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Distribution of Sexually Immature Components of 10 Northwest Atlantic Groundfish Species Based on Northeast Fisheries Center Bottom Trawl Surveys, 1968-86

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ABSTRACT

Analyses of data obtained from research vessel survey cruises over a 19-year period reveal distinctive patterns in the geographic occurrence of immature fish. These occurrences provide qualitative evidence for potentially significant fishing mortality of the sexually immature components of 10 species in the Gulf of Maine-Georges Bank-Southern New England region, where substantial overlap exists between unregulated mesh/exempted fishing areas and the distributions of these immature fish.

INTRODUCTION

If one goal of fishery management is to prevent recruitment overfishing, then it becomes important to define season and area combinations where juvenile mortality is likely to occur. While numerous distribution studies of Northwest Atlantic groundfish exist (Bigelow and Schroeder 1953; Leim and Scott 1966; Bowman 1981; Grosslein and Azarovitz 1982; Scott 1988), most do not specifically consider juvenile distribution patterns. A study by Bowman *et al.* (1987) on food habits and distribution of juveniles for 17 species was based upon fish of age 1 or less, but did not cover the full period to sexually maturity. Bowman (1981) examined the distribution and abundance of juveniles for 15 species, but not to the geographic and seasonal resolution necessary for evaluation from management perspectives.

This study describes distribution of juveniles of the 10 groundfish species in the Gulf of Maine-Georges Bank-Southern New England region (Figure 1) subject to regulation under the New England Fishery Management Council's Northeast Multispecies Fishery Management Plan (FMP), and evaluates the distribution patterns with respect to regulatory areas established by the FMP. Regulated species include haddock (*Melanogrammus aeglefinus*), Atlantic cod (*Gadus morhua*), yellowtail flounder (*Limanda ferruginea*), American plaice (*Hippoglossoides platessoides*), witch flounder (*Glyptocephalus cynoglossus*), redfish (*Sebastes fasciatus*), pollock (*Pollachius virens*), white hake (*Urophycis tenuis*), windowpane (*Scophthalmus aquosus*), and winter flounder (*Pseudopleuronectes americanus*). Under the FMP, otter-trawl stretch mesh size is regulated at 5.5 inches (140 mm) for most of Georges Bank and the Gulf of Maine (Figure 2); exempted small-mesh fisheries are allowed in the area extending from Cape Cod north along the inshore segment of the Gulf of Maine. Mesh size is generally not regulated in areas west and south of Cape Cod including the southern flank of Georges Bank; however, the Nantucket Shoals region is included in the large-mesh area and is regulated December through March (Figure 2). In addition, a spawning area closure to protect yellowtail flounder is in effect from March/April to May.[1] Results presented herein may be used to assess qualitatively the impacts of management measures (*e.g.*, effects of small-mesh areas) on the mortality of juvenile fish.

METHODS

Data have been obtained from annual Northeast Fisheries Center (NEFC) spring and autumn bottom trawl surveys (Grosslein 1969; Azarovitz 1981) conducted since 1968 during March to May and September to November, respectively. NEFC survey coverage within the study area is shown in Figure 3; sampling intensity within strata is summarized in Table 1. Maturity ogives were inspected to determine the smallest length at which individuals of each species were observed to be sexually mature (Table 2); immature fish were defined as those falling below that length. Catches (as number per tow) of immature fish were plotted by survey haul location. Data from 1968-86 surveys have been aggregated and plotted for each species by season (spring and autumn). Year-around regulated mesh areas delineated by the FMP (Figure 2) are superimposed for reference purposes; the seasonal areas (Nantucket Shoals and Southern New England spawning closure) are superimposed on spring plots only. Mean values of depth were calculated for juveniles of each species (Table 3).

RESULTS

Haddock

Immature haddock are most concentrated at depths near or less than 100 m during both spring and autumn (Table 3, Figures 4 and 5). In spring, concentrations appear from just south of Jeffreys Ledge to Cape Cod, and along the southern edge of Georges Bank. In autumn, these aggregations remain and are augmented by concentrations on Georges Bank extending from the Northeast Peak and along the Northern Edge to the Great South Channel region. The potential for juvenile mortality exists in the southern Gulf of Maine exempted area and the southern portion of Georges Bank during both seasons.

Atlantic Cod

Immature Atlantic cod are generally found at depths less than 100 m (Table 3, Figures 6 and 7). In the spring, concentrations occur between Jeffreys Ledge and Cape

[1] Specific coordinates are described in *Federal Register*, 50 CFR Part 651, September 17, 1987.

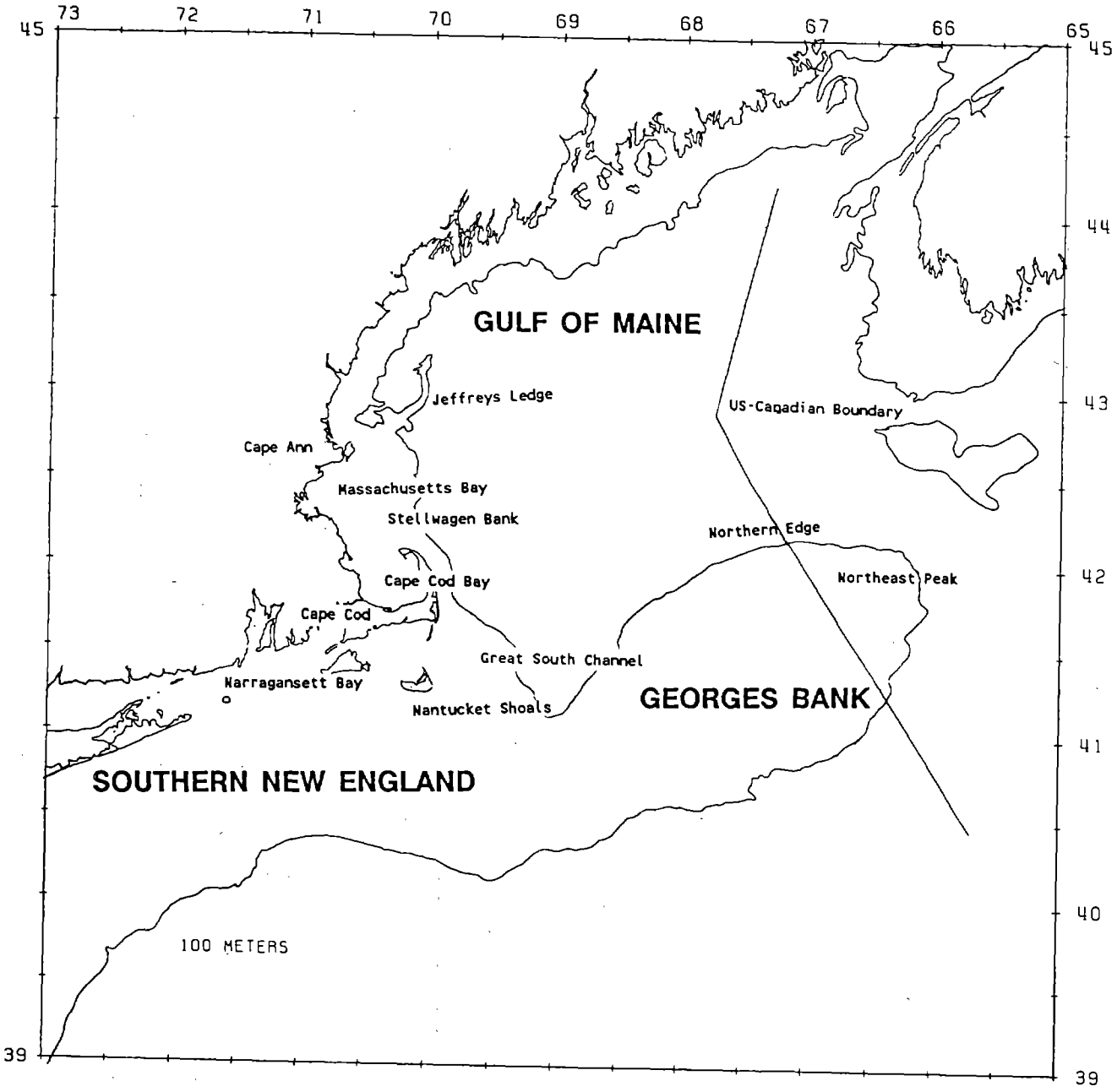

Figure 1. Gulf of Maine, Georges Bank, and Southern New England regions of the Northwest Atlantic Ocean, showing geographic features referred to in this study

Cod and in the Nantucket Shoals region, and are widely distributed over Georges Bank. Distributions in autumn are more restricted, occurring primarily inshore of the 100-m isobath and principally in three areas: Massachusetts Bay, southeast of Cape Cod, and the Northeast Peak of Georges Bank. Seasonal mesh regulations on Nantucket Shoals (Figure 2) have been established specifically to protect juvenile cod from December to March; however, juvenile mortality may occur in the southern Gulf of Maine exempted area during both seasons. A detailed account of juvenile cod distribution is given by Wigley and Serchuk (submitted).

Yellowtail Flounder

Immature yellowtail flounder are usually found well inshore of 100 m (Table 3). In the Gulf of Maine, they are concentrated between Massachusetts Bay and Cape Cod Bay, and along outer Cape Cod in both spring and autumn (Figures 8 and 9). Immature individuals are found during spring along the southern edge of Georges Bank where their distribution is within the regulated mesh area. In autumn, concentrations shift to the north, near the Great South Channel, but primarily eastward to slightly deeper waters along the southeastern part of Georges Bank. In Southern

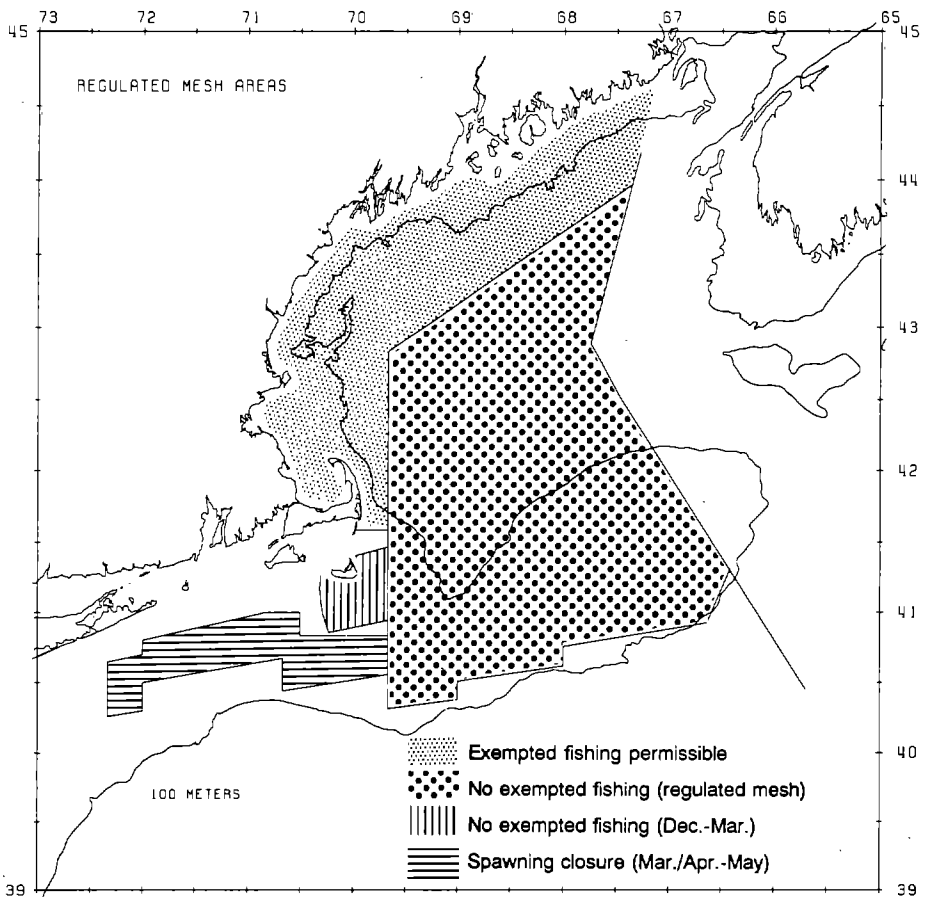

Figure 2. Regulated mesh (5.5 inches) and exempted fishery areas under the New England Fishery Management Council's Northeast Multispecies Fishery Management Plan

New England, immature fish are found mid-shelf at depths around 45 m in spring and 60 m in autumn (Table 3). Spring distribution is generally northward of the spawning area closure. Significant juvenile mortality may occur in the Southern New England region where mesh size is unregulated.

American Plaice

Immature American plaice are strongly concentrated along and inside the 100-m isobath in the western Gulf of Maine during spring and autumn (Table 3, Figures 10 and 11). They are found scattered in the deeper waters of the western and central Gulf of Maine, and on the northern edge of Georges Bank. For the most part, immature American plaice are unprotected by the regulated mesh area. Significant discarding of juvenile plaice has been observed in association with the small-mesh shrimp fishery in the western Gulf of Maine during December through May (Stephen H. Clark, NEFC, personal communication).

Witch Flounder

Immature witch flounder in the New England region concentrate between Cape Cod and Cape Ann, inshore of Jeffreys Ledge, and intermittently across the northern Gulf of Maine (Table 3, Figures 12 and 13). Distribution does not appear to shift widely between spring and autumn. As with American plaice, witch flounder juvenile aggregations do not occur within the regulated area, and are subject to mortality incurred from the shrimp fishery.

Redfish

Immature redfish are distributed over the entire Gulf of Maine (Table 3, Figures 14 and 15), but appear most concentrated from Stellwagen Bank north along the western side of the Gulf of Maine during spring. In autumn, this distribution extends northward into the central Gulf of Maine. Some juvenile mortality may occur in the exempted small-mesh fisheries prosecuted in the western Gulf of Maine.

Pollock

Immature pollock are distributed in the northern Gulf of Maine, and between Cape Cod and Jeffreys Ledge at depths less than 90 m (Table 3, Figures 16 and 17) in both spring and autumn. Juveniles also appear along the Northeast Peak of Georges Bank in the spring.

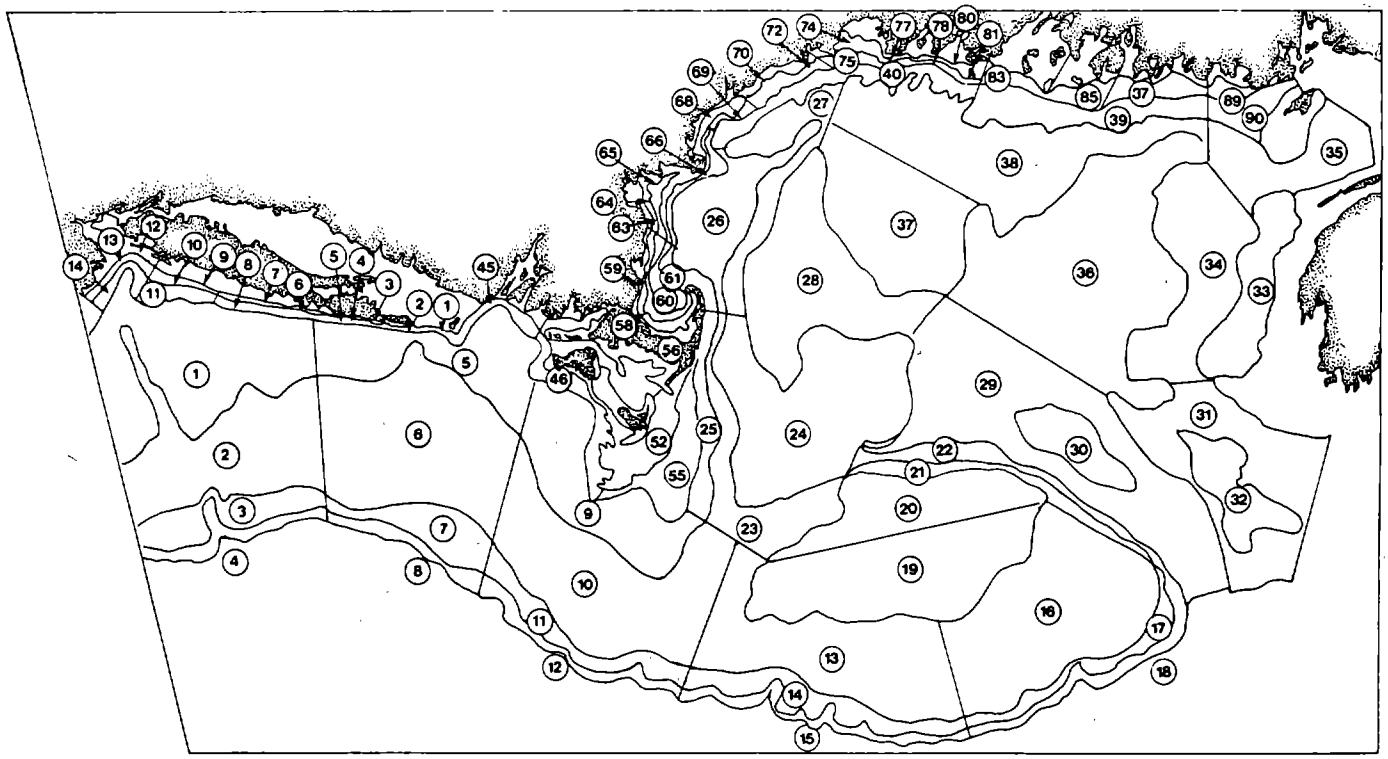

Figure 3. Northeast Fisheries Center bottom trawl survey strata used in this study: inshore = 1-14 and 45-90, and offshore = 1-40

White Hake

Immature white hake are common in the spring along the 100-m contour and in deeper waters from Cape Cod northward into the Gulf of Maine; however, some catches have been observed inshore of 100 m in Cape Cod Bay and Massachusetts Bay. During autumn, they are also concentrated along the 100-m contour. Immature white hake are more abundant in the central Gulf of Maine in the spring than autumn. The pattern is reversed for Georges Bank: juveniles are absent in spring, but relatively common in autumn over Georges Bank (Table 3, Figures 18 and 19). Significant juvenile mortality may occur in the western and northern Gulf of Maine, particularly in the autumn, in the exempted fishery area.

Windowpane

Immature windowpane are concentrated in Southern New England during both seasons at depths around 30 m (Table 3, Figures 20 and 21). In spring, concentrations extend along the southern boundary of the regulated mesh area of Georges Bank. However, in autumn, immature fish are concentrated in the central area of Georges Bank within the regulated area. The potential for high juvenile mortality exists in the Southern New England region except during the spring when juvenile windowpane aggregations coincide with the spawning area closure.

Winter Flounder

Sampling of immature winter flounder from inshore stocks by the NEFC surveys may not be representative: immature individuals are distributed close to estuaries and in shallower waters inside the limits of the survey. Concentrations are observed at 25 m during spring in Cape Cod Bay, and south and west of Narragansett Bay (Table 3, Figure 22), and may be subjected to significant mortality in these areas. In autumn, juvenile fish are dispersed throughout the region (Figure 23). Extremely few individuals have been observed along the outer edge of the shelf. Immature winter flounder occurring on Georges Bank are within the regulated mesh area.

DISCUSSION

The summary distributions of immature fish presented above are based on extensive data sets obtained over a period of 19 years. They reveal distinct patterns of geographic occurrence which are useful for management purposes. There are substantial overlaps between exempted fishing/unregulated mesh areas created by the New England Fishery Management Council's Northeast Multispecies FMP and distributions of the sexually immature components of many stocks.

Table 1. Standard number of tows per stratum, surface area of each stratum (square miles), and resulting ratio (square miles per tow) for NEFC inshore and offshore bottom trawl survey strata used in this analysis

Inshore Strata				Offshore Strata			
Stratum	Tows	Area	Ratio	Stratum	Tows	Area	Ratio
1	1	70	70.0	1	7	3470	495.7
2	2	75	37.5	2	7	2925	417.9
3	1	65	65.0	3	3	795	265.0
4	2	55	27.5	4	3	305	101.7
5	2	70	70.0	5	5	2005	401.0
6	1	70	70.0	6	8	3720	465.0
7	2	105	52.5	7	3	695	321.7
8	2	195	97.5	8	3	330	110.0
9	1	70	70.0	9	5	2115	423.0
10	2	65	32.5	10	8	3750	468.8
11	2	280	140.0	11	3	840	280.0
45	2	255	127.5	12	3	300	100.0
46	2	325	162.5	13	9	3280	364.4
47	2	130	65.0	14	4	930	232.5
49	2	460	230.0	15	3	400	133.3
51	2	185	92.5	16	10	4015	401.5
52	5	830	166.0	17	4	495	123.8
54	3	375	125.0	18	3	300	100.0
55	5	675	135.0	19	9	3345	371.7
56	1	65	65.0	20	6	1675	279.2
58	1	155	155.0	21	4	675	168.8
59	1	140	140.0	22	4	675	168.8
60	2	200	100.0	23	5	1400	280.0
61	2	255	127.5	24	6	3435	572.5
63	1	115	115.0	25	4	540	135.0
64	1	150	150.0	26	5	1390	278.0
65	1	125	125.0	27	4	1040	260.0
66	2	215	107.5	28	7	3145	449.3
68	1	70	70.0	29	8	4715	589.4
69	1	85	85.0	30	3	890	296.7
71	1	135	135.0	31	7	2645	377.9
72	2	195	97.5	32	5	930	186.0
74	1	110	110.0	33	4	1145	286.3
75	1	145	145.0	34	6	2420	403.3
77	1	50	50.0	35	4	1510	377.5
78	1	60	60.0	36	8	5570	696.3
80	1	95	95.0	37	5	2780	556.0
81	1	70	70.0	38	5	3470	694.0
83	1	120	120.0	39	5	1070	214.0
85	1	145	145.0	40	3	665	221.7
87	2	240	120.0				
89	1	95	95.0				
90	2	350	175.0				

The Gulf of Maine exempted fishery area, where small-mesh fisheries (*i.e.*, northern shrimp and silver hake) have been prosecuted traditionally, encompasses seasonal concentrations of juveniles for eight Gulf of Maine stocks: haddock, Atlantic cod, yellowtail flounder, American plaice, witch flounder, redfish, pollock, and white hake.

The unregulated mesh area extending along the southern edge of Georges Bank includes areas with relatively high concentrations of immature haddock and windowpane during the spring. Southern New England stocks of Atlantic cod, yellowtail flounder, windowpane, and winter flounder are potentially vulnerable to juvenile fishing mortality over their range due to the absence of mesh restrictions in the area.

This study suggests that it may be possible to reduce juvenile mortality considerably by different configurations of area/seasonal closures than those currently employed. As more catch and discard data become available from the NEFC Domestic Sea Sampling Program (initiated in 1989), greater spatial and temporal resolution will be possible.

Table 2. Length at which fish are first observed to be mature (*i.e.*, fraction mature below this length = 0)

Species	Length (cm)	Source
Haddock	31	Morse 1979
Atlantic cod	37	Morse 1979
Yellowtail flounder	20	Morse 1979
American plaice	20	Morse 1979
Witch flounder	25	Morse 1979
Redfish	22*	Perlmutter & Clarke 1949
Pollock	30*	Beacham 1983
White hake	34	Morse 1979
Windowpane	24	Bigelow and Schroeder 1953
Winter flounder	20	Morse 1979

*Estimated values.

Table 3. Mean depth, standard deviation, and range of depth for juveniles of 10 species from NEFC spring and autumn bottom trawl surveys, 1968-86

Species	Spring					Autumn				
	No.	Mean Depth (m)	Stand. Dev.	Range Min. (m)	Range Max. (m)	No.	Mean Depth (m)	Stand. Dev.	Range Min. (m)	Range Max. (m)
Haddock	20688	95.3	22.0	25.0	279.0	24018	87.8	27.4	23.0	516.0
Atlantic cod	4182	61.7	32.4	10.0	353.0	4969	74.9	29.0	11.0	331.0
Yellowtail flounder	3014	47.3	22.2	9.0	179.0	3115	63.0	26.9	14.0	287.0
American plaice	8124	95.2	37.6	20.0	307.0	6595	105.0	40.2	25.0	351.0
Witch flounder	1275	160.9	96.5	23.0	494.0	484	133.3	70.8	38.0	516.0
Redfish	8602	161.5	60.2	37.0	389.0	17189	147.6	50.3	34.0	382.0
Pollock	1727	88.2	44.5	13.0	232.0	419	78.5	41.6	26.0	240.0
White hake	2311	139.8	56.4	11.0	470.0	4735	77.5	49.2	11.0	369.0
Windowpane	10931	26.6	23.2	5.0	166.0	9374	38.3	18.2	7.0	175.0
Winter flounder	4099	25.6	12.5	5.0	204.0	856	39.8	13.7	7.0	94.0

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Figure 4. Distribution (as number per tow) of sexually immature haddock (<31 cm) based on spring NEFC bottom trawl survey cruises, 1968-86

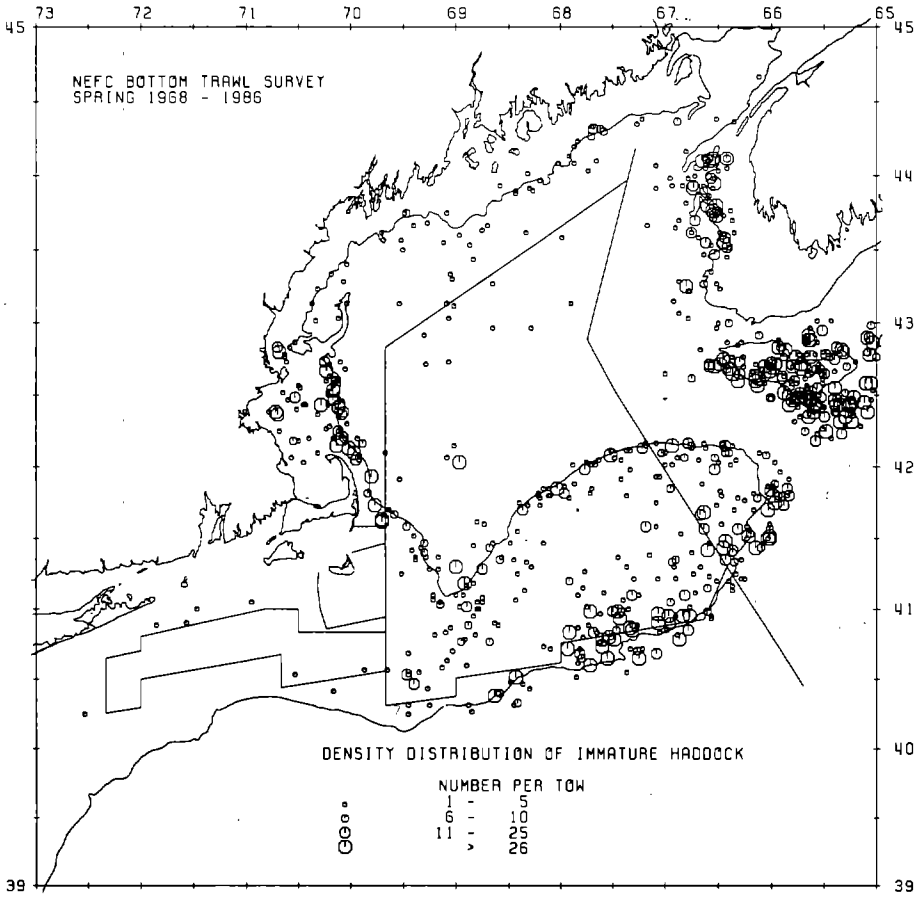
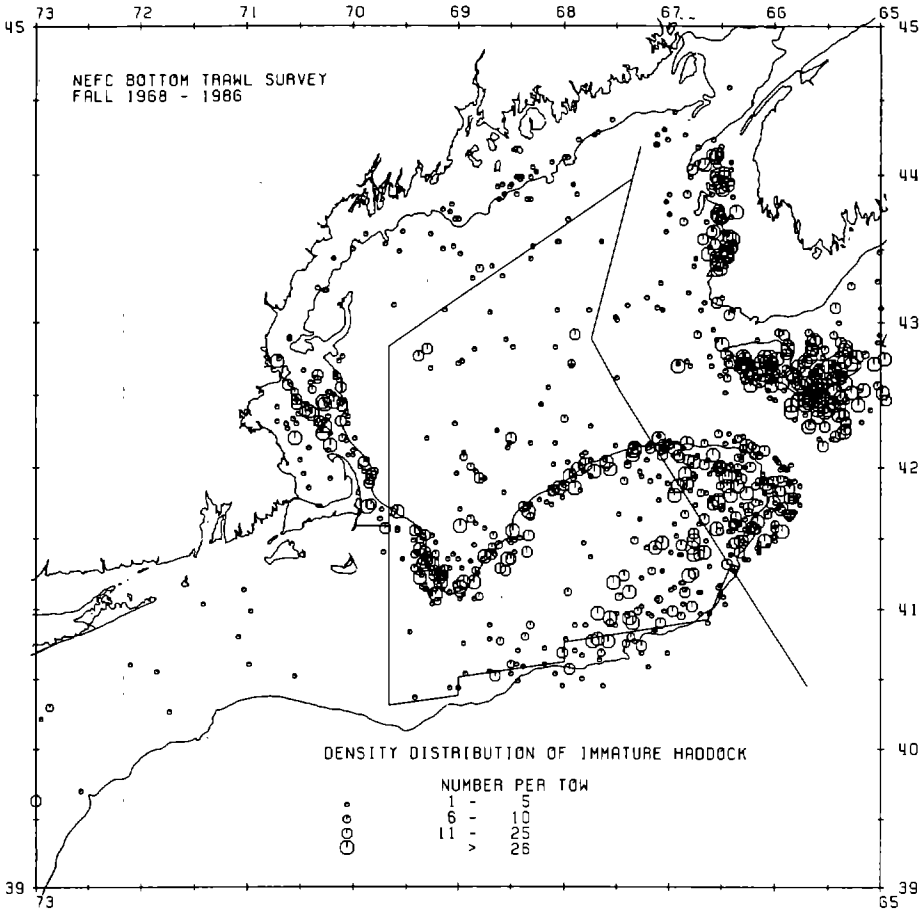


Figure 5. Distribution (as number per tow) of sexually immature haddock (<31 cm) based on autumn NEFC bottom trawl survey cruises, 1968-86



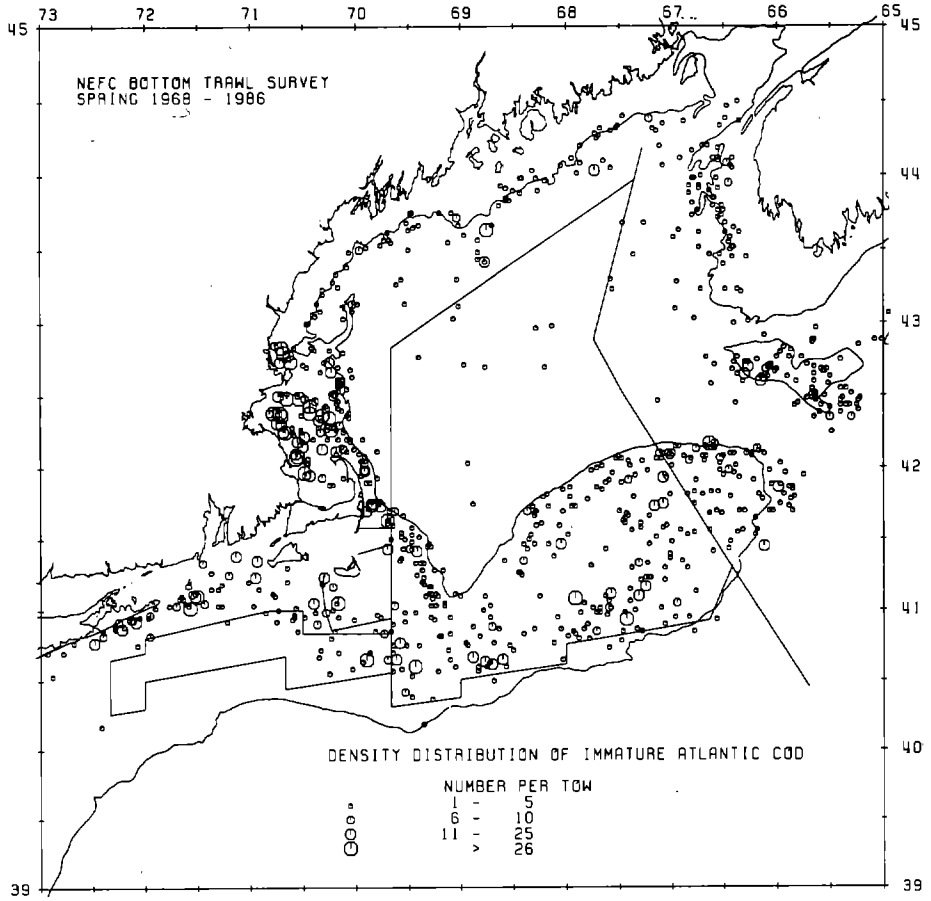


Figure 6. Distribution (as number per tow) of sexually immature Atlantic cod (<37 cm) based on spring NEFC bottom trawl survey cruises, 1968-86

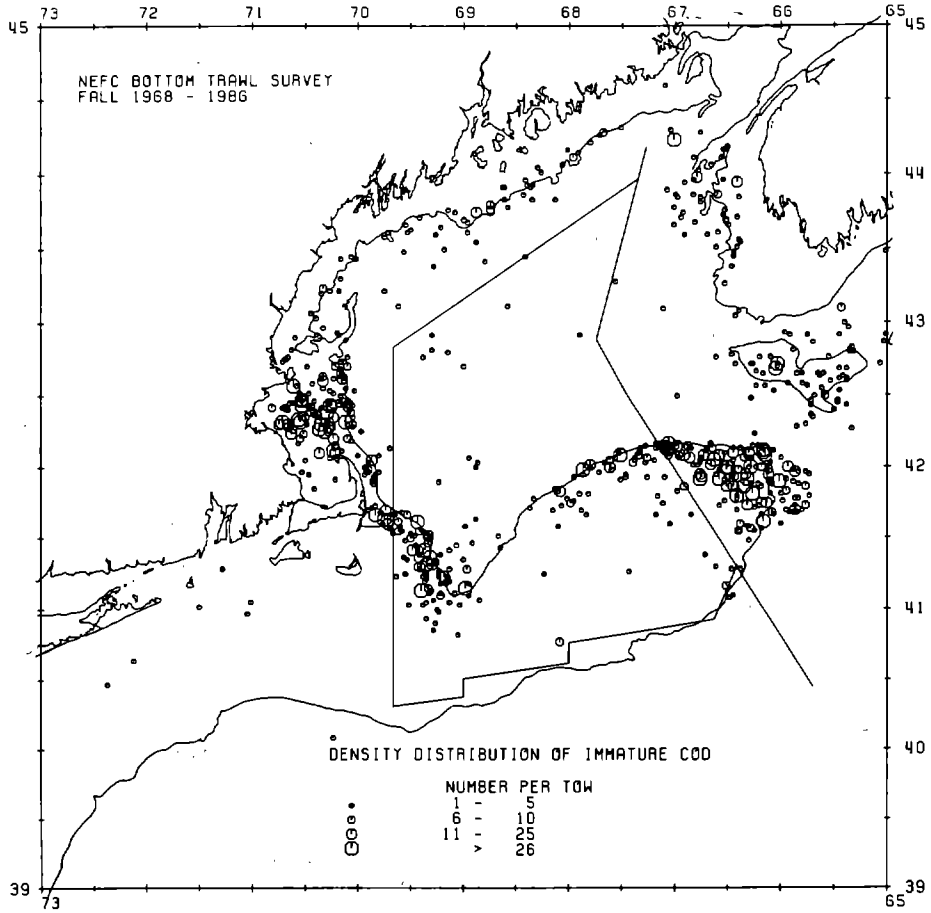


Figure 7. Distribution (as number per tow) of sexually immature Atlantic cod (<37 cm) based on autumn NEFC bottom trawl survey cruises, 1968-86

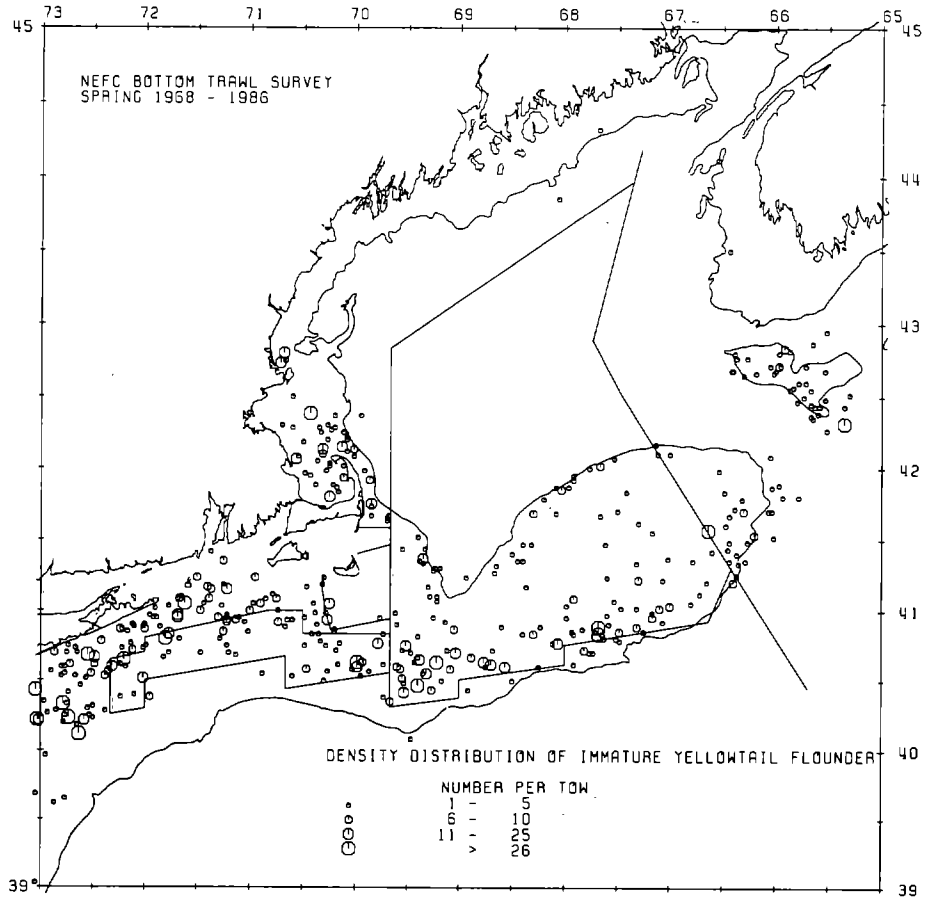


Figure 8. Distribution (as number per tow) of sexually immature yellowtail flounder (<20 cm) based on spring NEFC bottom trawl survey cruises, 1968-86

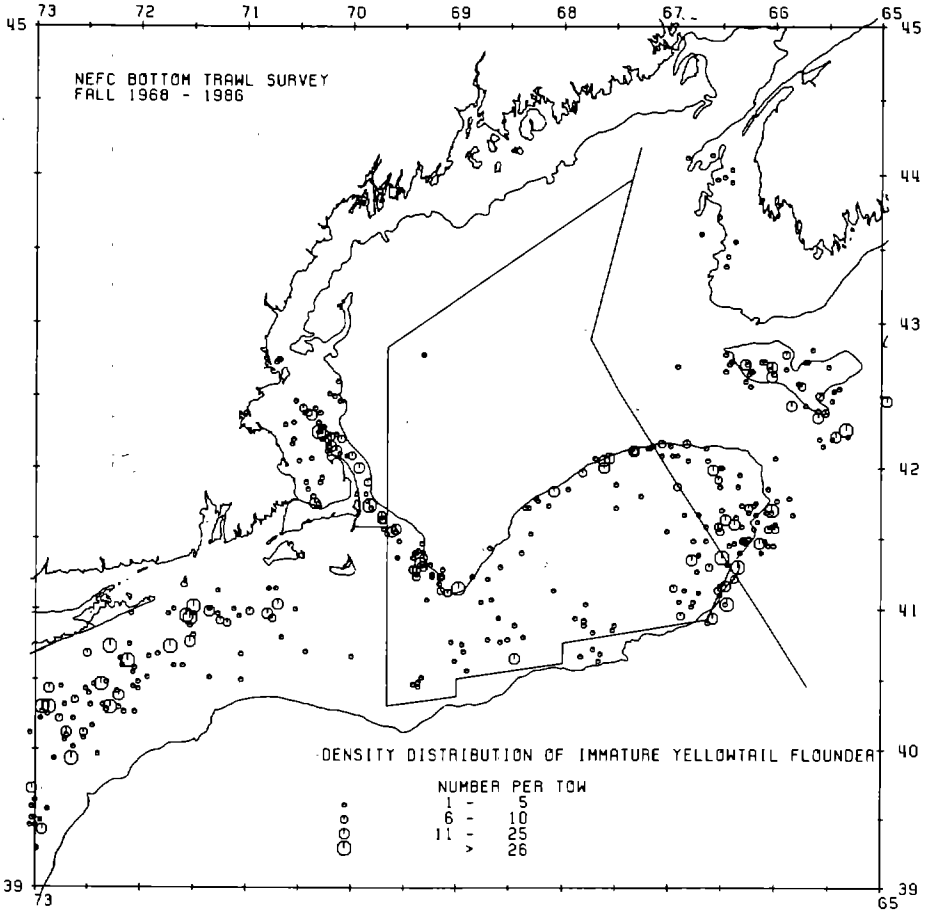


Figure 9. Distribution (as number per tow) of sexually immature yellowtail flounder (<20 cm) based on autumn NEFC bottom trawl survey cruises, 1968-86

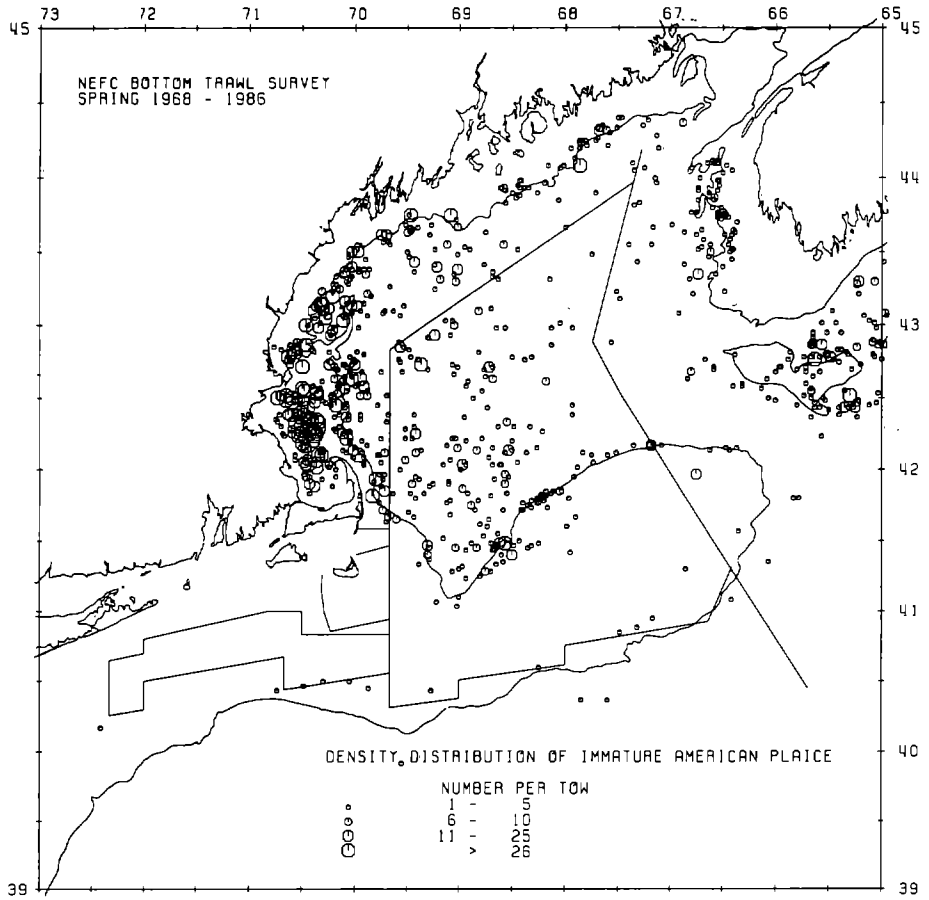


Figure 10. Distribution (as number per tow) of sexually immature American plaice (<20 cm) based on spring NEFC bottom trawl survey cruises, 1968-86

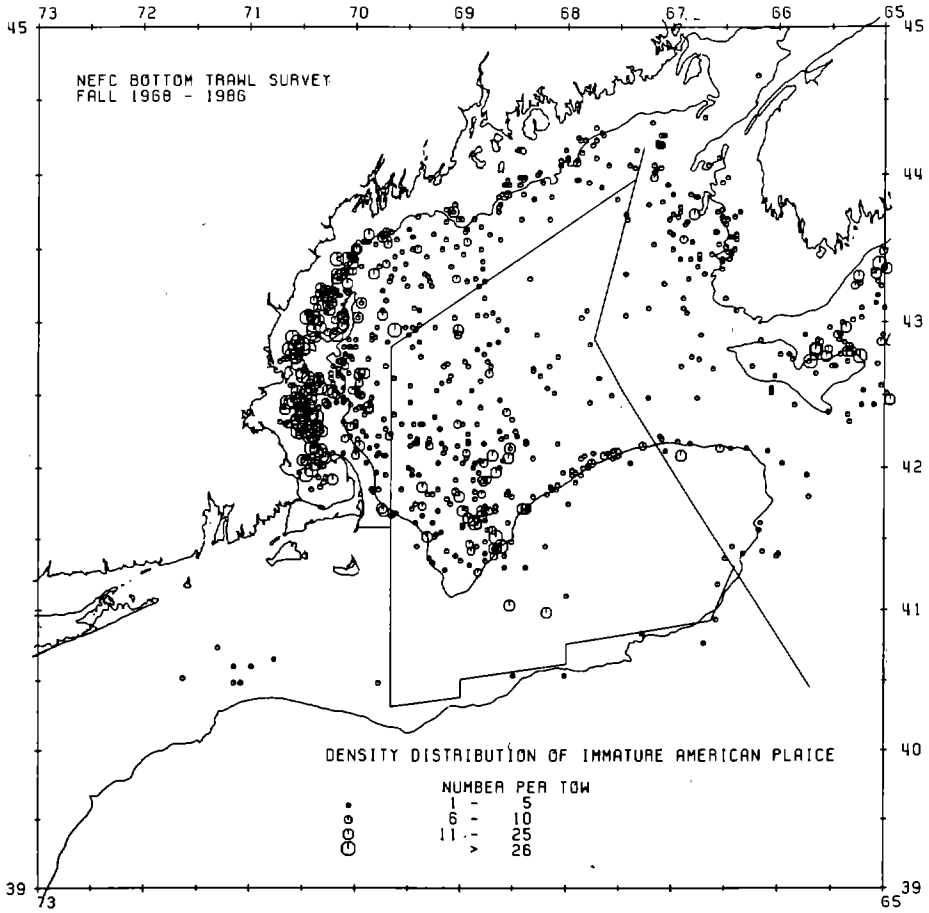


Figure 11. Distribution (as number per tow) of sexually immature American plaice (<20 cm) based on autumn NEFC bottom trawl survey cruises, 1968-86

Figure 12. Distribution (as number per tow) of sexually immature witch flounder (<25 cm) based on spring NEFC bottom trawl survey cruises, 1968-86

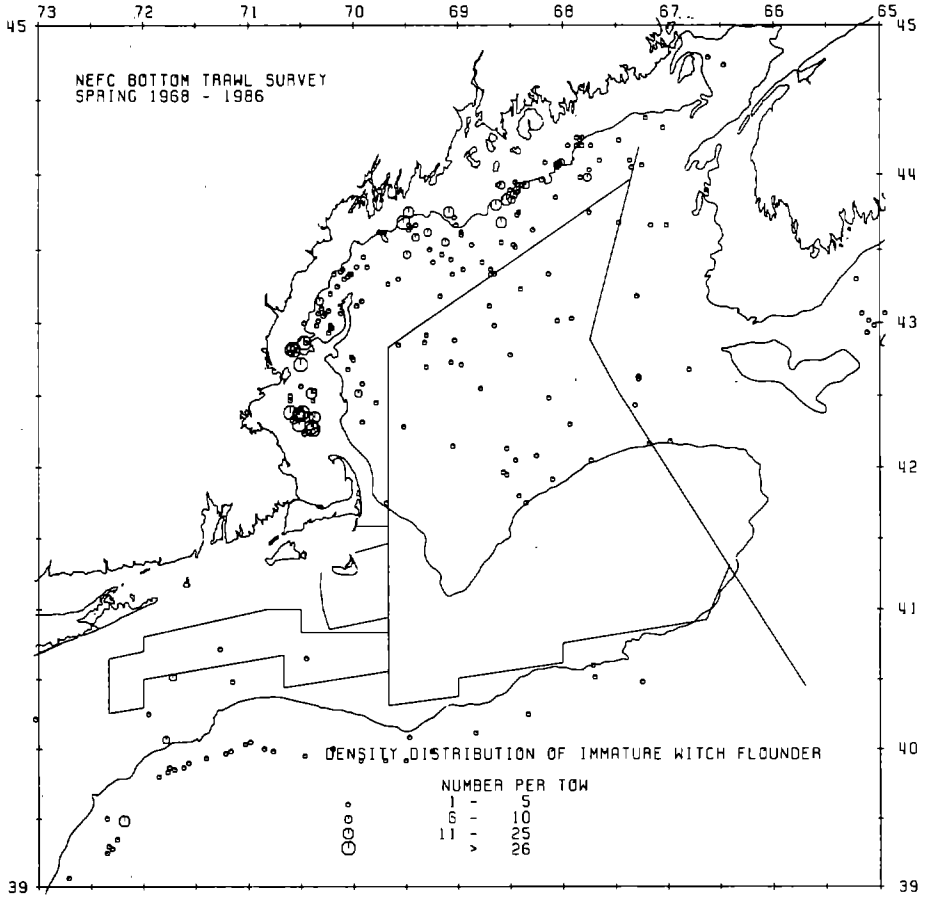
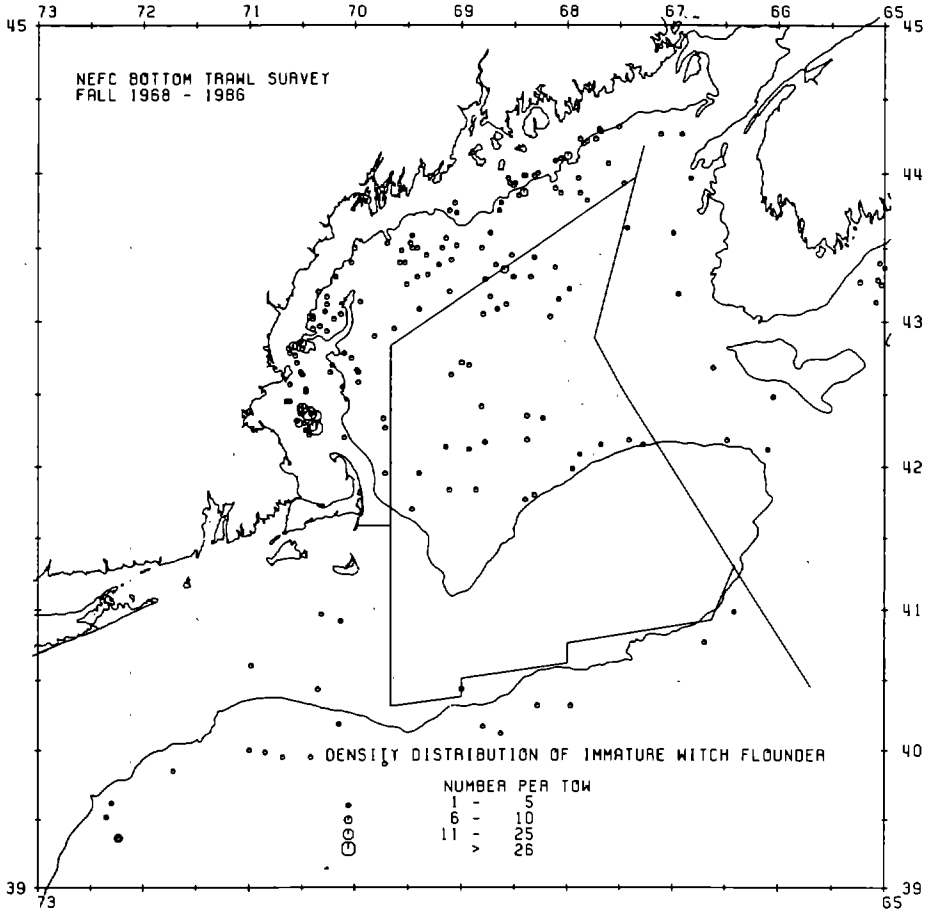


Figure 13. Distribution (as number per tow) of sexually immature witch flounder (<25 cm) based on autumn NEFC bottom trawl survey cruises, 1968-86



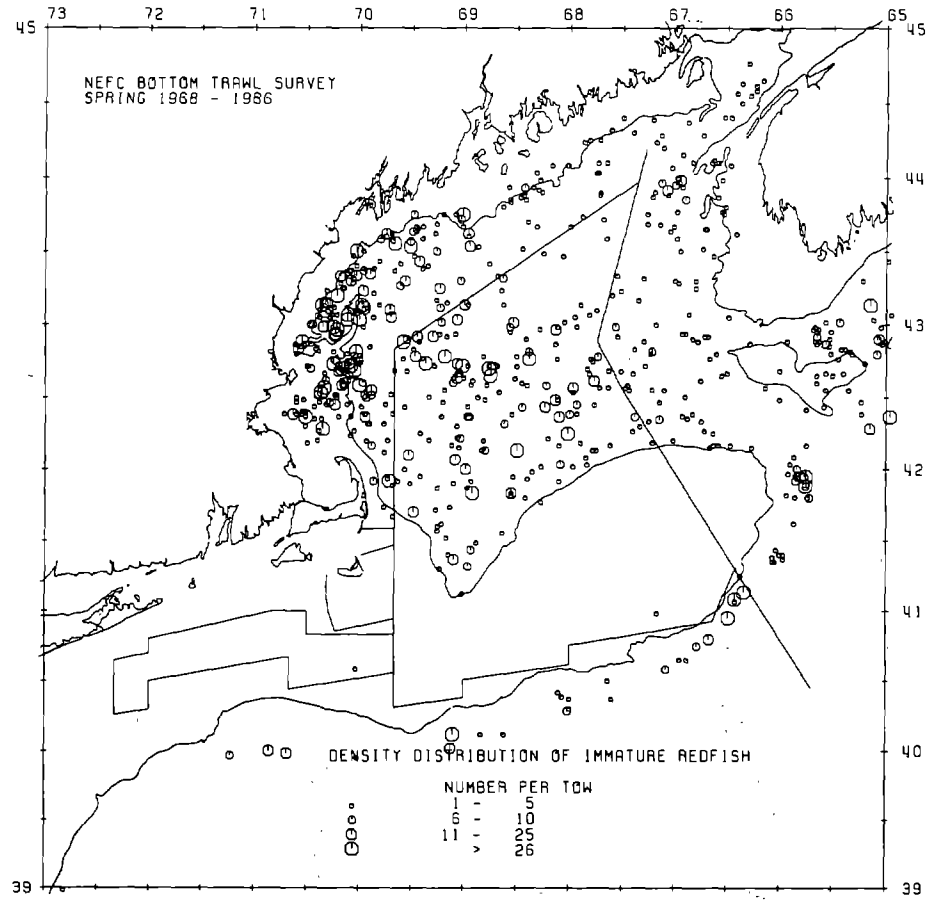


Figure 14. Distribution (as number per tow) of sexually immature redfish (<22 cm) based on spring NEFC bottom trawl survey cruises, 1968-86

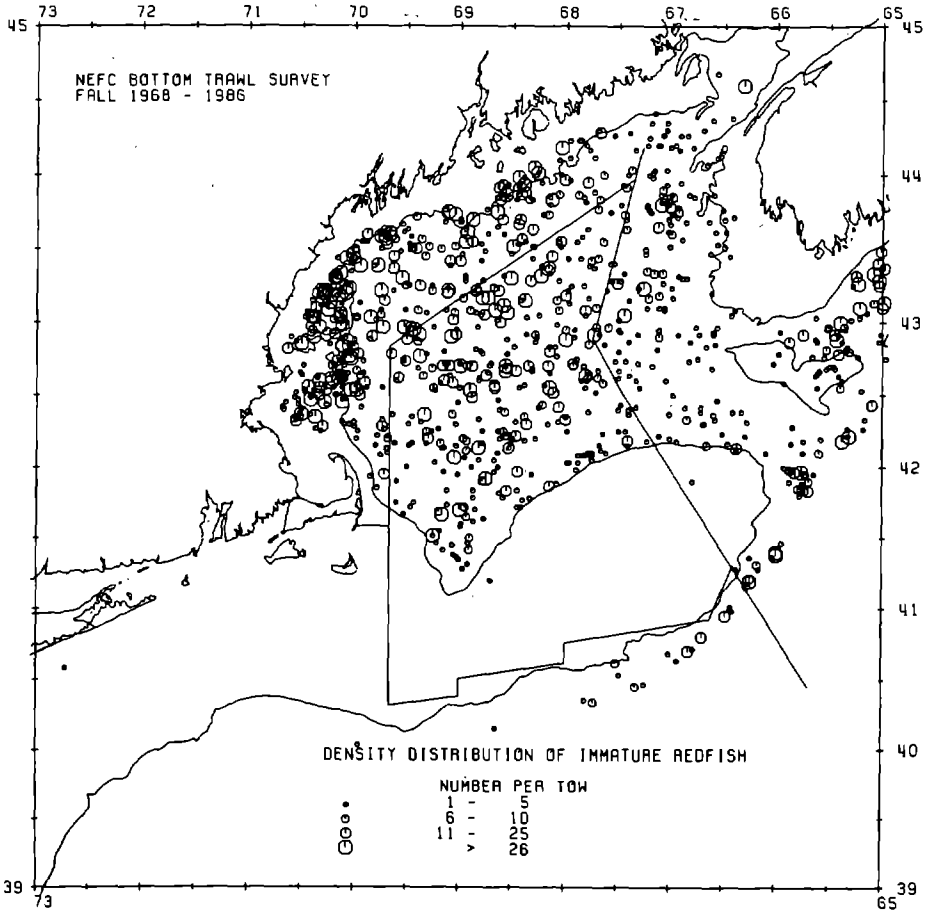


Figure 15. Distribution (as number per tow) of sexually immature redfish (<22 cm) based on autumn NEFC bottom trawl survey cruises, 1968-86

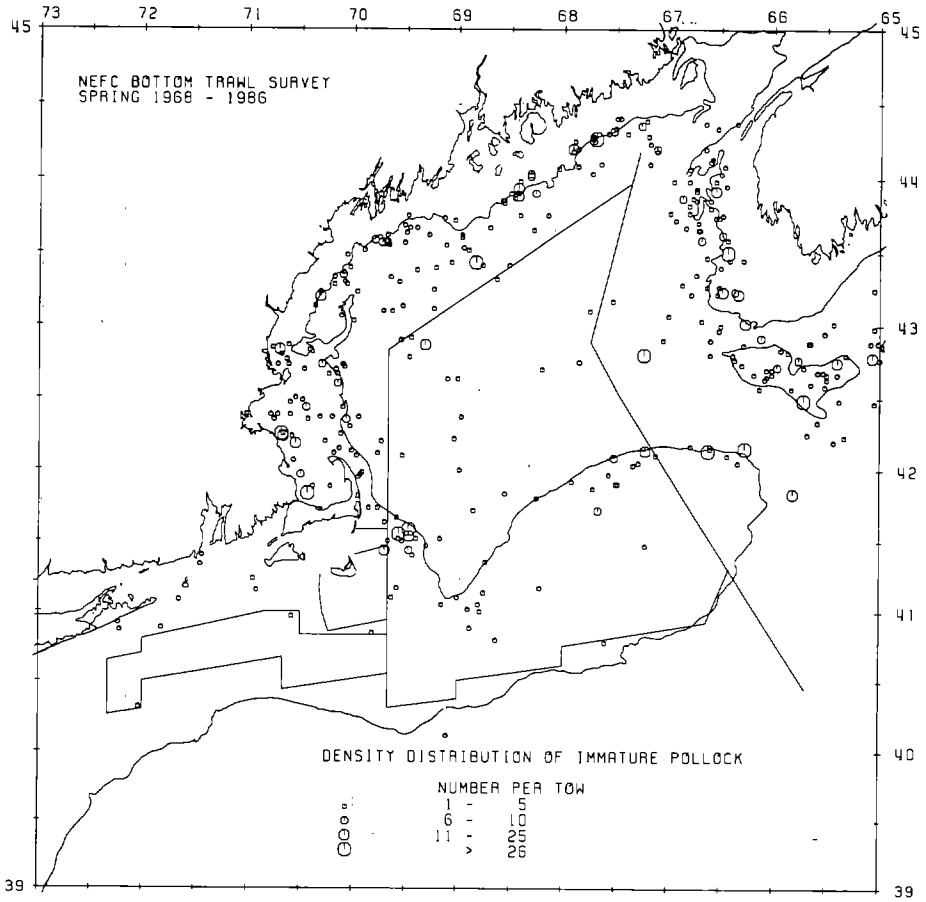


Figure 16. Distribution (as number per tow) of sexually immature pollock (<30 cm) based on spring NEFC bottom trawl survey cruises, 1968-86

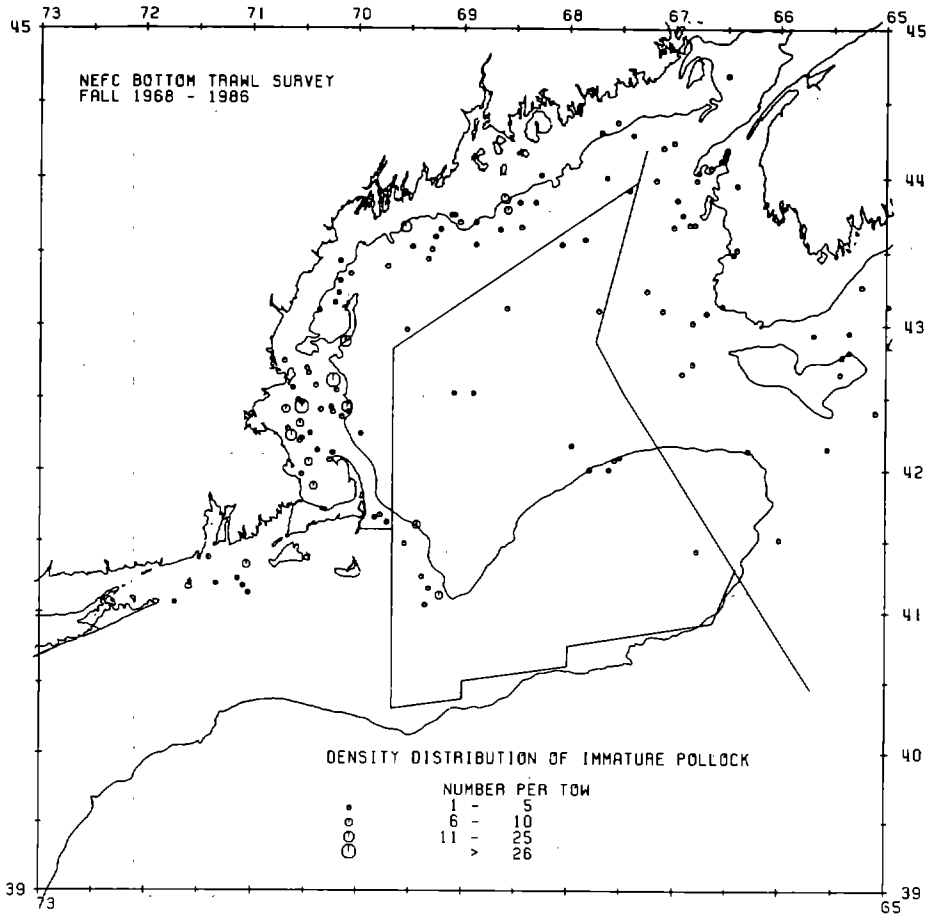


Figure 17. Distribution (as number per tow) of sexually immature pollock (<30 cm) based on autumn NEFC bottom trawl survey cruises, 1968-86

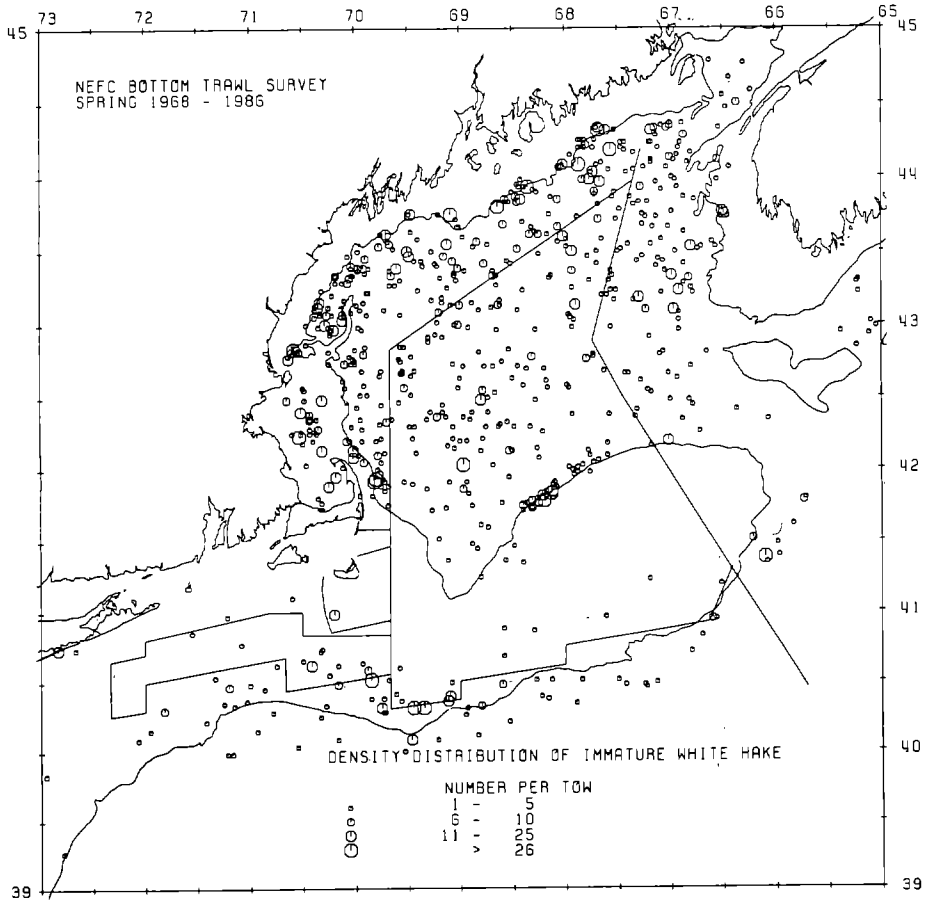


Figure 18. Distribution (as number per tow) of sexually immature white hake (<34 cm) based on spring NEFC bottom trawl survey cruises, 1968-86

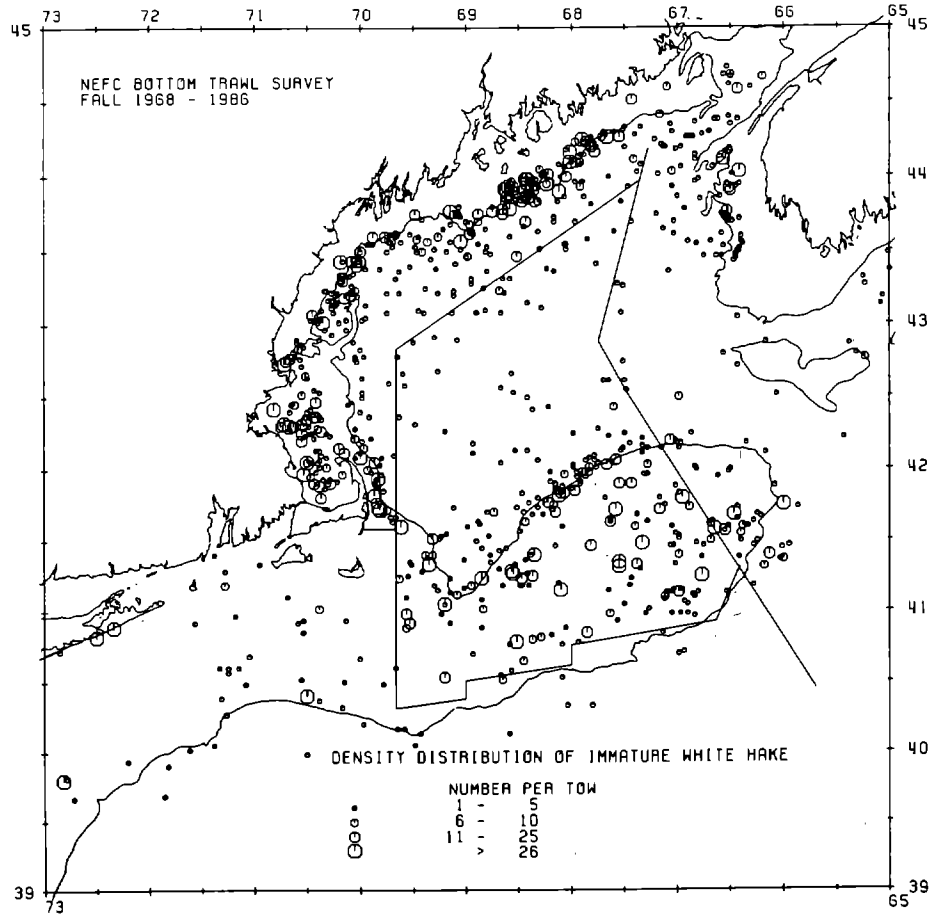


Figure 19. Distribution (as number per tow) of sexually immature white hake (<34 cm) based on autumn NEFC bottom trawl survey cruises, 1968-86

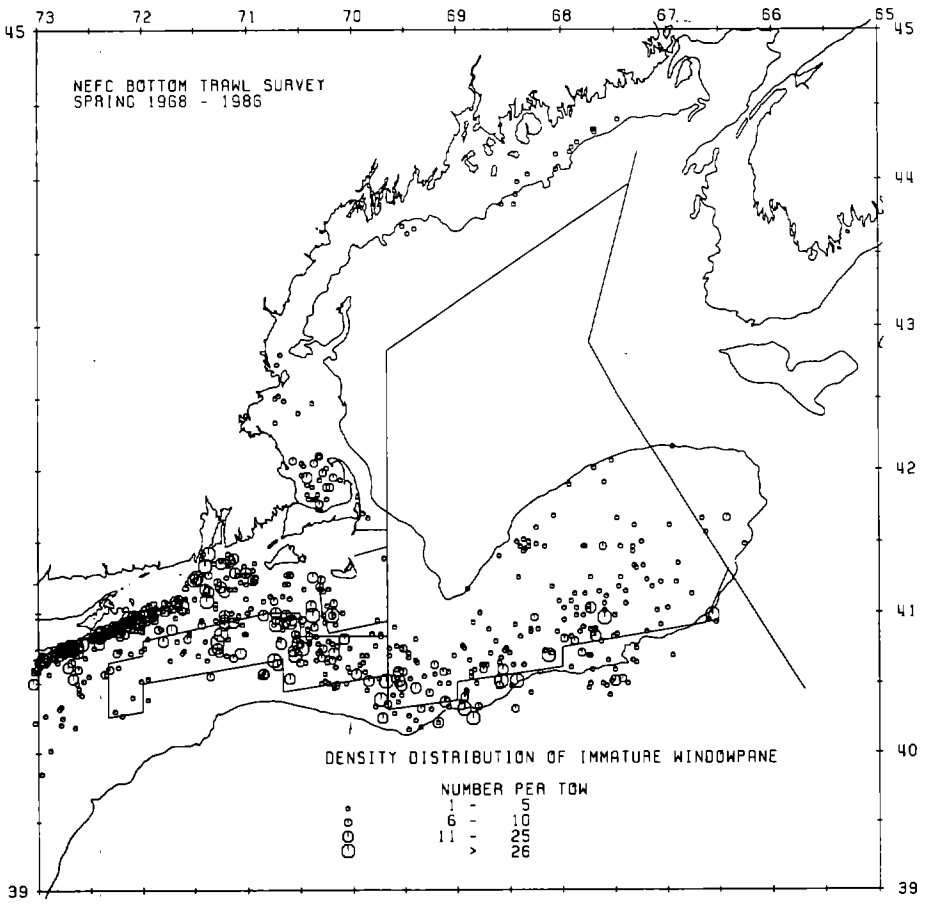


Figure 20. Distribution (as number per tow) of sexually immature windowpane (<24 cm) based on spring NEFC bottom trawl survey cruises, 1968-86

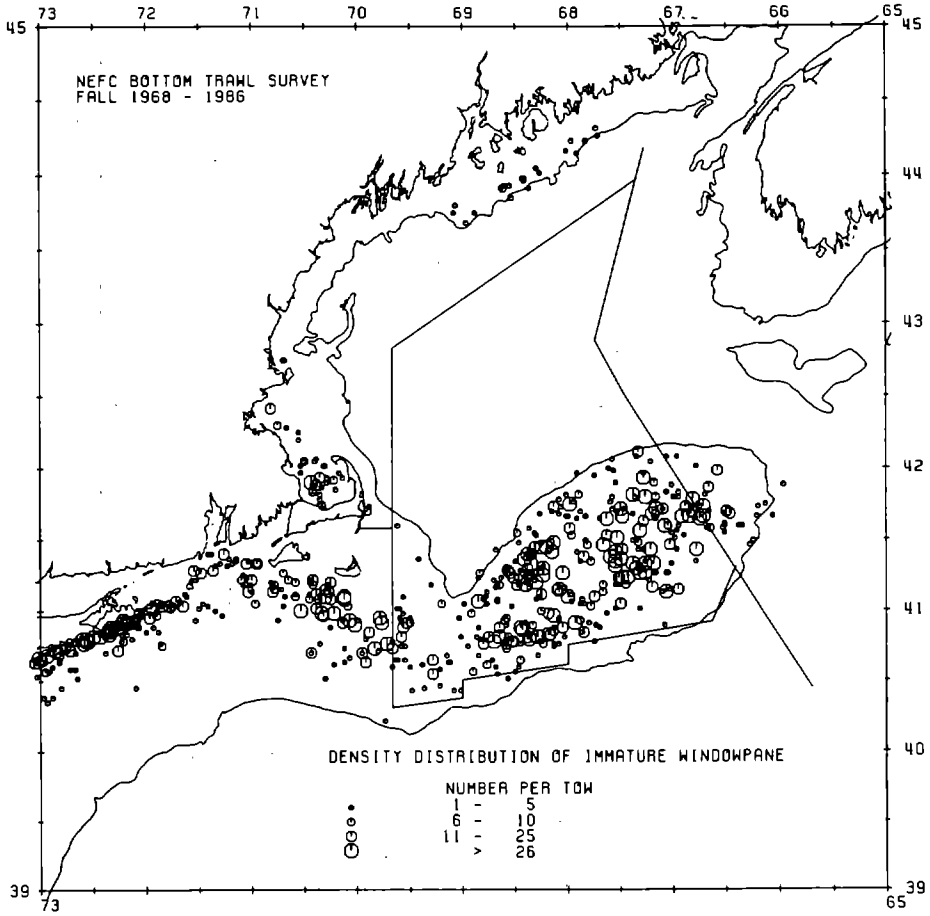


Figure 21. Distribution (as number per tow) of sexually immature windowpane (<24 cm) based on autumn NEFC bottom trawl survey cruises, 1968-86

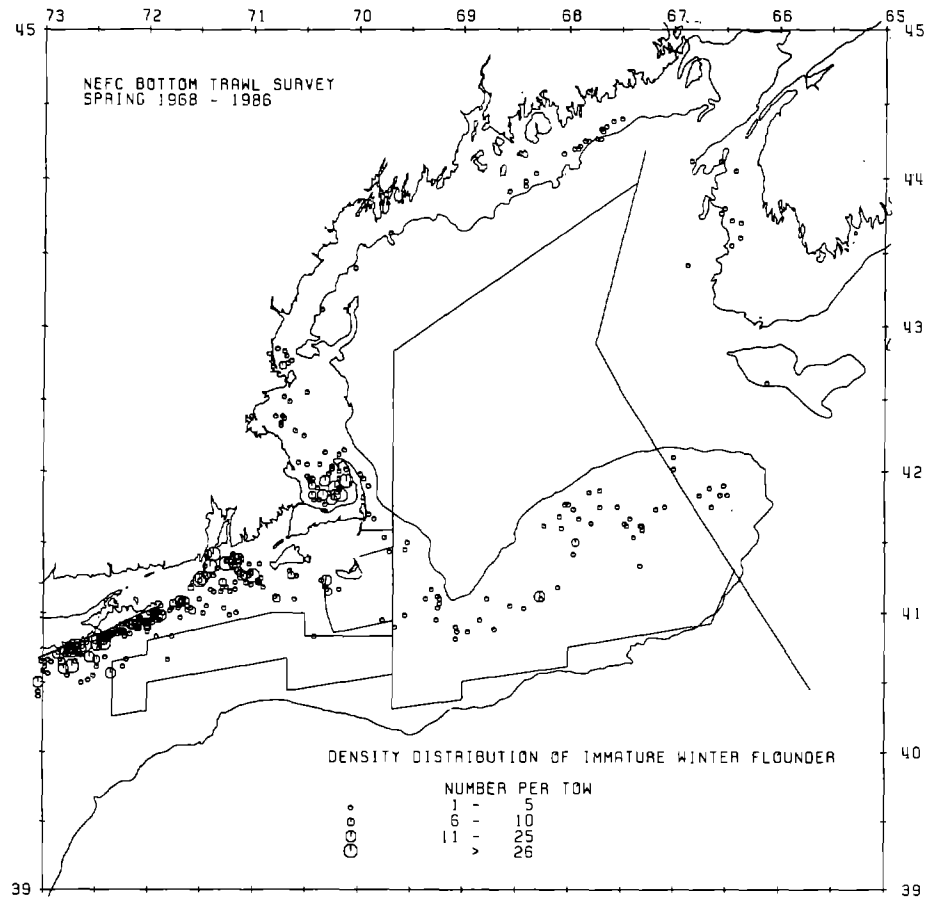


Figure 22. Distribution (as number per tow) of sexually immature winter flounder (<20 cm) based on spring NEFC bottom trawl survey cruises, 1968-86

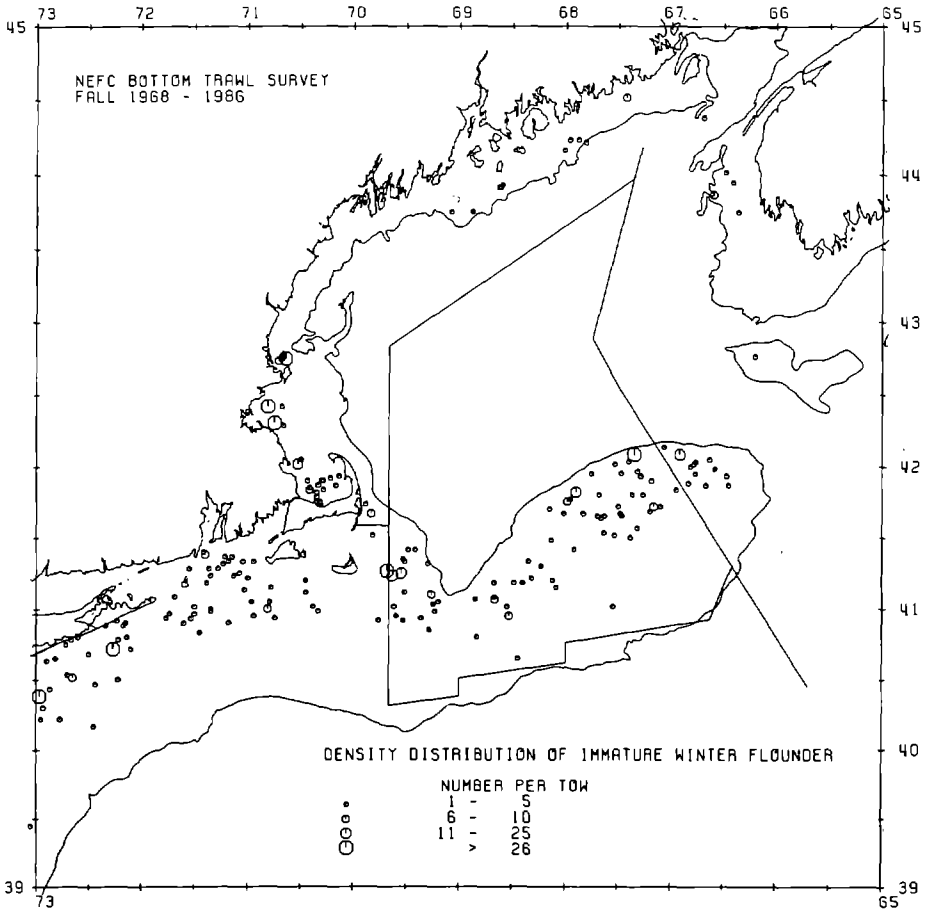


Figure 23. Distribution (as number per tow) of sexually immature winter flounder (<20 cm) based on autumn NEFC bottom trawl survey cruises, 1968-86

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