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Stock structure of yellowtail flounder in the Gulf of Maine area: implications for management

by

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Abstract

Present knowledge concerning the stock structure of yellowtail flounder (Limanda ferruginea) in the Gulf of Maine is reviewed. There appears to be considerable evidence, consisting of fishery and resource distribution, spawning area location, tagging, differences in population parameters and morphological and physiological characteristics, which define stocks occurring on the Nantucket Shoals, Cape Cod, Georges Bank and Browns Bank. However, the boundaries of Browns Bank stock with respect to the rest of the Scotian Shelf is unknown.

Résumé

Dans le présent texte, on examine les données dont on dispose sur la structure du stock de limande à queue jaune (Limanda ferruginea) du golfe du Maine. Un nombre considérable de données probantes, concernant la distribution des pêches et des ressources, l'emplacement des lieux de fraie, l'étiquetage, les différences dans les paramètres de populations et dans les caractéristiques morphologiques et physiologiques de cette dernière, permet de différencier les stocks des hauts fonds de Nantucket, ceux du banc de Cape Cod, ainsi que ceux des bancs George et Brown. Toutefois, les limites du stock du banc Brown par rapport au reste de la plate-forme Scotian sont inconnues.

Introduction and Problem Statement

The purpose of this document is to assess the extent of present knowledge concerning the stock structure of yellowtail flounder (*Limanda ferruginea*) in the Gulf of Maine area. The utility of present management area boundaries are assessed in light of information on stock structure and several alternatives considered. Finally, potential topics for further research which would help address shortcomings in current understanding of stock structure in the Gulf of Maine area are suggested.

Given the ambiguity of meaning associated with the term "stock" we felt it was advisable to offer a definition which would be used in a consistent fashion throughout the paper. We subscribe to the view of Gulland (1983), who stated that for many purposes of stock assessment analysis, the choice and definition of a unit stock can be considered as essentially an operational matter. A group of fish can be treated as a unit stock if possible differences within the group and interchanges with other groups can be ignored without making the conclusions reached depart from reality to an unacceptable extent.

Gulland notes that a number of aspects can be examined to provide information on possible stock separation. These include:

1. Distribution of the resource. A gap in the geographic distribution of fishing suggests a gap in the distribution of fish, which may correspond to a separation of stocks. Research vessel surveys are also of use in discerning the geographic distribution of the resource.

2. Spawning areas. A genetic separation of stocks more or less requires a clear separation of spawning groups, even if the fish mix at other times of life. Surveys of mature fish and subsequent reproductive products are of obvious utility in this regard.

3. Values of population parameters. If there are stock differences, and if they are important, differences should exist in growth and mortality, for example.

4. Morphological or physiological characteristics. Characteristics that are genetically determined can provide clear evidence that two groups are distinct, but genetic separation can, in principle, exist without this being evident in the characteristics examined. Moreover, the effects of environmental variables on morphological or physiological characteristics can often render the interpretation of variability difficult.

5. Tagging. Gulland notes that in principle, this method can give the clearest evidence of stock separation or otherwise.

In attempting to assess the biological basis for management units for yellowtail flounder, we addressed each of the five aspects identified above for evidence for discrete stocks in the Gulf of Maine region.

History of Management Area Definition

The history of the Subarea 4/5 boundary is discussed in Halliday et al. (MS 1985) and the interested reader is referred to that work for details. As noted by those authors, while the location and subsequent modifications of the boundary lines were well documented, the biological basis for the lines is less clear. The Subarea 4/5 boundary probably reflected the then current understanding of stock structure, particularly that of haddock (Melanogrammus aeglefinus).

Review of Biological Basis for Definition of Unit Stocks

1. Distribution of the Resource and Fishing Effort

We obtained United States survey data for use in plotting resource distributions in the Gulf of Maine area from 1982-1984, spring and fall. The distributions of sets are shown in Figs. 1 and 2 for spring and fall, respectively. We chose to use US rather than Canadian data because of the better coverage of the Gulf of Maine.

The spring distribution of catches of yellowtail flounder (Fig. 3) show that fish are generally found within the 50-fm contour, notably on Georges and Browns Banks, and in 5Yd. The fall distribution of yellowtail flounder is shown in Fig. 4, and is similar to the spring distribution. In both instances, distributions were discontinuous across the Fundian Channel, lending support to the view that Scotian Shelf and Georges Bank yellowtail flounder do not intermingle to a great extent.

During 1979-83, the Canadian catch of yellowtail in NAFO Division 4X and Subarea 5 averaged 259 t annually, most of this from 4Xo. Canadian catches on Georges Bank were restricted to the Northeast Peak (5Zej). US landings from Subdiv. 5Ze averaged 13,736 t over the same period, mostly from 5Zem, 5Zeg, and 5Zeo. Div. 5Y also has a significant fishery, with 2278 t caught annually over 1979-83, mostly from 5Ye.

2. Distribution of Spawners and their Reproductive Products

Yellowtail flounder spawn from March to September throughout the species' range (Bigelow and Schroeder 1953). Eggs and larvae are pelagic. The timing of peak spawning is progressively later with increasing latitude (Smith 1985). Spawning activity in the Gulf of Maine peaks in June, and is not as intense as in other locations throughout the range. On the Scotian Shelf, spawning begins in May and continues into August (Colton et al. 1979) with peak spawning again occurring in June (Scott 1954). Scott (1983) reported peak spawning activity in July for the Scotian Shelf population.

2.1 Distribution of ripening, ripe and spent females

The distribution of sets during spring (1979-1984) and summer (1978-1984) Marine Fish Division (MFD) groundfish survey cruises is shown in Figs. 5 and 6, respectively. The geographic distribution of ripening, ripe and spent females is shown on Fig. 7 and 8 for spring and summer, respectively. In spring, it is clear that mature yellowtail flounder concentrate on the banks, within the 50-fm contour. The spawning aggregations at Browns and

Georges Banks are therefore discrete. Similarly, summer distributions indicate that mature yellowtail flounder concentrate on Browns Bank, although relatively few fish were caught. Our comparatively recent observations are consistent with those of Scott (1983), who examined data from twelve research cruises conducted from 1971 - 1981 and concluded that a discrete concentration of mature yellowtail flounder occurred over Browns Bank. Georges Bank was not covered during those cruises. Neilson and Dale (MS 1984) found spawning concentrations associated with Browns, Emerald, Western, Sable Island and Banquereau Banks. In summary, there is substantial evidence that spawning concentrations are contagiously distributed throughout the Scotian Shelf and Gulf of Maine region.

2.2 Influence of hydrography of Gulf of Maine on distribution of eggs and larvae: Implications for Stock Discreteness

The earliest picture of circulation in the Gulf of Maine, including southwest Nova Scotia and Georges Bank, identified a large counterclockwise eddy in the centre of the Gulf, and a clockwise circulation on Georges Bank with an offshore flow from its southern flank (Bigelow 1927). Later, Bumpus and Lauzier (1965) used drift bottle experiments to develop an atlas of the surface circulation in the Gulf of Maine by one-half degree rectangles, and identified the circulation on Georges Bank as a clockwise gyre closed to the south, but somewhat "leaky" to the southwest over Nantucket Shoal. This atlas has been widely used by workers discussing the drift of ichthyoplankton in the Gulf of Maine (e.g. Boyar et al. 1973; Evseenko and Nevinsky 1980; Harding et al. 1983), but has been criticized recently (Butman et al. 1986) as providing only a general indication of the surface circulation. The drifters used by Bumpus and Lauzier (1965) provided information on release and recovery only, are very sensitive to slight offshore currents and can be lost at sea, thus giving no information on the often much stronger alongshore current component. Out of a total of 72,434 releases in the Gulf of Maine area between 1948 and 1962, only 11% were ever recovered.

The most recent understanding of the circulation on Georges Bank has been reviewed by Butman et al. (1986). They described a clockwise mean flow oriented parallel to the bathmetry, resulting in a relatively closed gyre encircling the bank. There is some seasonal variability in the strength of this circulation, with the weakest currents occurring in winter and the strongest in late summer. The gyre may become "leaky", during winter usually, and allow loss of water to the southwest. The circulation is also stronger and narrower on the northern edge of the bank, resulting in surface velocities 2-4 times that on its southern flank. During winter, current velocities are approximately the same at all depths, but in summer the near-surface speeds are about 4 times those at the bottom. At speeds of 10-15 cm s^{-1} during summer on the southern flank (at 60 m), a passive particle would make a complete circuit of the bank in 2 months. Based on model studies, Tee (1985) has suggested there may also be a small on-bank flow in the deep water of Georges Bank, and an off-bank flow near the surface, although these have been hard to detect in field data due to their small magnitude (1-2 cm s^{-1}).

Smith (1983, and pers. comm.) has studied the circulation off southwest Nova Scotia and Browns Bank. He found the general flow was to the west, driven by the Nova Scotia coastal current, and was strongest in winter.

There was also a clockwise gyre about Browns Bank, with near-surface currents tending to retain water on the cap of the bank, while deeper currents were dispersive to the north. The leak from the north-west corner then joined the Gulf of Maine circulation, which Brooks (1985) has recently found does not consist of a single large eddy moving about the coastal region, as previously thought. Instead, there are at least two important eddies located off the coast of Maine, which are likely to interrupt the continuous transport of larvae from Nova Scotia towards Cape Cod. There also appears to be a counterclockwise recirculation about Georges Basin, between Georges and Browns Banks. A diagrammatic summary of these circulation patterns is presented in Fig. 9.

Winds may affect near-surface waters, potentially causing transport of constituent eggs and larvae between Georges and Browns Banks. However, experiments with satellite-tracked drifters indicate a high degree of variability in trajectories, with occasional losses from Georges towards Browns Bank, although most losses from Georges Bank occurred to the south into slope water (Butman et al. 1986). Lawrence and Trites (1983) modelled the hypothetical drift of oil from Georges Bank, and suggested it would move northeastward to Nova Scotia and the Bay of Fundy in summer, and southwestward in winter, mostly due to strong prevailing winds. However, this would affect only the top few centimeters of the water column, upon which the oil was assumed to have spread, and so should transport only neustonic organisms.

In general, therefore, with the possible exception of ichthyoplankton remaining as neuston, there appears to be little opportunity for eggs and larvae of yellowtail flounder to be transported by prevailing currents between Georges and Browns Banks, or across the Gulf of Maine. Even if occasional wind events did allow transport of eggs and larvae between banks, it is difficult to conceive of this being a sufficiently regular event to result in a single recruitment area.

2.3 Ichthyoplankton distributions

When considering advective transport of eggs and larvae, it is important to realize the various stages of larvae may have different vertical distributions or migratory behaviours. When combined with depth variations of current speed and direction, the resultant transport may not be a simple extrapolation of the mean current patterns. Smith et al. (1978) have studied the diel vertical movements of larval yellowtail flounder at a site south of Long Island. They found the amplitude of the migrations increased with the size of larvae, and recently hatched larvae, rather than floating near the surface, remained just below the thermocline. They concluded that larvae could be transported by the wind driven circulation, when in the surface layer at night, but that subsurface circulation at this location was slow and therefore ineffective as a transport mechanism.

Assuming the vertical migratory behaviour of yellowtail flounder larvae on Georges Bank to be similar to that studied by Smith et al. (1978), we can expect considerable transport will occur due to the clockwise circulation about the bank. Transport will be faster in the upper water layers, particularily in spring and summer, but at all depths the direction of the current is similar. Since the same pattern can be assumed for Browns Bank, and the mean circulations are distinct between the two banks, little exchange of larvae should occur. Some exchange might possibly occur via the wind driven surface layer, however the eggs and larvae would have to remain at the surface. Smith et al. (1978) suggest that such a situation occurs only at night with vertically migrating larvae. The larvae would be expected to move deeper and rejoin the mean circulation at daybreak. Simple calculations, assuming the closest distance between Georges and Browns Banks is 24 nautical miles and that larvae remain at the surface for the 12 hours of darkness, suggest that continuous storm winds of greater than 65 knots would be required to transport larvae between banks in this manner.

Evseenko and Nevinsky (1980) have examined the broad features of the distribution of yellowtail flounder eggs and larvae in relation to the general circulation of the northwest Atlantic. They found general agreement between these distributions and the large-scale circulation, such as the anticyclonic gyre on Georges Bank and its south and westward "leaks", and the northward drift from Browns Bank. They concluded the independence of populations was determined by the degree of water exchange between areas, and therefore that Browns Bank could receive inputs from along the Scotian Shelf, while Georges Bank could supply areas south of Cape Cod. However, little transport between Georges and Browns Banks was implied.

However, much of the information on circulation used by Evseenko and Nevinsky (1980) was based on the atlas by Bumpus and Lauzier (1965). As discussed previously, this atlas represents the general features of the circulation, but not the details, which are more pertinent to discussions of exchange of eggs and larvae between spawning grounds.

Distributions of yellowtail flounder eggs and larvae off southwest Nova Scotia and the northeast peak of Georges Bank have been identified during spring from monthly Marine Fish Division (MFD), Fishery Ecology Program cruises. To date, results are available for cruises in February-June 1983 and February-May 1984, inclusive. Only late stage eggs of yellowtail flounder are discussed, as the early stage eggs cannot be positively identified.

The data suggest that spawning in 1983 occurred first on Georges Bank, where densities of eggs from 10-100 m^{-2} were found during April and May. Off southwest Nova Scotia at this time, only 2-3 stations had as many as 1-10 eggs m^{-2} (Fig. 10). Smigielski (1979) has found yellowtail flounder eggs will hatch in a week at 10°C. Assuming temperatures on Georges and Browns Banks of about 5°C, this suggests an egg incubation time of 2-3 weeks, implying spawning began on Georges Bank in April or perhaps late March in 1983. Data from May 1984 indicate similar results.

Late stage yellowtail flounder eggs did not appear on Browns Bank in significant numbers or at widespread locations until June in 1983 (Fig. 11), when they also occurred in significant, but decreasing, numbers north of the bank towards the Bay of Fundy. This decreasing distribution to the north may represent the drift of eggs from the Browns Bank gyre, although aggregations of ripe, running and spent females have been noted off St. Mary's Bay. However, spawning products from these fish should move north and into the Bay of Fundy with the strong local currents, rather than south as indicated by Fig. 11. Assuming the same 2-3 week egg incubation time, the data suggest spawning on Browns Bank occurred in May or perhaps late

April in 1983, at least one month later than on Georges Bank, based on these series of monthly cruises.

The occurrence of yellowtail larvae on these cruises is consistent with these proposed times of spawning, as larvae were sampled only from Georges Bank except for occurrences at one station south of Yarmouth in May 1983, and one station off St. Mary's Bay in June 1983. The apparent absence of larvae from southwest Nova Scotia is most likely due to the lack of cruises to this area during summer. It must be noted that late stage yellowtail flounder eggs and larvae were never sampled on these cruises from waters between Georges and Browns Banks. Results from US MARMAP surveys (Silverman 1983, 1985; Berrien 1981) are consistent with the pattern presented above, with high abundance of yellowtail larvae on Georges Bank, and low abundances in mid-spring off southwest Nova Scotia (their sampling grid did not extend to Browns Bank). Therefore, in addition to the lack of association of the mean currents between Georges and Browns Banks, there is no indication of transport of larvae between these banks, and they probably also have different spawning times.

3.0 Values of Populations Parameters

Lux and Nichy (1967) found that the growth rate of the southern New England, Georges Bank and Cape Cod stocks of yellowtail flounder differed slightly from each other. Disregarding such differences, they obtained an approximate growth rate by combining observations from the southern New England and Georges stocks. Male and female growth rates for each fishing ground, adjusted by the sex ratio in the catch, were combined to give a growth rate for the population as a whole and a von Bertalanffy relationship of the form:

$$l_t = 500(1-e^{-0.335(t+0.26)})$$

We attempted to generate a comparable von Bertalanffy relationship for yellowtail flounder from Div. 4X by combining commercial samples taken from 1980-1984 (all gear types). However, due probably to small sample sizes, we were unable to estimate L_∞ using the available software.

The length at age of yellowtail flounder originating from Subdiv. 5Ze are usually greater than corresponding lengths at age for fish from Div. 4X (Table 1), an observation also made by Scott (1954) and Jearld (1983). For further comparison, data from a MFD groundfish survey is also included. Such comparisons are necessarily limited, as during most cruises, only 30 or less yellowtail flounder of each sex were taken in Div. 4X, inadequate numbers for the development of a reliable age-length relationship. However, in 1979, sufficient numbers of yellowtail flounder were caught to give at least a preliminary indication of the length at age relationship.

Among other population parameters that may be indicative of discrete stocks, Scott (1954) observed that Gulf of Maine yellowtail flounder mature sexually at a much younger age and smaller size than did Scotian Shelf fish. Although the stocks compared were outside the Gulf of Maine region, Howell and Kesler (1977) found that southern New England yellowtail flounder matured earlier and had a greater fecundity at age when compared to a Grand Banks Stock. Penttila and Brown (1973) estimated total instantaneous mortality rates by four different methods for the southern New England and

Georges Bank yellowtail flounder stocks. Each method indicated a lower mortality rate for Georges Bank than for southern New England, with an average of the estimates giving Z = 1.00 and 1.25 for Georges Bank and southern New England, respectively.

The length-weight relationships for Div. 4X yellowtail flounder based on MFD research vessel collections over the period 1980 to 1984 (summer surveys) is:

$$\text{length} = 0.0177(\text{weight})^{2.9500} \quad \text{(males)}$$
$$\text{length} = 0.0095(\text{weight})^{3.0085} \quad \text{(females)}$$

Unfortunately, no such data are available for Subdiv. 5Ze yellowtail flounder.

Finally, we considered whether there was any evidence of year-class synchrony of yellowtail flounder from Subdiv. 5Ze and Div. 4X. If such synchrony did not occur, it could be taken as evidence that yellowtail flounder from Subdiv. 5Ze and Div. 4X are separate stocks. Both Neilson and Dale (1984) and Clark et al. (1984) present catch at age data in stock assessments of Div. 5Z/5Y and 4VWX yellowtail flounder, respectively. In comparisons of the catch-at-age matrices, there was no evidence of year-class synchrony. However, there were reservations concerning the reliability of the Canadian data as it was based on relatively few commercial samples and age information was not available for some recent years. Hence, the apparent lack of synchrony of year-class strength cannot be viewed as substantial evidence supporting the occurrence of separate stocks.

In summary, there is some evidence under the category of population parameters which supports the view that separate stocks of yellowtail flounder occur in Subdiv. 5Ze and Div. 4X. However, as noted by Ihssen et al. (1981), because of their high sensitivity to extrinsic factors, population parameters such as those described above tend to characterize the environment occupied by the population as well as the stock itself. Use of population parameters to ascribe stock discreteness without reference to other independent methods is therefore probably inadvisable.

4.0 Morphometric and Physiological Characteristics

Berthome (1974) conducted an important study of yellowtail morphometrics and meristics as indicators of stock structure. Four sites on the Scotian Shelf and one in Georges Bank were examined. The meristic characters examined were the number of dorsal fin rays, the number of anal fin rays and the number of gill rakers on both limbs of the anterior gill arch. The morphometric characters studied included the ratio of head length to total length and the ratio of snout length to head length.

However, it appears that Berthome used inappropriate statistical procedures for his comparisons. For example, in the case of the meristic data, he used parametric tests when in some cases his data do not meet the normality assumption, and employed t-tests for multiple comparisons instead of using an appropriate range test. In analyses employing the morphometric data, he employed an inappropriate means for treating the ratio type data (S. Smith, pers. comm.). Fortunately, Berthome did provide much of his original meristic data, so we were able to re-examine the validity of his inferences.

We used the Kruskal-Wallis test to examine the hypothesis that the mean of the meristic data did not significantly ($p=0.025$) vary among the sites. If such differences occurred, we identified the region with significant differences in meristics using the range test suggested by Conover (1980) for use with the Kruskal-Wallis procedure (Table 2). We rejected the null hypothesis for the three meristic characters examined. The multiple range tests revealed that yellowtail flounder from Georges Bank consistently differed from the Scotian Shelf groups.

Berthome's data provide significant evidence supporting the occurrence of separate stocks of yellowtail flounder on Georges Bank and the Scotian Shelf. However, it is unfortunate that similar data do not exist for Browns Bank yellowtail flounder, which would then permit a comparison of Georges Bank yellowtail flounder with a less geographically-removed group than those that Berthome selected.

Scott (1954) investigated differences in yellowtail flounder populations in two Nova Scotian fishing areas (Middle Ground and Western Bank) and off Cape Cod with reference to size at sexual maturity, age and size composition, otolith growth, relative growth of three body parts and a variety of meristic features. He found that the two Nova Scotia populations did not significantly differ in any character examined. However, the Cape Cod yellowtail flounder differed in all respects from either Middle Ground or Western Bank. Scott concluded that in 1946, the Cape Cod yellowtail flounder comprised a discrete group with respect to the Nova Scotia populations.

Scott's study appears to have limited significance relative to later works. The Canadian groups examined were sufficiently geographically removed from the Cape Cod group that the observed differences are not too surprising, given that yellowtail adults are relatively sedentary. Even then, the adequacy of the sampling regime must be questioned. The Cape Cod population was sampled on a random basis, with all length groups apparently included. However, the Canadian samples were obtained from the commercial fishery where only fish generally > 40 cm were landed. Hence, any conclusions based on growth rate differences as inferred from otolith examination seem dubious.

Lux (1963) examined fin ray counts from the three New England groups using analysis of variance techniques and found no significant differences in either dorsal or anal fin ray counts. However, the incidence of parasitism (Cryptocotyle lingua) in Cape Cod fish (36% in 1958) relative to the other two groups (0%) indicates that fish from the Cape Cod area are discrete with respect to the other two groups.

Problems associated with analyses of morphometric and physiological characteristics for stock discrimination include the lack of demonstrable relationships between observed phenotypic variations and the genome of the populations in question (Clayton 1981). Moreover, there are documented effects of environmental variables such as temperature on morphological and meristic features (see Ihssen et al. 1981 for a review). However, it appears that morphometric and meristic data have been used in support of conclusions obtained through other independent analyses.

5.0 Tagging Studies

A paper by Royce et al. (1959) comprises a comprehensive review of all aspects of the biology of yellowtail flounder off New England. In this paper the use of the term "population" refers to an assemblage of yellowtail in a small area at a definite time. The time specification was important because it appeared that different populations were found in a given area at different times. The authors used the term "stock" to specify larger groups of yellowtail flounder consisting of several intermingling populations all of which were fished by a single fleet of vessels. It is important to keep these usages in mind, as they do not conform with more modern definitions.

The authors used tag returns and patterns of fishing concentrations of four more or less distinct stocks in the Gulf of Maine:

1. A complex southern New England stock between Nantucket Shoals and Long Island.

2. Georges Bank stock on the shallower portions of the Bank.

3. Cape Cod stock from east of Cape Cod north to the vicinity of Cape Ann.

4. A northern Gulf of Maine stock along the coast of Maine.

The authors could find no evidence for migration from Georges Bank, although few returns from Georges Bank tagging experiment were obtained.

Tagging returns also gave evidence for the occurrence of a seasonal migration in the more southern populations studied. Another USA worker, Clyde C. Taylor, was cited as suggesting that a seasonal migration from Georges Bank to the southern new England grounds occurs in winter. However, seasonal patterns of migration were not evident from the Georges Bank recoveries. This conclusion should be viewed as tentative as relatively few recaptures were made on Georges Bank. In summary, the authors felt that the yellowtail flounder were found in relatively localized populations, which may make short, seasonal migrations. Their most distant recapture was only 170 miles from their point of release. An unpublished study by Powles, Halliday and Kohler in the northeast section of the Scotian Shelf also showed little movement of yellowtail flounder, with the longest migration covering 30 mi. In this respect, movements of the yellowtail flounder were considered not as localized as winter flounder but ranged far less widely than do cod or mackerel, for example.

Lux (1963) also used data from marking experiments to help define New England yellowtail flounder stocks. Fish from Georges Bank, Cape Cod and southern New England comprised his three postulated stocks. From his tagging studies, he concluded that fish on Georges Bank showed some movement to the westward in winter months, with some of the fish recaptured as far to the west as the southern New England grounds (stock #1 identified by Royce previously). The fish apparently returned to the vicinity of Georges Bank in the summer. Although there was some movement to other parts of Georges

Bank from the point of release, there was no clear migration pattern on the Bank itself. Moreover, there was no indication of movement between the Cape Cod stock and Georges Bank.

6.0 Conclusions Regarding Stock Structure

The case for separate stocks of yellowtail flounder occurring on Georges Bank and the Scotian Shelf, specifically Browns Bank, seems unequivocal. We summarize our conclusions with reference to the five criteria for stock identification suggested by Gulland (1983):

1. Fishery and resource distribution. Clearly the distributions between the two banks are not continuous.

2. Spawning areas. The available data appear to support the view that separate spawning groups occur, and that their reproductive products do not mix.

3. Values of population parameters. Lengths at age differ markedly between Georges and Browns Bank.

4. Morphological or physiological characteristics. There are several studies indicating that yellowtail flounder on Georges and Browns Bank were discrete stocks based on examination of meristic or morphometric data.
5. Tagging. While no tagging of the Browns Bank yellowtail flounder population has been completed, marked Georges Bank yellowtail flounder show no predisposition towards movement across the Fundian Channel.

Recommendations for Future Research

Yellowtail flounder generally appear not to undertake lengthy migrations, with Lux's (1963) results providing some evidence to the contrary. While yellowtail flounder movement between banks in the Gulf of Maine area is fairly well documented, their movement on Georges Bank is poorly understood. Royce et al. (1959) suggested yellowtail flounder mix freely throughout the bank, although no data were presented. The extent of yellowtail flounder movement throughout the bank has ramifications for possible joint Canada/USA management of the resources. The deficiency in our understanding could be addressed with a tagging program specially designed to gain a better appreciation of intrabank movement of yellowtail flounder.

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Table 1. Comparison of yellowtail flounder lengths at age, Subdiv. 5Ze and Div. 4X.

Source	Lux & Nichy (1967)	Lux & Nichy (1967)	MFD	MFD
Sex	male	female	male	female
Year	1957-64	1957-64	1979	1979
Region	5Z	5Z	4X	4X
Season	July-Sept.	July-Sept.	Summer	Summer
Age				
1	18.1	18.1	10.57	11
2	30.2	30.6	19	18
3	34.9	37.5	25.46	24.34
4	37.4	41.7	32.94	30.5
5	39.1	44.3	37.39	37.67
6	39.8	45.7	38.25	41.67
7	42.7	48.2	41.25	42.07
8		49.4		40.67
9		51.2		45
Total N	264	250	92	57

Table 2. Multiple comparison of rank-sum meristic data[1], using the data of Berthome (1974) for Northwest Atlantic yellowtail flounder groups.

Groups[2] Compared			Dorsal Fin Ray		Anal Fin Ray		Gill Raker Counts	
1	vs	2	33.27	46.35	20.46	46.32	41.21	44.28
1	"	3	44.63	62.17	42.32	62.13	93.61	59.27*
1	"	4	21.42	50.27	53.02	50.08*	42.3	48.13
1	"	5	73.64	44.24*[3]	48.9	44.21*	115.93	42.04*
2	"	3	11.36	68.9	21.86	68.85	134.81	65.76*
2	"	4	11.85	58.39	32.56	58.22	83.51	55.94*
2	"	5	106.9	53.28*	69.36	53.25*	74.73	50.79*
3	"	4	23.21	71.59	10.7	71.43	51.3	68.42
3	"	5	118.26	67.49*	92.21	67.45*	209.54	64.28*
4	"	5	95.05	56.73*	101.92	56.55*	158.24	54.18*

[1]Follows the method of Conover (1980), for multiple comparisons of data analyzed by non-parametric means.

[2]Area codes are:
1. East Banquereau Bank
2. Just north of The Gully
3. Just south of The Gully
4. Sable Island Bank (just south of the Island)
5. Georges Bank

[3]Significant at $P \leq 0.025$

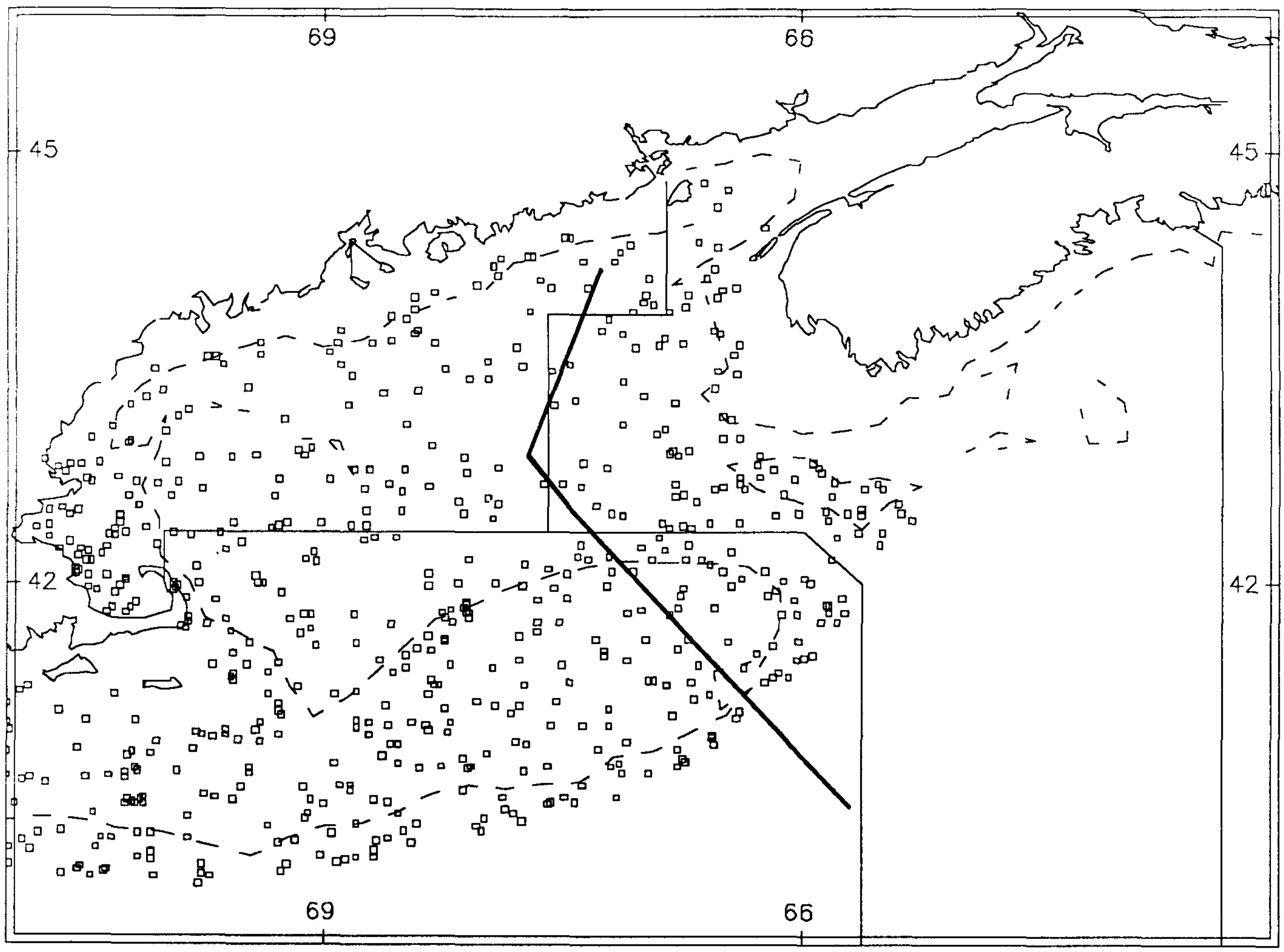

Fig. 1. Distribution of sets during United States National Marine Fisheries Service research vessel surveys, Gulf of Maine area, 1982-1984 (spring). The NAFO management boundaries and the ICJ line are also shown.

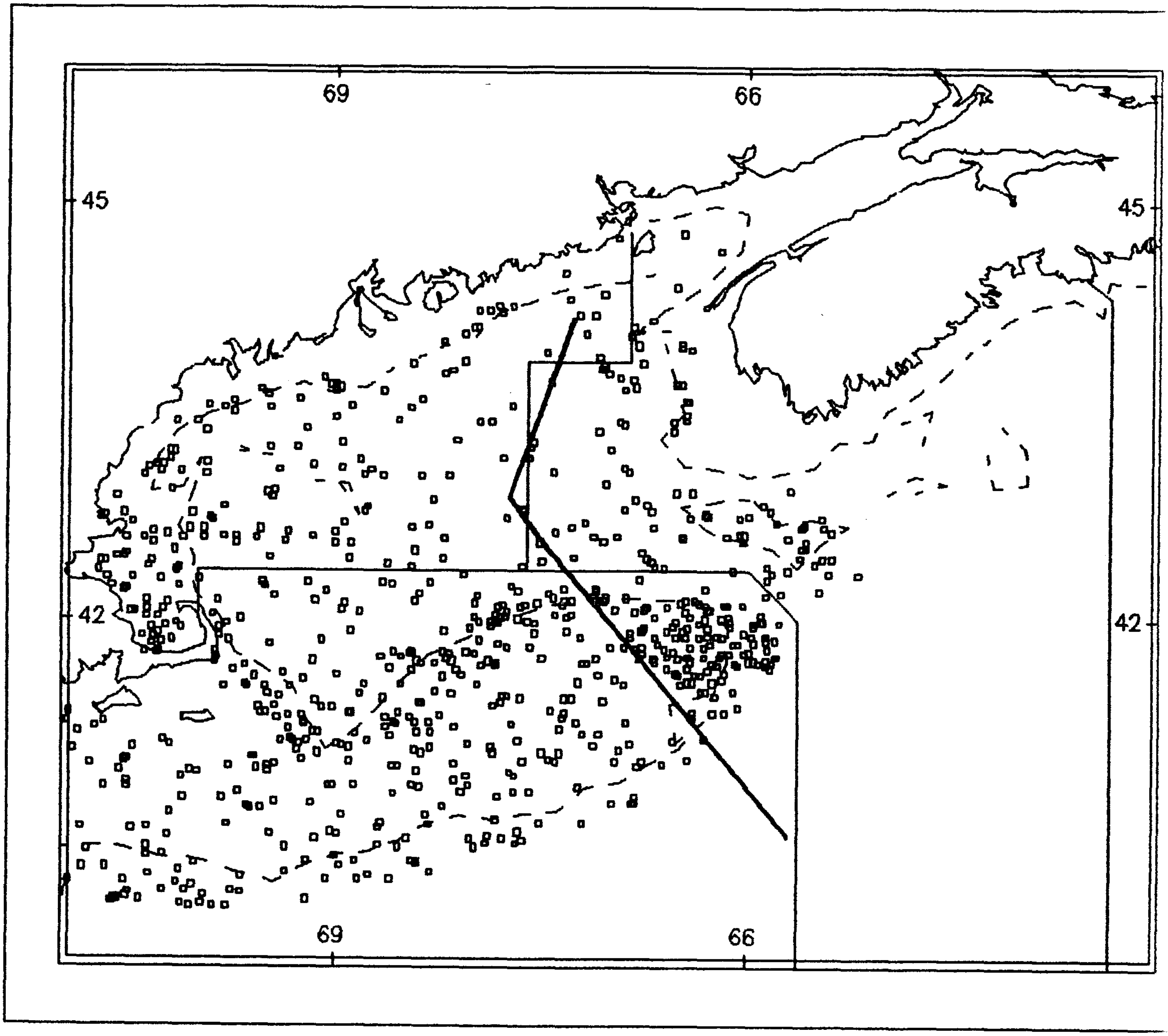

Fig. 2. Distribution of sets during United States National Marine Fisheries Service research vessel surveys, Gulf of Maine area, 1982-1984 (fall). The NAFO management boundaries and the ICJ line are also shown.

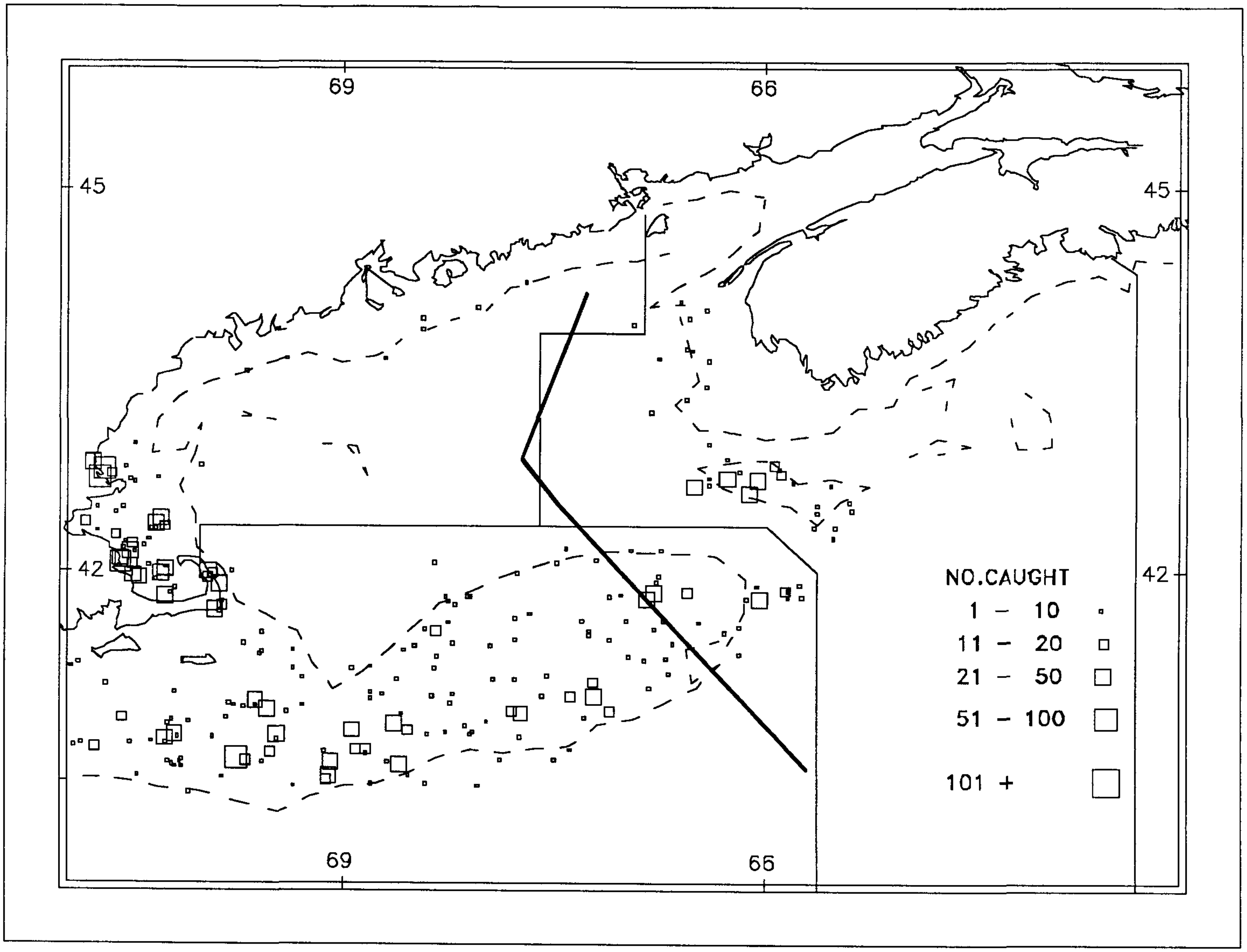

Fig. 3. Distribution of yellowtail flounder observed during NMFS spring surveys, 1982-1984.

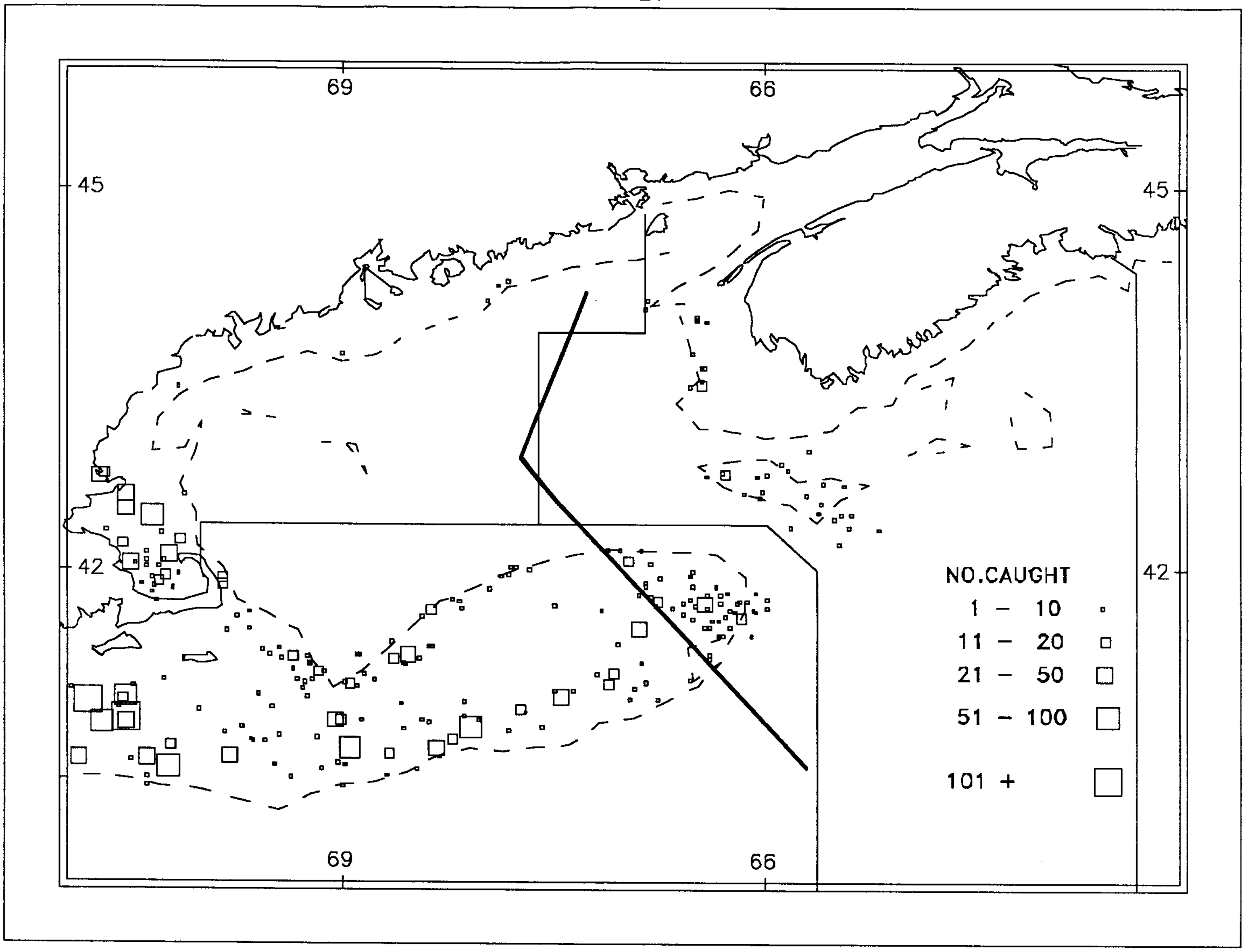

Fig. 4. Distribution of yellowtail flounder observed during NMFS fall surveys, 1982-1984.

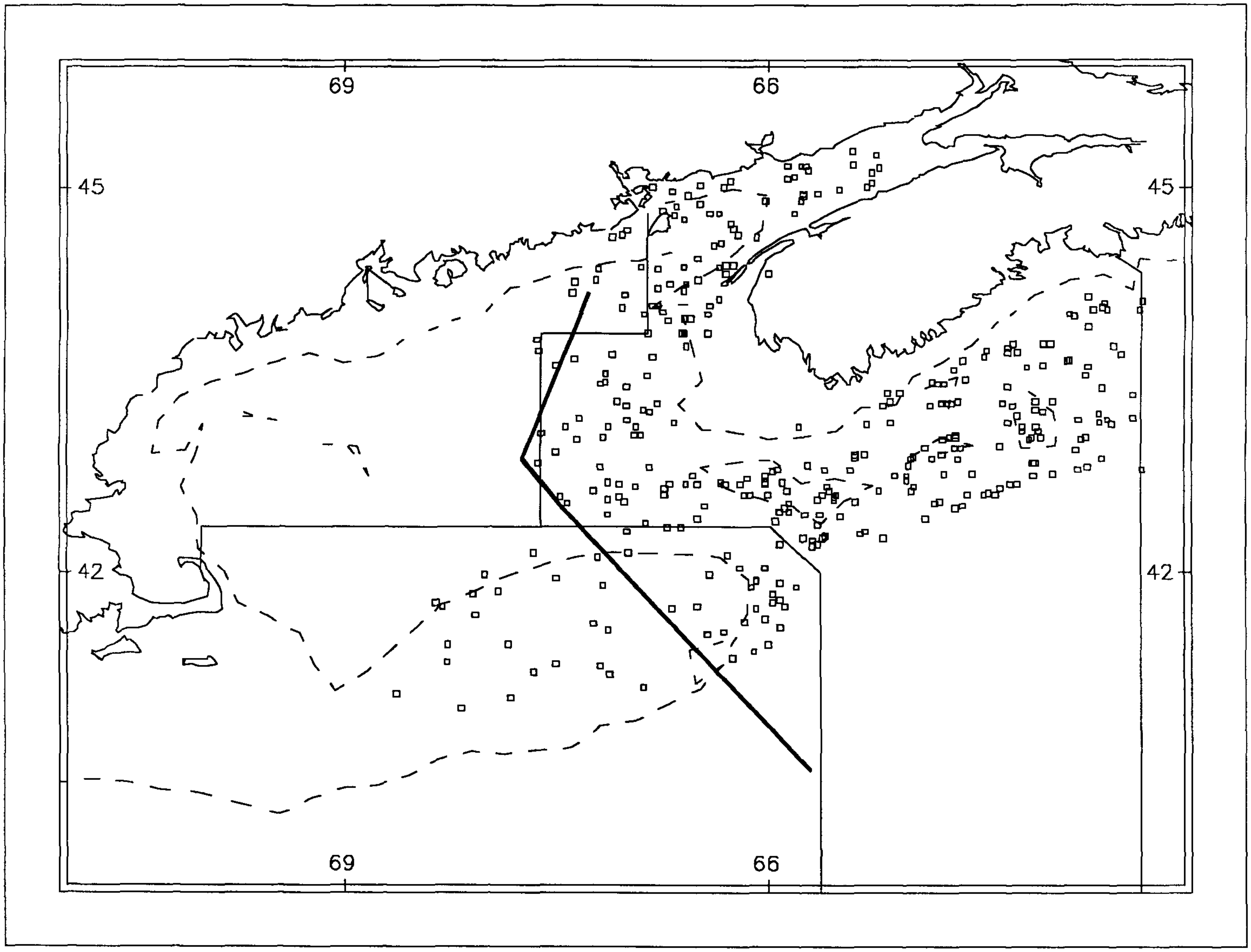

Fig. 5. Distribution of sets during Marine Fish Division research vessel surveys, Gulf of Maine area, 1979-1984 (spring). Coverage of Georges Bank was obtained only during the 1984 survey.

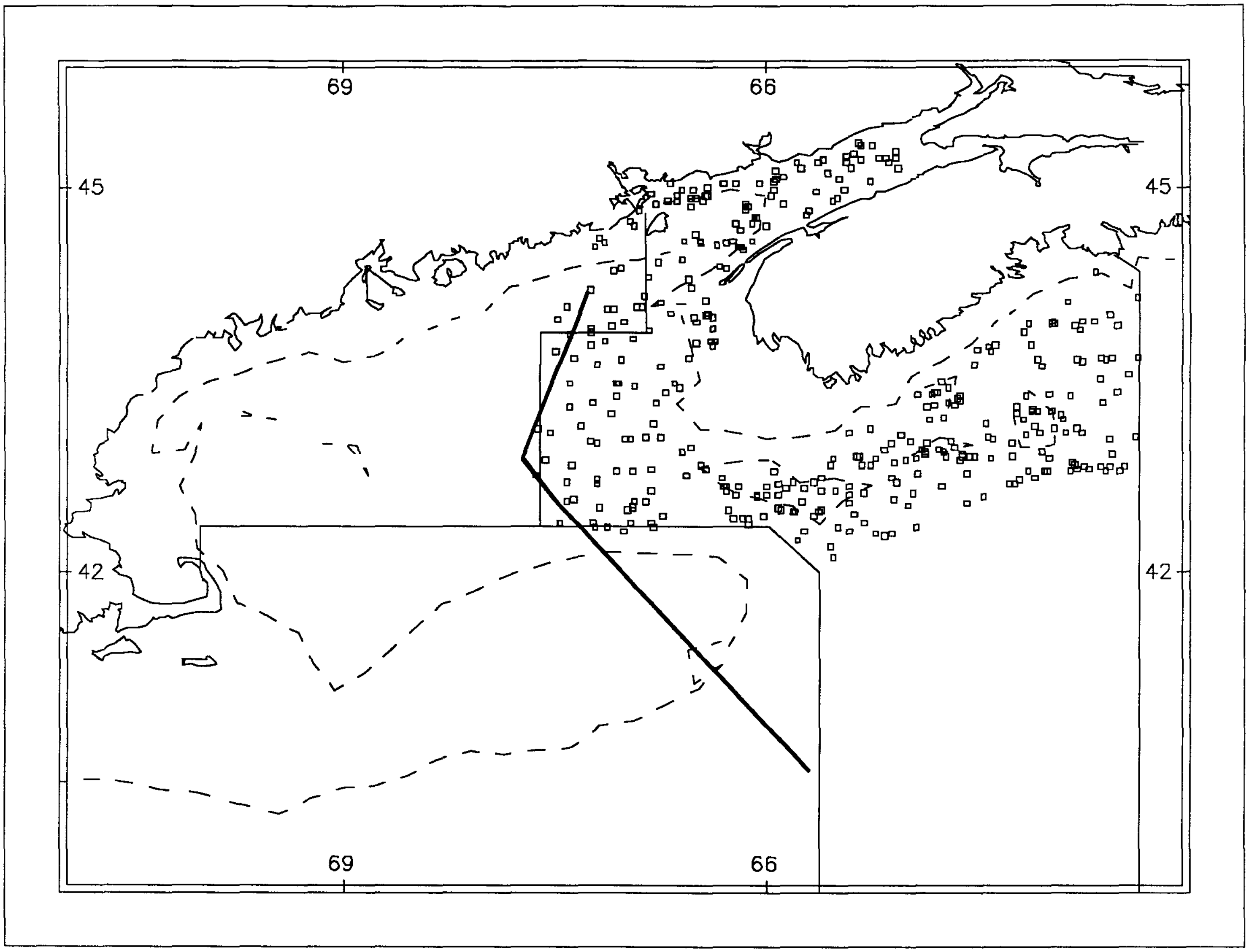

Fig. 6. Distribution of sets during Marine Fish Division research vessel surveys, Gulf of Maine area, 1979-1984 (summer).

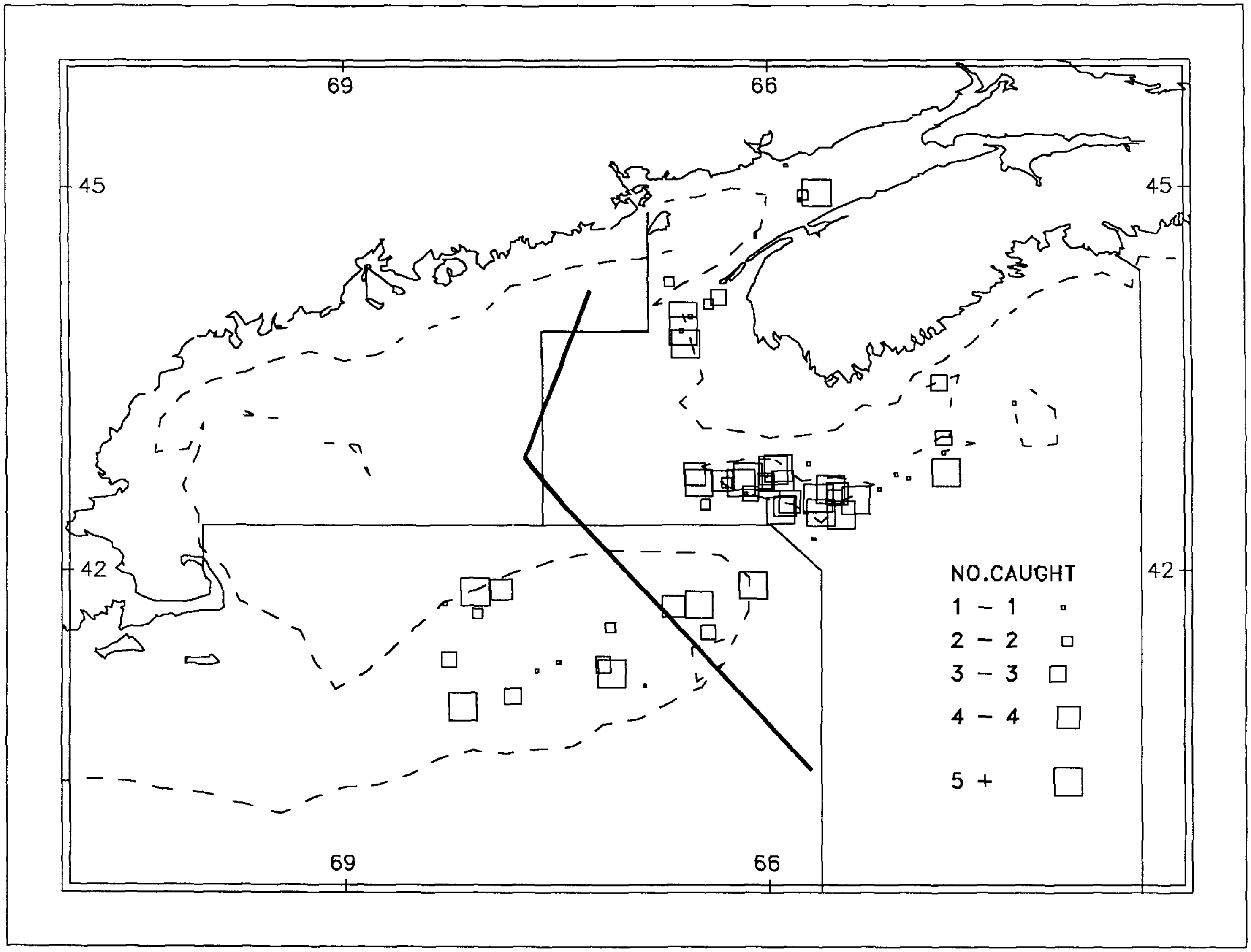

Fig. 7. Distribution of ripening, ripe and spent female yellowtail flounder during spring MFD research vessel cruises, 1979-1984.

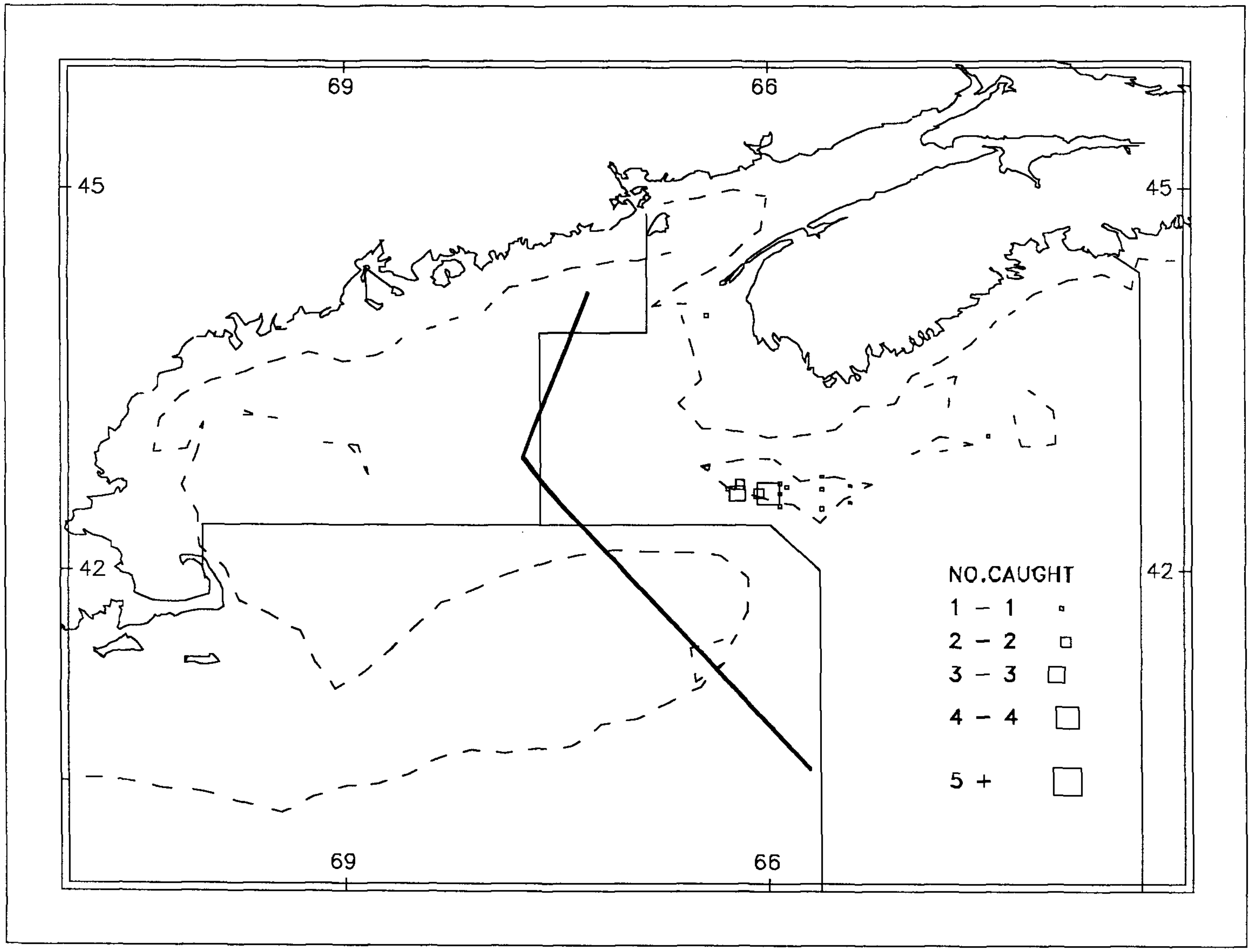

Fig. 8. Distribution of ripening, ripe and spent female yellowtail flounder during summer MFD research vessel cruises, 1979-1984.

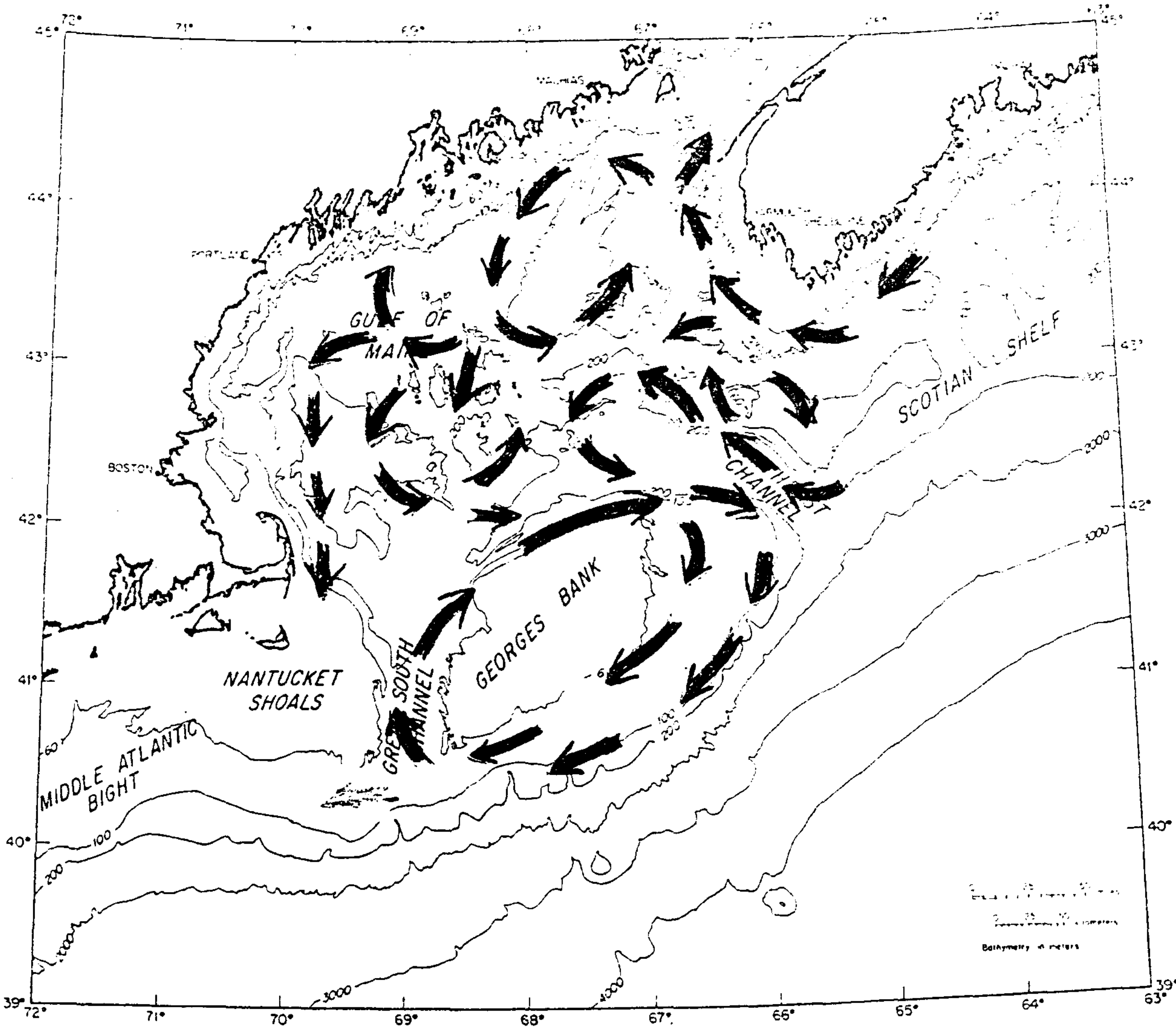

Fig. 9. Mean residual upper layer circulation in Gulf of Maine area. Compiled from Butman et al. (1986), Smith (1983, and personal communication) and Brooks (1985).

Fig. 10. Late stage yellowtail flounder eggs from FEP data, May 1983.

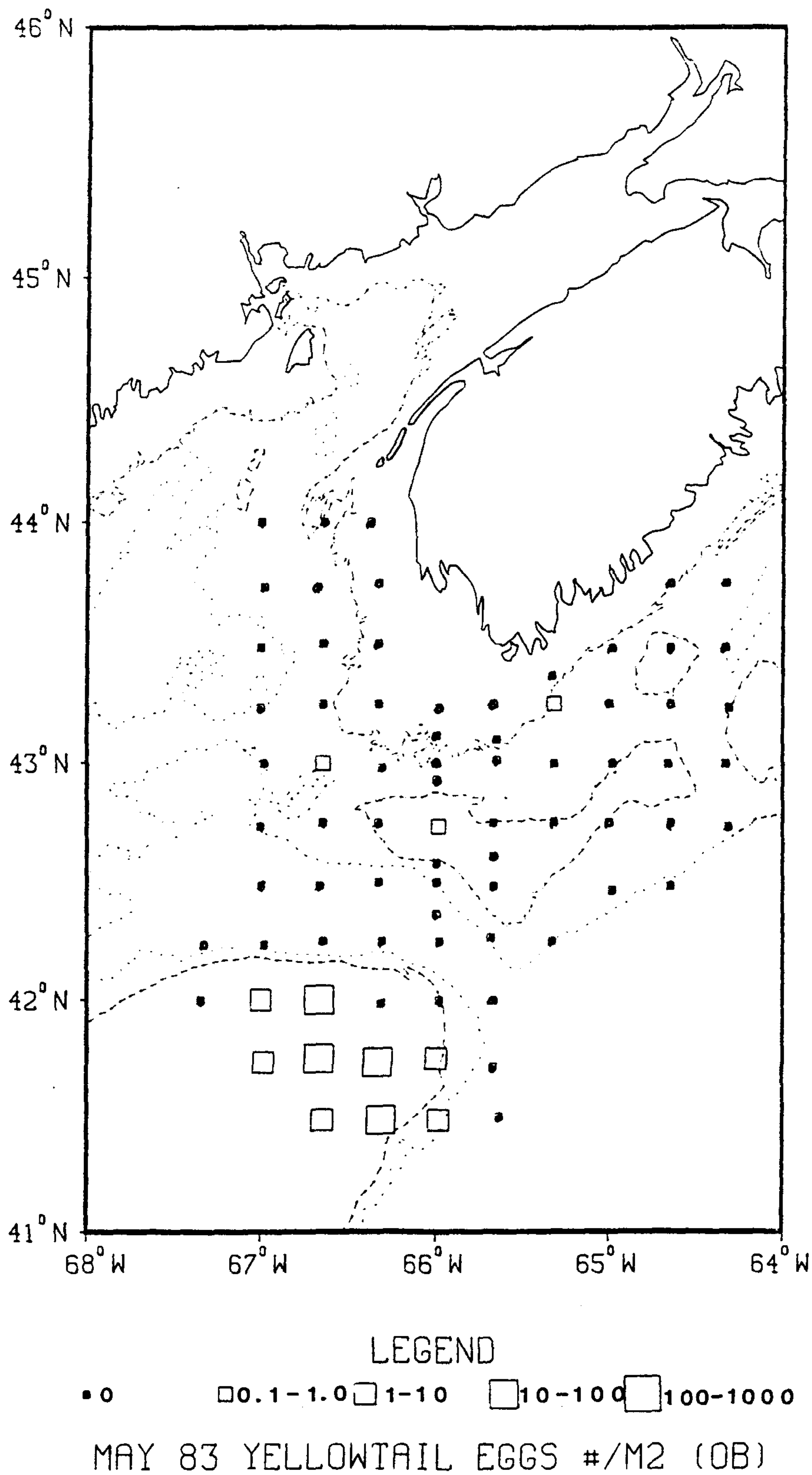

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Fig. 11. Late stage yellowtail flounder eggs from FEP data, June 1983.