Northeast Fisheries Science Center Reference Document 93-02

Ocean Quahog Populations from the Middle Atlantic to the Gulf of Maine in 1992

by

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This document was presented to and reviewed by the Stock Assessment Review Committee (SARC) of the 15th Northeast Regional Stock Assessment Workshop (15th SAW)

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CRD 93-05 Assessment of the Georges Bank cod stock for 1992 by F. Serchuk, R. Mayo, L. O'Brien, and S. Wigley

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CRD 93-07 Report of the 15th Northeast Regional Stock Assessment Workshop (15th SAW), Plenary and Advisory

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SUMMARY

An assessment of ocean quahog *(Arctica islandica)* populations from the Middle Atlantic, Southern New England and Georges Bank was last conducted in 1990. The current report represents an update, through October 1992, on the status of this species, including analysis of nonrandom samples collected in Massachusetts Bay and in the Gulf of Maine. Two types of data were analyzed for this update: 1) commercial landings/fishing effort and 2) catch per tow from National Marine Fisheries Service research vessel surveys. Commercial data are obtained from all participants in the fishery through vessel logbooks.

The fishery has been regulated by catch quotas since 1977 under provisions of the Surf Clam and Ocean Quahog Fishery Management Plan (FMP) developed by the Mid-Atlantic Fishery Management Council. There have been no regulations regarding legal sizes of quahogs which may be caught.

Since 1985, EEZ landings have remained fairly stable, ranging from 19,000 to 24,000 mt annually. During the last 10 years, the majority of the landed ocean quahog biomass was from the Middle Atlantic Bight, especially off the coast of New Jersey and Delaware. This is attributable to proximity of land-based shucking facilities, and not due to clam abundance or biomass in these areas. The fishery has recently spread out, moving north. Less than 1% by weight of the 1992 quahog landings were taken from the Gulf of Maine. Between 1982 and 1989, the Delmarva area had the greatest landings and effort, but New Jersey is now the primary area. Catch per unit effort (CPUE) began a steady decline in Delmarva after 1983, while CPUE in New Jersey began to rise. By 1986, however, annual CPUE was declining in both areas. In 1992, CPUEs for the Middle Atlantic region and the Delmarva and New Jersey areas have been reduced to 67%, 62%, and 71% of their 1986 values.

An analysis of commercial landings gave estimates of the fraction of quahog stocks that have been removed from specified areas. The analysis indicated that 45% of the Delmarva resource has been harvested to date. Analyses of individual 10-minute squares indicated that a greater percentage of the original resource remains as one moves north, from Delmarva to New Jersey.

Based on the slope of a regression between ln(CPUE) vs time (1986 to 1992), estimates of the instantaneous rate of total mortality (Z) in the Delmarva and New Jersey areas and the Mid-Atlantic region are 0.09, 0.06, and 0.08, respectively.

NMFS research vessel surveys provide an independent measure of changes in population size and structure. Based on survey data from the Delmarva area, density has been reduced by 43% from 1980 to 1992. Based on the decline in abundance over time shown by survey data, the estimate of Z in the Delmarva area is 0.03 (and the annual probability of survival, S, = 0.97). Mean weight per tow has fallen from 1.68 kg in 1980-1982 to 1.04 in 1992, a reduction of 62% from the 1980-1982 value. Based on the 1992 survey, small clams (i.e., <70 mm) are rare in the Delmarva area. Ocean quahogs probably take 20 to 30 years to grow to 70 mm in shell length.

Based on surveys from 1980 to 1992, the stratified mean number per tow in New Jersey has fallen by 31%. The estimate of Z in the New Jersey area is 0.04 (S=0.96). Mean weight per tow has fallen from 3.25 kg in 1980-1982 to 2.39 in 1992, a 26.4% reduction. Based on the 1992 survey, individuals <70 mm are rare in the New Jersey population.

Nonrandom samples from the Gulf of Maine averaged 170 quahogs per tow, but the mean weight per tow was very low, 0.42 kg. The Gulf of Maine samples consisted of many small (<70 mm) individuals. This is the only area in the 1992 survey where a significant number of small clams were found. Studies indicate that the growth rate of Maine quahogs is as slow as in other areas. Population density and size structure in the samples from Massachusetts Bay were more similar to samples from the Middle Atlantic Bight than from the Gulf of Maine.

There is little interannual variability in ocean quahog population size or structure in the Middle Atlantic, Southern New England, or Georges Bank. This is due to absence of recruitment, long time to maturity, slow adult growth rates, and low rates of adult mortality. A ranking of the six geographical areas from high to low density is as follows:

1. Southern New England
2. Long Island
3. Georges Bank
4. New Jersey
5. Delmarva
6. Southern Virginia-North Carolina.

For each area, confidence intervals for the mean abundance per tow are wide. Areas with high biomass are Southern New England, Georges Bank, and Long Island. Taken together, New Jersey and Delmarva account for only 20% of the stock biomass.

The total estimated biomass of ocean quahogs currently located between Georges Bank and North Carolina should be sufficient to support the fishery at the 1991 quota level for the next two to three

decades. However, ocean quahogs probably take at least 20 years to grow to commercial size, and good recruitment events are very rare and unpredictable. These characteristics make the species very vulnerable to exploitation. Once depleted, ocean quahog stocks may take 50 to 100 years to replenish themselves.

The concentration of the fishery off Delmarva, and more recently off New Jersey, is causing local stock depletions and a reduction in CPUE. At current removal rates, quahog supplies in these two areas may be exhausted within ten years. To maintain performance during the next 5 to 10 years, the fishery will have to move north to less depleted areas.

INTRODUCTION

The status of the ocean quahog, *Arctica islandica*, off the Atlantic coast of the United States is updated through 1992. Commercial landings and effort data are analyzed, as well as results from NEFSC research vessel surveys. Spatial and temporal trends in resource abundance and size composition are presented, and a medium-term resource prognosis is provided.

This stock was last assessed at the 10th SAW in 1990 (NEFC 1990). The 1990 assessment indicated that commercial CPUE had declined in the Delmarva and New Jersey areas in both 1989 and 1990, although declines in abundance were not evident in the research vessel survey indices for these areas. Size composition data from the 1980-1989 surveys indicated a lack of significant recruitment of quahogs during the preceding 20 to 30 years.

Presently, the entire EEZ ocean quahog resource is managed under a single catch quota (Mid-Atlantic Fishery Management Council 1992). The 1992 quota for the EEZ is 5.3 million bushels [equivalent to 24,040 metric tons (mt) of shucked meats].

Results and conclusions augment previous assessment reports and research publications (Murawski 1986; Murawski *et al.* 1982; Murawski and Serchuk 1983; 1989a; 1989b; Murawski *et al.* 1990; Ropes *et al.* 1984a; 1984b).

ANALYSIS OF COMMERCIAL DATA

Commercial landings data are from vessel logbooks, obtained from all participants in the fishery. These data are stored in the VAX computer's S1032 database. Logbook data collected before 1980 are not currently available for analysis. Files contain information on landings, effort, date and location of catch, and ship weight.

Previous assessments were done totally within S1032. This approach was abandoned because of problems retrieving data for analysis. The major obstacle to analyzing the SFyyVR datasets in S1032 is in determining the locations of clam catches. Data have not been entered in a consistent manner under the variables named LAT and LONG. Often, loran numbers are given instead of latitude and longitude. During retrieval, S1032 effectively multiplies these latitudes and longitudes by ten, because the four-digit numbers are left justified. This leads to retrieval of erroneous data. A second problem that leads to retrieval of incorrect data occurs when one maps between S1032 files to determine ship weights. This is related to the fact that some canceled permit numbers have been reused.

These problems were overcome by converting the S1032 files into ASCII files which were then analyzed using SAS. Location and ship weight are not available directly as variables, but this information was obtained by decomposing composite variables, and by using multiple criteria (*e.g.*, loran number, latitude, longitude, ten minute square, and sometimes, the state where the port was located) to assign catches to geographical areas. Every attempt was made to assign catches to the same geographical areas used in previous assessments (*e.g.* NEFC 1990; Murawski *et al.* 1990).

For 1980-1992 data, all tables and figures in the current report have been updated and converted to metric units (1 bushel of ocean quahogs = 10 lbs = 4.536 kg). By necessity, a minor change was made from previous assessments in the vessel size class categories: Class 1 was not changed, Class 2 was changed from 51-100 GRT to 51-104 GRT, and Class 3 was changed from 101+ GRT to 105+ GRT.

COMMERCIAL FISHERY

Since the inception of the offshore ocean quahog fishery in 1976, cumulative landings of ocean quahogs from the Exclusive Economic Zone (EEZ) have totaled 283,752 mt of shucked meats (Table 1; Figure 1). EEZ landings increased from 21,079 mt in 1990 to 22,246 mt in 1991 (+5.5%). Landings from state waters decreased from 116 mt in 1990 to 40 mt in 1991 (-65.5%). Total ocean quahog landings in 1991 were 22,287 mt of shucked meats, representing a 5.2% increase from 1990.

Since 1977, the offshore fishery has been regulated by catch quotas under provisions of the Surf Clam and Ocean Quahog Fishery Management Plan (FMP) developed by the Mid-Atlantic Fishery Management Council. Since 1985, annual EEZ landings have remained fairly stable, ranging between 19,000 and 24,000 mt (Table 1; Figure 1).

DISTRIBUTION OF LANDINGS AND CATCH PER UNIT EFFORT

During the last 10 years, the majority of ocean quahog landings have been from the Middle Atlantic Bight, especially off the coast of New

Table 1. Annual landings of ocean quahog (metric tons, meats) from state waters and the Exclusive Economic Zone[1]

Year	State Waters	EEZ	Total	Percent EEZ
1967	20	-	20	0
1968	102	-	102	0
1969	290	-	290	0
1970	792	-	792	0
1971	921	-	921	0
1972	634	-	634	0
1973	661	-	661	0
1974	365	-	365	0
1975	569	-	569	0
1976	656	1854	2510	74
1977	1118	7293	8411	87
1978	1218	9197	10,415	88
1979	1404	14,344	15,748	91
1980	1458	13,885	15,343	90
1981	410	15,966	16,375	97
1982	207	15,572	15,779	99
1983	701	15,228	15,978	96
1984	1200	16,401	17,602	93
1985	-	23,566	23,566	99[2]
1986	814	19,771	20,585	96
1987	569	22,226	22,795	98
1988	412	20,594	21,006	98
1989	184	22,996	23,145	99
1990	116	21,079	21,195	99
1991	40	22,246	22,287	100
1992[3]	-	22,461	-	-

[1] **Landings through 1991 are based on data in U.S. Dept. of Commerce 1992 and in Murawski *et al.* 1990.**

[2] **Some inshore landings were from Maine coastal waters, but the magnitude of the fishery was small and catch statistics are not available.**

[3] **The 1992 landings were estimated from data available on October 20, 1992. Landings for 1992 came from the Middle Atlantic Bight (55%), Georges Bank (0%), Southern New England (45%), and the Gulf of Maine (0%)**

Jersey and Delaware (Figure 2). This has been attributed to the proximity of land-based shucking facilities rather than to high quahog abundance. This fishery has expanded since 1983 to involve the entire Middle Atlantic region, as well as a portion of the Gulf of Maine (Figure 2). Less than 1% by weight of the 1992 quahog landings were taken from the Gulf of Maine (Table 1).

Tables 2 and 3 and Figures 2 through 6 provide data on catch, effort, and CPUE for various fishing areas during the 1979-1992 period. Annual landings from the Middle Atlantic region have been relatively stable since 1987, ranging between 19,000 and 21,000 mt (Table 2). During 1990-1992, Class 3 vessels accounted for about 80 to 85% of the total Middle Atlantic catch. Prior to 1990, landings and fishing effort were highest in the Delmarva area. Since 1990, however, most landings have come from the New Jersey area. In 1991, of the total Mid-Atlantic harvest of 19,708 mt of quahog meats, 39.1% was from the Delmarva area and 60.9% from New Jersey.

There have been no regulations regarding legal minimum landing sizes for quahogs, and little discarding occurs in the fishery. The recent shift in the fishery from Delmarva to New Jersey is related to changes in CPUE (Table 2; Figure 3). Although CPUE has been declining in both areas since 1988, CPUE in New Jersey has been greater (10%) than in Delmarva from 1990 onward (Table 2).

Estimates of the instantaneous rate of total mortality (Z) in each area were obtained by regressing ln(CPUE) vs time (1986 to 1992) [*e.g.*, the slope of the regression provides an estimate

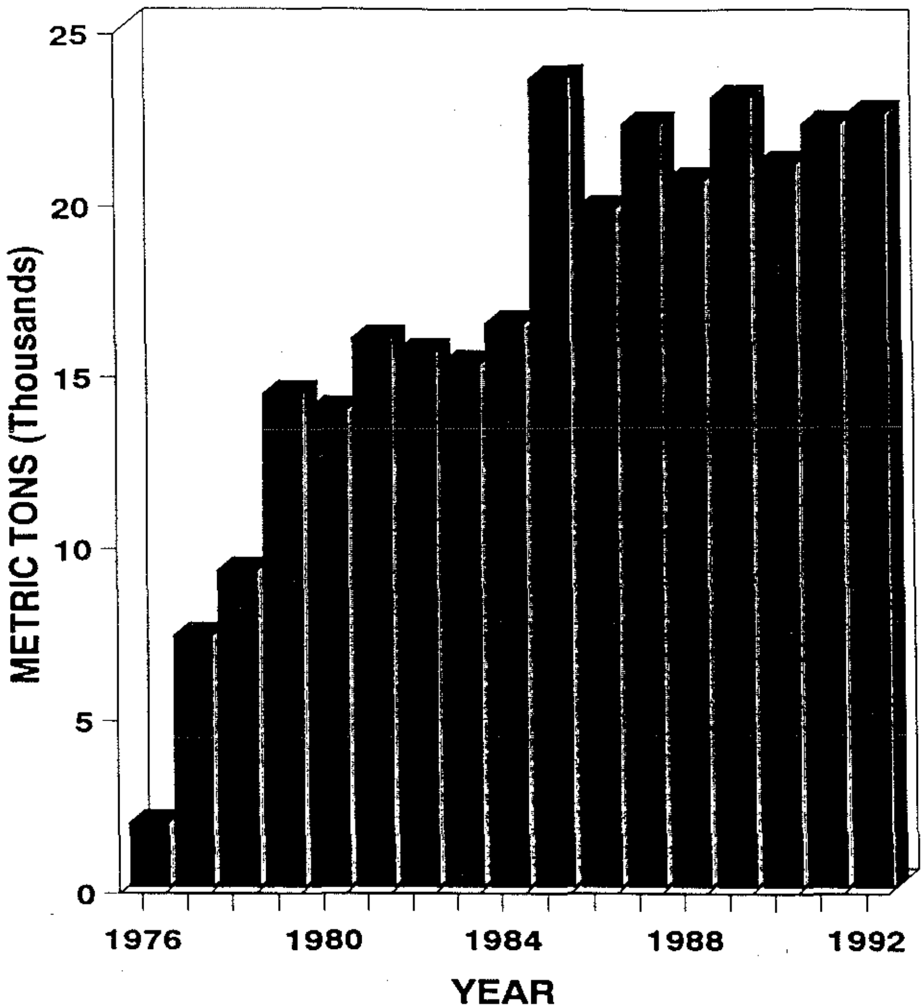

Figure 1. Landings of ocean quahog from the EEZ, 1976-1992. Data are given in thousands of metric tons of shucked meats. For 1992, landings are a prediction for the entire year based on logbook data available as of October 20, 1992.

of Z]. For the Delmarva and New Jersey areas and the total Mid-Atlantic region, the regression analyses gave estimates of Z = 0.09, 0.06, and 0.08, respectively. In all three regressions, the data fit was good (*i.e.*, R^2 >94%). Other estimates of Z, independent of those presented above, were derived using research survey data (see section on research vessel surveys).

A Leslie model was used to estimate the virgin biomass (how much resource was present when the quahog fishery began), and the fraction remaining today (Hilborn and Walters 1992). The analysis assumes no recruitment, balanced immigration/emigration and little or no growth. Although these assumptions are not strictly true, they are reasonable for ocean quahogs given their very slow growth rate and the absence of significant recruitment in the Middle Atlantic region during 1979-1992. The estimation procedure involves regressing CPUE at time t+1 on cumulative catch at time t, and then extrapolating from the regression the cumulative catch when CPUE is 0. For the Delmarva area, cumulative catch to date has been 118,000 mt (Figure 4); the corresponding estimate of prefishery biomass (in 1982) is 263,000 mt. This result suggests that 45% (118/263) of the Delmarva resource has been harvested to date. The first two data points in the time series were not used in the regression because they did not fit the overall trend. This is common in such plots, because points from early in the time series correspond to a learning stage among fisherman (Hilborn and Walters 1992).

The same analysis was applied to six ten-minute squares in the Mid-Atlantic to derive estimates of past and present quahog biomass on a finer geographical scale (Figure 5). The 10-minute squares selected were areas in which

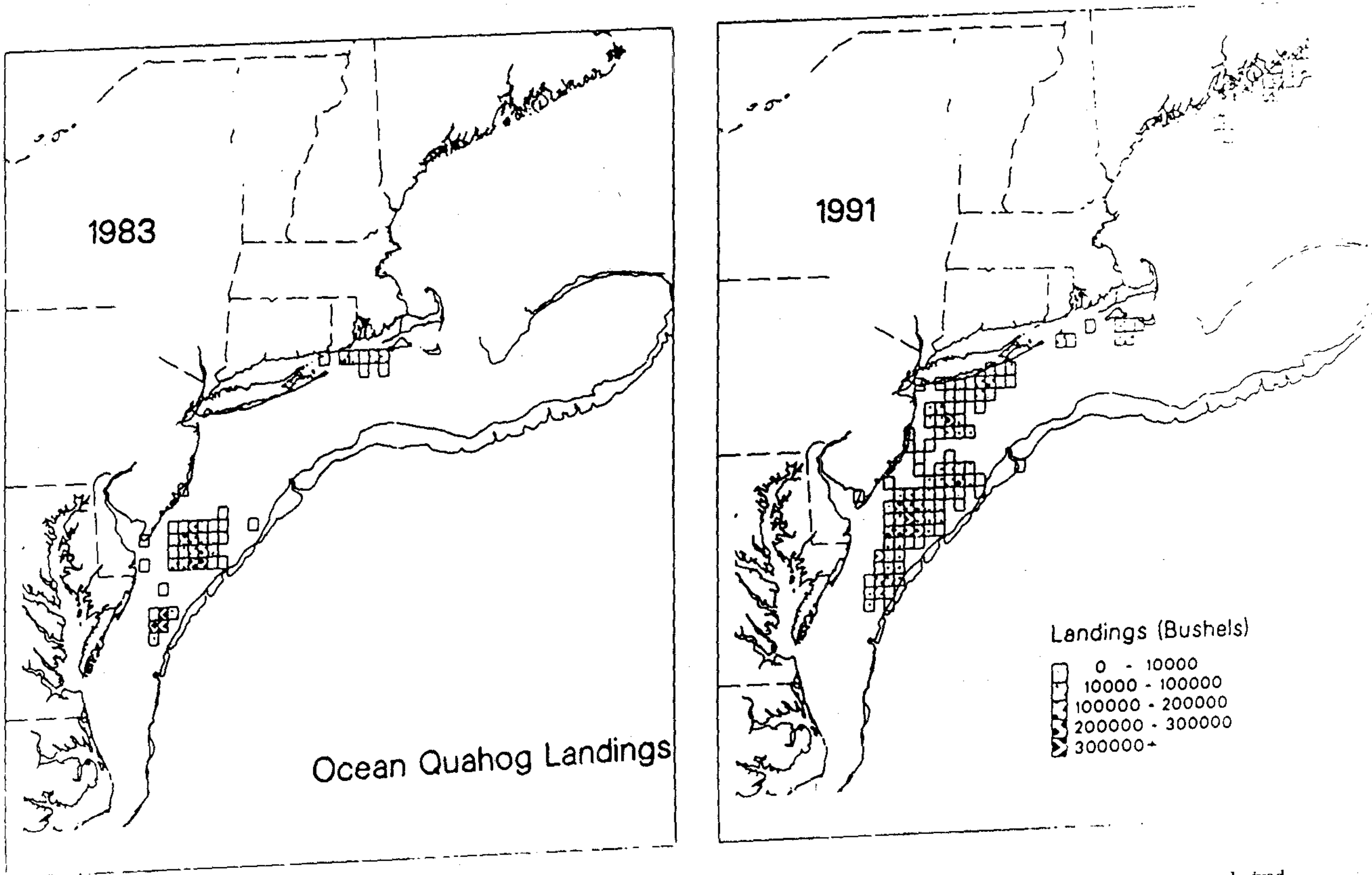

Figure 2. Geographic distribution of ocean quahog landings from the Middle Atlantic Bight to the Gulf of Maine, 1983 and 1991. Data were derived from mandatory logbook submissions, and are expressed in bushels of quahogs landed, by ten-minute square.

Table 2. Summary of annual ocean quahog catch (metric tons), effort (thousands of hours fished) and catch per unit effort (CPUE, kilograms per hour fished) for the Middle Atlantic fishery

	Total Area[1]				Delmarva[2]				New Jersey[3]			
Year	**Sum[4]**	**Catch[5]**	**Effort**	**CPUE**	**Sum**	**Catch**	**Effort**	**CPUE**	**Sum**	**Catch**	**Effort**	**CPUE**
1979[6]	12,859	8759	14.5	603	3125	1941	2.8	699	9680	6772	11.6	585
1980	12,143	10,746	20.4	526	4568	4409	7.4	599	7570	6332	13.0	485
1981	9598	8845	15.2	585	3656	3620	5.7	635	5869	5166	9.3	553
1982	9122	8600	13.0	662	6976	6845	9.5	721	2118	1728	3.5	499
1983	13,630	12,923	19.4	667	9675	9430	13.0	721	3960	3493	6.4	549
1984	15,921	14,420	23.3	617	11,213	10,523	16.1	653	4699	3887	7.2	535
1985	18,048	16,456	25.1	653	10,891	10,120	14.7	689	6994	6164	10.3	599
1986	17,513	15,644	23.3	671	10,192	8904	13.1	676	7321	6740	10.1	662
1987	20,416	18,824	28.2	667	12,936	11,984	17.8	671	7480	6840	10.4	658
1988	18,910	18,103	29.9	608	14,161	13,481	22.5	599	4704	4577	7.3	630
1989	20,697	18,157	32.5	558	11,975	10,188	18.5	549	8723	7965	14.0	567
1990	19,636	16,824	32.0	526	7611	6459	13.1	490	12,011	10,351	18.8	549
1991	19,708	16,864	37.4	449	7706	6473	15.6	413	12,002	10,392	21.7	476
1992[7]	9480	7607	16.9	449	3279	2708	6.5	417	6201	4894	10.4	467

[1] **Loran C coordinates 40600-43700, excluding Southern New England and Georges Bank**
[2] **Loran C coordinates 41350-42649**
[3] **Loran C coordinates 42650-43700**
[4] **"Sum" is sum of all landings by all vessel classes**
[5] **"Catch" is catch by Class 3 vessels used in the CPUE index**
[6] **1979 values are from Murawski *et al.* 1990.**
[7] **Estimated**

intensive harvesting of quahogs has occurred (Table 3). For the three ten-minute squares analyzed in the Delmarva area, estimates of the percentage of resource harvested were 76.4, 72.6, and 52.8%. For the two Southern New Jersey squares, the estimates of resource harvested to date were 42.7 and 44.2%. The proportion removed from the single 10-minute square analyzed in Northern New Jersey was 34.5% (Figure 6). In five of the six cases, there was good fit of data to mode, with R^2 values greater than 88%.

RESEARCH VESSEL SURVEYS

A series of research vessel survey cruises has been conducted between 1980 and 1992 to evaluate the distribution, relative abundance and size composition of ocean quahog populations in the Middle Atlantic, Southern New England, Georges Bank (Figure 7), and (most recently) Massachusetts Bay and the Gulf of Maine. Information from these surveys is used to predict relative year-class strength, and to evaluate the effects of fishery management measures. Assessments of both short- and long-term fishery productivity are based on trends in survey abundance and in indices of fishery yield.

The surveys are performed using a stratified random sampling design, allocating a predetermined number of tows to each stratum. Strata are assigned to geographical assessment areas (*e.g.*, Delmarva, New Jersey). In the 1992 survey, a set of nonrandom samples was taken from north of Cape Cod to the Gulf of Maine. In all surveys, one tow is collected per station, and normal tow duration is 5 min. Survey catches have been standardized to the catch of a 60-in. wide survey dredge towed for 5 min. Catch in meat weight per tow is computed by applying appropriate length-weight equations (Murawski and Serchuk 1979) to numbers caught in each 10 mm size category. Standardized sampling procedures used in these surveys are described further in Murawski and Serchuk (1989). Representative size frequency distributions per tow are presented for the Delmarva and New Jersey assessment areas for each survey date since 1980 (Figures 8 and 9; Tables 4 and 5). The sum of the individuals in each size-frequency distribution is equal to the stratified mean number of clams per tow for a particular assessment area. Stratified means are weighted by the proportional area of each stratum in the assessment area. The standard deviation of the stratified mean regional abundance per tow was computed as the square root of:

Table 3. Cumulative annual ocean quahog catch and CPUE data for six ten-minute squares in the Middle Atlantic Bight

Year	377422		377431		377441		387462		387463		407346	
	CUM[1]	CPUE[2]	CUM	CPUE	CUM	CPUE	CUM	CPUE	CUM	CPUE	CUM	CPUE
1983	1.68	814	1.94	816	0.06	862	0.38	619	1.42	740	-	-
1984	2.75	687	4.10	662	1.16	799	1.42	633	3.44	668	-	-
1985	3.76	782	6.00	742	3.66	852	3.91	604	4.73	644	0.15	841
1986	5.71	675	8.13	734	4.77	732	5.12	593	5.30	646	0.99	999
1987	7.56	753	10.84	718	6.87	637	6.42	607	5.91	597	1.70	625
1988	9.28	619	13.60	664	9.52	577	7.32	538	6.96	536	2.90	806
1989	9.54	439	14.12	514	10.81	497	9.59	513	8.40	545	3.99	728
1990	9.81	408	14.76	451	11.38	562	11.27	479	9.82	523	4.88	680
1991	10.04	259	15.55	362	12.24	404	12.43	396	10.67	435	6.44	672
1992	10.33	401	15.66	286	12.52	365	13.40	384	11.29	418	7.02	596

Ten-Minute Square

[1] **Cumulative catch data (CUM) are thousands of metric tons of shucked meats collected by vessels of all sizes.**
[2] **Catch per unit effort data (CPUE) are kg/hour fishing by Class 3 vessels.**

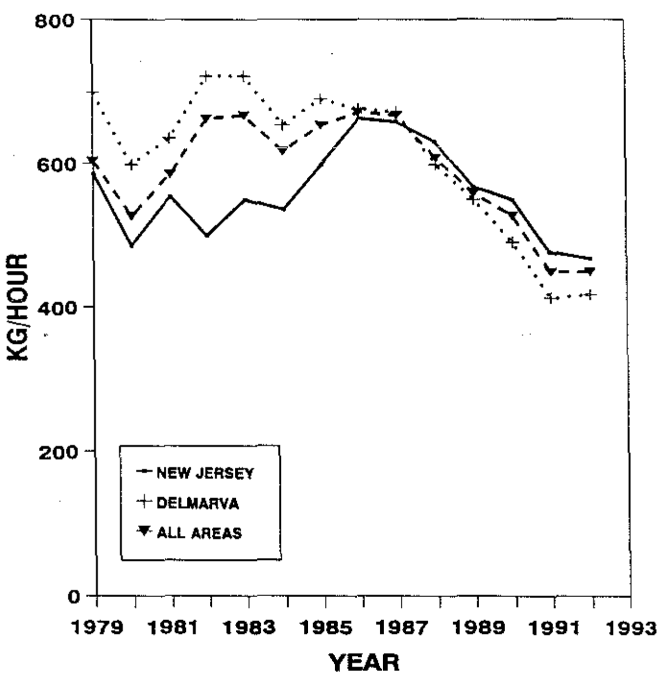

Figure 3. Catch per unit of effort (CPUE, kilograms per hour fishing) for Class 3 vessels (1979: 101+ GRT; 1980-1992: 105+ GRT), fishing in two areas of the Middle Atlantic Bight, 1979-1992. Data were derived from mandatory logbook submission data.

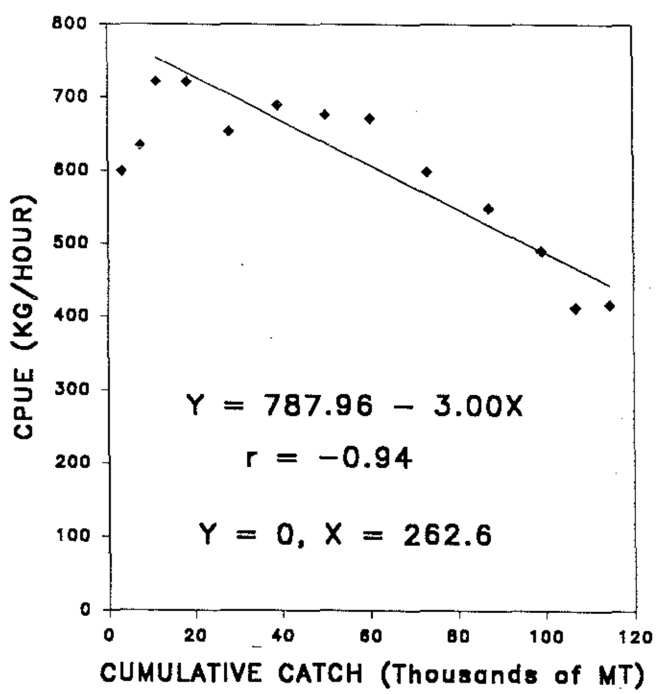

Figure 4. Relationship between CPUE (kilograms per hour fishing by Class 3 vessels, 105+ GRT), and cumulative ocean quahog catch in the Delmarva assessment area, 1982-1992. Regression statistics indicate the theoretical cumulative population extant at the beginning of the time series to be 262,000 mt of meats. Catch per unit effort is for time t+1 while cumulative catch is for time 0 to t.

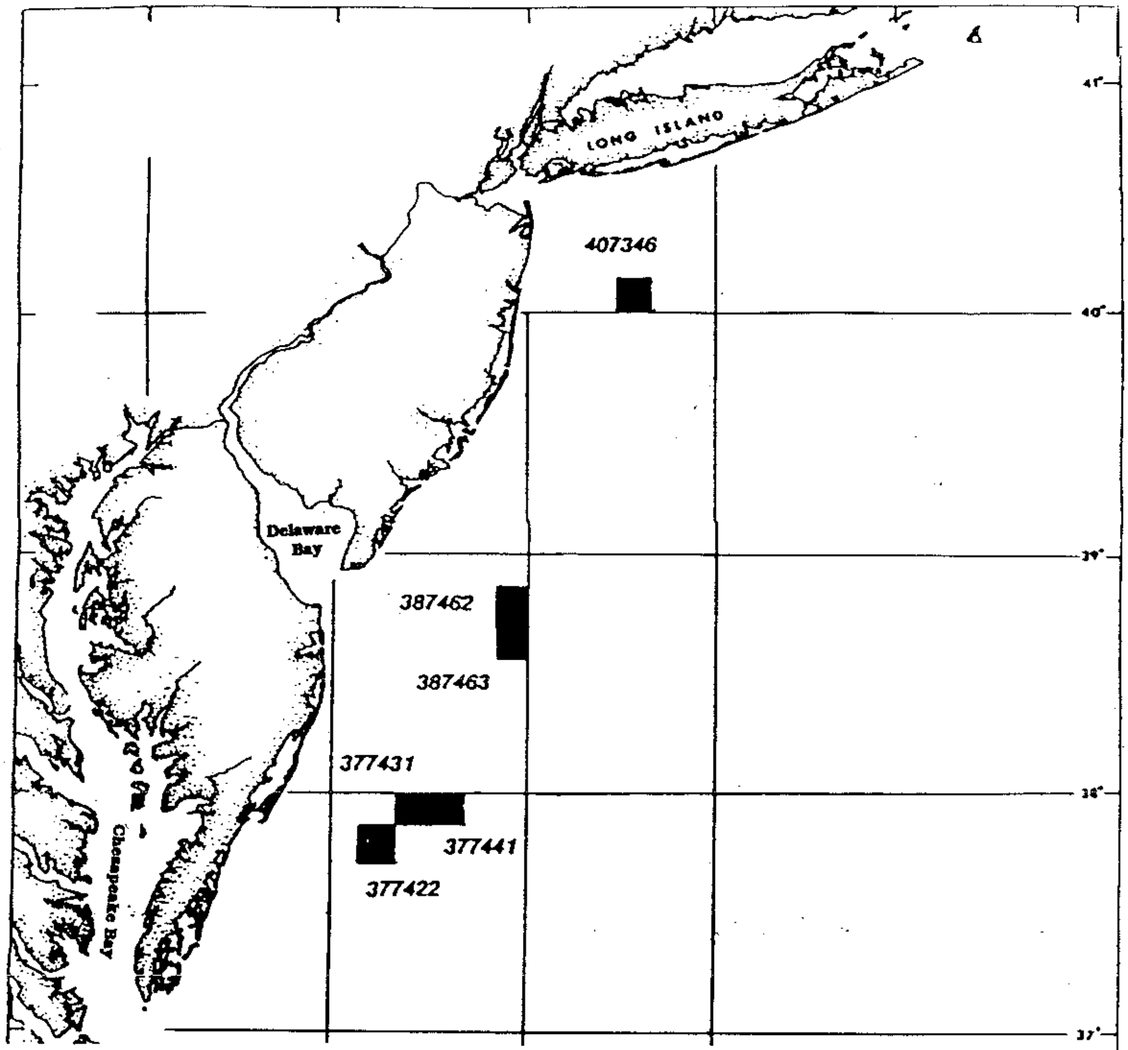

Figure 5. Locations of six ten-minute squares for fine-scale analysis of the relationship between cumulative ocean quahog catch and CPUE (Figure 6). These squares represent locations of previous or current intensive harvesting.

$$V\left(\sum_{j=1}^{m} a_{jl}\bar{Y}_{jl}\right) = \sum_{j=1}^{m} \left(a_{jl}^{2}\, V(\bar{Y}_{jl})\right) \quad \text{where,}$$

V = variance,

a_{jl} = probability{stratum j| region l}, and

$\bar{Y}_{jl}$ = mean abundance in stratum j, region l.

DELMARVA

The Delmarva area was the focus of the quahog fishery from 1982 to 1989. Since 1990, fishing effort and catch have continued at a lower intensity. Based on the Leslie model used earlier to analyze commercial data, 45% of the Delmarva biomass resource has been harvested to date (see above). Research vessel surveys conducted during the same period provide an independent measure of changes in population size and structure in this area (Table 4; Figure 8). Based on the surveys, the stratified mean number per tow has fallen from 47.63 to 28.21 individuals during the period 1980 to 1992. This represents a 42.9% reduction in density. The two estimates, one of loss in biomass and the other loss of abundance, differ from each other by less than 5%. Table 7 can be used to examine temporal changes in density at the stratum level. Stratum 14 had the highest quahog density in 1980-1982; by 1992, density in this stratum had declined by 55.9% (Table 7).

Of the 11 quahog strata in the Delmarva area, 6 had a stratified mean abundance greater than 0. Examining mean catch at length per tow in the 1992 survey for these strata demonstrates that small ocean quahogs are rare in the Delmarva area (also see Figure 8). For strata #9, #10, #11, #13, #14, and #15, mean number of individuals per tow was 4.3, 31.0, 23.0, 74.1, 221.3, and

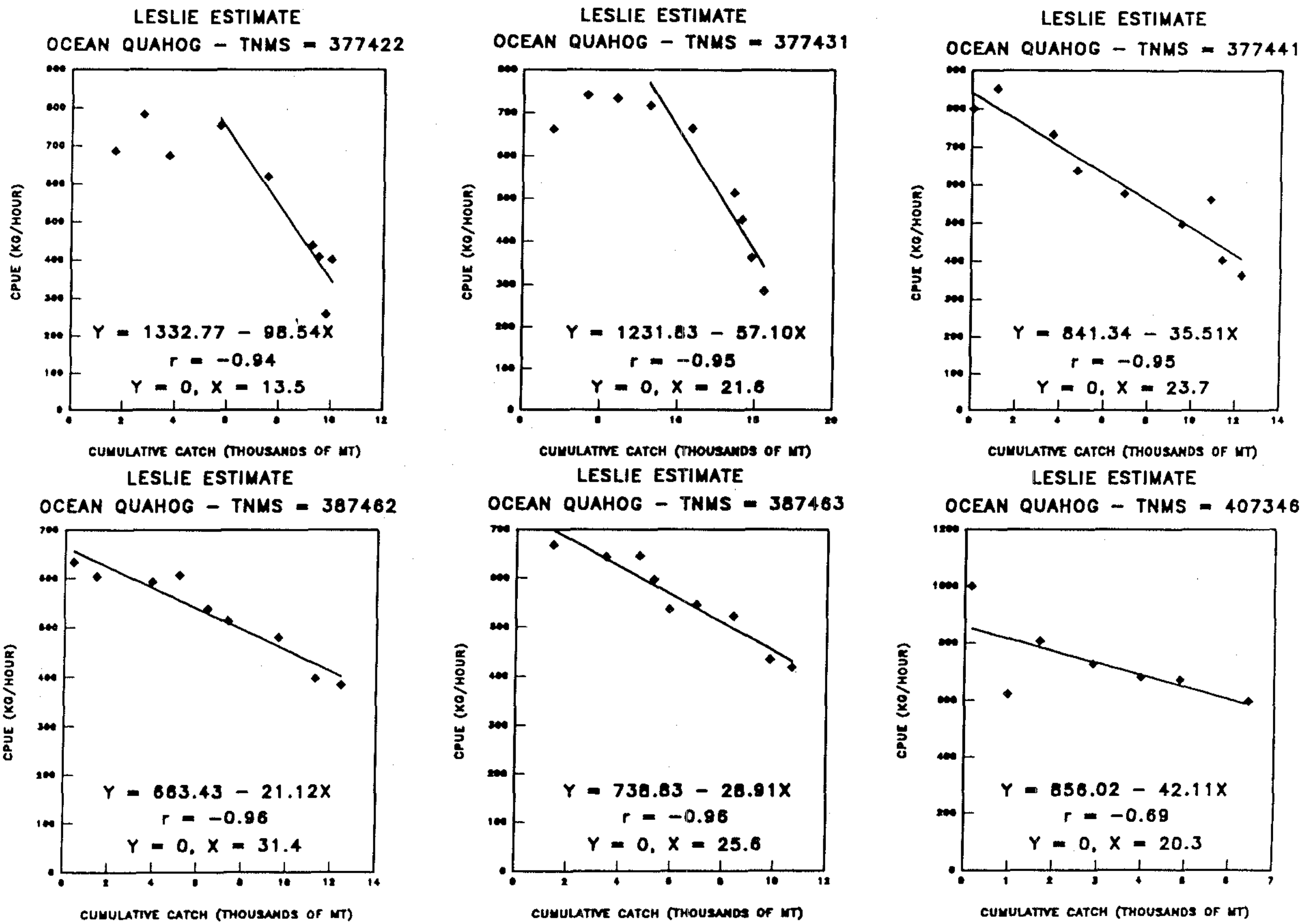

Figure 6. Relationship between cumulative ocean quahog catch (1000 mt of meats) and Class 3 vessel (105+ GRT) CPUE (kilograms per hour fished) for six ten-minute squares given in Figure 5. The CPUE is for time t+1, while cumulative catch is for time 0 to t.

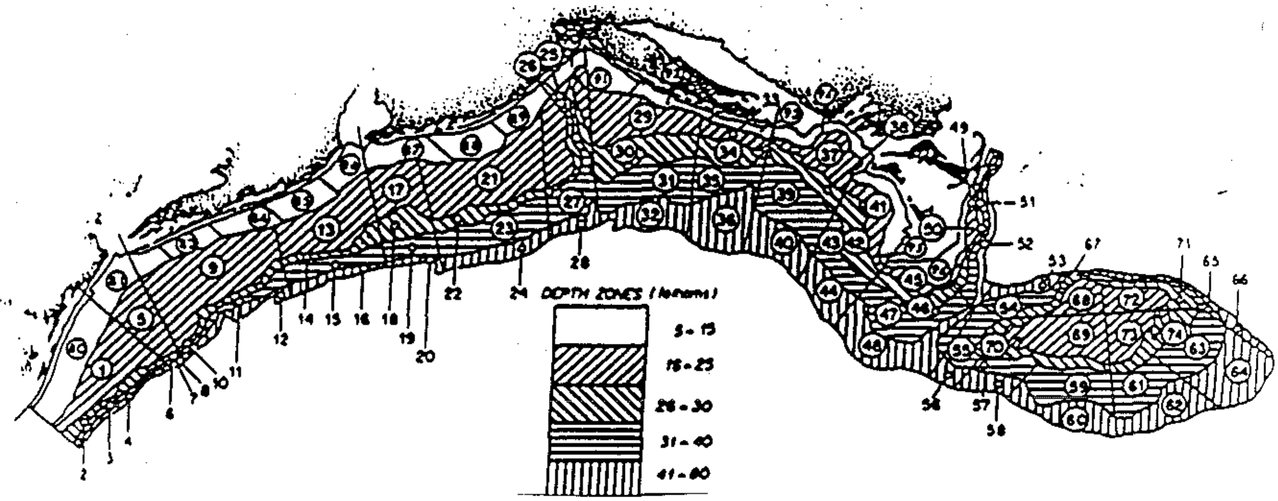

Figure 7. Ocean shellfish survey strata off the northeast United States. Stratification plan is used for both surveys and for sea scallop dredge surveys.

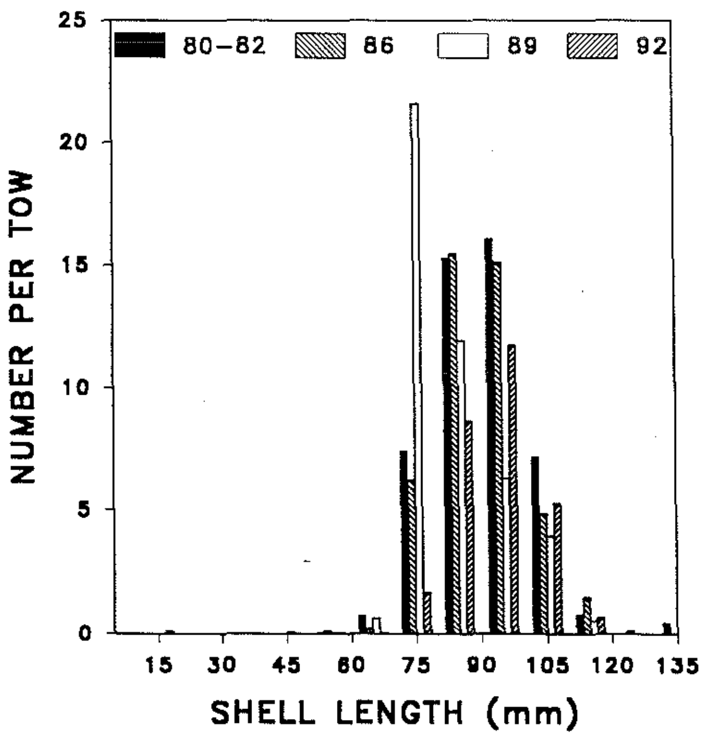

Figure 8. Survey length composition of ocean quahogs from the Delmarva assessment area during four time periods: 1980-1982, 1986, 1989, and 1992. Data are expressed as the stratified mean number per tow taken in each 1 cm size interval.

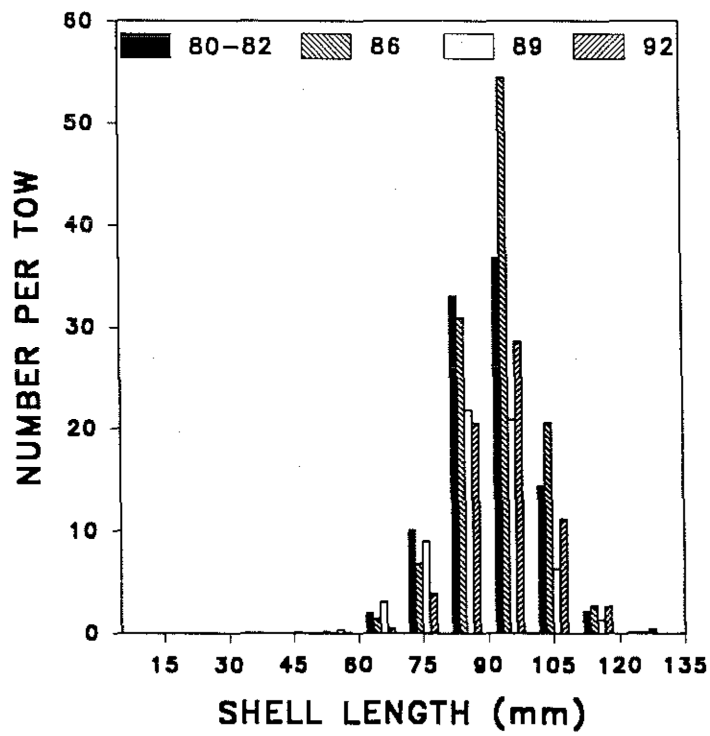

Figure 9. Survey length composition of ocean quahogs from the New Jersey assessment area during four time periods: 1980-1982, 1986, 1989, and 1992. Data are expressed as the stratified mean number per tow taken in each 1 cm size interval.

Table 4. Research vessel survey indices for ocean quahog in the Delmarva assessment area, 1980-1992, in stratified mean numbers and weights per survey tow, standardized for 5 minutes

Length Interval (mm)	Year of Survey Data				
	1980-1982[1]	1986	1989	1992	All Data
10-19			0.12	0.02	
20-29				0.00	0.00
30-39			0.03	0.01	0.01
40-49			0.06	0.01	0.01
50-59	0.07	0.13	0.04	0.07	0.07
60-69	0.75	0.21	0.63	0.02	0.50
70-79	7.42	6.21	21.59	1.68	8.53
80-89	15.30	15.47	11.94	8.66	13.48
90-99	16.07	15.09	6.27	11.73	13.36
100-109	7.18	4.84	3.93	5.25	6.03
110-119	0.80	1.49	0.52	0.66	0.86
120-129	0.03	0.14			0.04
130-139	0.47	0.01			0.00
Stratified mean	47.63	43.57	45.01	28.21	42.92
SD[2]	9.99	10.54	27.67	9.40	7.03
CV	0.21	0.24	0.61	0.33	0.16
n	250	76	88	75	489
Area of Surveyed Strata	5926	5715	5715	5715	5926
Mean Weight Per Tow (kilograms)	1.6832	1.5063	1.2561	1.0445	1.4433

[1] **Four surveys, two in 1980, one in 1981, one in 1982.**
[2] **SD is the standard deviation of the stratified mean per tow (see text for formula).**

25.3, respectively. For the same 6 strata, mean number of individuals per tow that were smaller than 70 mm in shell length was only 0.4, 0.0, 0.0, 0.2, 0.7, and 0.3. Individuals probably take 20 to 30 years to attain a shell length of 70 mm (Murawski *et al.* 1982; Ropes *et al.* 1984a,b).

Between 1980-82 and 1992, mean weight per tow in the Delmarva area declined by 38% (Table 4: 1.68 to 1.04 kg/tow).

Though it does not affect calculations described earlier, the estimate of total abundance per tow from 1989 may not be accurate (Table 4). The standard deviation of the mean for that survey is approximately three times larger than in other surveys. Furthermore, a) the estimate of the mean (45.0) does fit the trend in the time series, and b) the modal size is inconsistent with other surveys.

To estimate total mortality (Z) from the survey data, a regression model was fit to ln(survey abundance index) vs time (1981-1992), under the assumption that no migration or recruitment of quahogs occurred during this period. These assumptions are fairly reasonable since adult quahogs do not move, and there has been no evidence during the last ten years of any substantial recruitment. For the 1981 to 1992 period, Z is estimated to be 0.03 (implying an annual survival rate of 0.97). However, this estimate may be inaccurate because the coefficient of determination, R^2, for the regression model was only 33%.

NEW JERSEY

The New Jersey area has become the focus of the quahog fishery since 1990. Based on the surveys, the stratified mean number per tow has fallen from 99.16 to 68.05 individuals during the period 1980 to 1992 (Table 5). This represents a 31.4% reduction in density. This percent reduction is less severe than that estimated for the Delmarva area (42.9%). Table 7 can be used to

Table 5. Research vessel survey indices for ocean quahog in the New Jersey assessment area, 1980-1992, in stratified mean numbers and weights (meats, kilograms) per survey tow, standardized for 5 minutes

Length Interval (mm)	Year of Survey Data				
	1980-1982[1]	1986	1989	1992	All Data
10-19					
20-29			0.08		0.01
30-39	0.01	0.02	0.02	0.04	0.02
40-49	0.06	0.02	0.10	0.03	0.06
50-59	0.23	0.01	0.35	0.13	0.20
60-69	1.99	1.42	3.05	0.53	1.83
70-79	10.17	6.83	9.01	3.89	8.46
80-89	33.08	30.90	21.79	20.52	28.45
90-99	36.80	54.41	20.85	28.61	34.80
100-109	14.42	20.55	6.30	11.17	13.19
110-119	2.19	2.70	1.34	2.68	2.09
120-129	0.19	0.16	0.16	0.41	0.20
130-139	0.01	0.02		0.04	0.01
Stratified					
Mean	99.16	117.05	63.06	68.05	89.34
SD[2]	11.81	26.48	14.24	14.15	7.74
CV	0.12	0.23	0.23	0.21	0.09
n	360	105	111	104	680
Area of Surveyed Strata	7601	6856	7332	6856	.601
Mean Weight Per Tow kilograms	3.2462	4.0841	1.9212	2.3884	2.9573

[1] **Four surveys, two in 1980, one in 1981, one in 1982.**
[2] **SD is the standard deviation of the stratified mean per tow (see text for formula).**

examine temporal changes in density at the stratum level. Stratum 18 had the highest quahog density in 1980-1982; by 1992, this had declined by 83.6% (Table 7).

Of the 16 quahog strata in the New Jersey area, 13 had a stratified mean abundance greater than 0. Examining mean catch at length per tow in the 1992 survey for these strata demonstrates that small ocean quahogs are rare in the New Jersey area (also seen in Figure 9). In 6 of those strata the mean number of individuals per tow smaller than 70 mm in shell length was 0.0. In the remaining seven strata, #17, #18, #19, #21, #22, #23, and #27, mean number of individuals per tow was 80.8, 54.6, 198.6, 29.3, 260.6, 118.0, and 80.0, respectively. For the same seven strata, mean number of individuals per tow that were smaller than 70 mm in shell length was only 0.5, 2.3, 2.3, 0.1, 2.7, 0.3, and 5.3.

Between 1986 and 1992, mean weight per tow in the New Jersey area declined by 41%. (Table 5: 4.08 to 2.39 kg/tow).

Total annual mortality of quahogs in the New Jersey area was estimated from regression analysis of the 1981-1992 survey data to be Z=0.04 (S=0.96). The coefficient of determination, R^2, for the regression model was 57%.

GULF OF MAINE AND MASSACHUSETTS BAY

Nonrandom samples were collected during the 1992 survey to obtain initial estimates of the density and size structure of ocean quahog populations located north of Georges Bank. These estimates should be interpreted cautiously because samples were taken in commercial beds where quahogs were thought to be most dense.

Gulf of Maine samples averaged 170 quahogs per tow, but the mean weight per tow was very low, 0.4 kg (Table 6). The Gulf of Maine samples consisted of many small (<70 mm) individuals.

Table 6. Research vessel survey mean abundance and weight (meats, kilograms) per tow for ocean quahog at selected stations in the Gulf of Maine (GOM) and Massachusetts Bay (MB), July 1992[1]

Length Interval (mm)	Area GOM	MB
10-19	10.50	0.10
20-29	82.58	0.50
30-39	30.48	1.27
40-49	16.08	0.90
50-59	28.13	1.79
60-69	2.59	10.13
70-79		24.28
80-89		18.97
90-99		5.67
100-109		0.77
110-119		0.08
120-129		
130-139		
Stratified Mean	170.37	64.45
n	41	108
Mean Weight Per Tow (kilograms)	0.4239	1.2968

[1] **Survey tows standardized for 5 min.**

Ocean quahogs from Maine have slow growth rates (Kraus and Beal 1990), similar to those from Georges Bank and Long Island. Given the predominance of small individuals in the Gulf of Maine survey tows, the quahogs sampled were probably relatively young individuals, 1 to 30 years of age.

The population density and size structure of the quahogs sampled in Massachusetts Bay were more similar to those from the Middle Atlantic Bight than those from the Gulf of Maine (Table 6). Most individuals were larger than 70 mm. Massachusetts Bay survey catches averaged 64 quahogs per tow.

COMPARISON OF ALL AREAS

There is little interannual variability in ocean quahog population size or structure in the Middle Atlantic, Southern New England, or Georges Bank regions. This is due to absence of recruitment, slow adult growth rates and low rates of adult mortality. Accordingly, to derive a long-term depiction of the populations within each of these assessment areas, data from several different surveys were combined and analyzed (Table 8; Figure 10). Such pooling of survey data appears justified since these populations have

Table 7. Research vessel survey abundance indices for ocean quahog, by individual survey strata, 1980-1992, in mean numbers per standardized survey tow

Survey Stratum	Year of Survey Data 1980-1982[1]	1986	1989	1992	All Data
Delmarva					
9	15.72(4.68)	3.45(4.45)	4.41(3.69)	4.30(4.21)	10.02(5.38)
	103	29	37	33	202
10	77.00(1.33)	9.67(0.99)	28.33(1.67)	31.00(1.73)	48.41(1.61)
	8	3	3	3	17
11	27.25(0.62)	16.50(0.81)	9.00(0.94)	23.00(0.61)	20.60(0.68)
	4	2	2	2	10
13	66.45(2.82)	81.25(2.61)	40.85(1.74)	74.06(1.78)	65.71(2.58)
	60	20	20	17	17
14	501.50(1.11)	449.67(0.23)	176.00(0.86)	221.23(1.28)	385.47(1.07)
	8	3	3	3	17
15	106.17(1.59)	117.25(0.78)	397.75(1.92)	25.33(1.04)	148.26(2.24)
	12	4	4	3	23
New Jersey					
17	193.16(1.51)	126.42(1.26)	190.42(1.64)	80.83(1.18)	165.89(1.55)
	44	12	12	12	80
18	333.91(1.55)	250.67(1.25)	87.00(1.51)	54.66(0.66)	242.50(1.69)
	11	3	3	3	20
19	115.22(1.43)	79.67(0.44)	35.00(1.54)	198.66(0.78)	109.83(1.24)
	9	3	3	3	18

[1] **Mean (CV)**
n
[2] **Four surveys, two in 1980, one in 1981, one in 1982**

Table 8. Minimum population biomass estimates (metric tons of meats) by geographical area for ocean quahog, based on swept-area estimates from NMFS clam surveys, 1986-1992

Area	Years[1]	Tows (number)	Area (snm)	$\overline{N}$[2]	CV	Weight per Tow (kg of meats)	Minimum[3] Biomass	Percent
Southern Virginia-North Carolina								
	1989							
	1992 (2)	67	3,106	0.11	1.00	0.0053	154	0.01
Delmarva								
	1989							
	1992(2)	163	5,715	38.18	0.41	1.1784	62,999	6.01
New Jersey								
	1989							
	1992 (2)	215	7,332	63.41	0.16	2.0780	142,525	13.61
Long Island								
	1986-1992 (3)	119	4,478	236.08	0.15	5.6133	235,139	22.46
S. New England								
	1986-1992 (3)	91	5,370	241.33	0.14	6.3224	317,599	30.33
Georges Bank								
	1986							
	1992 (2)[4]	122	7,937	178.03	0.24	3.8862	288,539	27.56
Sum		777	33,938				1,046,954	100.00

[1] **Dates of resarch vessel surveys used in the calculation are listed, followed by number of surveys in parentheses.**
[2] **Stratified mean clam abundance per tow.**
[3] **Minimum biomass is estimated, based on a standardized tow sweeping 0.0001069 square nautical miles.**
[4] **Survey data for 1989 was not included here because it did not sample the entire bank.**

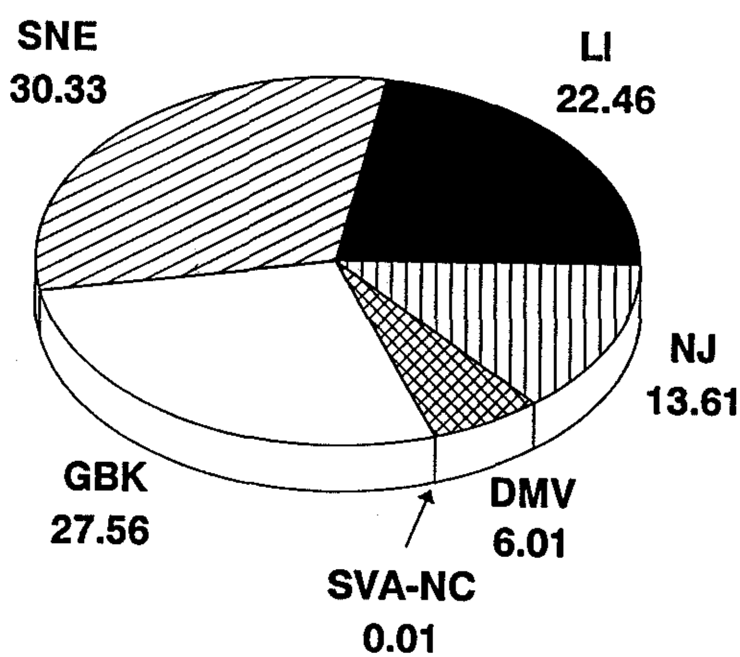

Figure 10. Relative distribution of ocean quahog biomass, based on research vessel survey data (Table 8). Total minimum swept-area biomass estimate for the entire region is 1.047 million metric tons of shucked meats.

not substantially changed over time spans of 3 to 6 years.

Each of the areas is dominated by individuals greater than 70 mm (Figures 8 and 9). With respect to mean catch (number) per tow, the six geographical areas can be ranked from high to low as follows (Table 8):

1. Southern New England
2. Long Island
3. Georges Bank
4. New Jersey
5. Delmarva
6. Southern Virginia-North Carolina

A similar ranking of areas also occurs based on average meat weight per tow (Table 8). Minimum swept-area biomass estimates for each area, derived from the survey results, are listed in Table 8 and plotted on a percentage basis in Figure 10. Areas with the highest biomass are Southern New England, Georges Bank, and Long Island. The New Jersey and Delmarva areas combined only account for 20% of the region-wide biomass.

Abundance indices and size frequency distributions from the most recent (1992) survey are presented, by geographical area, in Figures 11 to 13. The highest abundance indices were obtained in the Southern New England and Long Island areas, rather than in New Jersey or Delmarva where most of the present commercial fishery occurs (Figure 11). All areas, except for the Gulf of Maine, are characterized by unimodal size distributions comprised of mostly larger-sized individuals (Figures 12 and 13).

For the three most recent surveys (1986, 1989, 1992), minimum 95% confidence intervals (Cochran 1977) were calculated for the stratified mean number per tow index in each region (Table 9; Figure 14). In almost all cases, the confidence intervals are rather wide and overlap one another. Hence, temporal changes in mean abundance and biomass values should be interpreted with caution. However, in the New Jersey region [where most of the harvesting now takes place], quahog abundance appears to have declined between 1986 and 1989-1992.

The depletion equation,

$$B_{t+1}=(B_t-C_t)e^{-m} \quad \text{where}$$

t = time,
B = stock biomass,
C = annual catch, and
m = natural mortality rate

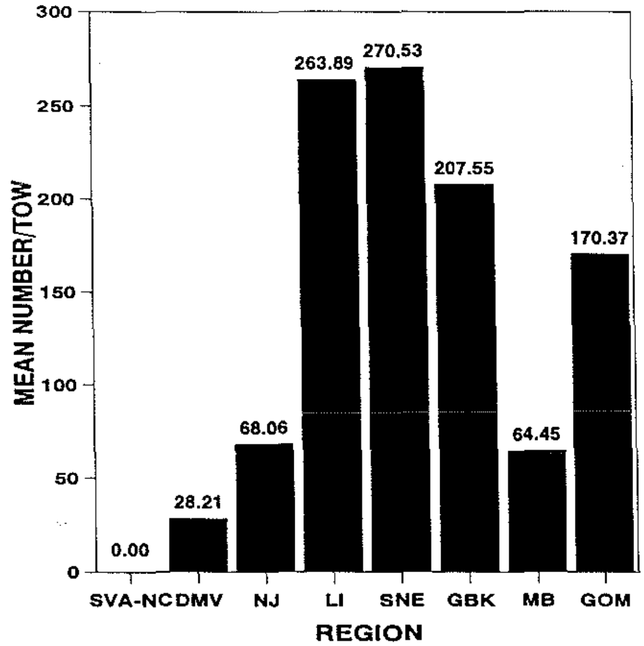

Figure 11. Ocean quahog abundance by region based on data from the 1992 survey.

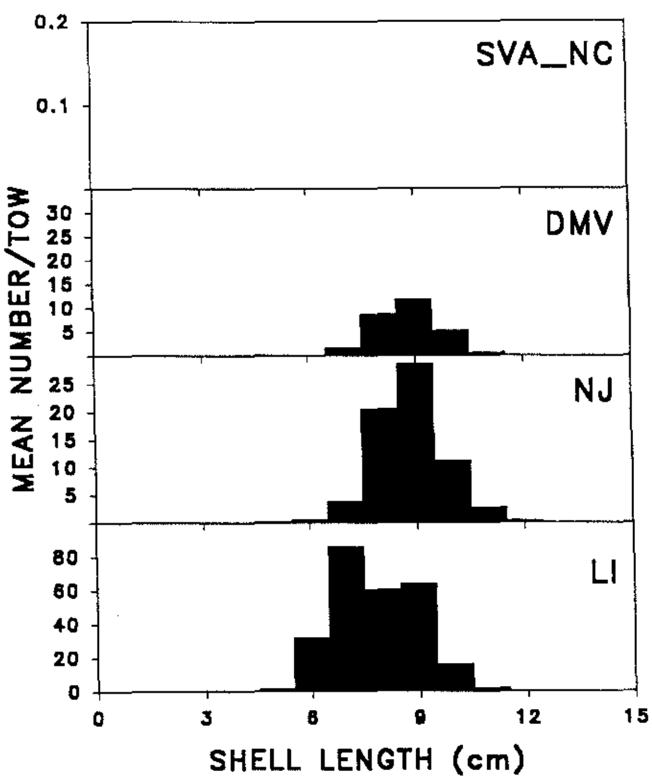

Figure 12. Size frequency distribution of ocean quahogs from Southern regions based on data from the 1992 survey.

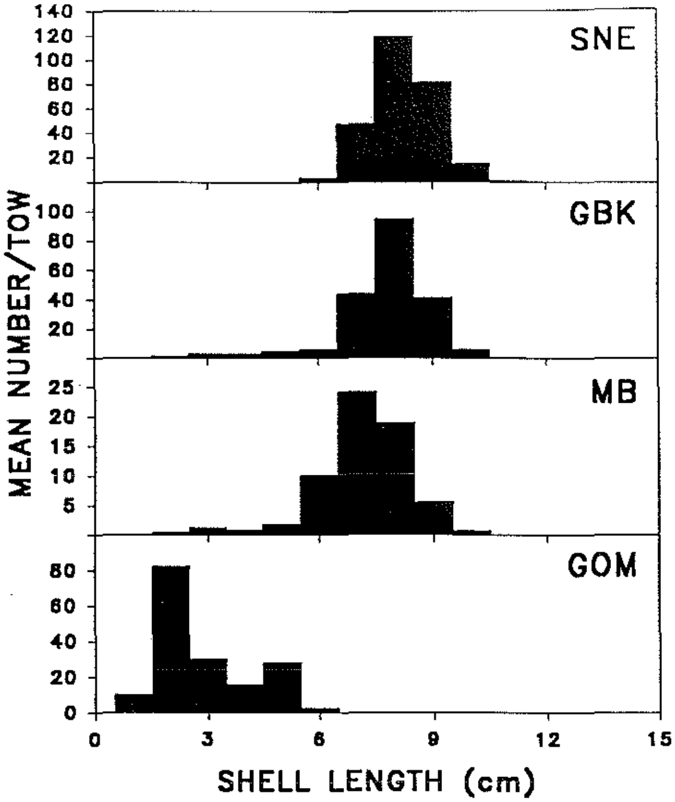

Figure 13. Size frequency distribution of ocean quahogs from Northern regions based on data from the 1992 survey.

was used to estimate how long the stock might support current rates of harvesting. Estimates were made for two values of m (0.02 and 0.06), both of which seem reasonable based on survey and CPUE data. Although the equation does not consider growth, recruitment, or the possibility of rare but high m values in some years, the results suggest that the entire stock can support annual landings at the 1991 level for 22 to 32 more years (Table 10). However, for this to occur, the quahog fishery will have to shift northward (to Southern New England/Long Island and Georges Bank) because, at current harvest levels, the New Jersey and Delmarva resources are estimated to last for only another 6 to 10 years.

OVERVIEW AND PROGNOSIS

At present, the total estimated biomass of ocean quahogs located between Georges Bank and North Carolina should be sufficient to support the fishery at the 1991 quota level for the next two to three decades. However, ocean quahogs take at least 20 years to grow to 70 mm (*i.e.*, commercial size) and good recruitment events are very rare and unpredictable. These charac-

Table 9. Summary statistics for ocean quahog abundance by region and year, computations made using untransformed data from three research vessel surveys

Region	Year	Stratified Mean per Tow	SD[1]	N max[2]	Minimum 95% CI	Upper Limit	Lower Limit
Delmarva							
	1986	43.56	10.54	76	20.98	64.54	22.59
	1989	45.01	27.67	88	55.06	100.07	-10.05
	1992	28.21	9.40	75	18.71	46.92	9.50
New Jersey							
	1986	117.05	26.47	105	52.68	169.76	64.37
	1989	63.06	14.24	111	28.34	91.40	34.72
	1992	68.05	14.15	104	28.16	96.21	39.89
Long Island							
	1986	243.51	56.02	38	113.22	356.73	130.30
	1989	185.78	69.42	41	140.30	326.10	45.48
	1992	263.89	48.18	40	97.37	361.26	166.52
Southern New England							
	1986	208.64	63.78	28	130.88	339.52	77.76
	1989	208.75	49.27	28	101.10	309.85	107.65
	1992	270.53	55.49	35	112.70	383.23	157.83
Georges Bank							
	1986	197.8	42.48	63	84.96	282.76	112.84
	1989	41.09	12.80	41	25.87	66.96	15.22
	1992	207.56	51.48	59	102.96	310.52	104.60

[1] SD is the standard deviation of the stratified mean (See text for formula).
[2] "N max" is the sum of all tows within a region.

Table 10. Landings, biomass (metric tons, meats) and current supplies of ocean quahogs, expressed in number of years, by geographical area

Geographical Area	1991 Landings	Minimum Stock[1] Biomass	Supply Years[2,3,4] m=0.02	Supply Years[2,3,4] m=0.06
Gulf of Maine	166.4	unknown	unknown	unknown
Georges Bank	0.0	288,539	50+[2]	36+[2]
Southern New England-Long Island	2327.5	552,738	50+	45
New Jersey	12,732.0	142,525	10	8
Delmarva	7738.9	62,999	7	6
Southern Virginia-North Carolina	0.0	154	0	0
Mid-Atlantic[5]	20,470.9	205,677	9	8
Total[6]	22,798.4	1,046,954	32	22

[1] **Biomass values are derived from recent research vessel surveys, see Table 8.**
[2] **Supply years are computed based on the 1991 landings from SNE + LI. Adjacent areas, SNE and LI, are treated as a single unit, because they are underutilized and have high quahog biomass.**
[3] **Estimates of supply years are based on 1991 landing rates, unless there were no landings in 1991.**
[4] **The instantaneous rate of natural mortality = m. "Unknown": because area has not been determined, biomass and supply years cannot be computed.**
[5] **The Mid-Atlantic region includes New Jersey, Delmarva, and Southern Virginia-North Virginia.**
[6] **Total is the sum of all areas except the Gulf of Maine.**

teristics make the species very vulnerable to exploitation. Once depleted, ocean quahog stocks may take 50 to 100 years to replenish themselves.

The concentration of the fishery off of Delmarva and, more recently, off of New Jersey is causing local stock depletions and a reduction in CPUE. At current removal rates, quahog supplies in these two areas may be exhausted within ten years. To maintain performance during the next 5 to 10 years, the fishery will have to move north to less depleted areas.

ACKNOWLEDGEMENTS

K. Sosebee and J. Idoine plotted the data, and J. McDonald typed the tables. S. Murawski wrote the first version of the edited FORTRAN program used to analyze survey data.

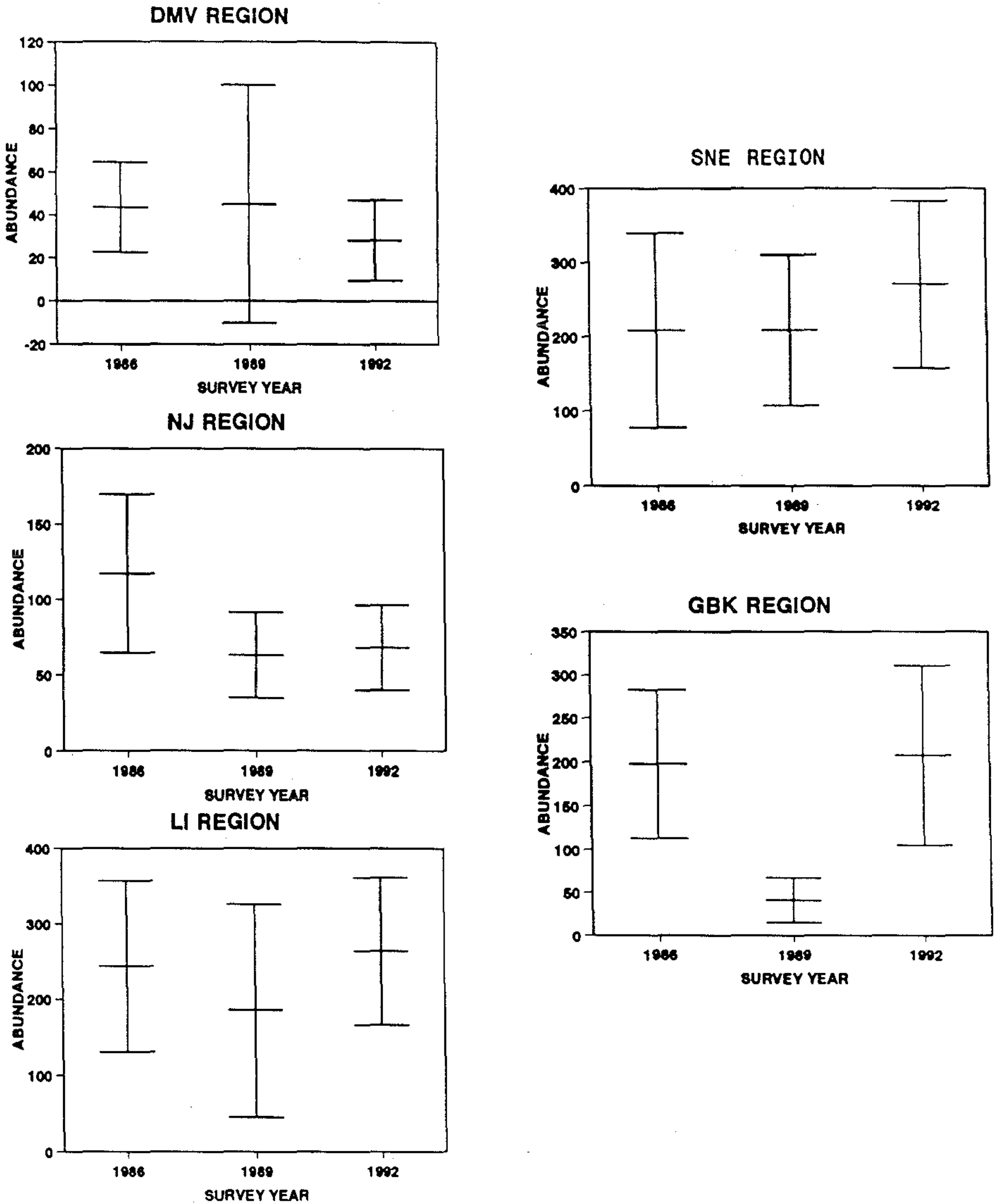

Figure 14. Minimum 95% confidence intervals for the stratified mean of ocean quahog abundance per tow by region. Computations were made on untransformed data from three research vessel surveys: 1986, 1989, 1992.

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