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The 1995 Update on Georges Bank 5Z Herring Stock

by

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Abstract

The results of the 1994 Canadian and United States fall surveys on Georges Bank indicated that the stock is well on its way to recovering. Abundance indices used to evaluate the relative stock status are among the highest observed in post-collapse years and are comparable with the 1960's and early 70's. Research samples collected on the bank during spawning season continue to be dominated by 3 and 4 year old herring, suggesting successful annual recruitment to the spawning stock. Furthermore, small (<10 mm) larvae have been observed in relatively large numbers on the northeastern portion of the bank for the past two years. Herring have not only reoccupied their historical spawning grounds, but their numbers and distribution on the Canadian portion of the bank have increased to historical levels. It is therefore considered that a commercial fishery could be developed on Georges Bank and that a combined Canada/US catch of 20,000 t would not exceed reference points commonly used for herring. Preliminary criteria for a stock status decision making framework are also presented.

Résumé

Les résultats des relevés de recherche d'automne sur le banc Georges réalisés en 1994 par le Canada et par les États-Unis révèlent que ce stock est nettement en voie de rétablissement. Les indices d'abondance servant à évaluer l'état relatif du stock sont parmi les plus élevés de ceux de la période qui a suivi l'effondrement des populations de hareng et sont comparables à ceux des années 1960 et du début des années 1970. Les échantillons prélevés sur le banc durant la saison de frai continuent d'être dominés par les harengs de 3 et 4 ans, ce qui dénote un bon recrutement annuel dans le stock de reproducteurs. De plus, les petites larves (< 10 mm) se sont avérées relativement abondantes dans la partie nord-est du banc au cours des deux dernières années. Non seulement le hareng réoccupe-t-il ses frayères traditionnelles, son abondance et sa distribution sur la partie canadienne du banc atteignent à nouveau des niveaux historiques. On considère donc qu'une pêche commerciale pourrait démarrer sur le banc Georges et que des prises combinées Canada-É.-U. de 20 000 t ne dépasseraient pas les points de référence généralement utilisés pour le hareng. On présente également ici les critères préliminaires d'un cadre décisionnel sur l'état du stock.

Historical Overview:

Prior to its collapse in 1977, Georges Bank supported the largest herring fishery on the western Atlantic. During the late 1960's and early 1970's, reported commercial landings from the bank exceeded 200,000 mt annually (Figure 1). The fishery peaked in 1968 with reported landings in the 374,000 mt range (NEFSC, 1993), however, actual landings are suspected to have been substantially higher. By 1977 reported landings had declined to less than 2,000 mt. The collapse has been attributed to over-fishing and poor recruitment. Although no directed herring fishery operated on the bank between 1977 and 1993, incidental catches during this period ranged from 2,000 to 11 t.

Between 1978 and 1985 virtually no adult or larval herring were detected on the bank by fall research surveys. The number of adult herring reported in US fall bottom trawl surveys fell to less than 0.10 herring per standard tow (Melvin et al., 1991). The first sign of a recovery occurred in 1984 when the Canadian R/V Alfred Needler collected more than 200 juvenile (age 1+) herring in a mid-water trawl (IGYPT) on Georges Bank (Stephenson and Power, 1989). However, it wasn't until 1986 that significant evidence appeared in both Canadian and US research surveys to indicate the stock was recovering. The first observed spawning on historical grounds on the northeastern portion of the bank was reported in October of 1992 (Melvin and Fife, 1993). This was later substantiated by the US fall larval survey (W. Smith, Pers. Com., 1993).

The recovery of the Georges Bank herring stock has been monitored by annual fall adult/larval surveys since 1987 (Figure 2). Each year the data has generally indicated an increasing relative level of abundance of herring on the bank. Recent reports from US larval studies also show that Georges Bank has had several strong year classes and that abundance may have recovered to a level which exceeds the mid-sixties (Anon. 1994). Details of the chronological reappearance of herring on the bank are discussed in Stephenson and Power, 1989 and Melvin et al. 1991.

Description of the fishery

In 1993 and 1994 an experimental fishery with a combined Canada/United States catch of 5,000 t was recommended for Georges Bank. In August of 1993 four vessels made a single excursion to the bank. Although no fish were caught, the lack of catch was not attributed to the absence of fish, but to their distribution within the water column. Most herring were observed too deep to capture with a purse seine. Effort increased in 1994 when a total of 14 trips were made to the bank by Scotia Fundy seiners; 11 in June and 3 in July. The total Canadian 5Z herring catch during this period was 228 t with the majority of sets occurring on the northern edge near the International Boundary (Figure 3). The USA catch, which occurred in the vicinity of the Great South Channel, was estimated at 350 t for 1994.

Industry Consultations

Several formal and informal consultations with industry took place in 1994. These included presentations at three Scotia-Fundy Herring Advisory Committee (SFHAC) meetings, annual industry meetings, ad hoc fishing excursions, Canada/US industry meetings and the pre-assessment input data review. This year many fishermen expressed concern about the unusual behaviour of herring in both 5Z and 4WX and the low fat content. On Georges Bank they reported that the herring remained close to bottom. One suggested explanation for this observation was the lack of feed in the upper water column to attract the fish off the bottom. Traditionally, processors cease buying fish for about three weeks in June because of poor quality (i.e. feedy). In 1994 feedy fish were not a problem. Other fishery sectors again reported a large number of herring on the northeastern portion of Georges Bank during the spring and early fall.

Research Survey Data:

Available Data:

Data sources used to assess the recovery of Georges Bank herring include the US fall bottom trawl survey (1965-94), which covers Massachusetts Bay, Nantucket Shoals and Georges Bank; and the Canadian fall Georges Bank larval/adult herring survey (1987-94). Sampling design and gear type differ between the two surveys. The US survey's use a random stratified design with a 36 Yankee trawl, compared to Canadian opportunistic (i.e. sets made when herring were observed on the ships sounder) bottom trawl (Western IIa) sets to collect adult herring samples during larval surveys.

The larval component of the Canadian survey was originally established to cover an area of the bank which was likely to show signs of a recovery using standard ichthyoplankton sampling protocol (Melvin et al., 1993). In 1991, at CAFSAC's request, the larval survey grid was expanded eastward to include the entire Canadian portion of the bank. The survey area was again expanded in 1992 westward to the Great South Channel to cover an area where further spawning was suspected (Figure 2.).

Several changes in gear type and vessels have occurred throughout the Canadian survey period. From 1987 to 1991 both larval and adult collections were made with standard sampling gear using the "Lady Hammond". Unfortunately, in 1992 the "Lady Hammond" was removed from its long term charter and two vessels were required to sample Georges Bank; the "Parizeau" for larval work and the "E.E. Prince" for bottom trawling. The bottom trawl component of the fall survey was dropped in 1993 to undertake an acoustic survey of the bank, but the larval component of the survey remained unchanged. An IGYPT mid-water trawl was used to sample adult herring and to verify acoustic backscatter. Gear and vessel changes resulted in poor adult sampling in 1992 and

in 1993. The pre-1992 survey approach was re-established in 1994 using the "Alfred Needler". Eighty-three larval stations and 13 bottom trawl stations were sampled in 1994.

Bottom Trawl Surveys

Bottom Trawl Abundance Index:

In previous years the number of herring per standard bottom trawl tow from the US fall bottom trawl survey for all Georges Bank strata was used as an index of abundance of adult fish during spawning time. This year the index was restricted to NAFO areas 522,555,552,561,562 and 525 in Strata 13, 16 and 21 to 24 for comparison with historical reports (Anthony and Waring, 1980). Southern slope water stratum were excluded as herring generally do not occur in this area. In addition, the index is presented in two forms; stratified weight per tow (Figure 4a) and number per tow (Figure 4b). Furthermore, because of an extremely large single herring catch in 1992 (2700 fish) the index was recalculated by substituting the next largest set in the strata. Corrections were also made for differences in US survey vessels.

Comparison of the bottom trawl index (weight/tow), although noisy, generally tracks the stock's decline from the late sixties to the mid-seventies. With the exception of 1978, few herring were observed on the bank between 1973 and 1986 by research surveys. However, from 1986 to 1988 the index increased rapidly, declined in the 1989-90 period and then increased to a peak in 1992. The 1993 index dropped substantially from the 1992 value. A significant portion of this decline is believed attributable to the apparent lack of sampling stations on the northern edge in the vicinity of the International Boundary where herring commonly occur (compare Figures 5cc and 5dd). In 1994 both the number/tow and weight/tow were double the 1993 levels.

Adult Distribution

The fall distribution of herring on Georges Bank from 1965-1994 from US surveys are presented in Figure 5a-dd. During the peak period of the commercial fishery, herring were found throughout most of the bank. However, about 1973 the occurrence, as reflected by the percent sets with herring, began to diminish. This trend continued, excluding 1978, until 1979 and 1980 when not a single herring was collected in 227 and 135 sets respectively. From 1981 to 1985 a few sets on Georges Bank contained herring, even in years when no fish were observed in Massachusetts Bay or on Nantucket Shoals. The number of sets with herring began to increase in 1986 and generally increased, with some inter-year variability, to present levels (Table 1).

The 1994 distribution of adult herring on Georges Bank was consistent with recent observations. Adult herring appear to be concentrated in an arc between the 100-200 m isobath north of Cultivator Shoals to the Northern Edge along the northern fringe of Georges Bank and

just west of the Great South Channel. Few adults were observed in the central and southern portions of the bank. Also, evident from comparison of the 1993 and 1994 sampling stations, is the critical nature of station location. In 1993 the US survey did not provide good coverage of the 100-200 m isobath on the northern fringe nor the portion of the bank just east of the International Boundary where the majority of fish were observed in past surveys. It is therefore uncertain if the adult herring were present in these areas, however, a month later the acoustic survey found several schools of herring in this area. Better coverage in 1994 showed a continuation of this trend in the occurrence of herring along the northern fringe. Canadian bottom trawl surveys, although approximately 1 month later, generally support the US observations and tend to fill in some gaps when coverage is limited in specific areas (Figure 6a-h).

Length Frequency

Comparison of the length frequency distributions from Canadian fall research samples (1987-1994) indicate a transition from a broad distribution to one which reflects the dominance of younger recruits (Figure 7). In the early years of the recovery (1987-1989) length frequencies covered almost the entire spectrum of possible lengths, with poor representation of sizes which approximate recruitable year classes. Around 1990 this trend began to change when herring 25-27 cm started to dominate catches. The trend continued to 1993. In 1994 the mode shifted upward by approximately 1 cm, suggesting that slightly older fish (4+) were dominating the stock.

Historically, a declining modal trend in the length frequency distribution was observed from Massachusetts Bay to Georges Bank in the US and Canadian bottom trawl samples. However, in 1993 the pattern changed to a similar length distribution for Massachusetts Bay and Georges Bank (Figure 8). The modal length of herring on Nantucket Shoals (27 cm) was 1-2 cm larger than on Georges Bank and Massachusetts Bay. In 1994 a similar length distribution with a mode at 28 cm was observed in all three areas (Figure 9). Frequency distributions from both the Canadian and US surveys were similar in 1993 and 1994, even though the Canadian surveys occurred approximately 1 month later.

The mean length of herring collected on Georges Bank in 1994 by both the Canadian and US fall surveys were significantly larger than in 1993 and similar to those observed between 1988 and 1992 (Table 1). The largest mean length of herring collected by the US survey occurred on Nantucket Shoal (29.2 cm) followed by Massachusetts Bay at 28.9 cm and Georges Bank at 27.9 cm (Table 1). Mean lengths of fish collected by the US survey on Georges Bank, which was conducted about four weeks earlier, and the Canadian survey, were almost identical at 27.9 and 27.5, respectively.

Age Distribution

Age data on Georges Bank herring are available for only the Canadian bottom trawl sets (1987-1992, 1994) and the acoustic mid-water trawl (1993) samples. A catch at age matrix (Table 3) was generated from research samples using the length frequency data, aged fish and assuming 1000 t catch as input for partitioning of age groups. Research samples have been dominated since the surveys began by 3 and 4 year old fish (Figure 10). This trend continued in 1994 where herring samples were mostly 4 (48.6%), however, 3 year olds (1991 year-class) were poorly represented (3.6%). The concern over the noticeable absence of fish older than 6 in the single sample collected in 1993 and 7 in 1992 appears to have been as suspected, poor sampling. An Increase in sample size in 1994 shows ages 2 through 9 to be present on the bank. The continued strong representation of young fish (4 yr old and younger) in annual catches since 1987 provides evidence of good annual recruitment to the spawning stock and continues to support the expansion of the stock.

To examine how the 1993 and 1994 age distributions compared with previous years the age distributions were plotted relative to the mean for 1988-1992 (Figure 11 and Figure 12). Evident from these figures is the dominance of the 1990 year-class as 3 year olds in 1993 and as 4 year olds in 1994. Five year old fish also made up a significant portion of the catch, while age 3 fish are well below average. The increased presence of older fish is also reflected in the length frequency distributions (Figure 8).

Natural Mortality:

Since Georges Bank herring have been subjected to virtually no exploitation during the past 15 years, except for the winter fishery south of Cape Cod, it was assumed that mortality estimates would reflect natural mortality. Unfortunately, while cohorts can to some extent be followed in the catch-at-age matrix (Table 3), their numbers are extremely variable and mortality estimates unrealistic. Figure 13 represents a catch curve for the 1986 year-class. Estimates of mortality from this curve for ages 3 to 6 exceed 0.4. Two factors appear to be affecting the estimates. Poor sampling is obviously a prime consideration given the absence of older fish in 1992 and 1993. This however may not be as significant as the continued strong annual recruitment, as suggested by dominance of 3 and 4 year old fish. Increasing recruitment over several years would have a tendency to tilt (decrease the slope) the curve through poor representation of older year classes, thereby increasing the estimate of mortality.

Larval Survey:

Larval Abundance Index

The larval abundance index (number of larvae/m^2) from 1987 to 1993 was estimated from the Canadian fall larval surveys for both stations contained only within the original survey grid (i.e. to maintain consistency) and for all stations which includes the expanded coverage initiated in 1991 (Figure 2). To investigate how these values compare with historical levels (1971-90) the number of larvae/m^2 were extracted from the literature (Smith and Morse, 1990) for the cruises which occurred at approximately the same time (late October/early November,1971-1986) and the Canada/US larval comparison study (Melvin and Fife, 1992).

The 1994 larval abundance index for both the original survey area (1987-90) and the expanded coverage has doubled the latter and tripled the former relative to 1993. This marks the first time in post-crash years that the larval index has exceeded reported values for the pre-crash period (Figure 14). Inconsistencies in the general increasing level of abundance, such as the 1991 decline, are believed to be a function of late spawning relative to survey timing. In 1991 the US December survey identified a spawning period which occurred after the Canadian survey was completed (Smith, Personal Communication). It is also likely that larval abundance indices(LAI's) between 1987 and 1991 are underestimated given the presence of unspawned fish on the bank during the survey.

The question of comparability between Canadian and US larval survey results has arisen on several occasions. During years when the surveys were conducted at approximately the same time, larval abundance indices were almost identical (Figure 14, 1988 and 1990). Yet, when only a few weeks separate the surveys major differences can occur. For example, in 1987 and 1989 approximately two weeks separated the surveys and marked differences were observed.

Larval Length Frequency:

During the early stages of the recovery on Georges Bank the larval length frequency distribution was generally unimodal (1987-1990) and dominated by smaller larvae (Figure 15). In 1991 a second mode appeared and the distribution expanded to many larvae greater than 20mm. This trend continued through to 1994. A trimodal distribution was observed in 1992 when the latest larval survey to date occurred. This would imply that in several years the larval abundance index was an underestimate of abundance as some unknown portion of the stock had not yet spawned. For 1991, the lowest index observed in recent times, approximately 20% of the mature herring collected on the bank were unspent(Table 4).

Spawning/Larval Distribution

The geographical distribution of larvae (all sizes) collected in 1994 was similar to 1992 and 1993, and covered a large part of the Canadian portion of the bank (Figure 16-23). However, the total number of larvae collected during the survey and the concentration almost tripled the 1993 observations (Table 2) . This is the highest number of larvae/m^2 observed since the Canadian surveys began and the second year in a row that a new maximum has been reached.

Examination of the distribution and abundance of larvae <10 mm (generally considered an indication of spawning areas) for 1993 and 1994 showed a marked change from most of the other surveys. During the early years of the survey (1987-91) no small larvae were observed on the Canadian portion of the bank. In 1992 two aggregations of larvae were found just east of the International Boundary suggesting that herring had, for the first time since the collapse, re-occupied their historical spawning grounds on the eastern portion of the bank. Spawning, as indicated by the presence of small larvae, covered a large area on the Canadian side of the bank in 1993 and 1994. Another difference observed in 1994 was the apparent reduction of young larvae in the vicinity of Little Georges and Cultivator Shoals where most spawning occurred during the early stages of the recovery. It now appears that the majority of spawning is occurring further eastward.

Prognosis

The 1994 data indicate that the Georges Bank herring stock is well on its way to recovering, or has recovered, from the collapse in 1977. The 1994 US bottom trawl survey index doubled the 1993 level and is above many years when catch levels were much higher (i.e. 1960's and 70's). The Canadian larval abundance index was, for the second year in a row, the highest observed in the time series. And, the age structure of research samples continued to show a dominance of young fish (4-yr-old) in the catches, indicating successful recruitment over the past several years. Better sampling in 1994 demonstrated the presence of older year-classes. Both newly hatched (i.e. <10 mm) and older larvae in 1992 and 1993, displayed a much broader geographical distribution than in other post-crash years, extending to the northeastern portion of the bank. Spawning on the Canadian side of the bank, as evident by the presence of larvae (<10 mm), was first documented in 1992 by four independent sources (Canada and US fall surveys, a seiner survey and the presence of eggs in groundfish stomachs). In 1993 and in 1994 spawning was observed over a much broader geographical area to include most of the eastern portion of the bank.

In the absence of an analytical assessment, it is noted that the larval abundance index has increased to levels comparable to those observed in the early 1970's and the bottom trawl abundance index has increased to levels observed during the late 1960's. Catches exceeding

100,000 t during the early 1970's led to a rapid collapse of the stock. The 3+ biomass during this period was in the range of 200-400,000 t. It is considered that a combined Canada/US catch of about 20,000 t for this stock would not exceed reference points commonly used for herring.

Other factors which might be considered related to stock size include; the mean length and percent of fish mature at age 3, both of which have shown a substantial decline (26.7 Vs 24.6 cm and 89% vs 48%, respectively) since the early stages of the recovery (1987). These characters may reflect a density-dependent relationship with stock abundance/biomass.

The fishing industry can play a key role in our better understanding of the stock's recovery and status. As the fishery develops it is critical that information be obtained regarding seasonal distribution of fish and that herring samples be collected to determine the size and age structure of the stock. Distributing fishing effort throughout the season, with some coverage during the spawning season (i.e. October), will be extremely informative assuming accurate logs are kept.

Caution is however warranted for this transboundary stock in that no estimate of biomass is available. While the development of a commercial fishery in the long term will provide additional scientific information to improve estimates of stock status, in the short term, uncertainties should err on the side of conservation.

Framework for decision making

As a developing fishery, it is important to be prepared for all eventualities and to anticipate changes in the Georges Bank fishery toward realizing the extent and reliability of managing herring stocks. Of prime concern is our inability to conduct an analytical assessment of the stock in absence of an established commercial fishery. Thus it is important that a strategic decision making process, based on biological characteristics, be established to deal with the emerging Georges Bank herring fishery.

The purpose of the decision making process will be to provide a proactive view to events in the fishery system over time. This would be accomplished through a more complete understanding of the source and extent of the evolving fishery, and its expected pattern of exploitation on the bank. An important element of the process is to set out objective criteria for explicit measurement of stock population status over time for contingent management responses and alternatives for maintaining the objectives of the plan.

Operation of the strategic plan would be reinforced by well-defined procedures for continual monitoring and feedback from the fishery, including review of the strategic objectives. This process would involve all participants in the fishery system as well as define their specific roles and contributions to consensus-building and co-management toward integrated decision making for stock evaluation.

As a starting point in this process we present a list of biological characteristics which during the course of time have demonstrated changes that appear to correspond with changes in stock abundance. The following characteristics and their levels are listed as an example of how we might evaluate such changes and upon which a pre-determined criteria for action can be established. Positive values have intentionally been set such that the 1994 criteria values signal encouragement in a general sense. Further work is required to define the specific range for each of the criteria.

Criteria	Signal Negative	Neutral	Positive
Research Surveys:			
Larval Abundance Index	<20/m	20-40/m2	>40/m2
Larval Coverage	<40% Can	40-60%	>60%
Spawning Coverage	<25% Can	25-40%	>40%
US Bottom Trawl Index (Weight)	<2kg/tow	2-3.5Kg	>3.5kg
US Bottom Trawl Index (number)	<10/tow	10-20	>20
Adult Distribution (define Area)	<40%	40-60	>60%
Recruitment (age 3-4)	<50%	50-60	>60%
Mean Length @ age 3	>26cm	25-26	<25cm
Mean length Imm Age 3	>25.5	24.5-25.5	<24.5cm
% mature at Age 3	>65%	45-65%	<45%

Industry Observations:

To be developed

Once the criteria and their ranges have been established the data can be put into a decision matrix which has pre-determined levels of action regarding the stock status and harvest options. One might imagine, in the simplist form, the following;

All Negative ----------> Reduction in recommended catch level.

Mixed ----------> Status Quo

All Positive ----------> Increase in recommended catch level.

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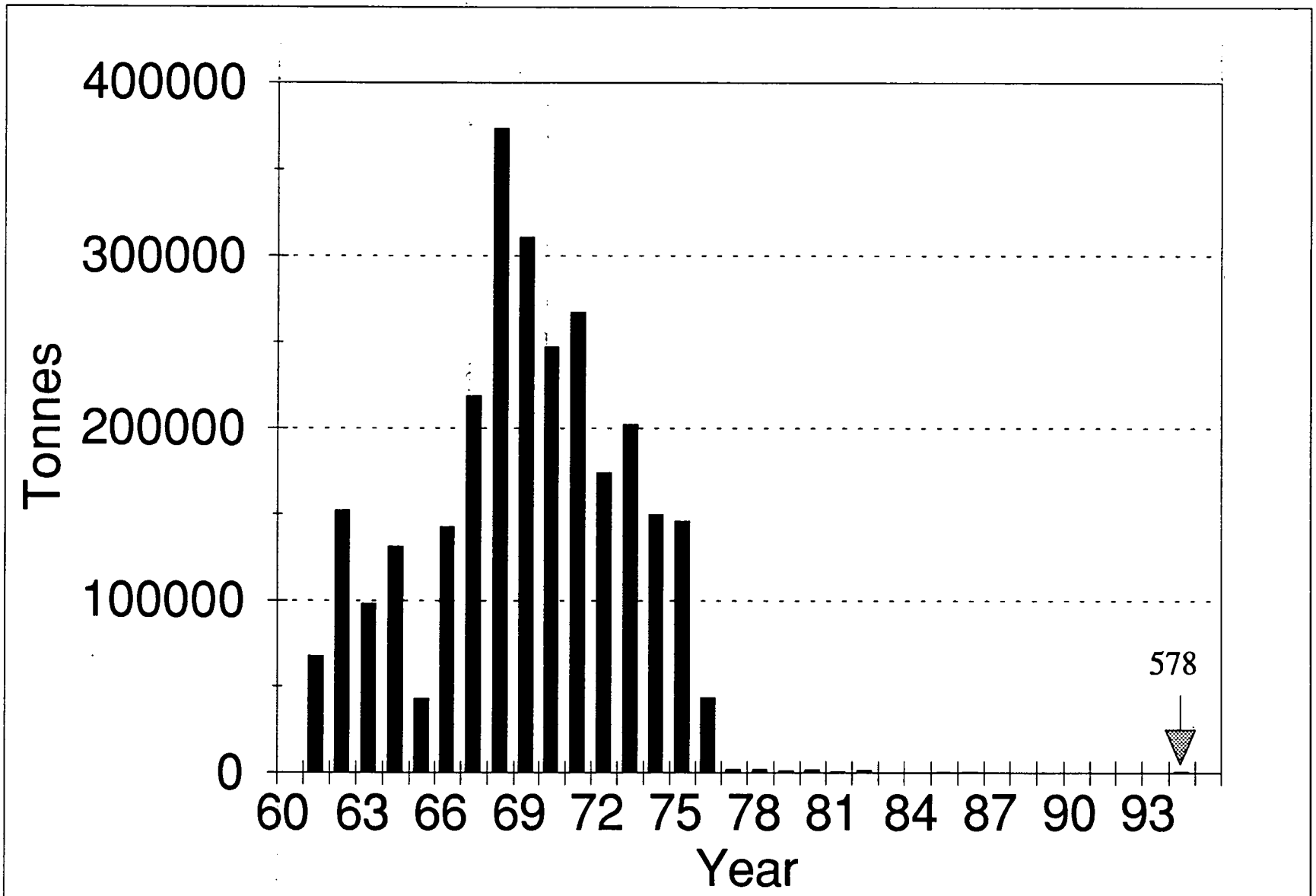


Figure 1. Summary of Georges Bank reported herring landings from 1960 to 1994.

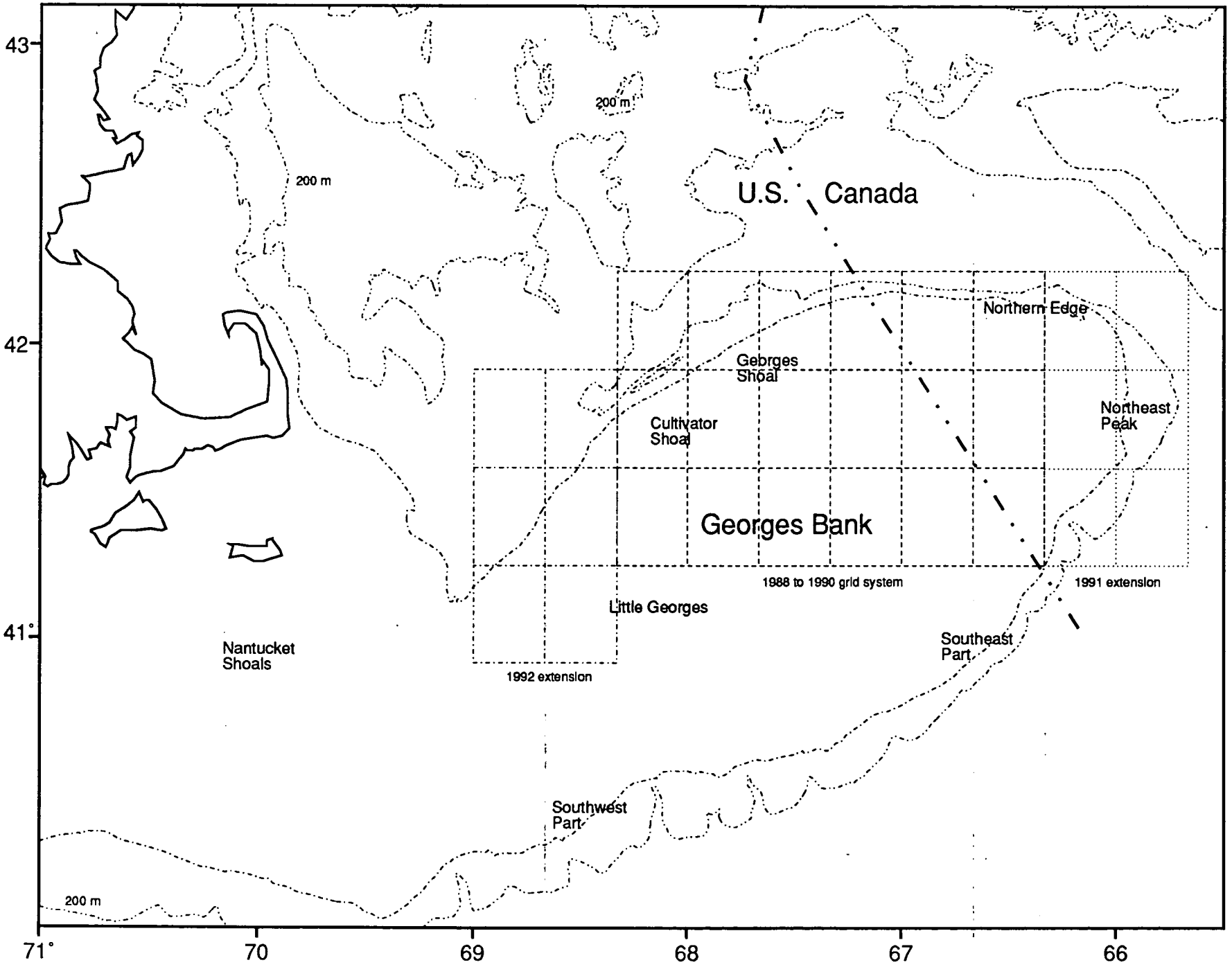


Figure 2. Georges Bank herring survey area including the original sampling grid (1988-1991) and the extensions in 1991 and 1992.

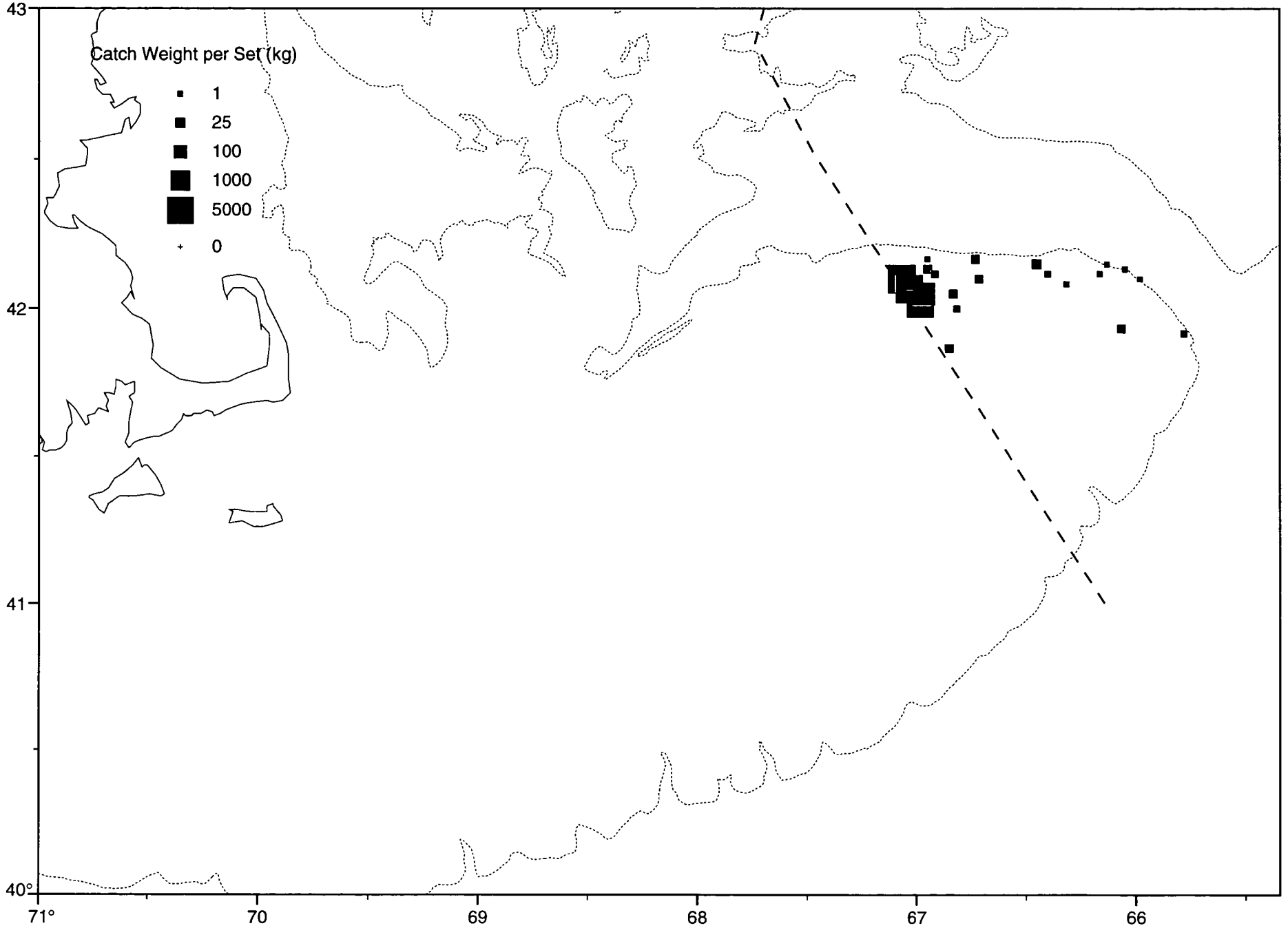


Figure 3. Atlantic herring catches for 1994 from the Canadian IOP database. Reported landings include both directed and by-catch fisheries.

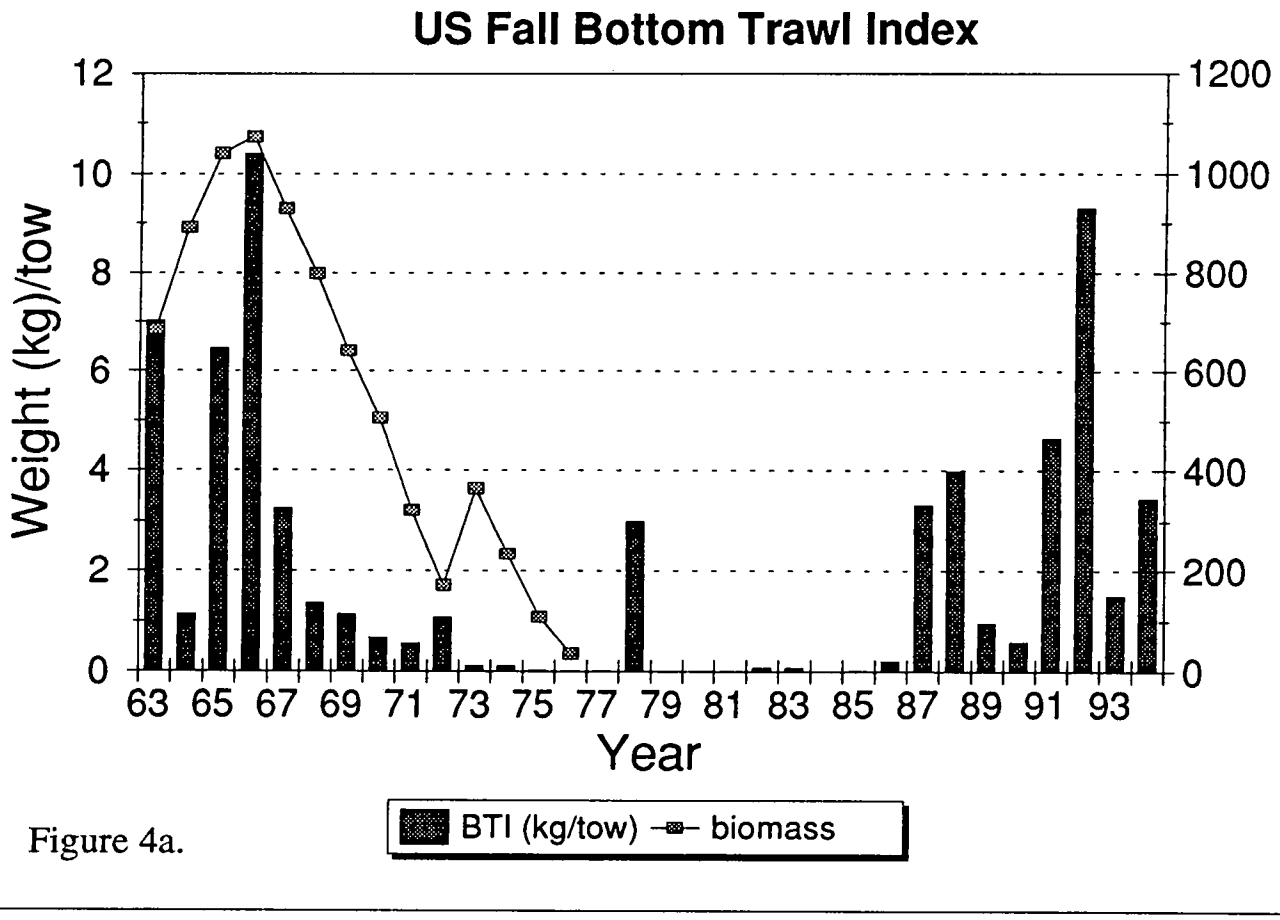


Figure 4a.

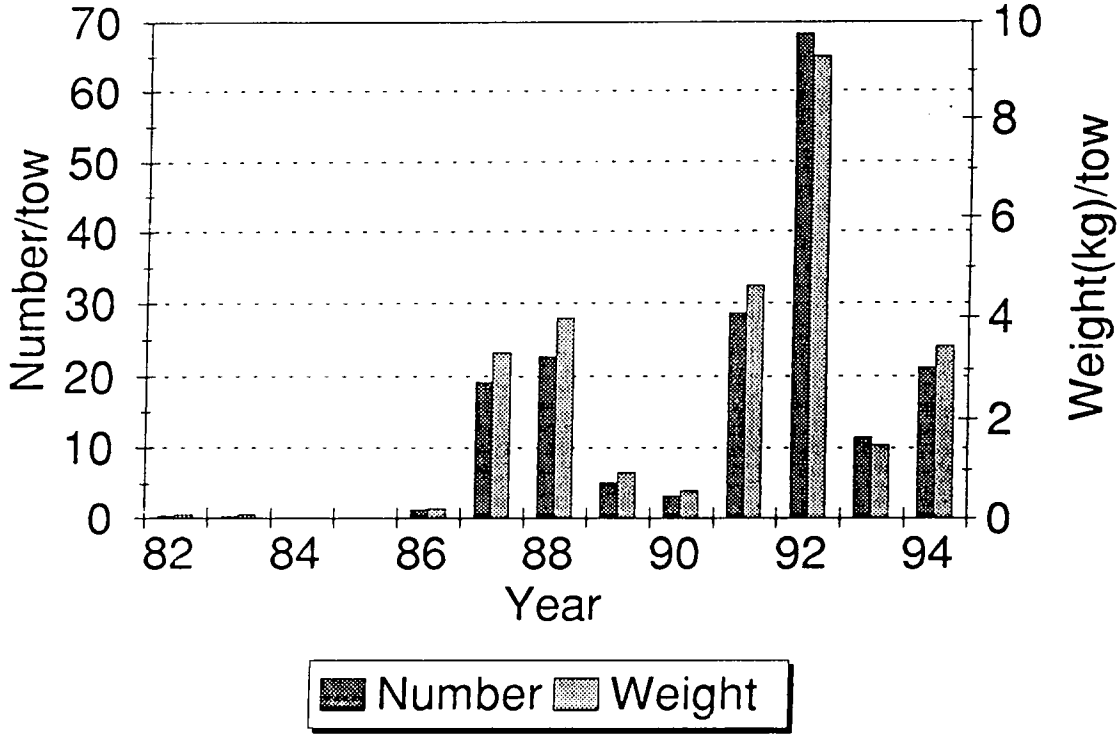


Figure 4. a) US bottom trawl survey. Stratified mean weight per tow (1963 - 1994).
b) US bottom trawl survey. Stratified mean number and weight per tow (1982 - 1994).

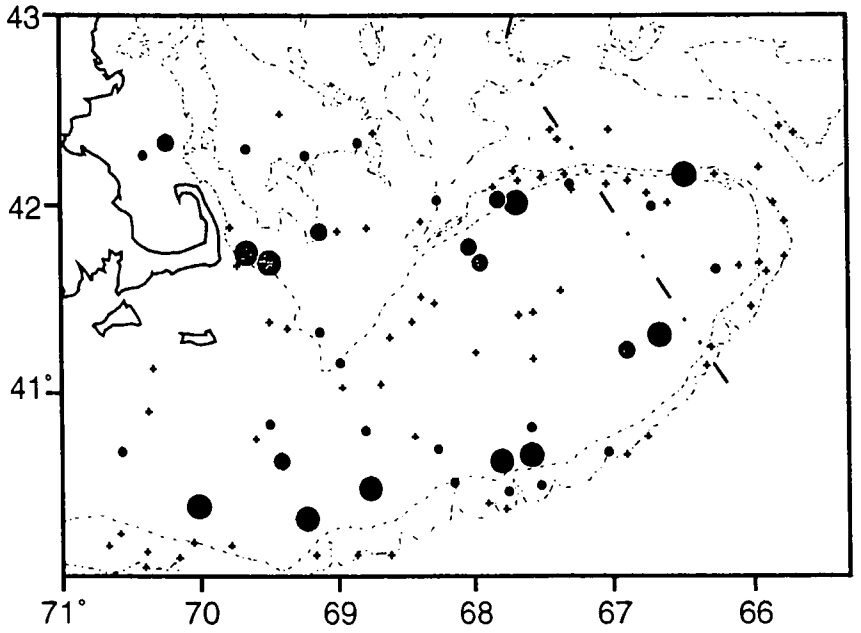


Figure 5a. US 1965 survey. Oct 6 - Nov 9
Adult herring as per adjacent scale.

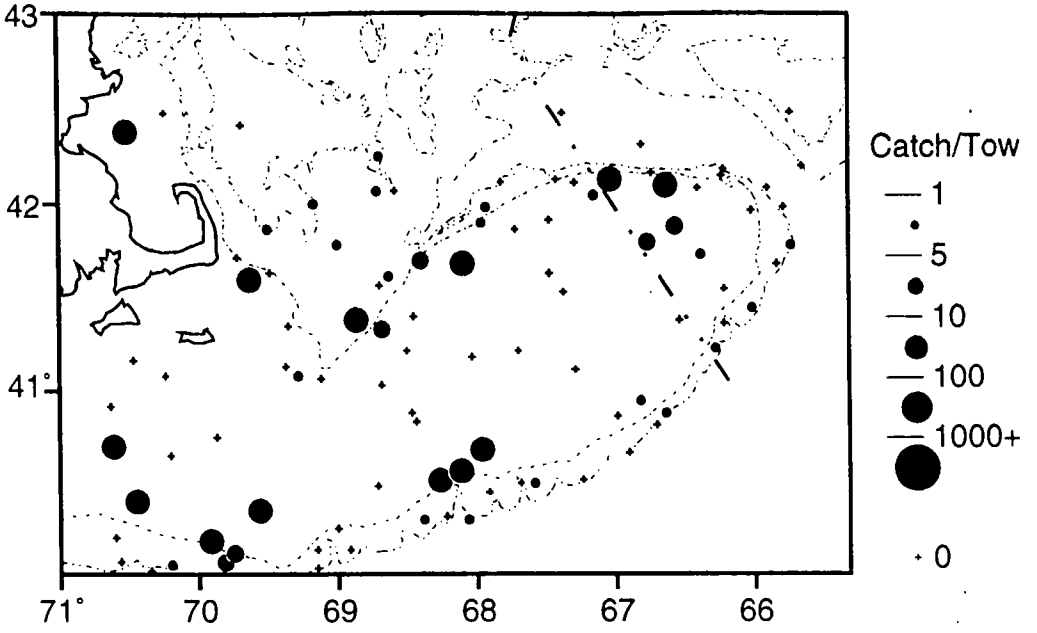


Figure 5b. US 1966 survey. Oct 12 - Nov 10
Adult herring as per adjacent scale.

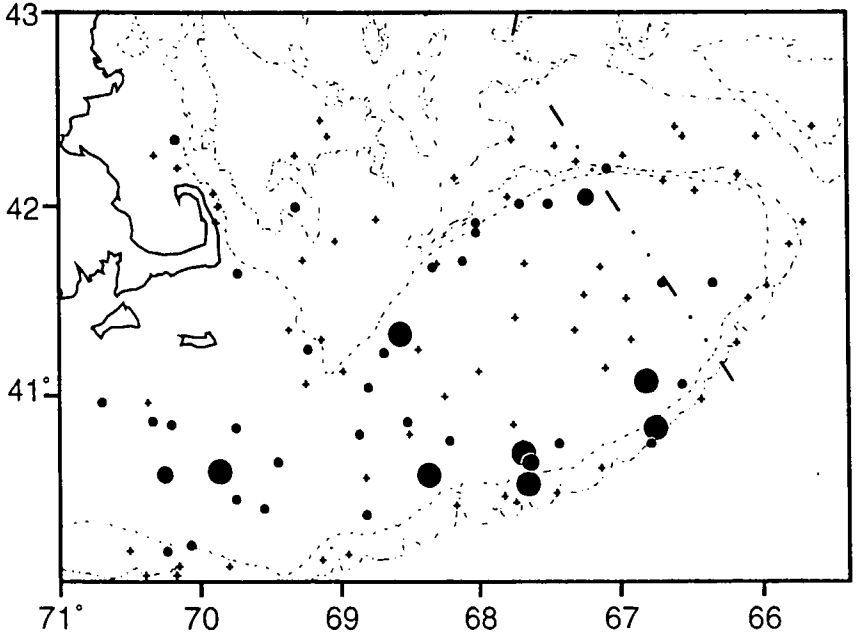


Figure 5c. US 1967 survey. Oct 17 - Dec 9
Adult herring as per adjacent scale.

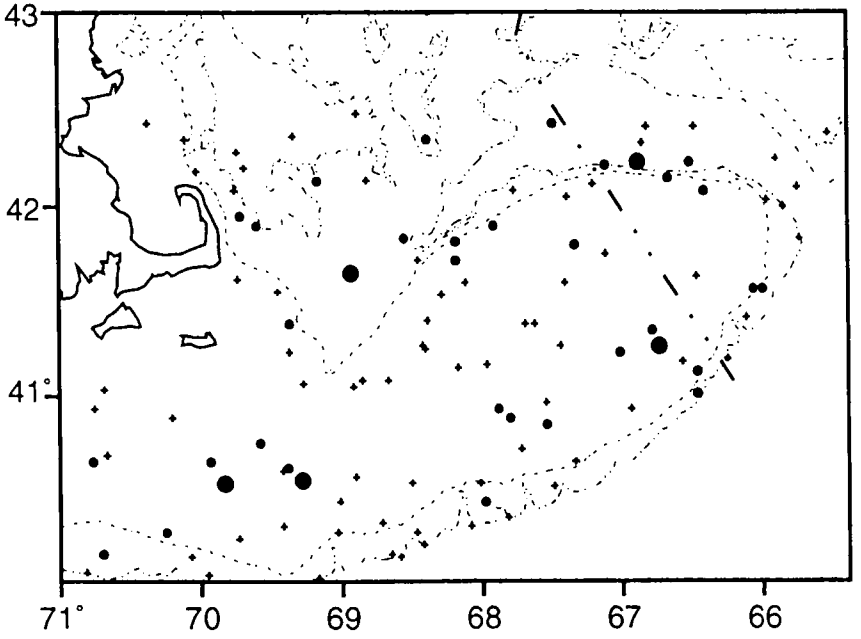


Figure 5d. US 1968 survey. Oct 10 - Nov 22
Adult herring as per adjacent scale.

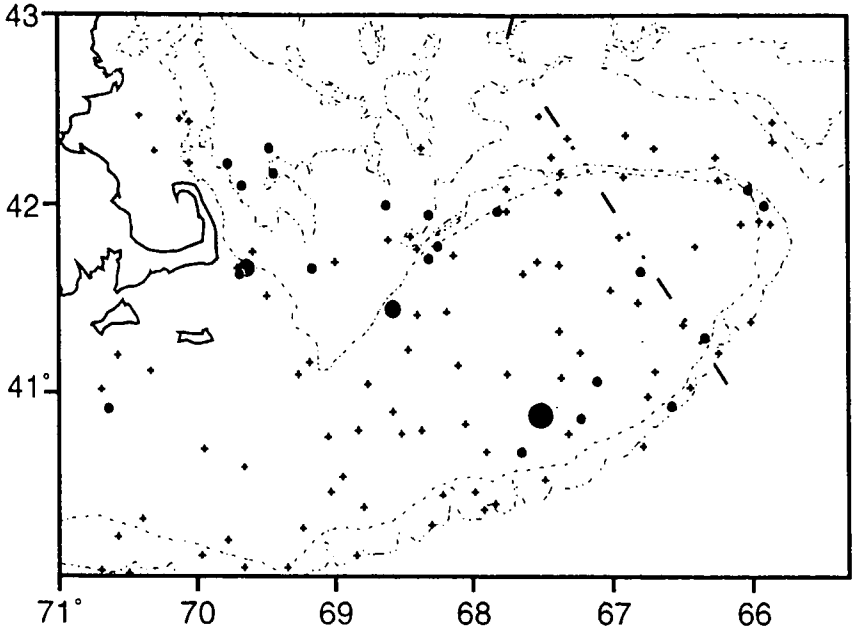


Figure 5e. US 1969 survey. Oct 9 - Nov 23
Adult herring as per adjacent scale.

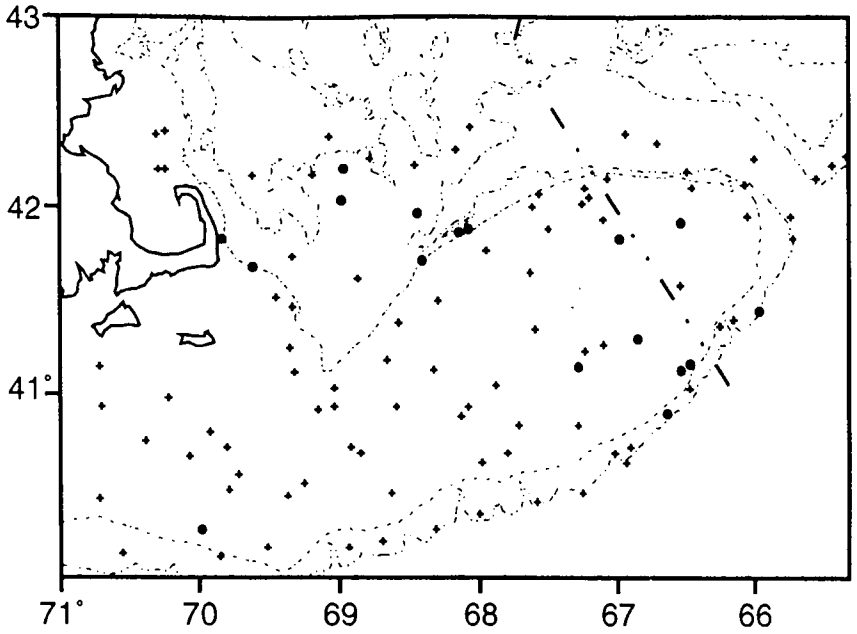


Figure 5f. US 1970 survey. Oct 16 - Nov 20
Adult herring as per adjacent scale.

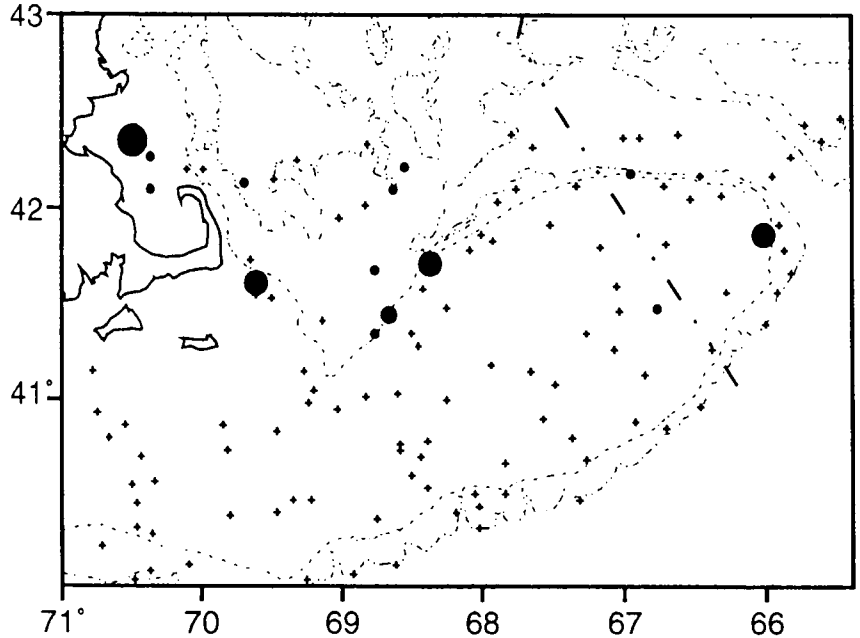


Figure 5g. US 1971 survey. Sept 29 - Nov 19
Adult herring as per adjacent scale.

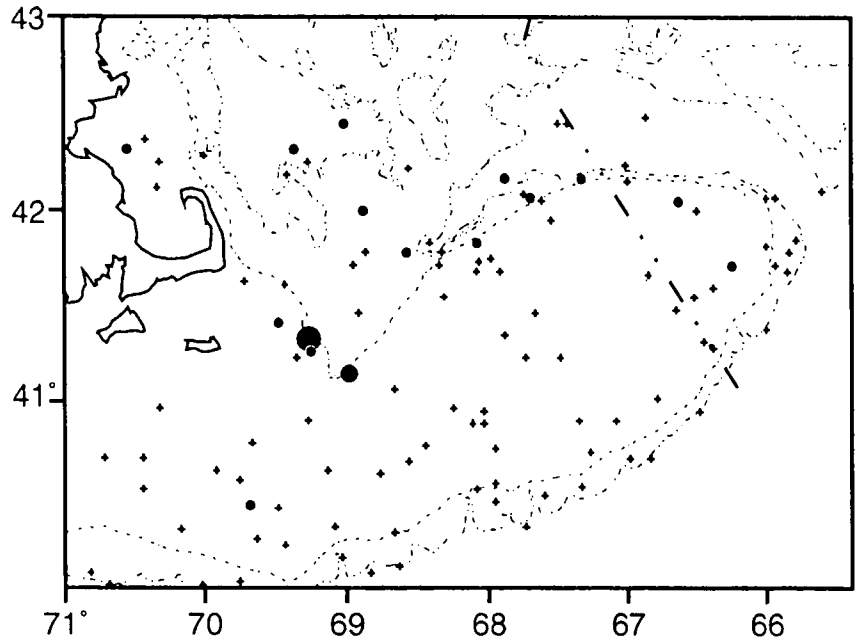


Figure 5h. US 1972 survey. Sept 29 - Nov 19
Adult herring as per adjacent scale.

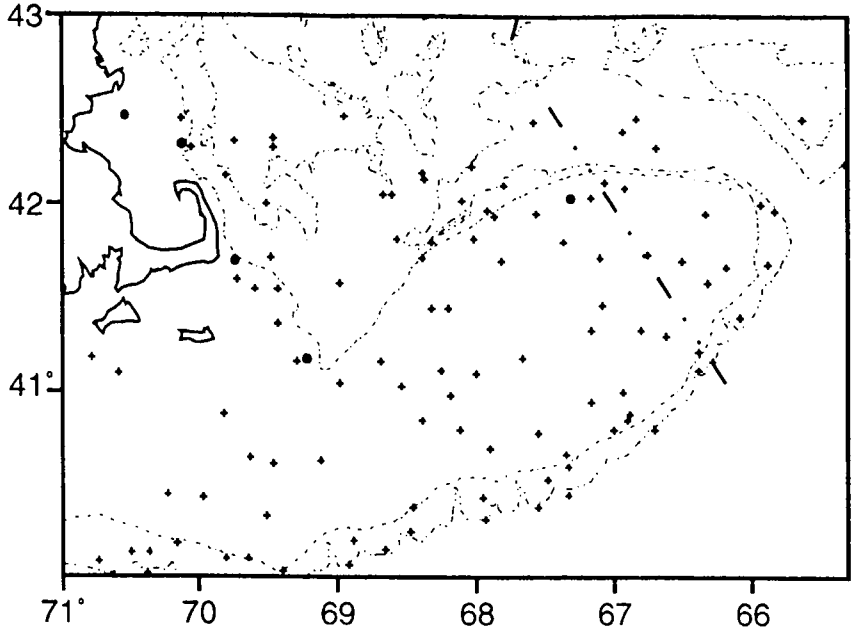
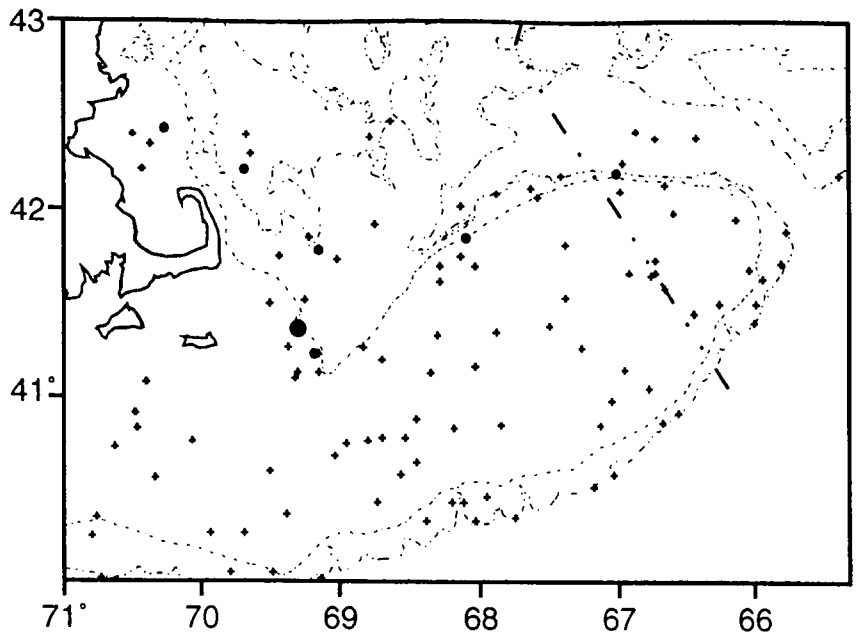


Figure 5i. US 1973 survey. Oct 6 - Nov 19
Adult herring as per adjacent scale.



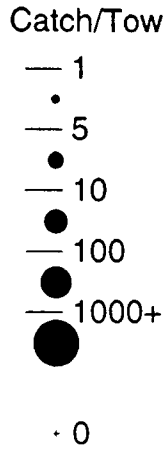


Figure 5j. US 1974 survey. Sept 23 - Nov 1
Adult herring as per adjacent scale.

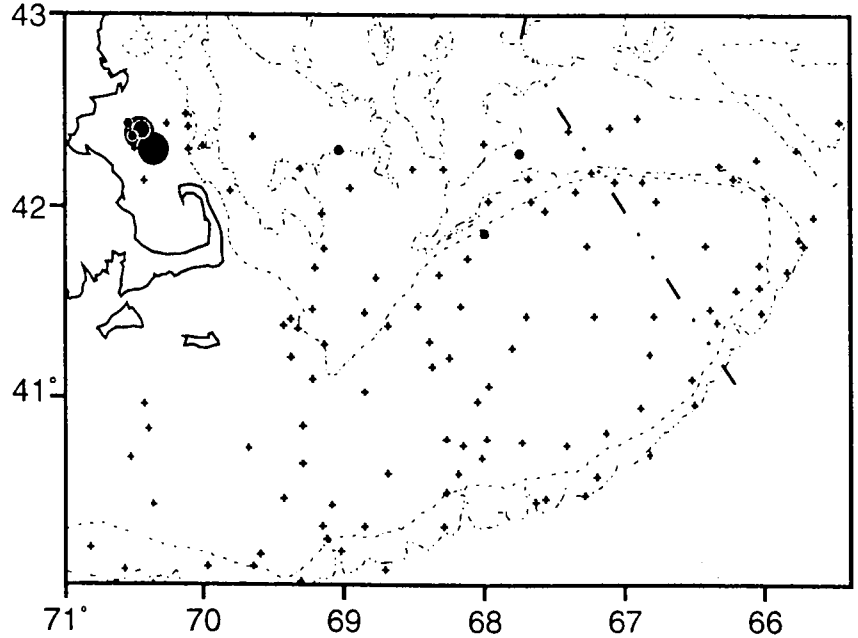


Figure 5k. US 1975 survey. Oct 7 - Nov 9
Adult herring as per adjacent scale.

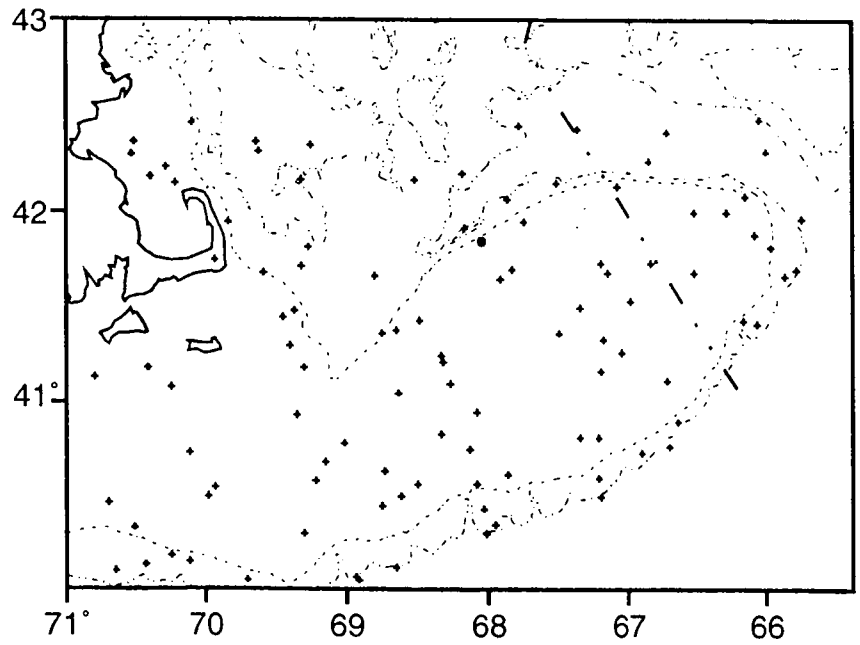


Figure 5l. US 1976 survey. Sept 29 - Nov 22
Adult herring as per adjacent scale.

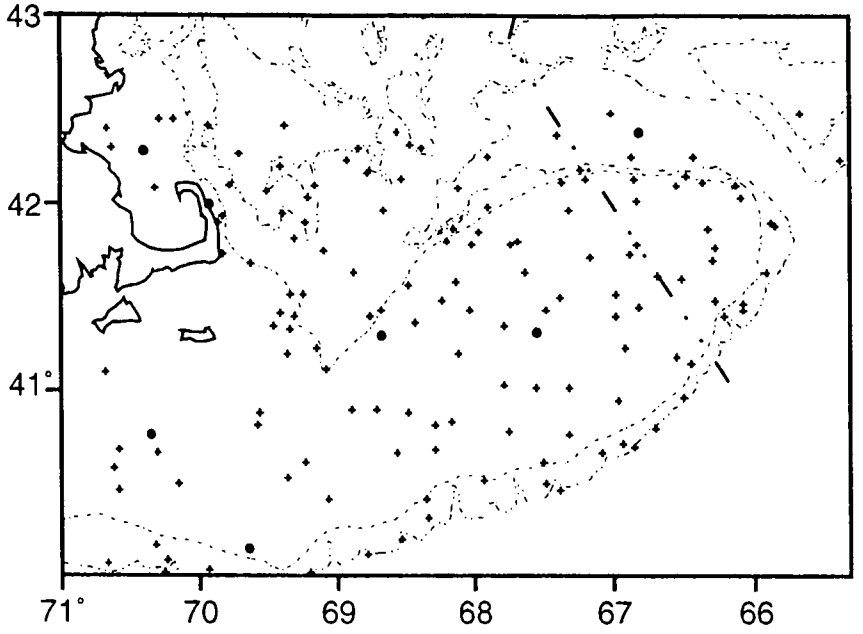


Figure 5m. US 1977 survey. Oct 16 - Dec 15
Adult herring as per adjacent scale.

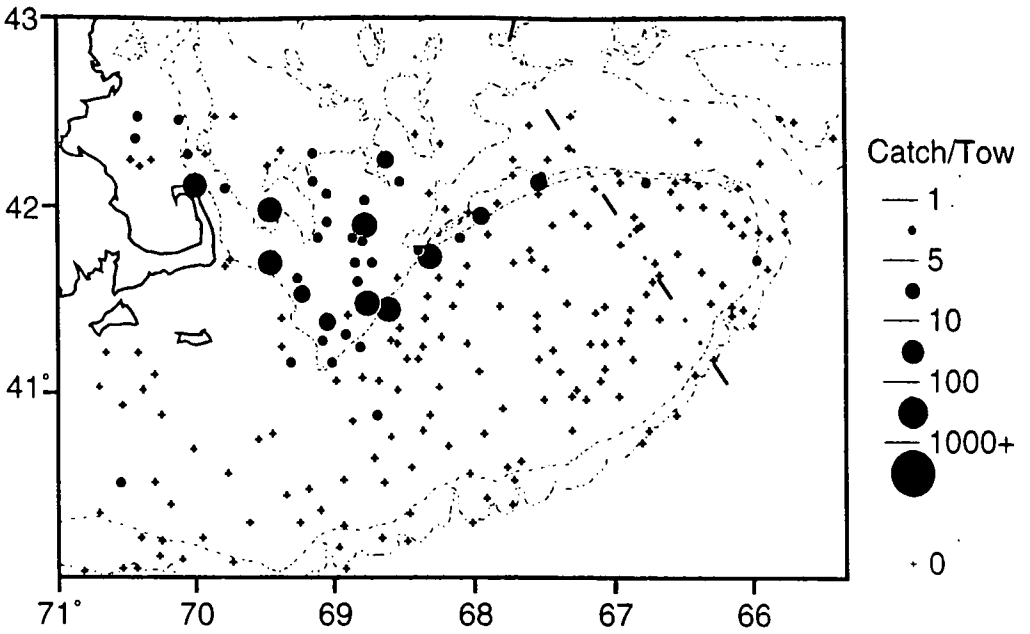


Figure 5n. US 1978 survey. Sept 26 - Nov 20
Adult herring as per adjacent scale.

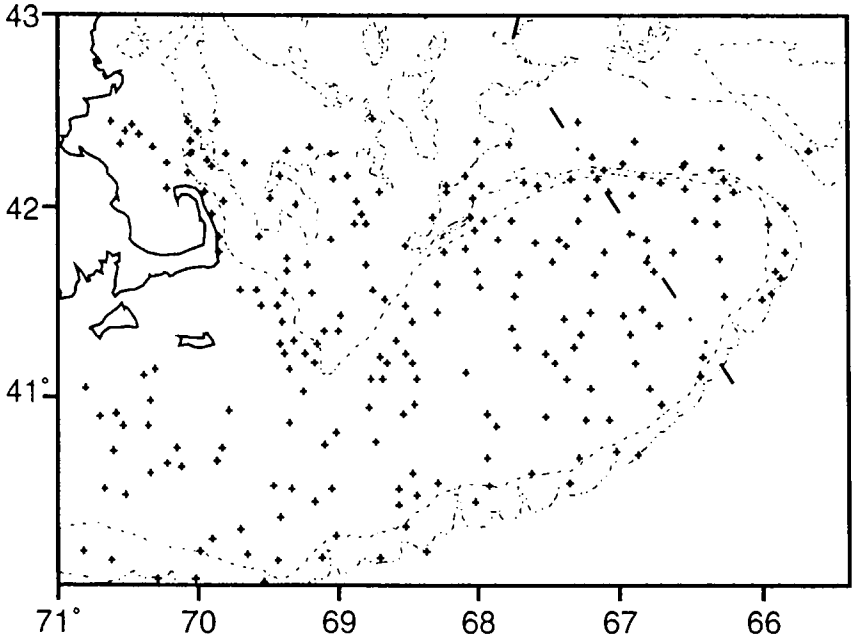


Figure 5o. US 1979 survey. Oct 12 - Nov 18
Adult herring as per adjacent scale.

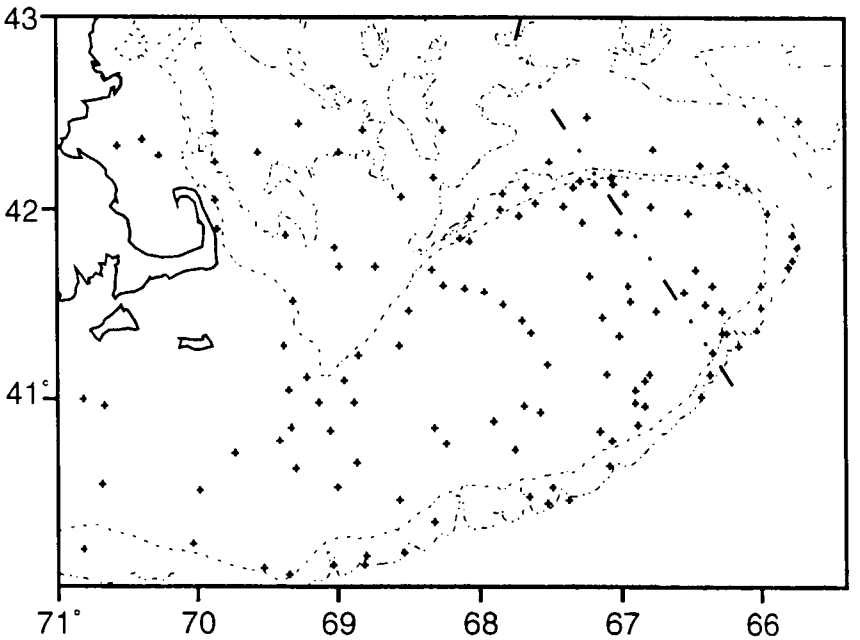


Figure 5p. US 1980 survey. Oct 7 - Nov 14
Adult herring as per adjacent scale.

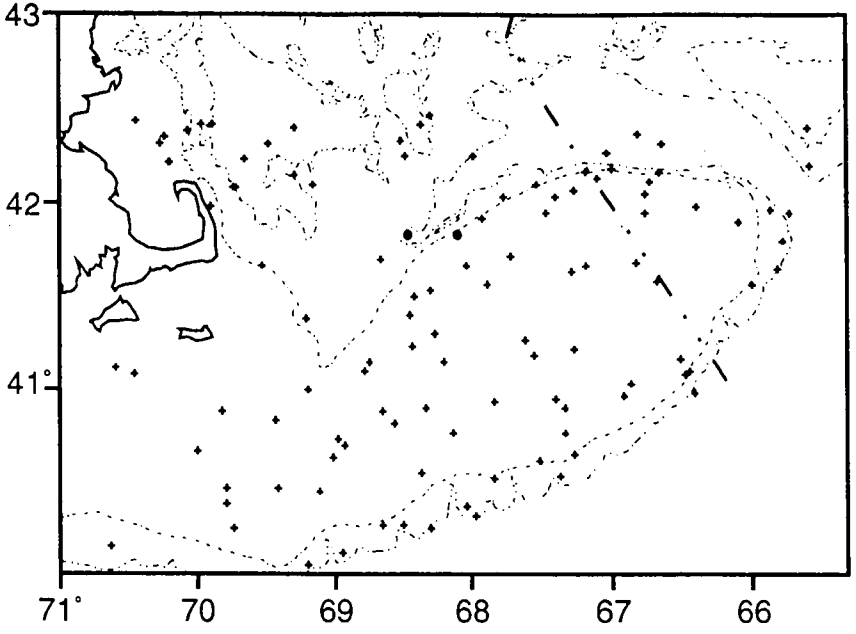


Figure 5q. US 1981 survey. Oct 6 - Nov 7
Adult herring as per adjacent scale.

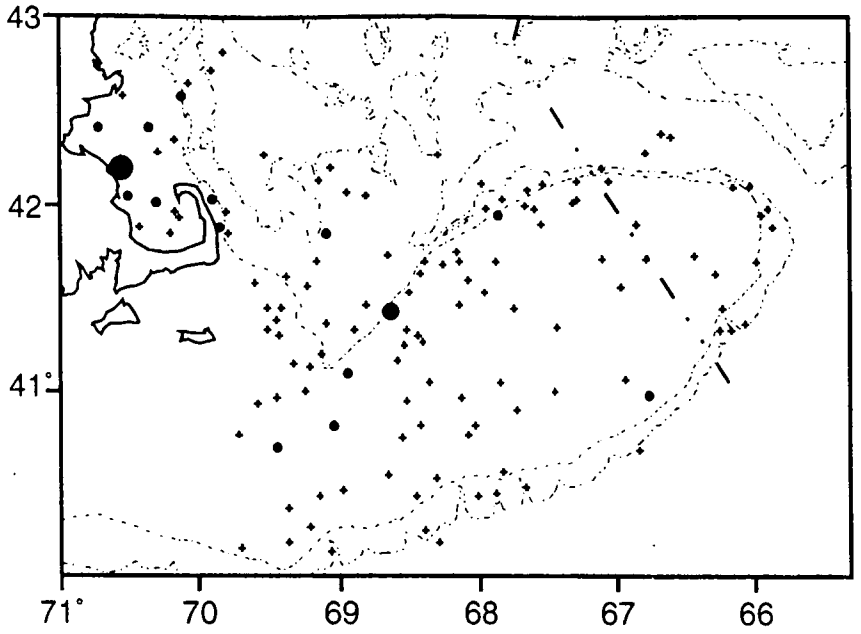


Figure 5r. US 1982 survey. Oct 12 - Nov 11
Adult herring as per adjacent scale.

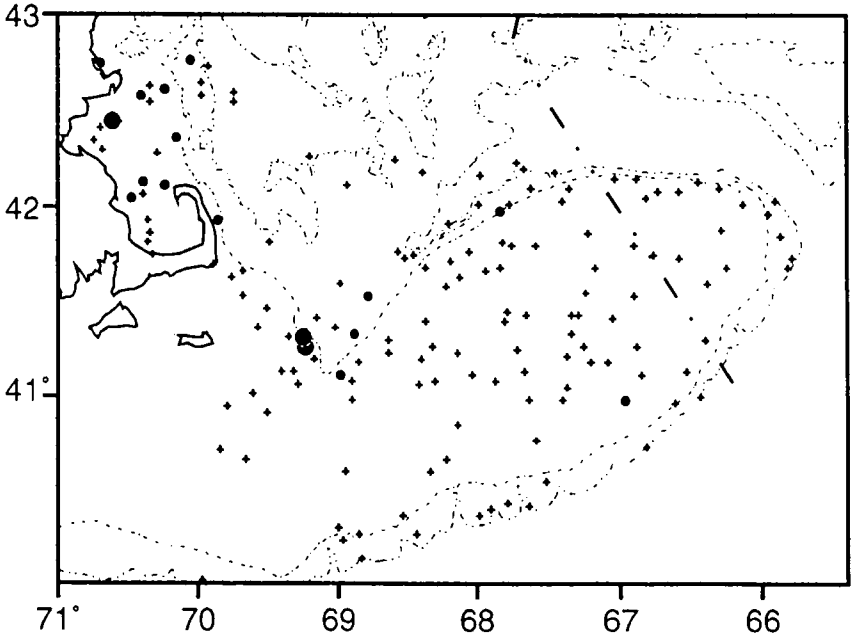


Figure 5s. US 1983 survey. Oct 8 - Nov 9
Adult herring as per adjacent scale.

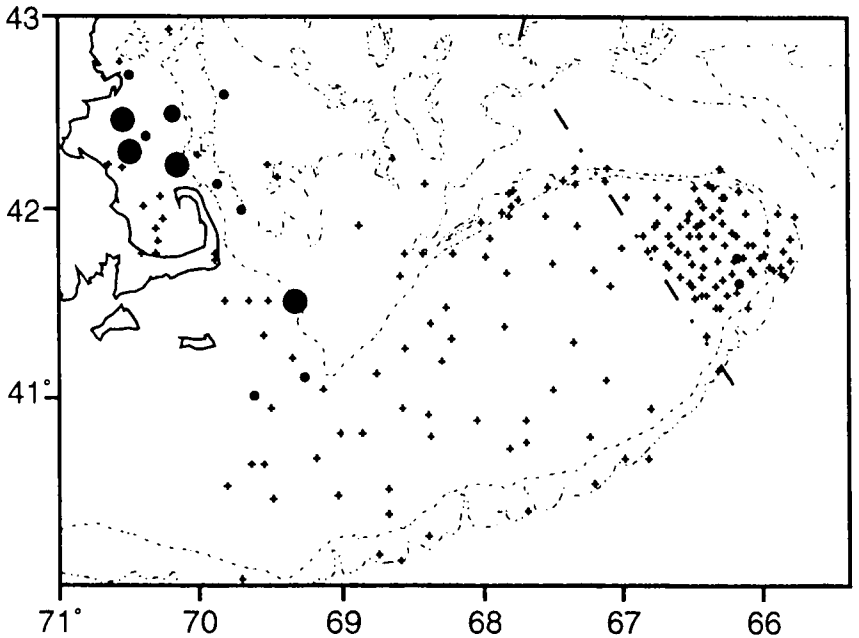


Figure 5t. US 1984 survey. Sept 11 - Nov 6
Adult herring as per adjacent scale.

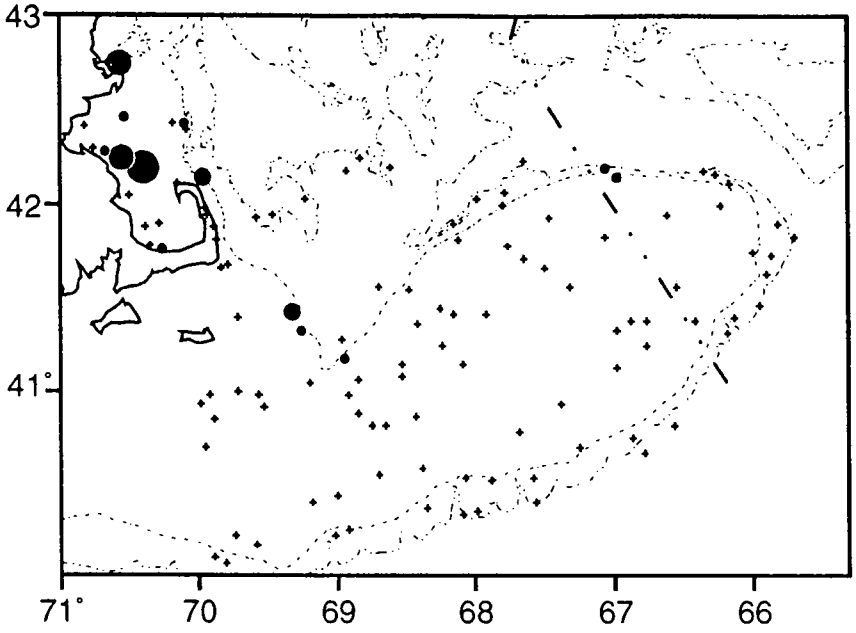


Figure 5u. US 1985 survey. Oct 17 - Nov 15
Adult herring as per adjacent scale.

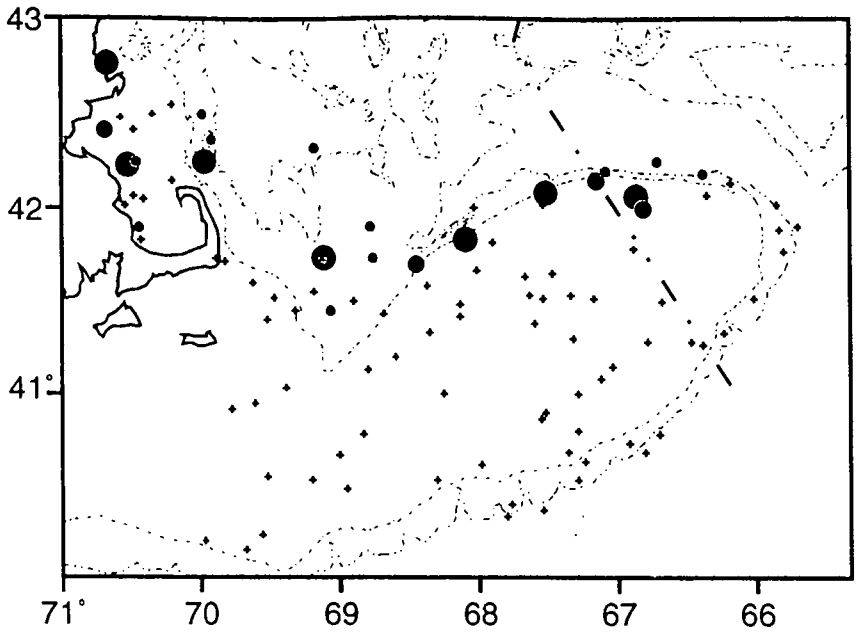


Figure 5v. US 1986 survey. Oct 7 - Nov 5
Adult herring as per adjacent scale.

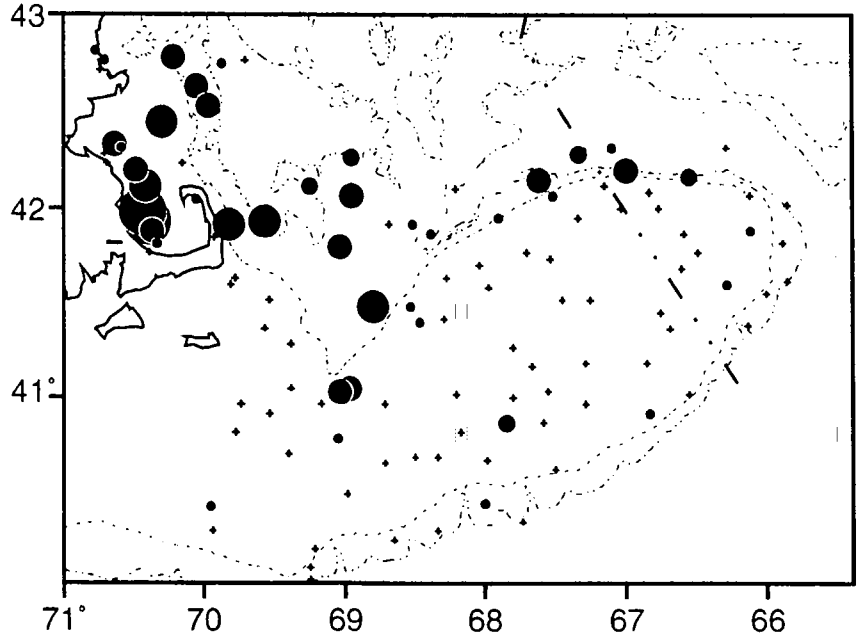


Figure 5w. US 1987 survey. Oct 2 - Nov 5
Adult herring as per adjacent scale.

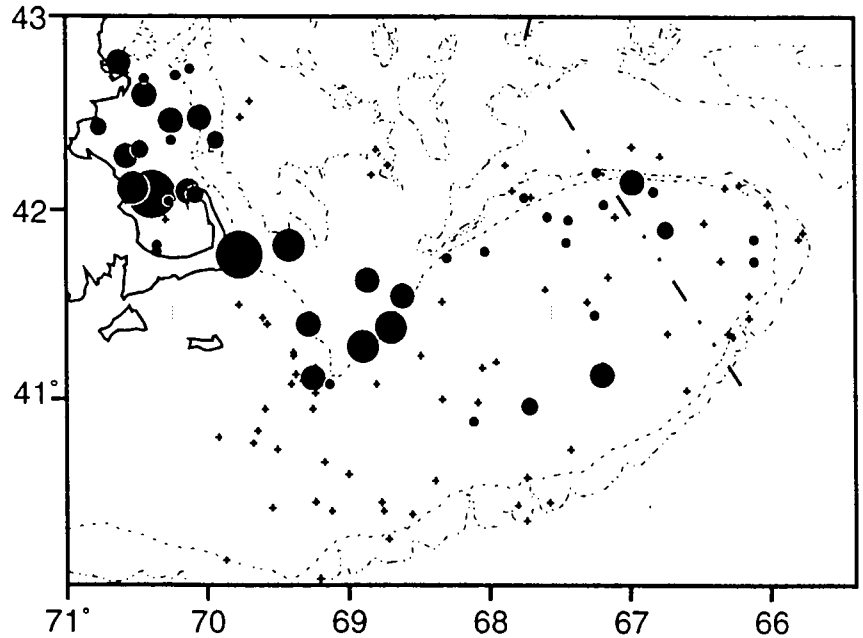


Figure 5x. US 1988 survey. Sept 29 - Oct 27
Adult herring as per adjacent scale.

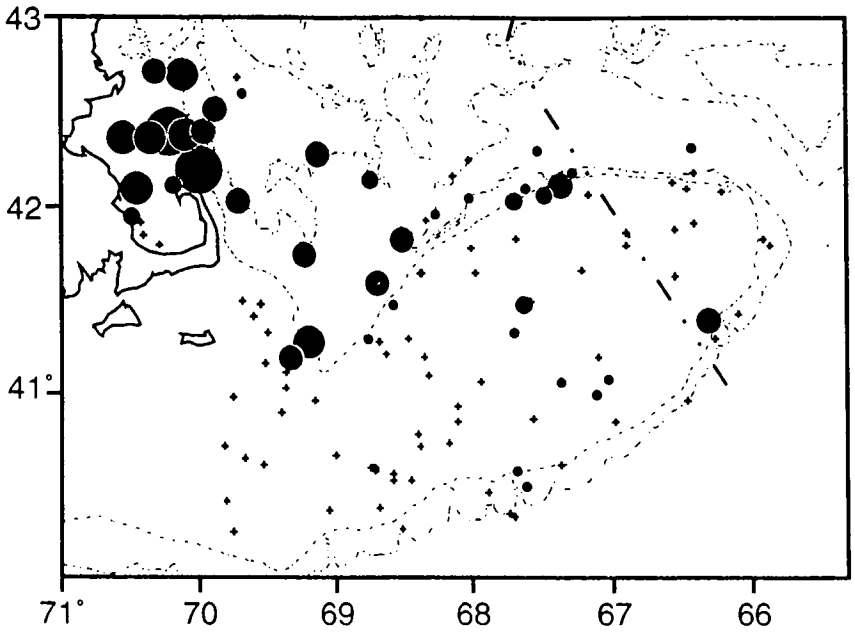


Figure 5y. US 1989 survey. Oct 6 - 31
Adult herring as per adjacent scale.

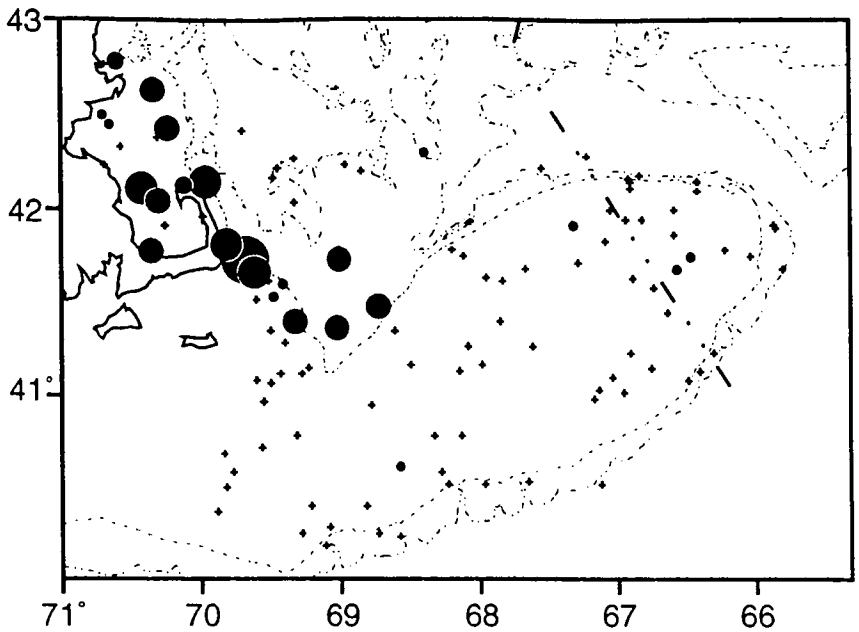


Figure 5z. US 1990 survey.Sept 27 - Oct 24
Adult herring as per adjacent scale.

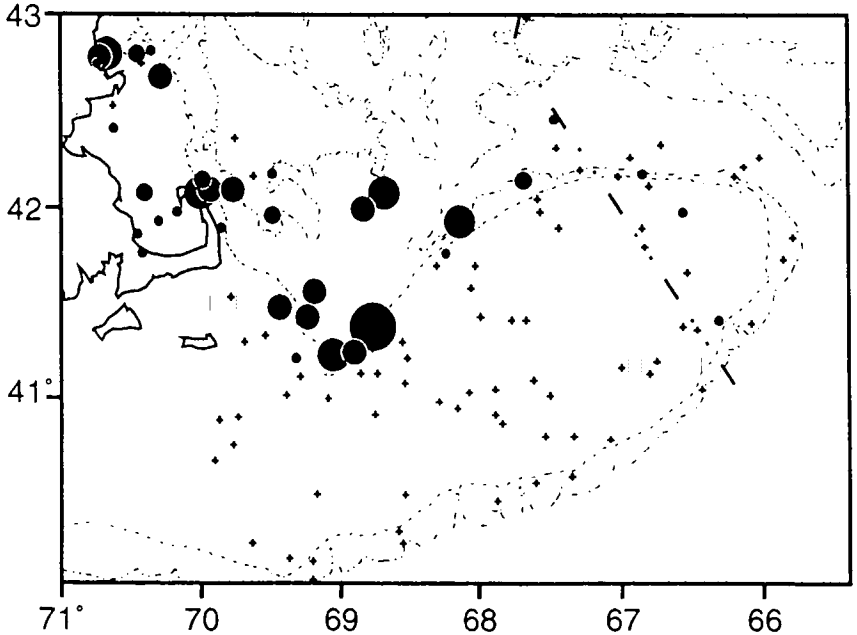


Figure 5aa. US 1991 survey. Sept 30 - Oct 24
Adult herring as per adjacent scale.

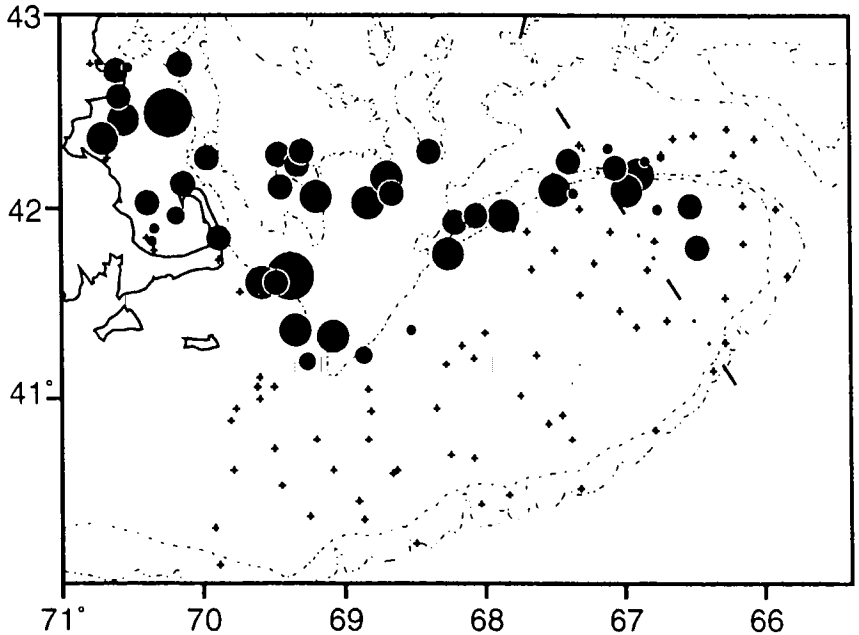


Figure 5bb. US 1992 survey. Oct 6 - 27
Adult herring as per adjacent scale.

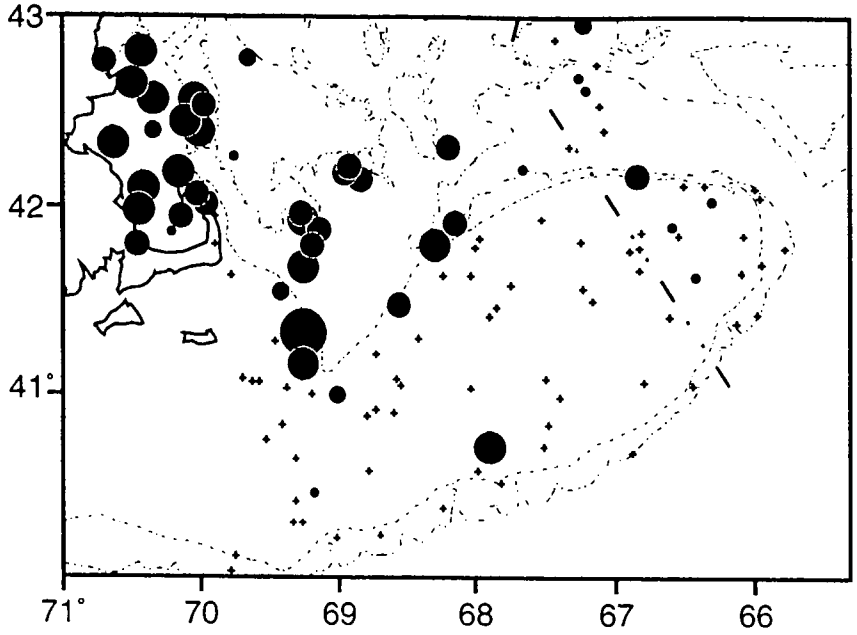


Figure 5cc. US 1993 survey. Sept 27 - Oct 20
Adult herring as per adjacent scale.

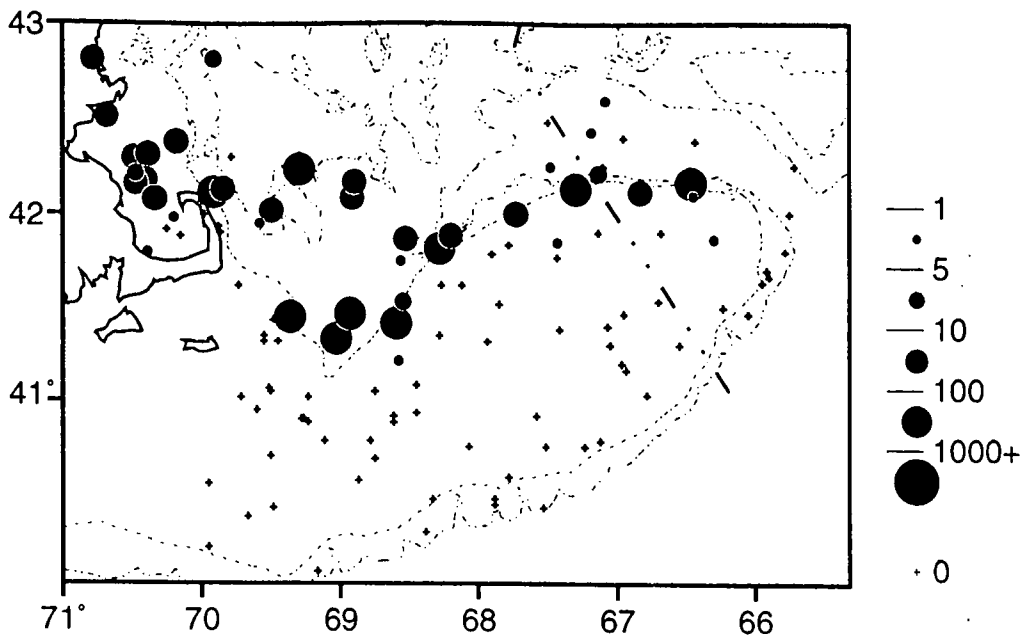


Figure 5dd. US 1994 survey. Oct 4 - 27
Adult herring as per adjacent scale.

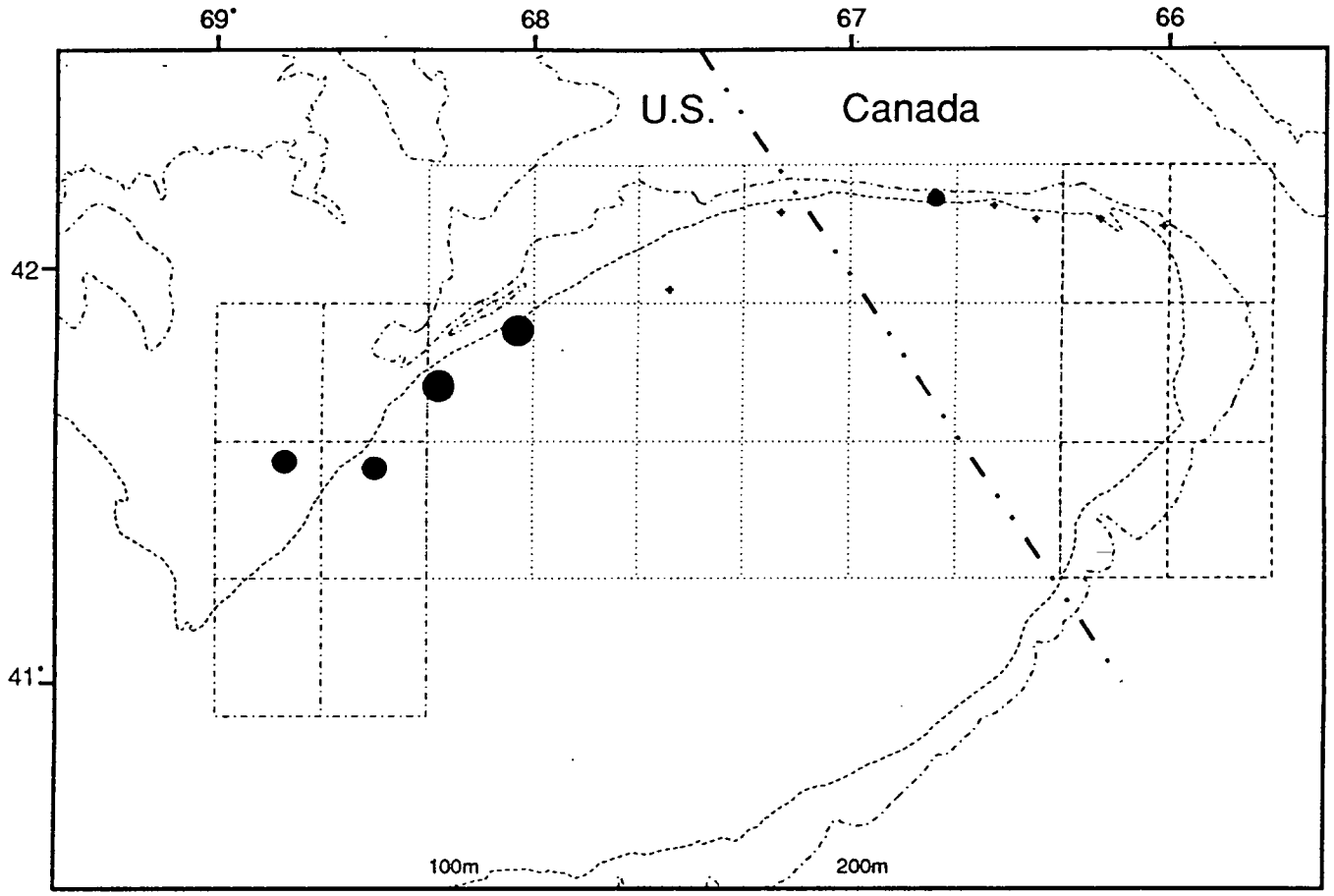


Figure 6a. Georges Bank Canadian 1987 research survey herring catch (#)/tow.

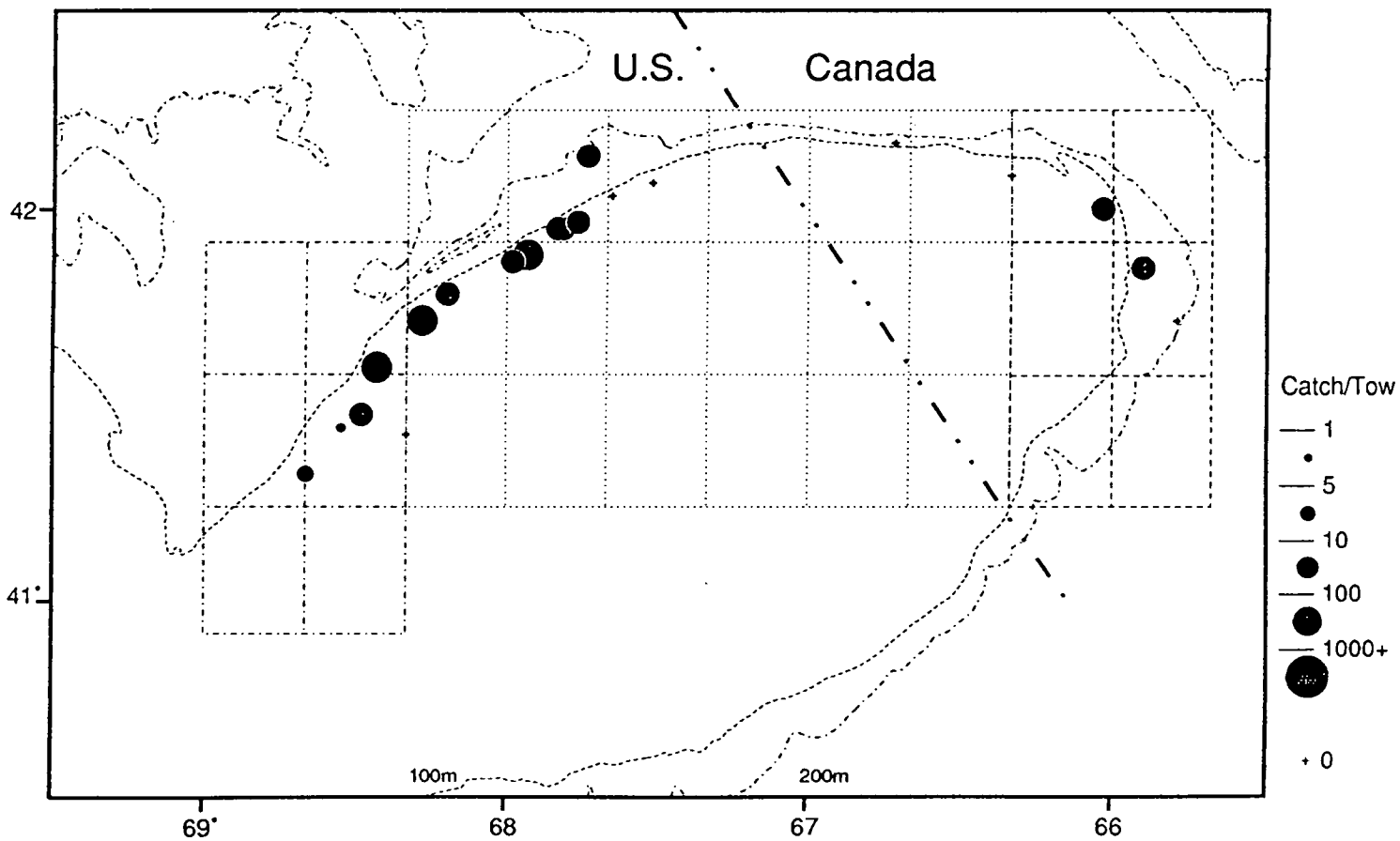


Figure 6b. Georges Bank Canadian 1988 research survey herring catch (#)/tow.

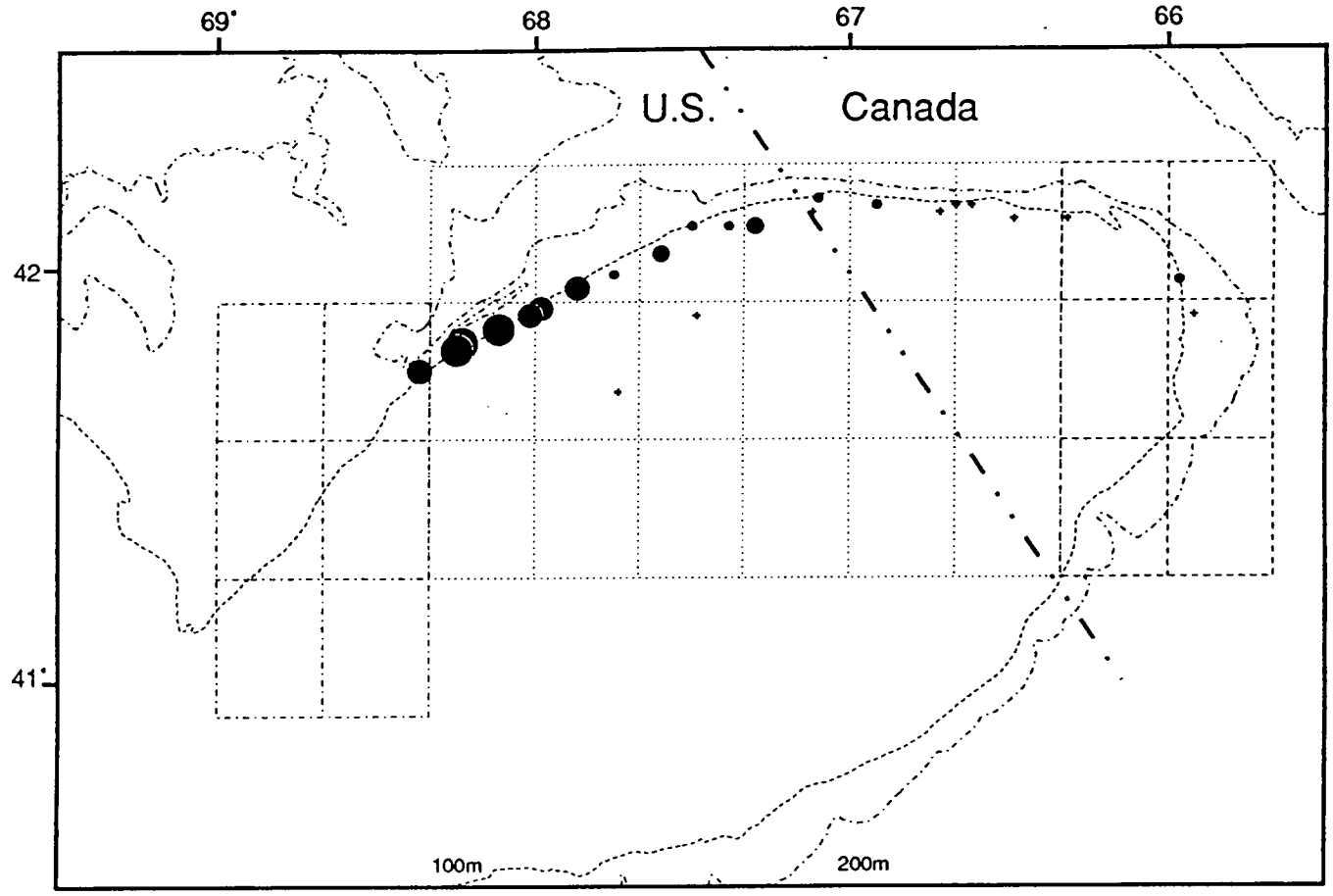


Figure 6c. Georges Bank Canadian 1989 research survey herring catch (#)/tow.

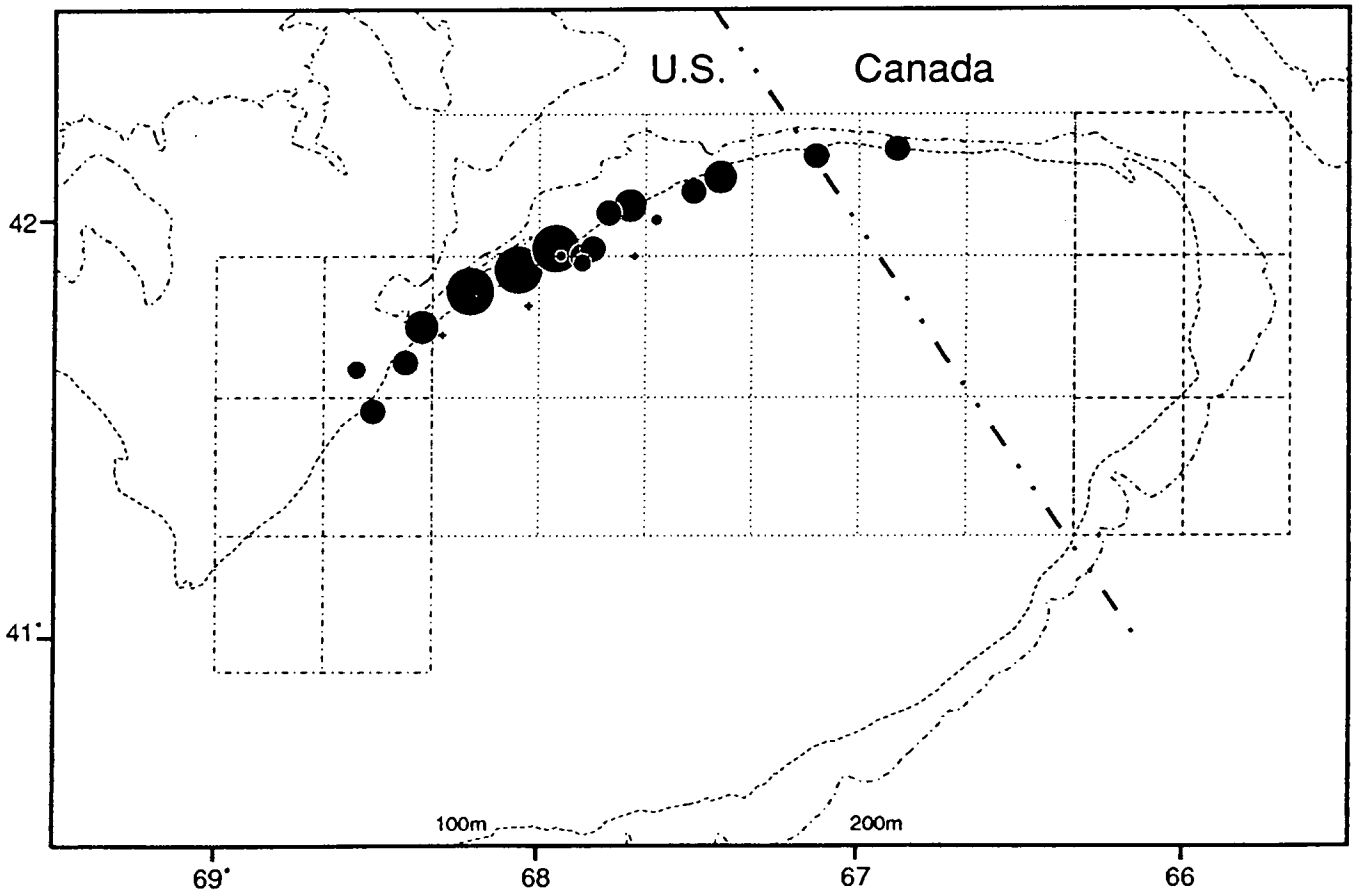


Figure 6d. Georges Bank Canadian 1990 research survey herring catch (#)/tow.

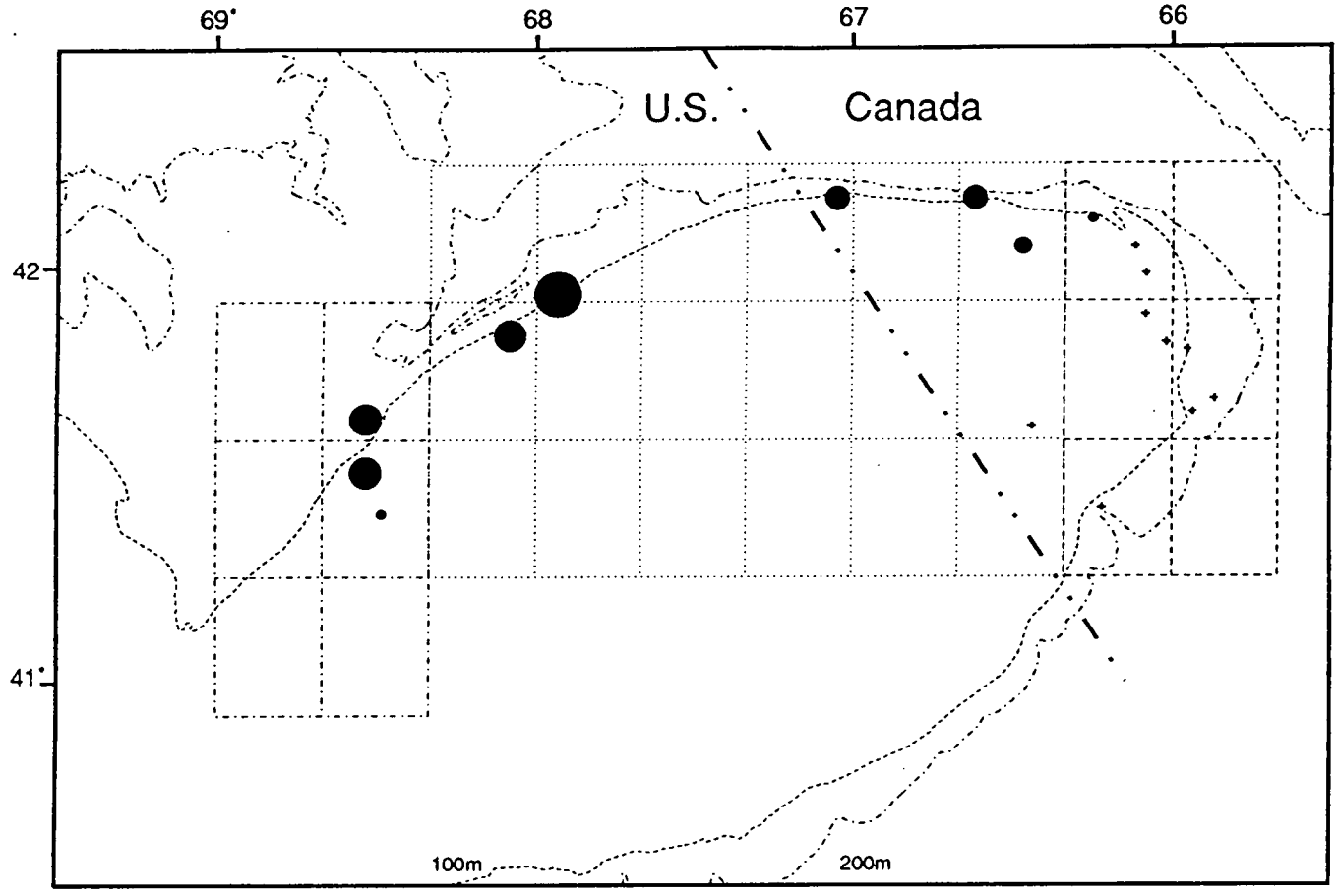


Figure 6e. Georges Bank Canadian 1991 research survey herring catch (#)/tow.

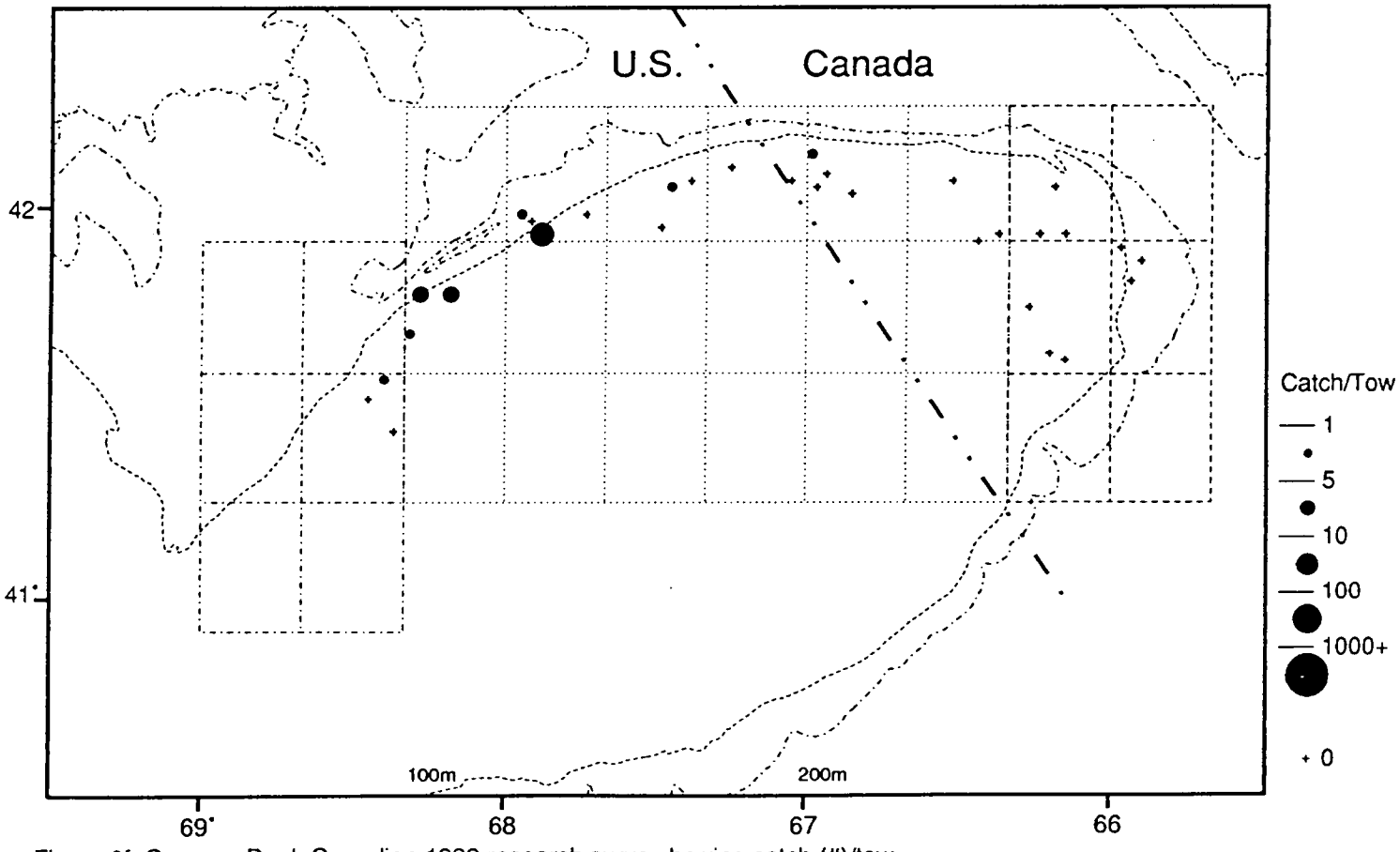


Figure 6f. Georges Bank Canadian 1992 research survey herring catch (#)/tow.

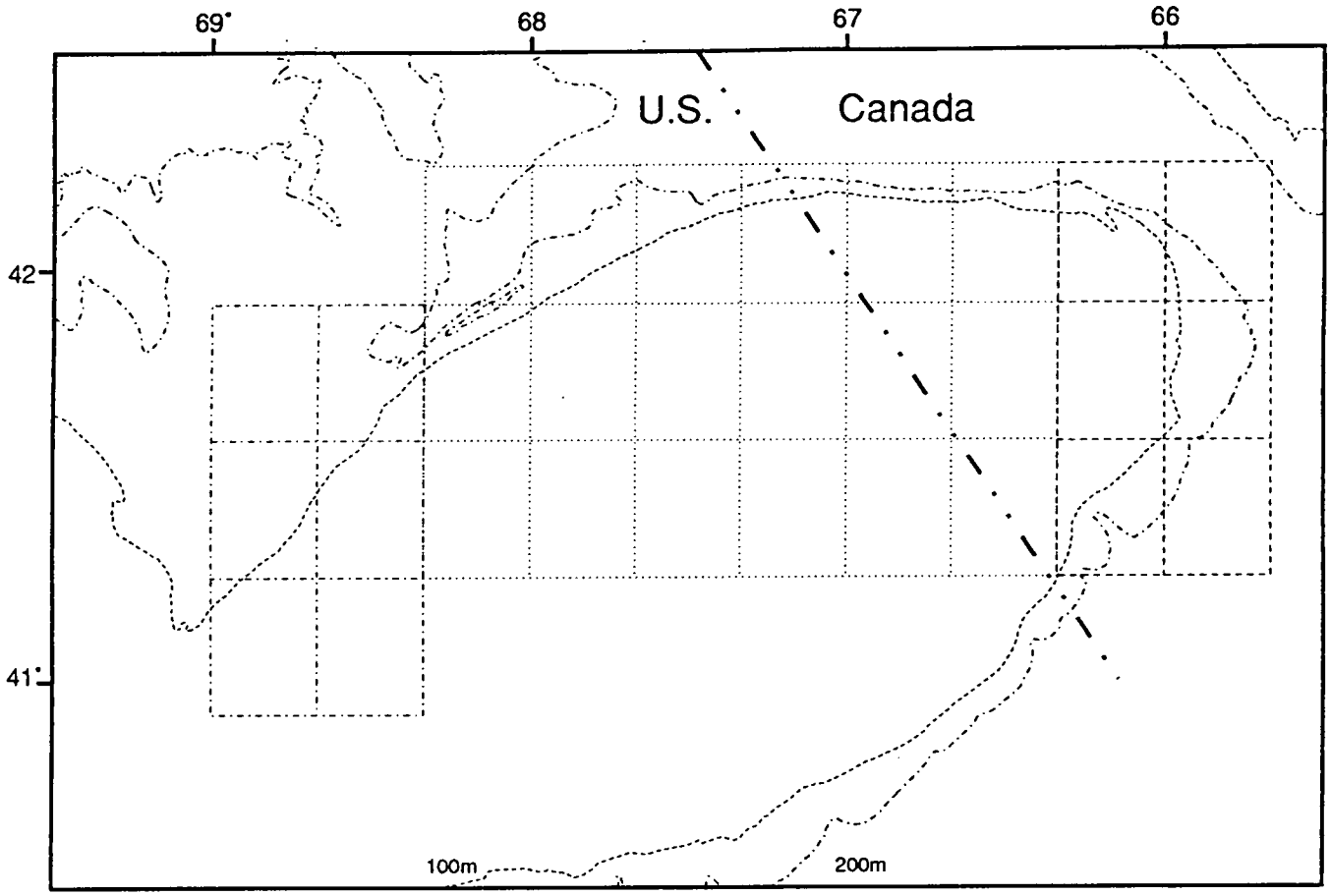


Figure 6g. Georges Bank Canadian 1993 research survey. No bottom trawl data.

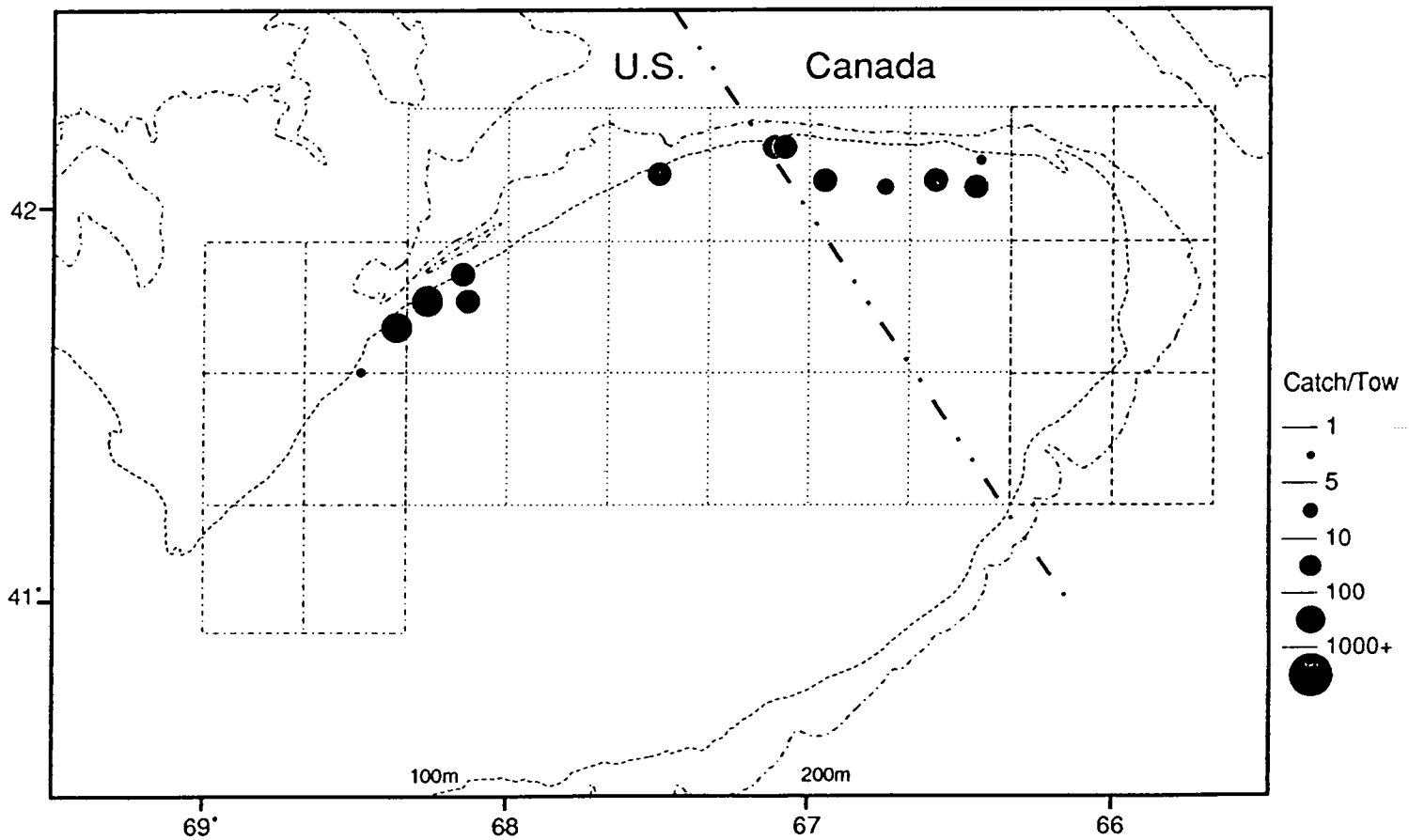


Figure 6h. Georges Bank Canadian 1994 research survey herring catch (#)/tow.

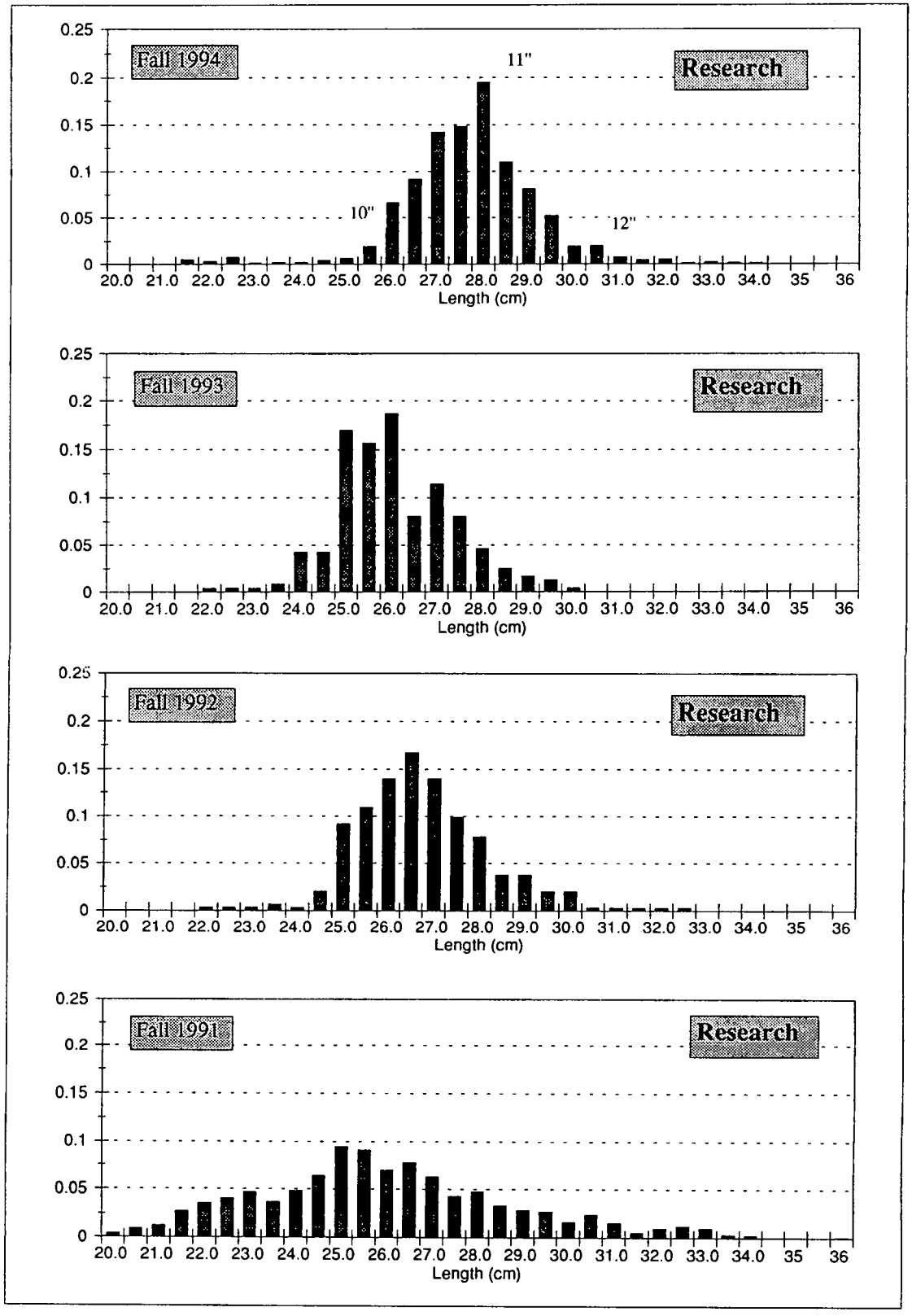


Figure 7a-d. Adult herring length frequencies from fall Canadian research cruises between the years 1994 - 1991.

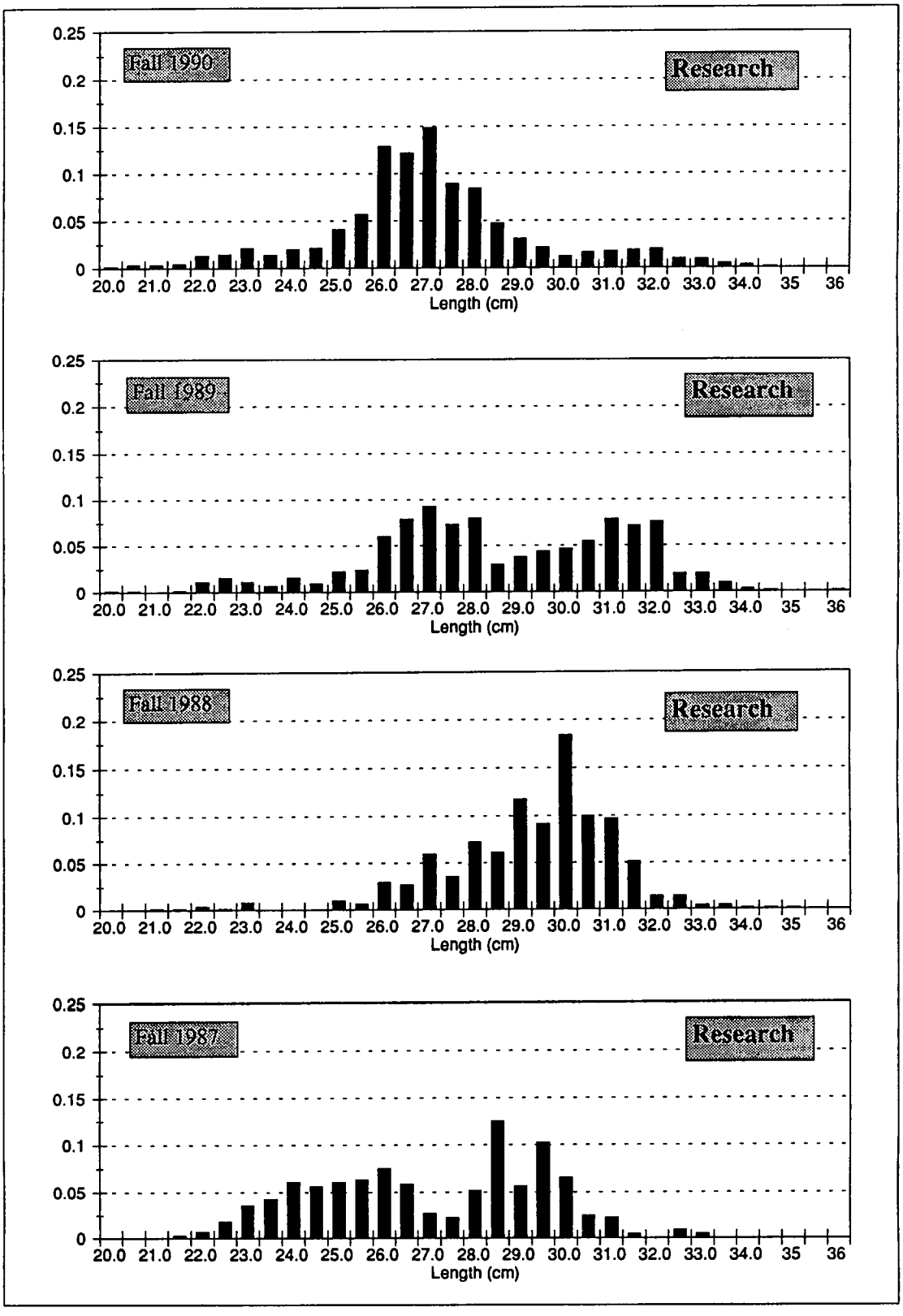


Figure 7e-h. Adult herring length frequencies from fall Canadian research cruises between the years 1990 - 1987.

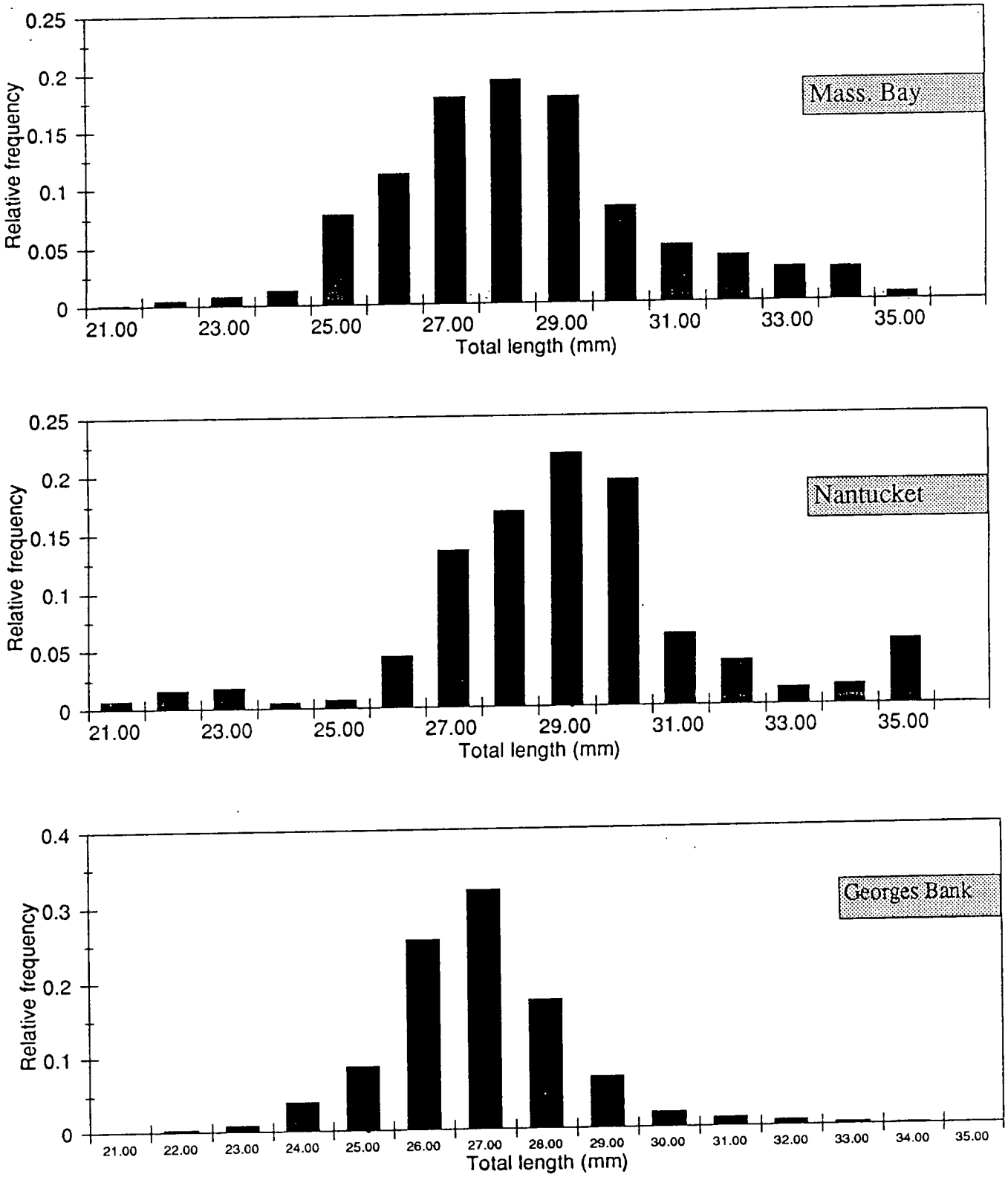


Figure 8. US 1993 bottom trawl survey length frequencies for Massachusetts Bay, Nantucket Shoal and Georges Bank.

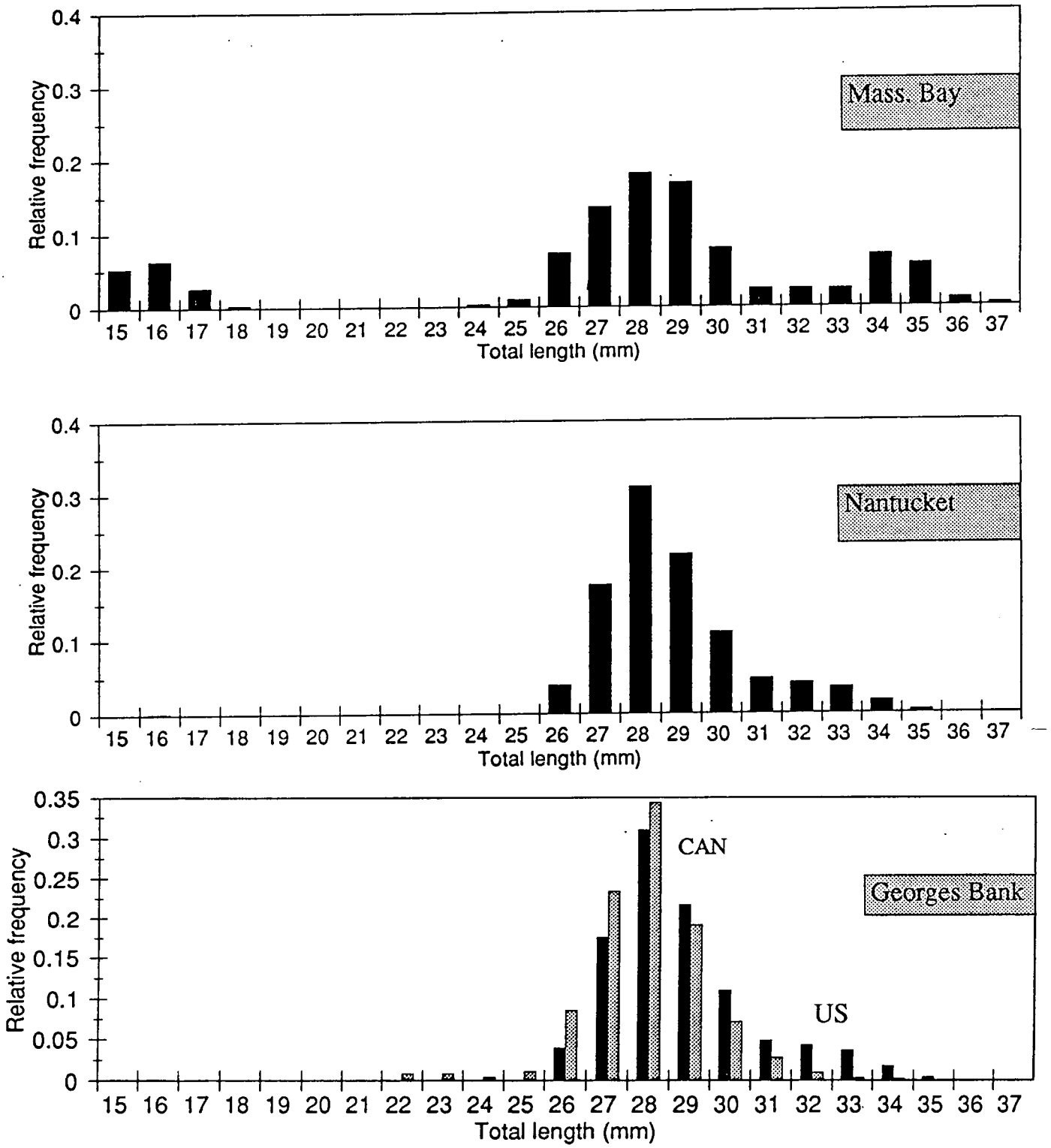


Figure 9. US 1994 bottom trawl survey length frequencies for Massachusetts Bay, Nantucket Shoal and Georges Bank. The Canadian 1994 bottom trawl survey length frequencies for Georges Bank in grey for comparison.

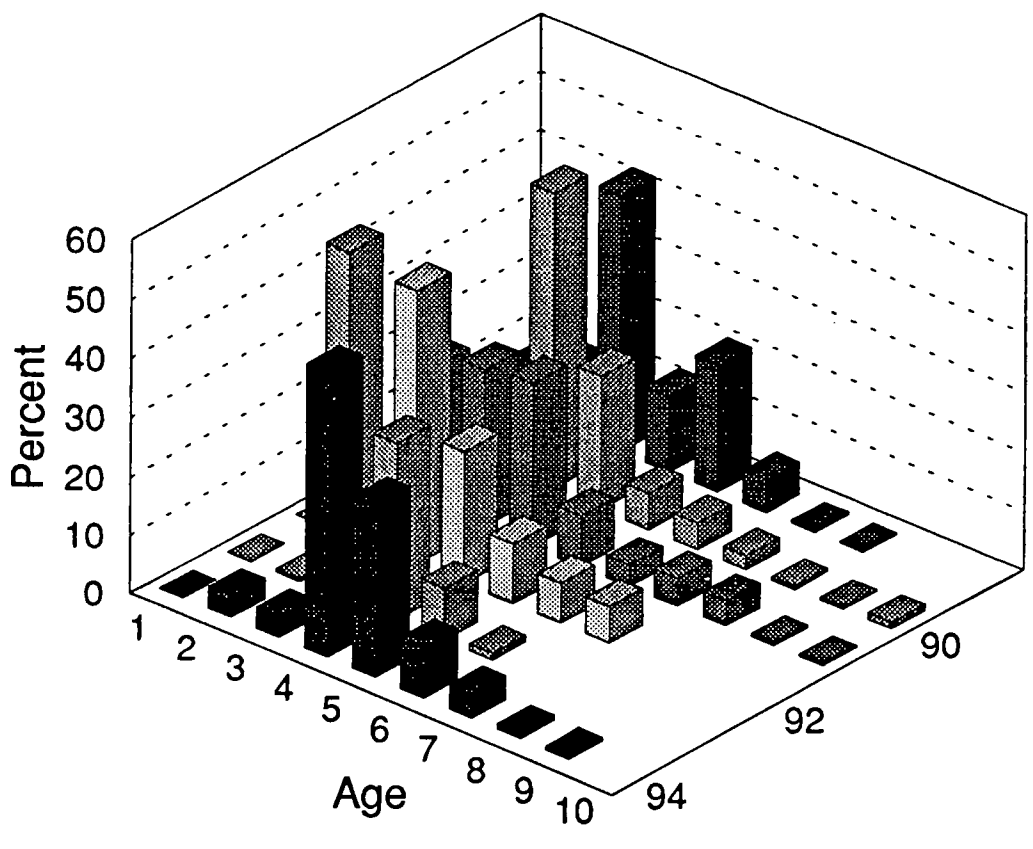


Figure 10.

Age frequency distribution of Georges Bank herring from 1989 - 1994 taken from Canadian survey results.

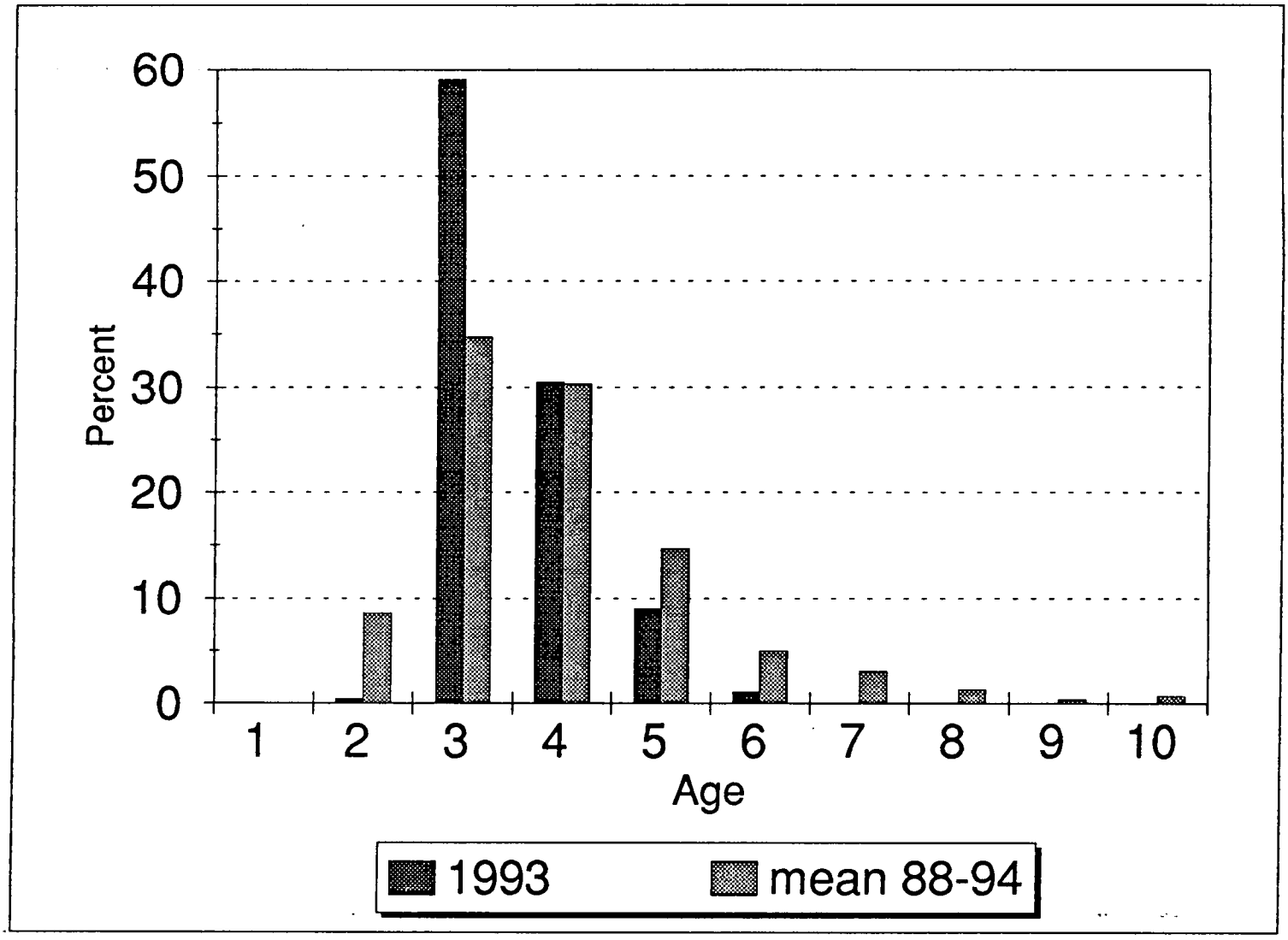


Figure 11. Georges Bank 1993 herring age distribution compared with the mean age diatribution between 1988 and 1994.

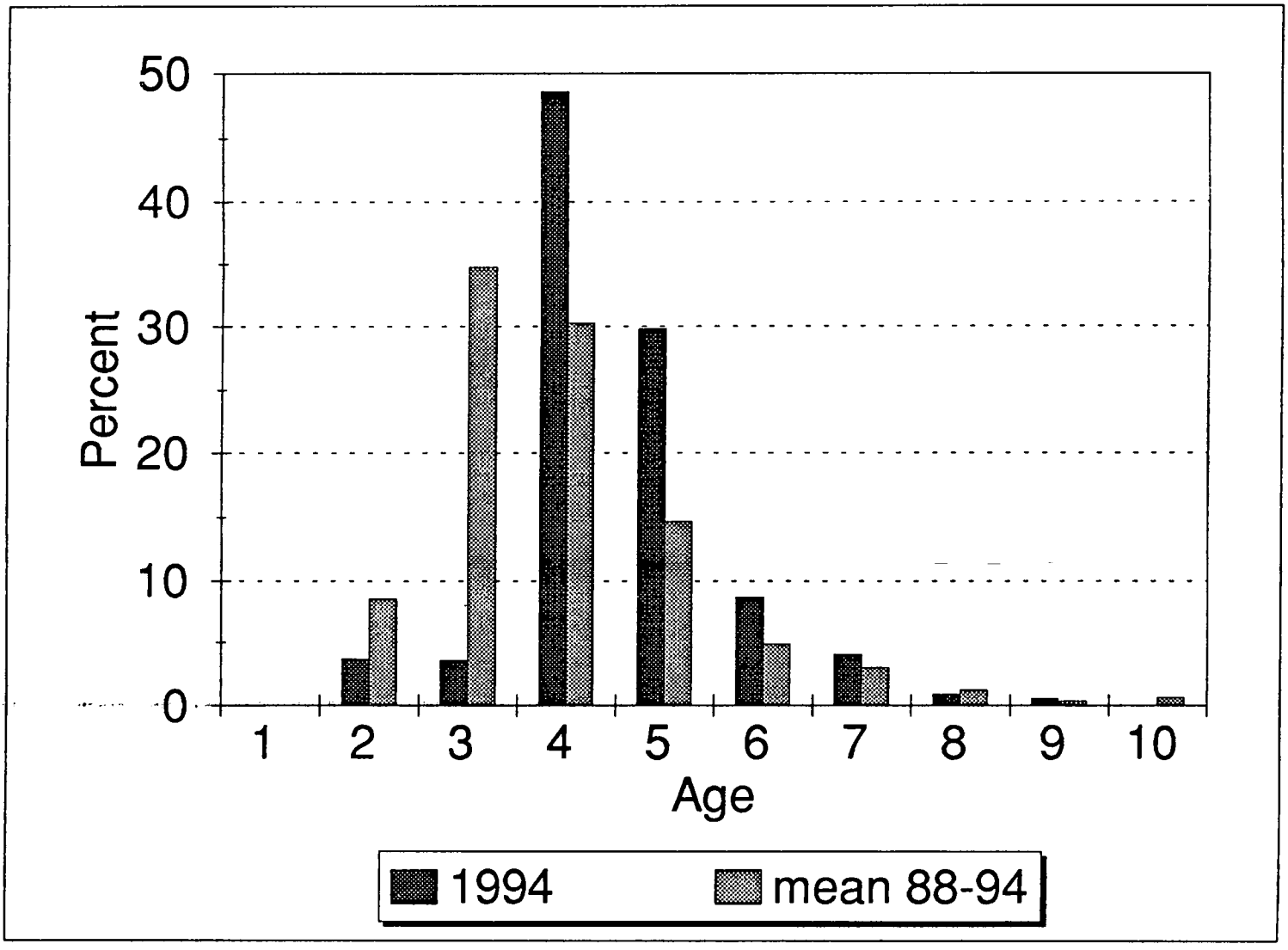


Figure 12. Georges Bank 1994 herring age distribution compared with the mean age distribution between 1988 and 1994.

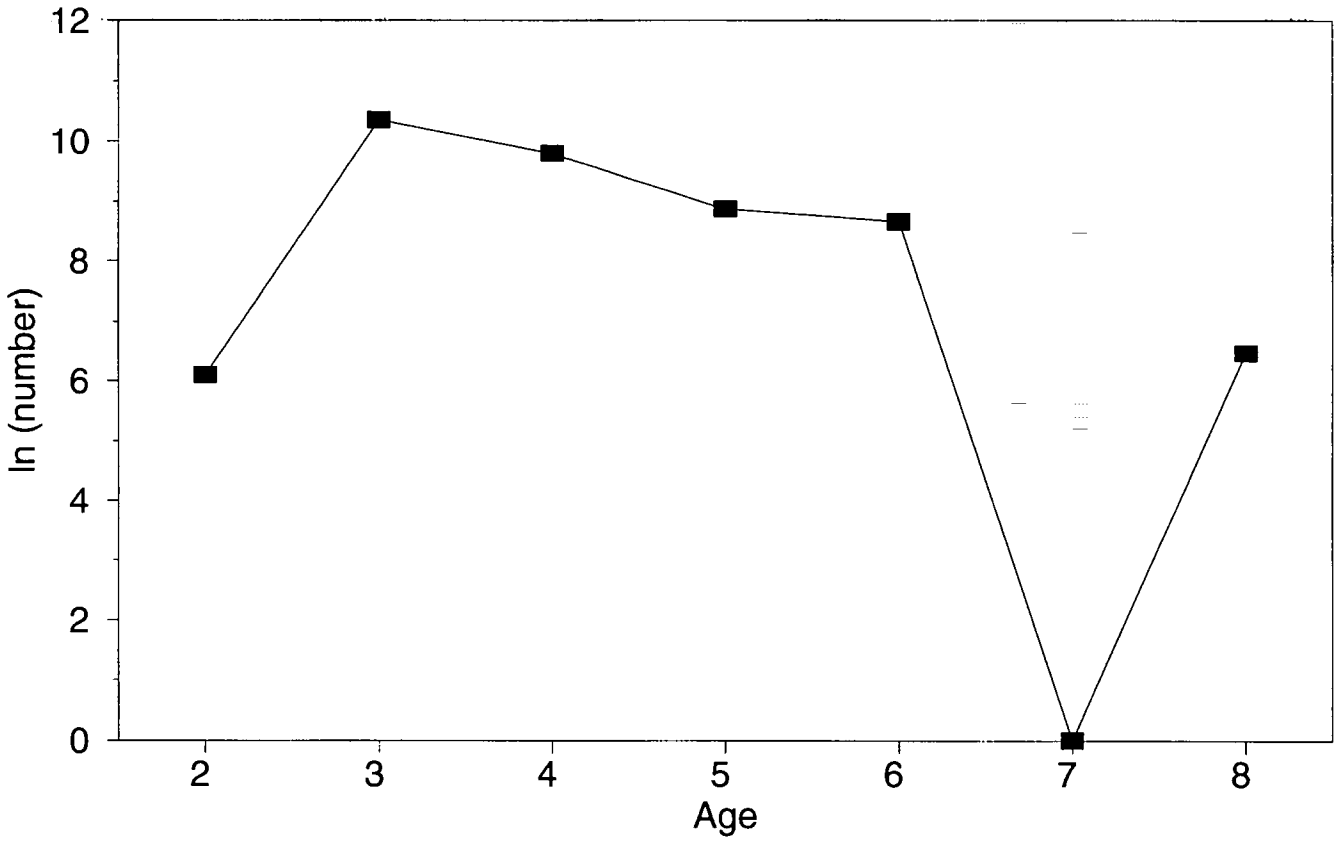


Figure 13. Catch curve for the 1986 year class.

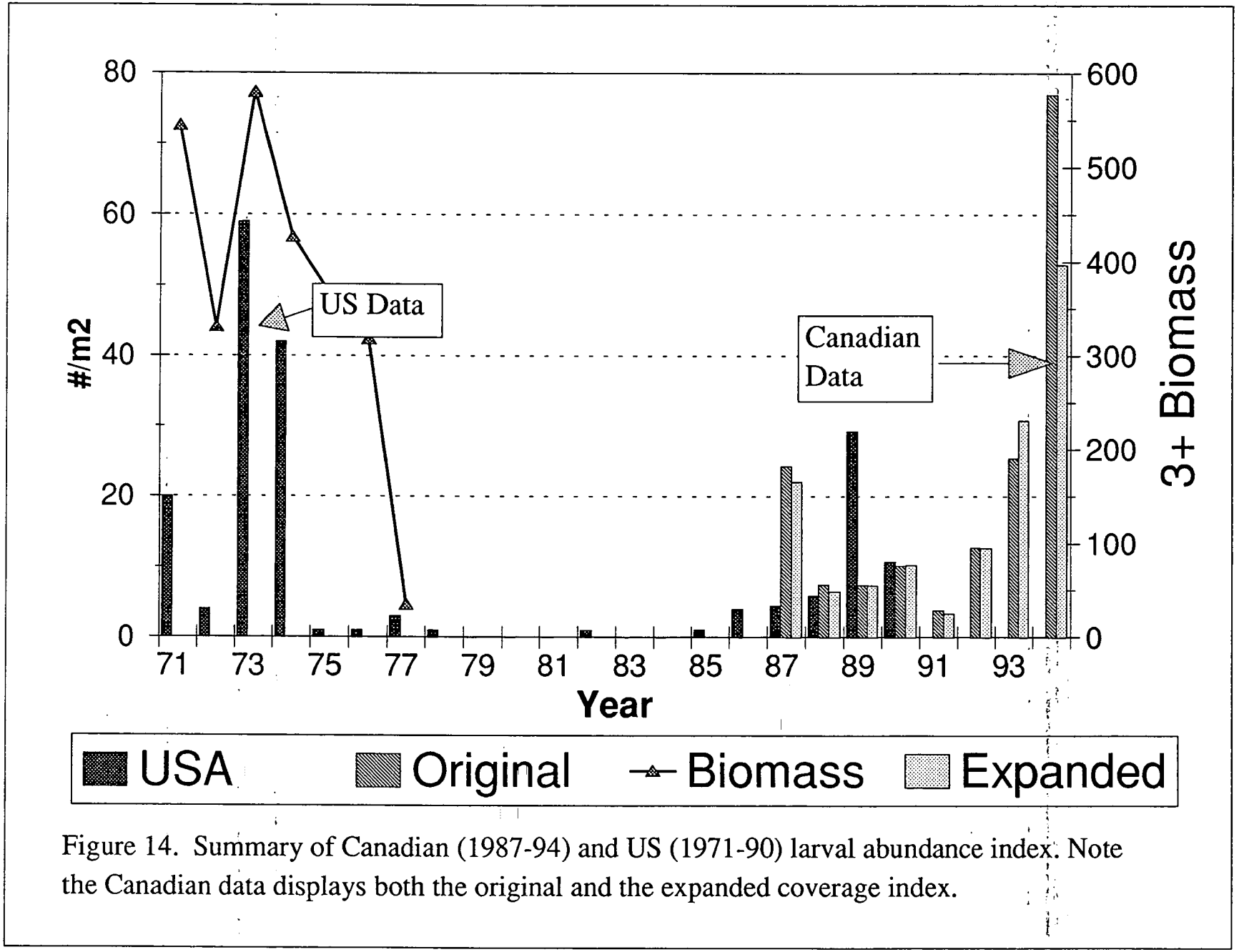


Figure 14. Summary of Canadian (1987-94) and US (1971-90) larval abundance index. Note the Canadian data displays both the original and the expanded coverage index.

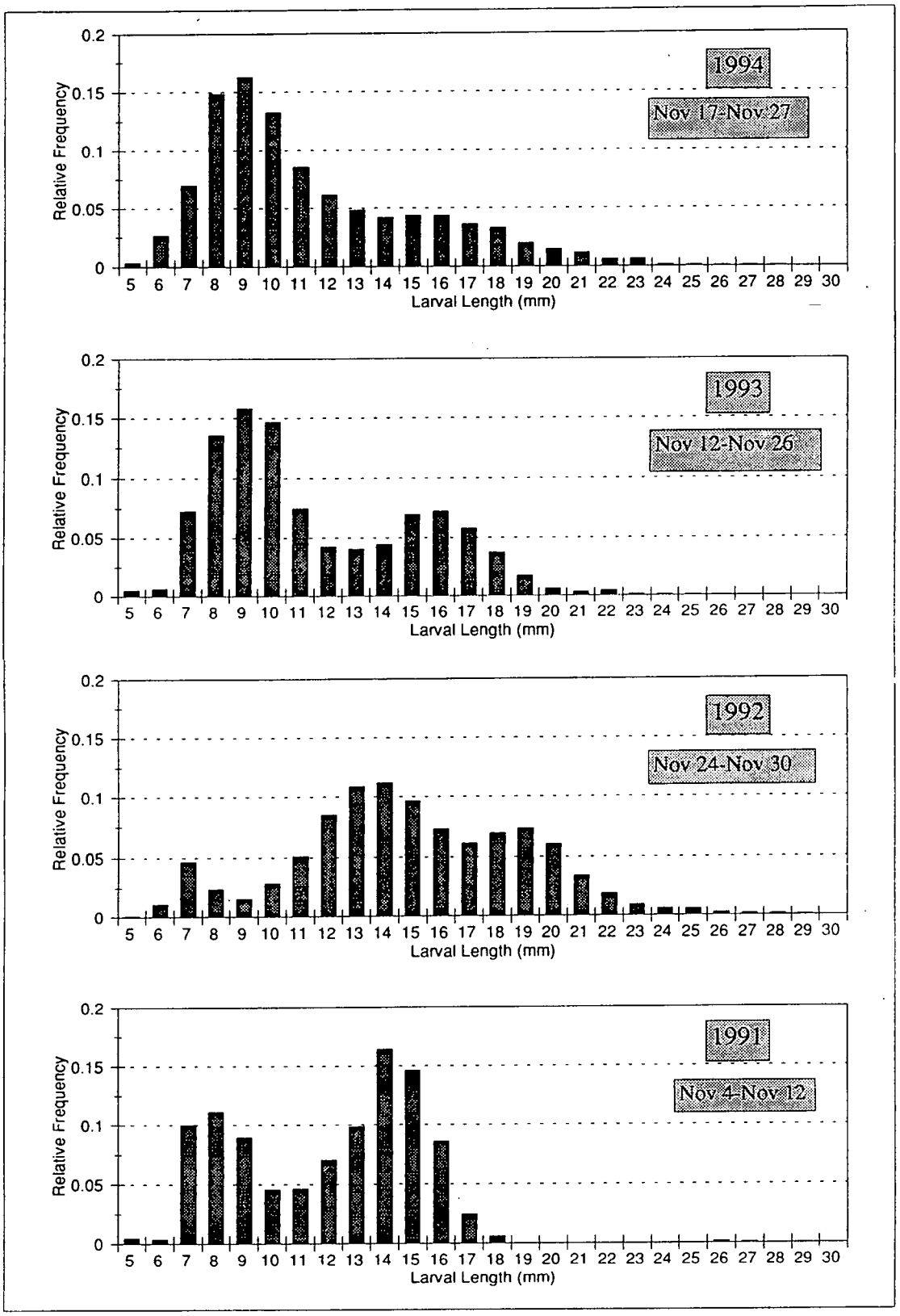


Figure 15a-e. Georges Bank larval length frequency distributions from Canadian fall surveys between 1994 and 1991.

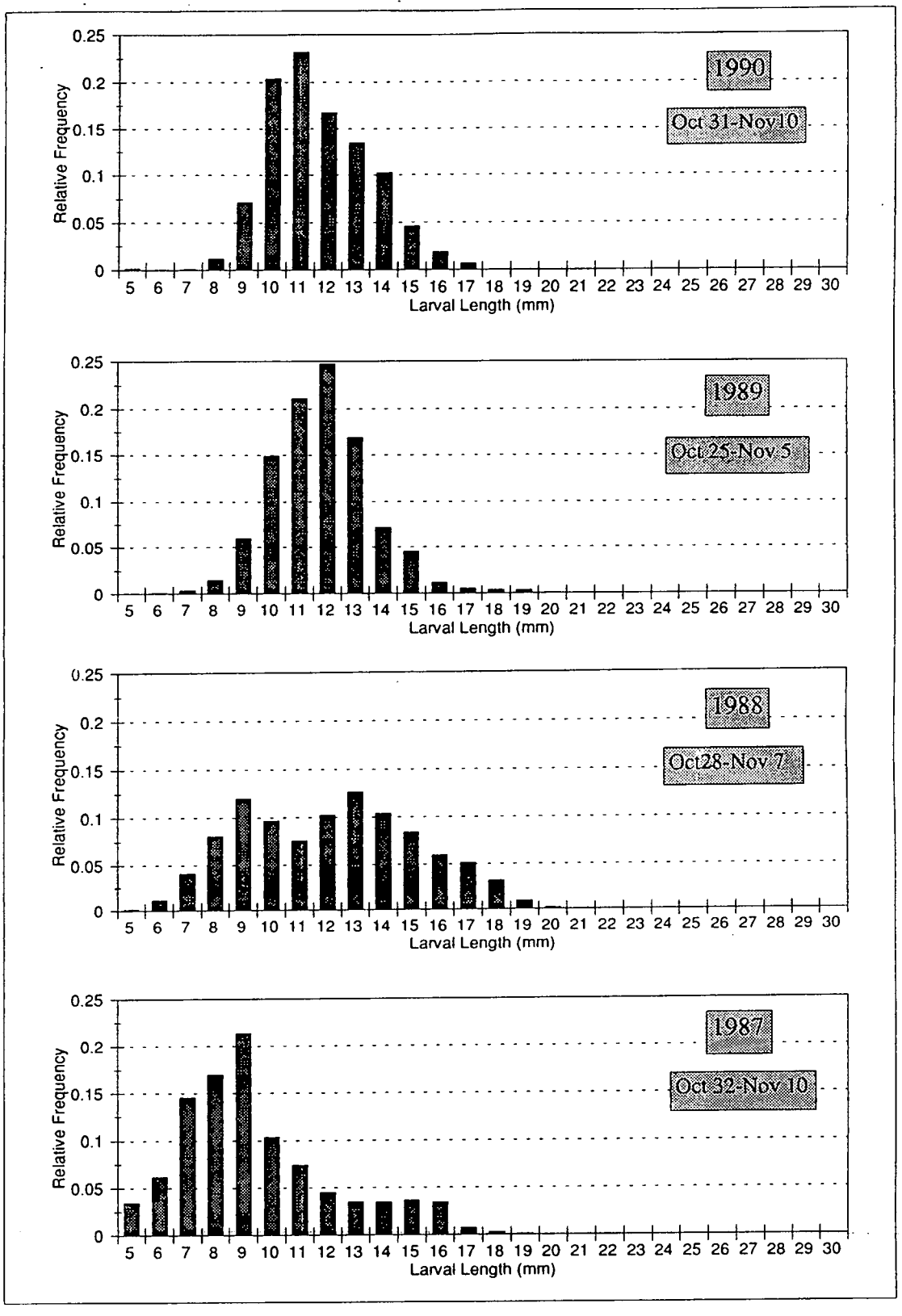


Figure 15e-h. Georges Bank larval length frequency distributions from Canadian fall surveys between 1990 and 1987.

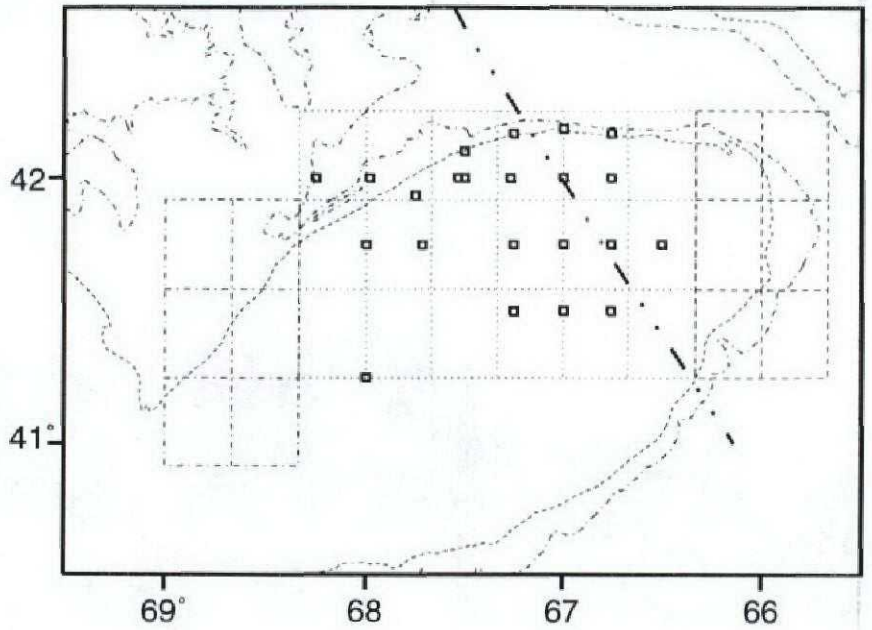


Figure 16a. 1987 Canadian larval survey (Oct 4 - 17). Sampling stations.

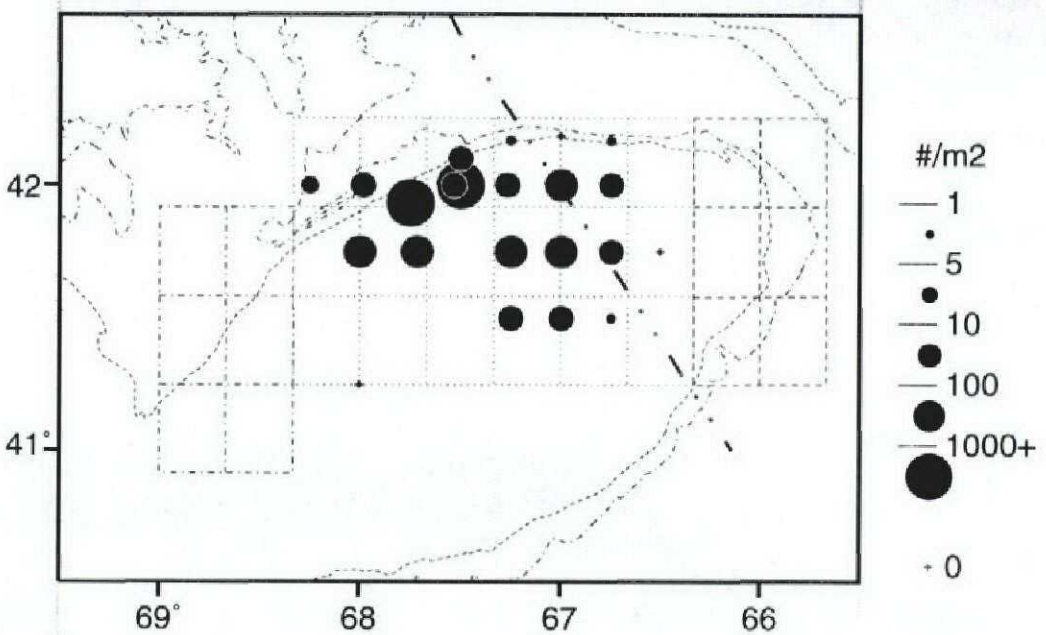


Figure 16b. 1987 Canadian larval survey (Oct 4 - 17). Larvae as per adjacent scale.

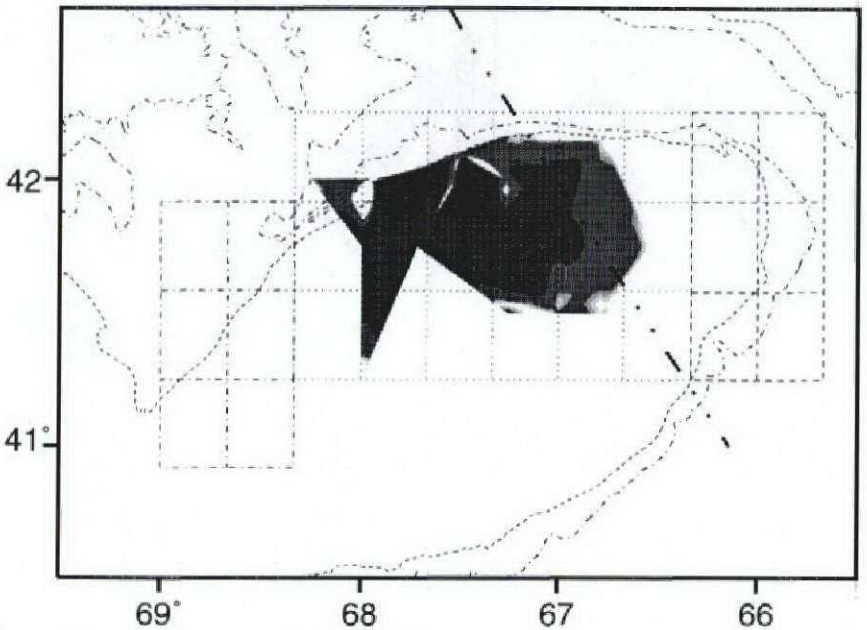


Figure 16c. 1987 Canadian larval survey (Oct 4 - 17). All larvae. Contours as per adjacent scale.

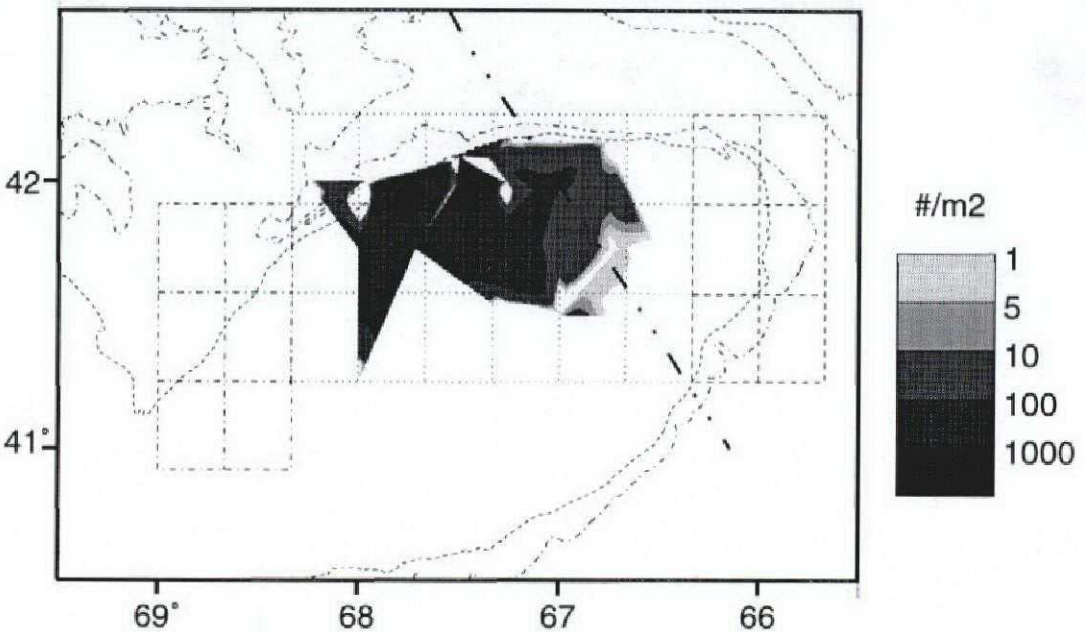


Figure 16d. 1987 Canadian larval survey (Oct 4 - 17). Larvae (<10mm). Contours as per adjacent scale.

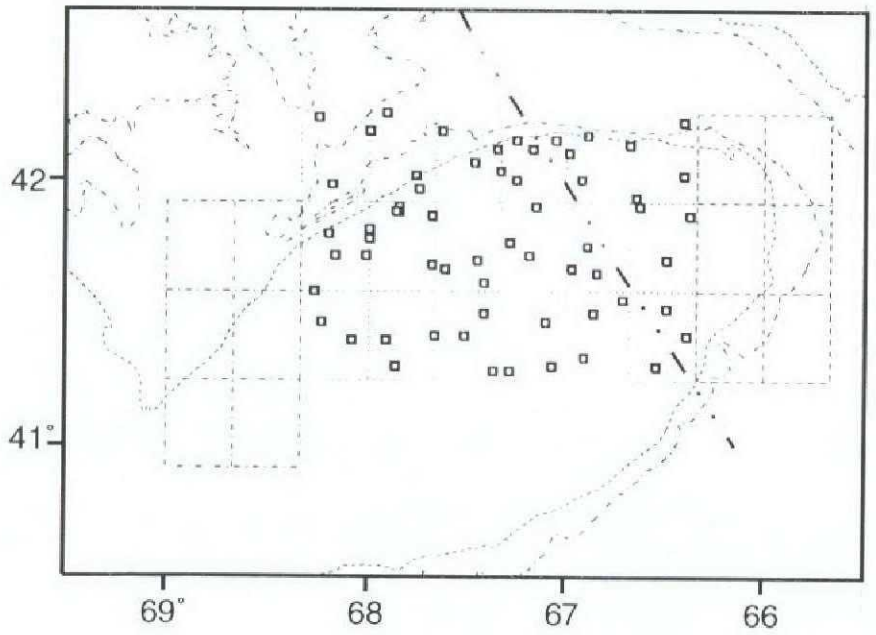


Figure 16e. 1988 Canadian larval survey (Oct 29 - Nov 9). Sampling stations.

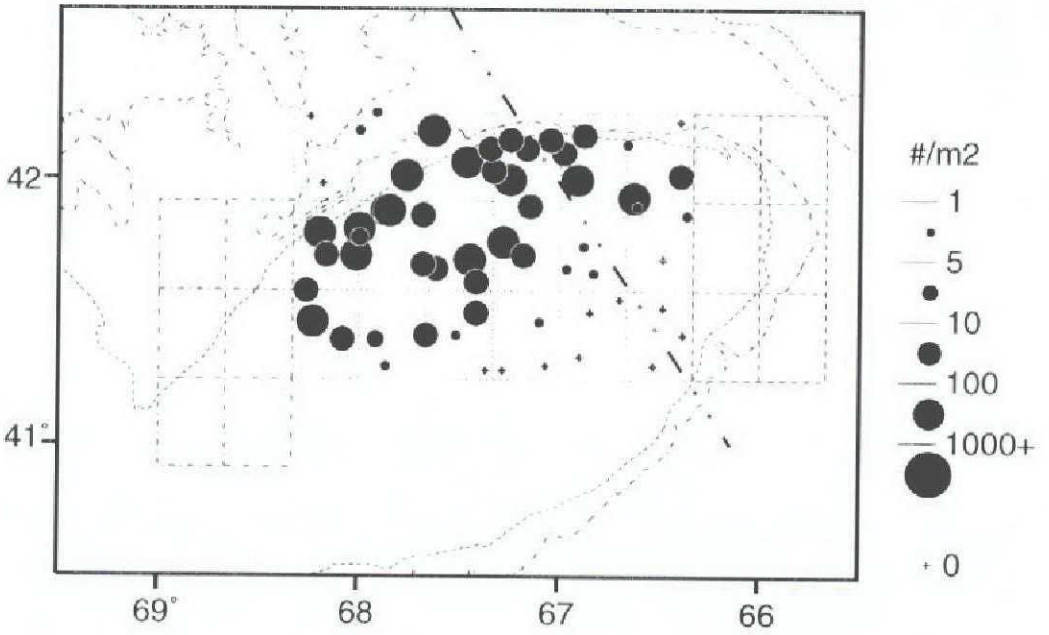


Figure 16f. 1988 Canadian larval survey (Oct 29 - Nov 9). Larvae as per adjacent scale.

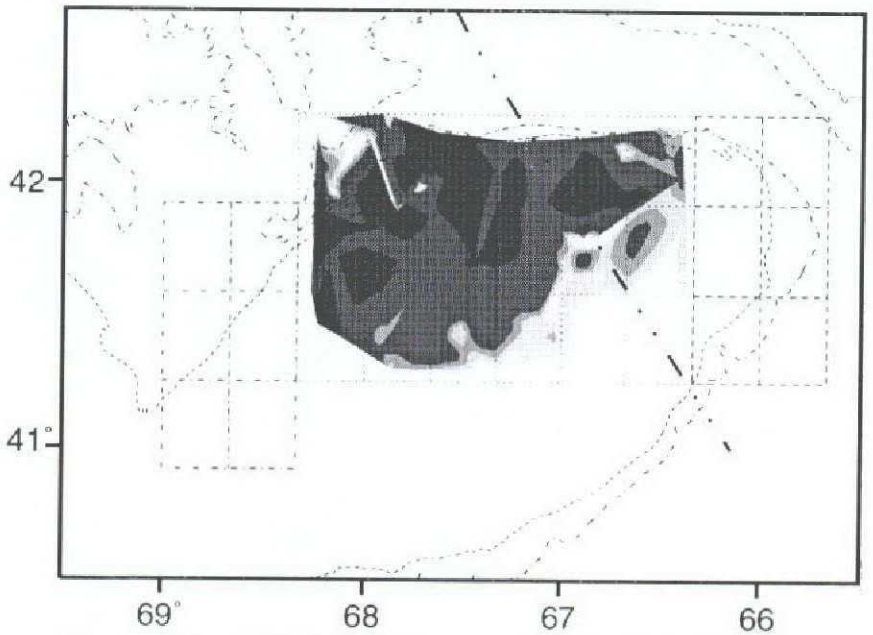


Figure 16g. 1988 Canadian larval survey (Oct 29 - Nov 9). All larvae. Contours as per adjacent scale.

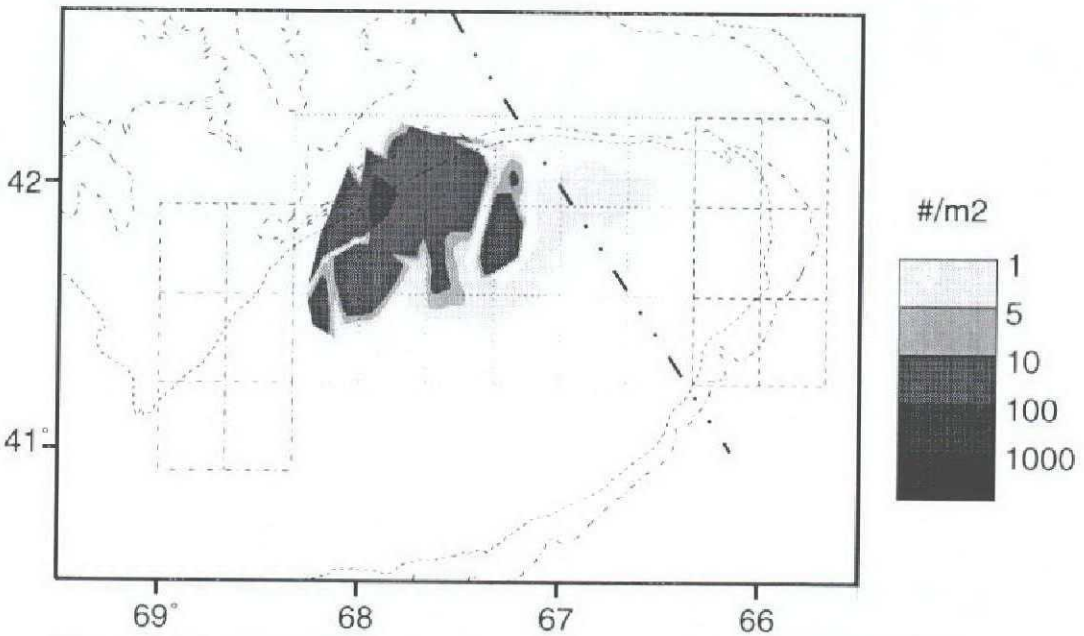


Figure 16h. 1988 Canadian larval survey (Oct 29 - Nov 9). Larvae (<10mm). Contours as per adjacent scale.

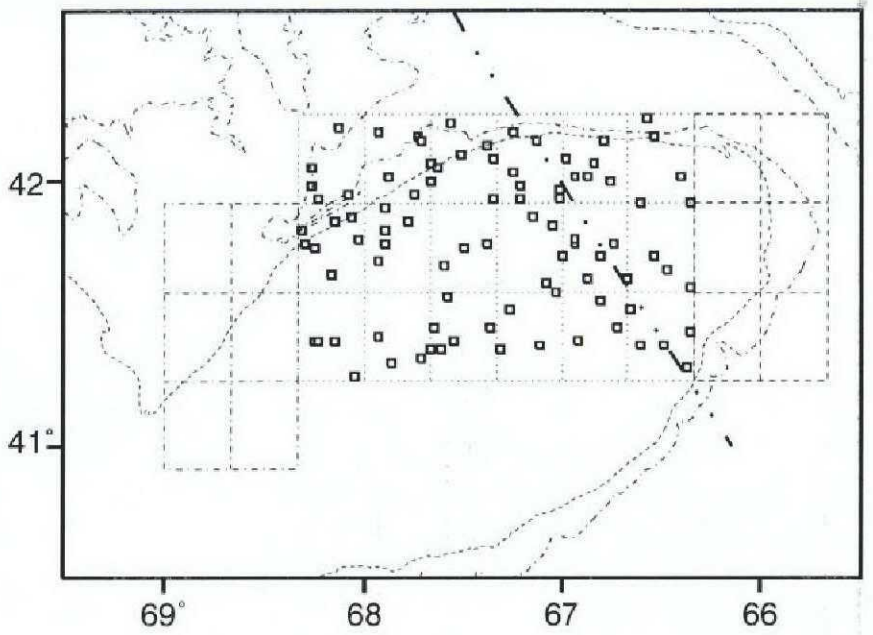


Figure 16i. 1989 Canadian larval survey (Oct 27 - Nov 6). Sampling stations.

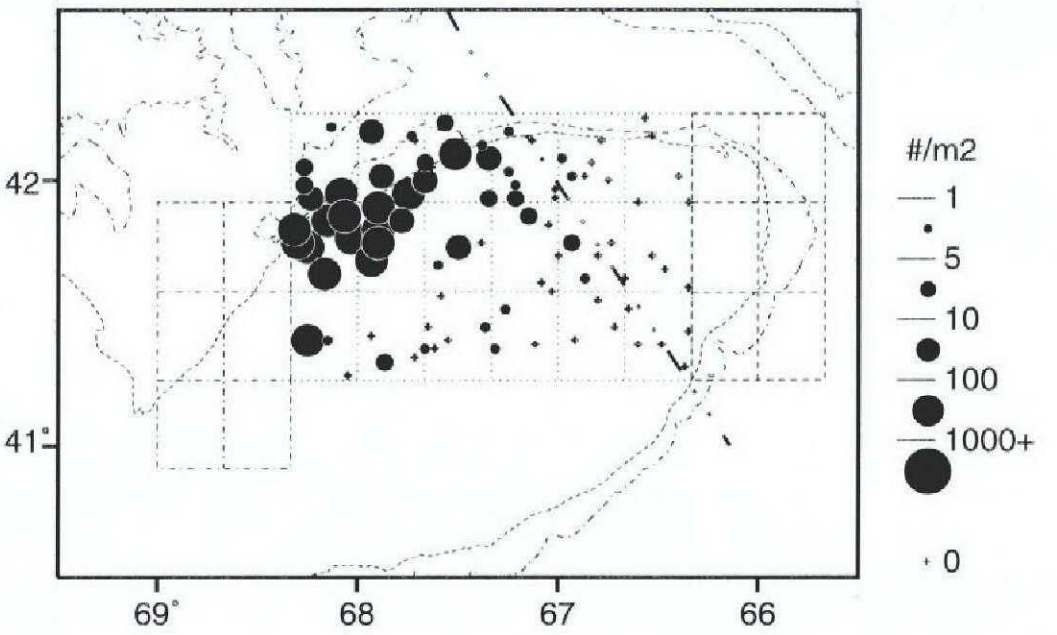


Figure 16j. 1989 Canadian larval survey (Oct 27 - Nov 6). Larvae as per adjacent scale.

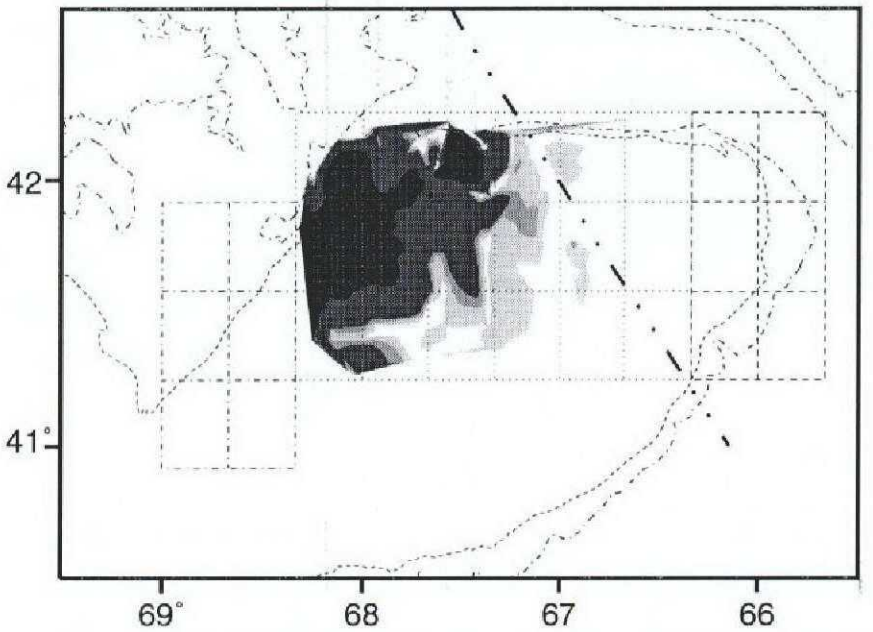


Figure 16k. 1989 Canadian larval survey (Oct 27 - Nov 6). All larvae. Contours as per adjacent scale.

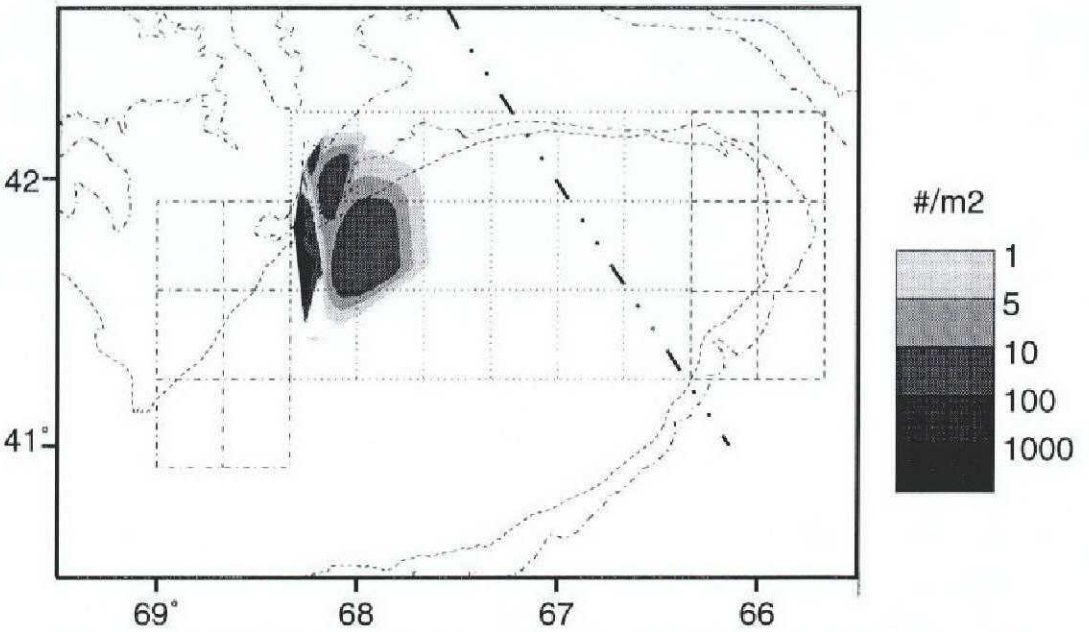


Figure 16l. 1989 Canadian larval survey (Oct 27 - Nov 6). Larvae (<10mm). Contours as per adjacent scale.

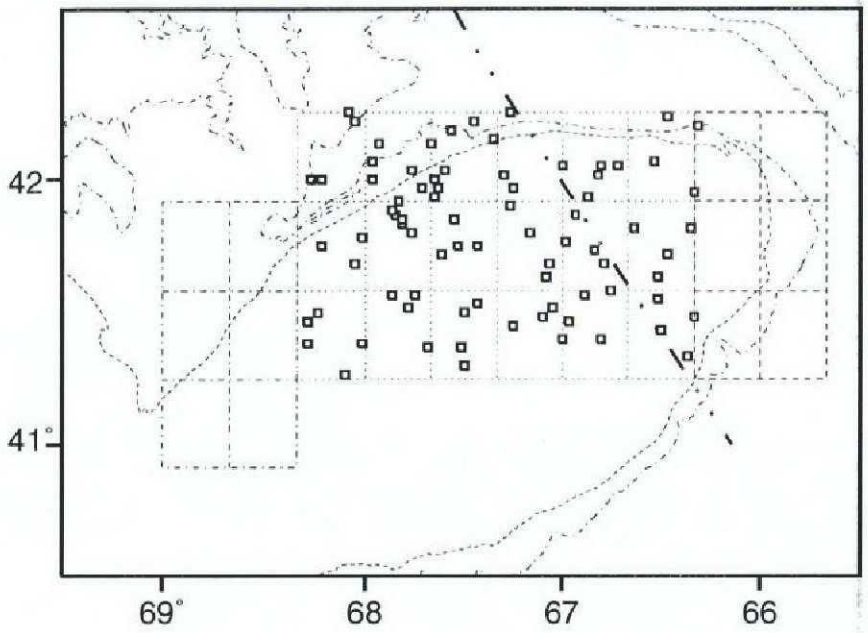


Figure 16m. 1990 Canadian larval survey (Nov 1 - 5). Sampling stations.

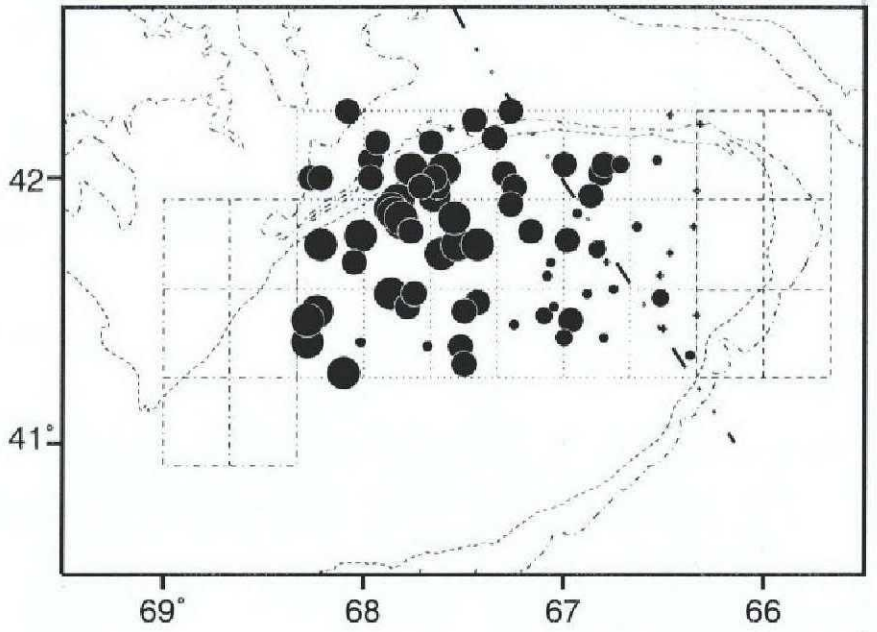


Figure 16n. 1990 Canadian larval survey (Nov 1 - 5). Larvae as per adjacent scale.

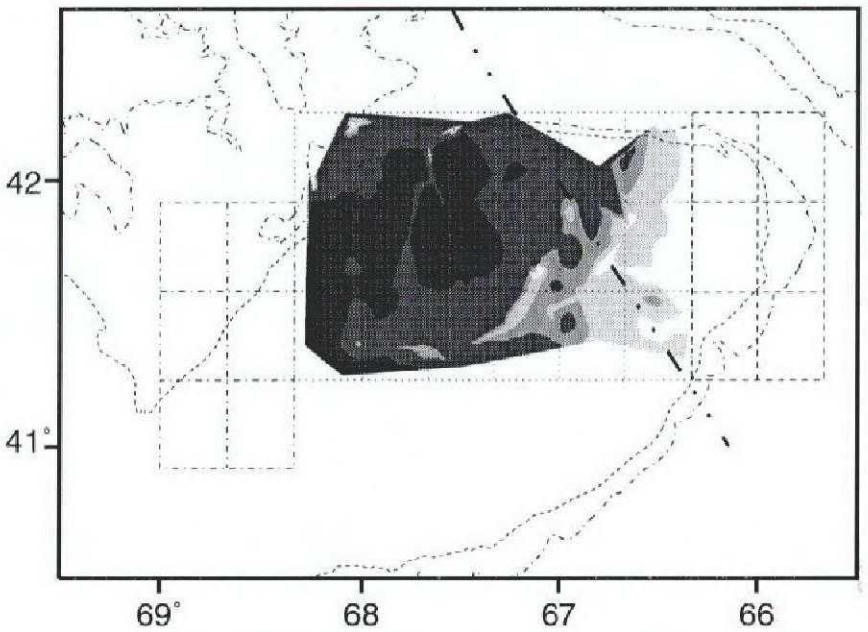


Figure 16o. 1990 Canadian larval survey (Nov 1 - 5). All larvae. Contours as per adjacent scale.

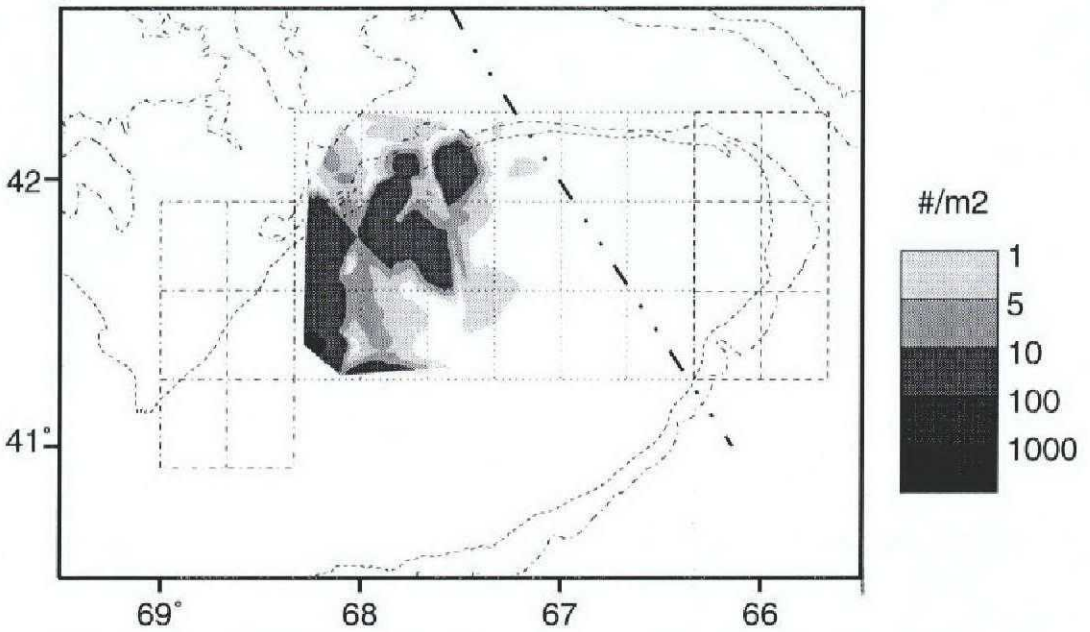


Figure 16p. 1990 Canadian larval survey (Nov 1 - 5). Larvae (<10mm). Contours as per adjacent scale.

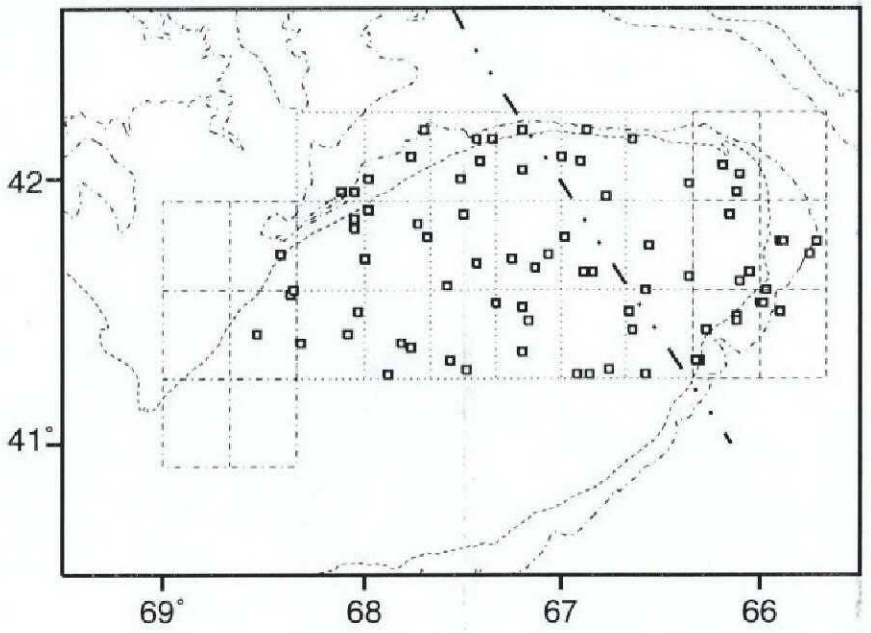


Figure 16q. 1991 Canadian larval survey (Nov 4 - 15). Sampling stations.

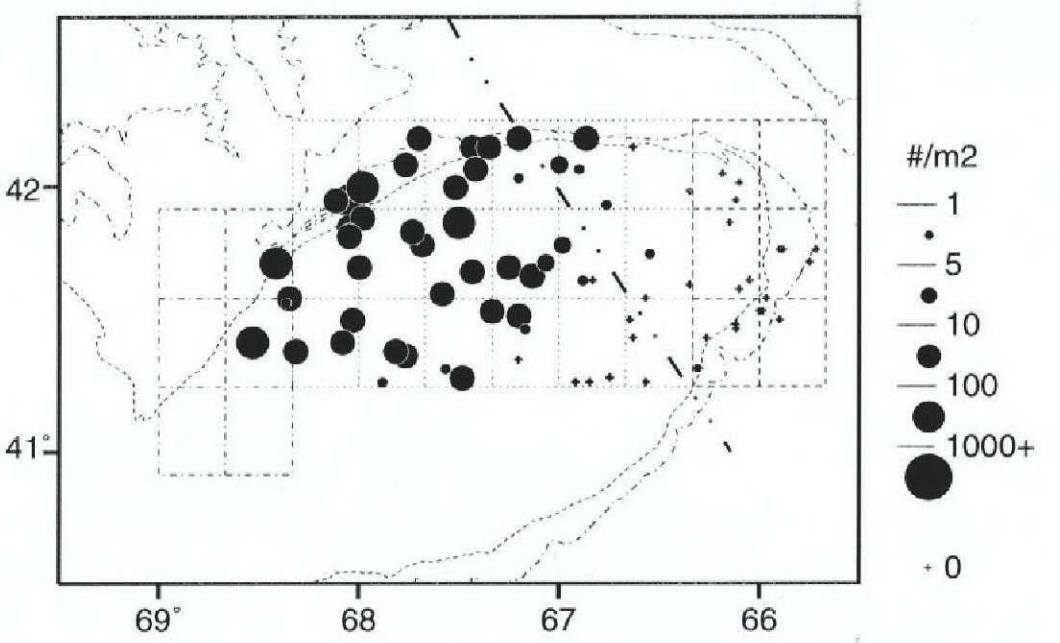


Figure 16r. 1991 Canadian larval survey (Nov 4 - 15). Larvae as per adjacent scale.

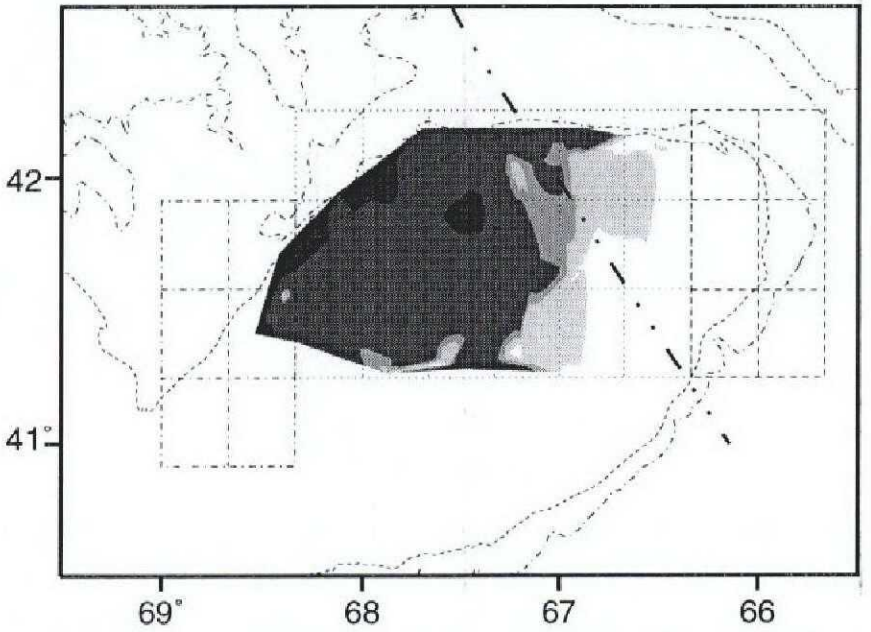


Figure 16s. 1991 Canadian larval survey (Nov 4 - 15). All larvae. Contours as per adjacent scale.

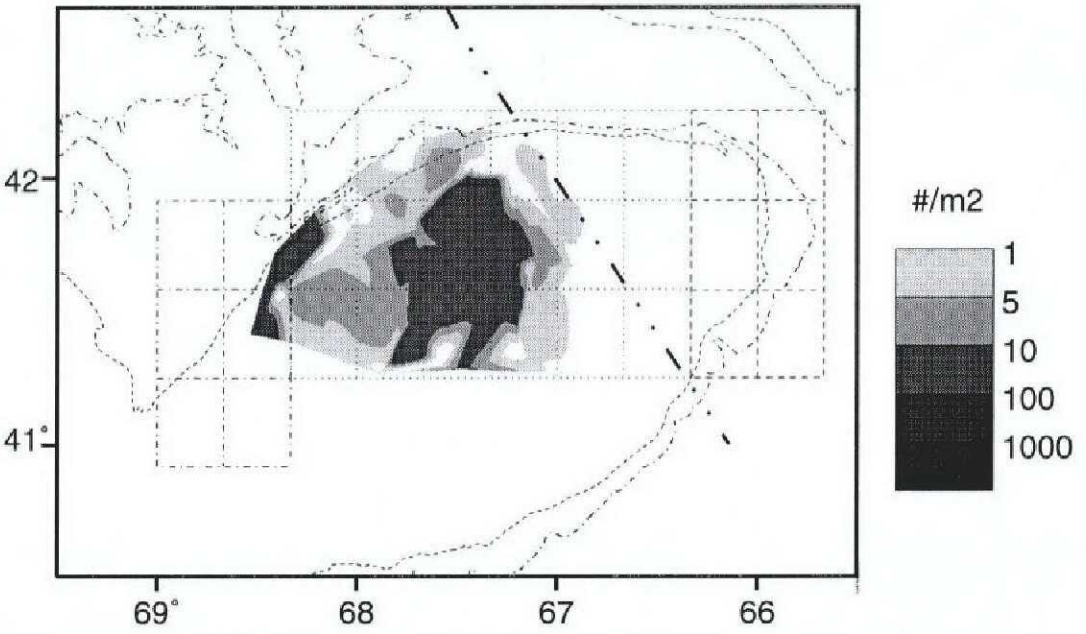


Figure 16t. 1991 Canadian larval survey (Nov 4 - 15). Larvae (<10mm). Contours as per adjacent scale.

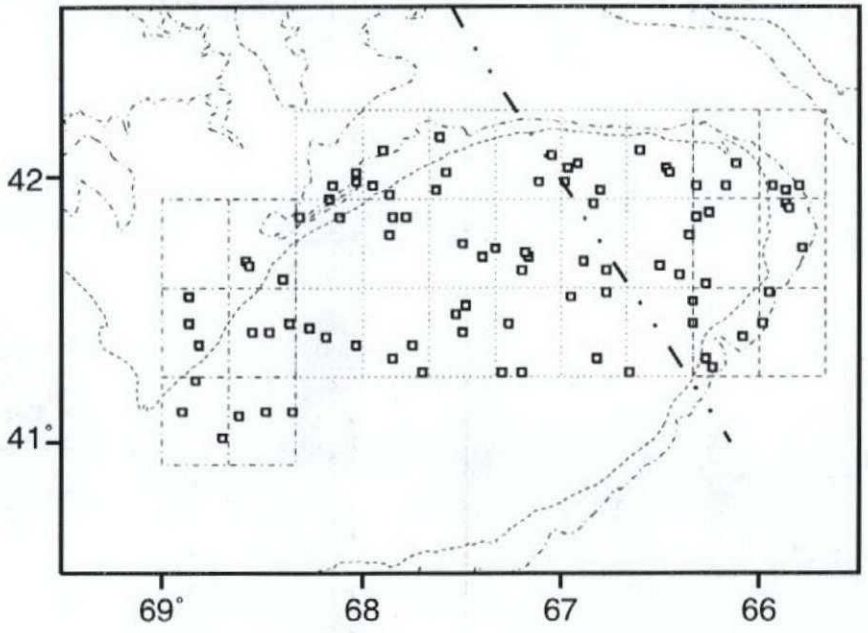


Figure 16u. 1992 Canadian larval survey (Nov 18 - 25). Sampling stations.

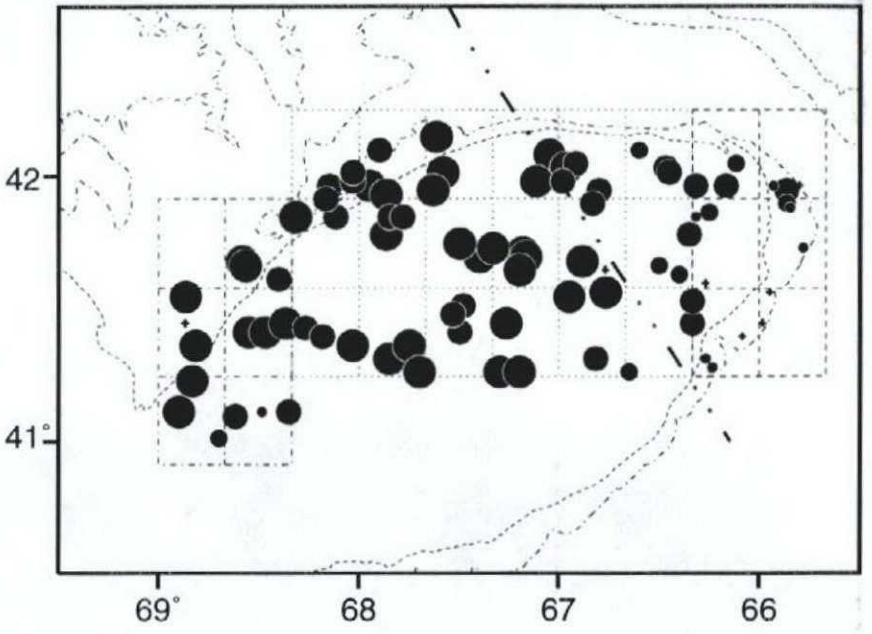


Figure 16v. 1992 Canadian larval survey (Nov 18 - 25). Larvae as per adjacent scale.

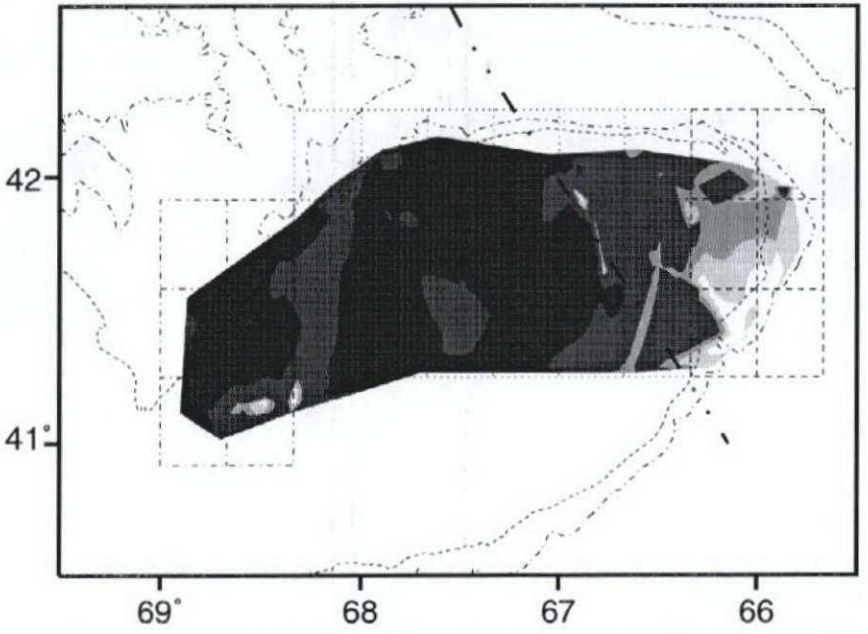


Figure 16w. 1992 Canadian larval survey (Nov 18 - 25). All larvae. Contours as per adjacent scale.

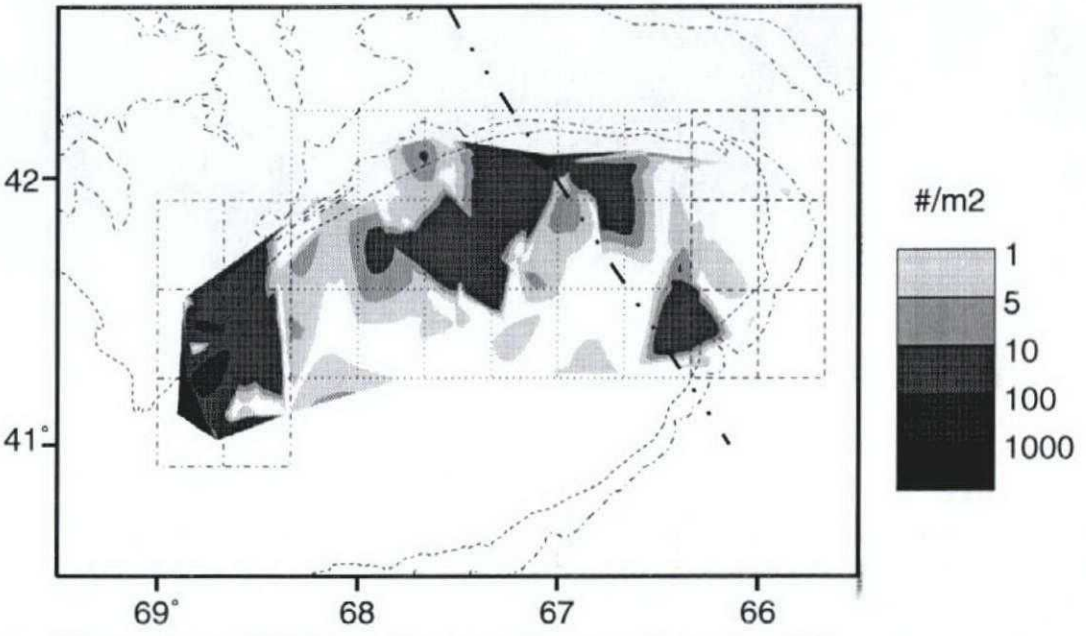


Figure 16x. 1992 Canadian larval survey (Nov 18 - 25). Larvae (<10mm). Contours as per adjacent scale.

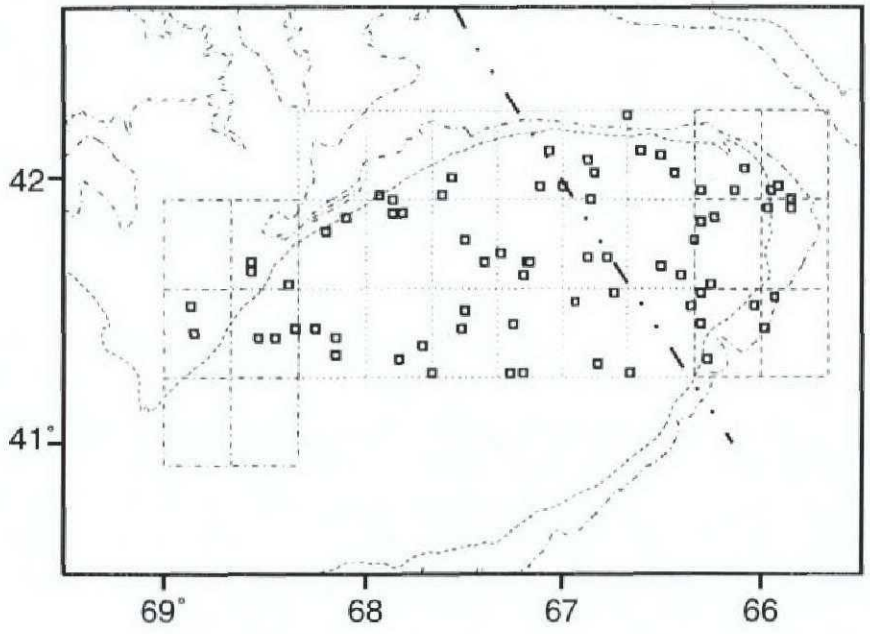


Figure 16y. 1993 Canadian larval survey (Nov 12 - 26). Sampling stations.

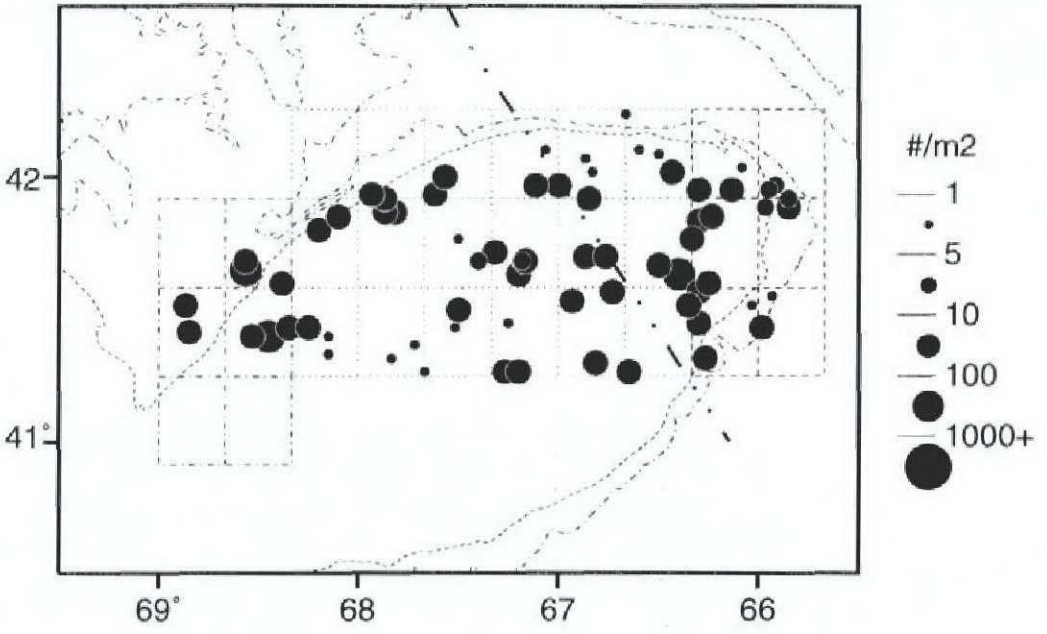


Figure 16z. 1994 Canadian larval survey (Nov 12 - 26). Larvae as per adjacent scale.

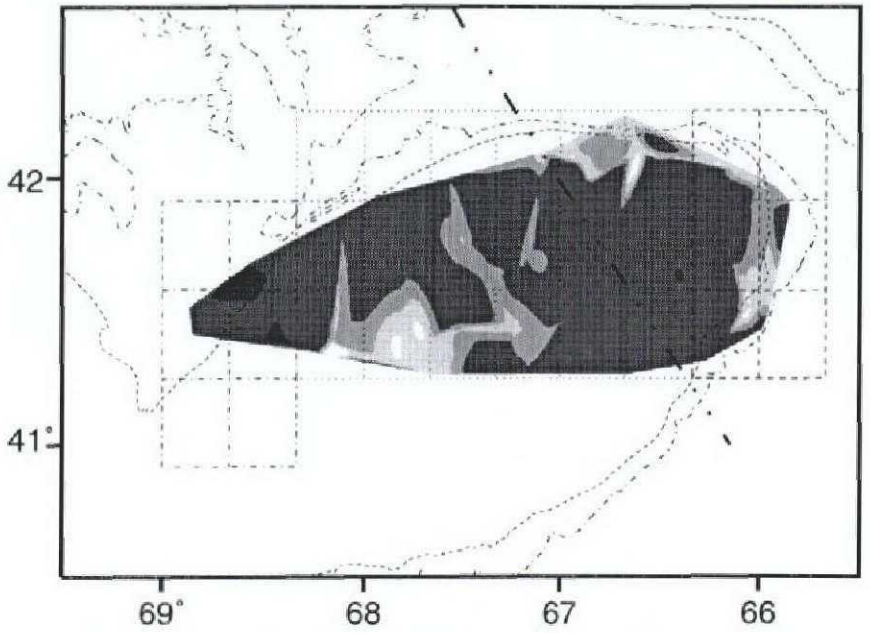


Figure 16aa. 1993 Canadian larval survey (Nov 12 - 26). All larvae. Contours as per adjacent scale.

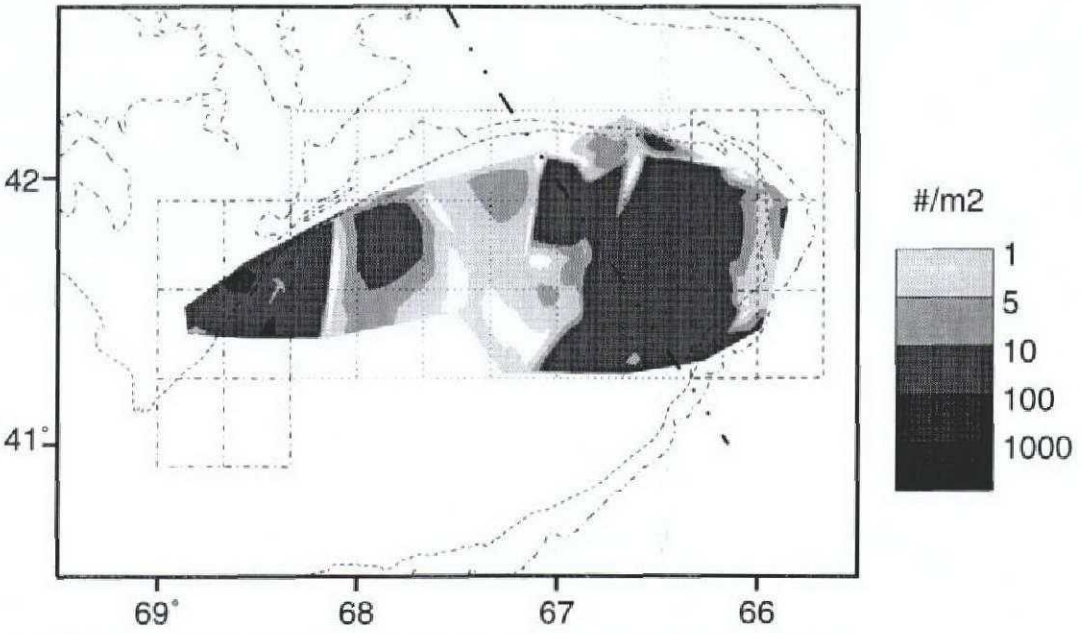


Figure 16bb. 1993 Canadian larval survey (Nov 12 - 26). Larvae (<10mm). Contours as per adjacent scale.

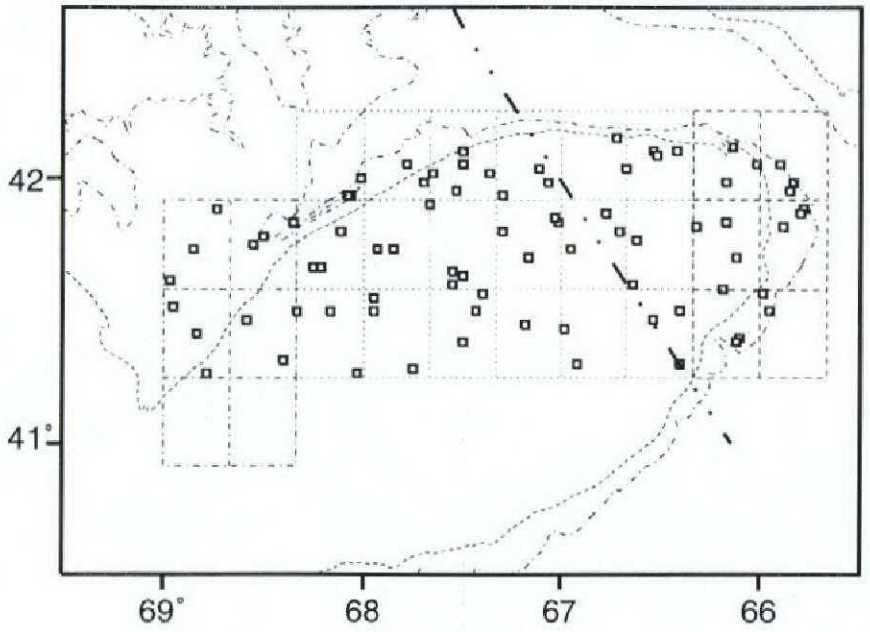


Figure 16cc. 1994 Canadian larval survey (Nov 16 - 29). Sampling stations.

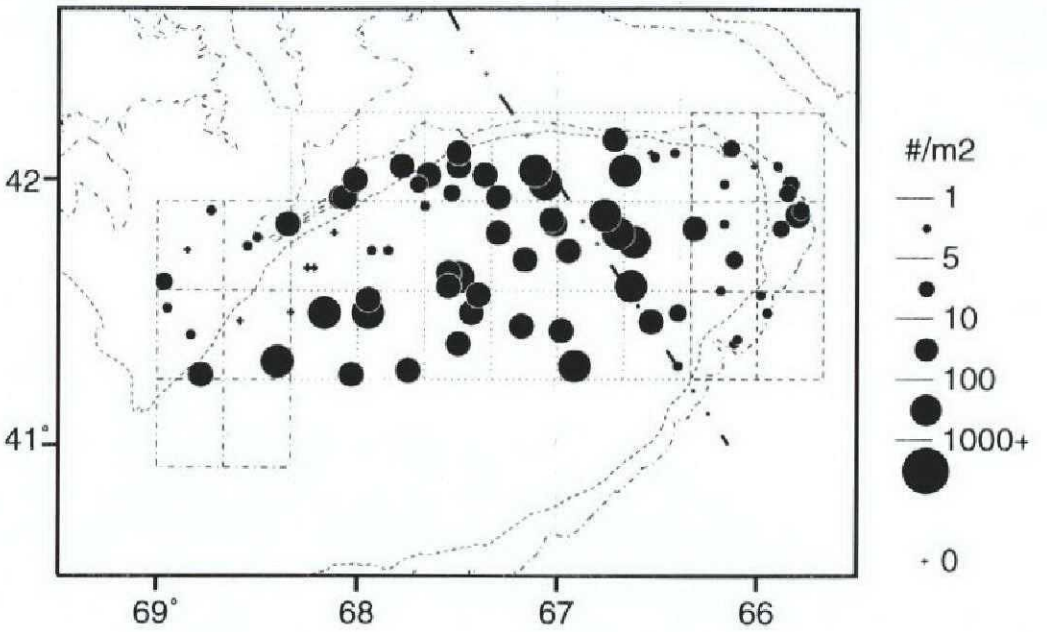


Figure 16dd. 1994 Canadian larval survey (Nov 16 - 29). Larvae as per adjacent scale.

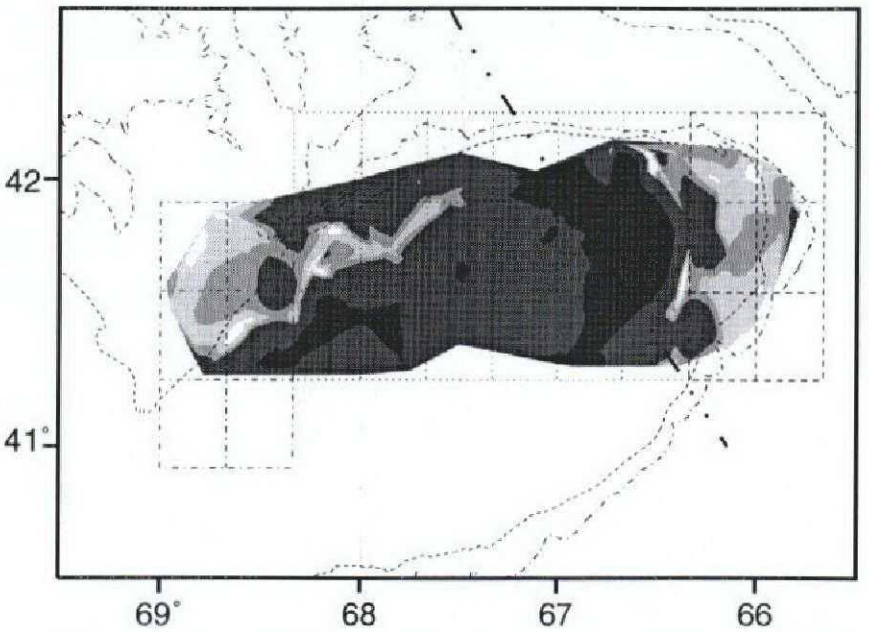


Figure 16ee. 1994 Canadian larval survey (Nov 16 - 29). All larvae. Contours as per adjacent scale.

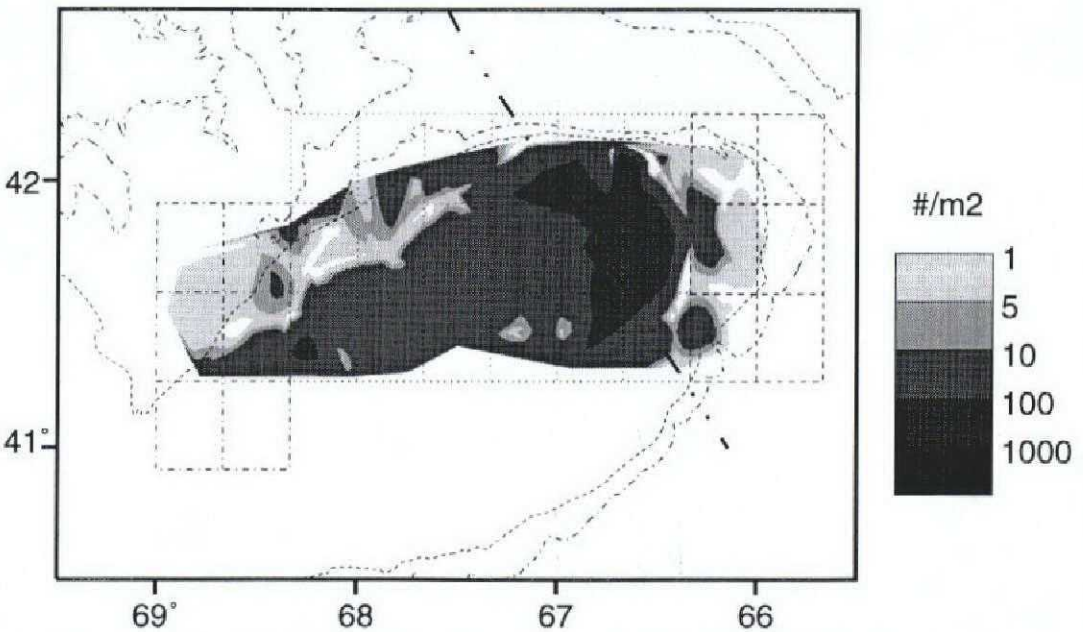


Figure 16ff. 1994 Canadian larval survey (Nov 16 - 29). Larvae (<10mm). Contours as per adjacent scale.

Table 1. Summary of the US fall bottom trawl survey for Massachusetts Bay (Area 1), Nantucket Shoals (Area 2) and Georges Bank (Area 3) by year.

Year	Area	Start Date	Date Finish	Total Sets	Sets with Herring	% with Herring	No. Herring	Length Mean	Length SE
1983	1	10-26	11-09	16	7	43.75	22	29.2	0.42
	2	10-12	11-09	33	5	15.15	18	33.3	0.30
	3	10-09	10-23	95	3	3.16	4	30.9	0.39
1984	1	10-11	11-06	9	6	66.67	145	33.1	0.32
	2	10-05	11-17	21	4	19.05	22	31.7	0.40
	3	10-07	10-25	73	0	0.00	0	-	-
1985	1	10-13	11-15	6	4	66.67	435	31.1	0.30
	2	10-18	11-07	26	4	15.38	16	31.5	0.24
	3	10-22	10-25	63	2	3.17	4	28.5	0.14
1986	1	10-27	11-05	8	3	37.50	9	32.8	0.32
	2	10-09	10-28	22	4	18.18	89	29.9	0.26
	3	10-09	10-21	103	23	22.33	241	27.3	0.23
1987	1	10-08	10-27	8	6	75.00	438	27.5	0.32
	2	10-02	10-29	24	10	41.67	832	28.9	0.33
	3	10-03	10-18	75	28	37.33	346	29.7	0.29
1988	1	10-26	10-27	11	9	81.82	85	38.7	0.28
	2	09-29	10-18	25	7	28.00	1650	29.2	0.30
	3	10-07	10-18	81	39	48.15	2127	27.3	0.41
1989	1	10-21	10-30	11	10	90.91	5182	31.2	0.29
	2	10-07	10-17	19	5	26.32	280	30.2	0.28
	3	10-08	10-25	88	46	52.27	881	27.9	0.36
1990	1	10-16	10-23	7	4	57.14	234	30.8	0.32
	2	09-27	10-16	35	9	25.71	3044	27.5	0.29
	3	10-06	10-11	83	27	32.53	2059	26.9	0.30
1991	1	10-17	10-24	6	4	66.67	29	32.2	0.29
	2	09-30	10-16	24	12	50.00	757	28.8	0.30
	3	09-30	10-12	77	17	22.08	14421	27.2	0.30
1992	1	10-20	10-27	4	4	100.00	1934	29.5	0.27
	2	10-06	10-20	30	15	50.00	4590	29.1	0.31
	3	10-08	10-14	62	12	19.35	2548	27.5	0.32
1993	1	10-20	10-20	18	18	100.00	3059	25.5	0.31
	2	09-27	10-14	34	15	44.12	3139	26.0	0.30
	3	09-28	10-10	58	10	17.24	671	24.9	0.24
1994	1			15	12	80.00	304	28.9	0.55
	2			39	10	25.64	1000	29.2	0.34
	3	10-04	10-27	85	16	18.82	1379	27.9	0.44

Table 2. Dates, catch of larval herring, mean number of larvae per tow and mean total length from Canadian fall surveys on Georges Bank.

		catch				Length (mm)			
Year	Dates	# caught	# of sets	mean #/tow	SE	mean	STD	min	max
1987	23 Oct - 10 Nov	4898	40	22.02	1.24	9.38	1.94	5	19
1988	28 Oct - 7 Nov	4075	76	6.51	0.41	13.09	3.05	6	21
1989	25 Oct - 05 Nov	4386	90	7.37	0.53	12.41	1.78	7	21
1990	31 Oct - 10 Nov	5903	79	10.21	0.46	11.64	1.88	7	19
1991	04 Nov - 12 Nov	1508	76	3.32	0.31	13.41	3.73	5	20
1992	24 Nov - 30 Nov	7743	86	12.61	0.44	14.55	4.40	5	29
1993	12 Nov - 26 Nov	15718	71	30.78	0.70	12.84	2.24	5	26
1994	16 Nov - 29 Nov	43106	81	52.90	0.96	11.34	1.60	5	28

Table 3 . Catch-at -age in numbers for Georges Bank research samples based on 1,000 t and the 1994 commercial fishery of 228 t.

	Age											
YEAR	1	2	3	4	5	6	7	8	9	10	11	TOTAL
1988	9372	445	9796	30689	11159	2450	160	304				64375
1989	4877	7574	31408	9255	15591	4013	295	137				73150
1990	0	10584	39633	17904	4905	3636	1845	382	121	808		79818
1991	0	19340	21693	22576	7098	3047	3932	3527	293	265		81772
1992	0	6360	38052	18553	8499	5753	5148					82365
1993	0	349	48661	25100	7430	906						82446
1994	0	2722	2627	35610	21863	6379	3005	647	414			73268
Commercial Fishery 1994	0	0	62	2193	5359	2301	2531	91	0	0		12537

Table 4. Summary of maturity stages of adult herring taken during Canadian fall surveys on Georges Bank (1986 - 1994).

Year	Gonad stages 1	2	3	4	5	6	7	8	Number samples
1986	-	10 (9.3)	1 (0.9)	-	6	30	2	59	108
1987	1 (0.2)	181 (45.9)	-	-	10 (2.5)	24 96.1)	14 (3.6)	164 (41.6)	394
1988	23 (7.7)	24 (8.8)	5 (1.7)	3 (1.0)	1 (0.3)	1 (0.3)	13 (4.3)	230 (76.7)	300
1989	-	24 (19.0)	4 (3.2)	-	1 (0.8)	3 (2.4)	33 (26.2)	61 (48.4)	126
1990	46 (8.8)	115 (22.0)	-	-	18 (3.4)	4 (0.8)	120 (23.0)	218 (41.8)	582
1991	14 (5.2)	48 (17.7)	-	-	19 (6.9)	20 (7.4)	33 (12.1)	137 (50.3)	272
1992	1 (2.8)	4 (11.1)	21 (58.3)	-	-	1 (2.8)	7 (19.4)	2 (5.5)	36
1993	-	33 (14.5)	1 (0.4)	-	-	-	28 (12.3)	166 (72.8)	228
1994	3 (1.0)	25 (8.0)	4 (1.3)	-	3 (1.0)	3 (1.0)	26 (8.3)	250 (79.6)	315