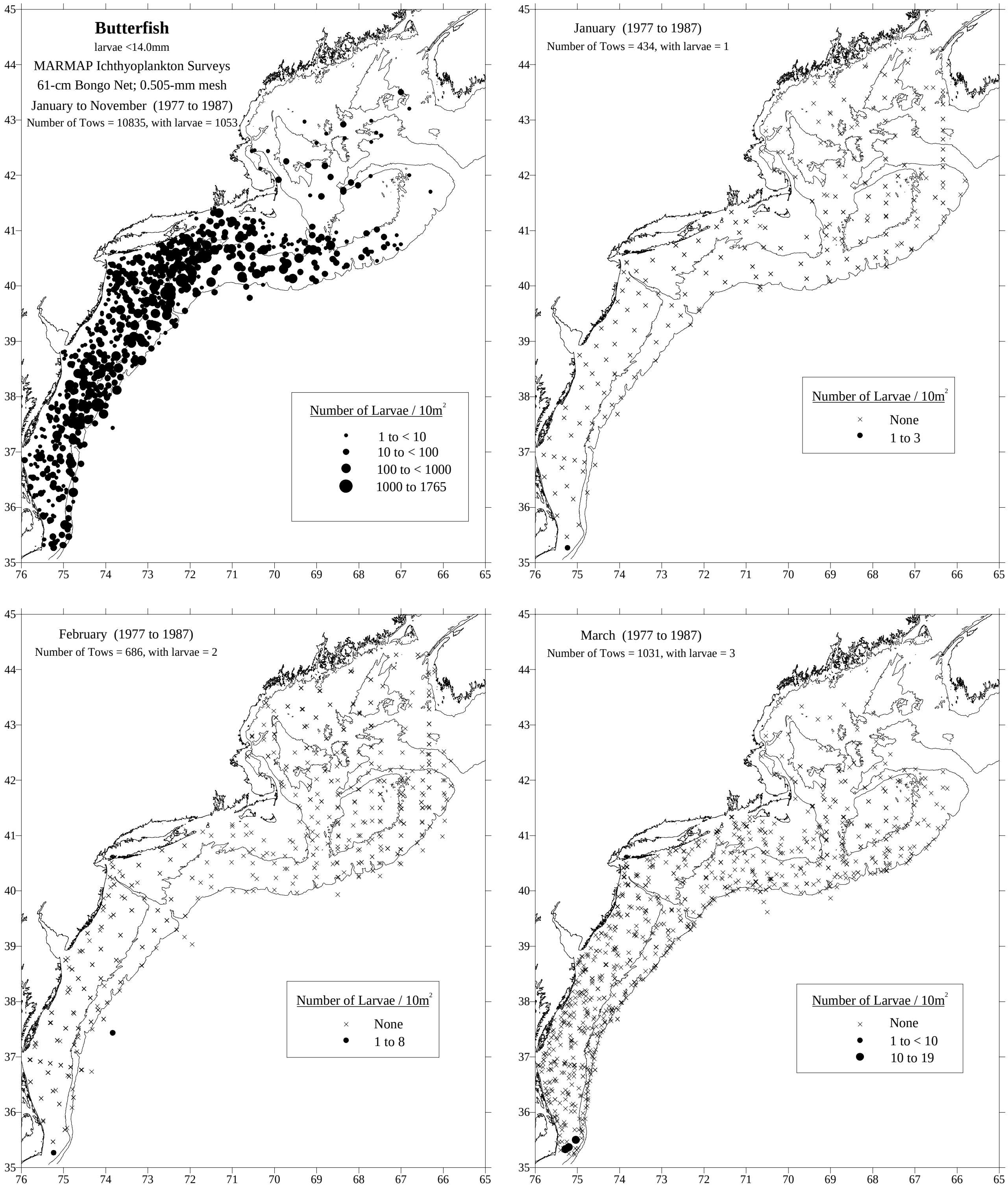
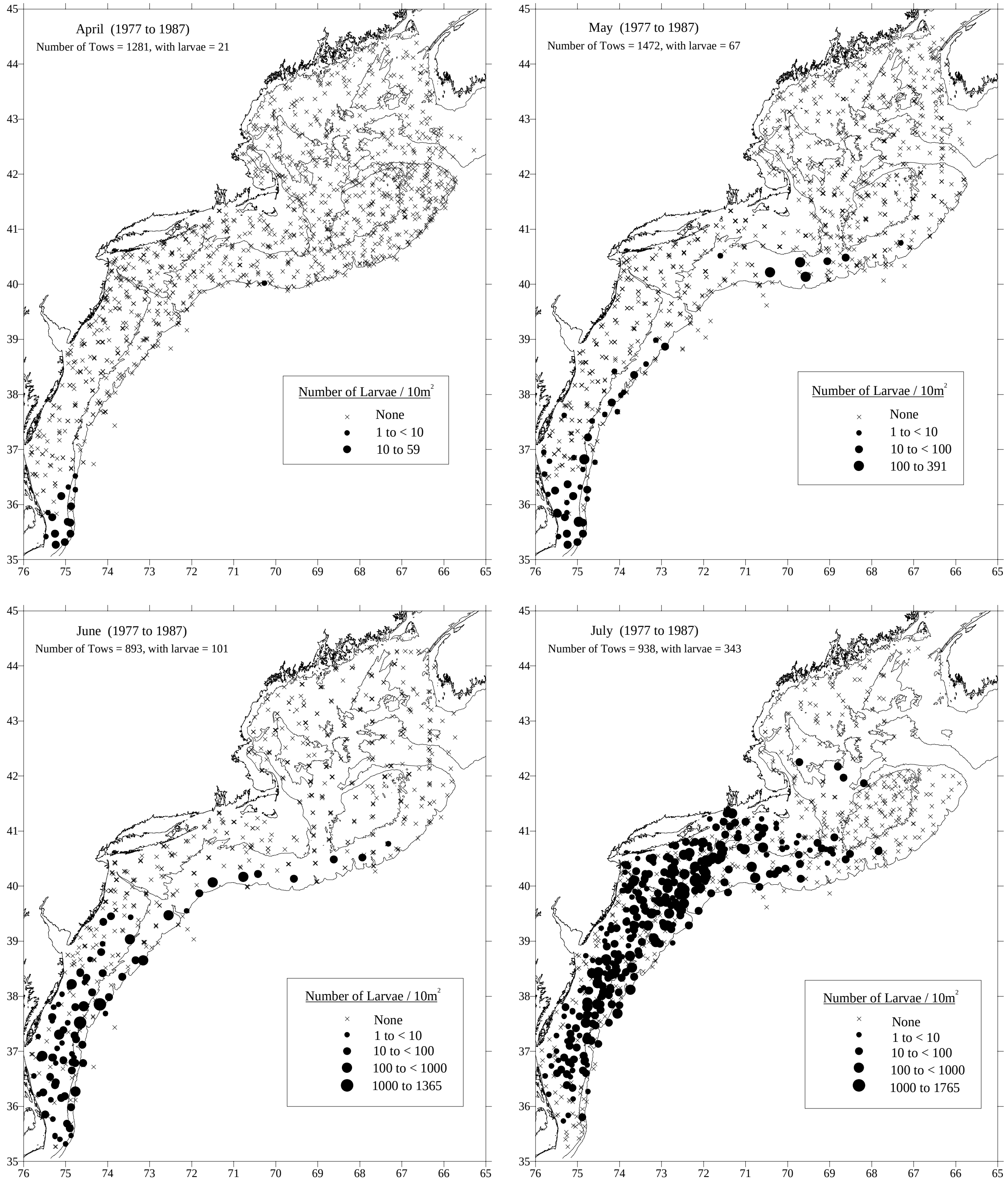


Figure 10. Distribution of butterfish larvae (< 14 mm) collected during NEFSC MARMAP ichthyoplankton surveys from January through November, 1977-1987 [see Reid *et al.* (1999) for details].



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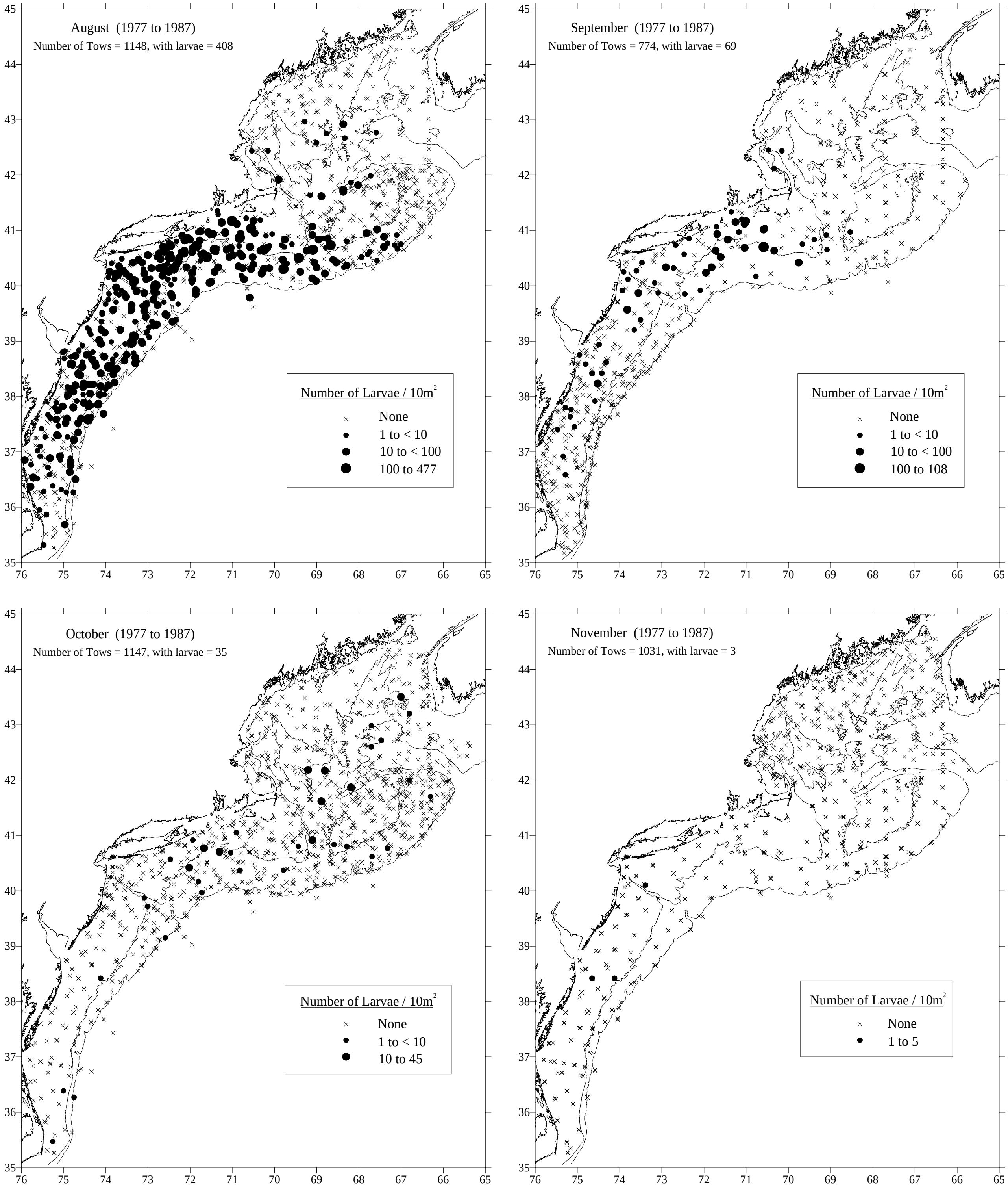

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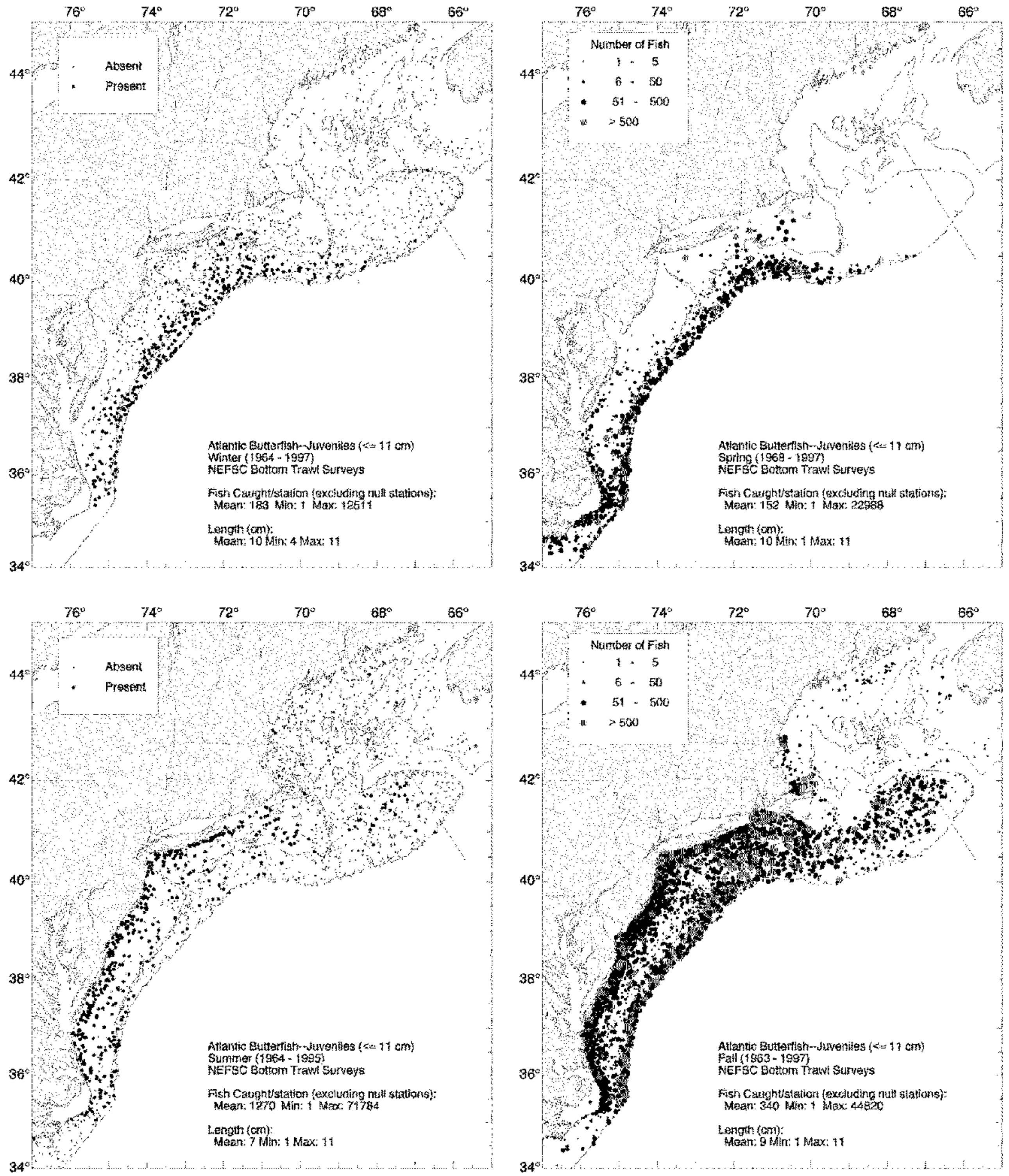
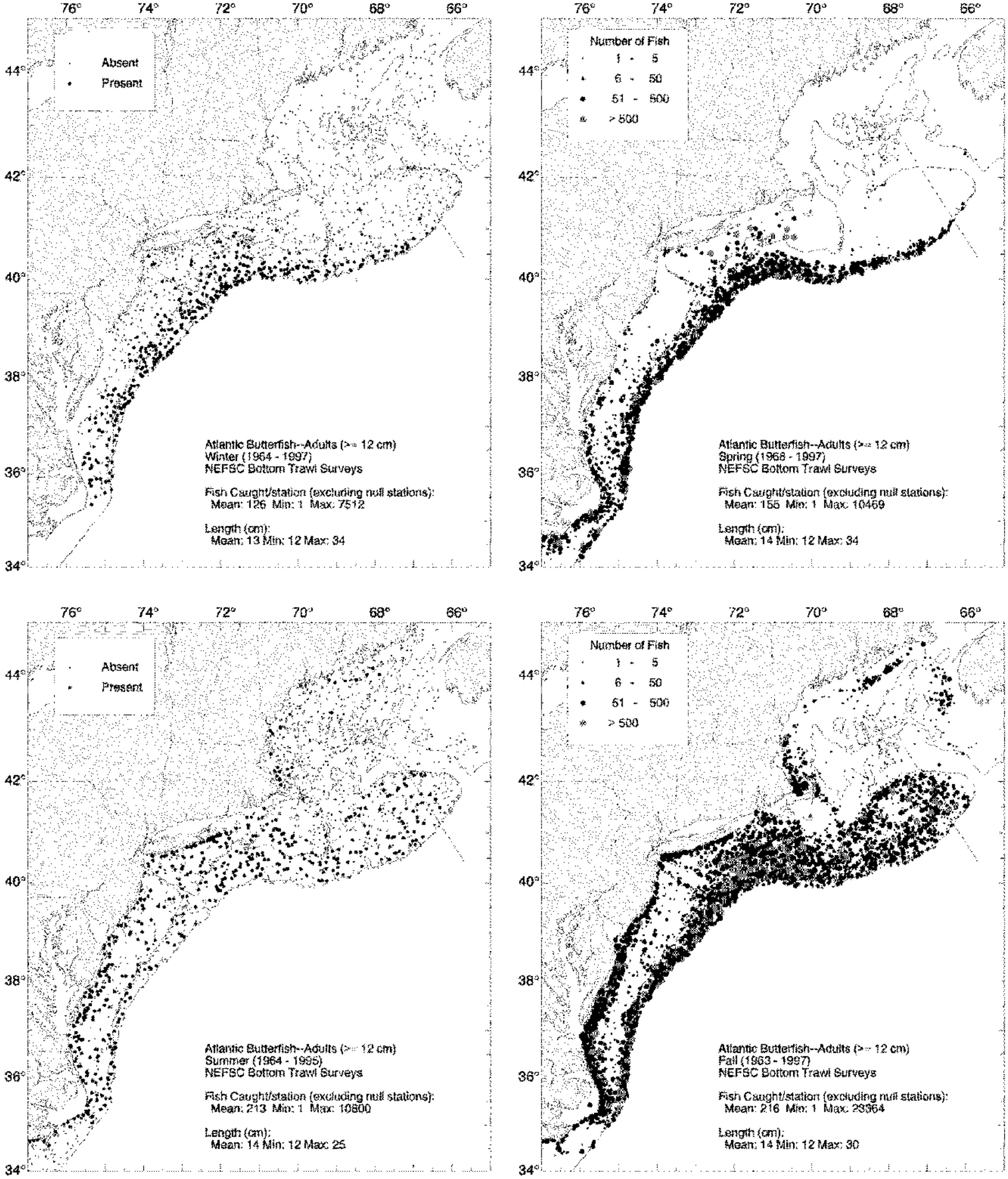


Figure 11. Distribution of juvenile and adult butterfish collected during NEFSC bottom trawl surveys during all seasons during 1963-1997. Densities are represented by dot size in spring and fall plots, while only presence and absence are represented in winter and summer plots [see Reid *et al.* (1999) for details].



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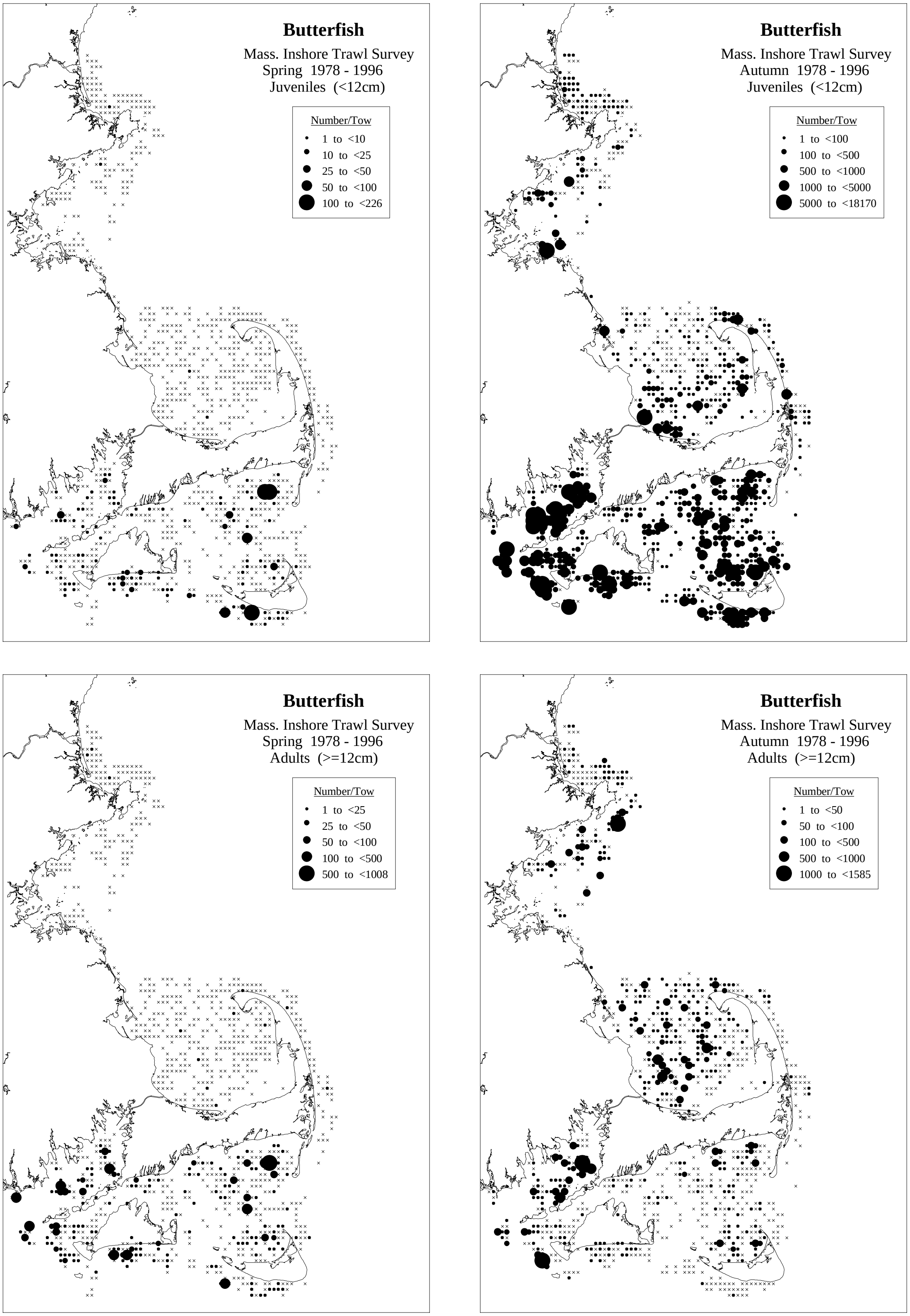

Figure 12. Distribution of juvenile and adult butterfish in Massachusetts coastal waters during spring and autumn Massachusetts trawl surveys, 1978-1996 [see Reid *et al.* (1999) for details].

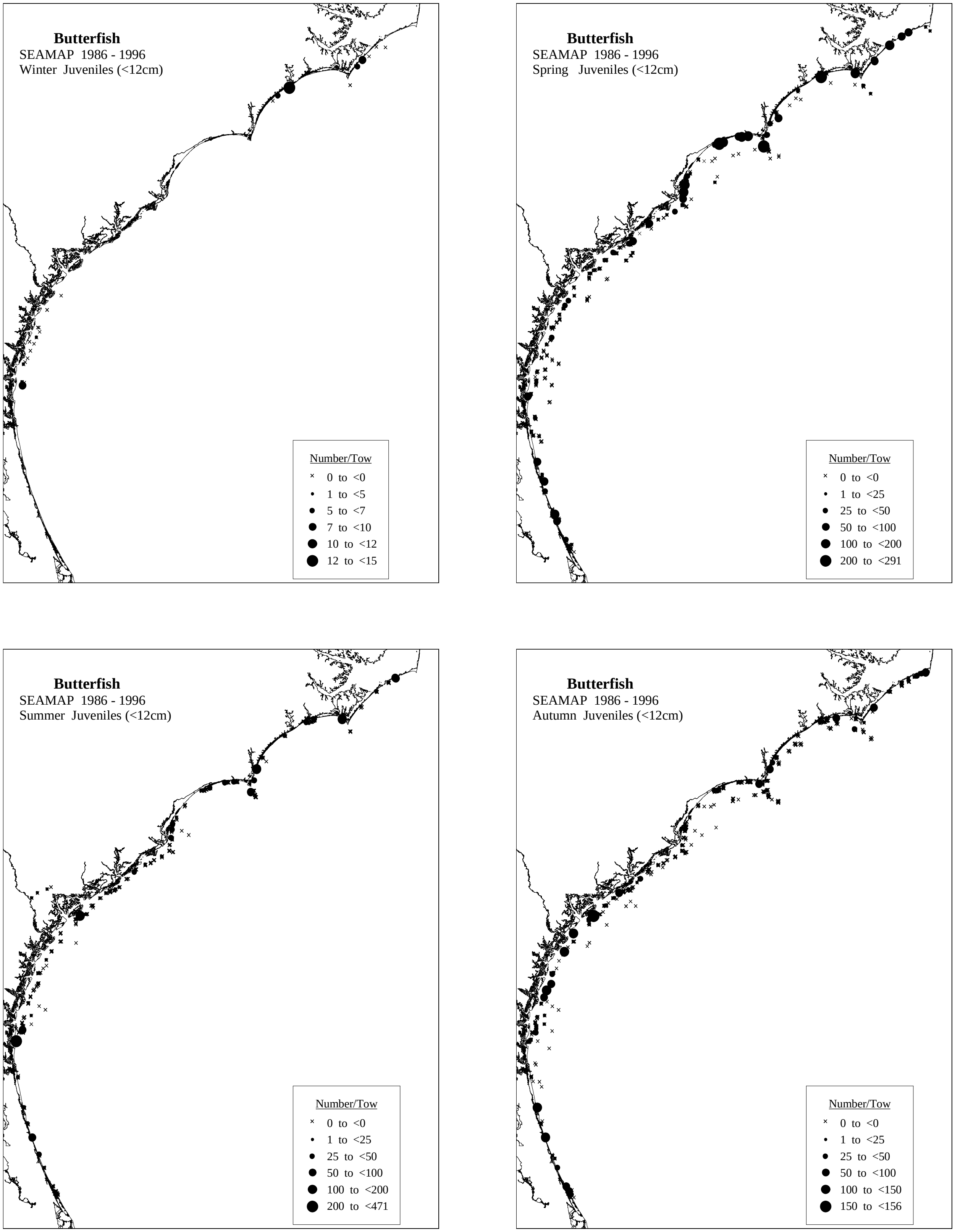

Figure 13. Distribution of juvenile and adult butterfish in the SEAMAP bottom trawl surveys in all seasons for all years combined (1986-1996).

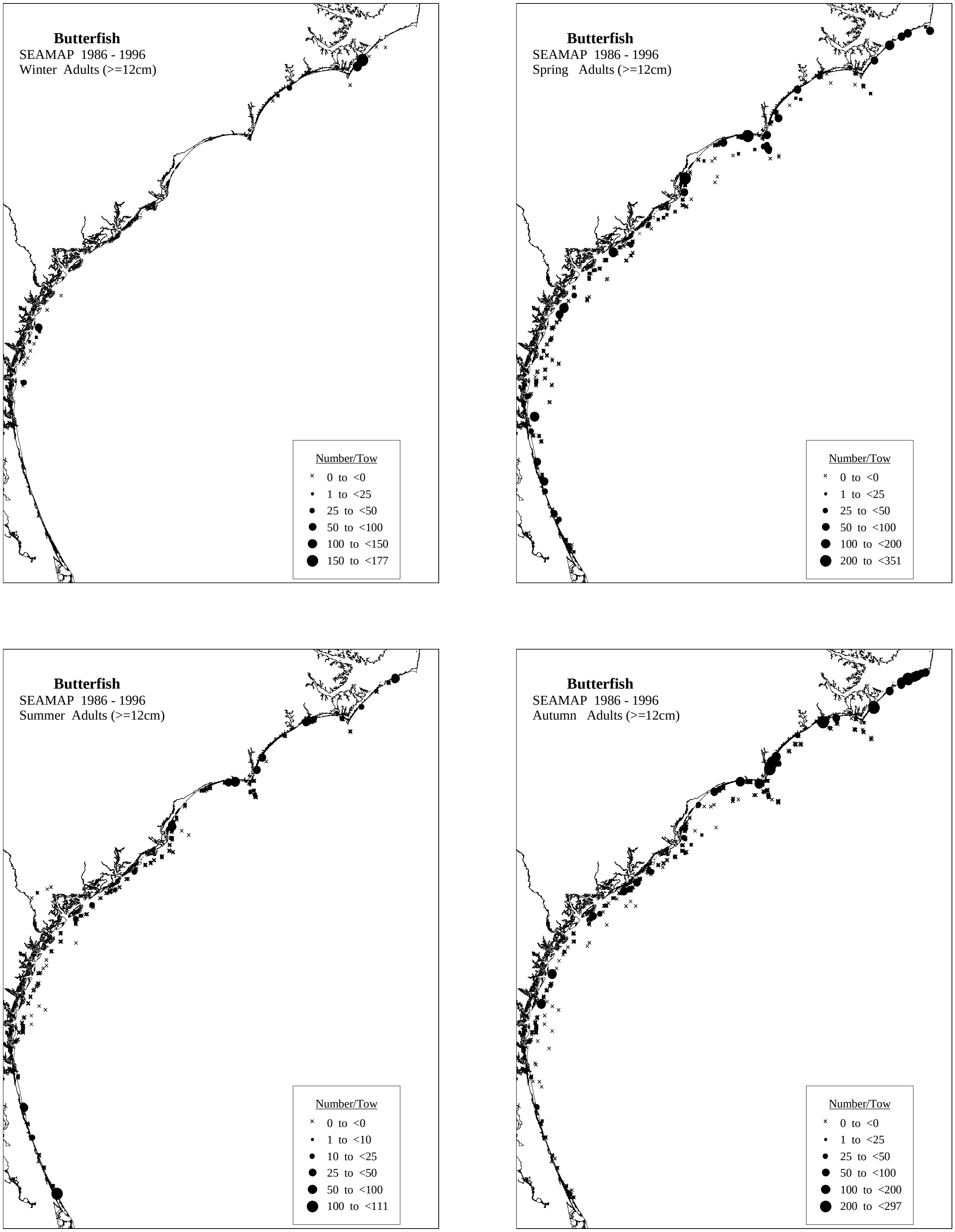

Figure 13. cont'd.

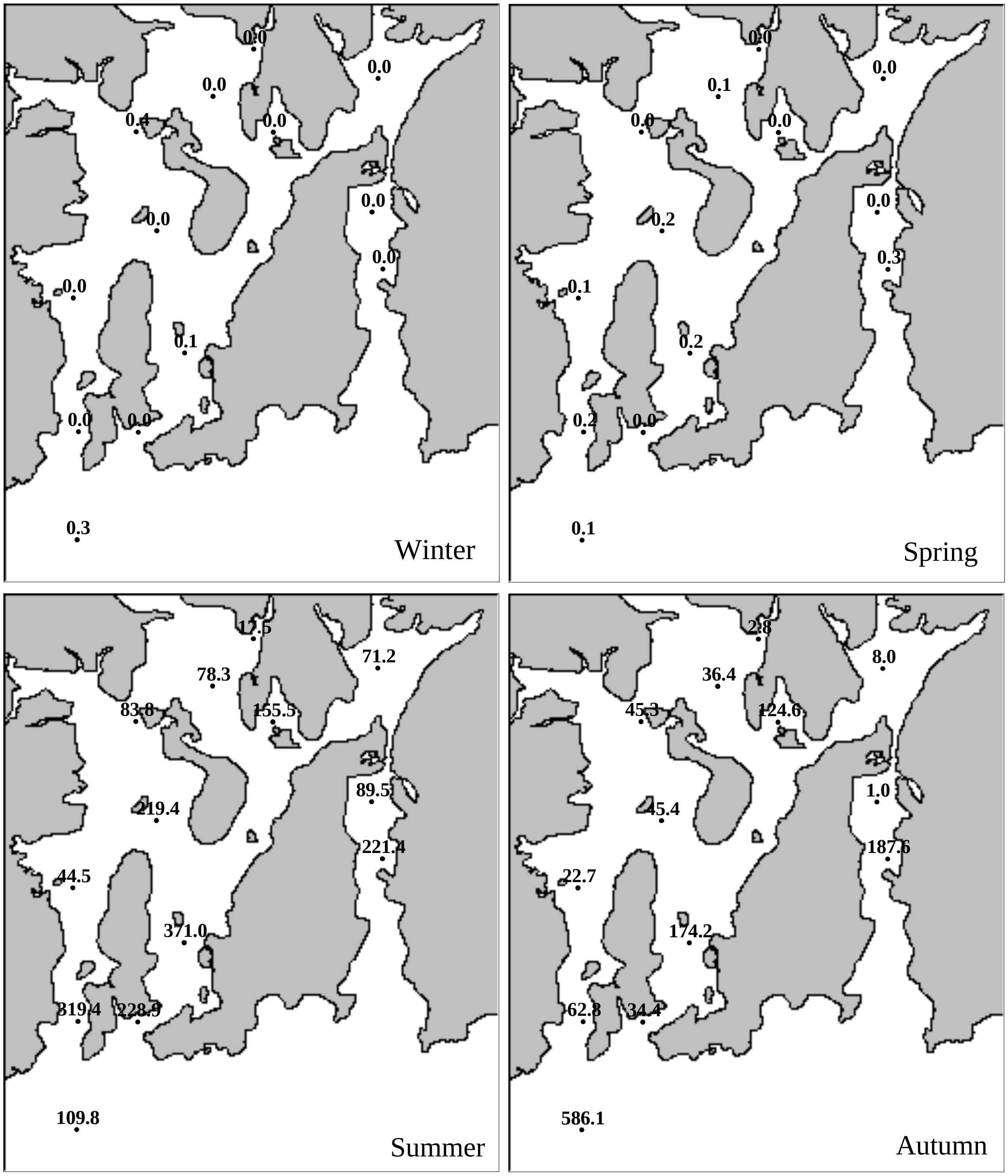
Butterfish Juveniles (< 12 cm)

Figure 14. Distribution of juvenile and adult butterfish collected in Narragansett Bay during 1990-1996 Rhode Island bottom trawl surveys. The numbers shown at each station are the average catch per tow rounded to one decimal place [see Reid *et al.* (1999) for details].

Butterfish Adults (>= 12 cm)

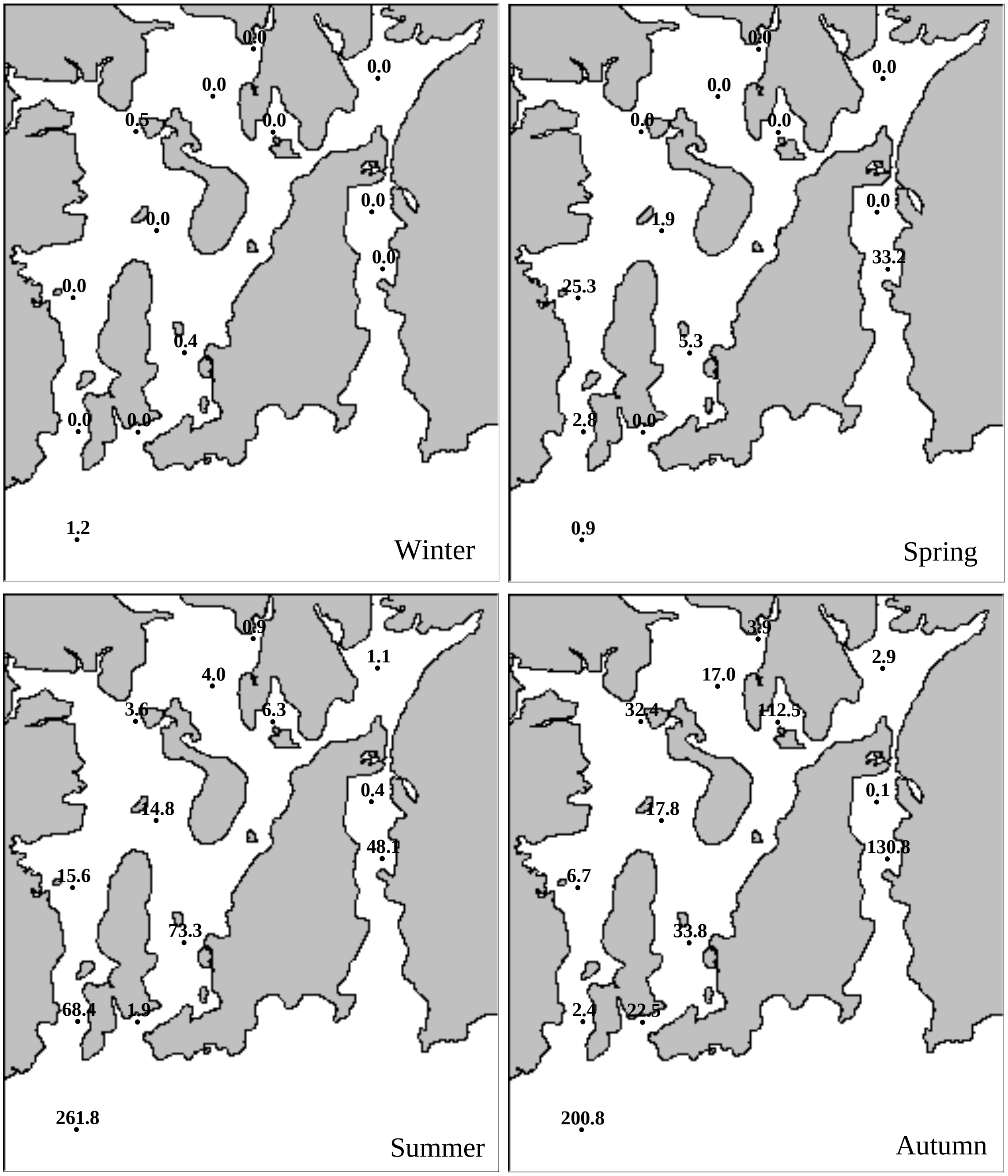

Figure 14. cont'd.

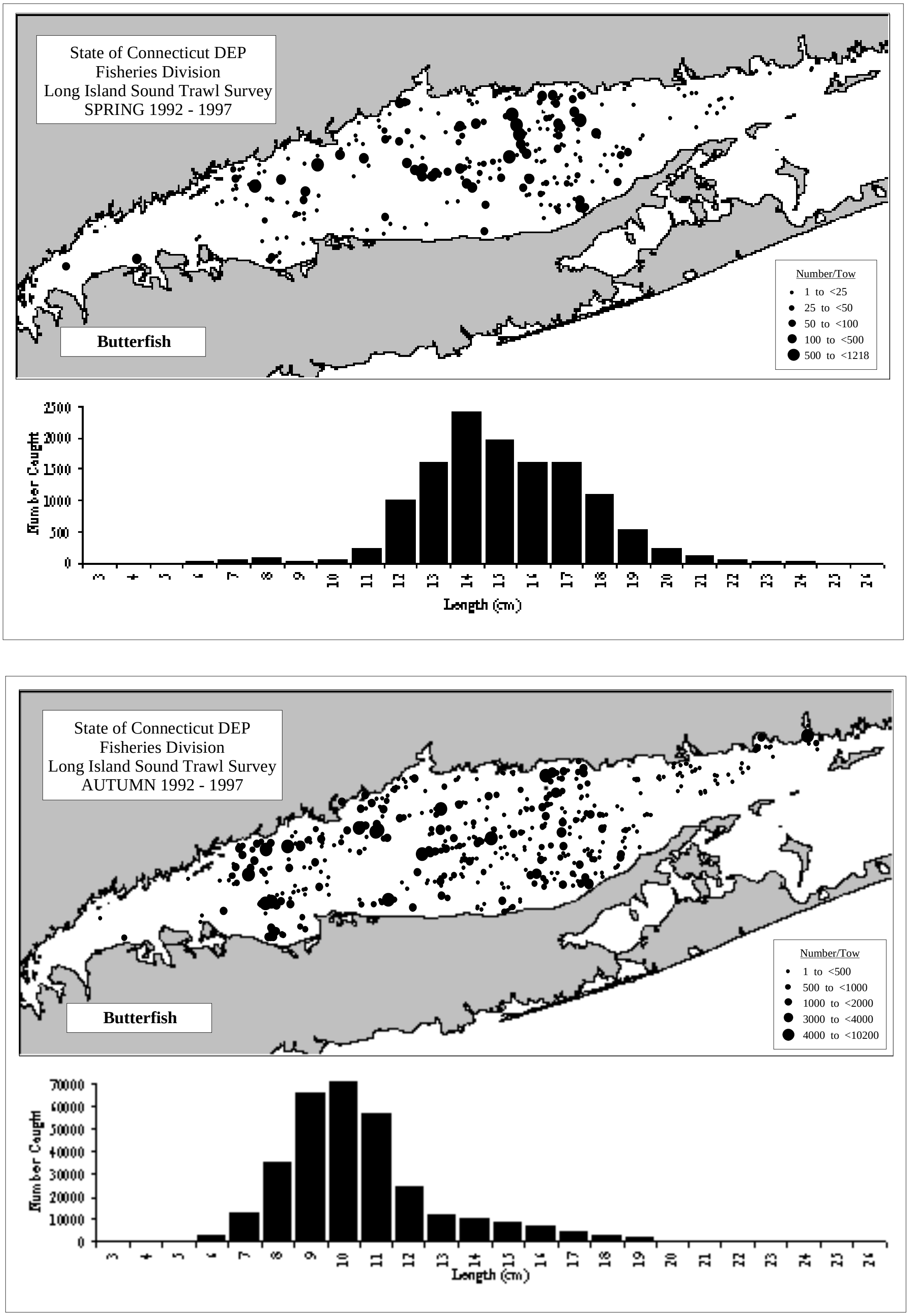

Figure 15. Distribution of juvenile and adult butterfish in Long Island Sound in spring and autumn, from the Connecticut bottom trawl surveys, 1992-1997 [see Reid *et al.* (1999) for details].

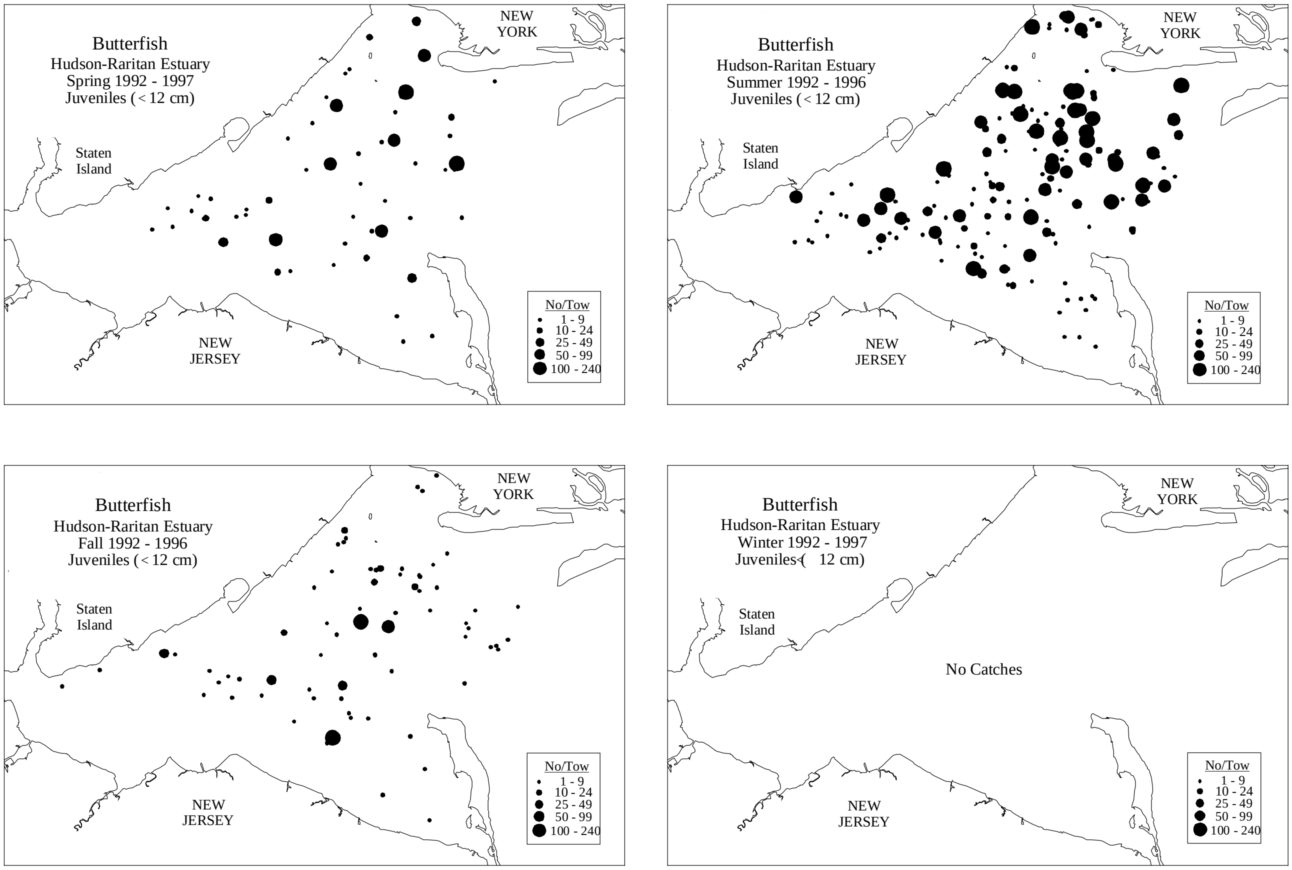

Figure 16. Distribution of juvenile and adult butterfish in the Hudson-Raritan estuary based on Hudson-Raritan trawl surveys, 1992-1997 [see Reid *et al.* (1999) for details].

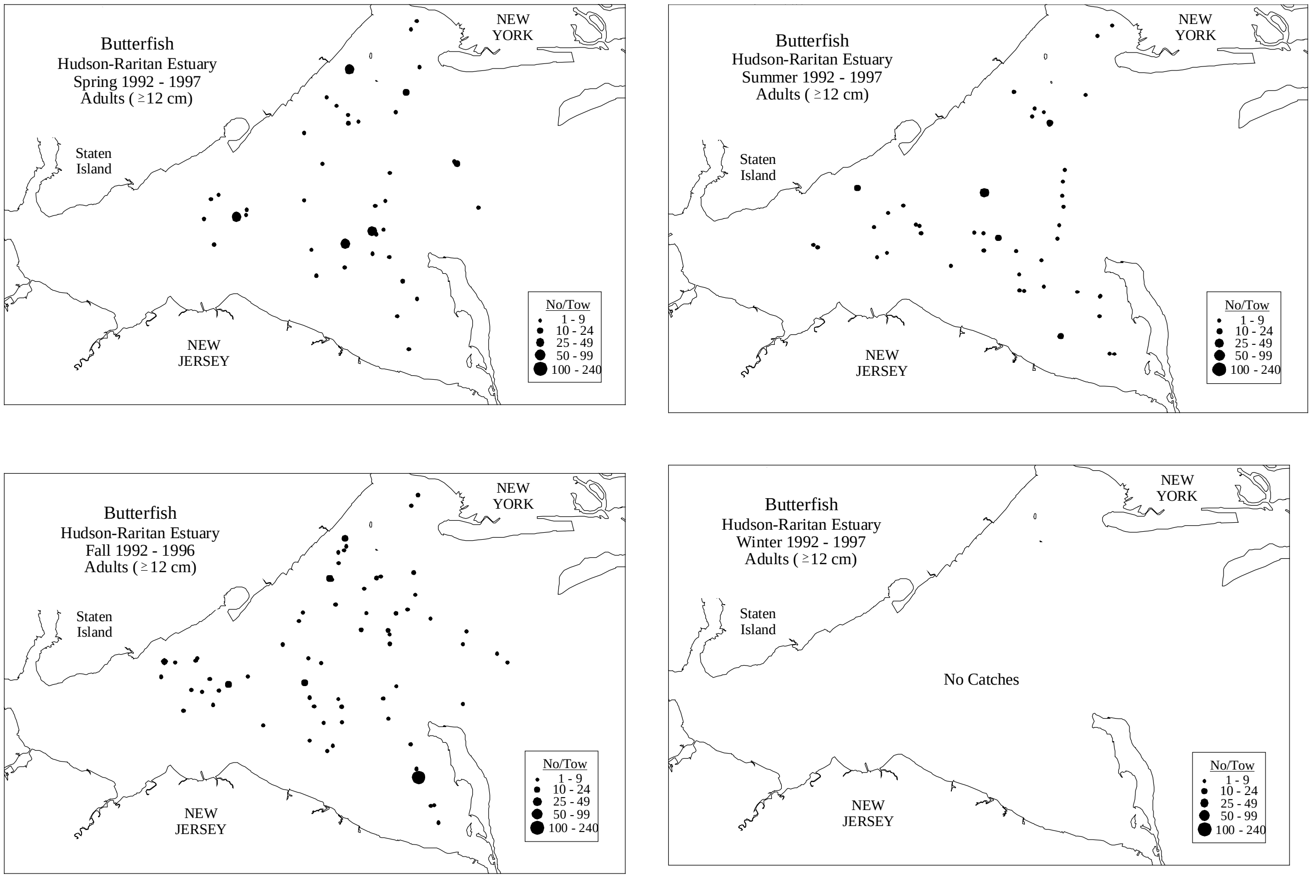

Figure 16. cont’d.

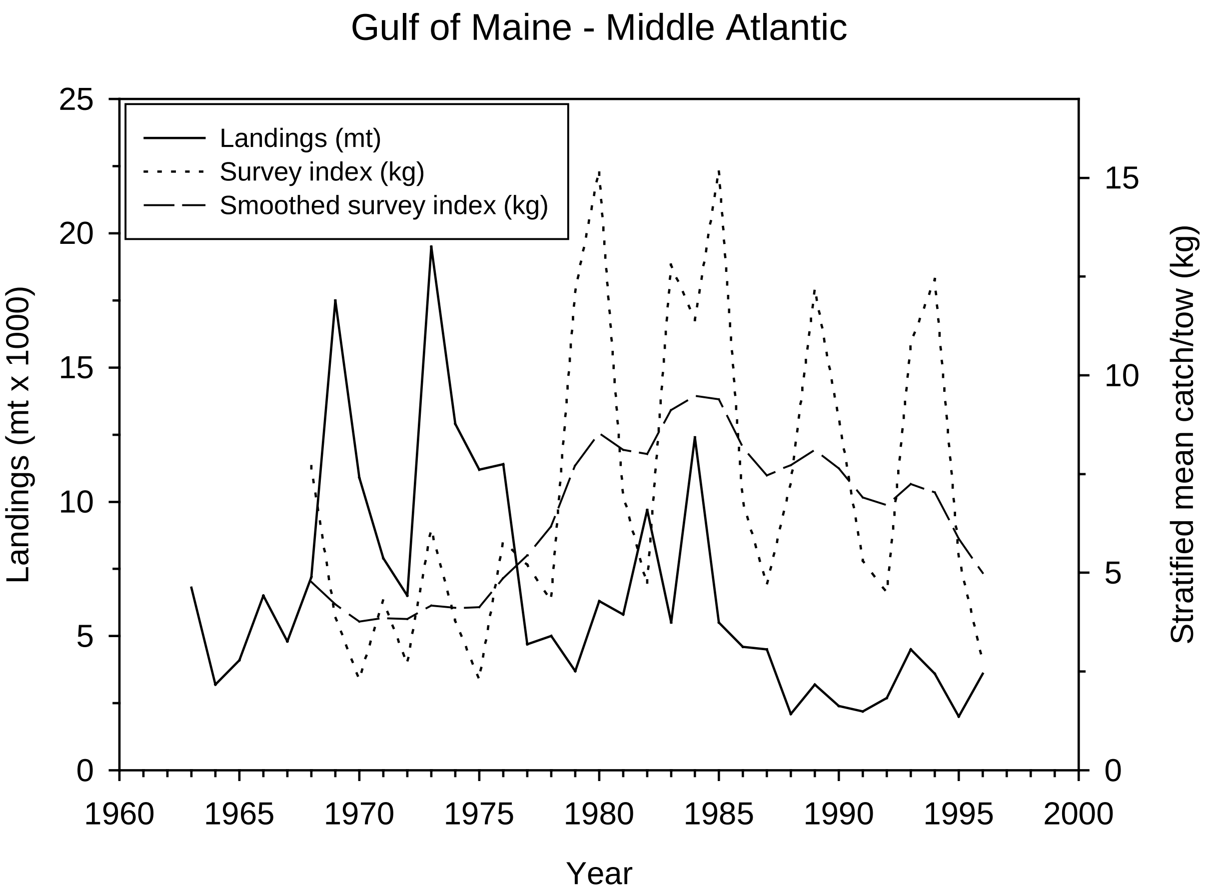

Figure 17. Commercial landings and abundance indices (from the NEFSC bottom trawl surveys) for butterfish from the Gulf of Maine to the Middle Atlantic.

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Appendix 9a

Port and Community Profiles for the Atlantic Mackerel, Squid and Butterfish Fisheries

The following port and community profiles were excerpted from a report prepared for the Mid-Atlantic Council and submitted by Bonnie J. McCay on behalf of The Fisheries Project, Rutgers University, with the assistance of Kevin St. Martin, Brent Stoffle, Bryan Oles, Eleanor Bochenek, Teresa Johnson, Johnelle Lamarque, Giovani Graziosi, Barbara Jones, Judie Hope, and Kate Albert. The correct citation for this report is given under McCay *et al.* 2002 in the references listed above.

“According to the Sustainable Fisheries Act of 1996, "[t]he term "fishing community" means a community which is substantially dependent on or substantially engaged in the harvest or processing of fishery resources to meet social and economic needs, and includes fishing vessel owners, operators, and crew and United States fish processors that are based in such community." Guidelines to the SFA indicate that by community is meant a recognized place, such as a village, town, or city. For the purposes of this social impact assessment, community is defined as a fishing port or a place where fish (and squid) are processed, although it is recognized that people involved in the fisheries may live and work elsewhere and that there are important social networks and cultural identities that transcend municipal boundaries.

Communities from Rhode Island to North Carolina are involved in the harvesting and processing of *Loligo* and *Illex* squid, Atlantic mackerel, and butterfish. The communities chosen for the profiles that follow are those with the greatest participation and dependency on the four species in the year 2000 (see Table 1).

Profiles are provided for the ports listed in Table 1 as well as for Shinnecock, NY, Brooklyn, NY, Newark, NJ, Hampton, VA, and Wanchese, NC, which are included in the study because of their engagement in one or more of the SMB fisheries. Numerous other ports are involved in the squid, mackerel, and butterfish fisheries but at a lower level of participation and/or dependence; information on most of the major fishing communities of New England and the Mid-Atlantic regions can be found in “New England’s Fishing Communities” (Hall-Arber et al. 2002) and “Fishing Ports of the Mid-Atlantic” (McCay and Cieri, 2000), both of which have contributed to these profiles, supplemented by more recent research.

The following profiles are organized from north to south, from Massachusetts to North Carolina; in most cases the county in which a port or other community is found is also briefly described, as an indicator of the larger socio-economic system.

Bristol County and New Bedford, Massachusetts

Bristol County, MA

According to the 2000 Census, Bristol County had a population of 534,678 (Table MA-RI). This was a 5.6% increase from 1990. Ninety-one percent of the county population was white and of the total population 24.6% were under 18 years of age and 14.1% were 65 years of age or over. In 1999, Bristol had a per capita income of $27,461. Based on a 1997 model based estimate, 11.9% were living below the poverty level. In 2000, the unemployment rate was 3.9% and seasonally the rate ranged from a high of7.2% to a low of 3.9%. In 1990, of those 16 years of age or older, 1.5% of the total number employed were engaged in the agriculture, forestry, and fisheries industry.

New Bedford, MA

New Bedford's census profile is that of a struggling, impoverished industrial city. According to the 2000 Census, New Bedford had a population of 93,768, a 6.2% decrease from 1990 (Table MA-RI). Seventeen percent of the population was minority, primarily Hispanic, and the median age was only 35.9 years. In 1990, New Bedford had a per capita income of $10,923 and of the total population 16.8% were classified as living below the poverty level. In 1990, the unemployment rate was 12.2%.

Of those 16 years of age or older, only 1.3% of the total number employed were engaged in the agriculture, forestry, and fisheries industry in 1990, suggesting that the fisheries are marginal to the community. However, more extensive research shows that between 5 and 8 percent of the people in the New Bedford metropolitan statistical area receive their livelihoods primarily from fishing. Even a conservative estimate, assuming two other individuals are supported by each fisherman and fishing-related worker employed, places the proportion of the population dependent on fishing between 11 and 18% (Hall-Arber et al. 2002).

Fisheries Infrastructure

New Bedford is a major deep-water port with a long history of commercial fishing (Hall-Arber et al. 2002). Fishing and allied industries still contribute one-fifth of the city's income. New Bedford remains one of the three premier fishing ports in New England and it is consistently numbered among the top U.S. ports for the value of its commercial fishery landings, number 1 in the year 2000. Its highly differentiated fishing infrastructure was developed early in its history and has continued to grow (Hall-Arber et al. 2002).

Of all major groundfishing ports in the eastern U.S., New Bedford and environs, including neighboring Fairhaven, has the most developed infrastructure for fishing, together with Portland, Maine and Chatham, MA (Hall-Arber et al. 2002). It has the most total capital invested in the fishing industry and the largest fleet of any port. According to one report (Hall-Arber et al. 2002), in the late 1990s there were a total of 1,131 crew manning 265 vessels. Of these, 82 are scallopers, typically with 7 member crews, and 183 were draggers with average crew size of four. In 2000 there were also 9 large ocean quahog vessels. There are also smaller lobstering and gill-net boats.

Estimates of the numbers of fishermen vary. Crew sizes on scallop and groundfish vessels have diminished in the past few years, partly due to regulations (e.g., scallop boats are restricted to 7 crewmembers). Consultants in a 1999 harbor planning process identified 2,600 jobs and $609 million in sales directly attributable to the core seafood industry. Another 500 jobs were indirectly related, as was about $44 million in sales (Hall-Arber et al. 2002.).

In addition to boat owners, captains, and crew, the full New Bedford/ Fairhaven fleet (neighboring Fairhaven is the home of many of the vessels) generates business for around 75 seafood processors and wholesale fish dealers and 200 other shoreside industries. Together, these businesses provide employment for around 6,000 to 8,000 additional workers (Hall-Arber et al. 2002).

Squid, Atlantic Mackerel, and Butterfish

New Bedford ranks 9th in terms of the value of squid, Atlantic mackerel, and butterfish landings, and 12th in terms of the proportion of total landings from these species (Table 1). They are part of a large suite of species caught by the draggers of New Bedford. The fishing grounds used are generally northeast of the areas considered as Essential Fish Habitat in this amendment to the FMP, with the consequence that there are few if any direct impacts of potential closures of EFH areas in the Mid-Atlantic, although this may change as groundfish regulations are stricter and more stringently applied. This port was not visited for the SIA but discussions with people in the industry indicate that there is currently little or no processing of these species in New Bedford; most facilities are just packing them. The 2000 weighout data indicate that 64 boats landed Loligo squid, 15% of the total boats landing in New Bedford that year.

Rhode Island's Fishing Ports and Communities

The following Rhode Island ports were determined to have a significant dependence on the species included in the FMP based on the value of the four species as a percent of the total value of all landings in the 2000 weigh-out data: North Kingstown, Point Judith, and Newport (Table 1). Newport and Point Judith, each having sizeable numbers of seagoing vessels, are located in the lower part of Narragansett Bay, as is North Kingstown, where there is an area called Quonset Point that hosts seafood processing and freezer trawlers.

Census data for 1990 and 2000 as well as other data are presented in Table MA-RI for the census units and counties. Newport is in Newport County, which has a total population of 85,433, in 2000, a 2% decline from 1990; Newport itself numbered 26,475 in 2000, a 6.2% decline. Newport has a sizeable minority population, primarily Black/African American (7.8%) and Hispanic (5.5%), a low median age (34.9 years) and high percentage of people living in poverty, based on a 1997 model (12.5%).

North Kingstown and Point Judith are in Washington County, population 123,546 in 2000, a 12.3% increase from 1990. North Kingstown's population was 26,326 in 2000, a 10.7% increase, and Point Judith's population (Narragansett census tract) was 16,361 in 2000, a 9.2% increase. These places have relatively small minority populations (Table MA-RI).

Newport and Point Judith were studied extensively by Hall-Arber et al. (2002). Newport is far less dependent on fishing than Point Judith is, based on fishing infrastructure and alternative activities. Point Judith ranked fifth and Newport 13th out of 36 New England ports in terms of fishing infrastructure differentiation (Hall-Arber et al. 2002: 39-40). However, they also ranked near the top of a scale of gentrification, Point Judith ranking 7 and Newport 5 out of 36 (Hall-Arber et al. 2002: 44). Rhode Island fishing communities are among the most "gentrified" in New England, many with long histories of tourism focusing on water sports, sailing, and summer "cottages." One consequence is that dockage (and other waterfront amenities) has become a problem in Newport and Point Judith due to competition for waterfront land and space, including areas for parking and gear. In Newport, commercial fishing activities have moved away from the tourist center, but they continue to be pressured to move farther away, competing with a highly active tourist trade and recreational boating sector (Hall-Arber et al. 2002: 45).

Point Judith remains one of the top fishing ports in the U.S. on the basis of quantity and value of landings. It is the most fisheries-dependent of Rhode Island's communities, with about 500 households directly involved in and another 400 indirectly dependent on the commercial fisheries (Hall-Arber et al. 2002: 80). Point Judith "fulfills the definition of a fishing community on the basis of central place theory. Fish are legally sold ex-vessel to a dealer, processor o r the public; fishing support services are provided; there are public facilities providing dockage; fishing people satisfy their daily and weekly social and/or economic needs here, and some fishermen and their representatives participate in fisheries resource management" (Hall-Arber et al. 2002: 78). In addition, "Despite changes," as one respondent put it, "there is still a distinct community of fishermen here." Fishermen comprise a social and occupational network: "People know each other." The small town atmosphere is punctuated by functions such as the Fishermen's Scholarship Fund's annual game feast where $6,000 was recently raised for the sons and daughters of fishermen" (Hall-Arber et al. 2002: 78).

The Blessing of the Fleet has become largely an activity of the recreational fishing community. There is little ethnic diversity in the fishing population, and many are relatively newcomers to fishing. Fishermen tend to live in small local communities of southern Rhode Island, within a 20-mile radius of the port; there is little residential housing near the port. The majority of the fish processing workers are ethnic minorities, often bussed in from the city of Providence, RI. There are numerous fisheries organizations in Point Judith (some serving the entire state) and fishing-related programs and services (Hall-Arber 2002: 83-84).

Newport, RI, has a long history of tourism and recreational boating, which started in the 1700s, but also a long and persistent engagement in commercial fishing historically based on floating fish traps but today divided between lobstering and a fleet of draggers and scallopers. Approximately 200 families are involved in the fisheries of Newport. The groundfish fleet has dramatically declined over the last 20 years, spurred by increasing property values that have restricted access to waterfront and other property, and the fisheries are minor compared with other economic and social activities (Hall-Arber 2002: 93-100). However, Newport remains a sizeable port. In 2000 90 boats landed fish and shellfish at Newport, according to the weighout data. There is no processing of squid, mackerel, or butterfish in Newport. The cultural importance of fishing to the community is evidenced in the museum at the Fishermen's Church Institute. Recreational fishing is mostly rod and reel fishing from shore for stripers.

North Kingstown is a large township with nine villages, one of which is maintained as a historic district (Wickford) (www.northkingstown.org, www.northkingstown.com). There is a charter boat company and about six marine-related businesses including marine repair, a mooring service, and a marina. The commercial fisheries are mainly found in the Quonset Point area, which was the site of a U.S. Naval Air Station, now a state airport, and a large industrial park, the Quonset Davisville Port and Commerce Park, the contested focus of plans for economic development including a container port (see www.sierraclubri.org/quonset).

Squid, Atlantic Mackerel, and Butterfish

Squid and butterfish have long been primary targets of fishermen from this area, together with whiting and scup--the diversified "small mesh" fishery of the Mid-Atlantic--and with the decline of groundfish in the northeast, these species have become even more important. According to the 2000 weigh-out data, 90 boats landed *Loligo* in Point Judith, or about 40% of all the boats that landed fish in Point Judith that year. Forty-two boats (47%) landed *Loligo* in Newport, and for North Kingstown, 7 boats landed *Loligo* in 2000, 20% of all the boats that year. Newport, North Kingstown and Pt. Judith land high volumes of *Illex*, *Loligo*, mackerel and butterfish, especially as groundfish landings in the area have declined. Loligo accounted for between 12 and 16% of the value of total landings in Point Judith, Newport and North Kingstown in 2000. Butterfish played a very small role in Point Judith and Newport, less than 2% of the total landings value, but in North Kingstown butterfish accounted for over 17% of the total value of landings.

Illex is important only in North Kingstown, where three vessels landed Illex in 2000; their catches accounted for 22% of the value of total landings in 2000. In North Kingstown a processor reported that 95% of his business is from *Loligo*, *Illex*, mackerel and butterfish and some percentage from Atlantic herring. This processor unpacks frozen fish and squid from the boats. Seven boats pack out at his facility; these boats have been unpacking at his facility for about 17 years. The dependency of North Kingston processing on these species has already been shown by the Gear Restricted Areas which went into effect in 2001. According to one processor, the GRAs reduced his business by 20-30%: "There are no other species to target if we can't catch these fish."

Most fish processing in Pt. Judith is done in a large industrial area, the location of six processing plants, including Town Dock, the former Point Judith Cooperative (now the Pt. Judith Fishermen's Company), South Pier Fish, and Sea Fresh Corporation (Hall-Arber et al. 2002: 79). In recent years the processors have shifted their focus away from groundfish (fluke, yellowtail flounder, cod, whiting, and other species) and toward squid, herring, and mackerel (Ibid). A processor from Pt. Judith interviewed in 2002 noted that their busy season is during the winter and slow season is in the summer with *Loligo* being his primary product for processing. He used to process a lot of butterfish, but because of the down turn in the Japanese market, there is less demand for butterfish. He derives 50% of his revenue from *Loligo*. He buys product from 20-22 boats. Most of the boats have landed at his dock for many years; only a few move around to other docks. Another Pt. Judith processor indicated that *Loligo* and butterfish are important to his business, but not *Illex* and mackerel. If he could obtain more volume of butterfish he could sell it. Thirteen boats land at his facility. He has bought product from the same boats for 20 years.

Connecticut's Fishing Ports and Communities

Connecticut's coast has been transformed by the expansion of metropolitan populations. "Most fishermen in Connecticut are embedded as fishing 'clusters' within their communities, and as such do not make up a significant economic component of local economies. The decline in the fishery is directly related to the loss of fishing community as a definite space and place dominated by a population sharing traditions of fishing. Nevertheless, fishing persists as enclaves,.... The historic loss of the core fishing population has proceeded simultaneously with an intense gentrification process that has converted fishing neighborhoods and dock space into expensive tourist weekend and summer homes surrounded by gentrified shops, restaurants, and marinas" (Hall-Arber et al. 2002: 52).

East Haven and Stonington, CT

East Haven numbered 28, 189 in 2000, a 7% increase from 1990 (Table CT). It is within New Haven County, and differs from it in having a much smaller minority population but also lower per capita incomes. The percent of those aged 16 and older employed in agriculture, forestry, and fisheries was only 0.3% in 1990. The importance of coastal tourism is indicated by the fact that of the vacant housing units, 30% have seasonal, recreational, or occasional uses.

Only Stonington persists as a port with an established and distinct dock space for fisheries, "the home port of Connecticut's last remaining commercial fishing fleet" (www.stonington.ct/harborplan.html). Stonington itself is a large township, made up of the Borough of Stonington and the villages of Mystic, Old Mystic, Pawcatuck, and Wequetequock. Stonington's population was 17,906 in 2000, a 6% increase from 1990. It has a very small minority population, and a relatively high median age, 41.7 years (Table CT). The per capita income was higher than that of New London County.

Tourism is the major emphasis for development of the Stoninigton area, building on the proven popularity of Old Mystic and the Mystic Aquarium (www.munic.state.ct.us/Stonington). The fishing community is an enclave within one borough, and its ties to the town and borough are not very strong. For example, no fishermen now live on the main street of Stonington, which consists of gift shops and fashionable year round and summer residences. However, the commercial fleet survives in part because of political support from the town, which has reserved the Town Dock for commercial operations (www.stonington.ct/harborplan.html). In other Connecticut ports, fishing boats must compete with recreational marinas and dockside tourist facilities as well as rising property values (Hall-Arber et al. 2002: 51). In Stonington there appears to be strong recognition of the economic and symbolic value of the commercial fisheries.

Stonington's fishing fleet is split between day boats and offshore draggers; the latter target scallops, squid, fluke, butterfish, shrimp, monkfish, and whiting (Hall-Arber et al. 2002: 56). Lobstering is important (although affected by the lobster disease problems of Long Island Sound), and conch has emerged as a niche fishery here as in other ports of the region. The commercial dock, the Town Dock, is maintained under a lease from the town and is reserved for fishing-related activities. Two packing houses handle fish and shellfish, and the Southern New England Fishermen and Lobstermen Association (SNEFLA) helps lower costs of ice, fuel, gear, and supplies (Hall-Arber et al. 2002: 57). Members of SNEFLA are from Connecticut, Rhode Island, and Massachusetts; it began in 1931 to help with common problems such as the hijacking of trucked shipments of fish to the urban markets (Hall-Arber et al. 2002: 58). Members are allotted tie-up space at the Stonington Pier and have attempted to join the fishermen's health care plan initiated by the Massachusetts Fishermen's Partnership. Stonington ranked fairly high in terms of fishing infrastructure differentiation (10 out of 36), which includes the presence or absence of icehouses, boat insurance, dockside diesel fuel, local trucking, a fishermen's supply house, monuments, and so forth (Hall-Arber et al. 2002: 38-39). Surprisingly, it ranked fairly low in the gentrification ranking of New England ports, 20 out or 36 (Ibid: 44). Comparable information is not available for East Haven.

There are very few fishermen living in the central part of Stonington, the historic "village" or Borough, but the Portuguese Holy Ghost Society and the Feast of the Holy Ghost persist as a social nexus, through the church, even though few Portuguese speakers are now in the fisheries. The Portuguese first came to Stonington industry from the Azores or Cape Verde Islands in the 1700s as participants in the sealing and whaling, and Portuguese ethnicity remains associated with Stonington (Hall-Arber et al. 2002). The SNEFLA hosts an annual Blessing of the Fleet after a requiem mass for fishermen who lost their lives at sea:

"St. Mary's Church is home to a tall pastel statue of St. Peter, the patron saint of fishermen. Every July the statue makes its way in a parade from St. Mary's Church down Water Street to the docks and up Main Street to the Holy Ghost Hall. The parade is a somewhat solemn occasion. It follows a requiem mass in honor of the fishermen who have lost their lives at sea. A pickup truck drags a decorated dory in back of it. The truck is followed by a car carrying several grieving widows of local fishermen. The wives are in mourning and are dressed in black, respectfully indicating their loss to the solemn-faced spectators who are watching the truck pass. The fishing draggers moored at the Stonington dock are loaded with visitors and passengers and then the procession of draggers heads out to the inner breakwater. The bishop rides on the first fishing boat along with the fisherman's widow. As the draggers pass the first fishing boat, the bishop blesses each boat with holy water and prayers are said requesting a safe and prosperous fishing season. The draggers then form a circle so all can view the honored widow as she throws the wreath overboard in honor of those fishermen who have lost their lives at sea." (Www.clemclay.com/thevillage.index.html).

Squid, Atlantic Mackerel, and Butterfish

The ports of East Haven and Stonington, CT, have small commercial fisheries that are engaged in fishing for the species of this FMP. For example, eleven out of the 17 boats in East Haven landed butterfish in 2000, and this species accounted for almost 5% of the total value in the port. Its landings of butterfish were roughly comparable in value to those of Point Pleasant, NJ, Freeport, NY, and Newport, RI. East Haven and Stonington also saw landings of *Illex* squid, at a low level but ranking 7th and 8th of the top 10. Stonington's catches of *Loligo* squid brought it into the top 10 for Loligo, comparable to the landings of Point Pleasant, NJ, in 2000.

New York's Fishing Ports and Communities

New York fishing ports, like those of Rhode Island and northern New Jersey, are on the boundary of the New England and the Mid-Atlantic ecological and institutional systems, and the diversity of species as well as fisheries agencies and laws involved is very high. In addition, the fisheries have a premium on adaptability, because of changes in the distribution and abundance of different species as well as market changes. Commercial fishing ports in New York State are concentrated on Long Island, which extends from Brooklyn, a borough of New York City, to the far eastern ports of Montauk (on the South Fork) and Greenport (on the North Fork). There are also small, but historically and culturally important, fisheries for migratory species on the Hudson River and other rivers (McCay and Cieri 2000).

New York's commercial fisheries are difficult to characterize in relation to NMFS weigh-out data and other information because they are quite widely dispersed. There are many well-known ports but large quantities of fish and shellfish are landed elsewhere. In addition, state waters (to

3 nautical miles) are extremely important. New York State's data on those fisheries do not include NMFS port codes. Consequently, the category "Other New York" in the NMFS weigh-out data is very large, accounting for 35% of the value and 23% of the pounds landed in 1998. Many of the fisheries of Long Island and Long Island Sound, particularly for lobsters, are represented in this category and not assigned to particular ports. The category also includes surf clamming and other fisheries that take place exclusively in state waters (McCay and Cieri 2000).

Of the four species included in the FMP, *Loligo* or long-finned squid figures most prominently in weigh-out data for the fishing ports on Long Island, followed by butterfish. *Loligo* accounted for 12% of the total value of commercial landings, as reported in weigh-out data for the year 2000. Butterfish accounted for 1% of the total value. Atlantic mackerel and *Illex*, or short-finned squid, accounted for less than 1% of the total value of fish landed in New York in 2000.

The following ports were determined to have a significant dependence on the species included in the FMP based on the value of the four species as a percent of the total value of all landings in the 2000 weigh-out data: Brooklyn, Freeport, Greenport, Hampton Bays, and Montauk. The value of the four species in each of these ports was between 20% and 50% of the total catch value in each port. Visits were made to each of these ports and interviews were conducted with fishermen, dock personnel, processing plant managers, and community representatives. Additional information for the following port profiles is derived from "Fishing Ports of the Mid-Atlantic" (McCay and Cieri 2000).

Suffolk County, NY

Suffolk County is the eastern half of Long Island and encompasses major fishing ports that include Hampton Bays/Shinnecock, Montauk, and Greenport, as well as numerous smaller ports that were not included in this analysis. The fisheries of Suffolk County are highly diverse and also highly dispersed, such that much of what is landed is recorded as "other" rather than assigned to a specific port. Although Suffolk County is being rapidly developed, it produces the largest agricultural revenue of the counties in New York. Table (NY) presents 1990 and 2000 census data for the county and the county’s ports that are included in this analysis.

Montauk, NY

Montauk, the largest fishing port in New York, is situated near the eastern tip of the South Fork of Long Island. A sign near the bay front marinas and docks welcomes visitors to Montauk: "The Fishing Capital of the World". The region's economy is heavily dependent on commercial and recreational fishing. Many of the local businesses provide services to the fishing industry. One informant estimated that there are approximately 300 fishing families in the area. According to the 1990 U.S. Census, there were approximately 290 residents who reported "fishing" as their occupation. Also of note is the 14.02% increase in the number of Hispanic residents since 1990 (Table NY). A large number of the dock workers in Montauk are Hispanic. Seasonal tourism is also extremely important to the local economy. The median house value in 1990 was $238,600, reflecting the high cost of housing in the vicinity. Informants working in the fishing industry who were interviewed for this study cite high housing costs as a challenge.

Fishing Infrastructure

The commercial fishing docks in Montauk are clustered at the northern end of the South Fork, in Montauk Harbor. Commercial dock space is limited in the area. Commercial fishing boats are docked in three primary locations, including a town dock next to the Coast Guard Station on the East side of the harbor, another town dock located near one of the packing businesses and the fish markets on the West side of the harbor, and a packing business located near the East side of the harbor's inlet. There are two primary businesses that pack commercial landings and a third that buys small quantities for both its retail market and for wholesale to restaurants. According to an informant at one of the docks, a packing business that used to operate recently moved out of the commercial packing business and now caters to recreational fishermen. In addition to the commercial docks in Montauk Harbor, there are a number of marinas dedicated to recreational fishing boats and pleasure craft. Numerous party and charter boats in Montauk Harbor cater to tourists and seasonal visitors.

Fishing Overview

According to NMFS weigh-out data for 1998, otter-trawls accounted for 80% of the pounds landed and 60% of the value in Montauk. *Loligo* squid (20% of the value) and silver hake (16% of the value) were the two most important finfish caught in 1998. Butterfish accounted for 2% of the value, and small amounts of *Illex* and Atlantic mackerel were also reported. Bottom longlining is traditionally important in Montauk. It accounted for 21% of the value in 1998, mainly derived from tilefish, swordfish and tunas. Montauk is the leading tilefish port in the U.S., but this fishery has declined greatly. In 1998 and 1999 some of the Montauk-based tilefish boats landed their catches in Rhode Island. Nonetheless, tilefish accounted for 21% of the value of landings in this port in 1998. There were 90 species landed at Montauk. The methods used to harvest fish and shellfish are diverse, including pound nets or fish weirs, box traps, haul seines, and spears, along with the more usual pots, lines, and trawl nets (McCay and Cieri 2000).

Squid, Atlantic Mackerel, and Butterfish

In 2000, 42 boats landed *Loligo* in Montauk, which was 21.6% of all the boats that landed catch in Montauk in that year. *Loligo* accounted for 18.9% of the value of total landings in Montauk in 2000. Thirty-eight boats, or 19.6% of all boats that packed in Montauk, landed butterfish in 2000.

Most of the fish and squid included in the plan are landed at one commercial packing facility in Montauk. Of the four species, *Loligo* has been the most significant for this facility. Six fishermen own this business, each of whom have been fishing for over 30 years. This packing facility is one of the only year-round labor employers in Montauk with the exception of a few resorts. During the winter when most other businesses are shut down, the dockworkers at this facility are putting in long hours to handle the large landings of *Loligo* and whiting. The business employs between six and 10 dockworkers, a secretary, and a manager. Ninety percent of the dockworkers are Hispanic. All of the employees live in Montauk or East Hampton.

According to the manager, 13 trawlers pack with the facility. In addition, 20 to 30 "pinhookers", or hand line boats, use the dock. The activity at the dock slows in the summer for the trawlers, but picks up for the small pinhookers. The business also relies on the charter boat businesses for buying fuel, bait, and ice. The majority of the business's revenue is generated through the packing and shipping of fish to dealers at Fulton Market, and processing plants in New Jersey and New York.

The commercial draggers that land *Loligo* and butterfish at this dock engage in a mixed-trawl fishery. In other words, the fishermen target a diversity of species that include *Loligo*, whiting, butterfish, mackerel, scup, flounder, and fluke, among others, depending on the boat size, season, and regulations. A number of the draggers that land here also engage in the groundfish fishery during the summer months. Diversification and adaptability are considered essential among those engaged in Montauk's mixed trawl fishing. One boat owner said that he maintains 17 permits on his vessel to allow him the option of moving into different fisheries as circumstances demand. *Loligo* are harvested all year long, but the winter months and early spring (December - April) are often the most productive times. *Loligo* are often harvested between 80 and 120 fathoms when they are offshore, but are also caught in shallow inshore water when they are spawning (Georgianna et al. 2001).

A number of the boat owners who pack *Loligo* at this dock explained the history of their involvement in the fishery. About fifteen years ago, management began to encourage fishermen who engaged in groundfish fishing to focus more of their fishing effort on the abundant stocks of underutilized, low value fish like *Loligo,* butterfish, mackerel, and whiting. Low interest government loans were provided for the purchase of the necessary boats and equipment.

Fishermen who took advantage of this opportunity were subsequently allotted fewer days at sea (DAS) in the multi-species groundfish plan of the New England Fishery Management Council. They now feel vulnerable to further cutbacks in DAS that have resulted from the May 2002 settlement of a lawsuit brought by environmental groups against the NMFS. The fishermen interviewed also expressed grave concern about the possibility that the new ruling will force fishermen from New England to move into their mixed-trawl fishery. They noted that current regulations are already having a negative impact on their operations. In 2000, the packing facility experienced a 66% decline in income between November and December due to the closure of area 6A, the Gear Restricted Area (GRA) designated to protect scup. The company had to let 2 employees go because of this decline, and the manager believes that it had an even greater impact on fishermen. Other regulations have limited the profitability of *Loligo* fishing including the 2500-pound trip limit that is triggered when 80% of the quota has been landed. One captain who had just returned from a trip that netted approximately 60,000 pounds of *Loligo* said that the 2500-pound trip limit does not allow him to even consider going out for *Loligo*. *Loligo* fishermen in Montauk feel especially frustrated by the fact that management decisions for an animal with a one-year lifespan are being based on 3-year-old data. Most expressed support for "real time management" of *Loligo*.

Fishing Community/Relations

Informants note that Montauk has a rich historical connection to commercial fishing that is very important to the village's identity. The manager of one of the commercial packing docks is also a member of the East Hampton Town Board's Fishing Committee. This committee represents the interests of those who are dependent on the fishing industry of the area for the development of the new Comprehensive Plan. The Fishing Committee recently reported to the board that commercial fishing contributes an estimated 34 million dollars ex-vessel to the town, 90% of which comes from Montauk. The East Hampton Comprehensive Plan, which is set to be ratified in the coming year, acknowledges that, "fishing is East Hampton's largest and most historically significant industry." The committee has submitted a number of recommendations for inclusion in the Comprehensive Plan that promote and encourage the development of businesses that are critical for the support of commercial fishing. In general, the municipal government has been supportive of the fishing industry. However, informants note that local ordinances and zoning laws make expansion of commercial fishing areas difficult (McCay and Cieri 2000).

Other fishermen interviewed for the study indicated that Montauk has few multigenerational fishing families. Most of the commercial fishermen in Montauk are first generation who moved into the area from other coastal towns on Long Island. One fisherman contrasted the single generation fishermen of Montauk with the multigenerational families of baymen in neighboring Amagansett. While there are few multigenerational fishing families in Montauk, there are many fishing families in Montauk. One informant in the industry estimated that there are at least 300 fishing families in the region. In addition, the fishermen and industry representatives who were interviewed expressed a very strong sense of solidarity and pride in their community. They also expressed an awareness of how dependent the local society and economy is on fishing. One fisherman cited a NOAA-funded study on the region reporting that the community of Montauk is highly dependent on commercial fishing. Another fisherman pointed out the businesses that rely on his fishing operation. He and his crew spend approximately $40,000 each year at the local supermarket for supplying the voyages, and at least $2000 per week on ice alone. In addition, there are a host of ancillary businesses across the state and across the country that depend on the fishing industry of Montauk.

Shinnecock/Hampton Bays, NY

Shinnecock/Hampton Bays is the second most important commercial port in New York in terms of the value of total landings. Hampton Bays is located at the western end of the South Fork on the Southern shore of Long Island. It is located just between East Quogue to the west and Southampton Village and Shinnecock Hills on the east. Its boundary extends to Great Peconic Bay on the north, and to the Atlantic Ocean on the south. The Shinnecock Inlet provides access to the Atlantic Ocean. The area surrounding the commercial fishing docks is considered to be "Shinnecock." The separate villages of the area consolidated under the name of Hampton Bays in 1922, in order to take advantage of the increasing tourism to the region (http://www.hamptonbaysonline.com/external/historical_history.cfm#intro). Hampton Bays is significantly dependent on its commercial fishing fleet. According to 1990 census data, 3.63% of the residents of Hampton Bays, and 5.59% of the residents in Shinnecock were employed in agriculture, forestry, and fisheries, relatively high percentages for the urban-industrial northeast/Mid-Atlantic region. The area is also dependent on seasonal tourism as evidenced by 2000 U.S. Census data (Table NY). In 2000, 29.06% of the housing units in Hampton Bays were vacant, and of these 84.28% were used for seasonal, recreational, or occasional use.

Fishing Infrastructure

The offshore commercial fishing fleet is concentrated on the bay side of an isolated barrier island, to the west of Shinnecock Inlet. According to a fisheries management official,

Shinnecock Inlet has a tendency to silt over, which can completely curtail ocean fishing. The official said that when the inlet silts over now, Shinnecock/Hampton Bays plummets in importance as far as landings go, whereas it usually vies with Montauk as the most important port on Long Island. The Shinnecock informant said that the last time the inlet closed up the federal government dredged the inlet very quickly. Pressure from the commercial fishing industry expedited the process (McCay and Cieri 2000).
The commercial docks are located on an isolated stretch of road, far removed from residential neighborhoods and beachfront rental property. They are bounded on the east and west by county parklands. The nearest building is a public beach access facility located a few hundred yards to the west of the dock area.

There are one municipal dock, two privately owned facilities for packing catch that have limited docking space, and a fishing cooperative that operates as a packing facility and a dock. According to data gathered in 1999 by key informants, there are 24 slips at the Municipal Dock but only 18 are being used by vessels, the other 6 being in a state of disrepair. The fishermen lease their slips from the town. The dock was created as the result of lobbying by one of the fishermen about 12 years ago and was financed by federal, state and local money. Since that time, the town and the county have been fighting over who owns it and should administer it (McCay and Cieri 2000). The manager of one of the commercial packing facilities indicated that dock space is severely limited. He and other fishermen have made numerous attempts to convince the county of the need for expanding the municipal dock but have not been successful.

Next to the municipal dock is a fish packing facility that also has four slips for commercial boats. The business sells ice and fuel to fishermen. According to one informant, eleven boats pack with this company. Next to this business is a fishing cooperative that packs out between 13 and 15 boats. The coop buys fuel, ice and other supplies in bulk, which is necessary in order to keep members' costs down. Most of the fish that's brought into the coop is sold to Fulton Fish Market, though some of it goes to local buyers. The business on the other side of the coop packs commercial landings and also provides slips for recreational/pleasure boats. The owner of this operation also runs a restaurant on the premises. There is a large fillet operation with a retail market in Shinnecock/Hampton Bays. Shinnecock/Hampton Bays has also been a surf clamming port but demand for clams from New York State waters has been low (McCay and Cieri 2000). Many of the marine supplies for the commercial fleet come from a well-known business in nearby Riverhead, Long Island, which services other ports in the eastern end of Long Island as well.

Fishing Overview

Codes for both Shinnecock (or Shinnecock Hills) and Hampton Bays are used in the NMFS weigh-out data. These are combined in this analysis because both refer to the same fishing port.

Shinnecock/Hampton Bays is primarily a dragger fishing port. Otter trawl landings accounted for 84% of the poundage and 74% of the value in 1998. Silver hake (whiting) and *Loligo* squid made up over 70% of these landings. Loligo accounted for 23% of the landings by weight and 27% by value in 1998. Butterfish, Atlantic mackerel, and Illex squid were much less important. Draggers landed 66 other species, reflecting the diversity of the region’s fisheries. Gillnets were second in importance, accounting for 12% of the value of landings in 1998. They too had diverse landings, totaling 39 species, led by bluefish, monkfish, and skates. Bottom longlines were used for tilefish and pelagic longlines for swordfish and tunas. There is also a diverse assemblage of inshore techniques, including haul seines, pound-nets, pots (for crab, fish, eel, conch, and both inshore and offshore lobster), fyke-nets, and the shellfish techniques of shovels, rakes, and "by hand" (McCay and Cieri 2000).

Squid, Atlantic Mackerel, and Butterfish

Loligo and butterfish are important to the trawler fishing fleet that operates out of Shinnecock/Hampton Bays. There were approximately 30 draggers working out of Shinnecock/Hampton Bays in 1999: 10 in the 45' to 60' range; 16 in the 60' to 65' range; 4 boats between 80' and 90'; and, 4 boats over 90' in length (McCay and Cieri 2000). In 2000, 64 boats (many from other ports) landed *Loligo*, which was 66% of all the boats that landed catch in Shinnecock/Hampton Bays in that year. Forty-nine boats, or 50.5% of all boats that packed in Shinnecock/Hampton Bays, landed butterfish in 2000. Mackerel, though less important in overall value, was landed by 35 boats, or 36% of the boats that landed catch in Shinnecock/Hampton Bays in 2000. *Illex* is infrequently landed at this port due to the highly perishable nature of *Illex* and the need to transport it in boats set up for RSW (refrigerated sea water). The commercial draggers that land *Loligo* and butterfish at the three packing facilities engage in a mixed-trawl fishery. Like the draggers in Montauk, the fishermen target a diversity of species depending on the boat size, season, and regulations. A number of the draggers that land here also engage in the groundfish fishery during the summer months.

Loligo makes up a large part of the catch that is landed in Shinnecock. *Loligo* accounted for 39.2% of the value of the total landings in Shinnecock/Hampton Bays in 2000. During the summer of 2000, *Loligo* was being caught in unusually large numbers just off the beach of Shinnecock.   Fishermen from Montauk and Rhode Island landed their catch in Shinnecock rather than steaming home. The local packing facilities did very well as did the fishermen. Compared to the lucrative summer of 2000, squid fishing in the summer of 2001 was not profitable. One local fisherman explained that his operation took a serious financial hit when the 2500 lb trip limit was instated. This fisherman lost his crew members due to the drop in income. He explained that it is difficult to find good crew, especially when the boat is not making money. He retained only one original crew member and the rest went “to bang nails," or work in construction, a common alternative to fishing.

Fishing Community/Relations

Inshore fishing has a long history in Shinnecock/Hampton Bays. Offshore commercial fishing started late relative to other places on Long Island due to the time needed to stabilize the Shinnecock Inlet in the 1950s (McCay and Cieri 2000). Most of the boat owners/operators and crew members live in Shinnecock/Hampton Bays. According to one informant, there are a number of fishing families that have historical roots in the area. This is primarily the case for baymen, but a number of offshore draggers also have roots in the area and strong family ties to the industry. However, like Montauk, a number of fishermen are first generation who came to the area from towns further west on Long Island. Many of the dockworkers in the area are immigrants from Central and South America.

Overall, the relationship between the fishermen and the municipality has been positive. According to one informant, the town has been supportive of the local fishing industry.

However, fishermen have lobbied unsuccessfully for an expanded municipal dock and the area remains difficult if not impossible to develop for the commercial industry. Commercial fishermen in the area have also organized efforts designed to convince the federal government to assist in dredging the Shinnecock Inlet (McCay and Cieri 2000).

Greenport, NY

Greenport is the largest fishing port on the North Fork of Long Island. The village was a prominent whaling port in the early to mid 1800s and later became an important port for menhaden or "bunker" fishing and processing between the mid 1800s and the mid 1900s. Oystering was also an important industry up until the mid 1900s. At one point there were 14 oyster processing companies in the port (http://www.greenport.cc/ourhist.htm). Today, commercial fishing is still important in Greenport, but the economy has increasingly become geared to the tourist trade. A sign that greets visitors who come across the North Ferry from Shelter Island welcomes people to Greenport: "Shopping Hub of the North Fork." Despite the growing tourist trade, the town has demonstrated a commitment to maintaining Greenport's "working waterfront."

Fishing Infrastructure

The number of commercial fishing boats in Greenport has declined over the past several decades. In 1999, one informant estimated that there were 5 large offshore vessels, one medium-sized dragger, two small 40' draggers, 3 trap vessels (with pound nets), approximately 4 lobstermen, 4 or 5 people who do conch potting, 4 or 5 gill netters and 25 or so baymen (McCay and Cieri 2000). Two large scallop boats owned by a company in Cape May, NJ use Greenport's docks for repairs, but they land their catch in New Bedford and New Jersey.

The municipal Railroad Dock, located next to the North Ferry on Peconic Bay, is the primary commercial dock used by the large boats. The village leases the space from the train company and charges fees for tying up at the dock and for the use of water and electricity. The village has also provided a municipal dock for baymen located in Stirling Harbor. There is one packing facility located in Stirling Harbor that usually packs 2-3 small draggers and a number of small handline, trap, and gillnet boats. They also pack an occasional longliner. This facility also runs a retail fish market. The business sells some of the product landed at the fish market, while the rest is typically sent to Fulton Fish Market on consignment. They provide their own ice and cartons and pay for the shipping. A whiting exporter recently moved out of the area and relocated in Massachusetts. Greenport used to have another packing and processing facility, but this went out of business some 15 years ago. Greenport is also home to a shipyard and a welding company that gets business from commercial boats that come from other areas. The one marine supply shop in Greenport no longer operates as a supply shop. The owners now use the business for commercial rental space and as a freezer facility for the storage of bait for area lobstermen.

Fishing Overview

Otter trawling accounted for 95.6% of the total poundage and 92.5% of the total value landed in Greenport and nearby Mattituck in 1998. Species harvested were led by silver hake (46.1% of total value) and *Loligo* (27.2% of total value), but also included butterfish, summer and winter flounder, scup, striped bass, monkfish, and other species. Pound-net fishing, haul-seining, gillnetting, handlining, pelagic longlining, lobster and conch pot fishing, and raking for clams and dredging for bay scallops also accounted for landings in 1998. (McCay and Cieri 2000).

Squid, Atlantic Mackerel, and Butterfish

Loligo and butterfish are important to the draggers that operate out of Greenport. In 2000, 11 boats landed *Loligo*, which was 61% of all the boats that landed in Greenport that year. *Loligo* accounted for 16.1 % of the total value of catch landed in Greenport in 2000. Eleven boats, again, landed butterfish in 2000. Butterfish accounted for 11.8 % of the total value of landings in Greenport in 2000. Very small quantities of mackerel and *Illex* were landed in Greenport. The smaller draggers of Greenport engage in a mixed trawl fishery, targeting a diversity of species, depending on seasons and regulations. In addition to dragging, the fishermen of Greenport engage in a diversity of additional fishing activities such as clamming, pound-netting, trapping, and gillnetting. The diversity of activities has allowed the fishermen to adapt to the changing natural and regulatory environments. One fisherman from Greenport explained that he used to do more squid fishing, but that the recent Scup GRAs made it difficult to make squid fishing profitable. He stayed with groundfishing all last winter, landing his catch away from Greenport, in places like New Bedford. The recent groundfish ruling, which is going to reduce his operations by 40%, will drive him to do more squid fishing than he has done recently. According to this informant, the other draggers who pack out of Greenport already rely heavily on *Loligo*. Regulations and state-by-state quotas are a concern to local fishermen because reduced limits have forced them to fish in different waters and pack their catch in different ports (McCay and Cieri 2000). One fisherman noted that area closures, if they occur, will be "another nail in the coffin" of the industry.

Fishing Community/Relations

The Village of Greenport is said to be "fisherman friendly," and is generally more supportive of the fishing industry than other communities according to informants. Greenport projects an image of being a seaport community through its tourism literature and waterfront revitalization efforts. The village features a maritime museum and also hosts a maritime festival. One example of the village's commitment to commercial fishing involves a local fish processing plant. Condominium residents located near the plant complained about noise and smells associated with the plant's operation. The village board upheld the plant's right to operate as it saw fit because it had been there for 100 years while the condominiums had just been built. The board said that while the plant must comply with health regulations, it could operate in the middle of the night if it had to in order to ship fish. The board had previously changed zoning so that no new condominiums could be built in the commercial waterfront district. A second development already existed and was allowed to stay (McCay and Cieri 2000). Greenport's waterfront revitalization program, which is the first in the state, includes a clause protecting the commercial docks. The "Waterfront Commercial" zoning areas allow most uses related to commercial fishing, often to the exclusion of other uses (McCay and Cieri 2000).

Despite the village's commitment to the fishing industry, one informant pointed to the reduced number of boats and the loss of fishing infrastructure as signs of the decline of Greenport's fishing industry. According to one fisherman, the reason for the decline is associated with the over regulation of fish stocks, restrictive quotas, and New York State's apparent lack of commitment to commercial fishermen.

Freeport, NY

Commercial fishing activity in Freeport, Nassau County, is concentrated in two areas - along a revitalized waterfront area known as "Nautical Mile," and in Point Lookout, a small beach town on the south side of Jones Inlet, across from Freeport. Freeport began promoting itself as the “Boating and Fishing Capital of the East” in the 1940s (http: www.lihistory.com/spectown/hist001k.htm). Commercial fishing has been declining in the area over the last several decades as tourism has expanded. According to one fisherman, "Nautical Mile" was once the homeport of 15 draggers. There are only four draggers that operate from small docks in this vicinity now, as well as a small number of lobster, clamming, and potting boats. A strip of restaurants, marinas, fish markets and small businesses that rely on tourism now dominates the waterfront. The canal that provides access to the bay is packed tightly with party boats, charter boats, gambling boats, and numerous pleasure craft. Unlike port towns located further east on Long Island, Freeport is much less reliant on seasonal tourism. In 2000, only 2.28% of the housing units were vacant, and of these only 14.6% were used for seasonal, recreational, or occasional use (Table NY).

Fishing Infrastructure

The following profile on Point Lookout comes from data gathered in 1999 (McCay and Cieri 2000). The main commercial fishing business in Point Lookout is family-run and consists of a wholesale fish market, retail fish market, clam bar and restaurant. The restaurant was started in part because a developer was going to build residential units right out to the waterfront on the land next to the business' dock. Not long ago there was a boatyard across the street where there are now only parking lots and private homes. The business has freezer space for 15-20,000 lb. of product. According to one informant who was interviewed in 1999, the business runs two of its own boats while other owner/ operators sell exclusively to it. Each boat has four crewmembers and multi-species permits. The business also buys from five local gillnetters. The business has a network of over 100 local restaurants that it wholesales to; the rest of its wholesale product goes to Fulton's Fish Market. Between the four phases of the business they employ 30-35 people at any one time, 10 of those on the fish dock. All the dock's crew and employees live within a couple of miles of the dock. According to one informant at the business, there used to be fourteen trawlers tied up in Pt. Lookout and that the operation used to do a lot of out-of-state business. Now all their sales are local. However, another observer reports that out-of-state boats still land there. In addition to this operation, there is a surf clam processing plant on the same road that has been in the seafood business since the beginning of this century. It primarily handles surf clams caught in New York state waters as well as other shellfish. Several surf clam boats also work out of Freeport (McCay and Cieri 2000).

In the town of Freeport, three fish docks are located along the waterfront of the "Nautical Mile" on Woodcleft Road. One of the docks also runs a seafood restaurant and retail market. One dragger ties up and unpacks here. A separate commercial docking and packing facility is associated with another fish market. There are 2 draggers and a number of lobster boats that dock and pack with this operation. The commercial infrastructure is literally surrounded by pleasure boats, party and charter boats, gambling boats and a host of tourist related businesses.

Fishing Overview

According to NMFS weigh-out data (which do not include all landings by port, including surfclams, which are important to Freeport), Freeport and neighboring Point Lookout (included in the Freeport port code) are almost entirely dependent on otter trawl landings. In 1998, otter trawling accounted for over 89% of the poundage, and 87% of the value. The primary species landed included *Loligo* (39.3% of total value) and silver hake (16.2% of total value), with smaller amounts of scup, weakfish, bluefish, butterfish, summer flounder, other flounders, and Atlantic mackerel. Gillnet, small handline, pot, pound-net and bay shellfisheries were also associated with these ports in the weigh-out data. These data are misleading in that surfclams were not reported by port in 1998.

Squid, Atlantic Mackerel, and Butterfish

Loligo is important to the draggers that operate out of Freeport, as is butterfish to a smaller degree. In 2000, 18 of the 43 boats that landed catch in Freeport landed *Loligo*. *Loligo* accounted for 45.5 % of the total value of landings in Freeport in 2000. Twelve boats, or 27.9% of all boats that packed in Freeport, landed butterfish in 2000. Butterfish accounted for 2.8% of the total value of landings in 2000. Very small quantities of mackerel were landed in Freeport.

The smaller draggers of Freeport engage in a mixed trawl fishery, targeting a diversity of species, depending on seasons and regulations. They are day boats for the most part, leaving in the early morning and returning by day's end. One fisherman who owns a 60' dragger said that he fishes for *Loligo* full-time from mid-May into August. He explained that regulations, including highly restrictive trip limits, prevent him from fishing for fluke when he is most capable of catching them. *Loligo* fishing has become a necessity. From January 1 to May 1 they can catch a limit of 500 lbs of fluke, but this is when the fish are offshore. The limit gets cut down precisely when the fish come inshore which prevents him from profiting because he has a smaller, inshore boat. This forces him to concentrate on *Loligo*.

Fishing Community/Relations

According to interviews conducted in 1999 the relationship between fishermen and the local community are strained (McCay and Cieri 2000). One informant explained that the town of Freeport was opposed to the idea of having a cooperative commercial fishing dock despite lobbying efforts on the part of local fishermen. He thinks they are developing the area for tourists and pleasure boaters, squeezing the commercial fishermen off the docks. According to him, the town views the fishing operations as an eyesore and an impediment to the development and revitalization of the waterfront. He thinks that the commercial fishermen are being pushed out. In June of 1999, major upgrades were being made to the road that ran directly in front of the commercial operations. According to the informant, the new sidewalk took away their parking. The relationship between the fishing industry and the town of Point Lookout is reportedly much less problematic. According to one informant, relationships with the community have been good and there has been no pressure to force them off the docks to this point. He added that he "pounds the people with pro-commercial fishing propaganda" (McCay and Cieri 2000).

Brooklyn, NY

Commercial fish landings in New York City's boroughs have declined markedly over the years. Landings for Brooklyn amounted to less than 30,000 pounds in 1998, mainly from otter-trawling and sink gillnets. The principal species, out of 17 landed, were butterfish, bluefish, weakfish, and *Loligo* squid. Sport fishing at Sheepshead Bay and other sites has become more important than commercial fishing in recent years. (Table NY) presents 1990 and 2000 census data for Brooklyn.

Loligo accounted for 28.5% of the total value of landings in Brooklyn in 2000. Fifty percent of the boats that landed catch in Brooklyn landed *Loligo*. There is a major *Loligo* processing plant in Brooklyn. This facility employs 50 full-time employees, including 40 processing personnel, and 10 secretarial and managing personnel. The number of processing personnel increases by 15 to 20 workers in the winter when more *Loligo* is being caught. Fifty percent of the company's processing personnel are Hispanic and 20% are female. For the most part, the employees are long standing Brooklyn residents who grew up in the area. According to one of the operation's managers, it is difficult to find employees, but they have a stable workforce with very little turnover. Nearly 100% of the business is based on the processing of *Loligo*. The *Loligo* is trucked in fresh from Cape May, Montauk, and Shinnecock. It is cleaned and packaged into 2.5-pound boxes that are made ready for sale. The product is shipped all over the U.S. but Long Island is the biggest market. The company buys *Loligo* from 10 to 15 boats on a consistent basis. He has been buying from the same boats for 10-12 years and although there has been some flux, the same boats have been fishing for squid through the years. According to the informant, the business is extremely important to the local Brooklyn area. The company makes a point of dealing with local businesses for supplies, trucking, and storage.

New Jersey's Fishing Ports and Communities

New Jersey is the most densely populated and one of the most industrialized and urbanized states in the nation. Although small in area, it also has a long coastline, about 100 miles, as well as two major tidal rivers, the Hudson and Delaware, and numerous estuaries inside its barrier islands and embayments. Much like New York, Connecticut, Rhode Island, and Massachusetts, its fisheries are found in both urban and rural settings and are often embedded in communities with very different orientations, whether industrial or tourist.

The major ports in New Jersey for the Squid, Atlantic Mackerel, and butterfish fisheries are Elizabeth, Point Pleasant, and Cape May (Table 1). Cape May ranked 3rd overall for fisheries value and 3rd for SMB in the northeast in 2000. It ranked 7th for dependence on these species. Point Pleasant ranked 4th in 2000 in terms of fisheries value; it ranked 8th for the value of SMB, and 11th in dependence on SMB fisheries that year. Elizabeth is an old industrial port city; its commercial fishing activities area very small, the catches going to a processing plant in the city of Newark, NJ. However, the value of Elizabeth s SMB fisheries ranks 12th, and it holds the top spot in the northeast for dependence on these fisheries (Table 1). The port of Belford also has significant landings of these species, and the recreational fisheries of Atlantic Highlands, Brielle, Cape May, and other ports are at times significantly involved in the Atlantic mackerel fisheries, but these are not discussed below (see McCay and Cieri 2000 for more information).

Union and Essex Counties, NJ

A major Squid, Atlantic Mackerel, and butterfish processing facility is located in the city of

Newark, NJ, Essex County, and some of the raw materials processed there are landed in the nearby port town of Elizabeth, NJ, Union County. Although the quantities landed in Elizabeth are small relative to landings at other ports, the processing facility is an important part of the industry and heavily dependent on the species covered by this FMP.

Union County, the site of the port of Elizabeth, is small in area, densely populated, highly urbanized and bounded on the east by the Newark Bay and Arthur Kill. Essex County is just to its north, dominated by the large city of Newark, the container port of Newark Bay, and Newark International Airport. Both are urban areas with high proportions of minority populations and large pockets of unemployment and poverty (Table NJ-1). In 2000 over 35% identified themselves as other than "white" in Union County, and over 63% in Essex County. Fisheries are extremely minor in terms of employment: in 1990 0.2% were in the occupational category of agriculture, fisheries, and forestry. However, unemployment is very high, especially in Newark, making the provision of any jobs there very important.

Elizabeth, NJ

The city of Elizabeth is located along New Jersey's northern waterfront, on Arthur Kill between New Jersey and Staten Island, New York. Elizabeth is one of New Jersey s oldest cities. It has gone through a long period of urban decline, recently checked by the creation of regional shopping centers on its periphery. In 2000 the population was 120,568, a 9.6% increase since 1990. In 2000 fifty percent of the population were Hispanic, 20% black (Table NJ-1). Twenty-five percent of the houses were vacant, and 19% of the family households were headed by females. The people of Elizabeth match the county's percentages for high school graduates. However, the percentage of people with bachelor's degrees, 7.5%, is less than the county level.

Newark, NJ

The city of Newark had a population of 273, 546 in 2000, a slight decline from 1990 (Table NJ-1). The white population was only 26.5% of the total. Fifty-five percent identified wholly or in part as black or African-American, and over 29% indicated Hispanic or Latino. The median age was 30.8, and 29% of the households were female-headed. In 1997 26% were living in poverty (compared with 16% in Elizabeth and 9.3% for the state as a whole).

Fishing Infrastructure

Although the fishery of Elizabeth is very small relative to that of other ports, it is particularly dependent on Loligo and Illex squid. *Loligo* accounted for 70% and *Illex* 21% of the value of total landings in Elizabeth in 2000. The squid and fishes offloaded in Elizabeth are processed at a plant in the city of Newark, NJ.

The owner of the Newark plant and one vessel that offloads in Elizabeth indicated that about 98% of his company's business comes from squid, primarily *Loligo*. He was the first one to start processing Loligo squid in this region, in 1977. In addition to the catch of his own vessel, he buys squid from 12 to15 docks in Rhode Island, Long Island, New Jersey and Virginia. The plant employs 8 skilled, 7 semi-skilled, and 105 unskilled workers who clean and pack mostly squid. The semi-skilled team captains and the unskilled line workers are almost entirely women, foreign-born, and speakers of Spanish or Portuguese, who are paid on a wage basis.

Ocean County, NJ

Ocean County is a long, large county the coast of which is dominated by seasonal tourism and commuter and retirement housing, shopping, and services. The commercial and recreational fisheries of Ocean County have very long histories of being ensconced in complex communities. A century ago, the barrier beach communities of Ocean and neighboring Monmouth County were referred to as the Riviera of the Atlantic because of the early development of elegant hotels and homes along the beaches, which the fishing communities supplied. Today Ocean County is more often called The St. Petersburg of the Northeast (Sokolic, 2001), referring to the fact that it has the largest retirement communities in the State. Several important fishing centers are found in Ocean County, particularly Point Pleasant, at the Monmouth County boundary, Barnegat Light, on one of the long barrier islands, and small bayman places such as Forked River and Cedar Creek. Sport fishing is done from every coastal community, especially those surrounding Barnegat Bay and Toms River. Major charter and party boat fleets are concentrated in Point Pleasant and Barnegat Light, where there is ready access to deep-draft inlets to the sea.

The total population in Ocean County was 510,916 in 2000 (Table NJ-2). This was an 8.6 percent increase from 1990. Ocean County has grown rapidly from coastal tourism, retirement community development, and general suburban expansion within the NY-NJ Metropolitan Area. In 1990, only 20.4% of the population was rural, and less than 1% lived on a farm. The population is ethnically diverse: In 2000, the white population was only 65.9% of the total. Twenty two percent were 65 years of age or older, and the median age was 41 years, making it second in New Jersey only to Cape May County, where the median age was 42.3 years.

In 1999, Ocean County had a per capita personal income of $27,694. Based on a 1997 model based estimate, 7.8% of the population was classified as living in poverty, compared with 9.3% for the State as a whole. In 2000, 3.9% of the population was unemployed. In 1990, of the employed persons 16 years of age and older, 1.5% were in the agriculture, forestry, and fishery industries sector.

Point Pleasant, NJ

Point Pleasant comprises the municipality of Point Pleasant Beach and Point Pleasant borough, located at the mouth of the Manasquan Inlet, where Ocean County borders on Monmouth County. The town's economy is geared toward the summer tourist and recreational business, as shown by the fact that according to the 2000 census, 26.6% of the vacant housing units in Point Pleasant Beach were used for seasonal, recreational, or occasional use (the figure for Point Pleasant borough, the more residential part of the town, was 6.4%).

The fisheries are concentrated in an area known as Channel Drive in Point Pleasant Beach, a sandy strip on which are found restaurants, a fisherman's supply store, small marinas, charter and party boat docks, and two large commercial fishing docks as well as several smaller ones. Although tourism is the major business, the town recognizes and builds on its commercial and recreational fisheries. For example, the web-site www.pointpleasant.com features a photograph of a memorial to fishermen who lost their lives at sea, as well as advertisements for local party boats.

According to the 2000 Census for Point Pleasant Beach, the population was 5,314, a small (3.95%) increase from 1990 (Table NJ-2). Point Pleasant borough was much larger in 2000 with 19,306 persons, a 6.21% increase from 1990. There are very few minority residents. In 2000, 95.9% and 97.8% of the population in Point Pleasant Beach and Point Pleasant borough were white, respectively. Mirroring the county as a whole, the median ages are high: 39.4 years for the borough, and 42.6 years for the beach.

Per capita incomes for 1999 were considerably lower in Point Pleasant than in the county as a whole (about $28,000 for the county, $19,000 for the borough and $16,500 for the beach) (Table NJ-2). In 1990, 1.45% and 3.0% of the persons 16 years of age or older were in the agriculture, forestry, and fisheries industries sector in Point Pleasant Borough and Point Pleasant Beach, respectively, an indicator of the importance of fishing. However, interviews conducted in 2002 indicate that most of the fishermen do not live in Point Pleasant Beach or Point Pleasant Borough but rather are spread among many other towns of coastal New Jersey.

Fisheries Infrastructure

Point Pleasant is primarily an ocean fishing port, with a long history involving ocean pound-nets and otter trawl and gillnet fisheries, as well as sportfishing, focusing on the nearshore wrecks and the offshore canyons of the New York Bight. In terms of landings, the commercial fisheries of Point Pleasant rank third in New Jersey to those of the Cape May-Wildwood area and Atlantic City.

Like so many ports of the Mid-Atlantic region, the port of Point Pleasant Beach is inlet-dependent. Ocean-going fishers must pass through the often dangerous Manasquan Inlet, a challenge shared with the recreational fishing community including the party and charter boat businesses of Point Pleasant and neighboring Brielle, in Monmouth County. This is a highly developed coastal region. Currently, there is a wholesale finfish packing dock and seafood retail store at Point Pleasant run by a fishermen's cooperative. Another dock is primarily used for offloading surfclams and ocean quahogs although finfish may be handled there as well. A dock once used for pelagic tunas and swordfish is now being used by a lobster boat.

As elsewhere in the Mid-Atlantic, the fisheries of Point Pleasant Beach are very diverse. Two stand out in terms of volume and value: otter trawls and gillnetting, the latter particularly important for spiny dogfish as well as bluefish, weakfish, and other species. However, sea scallop dredging has been very important, as are surfclamming/ocean quahogging and offshore lobstering. According to the 1998 landings (McCay and Cieri, 2000), the most valuable species was angler or monkfish, which was partly incident to the scallop fishery but also caught by specialized gill-netters both local and migrating from other ports in the northeast and mid-Atlantic. Sea scallops were next in terms of ex-vessel value, followed by *Loligo* squid, a major focus of the local dragger fishery in the last decade. Also important were summer flounder, also a traditional fishery of the area but sharply cut back by regulations; lobster; spiny dogfish (like monkfish, caught by gill-netters as well as other fishers), and silver hake, or whiting. Whiting was one of the mainstays of this port from the 1970s through the 1980s but its availability and abundance have since declined. In terms of pounds landed, menhaden (purse-seined) and surfclams and ocean quahogs were the leading species in 1998, having come to replace the traditional otter trawl finfish fishery in importance over the past decade. The total landings value for 1998 was over 16 million dollars, indicating the high value of the fisheries to the local economy and community.

Two of the fishing properties in Point Pleasant are owned by a Cape May seafood business. Each of these docks had been used for finfish until about 10 years ago. They are now used for offloading and trucking surfclams and ocean quahogs. From 6 to 10 boats, most homeported in Atlantic City or Cape May, land clams and quahogs here. There are 15 crew at the docks and up to about 50 on the boats, many of whom commute from South Jersey or even other states to the south. In 2000 a small hand-shucking plant for surfclams began business and continues in 2002 at a site that had been a surfclam processing facility in the 1960s and early 1970s.

A fishermen's dock and marketing cooperative owns two other waterfront properties, one for storing and working on gear and some dockage, the other including the coop's offices, gear storage, ice-making, packing house, and a retail market with a small restaurant (which serves both local fishermen and tourists alike). The cooperative mostly depends on its sixteen or so members, who have switched from older, wooden-hulled vessels to larger steel-hulled boats. They are outfitted for bottom otter trawling in a mixed-species, diversified fishery. The vessels usually have a two or three man crew, including the captain, who are paid shares of the profits. They are all hired locally. Although there are families with several generations in the fisheries, in recent years crewmembers are not often related to the captain or owner. Members of the cooperative are typically first-, second-, or third-generation immigrants from Northern and Mediterranean Europe and other places. A few women have crewed on these boats. The boats are all owner-operated. They tend to fish in areas of Hudson Canyon and "the Mudhole," an area between the Hudson Canyon and the mouth of the Hudson River.

Most of the draggermen at the cooperative consider themselves *Loligo* squid and whiting specialists, but different species are targeted at different times, depending on the conditions of the ocean, the market, and the preferences of the captain. Squid landings began to overtake silver hake landings in this fleet in 1992 and by the latter 1990s accounted for over 50% of the landed value of Point Pleasant trawlers. At first *Loligo* was a by-catch while silver hake fishing in the Gully. Then it was targeted by most of the captains. As one captain stated, "You can't help but target squid sometimes, there is so much out there." Squid is sold to processors in Cape May, Newark, and elsewhere in the region. The cooperative is at a disadvantage in marketing squid because members lack freezer boats or refrigerated sea water boats, and thus do not receive the same price that boats so equipped receive.

Declining catches and restricted fisheries, especially the scup GRAs [gear restricted areas] during the winter along the continental shelf, have hurt this fishing community severely. It is estimated that the GRAs have reduced the landings by 30 to 35% for the local cooperative (mostly for *Loligo* squid). Some boats have left the fishery or are for sale. Existing operations have difficulty investing in major improvements, either to the waterfront properties or to the vessels. However, even in the face of these difficulties, members of the cooperative banded together in order to raise enough money to make the required dock repairs, approximately one million dollars. It is this investment that the fishermen feel is necessary in order to compete and have an appropriate facility. Their fear is that with increased restrictions on what, where and when they can fish their profit margin will be so small that it will be impossible to meet the financial obligations.

Point Pleasant Beach also has a sizeable charter/party boat fleet which, like the neighboring one of Brielle, is well known for diverse fishing opportunities, including overnight and two-day offshore canyon trips and nearshore, bottom-fishing and wreck fishing. The Channel Drive area also hosts a recreational marina, a fisherman's supply company, and popular seafood restaurants. Nearby is a popular amusement park and beach and a U.S. Coast Guard station.

Squid, Atlantic Mackerel, Butterfish Fishery

In Point Pleasant, *Loligo* squid are more important than *Illex*, butterfish, or Atlantic mackerel. All but one of the members of the cooperative fish for *Loligo* during the winter months. According to the manager, *Loligo* squid makes up about 25% of the annual catch (value) for the draggers. However, while out targeting squid it is common to find large schools of butterfish and occasional Atlantic mackerel, especially in the areas around the head of the Hudson Canyon and the Hudson Canyon itself.

Point Pleasant’s fisheries have declined. In 2001, 81 boats landed in Point Pleasant, down from 123 in 2000 and 142 in 1997, and the total value of fish landed declined by 63% from 2000. In 2001, *Loligo* represented only 3.4% of the total value landed in Point Pleasant (which was dominated by surfclam and ocean quahog landings). In contrast, Loligo landings represented 9% of the total value of landings in 1994. In 2000 and 2001, Illex, butterfish, and mackerel contributed very little to the total value in Point Pleasant, even though they are recognized as important, especially to the recreational fisheries.

SMB and the Recreational Fisheries

Recreational fishermen use Atlantic mackerel in three ways: food, fun, and bait. As a food first generation Italians and other Mediterranean people enjoy it smoked, Asians eat it fresh (not smoked) and Polish people are said to can it. As a fun species, party boat captains report that it is a fun fish to catch because of the fight it puts up. As a bait, it is said to be a good all around bait, but especially good for sharks and marlin.

Atlantic mackerel is an important target for the party boat fishery in Point Pleasant (and elsewhere in the region). For many of the party boat fishermen and some of the charter boat fishermen Atlantic mackerel is a “ fill in” or a “get you through” fish because it appears at times when other sport fish are usually not available. Normally there are two discrete seasons, winter and spring, as Atlantic mackerel migrate up and down the coast, and these seasons tend to last from two to three weeks. The winter season is between late November and the beginning of January and the spring season is between mid-March and May. However, the winter and spring of 2002 saw Atlantic mackerel throughout the entire time period. Fishermen interviewed suggested that this was due to the warm air and sea temperatures. For some recreational fishermen, Atlantic mackerel makes up 12 to 15% of their annual trips, a significant contribution if not as important as bluefish, fluke or sea bass.

Recreational fishermen do not target squid, but there is little doubt about the importance of squid as bait, especially for the party boats going after fluke and sea bass. Most bait and tackle shops sell squid as a universal bait. Any reduction in the availability of squid for bait would diminish access to high quality bait for party, charter, and private boats, as well as shore and pier anglers.

Butterfish is not targeted by the recreational fishermen, but again there is little doubt to its importance in the recreational fishing industry as a high quality bait. It is considered to be such a good bait because once frozen and then used it holds its firmness and makes a good presentation in the water. Party boat captains say that butterfish is tremendously important for tuna fishing as well as bluefish. Considering the importance of both tuna and bluefish to the recreational fisheries of Point Pleasant and the larger region, a reduction in availability of butterfish would create a similar problem to that of squid. Charter and party boat captains are afraid that if they can no longer obtain such high quality bait, they will lose customers who otherwise are willing to pay large sums of money to run offshore to fish for tuna: why pay a large sum only to be “skunked” for want of high quality butterfish?

Fishing Community/Relations

The fishing community of Point Pleasant has received support of various kinds, including zoning for water-dependent uses which helps moderate the pace of gentrification of the waterfront. Although few fishermen live close to the docks, they use local supermarkets, convenience stores, and bars.

The fishing community of Point Pleasant was hard struck by the January 1999 tragedies in the surfclam and ocean quahog fishery. The Adriatic, the Beth Dee Bob, and the Ellie B, all working out of Point Pleasant, went down during storms that month, as well as another vessel, the Cape Fear, formerly based in New Jersey, up in Buzzards Bay, Massachusetts. Ten lives were lost. In the aftermath, members of the fishing community, led by the dock managers at the surfclam/ocean quahog dock, began the work of designing and funding a fishermen's memorial with support from the larger community. It was built by a local sculptor and set in a small park alongside the Manasquan inlet. The wall around it has the names of fishermen of this part of the coast who lost their lives at sea as well as the ship's bell of one of the vessels lost in January 1999. It is telling of the nature of Mid-Atlantic fisheries that both recreational and commercial fishermen are remembered on the memorial.

Cape May County, NJ

Cape May County, and the municipalities of Cape May and Lower Township, are major centers of the Squid, Atlantic Mackerel, and butterfish fisheries. Cape May County encompasses a large peninsula at the southern end of New Jersey, bounded by the Atlantic Ocean at one side and the Delaware Bay at the other. Its beaches have long been the focus of summer tourism, principally from the Philadelphia region, and in recent years the once rural county has also become the site of commuter and vacation home housing developments. However, both commercial and recreational fishing remain critical mainstays of the year-round economy of places like Cape May and Wildwood within the county.

In 2000 the population was 102,326, a 7.6% percent increase from 1990 (Table NJ-2). The minority population is very small, less than 8%. In 2000, the median age for Cape May County of 42.3 years was the oldest of any New Jersey county, bespeaking its increasing popularity as a retirement center. In 1999, Cape May County had a per capita income of $29,455. Based on a 1997 model based estimate, 11% of the population was classified as living in poverty. Unemployment tends to be higher in Cape May County than in most other parts of the state. In 2000, 8.6% of the civilian labor force was unemployed. Of the individuals in the labor force in 1990, 7.5% of the civilian labor force was unemployed . In 2000, 2.1% of the population were in the agriculture, forestry, and fisheries industries sector, an indicator of the importance of fishing (but also farming) in this area.

Cape May and Lower Township, NJ

The area popularly thought of as Cape May, at the very tip of the peninsula, is a popular tourist destination, famous for its Victorian architecture and the high quality of its “bed-and-breakfast” inns and restaurants. It is treated in the census separately from the area where much of the fishing activity takes place, Lower Township, which is more diversified. However, both are part of the effective community of the fisheries. Cape May’s 2000 population was 4,034, actually a 14% decline from 1990, and that of Lower Township was 22,945, a 10% increase from 1990 (Table NJ-2). Both are predominantly “white” in race/ethnicity. The median age for Lower Township, of 42 years, is identical to that of the larger county, which is known to be a haven for retirees from the Pennsylvania/New Jersey region. Per capita incomes are lower and poverty levels higher in Lower Township than in Cape May (Table NJ-2). In 1990, 1.6% of the population of Cape May 16 years of age or older, and 3% of the equivalent population in Lower Township, was in the agriculture, forestry, and fisheries industries sector.

Fisheries Infrastructure

Commercial and recreational fishing docks are found in Cape May but the majority are clustered in Lower Township along Ocean Drive, a road that leaves the main highway and crosses the marshes toward Wildwood. Another major dock is found at Schellenger's Landing, just over a large bridge that connects the mainland with the center of Cape May and its beaches.

Cape May is one of the largest commercial ports on the Atlantic seaboard. When combined with neighboring Wildwood (the fishing port is often referred to as "Cape May/Wildwood"), its 1998 landings exceeded 93 million lbs., worth over $29 million. Finfishing, squid fishing, and scalloping have been very important. It is a highly diversified port (McCay and Cieri 2000).

In 1998 otter-trawl equipped draggers accounted for 69% of Cape May's landings and 70% of its value. As elsewhere in the Mid-Atlantic region, they are highly diversified, and some in Cape May are also used for scalloping. Cape May has a long history of combined or alternating fin-fishing and scalloping. Squid is very important: In 1998 17% of Cape May's landed value came from Illex squid and another 22% from Loligo squid (McCay and Cieri 2000). Much of the squid is processed locally as is Atlantic mackerel, caught with draggers and midwater pair trawls. Summer flounder has been a major species but regulations have severely reduced catches. Scup is another dragger-caught species of historic importance in Cape May. Cape May is also the home of one of the very few vessels allowed to use purse seines for bluefin tuna in U.S. waters; this vessel lands its catch in Gloucester, MA. The only purse seine landings in Cape May in 1998 were for menhaden, using smaller vessels. Fishing for large pelagics is also done with longlines and troll lines (McCay and Cierri 2000).

A city planner interviewed in 1999 estimated that 500 people work in the fishing, processing, fresh fish market and restaurant enterprises of Lower Township and Cape May (McCay and Cieri 2000). However, “gentrification” has taken hold in Cape May as in many other coastal communities of the northeast and the mid-Atlantic. Despite being the most important commercial fishing port in New Jersey, commercial fishing businesses and uses of the waterfront are considered by planners and business people as lower priority than recreational and resort-oriented uses. Private recreational boating and fishing marinas are said to be a powerful political force in the township. Cape May has a substantial recreational fishery, both for-hire and private boat. Whale watching and dinner cruises have emerged as a profitable alternative or adjunct to recreational fishing charters (McCay et al 2002).

Schellenger's Landing is the most visible center of fishing in the Cape May area. Although most obviously a large restaurant and fish market, it is zoned "marine general business" with allowance for expansion of the marine industrial character. There is also a marine railway nearby. Other marine-related businesses in and around the landing include two recreational marinas, two marine suppliers, two bait and tackle shops, a whale research center, and a "marlin and tuna club." Also there are a pizza shop, a motel, a bar, a wildlife art gallery, an antique store, two restaurants, and a gasoline station. Some cater to people in the fishing industry and some do not. Further expansion of the fishing industry, commercial or recreational, is limited by the high cost of land near the waterfront (McCay et al 2002).

Lower Township has three "marine development" zones located along Ocean Drive, towards Wildwood, at Two Mile Landing and at Shaw Island and Cresse Island adjacent to Wildwood Crest. Recreational boats currently use these areas. Across from Shaw Island is a new development, where 325 new slips are being built. A complex on a saltwater creek includes a marina, bait and tackle, marine supply, and charter boats. The marina itself is small, about 28 slips. Access to this particular area is now difficult for large vessels because of silting due to a canal built between Cape May and the mainland (McCay et al 2002).

Ocean Drive is the location of several important commercial fishing businesses. One commercial fishing business in the Ocean Drive area owns a surf clam/ocean quahog vessel (currently at Point Pleasant) as well as a freezer trawler and seven "wet" boats and 2 refrigerated seawater (RSW) vessels. According to its owner, at this facility there are 15 shore employees, approximately 20 seasonal packers, and about 45 crew on the boats.(McCay et al 2002).

There are two other large commercial fishery companies on Ocean Drive, both of which are largely involved with finfish. One has a long history as a processor, wholesaler, and exporter. In 1999 14 vessels landed their catch here full-time, including a couple of freezer trawlers. Crew sizes are 3-5 men, and 8-9 for the freezer trawlers. There were 75 to 80 shoreside employees. In 1999 about 40% were Hispanic, 40% white, and 20% African-American, Asian, and other. They lived in the Cape May and Cumberland County region; many of the Hispanics came from the agricultural town of Bridgeton (McCay and Cieri 2000). The second large firm has a retail store as well as packinghouse and processing facility. There were 15 boats in 1999. About 20 people worked on the dock and in the retail store, and in 1999 at the time of a visit to the facility, about 35-40 people were processing squid. Five or so were Black-Americans. The rest were identified as Vietnamese, who came daily to work from Philadelphia through a labor contractor. Since then this firm has filed for Chapter 11 bankruptcy (McCay et al 2002).

Squid, Atlantic Mackerel, and Butterfish

Squid, Atlantic mackerel, and butterfish are important products for the first commercial packing and processing facility mentioned above, which is the only year-round industry in Cape May. Their primary business is with these "underutilized" species, and they handle large volumes. Decline in stocks of groundfish, whiting and summer flounder over the years has increased the importance of squid and mackerel to this business. The plant workers are primarily Hispanic and live in nearby Wildwood as well as the inland towns of Bridgeton and Vineland, and the office staff live within 20 mile radius of the facility. Many of the plant workers come through a labor contractor; the others are long-standing employees. The only competition for workers is from the tourist industry during the summer. He stated that seafood is the number two employer in Cape May. He derives all of his business from Loligo, Illex, mackerel and butterfish with Loligo and Illex comprising about 50% of his business. The only species that is important is Atlantic herring and is not part of this plan. He handles both fresh and frozen product from fishing boats and processes squid. About 90% of his product comes from the port of Cape May. A total of 15 boats land fish at his facility and the boats have been selling to his facility for generations.

In 2000, 51 boats landed Loligo in Cape May, which was 36.2% of all the boats that landed catch in Cape may in that year. Loligo accounted for 6.1% of the value of total landings in Cape May in 2000. However, Cape May lands scallops that are a high value product. Loligo is an important fishery during the winter months for Cape May draggers. As a result of the GRAs particularly the southern GRA (January-March 15 closure), fishermen and processor reported losing from 10-30% of their income. Fishermen were forced to fish for less valuable species such as scup or spend more time searching and steaming for Loligo in non-traditional grounds.

Ten boats landed Illex in Cape May during the 2000 fishing season and these were 7% of all the boats that landed catch in Cape May. According to the fishermen, 2000 was not a good fishing season for Illex. The Illex remained further east and were unavailable for capture in their gear. As a result, fewer boats participated in the 2000 fishery. Illex is primarily a June through September fishery for Cape May vessels. In Cape May in 2000, 15 boats landed mackerel out of 141 boats. Mackerel are not a high value product, but this fish did account for 7% of the value of total landings in Cape May in 2000. Fishermen stated that only larger vessels with the capacity to land high volume of mackerel participate in the fishery because they are only the boats who can make money on this species.

Fishing Community/Relations

Although Cape May portrays itself as a Victorian seaside resort with “gingerbread” homes and inns, it also includes emblems of the fisheries. A pamphlet “This Week in Cape May” lists a 45-minute Fisherman’s Wharf Tour that is scheduled to occur four times in May and June at the above-mentioned dock and fish packing plant. The tours are sponsored by the Mid-Atlantic Center for the Arts. There is a bronze plaque for fishermen lost at sea in a central pedestrian mall. A fisherman’s memorial at the end of Missouri Avene portrays a woman and a child looking out to sea. A fishermen's wives organization, now defunct, played a major role in creating this memorial. The inscription says,

Dedicated to the fishermen lost at sea - 1988
He hushed the storm to a gentle breeze,
And the billows of the sea were stilled .

Many of the captains of fishing vessels in Cape May indicated that they are from multigenerational fishing families. However, a few are first generation fishermen. Most of the captains as well as the crew live in Cape May County and many grew up in communities in or around Cape May.

A Seafood Festival in Cape May had been moribund for a while until it was taken over by the Chamber of Commerce in the mid-1990s. When asked whether the commercial fishers in the area had been involved in organizing or supporting the seafood festival, a representative of the Chamber of Commerce said that there is a "non-existent relationship between us and them. We tried, they tried, but it never worked out" (McCay and Cieri 2000).

One of the seafood companies has been very successful in marrying seaside tourism and the commercial fisheries (the Lobster Dock at Schellenger's Landing), but the other companies tend to keep their businesses separate from the larger community. As one of the managers said in an interview in the spring of 2002, "It's not like New England; people do not think of this as a fishing community even though fishing provides a lot of the jobs."

Hampton, Virginia

"Hampton Roads" is the fishing region at the mouth of the Chesapeake Bay which sees most of the EEZ fishing activity in Virginia. It is largely within the Metropolitan Statistical Area of Norfolk-Virginia Beach-Newport News. The "Hampton Roads" ports have close connections with Wanchese, North Carolina. They are within a major tourist region, anchored by Chincoteague, Williamsburg, and Virginia Beach. The military is also a large presence, as are numerous heavy and high tech industries. Chincoteague is also one of several ports where local seafood businesses depend on migratory fishing vessels from other regions, such as North Carolina or Massachusetts, for landings. The port of Hampton is the focus of this report; closely associated with Wanchese, in North Carolina, it has a recent history of significant engagement in the squid fisheries, including Illex, even though since 1998 these have been very minor due to shifts in the availability of the squid populations.

Hampton generally has a poor minority population, and fisheries are a very small part of the total employment mix (Table VA-NC). In 1990, less than 1% of the employed persons 16 years of age and older were in the agriculture, forestry, and fishery industries sector. The total population was 146,437 in 2000, a 9.5% increase from 1990. In 2000, the white population was 49.5% of the total, while Blacks and Hispanics made up much of the rest of the population. According to the 2000 census, the median age in Hampton is very young, 34 years. In 1999, Hampton had a per capita personal income of $22,250. Based on a 1997 model based estimate, 14.6% of the population were classified as living in poverty.

Hampton, like Newport News and nearby Seaford, is an important sea scalloping port. However, species diversity of the fisheries is extremely high. In 1998 there were 79 species landed, for all gear types, in Hampton and Seaford, combined (weighout data for these two ports were combined to preserve business confidentiality). Fourteen had either poundage or value at or above 2% in 1998, led by sea scallops, summer flounder, *Illex* squid, Atlantic croaker, blue crab, and angler (McCay and Cieri 2000). The value of the landings in 1998 was approximately 13 million dollars, showing that despite little appearance of fisheries in census data, the fisheries are significant contributors to the local economy. The species of this FMP are particularly important to the otter trawl fleet of Hampton. In 1998 the otter trawl fleet of Hampton took Illex and Loligo squid, black sea bass; Atlantic mackerel; Atlantic croaker, and angler. Some draggers were also used for scallops, although most scallops were caught with dredges. A small amount of pelagic longlining was also done from Hampton, for sharks and tuna. Gill-netting, crab potting, and bay clamming were also important activities.

The fisheries have declined. In 1993 there were 192 boats landing one or more of the species of this FMP in Hampton, according to weighout data, but in 2001 only 43 boats landed there. The total value of all landings in Hampton in 2001 was about $8.8 million, down from $13 million in 1998. Both *Loligo* and *Illex* squid landings have declined to less than 1% of the total value of landings in Hampton. *Illex* have not been available to this fleet since the end of 1997, according to leading fishermen in the area. In 1997, mackerel landings accounted for 1.3% of the total value of landings in Hampton, but in 2001, mackerel and butterfish landings were negligible.

Dare County and Wanchese, North Carolina[1]

Squid, Atlantic mackerel, and butterfish are currently not very important to the fisheries of North Carolina, except as bait for other fisheries. In this report, Dare County and Wanchese are the foci. Wanchese-based fishermen often use Hampton, VA, and more northern ports.

Wanchese is the site of the primary landing facilities for the ocean-going trawlers of North Carolina. In the early 1990s 30 to 40 vessels offloaded at 6 fish houses in Wanchese (North Carolina Division of Marine Fisheries 1993: 4). Beaufort-Morehead City was the 2nd largest port, with 5-6 fish houses serving 10 to15 full-time trawlers. At that time there were 26 to 32 other otter-trawl draggers fishing out of both Oregon and Ocracoke Inlets and packing out of ports of Lowland, Vandemere, Bayboro, Englehard, Pamlico Beach and Oriental.

Dare County, NC

In 2000 the population of Dare County was 29,967, a 32% increase from its 1990 level. It is almost entirely rural. About 95% of the population was white, 2,7% were Black/African American, and 2.2% identified as Hispanic or Latino (Table VA-NC). The median age of the county's population was 40.4 years. In 2000, 74.5% of all housing units were owned and 52.4% were vacant. Of the vacant housing units, 50.1% were for seasonal, recreational or occasional use, reflecting the importance of tourism in the rapid development of North Carolina's Outer Banks.

In 1990, 5.35% of the civilian labor force were employed in agriculture, forestry, and fisheries, a very high percentage for the northeast and mid-Atlantic regions. There were 30 white male vessel captains or officers, as well as 391 male and 49 female fishers, living in Dare County, according to the Census Bureau. According to Diaby (1999: 35), the fishing incomes of Dare County in 1997 ($29,296) were considerably higher than all wages combined ($17,989), bespeaking the importance of fishing.

Profile of Dare County Fisheries

Dare County saw over 36.6 million pounds and 23.5 million dollars from fish and shellfish (and turtle) landings in 1998. Fishing centers include Wanchese, Hatteras, and Mann's Harbor. Fluke (15%) was second to crabs (40%) in terms of value, but a much wider range of products were significant than in other North Carolina counties because of the importance of ocean as well as estuarine fisheries. These included bluefish, dogfish, squid, weakfish, anglerfish, king mackerel, sharks, and tuna. The fisheries range from estuarine fisheries (crab-pots, pound-nets, turtle pots,

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[1] Commercial fisheries data are kept on a county basis rather than port basis by the North Carolina Division of Marine Fisheries, the source of the data used, and that many of the data are confidential, due to there being only one or two dealers involved.

fyke nets, etc.) to offshore longlining (McCay and Cieri 2000).

Since 1998, North Carolina s commercial and recreational fishermen have been affected by new fishery regulations (such as for dogfish and monkfish) as well as what is believed by fishermen to be a climatic shift causing a warming of the ocean and changing some of the migratory patterns of certain species. For example, while 1998 was a good year for squid landings, the three years after 1998 have been disappointing: the three years combined are not equal to 1998 (North Carolina Division of Marine Fisheries 2001).

Wanchese, NC

Wanchese is a small village on the Outer Banks that is heavily dependent on the fisheries. It is on the northern part of North Carolina's coast, not far from the Virginia border, and on the southern end of Roanoke Island, which is where English efforts to settle North America began–and failed. In 1990 the village, together with neighboring Nags Head and Roanoke Island, had only 1,374 residents, and in 2000 there were 1,527, an increase of 11% (Table VA-NC). The resident population is almost entirely "white," and the median age is 37.2, lower than that of the county as a whole. The per capita income in 1999 was very low, $10,830, and only 67% of those 25 years of age or older had completed high school. Tourism is much less important here than elsewhere on the Outer Banks: only 7% of the vacant housing units were used for seasonal, recreational, or occasional purposes.

In 1990, 20% of the community's workers were employed in "agriculture, forestry and fishing," the highest of all mid-Atlantic and northeast coastal communities. According to local residents interviewed in the spring of 2002, this level of dependency continues and may have increased. It is rooted in a history of commercial fishing that goes back to the 19th century (Wilson and McCay 1998). Today the village still revolves around fishing but has expanded to include processing plants and boat building (which began in 1992). Though traditionally a commercial fishing community, recent growth in tourism and recreational fishing has sparked competition between the new and the old for a restricted resource. However, residents interviewed in 2002 indicated that at least half, if not more, of the labor force of Wanchese and environs is engaged in fishing and boat building.

One of the major ethnic shifts, as reported by fishermen interviewed in 2002, is the increased numbers of Hispanic people working in the fish houses and plants, some of whom have reportedly settled in the Wanchese area. Hispanics have also come to Wanchese to work in the developing boat building industry, reportedly from the agricultural sector.

In 2001, a total of 116 boats landed in Wanchese. The number of boats landing in Wanchese increased dramatically from 1996-1997, from 45 to 95 boats. The number of boats landing in Wanchese continued to increase until 2000, to 119 boats. In 2001, the total value of all fisheries landed was over $8 million, and *Loligo, Illex,* butterfish, and Atlantic mackerel landings represented less than one percent of that value, altogether, in contrast with 1998 when *Illex* itself represented 1.2% of the total value.

Fishing Community/Relations

Fishing related associations include the Oregon Inlet Users Association and the North Carolina Fisheries Association. The former is involved with supporting the plans for jetties at Oregon Inlet;

they are responsible for organizing both the Wanchese Seafood Festival and the Blessing of the Fleet. The latter is a trade organization of seafood dealers and commercial fishermen from the state; two members of the 18 member Board of Directors are from Wanchese.

Table 1: Major Fishing Ports, Squid, Atlantic Mackerel, and Butterfish (SMB) Fisheries, as Ranked by Total Value of Fish Landings, Value of SMB Landings, and Percent SMB Landings to Total Landings, 2000.

PORT	STATE	COUNTY	Rank:Total Value	Rank: SMB Value	Rank SMB/Total %
New Bedford	MA	Bristol	1	9	12
Point Judith	RI	Washington	2	1	8
No. Kingstown	RI	Washington	7	2	2
Newport	RI	Newport	8	6	9
Stonington	CT	New London	9	11	10
Montauk	NY	Suffolk	5	5	6
Hampton Bays/ Shinnecock	NY	Suffolk	6	4	4
Greenport	NY	Suffolk	11	12	5
Freeport	NY	Nassau	10	7	3
Elizabeth	NJ	Union	12	10	1
Point Pleasant	NJ	Ocean	4	8	11
Cape May	NJ	Cape May	3	3	2

Source: National Marine Fisheries Service Weighout Data, 2000.

Table MA-RI: Census Information, Selected Counties and Municipalities, Massachusetts and Rhode Island 1990, 2000.

	MASSACHUSETTS:		RHODE ISLAND:				
	Bristol County	New Bedford	Newport County	Newport	Washington County	North Kingstown***	Point Judith**
Population							
Total (2000)	534,678	93,768	85,433	26,475	123,546	26,326	16,361
Total (1990)	506,325	99,922	87,194	28,227	110,006	23,786	14,985
% Change from 1990	5.60%	-6.20%	-2.02%	-6.21%	12.31%	10.68%	9.18
% Rural (1990)	83.70%	0%	18.14%	0.00%	53.80%	NA	NA
% Racial/Ethnic Composition (2000)							
White	97.70%	83%	91.50%	81.40%	94.80%	95.70%	97.25
Non-White	2.30%	17%	8.50%	19.00%	5.20%	4.30%	2.75
Black/African American	2%	4.40%	3.70%	7.80%	0.90%	1.00%	0.75
Asian	1.30%	0.70%	1.20%	1.30%	1.50%	1.00%	0.76
Native American	0.20%	0.60%	0.40%	0.80%	0.90%	0.60%	0.91
Hispanic*	3.60%	10.20%	2.80%	5.50%	1.40%	1.80%	1.2
Age Structure							
Median Age	36.7	35.9	38.60	34.90	37.4	38.70	36.4
Income							
Per capita income (1989)	$ 10,923	$ 10,923	$ 16,891	$16,358	$16,182	NA	$ 16,986
% living in poverty (1997)	16.80%	16.78%	7.40%	12.47%	6.50%	NA	NA
Education							
% High school	65%	49.70%	28.90%	28.20%	28.90%	NA	15.93
% College	15.90%	9.70%	18.90%	20.10%	17.50%	NA	27.39
Employment							
Unemployment rate (2000)	3.90%	5.10%	3.60%	4.10%	3%	3.10%	NA
% Unemployed (1990)	8.10%	12.20%	NA	0.00%	5.60%	5.20%	3.65
Industry							
% Employment in agriculture, forestry, and fisheries (1990)	1.60%	3.10%	3.00%	2.00%	3.00%	NA	NA
Housing (2000)							
% Female headed households	13%	18.90%	10.30%	13.60%	9.40%	10.10%	8.7
# of housing units	216,918	41,511	39,561	13,226	56,861	10,743	9,159
% vacant units	5.30%	8%	11.00%	12.60%	17.40%	5.50%	25.25
% vacant for seasonal, recreational or occasional use (2000)	0.90%	3.20%	6.40%	6.50%	14.40%	2.50%	22.21
Median housing value (1990)	$141,700	$115,900	$ 160,900	$155,000	$152,700	$ 151,700	$ 152,700

*Hispanic regardless of race

** The data comes from the Narragansett town census classification

***1990 data not available

Table CT: Census Information, Selected Counties and Municipalities, Connecticut 1990, 2000.

	New Haven County	East Haven	New London County	Stonington
Population				
Total (2000)	**824,008**	**28,189**	**259,088**	**17,906**
Total (1990)	**804,219**	**26,144**	**254,957**	**16919**
% Change from 1990	**11.80%**	**7%**	**1.60%**	**6%**
% Rural (1990)	**2%**	**0%**	**34.1%**	**NA**
% Racial/Ethnic Composition (2000)				
White	**79.40%**	**93.90%**	**87.00%**	**95.80%**
Non-White	**20.60%**	**6.10%**	**13.00%**	**4.20%**
Black/African American	**11.30%**	**1.40%**	**5.30%**	**0.60%**
Asian	**2.30%**	**1.90%**	**2.00%**	**1.30%**
Native American	**0.20%**	**0.10%**	**1.00%**	**0.40%**
Hispanic*	**10.10%**	**4.40%**	**5.10%**	**1.30%**
Age Structure				
Median Age	**37**	**38.8**	**37**	**41.7**
Income				
Per capita income (1989)	**$ 33,201**	**$ 16,389**	**$ 16,702**	**$27,965**
% living in poverty (1997)	**10.60%**	**5%**	**8.10%**	**NA**
Education				
% High school	**31.30%**	**39.40%**	**80.9%**	**NA**
% College	**13.70%**	**9.80%**	**21.8%**	**NA**
Employment				
Unemployment rate (2000)	**2.50%**	**2.40%**	**2.20%**	**NA**
% Unemployed (1990)	**6.20%**	**5.80%**	**6.0%**	**NA**
Industry				
% Employment in agriculture, forestry, and fisheries (1990)	**0.30%**	**0.30%**	**2.0%**	**1.20%**
Housing (2000)				
% Female headed households	**14%**	**12%**	**11%**	**8.90%**
# Housing Units	**340,732**	**11,698**	**110,674**	**8,591**
% vacant housing units	**6.60%**	**4.10%**	**9.80%**	**10.80%**
% vacent for seasonal, recreational or occasional use (2000)	**11.40%**	**30.10%**	**4.70%**	**5.60%**
Median housing value (1990)	**$ 165,200.00**	**$ 144,600.00**	**$ 149,200**	**NA**

*****Hispanic regardless of race

Table NY: Census Information, Selected Counties and Municipalities, New York, 1990, 2000.

	Sussex County	Greenport	Montauk	Hampton Bay	Shinnecock	Nassau County	Freeport	Kings County/ Brooklyn
Population								
Total (2000)	**1,419,369**	**2048**	**3851**	**12236**	**1749**	**1,334,544**	**43783**	**2,465,326**
Total (1990)	**1,321,864**	**2070**	**3001**	**7893**	**2847**	**1,287,348**	**39894**	**2,300,664**
% Change from 1990	**7.38%**	**-1.06%**	**28.32%**	**55.02%**	**-38.57%**	**3.67%**	**9.75%**	**7.16%**
% Rural (1990)	**3.67%**	**100.00%**	**0.00%**	**0.00%**	**0.00%**	**0.36%**	**0.00%**	**0.00%**
% Racial/Ethnic Composition (2000)								
White	**84.60%**	**76.17%**	**87%**	**92.90%**	**89.99%**	**79.30%**	**43.00%**	**41.2%**
Non-White	**15.40%**	**23.82%**	**13%**	**7.10%**	**10.01%**	**20.70%**	**57.00%**	**58.8%**
Black/African American	**6.90%**	**14.26%**	**0.85%**	**0.87%**		**10.10%**	**32.57%**	**36.40%**
Asian	**2.40%**	**0.39%**	**0.83%**	**0.70%**	**4.23%**	**4.70%**	**1.38%**	**7.50%**
Native American	**0.30%**	**0%**	**0.10%**	**0.13%**	**0.97%**	**0.20%**	**0.46%**	**0.40%**
Hispanic*	**10.50%**	**17.48%**	**23.90%**	**12.50%**	**0.97%**	**10%**	**33.46%**	**19.80%**
Age Structure								
Median Age	**36.5**	**40.3**	**39.3**	**38.8**	**10.41%**	**38.5**	**34.6**	**33.1**
Income								
Per capita income (1989)	**$ 18,481**	**$ 14,002**	**$ 20,502**	**$ 18,249**	**$21,809**	**$ 23,352**	**$ 17,018**	**$ 24,596**
% living in poverty (1997)	**7.60%**	**11.67%**	**2.88%**	**6%**	**2.56%**	**5.80%**	**7.40%**	**26.50%**
Education								
% High school	**82.20%**	**36.16%**	**36.30%**	**34.40%**	**33.05%**	**84.20%**	**29.60%**	**28.50%**
% College	**23%**	**6.32%**	**2.70%**	**8.10%**	**6.35%**	**30%**	**6.60%**	**9.40%**
Employment								
Unemployment rate (2000)	**3.20%**	**NA**	**NA**	**NA**	**NA**	**2.70%**	**NA**	**6.80%**
% Unemployed (1990)	**4.14%**	**5.40%**	**7.20%**	**3.90%**	**NA**	**4.799%**	**4.80%**	**11.50%**
Industry								
% Employment in agriculture, forestry, and fisheries (1990)	**0.82%**	**3.90%**	**8.30%**	**3.60%**	**0.06**	**1.40%**	**1.10%**	**0.10%**
Housing (2000)								
% Female headed households	**10.80%**	**15.97%**	**8.70%**	**8.30%**	**6.77%**	**10.90%**	**17.80%**	**22.30%**
# Housing Units	**522,323**	**1075**	**4815**	**6875**	**928**	**458,151**	**13819**	**930,866**
% vacant housing units	**10.20%**	**27.80%**	**66.90%**	**29%**	**45.91%**	**2.30%**	**2.27%**	**5.40%**
% vacent for seasonal, recreational or occasional use (2000)	**7.30%**	**79.26%**	**97%**	**84.20%**	**42.46%**	**0.70%**	**14.60%**	**5.20%**
Median housing value (1990)	**$ 165,900**	**$ 142,700**	**$ 238,600**	**$ 167,300**	**$ 235,000**	**$ 209,500**	**$ 170,800**	**$ 196,100**

***Hispanic regardless of race**
**** Brooklyn and Kings County are one-and-the-same in the census**

Table NJ-1: Census Information, Selected Counties and Municipalities, Northern New Jersey, 1990, 2000.

	Union County	Elizabeth	Essex County	Newark
Population				
Total (2000)	522,541	120,568	793,633	273,546
Total (1990)	493,819	110,002	778,206	275,221
% Change from 1990	5.82%	9.61%	1.98%	-0.61%
% Rural (1990)	0%	0%	0%	0%
% Racial/Ethnic Composition (2000)				
White	65.51%	55.78%	44.50%	26.50%
Non-White	34.49%	44.22%	55.50%	73.50%
Black/African American	20.78%	19.98%	41.20%	53.50%
Asian	3.83%	2.35%	3.70%	1.20%
Native American	0.23%	0.48%	0.20%	0.40%
Hispanic*	19.71%	49.46%	15.40%	29.50%
Age Structure				
Median Age	36.6	32.6	34.7	30.8
Income				
Per capita income (1989)	$ 38,487	$ 12,112	$ 17,574	$ 9,424
% living in poverty (1997)	9.3%	16%	17.30%	26.34%
Education				
% High school	31.2%	31.43%	70.10%	51.20%
% College	15.7%	7.54%	24.00%	8.50%
Employment				
Unemployment rate (2000)	4.0%	6.5%	4.7	8.10%
% Unemployed (1990)	6.5%	11.0%	8.84%	14.74%
Industry				
% Employment in agriculture, forestry, and fisheries (1990)	0.20%	0.20%	0.56%	0.55%
Housing (2000)				
% Female headed households	14.20%	19%	20.40%	29.30%
# Housing Units	192945	42838	301,011	100,141
% vacant housing units	3.5%	24.9%	5.70%	8.70%
% vacent for seasonal, recreational or occasional use (2000)	7.0%	197.0%	0.20%	0.10%
Median housing value (1990)	$ 180,500	$ 145,400	$ 196,100	$ 110,000

***Hispanic regardless of race**

Table NJ-2: Census Information, Selected Counties and Municipalities, Coastal New Jersey, 1990, 2000.

	Ocean County	Point Pleasant Borough	Point Pleasant Beach	Cape May County	Cape May	Lower Township
Population						
Total (2000)	**510,916**	**19,306**	**5314**	**102,326**	**4,034**	**22,945**
Total (1990)	**433,203**	**18,177**	**5112**	**95,089**	**4,668**	
% Change from 1990	**17.94%**	**6.21%**	**3.95%**	**7.61%**	**-13.58%**	**10.20%**
% Rural (1990)	**20.38%**	**0%**	**0.00**	**33%**	**0%**	
% Racial/Ethnic Composition (2000)						
White	**93%**	**97.80%**	**95.90%**	**92%**	**91.32%**	**96%**
Non-White				**8%**	**8.68%**	**4%**
Black/African American	**3%**	**0.30%**		**5%**	**5.26%**	**1%**
Asian	**1.30%**	**0.50%**		**1%**	**0.40%**	**1%**
Native American	**0.10%**	**0.10%**		**0.18%**	**0.20%**	**0%**
Hispanic*	**5%**	**2.40%**		**3%**	**3.79%**	**2%**
Age Structure						
Median Age	**41**	**39.40**	**42.60**	**42.3**		**42**
Income						
Per capita income (1989)	**$27,694**	**$18,770**	**$ 16,542**	**$ 29,455**	**$15,884**	**$12,671**
% living in poverty (1997)	**7.80%**	**3.10%**	**5.10%**	**11%**	**4.90%**	**8.80%**
Education						
% High school	**74.90%**	**81.10%**	**78.90%**	**36%**	**29%**	
% College	**15.30%**	**20.20%**	**19.70%**	**12%**	**17%**	
Employment						
Unemployment rate (2000)	**3.90%**	**NA**	**NA**	**8.60%**	**6.30%**	**9.10%**
% Unemployed (1990)	**5.89%**	**4.49%**	**3.90%**	**7.55%**	**6.35%**	
Industry						
% Employment in agriculture, forestry, and fisheries (1990)	**1.50%**	**1.45%**	**3.00%**	**2.10%**	**1.57%**	**3%**
Housing (2000)						
%Female headed households	**9.20%**	**10.90%**	**9.60%**	**10.90%**	**7%**	
# Housing Units	**248711**	**8350**	**3558**	**91047**	**4064**	
% vacant housing units	**19.40%**	**9.50%**	**34.90%**	**53.70%**	**55.20%**	
% vacent for seasonal, recreational or occasional use (2000)	**13.30%**	**6.40%**	**26.60%**	**47.40%**	**51.40%**	**29.60%**
Median housing value (1990)	**$126,000**	**$ 153,200**	**$ 197,300**	**$112,800**	**$156,800**	

***Hispanic regardless of race**

Table VA-NC: Census Information, Selected Counties and Municipalities, Virginia and North Carolina, 1990, 2000.

	Hampton City, VA	Dare Co., NC	Wanchese, NC
Population			
Total (2000)	146,437	29,967	1,527
Total (1990)	13911.5	22,746	1,374
% Change from 1990	9.50%	31.75%	11.14%
% Rural (1990)	0%	81.37%	100.00%
% Racial/Ethnic Composition (2000)			
White	49.50%	94.70%	98.10%
Non-White	50.50%	5.30%	1.90%
Black/African American	44.70%	2.70%	0.30%
Asian	1.80%	0.40%	0.10%
Native American	0.40%	0.30%	0.60%
Hispanic*	2.80%	2.20%	1.80%
Age Structure			
Median Age	34.00%	40.4	37.2
Income			
Per capita income (1989)	$22,250	$15,107	$10,830
% living in poverty (1997)	14.60%	8.26%	9.30%
Education			
% High school	79.70%	81%	67.30%
% College	19.10%	21.40%	7.80%
Employment			
Unemployment rate (2000)		5.1	NA
% Unemployed (1990)	6.68%	4.49%	9.96%
Industry			
% Employment in agriculture, forestry, and fisheries (1990)	0.96%	5.35%	19.68%
Housing (2000)			
% Female headed households	16.40%	8.10%	9.80%
# of housing units	57311	26,671	690
% vacant units	6	52.40%	11%
% vacant for seasonal, recreational or occasional use (2000)	0.5	50.10%	7.10%
Median housing value (1990)	$ 78,200	$ 108,100	$ 75,200

*Hispanic regardless of race

Appendix 9b

Additional Port and Community Profiles

for

Newport, RI
New Bedford, MA
Elizabeth, NJ

NEWPORT, RI
Community Profile

People and Places

Regional Orientation

Newport, Rhode Island (41.50°N, 71.30°W) is located at the southern end of Aquidneck Island. The city is located 11.3 miles from Narragansett Pier, 59.7 miles from Boston, MA, and 187 miles from New York City.

Figure 1: Map of Newport's location within Rhode Island[1]

Historical/Background

English settlers founded Newport in 1639.[2] Although Newport's port is now dedicated to tourism and recreational boating, it has had a long commercial fishing presence. In the mid 1700s Newport was one of the five largest ports in colonial North America and until Point Judith's docking facilities were developed it was the center for fishing and shipping in Rhode Island.[3]

Between 1800 and 1930, the bay and inshore fleet dominated the fishing industry of Newport. Menhaden was the most important fishery in Newport and all of Rhode Island until the 1930s when the fishery collapsed. At this time the fishing industry shifted to groundfish trawling. The use of the diesel engine, beginning in the 1920s, facilitated fishing farther from shore than was done in prior years.[4]

Demographics

According to Census 2000 data[5], Newport has a total population of 26,475, down from the reported population of 28,227 in 1990.[6] Of this 2000 total, 51.8% are female and 48.2% are male. The median age for Newport in the year 2000 was 34.9 years and 73.4% of the population was 21 years or older while 14.8% of the population was 62 or older.

Unlike many fishing communities, Newport's age structure is skewed to some degree to the younger age groups; the largest percentage of the population is to be found in the age group from 20 to 29, which in part reflects the presence of the nearby naval base. Gender balance is fairly even until age 70 and above.

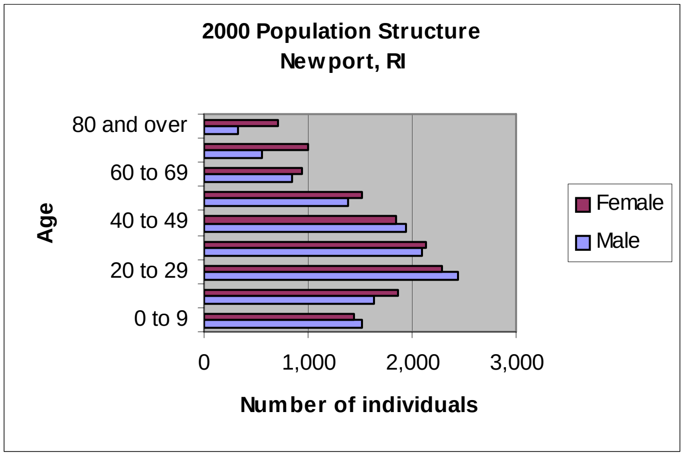

Figure 2: Newport's population structure by sex in 2000 (U.S. Census 2000)[7]

The majority of the population of Newport is white (84.1%), with 7.8% Black or African American, 0.8% Native American, 1.3% Asian, and 0.1% Pacific Islander or Hawaiian. Of the total population 5.5% are Hispanic/Latino. Residents link their heritage to a number of foreign countries including the following: Irish (27.8%), English (12.9%), Italian (11.4%) and Portuguese (7.3%). With regard to region of birth, 45.6% were born in Rhode Island, 46.7% were born in a different state and 5.6% were born outside of the U.S. (including 2.9% who are not United States citizens).

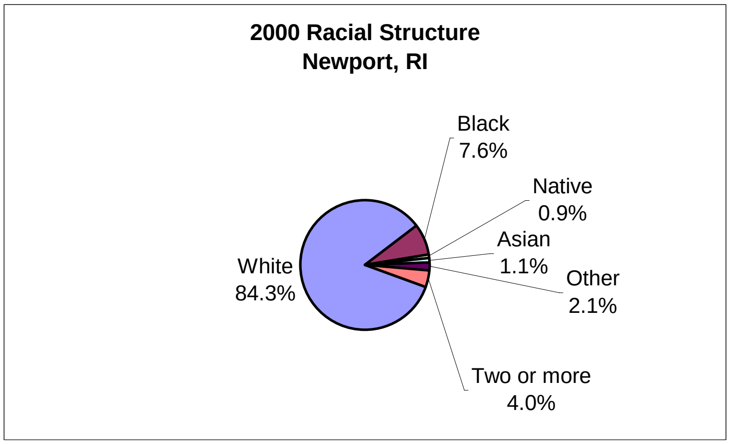

Figure 3: Newport's Racial Structure in 2000 (U.S. Census 2000)

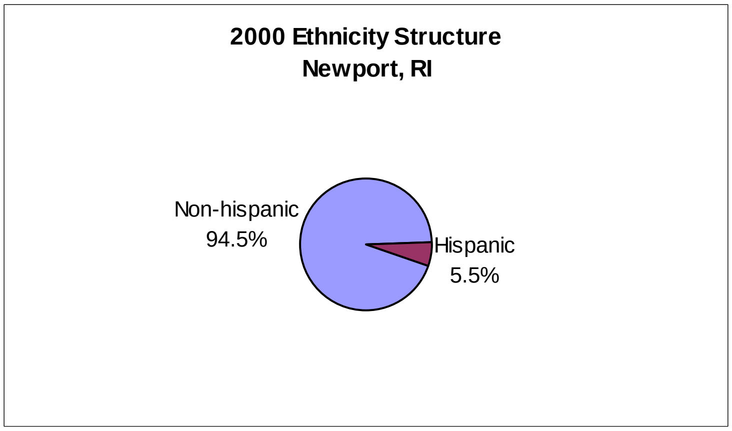

Figure 4: Newport's Ethnic Structure in 2000 (U.S. Census 2000)

For 90.4% of the population, only English is spoken in the home, leaving 9.6% in homes where a language other than English is spoken, including 3.6% of the population who speak English less than 'very well' according to the 2000 Census.

Of the population 25 years and over, 21.4% are high school graduates or higher and 26.3% have a bachelor's degree or higher. Again of the population 25 years and over, 4.5% did not reach ninth grade, 8.4% attended some high school but did not graduate, 21.4% completed high school, 18.7% had some college with no degree, 5.5% received their associate degree, 26.3% earned their bachelor's degree, and 15.1% received either their graduate or professional degree.

Although religious percentages are not available through U.S. Census data, according to the American Religion Data Archive the religions with the highest number of congregations in Newport County included Catholic (13 with over 68,668 adherents), Episcopal (10 with 4,720), and American Baptist (15 with 3,022). The total number of adherents to any religion was up 57.3% from 1990. [8]

Issues/Processes

Like other fishing communities in the Northeast, Amendment 13 brought significant changes to the local fishing industry. This amendment attempts to rebuild groundfish stocks by decreasing the allowed fishing days at sea, simplifying what was a complicated schedule of allowed fishing days mixed with restricted fishing areas. In addition to Amendment 13, pollution impacts, increase of tourism, increasing property values, and competition with recreational vessel for limited wharf space restrict fishing industry infrastructure and cause the decline of the Newport's fleet.[9]

Cultural attributes

With such a diverse background the city of Newport makes every effort to embrace its heritage through the many festivals that the city holds. One of the major events for the city is The Tall Ships Rhode Island 2004. The event includes tours of historic national and international Tall Ships, an international marketplace, and family entertainment.[10] The Great Chowder Cook Off and the Taste of Rhode Island festivals both celebrate the region's past and present ties with the fishing industry, at least indirectly, through a celebration of the state's culinary heritage.[11]

For a weekend in September, the city celebrates Irish music, culture, cuisine, and crafts. The Newport Waterfront Irish Festival provides quality family entertainment in the heart of Newport's beautiful historic waterfront. This three day community celebration features five stages of national and international entertainment, the Special Event Community Tent, Travel to Ireland exhibits, an Irish Marketplace with Irish and handcrafted items for sale, a dance hall, and children's play area to release the Irish spirit in all ages![12]

Newport Kids Fest - Maritime Fair is another event that remembers the city's maritime history. The event is hosted by the Museum of Yachting with loads of maritime related activities including knot tying, lobster races, model boat kits, coast guard safety, navigation and much more for those young and old. [13]

The annual Blessing of the Fleet takes place in early December as part of the Christmas in Newport festival, and includes a parade by both commercial and recreational vessels decorated for the holidays.[14] The city also celebrates both Irish Heritage Month[15] and Oktoberfest[16] to remember and embrace its roots.

Infrastructure

Current Economy

Aquidneck Lobster Co., Dry Dock Seafood, International Marine Industries Inc., Long Wharf Seafood, Neptune Trading Group Ltd., Parascandolo and Sons Inc., and Omega Sea are wholesalers and retailers of seafood in Newport.[17] Parascandolo and Sons Inc. owns a privately operated pier used primarily by the large mesh multispecies fleet.

According to the U.S. Census 2000, 70.1% (15,266 individuals) of the total population 16 years of age and over are in the labor force, of which 4.7% are unemployed and 7.3% are in the Armed Forces.[18]

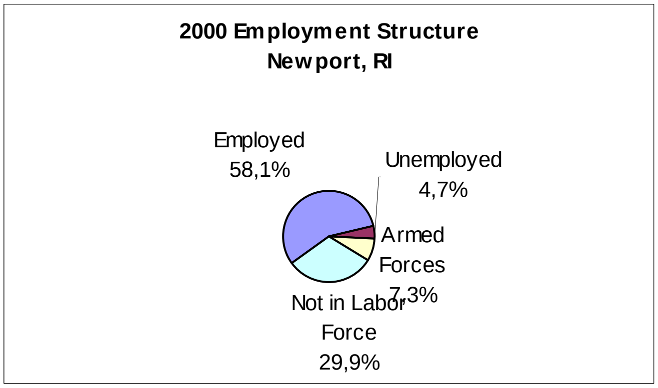

Figure 5: Newport's employment structure in 2000 (U.S. Census 2000 website)

According to Census 2000 data, jobs with agriculture, forestry, fishing and hunting accounted for merely 91 or 0.7% of all jobs. Self employed workers, a category where fishermen might be found, accounts for 1,056 or 8.3% of the labor force. Educational, health and social services (19.9%), arts, entertainment, recreation, accommodation and food services (18.6%), professional, scientific, management, administrative, and waste management services (12.3%), retail trade (10.9%), and manufacturing (7.2%) were the primary industries.

The median household income in 2000 was $40,669 (which increased since 1990 when the median household income was $30,534[19]) and median per capita income was $25,441. For full-time year round workers, males made approximately $10,288 more per year than females.

The average family in Newport consists of 2.86 persons. With respect to poverty, 12.9% of families (up from 10.0% in 1990[20]) and 14.4% of individuals earn below the official US Government poverty line, and 32.4% of families in 2000 earned less than $35,000 per year.

In 2000, Newport had a total of housing 13,266 units of which 87.4% were occupied and 37.3% were detached one unit homes. Approximately half (54.4%) of these homes were built before 1940. Mobile homes and boats account for 0.0% of the total housing units; 88.9% of detached units have between 2 and 9 rooms. In 2000, the median cost for a home in this area was $161,700, though it is likely this number has since increased due to escalating housing prices.[21] Of vacant housing units, 51.7% were used for seasonal, recreational, or occasional use. Of occupied units, 58.1% were renter occupied.[22]

Governmental

The city of Newport is governed through a Council/City Manager form of government. There are seven members; one representative is elected from the City's four voting wards and three are elected at-large, all for two year terms. The Mayor is elected by the Council from among the three at-large councilors.[23]

Institutional

Fisheries involvement in the government

No information has been collected about fisheries involvement in the government in Newport.

Fishing associations

There are several fishing associations which aid the fishing industry in Newport. The Ocean State Fishermen's Association is located in Barrington; the Rhode Island Commercial Fishermen's Association, as well as the Rhode Island Lobstermen's Association, are in Wakefield; and the Massachusetts Lobstermen's Association is in Scituate, Massachusetts. The State Pier 9 Association and Atlantic Offshore Fishermen's Association are involved in the Newport's fishing industry.[24]

Other fishing related institutions

The Rhode Island Seafood Council is located in Charlestown. The Seamen's Church Institute is an organization that brings soup around to the docks for workers and fishermen.

Physical

There are several ways to access Newport and to travel within the city. The Rhode Island Public Transit Authority (RIPTA) buses, and state highway systems provide public access to the city. RIPTA trolleys are generally used to visit Newport. RIPTA's

Providence/Newport Water Ferry in Narragansett Bay connects Providence's Point Street Landing and Newport's Perrotti Park.[25] The Rhode Island state airport, the Theodore Francis Green airport is located in Providence. There are three Amtrak stations in Rhode Island, in Kingston, Westerly and Providence.

As for fishing infrastructure, Newport has the State pier #9 which is the only state owned facility for commercial fishing in Newport Harbor, providing dockage for approximately 60 full-time fishing vessels primarily used by the lobster fleet.[26]

Involvement in Northeast Fisheries

Commercial

Both the value of landings and the value to home ported vessels in Newport increased over the period from 1997-2003. Of the federal landed species, lobster had the highest value in 2003 and for the average between 1997-2004. The second most important species in 2003 was loligo squid ($1,106,117) followed by monkfish ($1,085,465).

The South of Cape Cod midwater trawl fleet (pair and single) consists of eight vessels with principal ports of New Bedford, MA; Newport, RI; North Kingstown, RI; and Point Judith, RI. This sector made 181 trips and landed 17,189 mt of herring in 2003. Maine had the highest reported landings (46%) in 2003, followed by Massachusetts (38%), New Hampshire (8%), and Rhode Island (7%).[27]

Landings by species

	Average from 1997-2004	**2003 only**
Lobster	2,673,397	2,979,110
Butmacsq[28]	1,356,231	1,810,918
Largemesh[29]	1,108,761	1,692,614
Monkfish	841,475	1,085,465
Sfscupbsb[30]	643,446	868,455
Scallop	308,642	1,390
Smallmesh[31]	207,901	191,590
Dogfish	30,961	4,532
Skate	28,326	52,569
Redcrab	19,451	0
Bluefish	11,311	21,155
Tilefish	6,482	12,325
Herring	5,961	919
Other	189,219	361,518

Table 1: Dollar value by Federally Managed Groups of Landings in Newport

Vessels by year

Year	# Vessels home ported	# vessels (owner's city)	Home port value ($)	Landed port value ($)
1997	52	13	5,130,647	7,598,103
1998	52	16	6,123,619	8,196,648
1999	52	14	6,313,350	8,740,253
2000	59	14	6,351,986	8,296,017
2001	52	15	5,813,509	7,485,584
2002	55	17	6,683,412	7,567,366
2003	52	16	7,859,242	9,082,560

Table 2: All columns represent Federal Vessel Permits or Landings Value between 1997 and 2003

Recreational

There is a large recreational fishing sector in Rhode Island. URI SeaGrant reports an approximation of 300,000 saltwater anglers, most from out-of-state, made 1 million fishing trips in 2000.[32] "This indicates that the recreational component is significant both in terms of the associated revenues generated (support industries) and harvesting capacity. Newport is also home to a number of fishing charter vessels targeting striped bass, bluefish, blue sharks, black sea bass, and other species."

Subsistence

Information on subsistence fishing in Newport is either unavailable through secondary data collection or the practice does not exist.

Future

Plans for the future-infrastructure development, foreseeable changes

From interviews collected for the "New England Fishing Communities" report, Hall-Arber and others found that fishermen fear that increasing tourism and cruise ships will cause the State Pier 9 to be used more for tourism than a harbor for commercial fishing, as the fishing industry is far from being a major economic input to Newport.[33] Until 1973, Newport was Rhode Island's fishing and shipping center. For example, in 1971 over half of the state's total commercial fisheries landings were in Newport. In 1973 Point Judith became and presides as the most important commercial port.[34]

People's perception of the future, expectations

As the general direction of the community's development does not seem promising for the future of fishing and because of stricter governmental regulations on catches and declining fish stocks, the remaining fishing fleet might decline again.

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[1] http://factfinder.census.gov/servlet/SAFFFacts?_event=ChangeGeoContext&geo_id=16000US4449960&_geoContext=01000US%7C04000US44%7C05000US44009%7C06000US4400951580&_street=&_county

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=newport&_cityTown=newport&_state=04000US44&_zip=&_lang=en&_sse=on&ActiveGeoDiv=geoSelect&_useEV=&pctxt=fph&pgsl=010

[2] http://new.cityofnewport.com/history.html

[3] Hall-Arber et al. 2001. New England Fishing Communities. Available at: http://web.mit.edu/seagrant/aqua/cmss/marfin/index.html*; see also*, http://new.cityofnewport.com/history.html.

[4] Hall-Arber et al. 2001. New England Fishing Communities. Available at: http://web.mit.edu/seagrant/aqua/cmss/marfin/index.html

[5] U.S. Census: American Factfinder 2000 http://factfinder.census.gov/servlet/SAFFFacts?_sse=on

[6] U.S. Census: 1990 Decennial Census (STF 1, Table DP-1): http://factfinder.census.gov/servlet/QTGeoSearchByListServlet?ds_name=DEC_1990_STF1_&_lang=en&_ts=126539286370

[7] U.S. Census : 2000 Decennial Census (STF1, Table QT-P1): http://factfinder.census.gov/servlet/DatasetMainPageServlet?_lang=en&_ts=126785307368&_ds_name=DEC_2000_SF1_U&_program=

[8] ARDA (American Religion Data Archive 2000), Interactive Maps and Reports, Counties: http://www.thearda.com/

[9] Hall-Arber et al. 2001. New England Fishing Communities. Available at: http://web.mit.edu/seagrant/aqua/cmss/marfin/index.html

[10] http://www.tallshipsrhodeisland.org

[11] http://www.newportfestivals.com/

[12] http://www.newportfestivals.com/Irish_Festival

[13] http://www.gonewport.com/whattodo/april.htm

[14] http://www.christmasinnewport.org/

[15] http://www.gonewport.com/whattodo/march.htm

[16] http://www.newportfestivals.com/Oktoberfest

[17] http://www.lobsterzusa.com/RI/Newport-Lobster-Seafood.htm

[18] U.S. Census: American Factfinder 2000 http://factfinder.census.gov/servlet/SAFFFacts?_sse=on

[19] U.S. Census: 1990 Decennial Census, (STF 3, Table DP-4): http://factfinder.census.gov/servlet/DatasetMainPageServlet?_lang=en&_ts=126625731620&_ds_name=DEC_1990_STF1_&_program=

[20] U.S. Census: 1990 Decennial Census, (STF 3, Table DP-4): http://factfinder.census.gov/servlet/DatasetMainPageServlet?_lang=en&_ts=126625731620&_ds_name=DEC_1990_STF1_&_program=

[21] U.S. Census: American Factfinder 2000 http://factfinder.census.gov/servlet/SAFFFacts?_sse=on

[22] U.S. Census 2000 (SF 1,Table QT-H1): http://factfinder.census.gov/servlet/DatasetMainPageServlet?_ds_name=DEC_2000_SF1_U&_program=DEC&_lang=en

[23] http://new.cityofnewport.com/dept/citycouncil/home.html

[24] Hall-Arber et al. 2001. New England Fishing Communities. Available at: http://web.mit.edu/seagrant/aqua/cmss/marfin/index.html

[25] http://www.ripta.com

[26] http://www.state.ri.us/dem/programs/bnatres/coastal/

[27] http://www.nefmc.org/herring/final_2005_herring_specs.pdf

[28] Butmacsq: Butterfish, mackerel, and squid

[29] Largemesh Groundfish: cod, winter flounder, witch flounder, yellowtail flounder, am. plaice, sand-dab flounder, haddock, white hake, redfish, and pollock

[30] Sfscupbsb: Summer flounder, scup, and black sea bass

[31] Smallmesh Multi-Species: red hake, ocean pout, mixed hake, black whiting, silver hake (whiting)

[32] http://seagrant.gso.uri.edu/fa/commrec.html

[33] Hall-Arber et al. 2001. New England Fishing Communities. Available at: http://web.mit.edu/seagrant/aqua/cmss/marfin/index.html

[34] http://www.nefsc.noaa.gov/clay/Glouc4n.htm#D.%20Newport,%20Rhode%20Island

NEW BEDFORD, MA
Community Profile

People and Places

Regional Orientation

New Bedford is the fourth largest city in the commonwealth of Massachusetts. It is situated on Buzzard Bay, located in the southeastern section of the state. New Bedford is bordered by Dartmouth on the west, Freetown on the north, Acushnet on the east, and Buzzards Bay on the south. It is 54 miles south of Boston, 33 miles southeast of Providence, Rhode Island, and approximately 208 miles from New York City.[1]

Figure 1: New Bedford's location in Massachusetts[2]

Historical/Background information

New Bedford, originally part of Dartmouth, was settled by Plymouth colonists in 1652. Fishermen established a community in 1760 and developed it into a small whaling port and shipbuilding center within the next five years. By the early 1800s New Bedford had become one of the world's leading whaling ports. Over one half of the U.S. whaling fleet, which totaled more than 700 vessels, was registered in New Bedford by the mid 1800s.

The discovery of petroleum greatly decreased the demand for sperm oil, bringing economic devastation to New Bedford and all other whaling ports in New England. The last whale ship sailed out of New Bedford in 1925.[3] In attempts to diversify the economy, the town manufactured textiles until the southeast cotton boom in the 1920s. Since then, New Bedford has continued to diversify its economy, but the commercial fishery is very dominant.[4]

Demographics

According to Census 2000 data[5], New Bedford has a total population of 93,768, down from the reported population of 99,922 in 1990.[6] Of this population 47.1% are males and 52.9% are females. The median age is 35.9 years and 71.2 % of the population is 21 years or older while 18.9% are 62 or older.

New Bedford's age structure by sex shows a higher number of females in each age group between 20 and over 80 years. There is no drop in the 20-29 age group (as occurs in many smaller fishing communities), which could be due to New Bedford's proximity to Boston (several universities) and the local sailing school, the Northeast Maritime Institute.

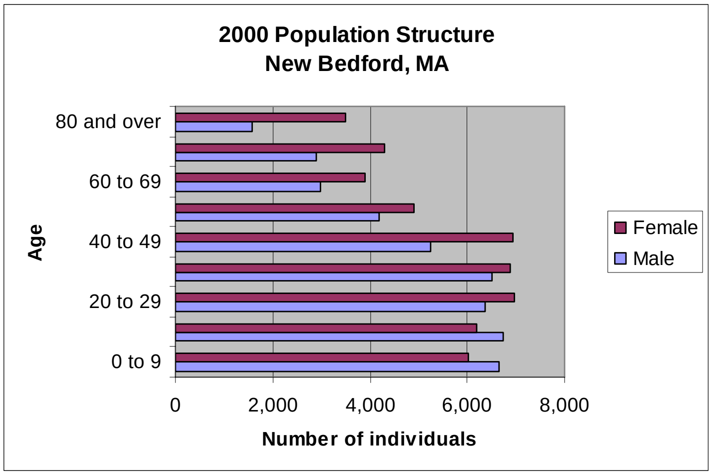

Figure 2: New Bedford's population structure by sex in 2000 (U.S. Census 2000)[3]

New Bedford's racial composition holds at 79% white, 9.1% other, 6.1% claiming two or more races, and 4.5% Black or African American. In addition, Hispanic/Latinos make up 10.2% of the population. In terms of ancestry, the residents of New Bedford trace their backgrounds to several countries, but most of all to Portugal. The ethnic breakdown is such that the Portuguese background holds 41.2% of the population, with 9.1% Sub-Saharan African and 8.9% Cape Verdean (also Portuguese speakers) following closely behind.

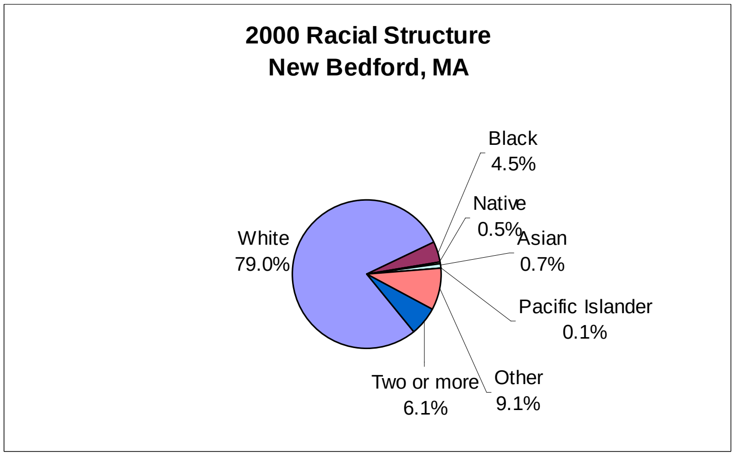

Figure 3: New Bedford's Racial Structure in 2000 (U.S. Census 2000)

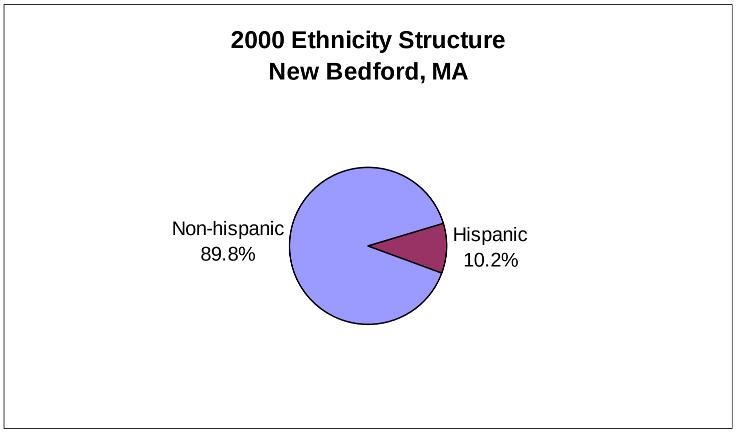

Figure 4: New Bedford's ethnicity structure in 2000 (U.S. Census 2000)

For 62.2% of the population, only English is spoken in the home, leaving 37.8% in homes where a language other than English is spoken, including 17.3% of the population who speak English less than 'very well' according to the 2000 Census.

Of the population 25 years and over, 57.6% are high school graduates or higher and 10.7% have a bachelor's degree or higher. Again of the population 25 years and over, 24.3% did not reach ninth grade, 18.1% attended some high school but did not graduate, 27.7% completed high school, 13.9% had some college with no degree, 5.3% received their associate degree, 7.5% earned their bachelor's degree, and 3.2% received either their graduate or professional degree.

Although religious percentages are not available through U.S. Census data, according to the American Religious Data Archive, in 2000 the religion with the highest number of congregations and adherents in the Bristol County was Catholic with 85 congregations and 268,434 adherents. Other prominent congregations in the county were United Methodist (17 with 3,583 adherents), United Church of Christ (19 with 5,728) and Episcopal (18 with 5,100). The total number of adherents to any religion was up 9.4% from 1990. [7]

Issues/Processes

New Bedford struggles with a highly contaminated harbor and harbor sediment. New Bedford Harbor is contaminated with metals and organic compounds, including polychlorinated biphenyls (PCBs).[8] Because of the high concentrations of PCBs in the sediment, New Bedford Harbor was listed by the U.S. Environmental Protection Agency (EPA) as a Superfund site in 1982 and cleanup is underway. Significant levels of these pollutants have accumulated in sediments, water, fish, lobsters, and shellfish in the Harbor and adjacent areas. Lobsters in the Harbor typically have PCB concentrations of 1.0 to 4.9 parts per million (ppm) in their bodies, with some lobsters containing up to 23.8 ppm (Hillman et al., 1990; Schwartz, 1987).[9] New Bedford is also the only major municipality in the Buzzards Bay area to discharge significant amounts of untreated combined sewage, industrial waste, and storm water from combined sewer overflows.[10]

The pollution problem not only affects health and the ecosystem but has a large impact on New Bedford's economy. For example, closures of fishing areas in the harbor have caused economic losses in the millions for the quahog landings alone.[11] Closure of the lobster fishery has resulted in an estimated loss of $250,000 per year and the finfish industry and recreational fishing have been negatively affected as well.[12]. In addition to contaminated harbor sediments, numerous brownfield properties are located in proximity to the port, especially on the New Bedford side.[13]

Fishing vessel owners complain of a shortage of crewmen. They attribute this scarcity to low unemployment rates that have kept laborers from the docks. Many choose to bypass work that government statistics place among the most dangerous jobs in the country. Many crewmembers are either inexperienced or come from foreign countries. Both present safety issues, according to one fisherman, because inexperienced crew get hurt more often and foreign crew have significant language barriers that impede communication. Additionally, those willing to work sometimes struggle with alcohol and drug dependency. Ship captains routinely have applicants roll up their shirt sleeves to check for traces of heroin use.[14]

Cultural attributes

In September 2005, New Bedford will host the second annual Working Waterfront Festival, dedicated to the commercial fishing industry in New Bedford. This festival is a chance for the commercial fishing industry to educate the public about its role in the community and in providing seafood to consumers, through boat tours, demonstrations, and contests. The annual Blessing of the Fleet is held as part of the Working Waterfront Festival.[15]

The New Bedford community celebrates its maritime history with a culmination of activities in the New Bedford Summerfest. The Summerfest is held annually in July in conjunction with the New Bedford State Pier and the New Bedford National Whaling Historical Park. Summerfest also includes the Cape Verdean Recognition Day Parade and the Cape Verdean American Family Festival.[16]

The community has taken an active role in the remembrance of its maritime heritage. The Azorean Maritime Heritage Society in conjunction with the New Bedford Whaling Museum and the New Bedford Whaling National Historical Park plans to construct two Azorean whaleboats to raise awareness of the maritime history of the Azorean community on both sides of the Atlantic.

The New Bedford Whaling museum was established by the Old Dartmouth Historical Society in 1907 to tell the story of American whaling and to describe the role that New Bedford played as the whaling capital of the world in the nineteenth century. Today the whaling Museum is the largest museum in America devoted to the history of the American whaling industry and its greatest port.[17]

The New Bedford Whaling National Historical Park, created in 1996, commemorates the heritage of city as a whaling port. The park is spread over 13 city blocks and includes a visitor center, the New Bedford Whaling Museum, and the Rotch-Jones-Duff House and Garden Museum.[18]

Infrastructure

Current Economy

The fishing community of New Bedford is amply supported by the infrastructure of the city. There are several choices for the marine industry to take part in. The New Bedford Economic Development Council (NBEDC), Inc was established in 1998 to improve the city’s economic development by helping to attract business and job opportunities to the city. The NBEDC also provides small business funds and offers financial support (in loans) for new businesses or those who want to expand. The NBEDC has substantially assisted the economy of New Bedford, creating more than 850 jobs and providing assistance to over 1,600.[19]

With a federal grant and local funds, the city and the Harbor Development Council (HDC) will in 2005 begin construction on a $1 million, 8,500-square foot passenger terminal at State Pier to support passenger ferry service. The HDC received a federal grant for more than $700,000 to construct the passenger terminal and to improve berthing at the New Bedford Ferry Terminal.

The Community Economic Development Center is a non-profit organization vested in the economic development of the local community. The organization is unique in that it is involved with fisheries management. The center is currently engaged in a research project to better understand the employment status in the fishing industry. The center is a liaison for migrant workers and other newcomers to the community to have access to the benefits provided by the city. In the past the center at one time had a re-training program for displaced fishermen to move into aquaculture.

According to the U.S. Census 2000, 57.7% (42,308 individuals) of the total population 16 years of age and over are in the labor force, of which 5.0% are unemployed and 0.2% are in the Armed Forces.[20]

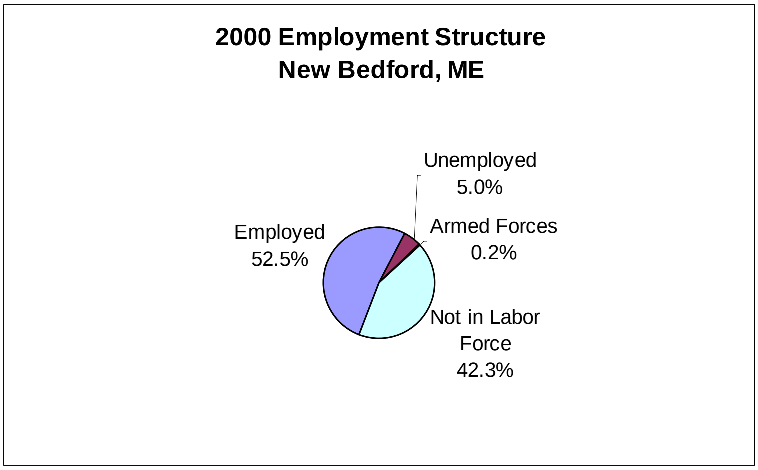

Figure 4: New Bedford’s employment structure in 2000 (U.S. Census website)

According to Census 2000 data, jobs with agriculture, forestry, fishing and hunting accounted for 407 or 1.1% of all jobs. Self employed workers, a category where fishermen might be found, accounts for 1,485 or 3.9% of the labor force. Educational, health and social services (20.9%), manufacturing (20.7%), retail trade (12.1%), entertainment, recreation, accommodation and food services (7.4%), and construction (7.1%) were the primary industries. Major employers that provide over 100 jobs in New Bedford include the following businesses with the number of employees in parentheses: Acushnet Company (1,600), Cliftex (1,400), Aerovox (800), Calish Clothing (750), and Polaroid (465).[21]

Median household income in Eastport was $27,569 (which increased since 1990 when the median household income was $22,647[22]) and median per capita income was

$15,602. For full-time year round workers, males made approximately $9,110 more per year than females.

The average family in New Bedford consists of 3.01 persons. With respect to poverty, 17.3% of families (up slightly from 16.8% in 1990[23]) and 20.2% of individuals earn below the official US Government poverty line, and 48.8% of families in 2000 earned less than $35,000 per year.

In 2000, New Bedford had a total of 41,511 housing units of which 92.0% were occupied and 30.2% were detached one unit homes. Approximately half (49.9%) of these homes were built before 1940. Mobile homes in this area accounted for 0.3% of the total housing units; 95.0% of detached units have between 2 and 9 rooms. In 2000, the median cost for a home in this area was $113,500.[24] Of housing units 0.3% were used for seasonal, recreational, or occasional use while 56.2% were renter occupied.[25]

Governmental

New Bedford was incorporated as a town in 1787 and as a city in 1847. The city of New Bedford is run on a Mayor and City Council basis. Of the 38,025 registered voters, 62.9% (23,913) are Democrats; 7.9% (3,021) are Republicans and 29.2% (11,091) are un-enrolled.[26] The Harbor Planning Commission includes representatives from the fish-processing and harvest sectors of the industry.

Institutional

Fishing associations

There are several fishing associations which aid the fishing industry in New Bedford, such as the American Dogfish Association, the American Scallop Association and the Commercial Anglers Association. New Bedford also is home to a Fishermen's Wives Association which began in the early 1960s. Additionally, New Bedford has the Offshore Mariner's Wives Association which includes a handful of participants that organize the "Blessing of the Fleet."

Fishing Assistance Centers

Shore Support has been the primary fishing assistance center in New Bedford since 2000,[27] though the New Bedford Fishermen and Families Assistance Centers are also available as is the Trawlers Survival Fund.

Other fish-related organizations

There are several other fishing related organizations and associations that are vital to the fishing industry such as the Fisheries' Survival Fund (Fairhaven), the New Bedford Fishermen's Union, the New Bedford Seafood Coalition, the New Bedford Seafood Council and the Offshore Mariner's Association.

Physical

The New Bedford Municipal Airport is located 2 miles NW of the city. Interstate 195 and State routes 24 and 140 provide access to the airports, ports, and facilities of Providence and Boston. The Consolidated Rail Corporation (Conrail) provides services into New Bedford.[28]

Involvement in Northeast Fisheries

Commercial

The fishing industry in New Bedford has consistently experienced decadal change. In the 1980s fishermen reaped high landings and bought new boats. Then in the 1990s they experienced a dramatic decrease in groundfish catches, a vessel buyback program, and strict federal regulations in attempts to rebuild the depleted fish stocks. A new decade brought more changes for the fishing industry.[29] By 2000 and 2001 New Bedford was the highest value port in the U.S. (generating $150.5 million in dockside revenue).[30] According to the federal commercial landings data, New Bedford's most successful fishery in the past seven years has been scallops, followed by groundfish. Both were worth significantly more in 2003 than the 1997-2004 average values, and the total value of landings for New Bedford generally increased over the same time period.

New Bedford contains approximately 44 fish wholesale companies,[31] 75 seafood processors and some 200 shore side industries.[32] Maritime International is also located in New Bedford which has one of the largest U.S. Department of Agriculture-approved cold treatment centers on the East Coast. The terminal receives approximately 25 vessels a year. Each vessel carries about 1,000 tons of fish.[33]

Landings by species – State Only Permits

Species	**Pounds landed**
Cod**	6,311,413
Haddock**	5,949,880
Lobster***	1,168,884
Scup**	593,394
Fluke**	480,165
Crab***	315,395
Loligo Squid**	207,769
Striped Bass**	189,055
Quahog (littleneck)*	147,249
Monkfish	137,300
Conch*	136,276
Skate	121,522
Quahog (cherrystone)	113,341
Black Sea Bass**	113,071
Pollock	65,500
Quahog (Chowder)*	64,999
Bluefish**	44,045
Quahog (mixed)*	11,513
Red Hake	10,100
Cusk	1,880
Illex Squid**	1,305
Soft Shell Clam*	985
Dab (Plaice)	870

Dogfish**	537
Winter Flounder	500
Yellowtail Flounder	383
Gray Sole (Witch)	200

Table 1: Landings in pounds for state-only permits. Asterisks indicate data sources: Zero: MA DMF has 2 gear-specific catch reports: Gillnet & Fish Weirs. All state-permitted fish-weir and gillnet fishermen report landings of all species via annual catch reports. NOTE: Data for these species do not include landings from other gear types (trawls, hook & line, etc.) and therefore should be considered as a subset of the total landings. (Massachusetts Division Marine Fisheries).

Landings by species – Federal Permits

Catch	**1997-2004 Average**	**2003**
SCALLOPS	68,458,919	102,785,405
LARGEMESH[34]	29,234,009	38,101,563
MONKFISH	9,860,316	7,461,998
SURFOQ[35]	6,292,742	7,584,792
OTHER	4,469,666	3,946,386
LOBSTER	4,145,961	5,545,729
SKATES	1,554,432	1,775,930
BUTMACSQ[36]	1,337,329	1,606,276
SFSCUPBSB[37]	1,124,292	1,124,486
REDCRAB	925,401	1,563,422
SMALLMESH[38]	617,155	2,135,623
HERRING	398,074	2,553,863
DOGFISH	108,169	171
BLUEFISH	9,211	13,439
TILEFISH	2,310	1,483

Table 2: Dollar value by species landed in New Bedford.

Vessels by Year

Year	**# Vessels home ported**	**# vessels (owner's city)**	**Home port value ($)**	**Landed port value($)**
1997	244	162	80,472,279	103,723,261
1998	213	137	74,686,581	94,880,103
1999	204	140	89,092,544	129,880,525
2000	211	148	101,633,975	148,806,074
2001	226	153	111,508,249	151,382,187
2002	237	164	120,426,514	168,612,006
2003	245	181	125,788,011	166,680,126

Table 3: All columns represent vessel permits or total landings value between 1997 and 2003.

Recreational

A number of companies in New Bedford offer the public recreational fishing excursions including boat charters.[39]

Subsistence

Information on subsistence fishing in New Bedford is either unavailable through secondary data collection or the practice does not exist.

FUTURE

Plans for the future – infrastructure development, foreseeable changes

For several years work was underway to construct the New Bedford Oceanarium that would include exhibits on New Bedford's history as a whaling and fishing port, and was expected to revitalize the city's tourist industry and create jobs for the area. The Oceanarium project failed to receive its necessary funding in 2003 and 2004, and while the project has not been abandoned, it seems unlikely the Oceanarium will be built anytime in the near future.

People's perception of the future, expectations

Many fishermen believe that based on the quantity and ages of the specimens they catch – the fish are coming back faster than studies indicate. While most admit that regulations have worked, they believe further restrictions are unnecessary and could effectively wipe out the industry.[40] "If they push these regs too hard, the whole infrastructure of fishing here could collapse," according to a New Bedford fishermen.[41]

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[1] http://www.usgennet.org/usa/ma/county/bristol/newbedford/greatnewbed.htm, http://www.ci.new-bedford.ma.us/ECONOMIC/CD/commprofile.html

[2] http://factfinder.census.gov/servlet/SAFFFacts?_event=Search&geo_id=06000US3301551620&_geoContext=01000US%7C04000US33%7C05000US33015%7C06000US3301551620&_street=&_county=new+bedford&_cityTown=new+bedford&_state=04000US25&_zip=&_lang=en&_sse=on&ActiveGeoDiv=geoSelect&_useEV=&pctxt=fph&pgsl=060

[3] http://travel.lycos.com/Destinations/location.asp?pid=243839

[4] http://www.usgennet.org/usa/ma/county/bristol/newbedford/greatnewbed.htm

[5] U.S. Census: American Factfinder 2000 http://factfinder.census.gov/servlet/SAFFFacts?_sse=on

[6] U.S. Census: 1990 Decennial Census (STF 1, Table DP-1): http://factfinder.census.gov/servlet/QTGeoSearchByListServlet?ds_name=DEC_1990_STF1_&_lang=en&_ts=126539286370

[3] U.S. Census : 200 Decennial Census (STF1, Table QT-P1): http://factfinder.census.gov/servlet/DatasetMainPageServlet?_lang=en&_ts=126785307368&_ds_name=DEC_2000_SF1_U&_program=

[7] ARDA (American Religion Data Archive 2000), Interactive Maps and Reports, Counties: http://www.thearda.com/

[8] http://www.brownfields.noaa.gov/htmls/portfields/pilot_newbed.html

[9] http://www.buzzardsbay.org/nbprobs.htm

[10] http://www.buzzardsbay.org/nbprobs.htm

[11] *Id.*

[12] *Id.*

[13] http://www.brownfields.noaa.gov/htmls/portfields/pilot_newbed.html

[14] http://www.csmonitor.com/2002/0429/p15s03-wmwo.html

[15] http://www.workingwaterfrontfestival.org/

[16] http://www.rixsan.com/nbvisit/events/blesflet.htm

[17] www.whalingmuseum.org

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[18] www.nps.gov/nebe

[19] http://www.ci.new-bedford.ma.us/ECONOMIC/CD/commprofile.html#D

[20] U.S. Census: American Factfinder 2000 http://factfinder.census.gov/servlet/SAFFFacts?_sse=on

[21] www.ci.new-bedford.ma.us/economic/economic/deomgraf.htm

[22] U.S. Census: 1990 Decennial Census, (STF 3, Table DP-4): http://factfinder.census.gov/servlet/DatasetMainPageServlet?_lang=en&_ts=126625731620&_ds_name=DEC_1990_STF1_&_program=

[23] U.S. Census: 1990 Decennial Census, (STF 3, Table DP-4): http://factfinder.census.gov/servlet/DatasetMainPageServlet?_lang=en&_ts=126625731620&_ds_name=DEC_1990_STF1_&_program=

[24] U.S. Census: American Factfinder 2000 http://factfinder.census.gov/servlet/SAFFFacts?_sse=on

[25] U.S. Census 2000 (SF 1,Table QT-H1): http://factfinder.census.gov/servlet/DatasetMainPageServlet?_ds_name=DEC_2000_SF1_U&_program=DEC&_lang=en

[26] http://www.mass.gov/dhcd/iprofile/205.pdf

[27] Hall-Arber et al. 2001. New England Fishing Communities. Available at: http://web.mit.edu/seagrant/aqua/cmss/marfin/index.html

[28] http://www.mass.gov/seaports/newbed.htm, http://www.mass.gov/dhcd/iprofile/205.pdf

[29] http://www.fishresearch.org/Articles/2001/07/New_Bedford.asp

[30] http://www.fishresearch.org/Articles/2002/09/landings.asp

[31] http://www.ci.new-bedford.ma.us/ECONOMIC/HDC/Directory2.asp

[32] Hall-Arbor et. al. 2001.

[33] http://www.ci.new-bedford.ma.us/ECONOMIC/HDC/wtrgeneral.htm

[34] Largemesh Groundfish: cod, winter flounder, witch flounder, yellowtail flounder, am. plaice, sand-dab flounder, haddock, white hake, redfish, and pollock

[35] SURFOQ: Surf clam and ocean quahog

[36] Butmacsq: Butterfish, mackerel, and squid

[37] Sfscupbsb: Summer flounder, scup, and black sea bass

[38] Smallmesh Multi-Species: red hake, ocean pout, mixed hake, black whiting, silver hake (whiting)

[39] http://www.maineharbors.com

[40] http://www.csmonitor.com/2002/0429/p15s03-wmwo.html

[41] *Id*.

ELIZABETH, NJ

Community Profile

People and Places

Regional orientation

The city of Elizabeth is the seat of Union County, New Jersey, and is located along Newark Bay. It borders Newark and is connected to Staten Island and the rest of New York City via the Goethals Bridge, which passes over Arthur Kill, the river separating Elizabeth from Staten Island.

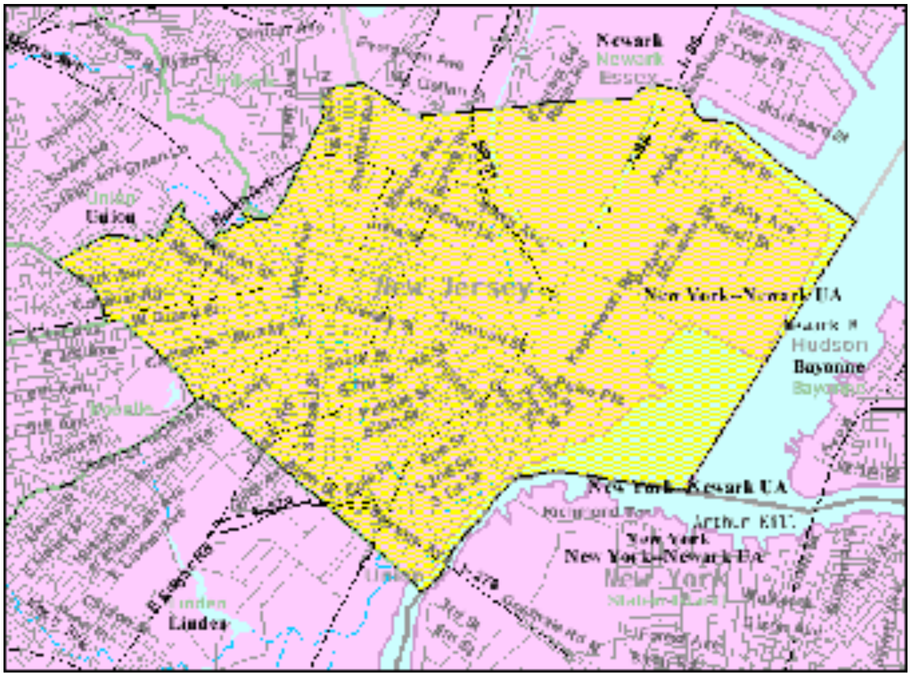

Figure 1: Map of Elizabeth's location in New Jersey.[1]

Historical/Background information

Elizabeth was first settled in 1664, initially known as Elizabethtown and purchased from the Lenni Lenapi Indians, or the Delaware tribe, as part of a large tract of land in what is now New Jersey. [2] Elizabethtown was the first permanent English settlement in New Jersey.[3] Until 1686, it was the capital of New Jersey. Many clashes of the Revolutionary War took place in Elizabeth, and much of the city was burned in 1780. It was incorporated as a town in 1855, and is today the seat of Union County. During the 19th century, because of its proximity to New York and the arrival of the railroad, Elizabeth was the site of much industrial activity, including ship building, machine production, and oil refining.[4] Many immigrants have moved to the city throughout the years, attracted by its many industries, giving the city a very diverse feel. The city was hard hit by the recession of the 1970s when some industries were forced to shut down because of the oil shortages. The city is working hard to revitalize itself by attracting a variety of new industries. Elizabeth is known as "America's Containership Capital",[5] and has one of the world's largest containerized dock facilities. It is the principal container facility for goods moving in and out of the New York City region. A number of products are manufactured in Elizabeth, including furnaces, plastics, chemicals, metal and food products, tea, paperboard boxes, and pharmaceuticals.[6] Today it is New Jersey's fourth largest city.[7]

Demographic Profile

According to Census 2000 data[8], Elizabeth, New Jersey has a total population of 120,568, up from a reported population of 110,002 in 1990[9]. Of this 2000 total, 49.5% are males and 50.5% are females. The median age is 32.6 years and 69.4% of the population is 21 years or older while 12.0% are 62 or older.

The largest population segment in Elizabeth is from the ages of 30-39, followed by 20-29. There are also large numbers of children, indicating that Elizabeth has a large number of families. The older populations are considerably smaller; it is likely that either older, retired residents move out of Elizabeth, or that younger residents are migrating here for jobs in New York or within Elizabeth itself.

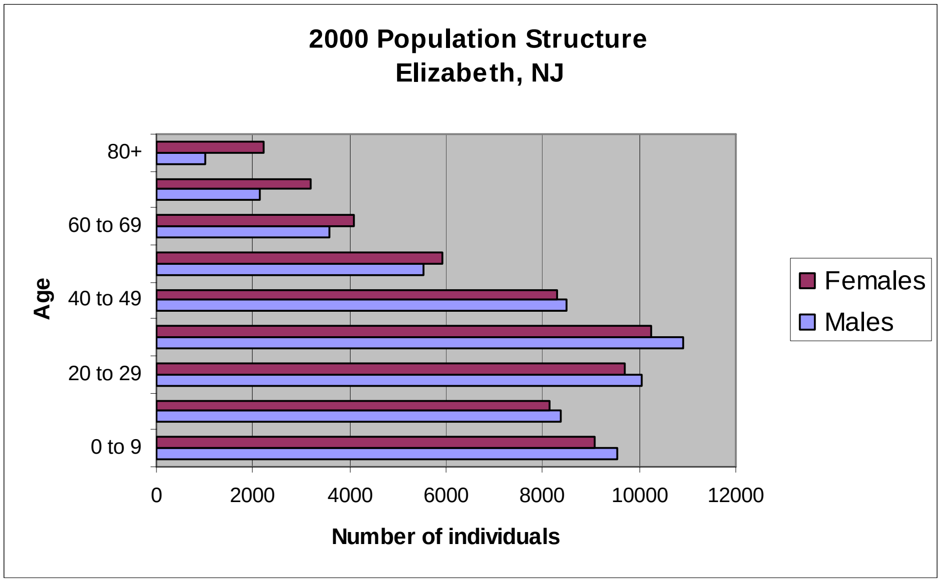

Figure 2: Elizabeth's population structure by sex in 2000[10]

The majority of the population is White (55.8%), with 20.0% Black, 5.9% citing two or more races, and 15.5% other. Hispanics are identified as 49.5% of the population. Residents trace their backgrounds to a number of different European ancestries including the following: Portuguese (5.5%), Italian (5.0%), Irish (3.3%), West Indian (3.3%), and other ancestries (61.8%). With regard to region of birth, 39.9% were born in New Jersey, 10.3% were born in a different state and 43.9% were born outside of the U.S. (including 27.9% who are not United States citizens).

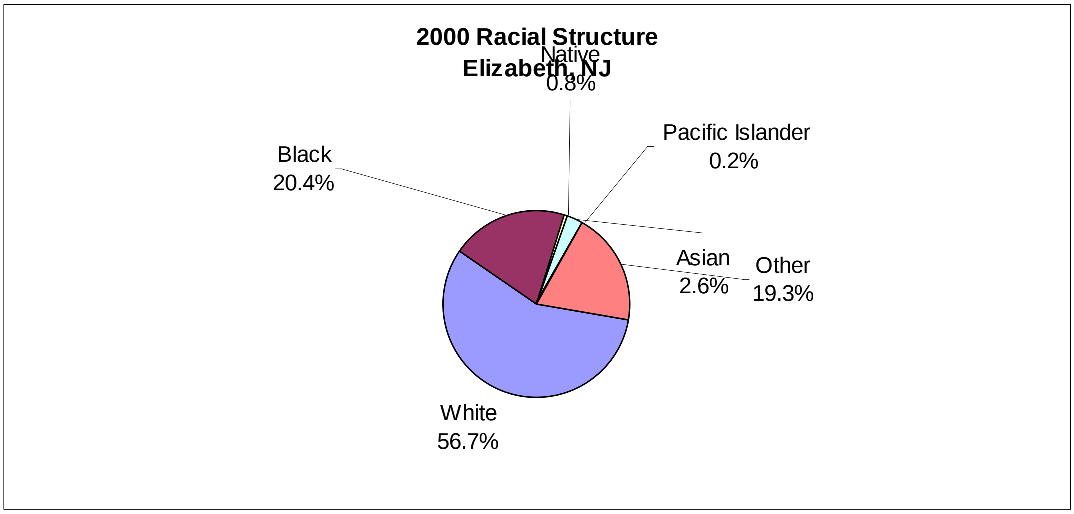

Figure 3: Racial Structure in 2000 (U.S. Census 2000)

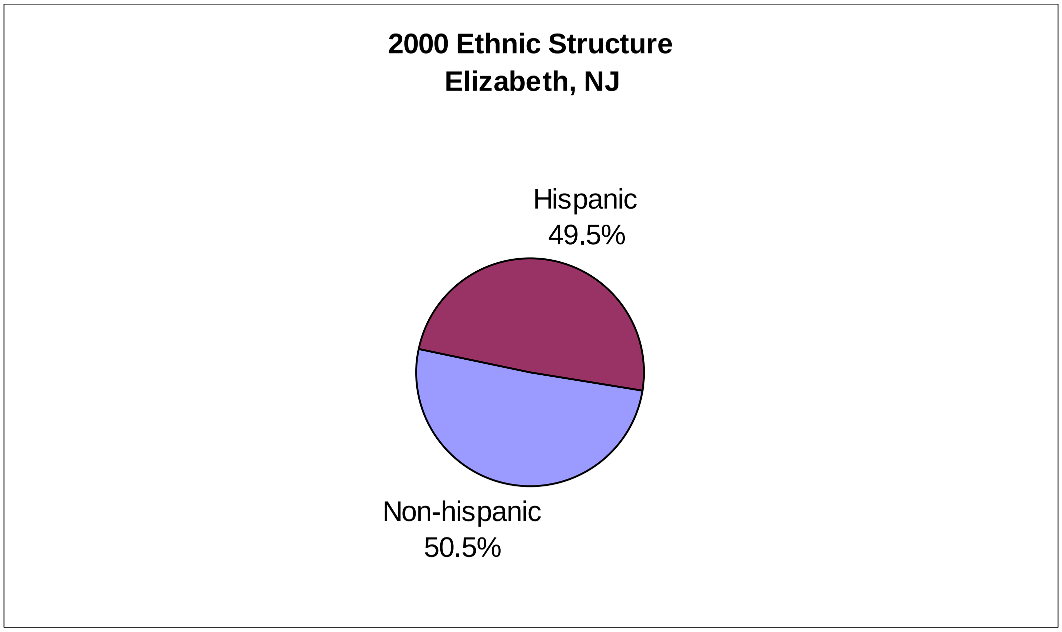

Figure 4: Ethnic Structure in 2000 (U.S. Census 2000)

For 32.5% of the population, only English is spoken in the home, leaving 67.5% in homes where a language other than English is spoken, including 36.8% of the population who speak English less than ‘very well’ according to the 2000 Census.

Of the population 25 years and over, 61.7% have graduated high school, and 12.1% have a Bachelors Degree. Again of the population 25 years and over, 18.1% did not reach ninth grade, 20.1% attended some high school but did not graduate, 32% completed high school, 14% had some college with no degree, 3.5% received their associate degree, 7.9% earned their bachelor’s degree, and 4.2% received either their graduate or professional degree.

Although religious percentages are not available through U.S. Census data, according to the American Religious Data Archive in 2000, 34.5% of Union County did not claim membership to any religious affiliation. The religions with the highest number of congregations in Union County included Catholic (46 with 251,815 adherents), Presbyterian

Church (U.S.A.) (30 with 11,826 adherents), American Baptist Churches in the USA (24 with 9,964 adherents), United Methodist (17 with 5,022 adherents), and Episcopal (17 with 6,705 adherents). The total numbers of adherents to any religion was down 2.9% from 1990.[11]

Issues/Processes

The New Jersey Department of Environmental Protection has issued a consumption advisory against eating most fish and crabs taken from the Newark Bay Estuary because of high levels of PCBs and dioxins.[12] A 1996 study found that only 60% of people fishing in Arthur Kill were aware of the advisories, and that roughly 30% probably exceed the limit on advised consumption.[13] The Elizabethport neighborhood, which is generally poor and has a high percentage of minority residents, is surrounded by industrial facilities, including 22 sites designated as contaminated by the NJ Department of Environmental Protection. The city has received a $200,000 brownfields assessment grant.[14]

Cultural attributes

Elizabeth Estuary Day celebrates the Elizabeth River and the Arthur Kill, and educates residents about the importance of the local estuary.[15] The Elizabeth River/ Arthur Kill Watershed Association hosted a harbor inspection by local high school students to raise awareness of the threats to this environment.[16]

Infrastructure

Current economy

The seaport and the Newark/Elizabeth Liberty International Airport employ hundreds of thousands of people alone,[17] not to mention the city's many other industries. The container ships that load and unload at Port Elizabeth generate up to $20 billion annually in economic activity as well as 166,000 direct and indirect jobs. There are 2,400 people employed at the terminal in Port Elizabeth.[18] The New York/New Jersey Port Authority oversees both the airport and seaport, and maintains planning and development rights for both facilities.[19] As a distressed urban area, Elizabeth qualifies for the state of New Jersey's Urban Enterprise Zone program, which promotes redevelopment by providing tax and other incentives to businesses that move to Elizabeth. Recently a number of large retail operations have opened here, including IKEA and the Jersey Gardens outlet mall; approximately 1,000 businesses have taken advantage of the Urban Enterprise Zone in Elizabeth.[20]

The top ten non-governmental employers in Union County in 1997, the most recent year for which data were readily available, are as follows[21]:

Firm	**Business**	**Number of Employees**
Merck & Company	Pharmaceuticals	6,500
Schering Plough	Pharmaceuticals	4,745
Overlook Hospital	Medical Center	3,000
General Motors	Automobile Assembly	2,500
Lucent Technologies	Telecommunications Research	2,000
Elizabeth General Hospital	Medical Center	1,900
Novartis	Pharmaceuticals	1,500
Wakefern Foods	Food Distribution	1,400
Muhlenberg Medical Center	Medical Center	1,300

Exxon Research Center	Petroleum /Refining	1,250

According to the U.S. Census 2000, 57.1% (individuals) of the total population 16 years of age and over are in the labor force, of which 5.2% are unemployed and 0.0% are in the Armed Forces.[22]

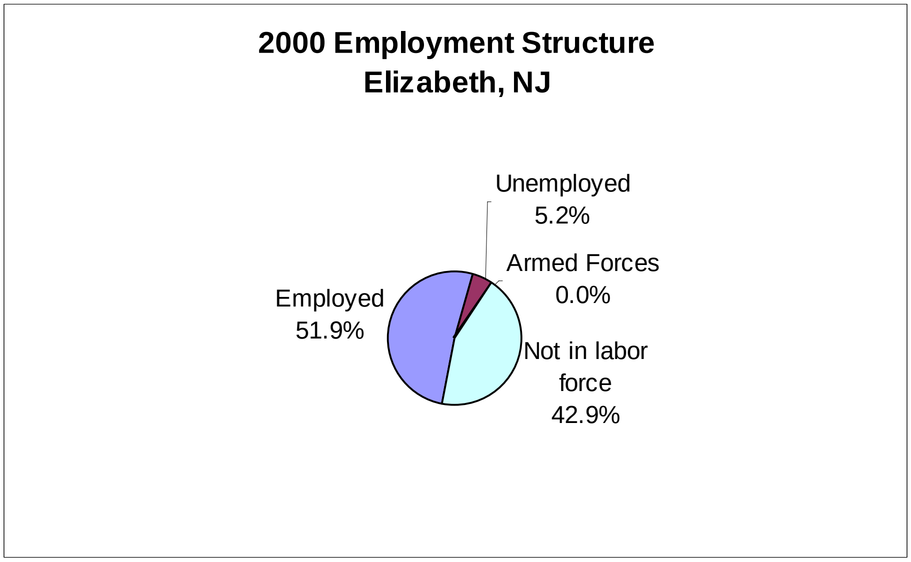

Figure 5: Employment Structure in 2000

According to Census 2000 data, jobs with agriculture, forestry, fishing and hunting accounted for 39 or .1% of all jobs. Self employed workers, a category where fishermen might be found, accounts for 1,774 or 3.7% of the labor force. Manufacturing (18.7%), educational, health and social services (14.9%), retail trade (11.5%), transportation and warehousing, and utilities (10.7%), professional, scientific, management, administrative, and waste management services (8.0%), and arts, entertainment, recreation, accommodation and food services (7.0%) were the primary industries.

Median household income in Elizabeth was $35,175 (up 27.3% from $27,631 in 1990[23]) and median per capita income was $15,114. For full-time year round workers, males made approximately 28.5% more per year than females.

The average family in Elizabeth consists of 3.45 persons. With respect to poverty, 15.6% of families (up from 13.7% in 1990[24]) and 17.8% of individuals earn below the official US Government poverty line, and 44.8% of families in 2000 earned less than $35,000 per year.

In 2000, Elizabeth had a total of 42,838 housing units of which 94.5% were occupied and 17% were detached one unit homes. Only 31.0% of these homes were built before 1940. Mobile homes were reported as .1% of housing units; 93.1% of detached units have between 2 and 9 rooms. In 2000, the median cost for a home in this area is $143,000. Of vacant housing units, 5.1% were used for seasonal, recreational, or occasional use, while of occupied units, 66.3% were renter occupied.[25]

Governmental

Elizabeth has a mayor, currently J. Christian Bollwage, and a nine-member elected City Council. Three of the City Council members are elected at large, and the other six are elected from each of the city's six wards.[26]

Fishery involvement in government

New Jersey's Department of Environmental Protection runs the Harbor Watershed Education and Urban Fishing Program to educate citizens about the Newark Bay Estuary and about recreational fishing within the estuary. The program focuses on educating school children in Elizabeth and neighboring communities about contamination in fish, where they can and cannot fish, and what they can and cannot eat.[27]

Institutional

Fishing associations

No information has been obtained at this time on fishing associations in Elizabeth.

Fishery assistance centers

No information has been obtained at this time on fishery assistance centers in Elizabeth.

Other fishing related institutions

The Elizabeth River/ Arthur Kill Watershed Association aims to improve the quality of live for human and non-human residents of the watershed by removing threats to the watershed. This organization sponsors the Elizabeth Estuary Day and a catch and release program to study the fish of the watershed.[28] In addition, the New York – New Jersey Harbor Estuary Program encompasses the areas of the harbor bordering Elizabeth, and is dedicated to protecting, conserving, and restoring this estuary.[29]

Physical

Elizabeth has three fully equipped containership terminals, overseen by the New York and New Jersey Port Authority.[30] The Goethals Bridge connects Elizabeth with Staten Island, and with the rest of New York City. Elizabeth is roughly 6 miles from Newark and 19 miles from Manhattan via car. The Newark/Elizabeth Liberty International Airport is located in Elizabeth. There are two NJ transit stations in Elizabeth which provide convenient access to New York City and other areas of New Jersey via train,[31] as well as a variety of regional buses.[32] In addition, Interstates 95 and 278 run through Elizabeth, with the New Jersey Turnpike (Route 95), splitting the city in half geographically.[33] The city borders Newark Bay and Arthur Kill, the river that divides Elizabeth from Staten Island.

Elizabeth has a city-run marina with dock space and slips for more than 60 fishing and pleasure boats.[34] Spring Garden Marina is another marine found in Elizabeth. There is a municipal boat ramp on Front Street.[35]

Elizabeth is home to a number of large seafood distributors. The Atalanta Corporation is a large importer and exporter of frozen seafood and other food items headquartered in Elizabeth, and with several offices in five countries and three continents. Most of the seafood bought and sold by Atalanta is imported shrimp from Indonesia. Atalanta's location in Elizabeth allows the corporation to take advantage of the containership port for trading large quantities of many types of food products.[36] True World Foods, originally the New York Fish House, is another large seafood distributor headquartered in Elizabeth, delivering sushi-quality seafood to more than 2,000 restaurants in the United States each day and with more than 20 offices throughout North America.[37] PFG-AFI Food Service is another large food service industry supplier located in Elizabeth, whose sales include sushi.[38] It appears that none of these seafood distributors sell seafood from vessels in Elizabeth.

Involvement in Northeast Fisheries

Commercial

There appears to be a small, and perhaps diminishing, commercial fishing industry operating in Elizabeth. In 2003, there were no vessels listing Elizabeth as their home port, down from 2 in 1997. There were some landings made in Elizabeth in 2003, totaling just over $100,000. The most significant landings in 2003 were loligo squid, worth $89,840 followed by summer flounder at $20,217. The butterfish, mackerel, and squid category has had the highest average landings for the period of 1997-2004. Landings in 2003 had declined considerably from 2002, when they totaled over $1 million. Most of these landings may have been from the one vessel still in Elizabeth that year. For the seven years for which we have data, no vessel owners have lived in Elizabeth. There were no landings in Elizabeth from 1997-1999. The Elizabeth Public Information office noted that commercial fishing doesn't really exist here anymore.[39]

Landings by species

	Average from 1997-2004	**2003 only**
Butmacsq[40]	283,796	89,840
Sfscupbsb[41]	20,685	23,213
Smallmesh[42]	858	0
Other	739	0
Monkfish	140	0
Scallop	31	0
Largemesh[43]	12	0
Bluefish	12	0

Table 1: Dollar value of Federally Managed Groups of landing in Elizabeth.

Vessels by Year

Year	**# Vessels home ported**	**# vessels (owner's city)**	**Level of fishing home port ($)**	**Level of fishing landed port ($)**
1997	2	0	1,128,521	0
1998	1	0	920,390	0
1999	1	0	705,661	0
2000	1	0	610,684	454,074
2001	1	0	749,752	797,027
2002	1	0	937,309	1,086,028
2003	0	0	0	113,053

Table 2: All columns represent vessel permits or landings value combined between 1997-2003.

Recreational

Elizabeth has a municipal fishing pier along the city's boardwalk,[44] and many people used to fish at the Veteran's Memorial Waterfront Park.[45] Species commonly targeted in recreational fisheries around Elizabeth include striped bass, bluefish, fluke, and winter flounder. The state of New Jersey recommends against the consumption of crabs and striped bass, among other species, from this area.[46] The Elizabeth Public Information office noted that some people do eat the fish caught from this area, although they are discouraged from doing so.[47]

Subsistence

No information has been obtained at this time on subsistence fishing in Elizabeth.

Future

Plans for the future- infrastructure development, foreseeable changes

Elizabeth was awarded two Smart Growth awards from the State Department of Community Affairs to revitalize the Elizabethport neighborhood, where the port is located. There are also plans for a ferry terminal to link Elizabeth with Lower Manhattan via a water route. The Elizabethport neighborhood has traditionally been Elizabeth's poorest area, with many dilapidated buildings and large tracts of public housing. A recent plan for the waterfront will construct more than 600 mixed-income housing units, of which some will be designated for affordable housing and some will be sold at market rate in an attempt to revitalize this section of town. The $30 million for this project comes from a Hope VI grant to the city.[48] Some of the projects taking place in this neighborhood may also revitalize the marina and recreational areas here.[49] Elizabeth has also been in the midst of a real estate boom in recent years, with home sales growing 78.8% in the last four years.[50]

People's perception of the future

No information has been obtained at this time on people's perception of the future in Elizabeth.

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[1] U.S. Census: American Fact finder 2000 http://factfinder.census.gov/servlet/SAFFFacts?_sse=on

[2] http://www.answers.com/main/ntquery?method=4&dsid=2222&dekey=Elizabeth%2C+New+Jersey&gwp=8&curtab=2222_1&linktext=Elizabeth%2C%20New%20Jersey

[3] http://www.visithistoricalelizabethnj.org/timeline.htm

[4] http://www.answers.com/main/ntquery?method=4&dsid=2222&dekey=Elizabeth%2C+New+Jersey&gwp=8&curtab=2222_1&linktext=Elizabeth%2C%20New%20Jersey

[5] http://www.panynj.gov/

[6] http://www.answers.com/main/ntquery?method=4&dsid=2222&dekey=Elizabeth%2C+New+Jersey&gwp=8&curtab=2222_1&linktext=Elizabeth%2C%20New%20Jersey

[7] http://www.villageprofile.com/newjersey/elizabeth/

[8] U.S. Census: American Factfinder 2000 http://factfinder.census.gov/servlet/SAFFFacts?_sse=on

[9] U.S. Census: 1990 Decennial Census (STF 1, Table DP-1): http://factfinder.census.gov/servlet/QTGeoSearchByListServlet?ds_name=DEC_1990_STF1_&_lang=en&_ts=126539286370

[10] U.S. Census 2000

[11] ARDA (American Religion Data Archive 2000), Interactive Maps and Reports, Counties: http://www.thearda.com/

[12] http://www.state.nj.us/dep/dsr/fishadvisory05.pdf

[13] http://www.rff.org/Documents/RFF-DP-02-55.pdf

[14] http://www.epa.gov/swerosps/bf/05grants/elizabeth.htm

[15] http://www.epa.gov/region02/news/2003/03105.htm

[16] http://www.futurecitynj.org/watershed.html

[17] http://www.villageprofile.com/newjersey/elizabeth/

[18] http://www.injersey.com/day/story/0,2379,409670,00.html

[19] http://www.unioncountynj.org/svcsgov/econdev/Ucecon.htm#a

[20] http://www.elizabethnj.org/dev_uez.html

[21] http://www.unioncountynj.org/svcsgov/econdev/Ucecon.htm#a

[22] U.S. Census: American Factfinder 2000 http://factfinder.census.gov/servlet/SAFFFacts?_sse=on

[23] U.S. Census: 1990 Decennial Census, (STF 3, Table DP-4): http://factfinder.census.gov/servlet/DatasetMainPageServlet?_program=DEC&_lang=en&_ts=

[24] U.S. Census: 1990 Decennial Census, (STF 3, Table DP-4): http://factfinder.census.gov/servlet/DatasetMainPageServlet?_lang=en&_ts=126625731620&_ds_name=DEC_1990_STF1_&_program=

[25] U.S. Census: American Factfinder 2000 http://factfinder.census.gov/servlet/SAFFFacts?_sse=on

[26] http://www.elizabethnj.org/government.html

[27] http://www.state.nj.us/dep/dsr/urbanfishing/goals.htm

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[28] http://www.futurecitynj.org/watershed.html
[29] http://www.seagrant.sunysb.edu/hep/about.htm
[30] http://www.panynj.gov/
[31] http://www.villageprofile.com/newjersey/elizabeth/
[32] http://www.njtransit.com/sf_bu_schedules.shtml
[33] http://www.injersey.com/day/story/0,2379,409750,00.html
[34] http://www.villageprofile.com/newjersey/elizabeth/08/topic.html
[35] http://www.thefishingline.com/njramp.htm
[36] http://www.atalantacorporation.com/products.asp?cat=4
[37] http://www.trueworldfoods.com/profile.php
[38] http://www.afifoods.com/OpCo_Source/announcements/default.asp?Announcment_Id=814
[39] Public Information office, Elizabeth, NJ, personal communication, 2/9/06
[40] Butmacsq: Butterfish, mackerel, and squid
[41] Sfscupbsb: Summer flounder, scup, and black sea bass
[42] Smallmesh Multi-Species: red hake, ocean pout, mixed hake, black whiting, silver hake (whiting)
[43] Largemesh Groundfish: cod, winter flounder, yellowtail flounder, American plaice, sand-dab flounder, haddock, white hake, redfish, and pollock
[44] http://www.villageprofile.com/newjersey/elizabeth/08/topic.html
[45] http://www.injersey.com/day/story/0,2379,409669,00.html
[46] http://www.seagrant.sunysb.edu/hep/_pdf/ccmphab.pdf
[47] Public Information office, Elizabeth, NJ, personal communication, 2/9/06
[48] Tide shifting along the waterfront in Elizabeth. The Star Ledger. January 29, 2006. Accessed 2/7/06 at: http://www.exit13a.com/
[49] http://www.epa.gov/swerosps/bf/05grants/elizabeth.htm
[50] http://www.villageprofile.com/newjersey/elizabeth/06/topic.html

APPENDIX 10

ILLEX MORATORIUM ANALYSIS

Assessing the Potential for Excess Capacity

Previous analyses of the *Illex* moratorium by MAFMC staff indicated that there was the potential for over-capitalization and excess capacity (MAFMC 1996). That is, investment in capital could be excessive and the fleet had the potential to harvest in excess of the TAC. Analyses by the Northeast Fisheries Science Center staff (NEFSC 2002) also indicated that there was excess harvesting capacity relative to *Illex*. In this more recent analysis, however, excess capacity was simply defined as the ability to harvest in excess of what was actually harvested; the analysis did not assess whether or not the fleet had the capability to harvest *Illex* in excess of the 24,000 mt TAC. The analysis by the NEFSC staff considers two multi-species fisheries—the large mesh multi-species fishery and the small-mesh multi-species fishery. A method called data envelopment analysis (DEA) was used to estimate capacity.

Data envelopment analysis is based on mathematical programming. The approach was originally developed by Charnes, Cooper, and Rhodes (1978) as a way to estimate technical efficiency. Färe et al. (1989), subsequently, offer a DEA framework for estimating capacity output; Kirkley et al. (2000) provide a detailed discussing on using DEA to estimate capacity in fisheries. The approach attempts to determine the maximum potential output that could be produced given fixed (e.g., engine horsepower and vessel hold capacity) and variable inputs (e.g., fuel and labor). Numerous other approaches may also be used to estimate capacity (see, for example, Kirkley et al. 2002).

Estimates of Excess Capacity

In this section, the potential for the fleet to harvest in excess of the 24,000 mt TAC is analyzed. Initially, 1998 is established as a reference year; this is because fleet activity and landings were highest in 1998; 1998 was also a year in which the landings of *Illex* exceed the 19,000 mt TAC. It must be remembered, however, that landings and fleet activity directed at *Illex* since 1998 have declined. Important issues related to the various regulatory alternatives, however, cannot be adequately analyzed. For example, options two and three, which respectively extend the moratorium for five years or discontinue the moratorium, require an assessment of potential entry into the fishery and the potential number of trips or days that would be directed at harvesting *Illex*. Available data, however, suggest declining activity relative to *Illex*; the number of trips and total days steadily declined between 1998 and 2003, the latest year for which data for a complete year are available. Any forecasts of future activity, based on available data, would suggest a continued decline in the number of trips targeting *Illex*. For example, statistical results of a simple regression of the number of trips for which landings per trip were greater than 5,000 pounds against time suggests an average decline of 54 trips per year. Alternatively, a regression of the number of trips per year, by the same fleet, against price or expected price, which equals ex-vessel prices lagged one year, was found to be statistically insignificant. Data required to estimate entry/exit and effort models, which are required to assess the potential entry given the different regulatory options, are not available.

There are two additional major problems with estimating or assessing capacity relative to *Illex*. First, *Illex* is just one of many other species taken throughout the year, and thus, any analysis of capacity must consider the fact that these vessels pursue and land a multitude of species in addition to *Illex* ; this was well recognized by the NEFSC staff in their 2002 analysis. Second, there are rather severe data problems. Presently, three data sets must be used to conduct an analysis of capacity—the dealer or weigh-out data, the vessel trip reporting data (VTR data), and the NMFS permit file. The dealer or weigh-out data file contains information on the quantity landed by vessel permit, but no information about days at sea or vessel characteristics, such as vessel gross registered tonnage (GRT), vessel length, and engine horsepower. The VTR data file provide information about days at sea and crew size, but report only hail or skipper estimates of the weight of each species landed; landings reported in the dealer and VTR data files typically do not match. A remaining problem is that information about vessel characteristics must be obtained from the NMFS permit file; it is not uncommon for the permit file to have discrepancies about vessel characteristics. Information on landings, vessel characteristics, days at sea, and crew size are necessary for estimating the capacity of a fishing vessel and the fleet.

The critical issue that must be examined relative to all three moratorium options is whether or not the fleet has the potential to harvest more than the TAC. Using the NEFSC estimates of capacity, the 1998 fleet would have been able to harvest approximately 3.74 times the observed total level of production, or 194.3 million pounds. This would require that each vessel, on average, be at sea approximately 73 days per year and landing *Illex* along with numerous other species. The NMFS estimates of capacity, however, were based on average annual landings and days at sea per vessel operating between 1999 and 2001; *Illex* activity between 1999 and 2001 was considerably less than it was in 1998. The NMFS analysis was based on the various species routinely considered to comprise the large and small mesh fleets; NMFS included skates, *Loligo, Illex,* silver hake or whiting, croaker, fluke, monkfish, scup, crabs, and black seabass in their analysis of capacity

Using information specific for 1998 and considering trips between active *Illex* moratorium permitted vessels and the open-access vessels, alternative estimates of capacity were obtained using DEA. In 1998, 34 vessels had trips for which landings exceeded 5,000 pounds (vessels required to have a moratorium permit to land greater than 5,00 pounds in 1998). One-hundred vessels had landings for which trips were less than or equal to 5,000 pounds, some of which also held *Illex* moratorium permits. From the weigh-out data, 120 vessels can be uniquely identified. The 34 vessels landing greater than 5,000 pounds in 1998 had the capability to harvest 51.7 million pounds of *Illex*, provided they increased their days at sea for the year to approximately 75 per vessel. The average capacity output per vessel for the fleet of 34 moratorium vessels equaled 1.52 million pounds in 1998. There are 72 vessels holding *Illex* moratorium permits. If the additional 38 *Illex* moratorium permitted vessels had also operated at full capacity in 1998, they would have had the capability to harvest 57.8 million pounds. The remaining 47 vessels, recognizing the restriction that landings cannot exceed 5,000 pounds for 24 hour or longer trip, had the potential to harvest 223.8 thousand pounds or 4,762 pounds per vessel in 1998. The analysis for the non-moratorium permitted vessels assumes customary and usual operating procedures and no major changes in their fishing strategies. In actuality, they have a much higher capability. If the 47 vessels operated only their observed average number of trips per year—5, and caught only the average capacity per trip of 4,762 pounds, they had the potential to harvest 1.1 million pounds. The combined capacity of the 120 vessels operating in 1998 equaled about 110 million pounds, which is more than double the present TAC of 24,000 mt or 52.9 million pounds. It must be remembered, however, that landings exceeded the TAC in 1998. The

TAC was 41.9 million pounds in 1998, and landings equaled nearly 52.0 million pounds. The fishery was shut down prematurely in August. Therefore, it is highly likely that additional landings would have been taken had the fishery not been shut down. Given the high catch rates of *Illex* at the time the directed fishery was closed in 1998, unrestricted landings would have been on the order of 15-30% higher.

The estimates of capacity, however, may be problematic. This is because of severe data problems, which limited a more detailed analysis of capacity. Alternatively, it was simply not possible to adequately estimate capacity for all vessels because actual landings for all vessels landing in 1998 were not available. In addition, the analysis restricts some of the moratorium vessels to levels of landings less than or equal to 5,000 pounds; this was necessary since some trips for moratorium permitted vessels could not be identified. According to the dealer data and the VTR data, 167 vessels landed some quantity of *Illex* in 1998. The 1998 VTR data contains information on 93 vessels, and the weigh-out data contains information on 120 unique vessels. When the two data sets are combined, information for estimating capacity is available for only 50 vessels. These 50 vessels, however, accounted for 94.3 percent of the total *Illex* landings of reported in 1998.

An alternative analysis conducted using 1998 data obtained directly from the Northeast Fisheries Science Center provided a somewhat different conclusion relative to excess capacity. The data provided pertained only to the small mesh fleet. The NEFSC Economic and Social Sciences Division have allocated substantial resources to improving the data base for the small mesh fleet.

The NEFSC considers ten possible species for the small mesh fleet: (1) bluefish, (2) mackerel, (3) butterfish, (4) *Loligo*, (5) *Illex*, (6) silver hake or whiting, (7) red hake, (8) herring, (9) tilefish, (10) croaker, (11) fluke or summer flounder, and (12) weakfish.

There were 321 trips for which *Illex* was reported to be landed; of this total, 236 trips had landings higher than 5,000 pounds and 85 trips had landings less than or equal to 5,000 pounds. The number of vessels included in the 5,000 pound plus trips equaled 28; the number of vessels corresponding to the 5,000 pounds or less level of landings equaled 30. The data were separated based on trip landings--5,000 plus pound trips and less than or equal to 5,000 pound trips. Subsequently, DEA models were formulated and estimated for each group. Both models involved multi-species activities. Vessel tonnage, length, and horsepower were the fixed inputs. For the 5,000 plus pound trips, *Loligo* and *Illex* were the only species of any significance relative to landings; mackerel, butterfish, *Loligo*, and *Illex* were included for the trips landing 5,000 pounds or less. Estimates of Capacity for just the 5,000 pound plus trips are presented in Table 66.

The selection of the species to include in the analysis was based on mean levels of landings per trip and number of trips in which a given species was landed (Table SEIS-1). It was determined to base the inclusion of species on average landings per trip and number of trips in which the species was landed. For the trips landing 5,000 pounds or more, *Loligo* and *Illex* were included; butterfish might also have been included, but only six out of 236 trips had reported landings of butterfish. For the trips landing less than 5,000 pounds, only mackerel, butterfish, *Loligo*, and *Illex* were included in the analysis. An argument could be made that silver hake or whiting and croaker should have been included in the analysis. Croaker was excluded because only ten out of the 85 trips had reported landings of croaker. Silver hake was considered in an initial analysis, but subsequently removed from the analysis because the capacity estimates for *Illex*, with silver hake included, were nearly identical to the estimates with silver hake excluded.

Table SEIS-1. Mean Landings and Number of Trips in Which Species Landed

Species	Mean Landings Per Trip		Number of Trips Species Landed	
	≥ 5,000 lbs	< 5,000 lbs	≥ 5,000 lbs	< 5,000 lbs
Bluefish	3.00	139.34	3	16
Mackerel	235.97	2371.94	4	13
Butterfish	1436.82	154.08	6	42
Loligo	1437.79	15976.02	11	29
Illex	111805.80	837.22	236	85
Silver Hake	0.55	390.40	NA[a]	42
Red Hake	0.08	11.71	NA[a]	5
Herring	0.00	235.59	0	NA[a]
Tilefish	0.52	2.00	3	3
Croaker	1.70	772.33	NA[a]	10
Fluke	0.99	84.66	NA[a]	23
Weakfish	0.00	177.29	0	14

[a] Information pertaining to fewer than three observations is viewed as being confidential and cannot be published; NA indicates not available.

Capacity output estimated for the 28 vessels holding moratorium permits equals 62.0 million pounds, which is nearly 10.0 million pounds higher than the present TAC. Capacity output for the non-moratorium vessels was estimated to equal only 126,247 pounds. Observed landings for observations used in the analysis corresponding, respectively, to the moratorium and non-moratorium trips equaled 26.4 million and 71,164 pounds. The average capacity output per trip for the moratorium and non-moratorium trips was estimated to equal, respectively, 262,798 and 1,485 pounds.

As of November 1, 2004, however, 51 vessels landed 54.3 million pounds of *Illex* on 514 trips. The mean level of landings per trip for those vessels landing less than 5,000 pounds per trip equaled 581.4 pounds; the mean level of landings per trip for those vessels landing more than

5,000 pounds per trip equaled 123,523 pounds. The mean level of landings for those vessels landing more than 5,000 pounds per trip in 2004 was nearly 11,700 pounds higher per trip than it was in 1998–the previous year when the TAC was realized. There is, thus, sufficient evidence to indicate that the fleet has the harvesting capacity to harvest in excess of the TAC.

One reason believed to be responsible for the increased U.S. landings of Illex was the decline of squid landings in South America, brought on, in part, by the Peruvian policy to increase the domestic utilization of squid, which would reduce the supply to the world market and increase the world price of squid. Between December 2002 and June 2003, the world price for squid increased from $4,300 to $5,300 per mt (Fish Info Network). In 2003, catches of *Illex* in the South West Atlantic were considerably down, which also affected the world market for squid. Also, in late 2003, the world average price of squid increased by approximately 20.4 % (FoodMarket Exchange.com). Since 1996, there has also been a decline in total landings of squid in the Northwest Pacific, which is the primary supply for the world market of squid. The largest harvesters of squid in the Northwest Pacific are Japan, Korea, Taiwan, China, and Russia.

Assessing the potential ramifications of moratorium options

In 1998, the average revenue per vessel associated with *Illex* landings equaled $81,110; after adjusting for inflation, the average revenue per vessel associated with *Illex* was $88,126 (2001 constant dollar value). A critical aspect relative to the moratorium options is the potential economic ramification of entry into the fishery (i.e., changes in ex-vessel revenues). In 2001, there are 73 *Illex* moratorium permit holders. All 73 permit holders do not capture large quantities of *Illex*. In order to estimate potential changes in revenues associated with new entry or increased exploitation of *Illex*, an inverse demand model must be estimated.

The inverse demand for short-finned squid (*Illex*) is specified in terms of the partial adjustment model of Nerlove (1956). Although imported squid might be a substitute for *Illex*, the possibility of substituting other squid for *Illex* could not be determined from the available data. In addition, the prices of imported squid were too high for them to be a substitute. We could not determine a reasonable way to select a price below which the import could be defined as an *Illex* substitute. The data used for estimation corresponded to monthly landings and value between 1990 and 2001. The estimation voided months during which there were fewer than 100,000 pounds of *Illex* harvested. The rationale for this decision is that the small harvest months may reflect actions not representative of the entire market.

There is also the possibility that the processors/wholesalers adjust their bids slowly, in a fashion in which they only partially adjust prices in a given period (Nerlove,1956). Specifically, the wholesalers have a "desired" price (P^*_t) in period t based on the level of harvest q_t and the level of harvest and existing stocks (S_t). Let the relationship between the desired price and the level of harvest and existing stocks be linear so that

$$P^*_t = \phi + \beta q_t + \gamma S_t$$

Given that the adjusted actual current price and the previous period's price can be described as a

a proportion of the desired price to previous price,

$P_t - P_{t-1} = \alpha(P^*_t - P_{t-1})$, then the inverse demand is given by

$$P_t = \phi/(1-\alpha) + \beta/(1-\alpha) q_t + \gamma/(1-\alpha) S_t + (1-\alpha) P_{t-1}$$

In addition to this fundamental relationship, we also include monthly and annual dummy variables to adjust for seasonal and annual variations in other variables. The results of the estimation are provided in Table SEIS-2. The estimation indicates a negative relationship between ex-vessel price and harvest that can be interpreted as the demand response. The ex-vessel price was negatively related to price, and its coefficient was statistically significant. The estimated effect on price of quantity changes is, however, quite small, and thus, nearly indicating no price response to changes in quantities. This suggests that regulations that reduce harvests would produce a small economic loss for *Illex* consumers. The partial adjustment coefficient (α) is estimated to be 0.78 (1-0.22) indicating that nearly 80% of the adjustment to desired price is accomplished in the first month. Nearly one-hundred percent of the adjustment will occur after two months.

The estimation indicates strong seasonal variation, with the greatest demand from July through December. There is also an indication of the weak economy since 2000. All years prior to 2000 have significantly greater prices (after adjusting for landings and seasonality). This may also be a reflection of greater imports but it is difficult to ascertain which of the imports are competing with *Illex*.

Based on the inverse demand model for *Illex*, price changes and revenues were estimated relative to different levels of entry (all estimates are in terms for 2001 constant dollar values). As previously illustrated, 28 small mesh vessels had the capability to harvest the TAC in 1998; approximately 24 vessels operating at full capacity (2.2 million pounds per year) could, thus, harvest the TAC of 52.9 million pounds. In terms of 2001 constant dollar values, the ex-vessel revenue corresponding to the 1998 harvest by the 28 moratorium vessels equaled $10.5 million. The revenue corresponding to the TAC is estimated to equal $9.9 million; the decline in revenue is associated with price decreases resulting from the slight increase in annual landings (observed landings in 1998 equaled 51.958 million pounds and landings corresponding to the TAC equal 52.9 million pounds). The real or 2001 constant dollar price was estimated to decrease from $0.202 to $0.187 per pound; this is with respect to the 1998 price level.

Table SEIS-2: Estimated Monthly Inverse Demand for East Coast Short-finned Squid (*Illex*), 1990-2001

Variable	**Mean**	**Estimated Coefficient**	**T-ratio**[1]
Intercept	1.00	0.19	2.95
Illex harvest	1.705 million lbs/month	-0.0065	-3.22
Lagged *Illex* Ex-vessel Price	$ 0.24/lb	0.221	2.68
January	0.000	0.000	-0.76
February	0.001	0.001	-1.08
April	0.004	0.004	-2.2
May	0.035	0.035	-4.54
June	0.209	0.209	-2.55
August	0.306	0.306	-1.74
September	0.261	0.261	-1.49
October	0.113	0.113	-1.06
December	0.060	0.060	-0.35
1990	0.037	0.037	2.11
1991	0.032	0.032	2.24
1992	0.078	0.078	2.14
1993	0.088	0.088	1.12
1994	0.093	0.093	2.4
1995	0.084	0.084	2.35
1996	0.163	0.163	2.87
1997	0.127	0.127	1.93
1998	0.224	0.224	2.54
1999	0.030	0.030	1.14
2000	0.039	0.039	0.27
Observations=66, F-Stat=12.81, Rbar^2 = .83, Durbin/Watson statistic=2.11			

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[1] The t-ratio is based on the null hypothesis of the coefficient value equally zero.

Potential Economic Impacts of Moratorium Options

Regulatory analysis in support of fisheries management and regulation typically requires a full assessment of the potential economic ramifications of proposed regulatory actions. The Council is considering three alternatives relative to the *Illex* moratorium in this amendment: (1) extend the moratorium on entry to the *Illex* fishery without a sunset provision; (2) no action (the moratorium on entry to the *Illex* fishery would expire in 2009 unless extended in a future amendment); (3) terminate the moratorium on entry to the *Illex* fishery. At a minimum, the economic assessment of proposed regulatory options should consider changes in ex-vessel prices and revenues, and changes in gross benefits, consumer surplus, and producer surplus (the combination of consumer and producer surplus is typically referred to as net national benefits). Consumer surplus equals the amount consumers are willing to pay less what they actually have to pay to acquire a good or service. Producer surplus is approximately equal to rent or profit; more formally, producer surplus equals total revenue minus total variable cost (the cost of using items that vary with production such as fuel and labor).

Unfortunately, it is not possible to provide a comprehensive assessment of the potential economic ramifications of the various moratorium options. Data necessary for estimating producer surplus are simply not available (e.g., costs and earnings). More important, however, there is no basis upon which to develop economic models for assessing potential responses by industry to the various proposed moratorium options. That is, it is difficult to predict how the existing fleet of moratorium and non-moratorium permit holders would respond to each of the regulatory options. There is no indication that removing the moratorium would result in a large increase in landings of *Illex*. It is true, however, that landings in 1998 and 2004 exceeded the 19,000 (1998 TAC) mt (41.9 million pounds) and 24,000 (2004 TAC) mt TACs, and the fishery was closed prematurely in both years. Increased landings are thought to be related to higher world prices caused by declining landings in the South West Atlantic. All indications are that without the directed fishery closure, more landings would have been taken.

Albeit information prior to 2004 indicates a decline in *Illex* directed activity, there is always the possibility that changes in the management, availability, resource abundance, or prices of other species could occur, and that these changes could induce additional entry and enhanced fishing in the absence of a moratorium. This appears to be precisely what happened in 2004. World supplies, particularly of *Illex*, declined, and subsequently the world price increased. Prices are generally set via world-wide demand and supply for squid. In 2003 and 2004, landings in the South West Atlantic substantially declined, which put additional pressure on the world price of squid. Unfortunately, available data are inadequate to assess the influences of world demand and supply on domestic ex-vessel price in 2004.

The fact that the domestic commercial fishery for *Illex* was closed in late 2004 indicates that there is sufficient harvesting capacity to harvest in excess of the TAC. Vessel operators apparently responded to changing market conditions and increased their exploitation of squid. The assessment of potential changes in entry/exit and fishing strategies, however, requires development of a comprehensive behavioral model. The data necessary for developing an appropriate behavioral model of potential entry/exit behavior or supply response are not available.

It was hypothesized that a relatively simple model relating pounds landed to expected ex-vessel prices (prices lagged one year) and a time trend might indicate a possible trend in landings relative to time and prices. The statistical results of an analysis between landings, expected prices, and a time trend, however, revealed no significant results that could provide a basis for predicting behavior in response to price and temporal changes.

Although it is not possible to adequately assess the three proposed moratorium options, it is possible to provide an analysis of consumer surplus and gross benefits to the nation from *Illex* landings in 1998, which provides a reference year during which the fleet harvested close to the present 24,000 mt TAC. The inverse demand model provides the mathematical specification for assessing changes in ex-vessel prices, gross benefits, and consumer surplus.

he welfare change, as measured in terms of consumer surplus, from a policy change when using a linear inverse demand is straightforward to estimate. The consumer surplus from a quantity change is given by:

$$CS = \frac{\Delta q\,\Delta \mathrm{p}}{2} = \frac{\Delta q(\beta\Delta q)}{2} = \frac{\beta\Delta q^2}{2}$$

where the β is the coefficient associated with the harvest variable.

Alternatively, consumer surplus may be estimated as the area underneath a demand curve less total expenditures of a given quantity of a good or service. The area underneath a demand curve may be calculated by determining the value of the corresponding mathematical integral.

We also stress, however, that one area that we cannot analyze, but that would be affected by selecting the different options, is producer surplus. Provided the TAC is maintained at 24,000 mt and enforced and given current conditions in the fishery, it is doubtful that the ex-vessel price, revenue, and subsequent consumer surplus would change under the current regulatory regime. It would, however, be possible for landings to become even more concentrated in a given month if the moratorium were allowed to expire. This would likely result in producer surplus becoming zero and consumer surplus decreasing. The latter would likely happen because of increased landings and depressed prices over a short period of time. These changes, however, would depend upon whether or not existing participants increased their landings of *Illex,* and the world wide demand and supply for squid.

Using data obtained from NOAA Fisheries, “Commercial Landings,” electronic data base and the estimated inverse demand curve for *Illex*, estimates of consumer surplus for the 1998 status quo are presented. Consumer surplus is estimated as the mathematical value of the area below the demand curve, but with total revenue deducted. We stress, however, that the NOAA Fisheries data obtained from their electronic data base are different than those provided by the MAFMC and the NEFSC. In 1998, society received $1.35 million in consumer benefits. Gross benefits (before deducting revenues and producer surplus) equaled $9.3 million to society. The observed revenue equaled $5.7 million. The estimate of consumer surplus is derived from deducting estimated revenues from the mathematical value of the area below the inverse demand curve. Also, it should be observed that most of the consumer surplus occurs between June and August, periods during which landings of *Illex* are highest. In previous analyses conducted to support management and regulation of the *Illex* resource, there were no estimates of the inverse demand curve for *Illex*.

Conclusions of Economic Analysis

For this amendment, the MAFMC has proposed three possible alternatives: (1) extend the moratorium on entry to the *Illex* fishery without a sunset provision; (2) no action (the moratorium on entry to the *Illex* fishery would expire in 2009 unless extended in a future amendment); (3) terminate the moratorium on entry to the *Illex* fishery. Analysis of the potential benefits and costs of the various options is complicated by the fact that the fishery for *Illex* has been in an apparent state of decline until 2003 and 2004. Landings and number of trips by moratorium permitted vessels had been decreasing, particularly relative to 1998, which was the year with the highest level of reported activity for *Illex*. In 2004, however, landings of Illex substantially increased; the fishery had to be closed because the TAC was harvested by November of 2004.

It was possible to provide only a limited analysis of capacity and the potential economic ramifications of the various alternatives considered relative to the moratorium. There is no doubt that the existing fleet has the capability to harvest in excess of the present TAC. Analysis indicated that 24 moratorium permitted vessels had the capability in 1998 to harvest more than the present TAC of 24,000 mt. The 1998 fleet harvested well in excess of the allowable 19,000 mt TAC and only about 900,000 pounds (408.2 mt) less than the present TAC. If the fleet had been allowed to continue fishing in 1998, it is highly likely that landings would have been considerably higher than the nearly 52.0 million pounds actually landed. In 2004, 51 vessels landed 54.3 million pounds of *Illex*, and the fishery had to be closed. Without the present moratorium, it is likely that the fishery would have been closed earlier than it actually was closed.

Prior to 2004, there had been a downward trend in fishing activity for *Illex*, particularly relative to 1998. Landings in 2002, the most recent year for which complete data are available, equaled 11.3 percent of the TAC. Reported landings as of November 1, 2004 equaled 54.3 million pounds or 630 mt higher than the TAC. To a large extent, the landings of *Illex* are believed to be highly related to availability (MAFMC, 1998). The last stock assessment of *Illex* was conducted in 2003. This recent assessment indicated that the stock is currently in a low productivity regime. In addition, another indicator of the low productivity is the extended period of low mean body weights, which has occurred since 1982. Both the mean kg per tow, a relative biomass indicator, and the mean body weight indicate low productivity of the resource. Low abundance of the resource is likely the major reason why landings did not increase after 1998.

The available economic analysis does lead to a clear conclusion that would allow the Council to determine the most appropriate regulatory option regarding the moratorium. The fact that the 2004 fleet harvested slightly more than the TAC by November clearly indicates that the fleet is capable of harvesting well in excess of the TAC of 24,000 mt. Reduced world supplies of squid and increased world prices for squid are believed to be responsible for the increased effort on domestic squid. International market reports suggest that the world supplies of squid will be tight for several years, and therefore, prices are expected to be high (www.globefish.org). This, coupled with the fact that resource productivity is low to moderate, argue for making the moratorium permanent (Alternative 1).

Unfortunately, the benefits and costs of the moratorium options cannot be easily analyzed. Maintaining the moratorium, however, does offer the opportunity to prevent the dissipation of rent or producer surplus in the future. Available data suggest that vessel activity related to *Illex* in the near future, and thus, implementing Alternative 1 would help maintain net benefits to society, or at least, prevent the decrease of net benefits.

It is possible to provide a qualitative analysis of the potential moratorium options. The available information suggests that if the moratorium were terminated or were allowed to expire in 2009 and economic and resource conditions remain relatively unchanged from recent levels, there would not be any substantial increase in landings of *Illex* relative to the landings likely to occur with or without a moratorium. If, however, economic conditions changed to promote increased activity on *Illex* as occurred in 2004, landings of not only *Illex* would increase, but so would the landings of other species (e.g., croaker, butterfish, mackerel, *Loligo*, silver hake, etc.). In 1998, the nominal price of *Illex* was $0.19 per pound; in 2001 constant dollar value, it was $0.21 per pound. In 1999, the 2001 price equaled $0.23 per pound, but landings were only 6.8 million pounds, which represented a decline of 86.5 percent in landings relative to landings in 1998.

Alternatives 1and 2 do offer protection against risk of an expanding fishery and risk of further depressing the resource. These options, however, do not appear to generate landings, revenue, or potential benefit streams any different that those levels most likely to occur with a removal of the moratorium (given current conditions). This is primarily based on a qualitative assessment of available information. Alternatives 1 and 2 do, however, offer protection against the possibility that fishing activity for *Illex* might increase in the future. Moreover and as observed in 2004, the fishery had to be closed because the fleet harvested the TAC of 24,000 mt by early November. Changes in economic conditions appear to have a substantial impact of harvesting activities by this fleet. Since world supplies are expected to be tight for the next few years and prices will likely be higher, it is expected that the existing fleet will continue to pursue *Illex* for the next few years. Alternative 1 offers the protection necessary to ensure the fleet does not expand beyond the number of vessels required to harvest the TAC.

In summary, it appears that all three options would generate approximately the same level of landings, revenues, and consumer surplus in the near term, unless prices and market opportunities remain the same as observed during 2004. Given current stock and economic conditions, Alternative 1and 2 would likely yield landings and revenue much different than those likely to occur with the termination of the moratorium. Given the present world price levels for squid, removal of the moratorium could well result in expanded effort in the fishery. The expanded effort, however, would not increase landings beyond the TAC, but it would result in increased costs and decreased profits for the fleet. The net result would be a decrease in net social benefits. These two options do impose some short-run costs in that they prevent entry into the fishery, either until 2009 or permanently. That is, individuals desiring to enter the fishery would be denied the potential revenues that might be realized if they could land more *Illex*. However, the Council could offset these losses by increasing the non-moratorium catch allowance to allow increased participation- albeit controlled. For example, in 2004, the Council increased the non-moratorium incidental catch limit to 10,000 pounds of *Illex* per day. In the future, the Council could increase the incidental catch allowance to even higher levels. This would allow temporary entry into the fishery, but would not result in permanent, long term over-capitalization of the fishery. Alternatives 1and 2 offer protection against the dissipation of rent in the case that the moratorium was lifted and vessel operators desired to expand production.

Unfortunately, the benefits and costs of the moratorium options cannot be easily analyzed. Imposing a permanent moratorium, however, does offer the opportunity to prevent the dissipation of rent or producer surplus in the future. Available data suggest that vessel activity related to *Illex* is highly uncertain. Landings and effort appear to be closely related to world wide market conditions. In 2004, landings of *Illex* reached the TAC by early November. It is believed that increased market prices associated with decreased activity in the South West Atlantic was, at least, partially responsible for increased domestic landings of *Illex*. Supplies are expected to be low for the next few years, and thus, it is likely that, without a moratorium on entry, there would be an increase in the number of vessels actively engaged in the fishery. Analyses of harvest capacity of the existing *Illex* moratorium fleet clearly indicate that overcapacity for the *Illex* fishery currently exists (i.e., the maximum harvest capacity of current moratorium permit holders far exceeds the long term sustainable yield for the species). As a result, in the future the Council may be required to implement measures to reduce harvest capacity in this fishery in accordance with the Build Sustainable Fisheries element of the NOAA Fisheries Strategic Plan, which specifies that a 20 percent reduction in the number of overcapitalized fisheries must be achieved by the year 2005.