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Capelin in SA2 + Div. 3KL

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Abstract

This document contains a number of discrete research results which were considered during the 1998 assessment of capelin in SA2 + Div. 3KL. These results are arranged in seven chapters. In addition, a meeting report, cross-referenced by chapter, is provided. The data available included the results of studies on inshore capelin, 0-group and larval capelin, bycatches of capelin in groundfish surveys and capelin lengths.

Résumé

Le document contient divers résultats de recherches distinctes qui ont été examinés au moment de l'évaluation de 1998 du capelan de la sous-zone 2 et des divisions 3KL. Les résultats sont répartis en sept chapitres. On y trouve aussi un rapport de réunion avec renvois aux chapitres. Les données présentées ont trait aux résultats d'études portant sur le capelan côtier, les capelans du groupe d'âge 0 ou de stade larvaire, les capelans ayant fait l'objet de prises accidentelles au moment des relevés du poisson de fond et la longueur des capelans.

Capelin in SA2 + Div. 3KL

1) Introduction

A capelin assessment committee met during March and April 1998 at NAFC, St. John's to assess the capelin stock in SA2 + Div. 3KL. A list of attendees is given in Appendix 1. Since 1994, capelin in SA2 and Div. 3KL have been assessed as one stock, based on evidence of movement of capelin in these areas.

2) Catch Trends

i) SA2 + Div. 3K

The capelin fishery in NAFO SA2 + Div. 3K was, until 1972, limited to inshore catches during the spawning season. In 1972, substantial catches were taken offshore by vessels from several countries. Catches peaked in 1976 at 212,000 t before declining in the late 1970's to 11,000 t in 1979.

Offshore catches during 1980-91 were restricted by quota and ranged between 500 and 57,000 t. The offshore fishery was generally conducted during August-November. The offshore fishery was closed beginning in 1992.

During the 1980's, an inshore directed roe fishery during June and July has occurred, primarily in Div. 3L. Beginning in 1988, landings increased because of an increased share of the market for Canadian capelin with the closure of the Barents Sea capelin fishery. TACs generally reflected market demand and the increase of the TACs during the late 1980's can be attributed to the larger market share. These did, however, remain below the 10% of total spawning biomass that had been set as the biological criterion for setting the TAC.

During 1994 and 1995, a fishery was not prosecuted largely because female fish were too small to meet the size criterion in the management plan (sea run 50 count/kg). This size criterion was excluded from the 1996 management plan and a fishery proceeded when fish were marketable based on monitoring. Preliminary landings in SA2 + Div. 3K during 1997, were 5,500 t compared to the quota of 11,400 t.

ii) Div. 3L

Catches in NAFO Div. 3L were less than 4,000 t prior to 1970, increased to a peak of 58,000 t in 1974, and declined to 12,000 t in 1979. During the 1980's an inshore roe fishery employing purse seines, capelin traps and beach seines occurred during June and July. This fishery has been later since 1991 due to the late arrival of capelin. In recent years, TACs have reflected market demand. In years when biological data were adequate to advise a specific TAC, the actual TACs have been less than advised on a biological basis.

The situation in Div. 3L regarding low landings in 1994 and 1995, the exclusion of the size criterion in the management plan in 1996 and 1997, and the monitoring programme in 1996 and 1997 were similar to that in Div. 3K. Preliminary landings in Div. 3L during 1997 were 3,600 t compared to a quota of 21,730 t.

Area	1991	1992	1993	1994	1995	1996	1997
SA2 + Div. 3K							
Offshore							
TAC							
Nominal Catch	57	0	0	0	0	-	-
	0.5	0	0	0	0	-	-
Inshore							
TAC							
Nominal Catch	29	17	11.4	11.5	11.5	9.7	11.4
	20	18	13a	11.5	1a	8.9a	5.5a
				<.1a			
Div. 3L							
Inshore							
TAC							
Nominal Catch	56	19.3	21	21	22	18.3	21.7
	22	3	23a	1a	1a	16.8	3.6a
SA2 + Div. 3KL							
Total nominal catch	42.5	21	36	1	1	25.7	9.1

a provisional

3) Information from Licensed Fixed Gear Fishers (Chapter 1)

During 1994-95, a questionnaire was designed to quantitatively evaluate biological and fishery-related information obtained from capelin fishermen. This survey was undertaken because of concerns about the utility of qualitative information coming from comments in some research logbooks or made directly to research personnel.

For the 1997 survey, the survey population size (n = 1830) was defined as all capelin fixed gear (traps and beach seines) fishermen licenced to fish capelin in NAFO Div. 3L and 3K in 1997. Employing a simple random sampling design and an expected response rate of 85% a sample population with 219 names was chosen to achieve a ±7% margin of error with 95% confidence intervals. Telephone interviews were completed between October 6 and November 16, 1997. The 189 completed questionnaires represented an 86% response rate compared to the 85% expected.

Most respondents indicated that capelin abundance in their area was low with a mean response equal to 3.8. This is lower than 5.4 in 1996 and comparable to 3.4 in 1995. The abundance of capelin in 1996 was estimated to be 4.7 by respondents of this survey which was slightly lower than the 5.4 estimate from the 1996 survey. Unlike the last two years, the perception was that the relative abundance the previous year declined with time. Respondents clearly indicated that capelin abundance in 1997 was lower than when they first started to fish capelin. This response has been the same for all four surveys. Generally, most respondents considered capelin abundance to be low and to have decreased from 1996.

According to the respondents, capelin occupied a small proportion of the spawning beaches in 1997. The number of respondents reporting no spawning increased from 1996. The intensity of spawning was 4.1 (scale of 1, lowest, to 10, highest) compared to 6.5 in 1996 and 3.8 in 1995.

Spawning times were again delayed compared to the 1980's. The distribution of spawning times was similar to 1995 and marginally later than 1996.

The general size of females in 1997 was reported to be small or average with few reports of large females.

4) Inshore Data

i) Sampling

Commercial and monitoring samples were collected where possible. Age-composition data for these samples were not presented since ageing difficulties have not yet been resolved. Since the catch rate data were not used in the multiplicative analysis, age compositions from these collections were not relevant to the quantitative analysis of stock status.

ii) Aerial Survey (Chapter 3)

From 1990 to 1996, school areas had been estimated from digital imagery but 1997, a video camera was used. The switch to video technology was necessitated by budget reductions.

The total number of hours flown in 1997 was one of the highest since surveys began. Two transects, both in the inside part of Conception and Trinity Bays respectively, instead of three transects, allowed for greater coverage. However, the impact of deleting the third transect has not been evaluated.

In Trinity Bay, the highest school area estimate was observed on July 13-14, similar to 1994-96. This time also corresponds to the peak period (July 11-21) of egg deposition on Bellevue Beach. In Conception Bay, the highest total school area (Trinity Bay and Conception Bay) was also observed on July 14. The total school surface area in 1997 was lower than the 1996 estimate and fourth highest in the series. The 1997 estimate was 554,095 m^2 (range 107,736 m^2 (1984) to 759,486 m^2 (1996)).

iii) Beach Survey (Chapter 4)

In 1990, spawning times, egg deposition and development, larval emergence and various environmental variables were monitored on two spawning beaches located at Arnold's Cove (Div. 3Ps) and Bellevue Beach (Div. 3L). The number of sites was expanded in 1991 to include five additional beaches in Div. 3KL. In 1995 only two beaches, Chapels Cove and Bellevue Beach were sampled and in 1996 and 1997, only Bellevue Beach was sampled.

The 1997 spawning population mainly consisted of the 1994 yearclass (49%) followed by the 1993 yearclass (32%). This dominance by three-year-olds is similar to previous years from 1990 to 1996, except 1991 and 1992 when four-year-olds dominated. In 1997, the proportion of age 2 fish was considerably higher for females than for males. The 1995 yearclass represented 10% of the overall mature population spawning at Bellevue Beach.

Four modes of egg density assumed to represent spawning runs were observed on Bellevue Beach in early July, mid-July, late July and early August. Egg densities on Bellevue Beach were the second highest since 1990 and slightly higher than 1996. This implies that the mature biomass was similar in the last two years.

The majority of pre-emergent larvae observed in beach sediments in Bellevue Beach in 1997 occurred between August 7 and 13. The annual mean of the normalized estimates indicates that overall pre-emergent larval densities in 1997 were the fourth highest since 1990. This implies that the 1997 yearclass is of average strength for the 1990's, stronger than the 1991 and weaker than the 1992 yearclasses.

Data are no longer being collected on emerging larvae.

iv) Research Logbooks (Chapter 2)

The return rate of completed logbooks was lower than in previous years, 29% for fixed gear and 66% for mobile gear. In most of Div. 3L, the fixed gear fishery never opened and the mobile fishery was opened for less than a day in many bays. The main reasons for discarding (live and dumped) capelin were variable but the ones mentioned most often were low percentage of females, small fish size, redfeed and boat quotas. The overall discarding rate of 75% for traps was comparable to the highest rate in 1987 and the rate of 44% for purse seines was higher than 1996 and similar to 1990. Fishing effort for traps and purse seines was the lowest since data have been collected. Although catch rates for

1997 were high, it is suspected that these values should not be compared directly to catch rates from the 1980's. Effort has steadily declined from the early 1980's and most recently has been low due to monitoring. The effect has been to concentrate fishing effort only when capelin are most available.

Because of the very low effort concentrated over a short time period and the lack of a fishery in Div. 3L, catch rates for 1997 were not accepted for use in the multiplicative model.

5) Offshore Data

i) Bycatch in Bottom Trawl Surveys in Div. 2J3KL (Chapter 6)

Capelin are frequently caught during bottom trawl surveys directed towards groundfish off southern Labrador and eastern Newfoundland. The distribution and magnitude of capelin catches from the surveys in Div. 2J and 3K during the autumns of 1978-94 have been compared with acoustic surveys for capelin to help evaluate acoustic survey coverage. As a result of these comparisons, acoustic surveys were expanded temporally and spatially during the late 1980's and 1990's.

Beginning in 1995, fall groundfish surveys have been conducted differently. The major difference was the adoption of a Campelen 1800 shrimp trawl as the sampling gear. Comparative fishing for capelin between the old and new gear was not conducted so the results starting in 1995 are not directly comparable to results from previous years. As a result trawl bycatch data after 1994 have not been incorporated into the multiplicative model.

The autumn distribution of capelin in Div. 2J and 3K changed in the early 1990's. In years prior to 1991 most of the capelin in Div. 2J3K were concentrated either in Div. 2J or in central Div. 3K, but after about 1991 most of the capelin caught during the bottom-trawl surveys or found in stomachs of cod caught during those surveys came from southeastern Div. 3K. In 1997 the distribution was still concentrated toward the southeast but with some indication of a return to the west. The geographic distribution of mean capelin weights is in agreement with previous studies that showed that the large capelin were mainly toward the north and that small capelin were mainly toward the south, especially on the northern slope of Grand Bank.

In 1997 both the frequency of occurrence and minimum trawlable biomass of capelin were intermediate between values from the 1995 and 1996 surveys.

In the spring surveys in Div. 3L, the Campelen trawl was not used until 1996. The extensive distribution and moderate to large catches of capelin in Div. 3L in the springs of 1996 and 1997 contrast markedly with the very small catches in 1991-95. Part of the increase may be attributed to the change of the Campelen trawl in 1996. However, the Engels trawl was capable of making substantial catches of capelin in years prior to 1991, so the increase in 1996 may also reflect increased abundance in the survey area at the time of the survey.

There is a notable contrast between the autumn surveys and the spring surveys with respect to the increase in trawlable biomass of capelin attending the change to the Campelen trawl. In the autumn series the biomass estimates in 1995-97 were about an order of magnitude greater than estimates in the mid-1980's. The extent of the increase in the spring series is less clear because of the considerable difference between the estimates of 1996 and 1997. However, the estimate in 1997 was of similar magnitude to several estimates in the 1970's and 1980's. This might indicate that the quantity of capelin in Div. 3L at the time of the survey in 1997 was substantially lower than the quantity present at the time of several of the surveys in the 1970's and 1980's.

ii) Catches of Pelagic 0-group Surveys (Chapter 7)

A research program to develop a multispecies, pre-recruit survey was carried out during 1991-93, as part of the Northern Cod Science Program. Beginning in 1994, a two-ship survey was initiated to measure pre-recruit abundances of cod and capelin throughout NAFO Div. 2J3KLNO, including both inshore and offshore areas. Large and small gear types were used to sample capelin in the upper water column, for the larval state (0-group; 3-50 mm), one year old

(50-120 mm), and two year old capelin (2+, >120 mm). The intent of the survey was to sample pelagic juvenile cod, before they settle to the bottom and larval capelin, released from beach and bottom sediments.

The abundance data for larval (0-group) capelin were adjusted to account for different survey times in different years.

In 1997, the survey was conducted earlier than 1994 and 1996 by about 8 days and 1995 by about 24 days. The number of null catches of 0-group capelin in areas common to all years was the highest of all surveys, indicating that capelin were not dispersed as widely in 1997 and consistent with the earlier survey. However, the mean length of capelin in the bongos was 10.0 mm, similar in mean lengths in 1994-96. The adjusted larval capelin abundance (0-group) in 1997 ranked second for all areas with non-zero catches and fifth for common areas, null catches (1991-97 time series). Capelin larvae were abundant along the northeast coast and none were observed off southern Labrador.

The abundance of one-year-old capelin (1996 yearclass) was the highest in the time series (1991-96 yearclasses). The mean length of one-year-olds at 88 mm was similar to 1995 and 1992 yearclasses, smaller than the 1994 yearclass and bigger than the 1990 and 1991 yearclasses. One-year-old capelin were distributed mainly within the northeast coast bays and offshore on the northern Grand Bank with few off southern Labrador or on the Northeast Newfoundland Shelf.

6) Information on Capelin Predators

The timing of egg-laying by black-legged kittiwakes in southeastern Newfoundland during 1997 was later than 1996, which had been considered more "normal", and more similar to other years in the 1990's. It appears that water temperatures and breeding times are correlated with later breeding occurring in cold years. There has been an improvement in the number of two-egg clutches in 1996 and 1997 with a movement towards the situation in the 1960's. In contrast, during 1991-93, there were more one-egg clutches. Kittiwakes are surface-feeders and the poor success in the early 1990's has been considered to be linked to the vertical distribution of capelin. Gulls are also surface feeders and during those years, gull predation on kittiwakes chicks also increased.

In contrast, puffins are deep-divers and they have experienced good breeding success throughout the 1990's. Data from the 1960's, 1980's and mid-1990's indicates that the size of food loads to chicks was similar. However, since the mean length of capelin was smaller in the 1990's, more individual capelin were being fed.

On the Gannet Islands, near Labrador, the proportions of capelin in the diet of common murres and thick-billed murres declined dramatically in 1996 and 1997 compared to 1982 and 1983. However, breeding success for both species showed no significant change between the time periods. Chick growth in thick-billed murres during 1996 and 1997 was better than many other colonies worldwide. For common murres, early season growth was high but final fledging weights were slightly lower than in the 1980's. For both species, the time spent at the nesting sites was less than other sites indicating more time was spent foraging.

On Funk Island, the diet of gannet chicks has changed between 1977 and 1997. In warm water years, mackerel, saury and/or squid were common in the diet. In cold-water years, such as the 1990's, capelin have been important. The appearance of capelin in the diets coincides with the later spawning time of capelin, which makes them more available to foraging gannets. It is possible that it represents a spatial shift as well.

There is a considerable database on seabirds and capelin being accumulated. It may be possible to eventually incorporate data from the seabird observations into the multiplicative model. However, the different diving habits and how they affect the interpretation of capelin data must be accounted for prior to the incorporation into the model.

7) Other Studies

i) Predicting Mean Lengths (Chapter 5)

During recent assessments, positive relationships between mean lengths from fall offshore surveys and inshore the following year had been used to predict mean lengths of ripe females. In the 1997 assessment, two relationships were used to predict the likely sizes of mature females in 1997. The existing relationship between maturing capelin in the fall and mature capelin the next year indicated that female capelin in 1997 would be about the same size as the 1981-96 mean, slightly shorter than the 1981-90 mean but larger than the mean observed during the 1990's. The second relationship used was the relationship between immature females in the spring and mature females the following year. Using the mean lengths of females from the 1996 acoustic survey indicated that capelin in 1997 would be larger than the early 1990's.

The female capelin in 1997 did not achieve the mean lengths predicted using the relationships outlined above. The relatively small sizes, especially in Div. 3L, resulted in a poor or non-existent fishery. The reasons for the failed prediction are not known but could include: inadequate sampling either offshore in 1996, inshore in 1997 or both; inappropriate gear during the fall (Campelen has been used in recent years compared to midwater trawl previously); the source of the fall samples in recent years is the groundfish survey which is later than the source of samples in previous years, the acoustic survey; the growth between the fall and spring has not been as great in the 1990's as in the 1980's. In the latter case, the points from the 1990's form a cluster in the regression that is separate from the 1980's cluster. This shift in the 1990's is consistent with other biological changes such as later spawning and change in distribution.

Growth increments of maturing females between fall 1997 and spawning season 1998 cannot be predicted. Probability distributions for the mean length in 1998 were calculated separately for data from the 1980's and 1990's, based on a mean length of 144 mm observed in bycatch from the Campelen trawl from the fall groundfish surveys in Div. 2J3KL. If growth is similar to that observed during the 1990's there is about a 60% chance that the average length will exceed 151 mm (approximately equal to 50 count). However, the probability is zero that the average mean length will exceed 155 mm which means the average count is unlikely to be less than 45 count. However, if growth increments are more comparable to those observed in the 1980's, there is a 100% probability that the average mean length will be greater than 151 mm (50 count) and about a 65% chance that the average mean length will correspond to 40 count or lower. This analysis describes only the variation observed since 1981 and cannot rule out circumstances as yet unobserved. The analysis also uses pooled data from Div. 2J3KL and as such cannot account for variations that might be observed in local geographical areas and different spawning runs.

ii) Incidence of Repeat Spawning

Spawning mortality of capelin has been considered high based on the age structure of the population, observations of dead capelin near spawning beaches, and estimates derived analytically. Based on a study presented last year, histological examination of female gonads collected in the fall indicated that 20% and 60% of fish were recovering in 1995 and 1996, respectively. The present method using visual examination resulted in lower proportions of recovering females.

There were no histological results available for 1997. However, from 290 females (mean length >130 mm) collected in the fall and examined visually, about 40% were recovering compared to about 30% in 1996 and about 10% in 1995.

The capelin database back to 1978 was examined for the occurrence of recovering fish in females >130 mm, in NAFO 2J3KL, September-December. In most years between 1978 and 1991, the proportion of maturing females was less than 2%. Exceptions were 1980 (15%) and 1987 (5%). However, between 1992 and 1997, the proportions of maturing females ranged from 3% to about 11%.

Biology and Resource Status

During the 1990's, several biological changes, coincident with below normal water temperatures, have been documented. During offshore fall surveys in the 1980's, capelin were widely distributed from Div. 2J to Div. 3L, with a cline of larger to smaller capelin from north to south. In the 1990's, few capelin have been observed in Div. 2J and northern Div. 3K while most have been detected in southern Div. 3K and northern Div. 3L. The trends in size have been similar to the 1980's with larger capelin occurring in the northern part of the new distribution range and smaller capelin in the south. Also during the 1990's, capelin abundance measured by acoustic surveys was low.

During the late 1980's and through the 1990's, capelin bycatches increased one hundred fold in groundfish surveys on the eastern Scotian Shelf (Div. 4VW). Capelin occur sporadically in this area and as a result, it is not known whether the increase was a result of immigration or enhanced reproductive success. Capelin also appeared on the Flemish Cap (Div. 3M) during the 1990's as bycatch in groundfish surveys and the shrimp fishery. Capelin are rare here and this appearance was most likely due to migration. Increases in abundance in both areas, both historically and recently, have coincided with cold water.

The average size of capelin has declined during the 1990's. At the same time, the timing of inshore spawning has been delayed by up to four weeks. The later spawning has been correlated with colder water and smaller fish size.

Other observations of unusual characteristics of capelin biology during the 1990's, not documented in the scientific literature, include: an increase in the relative proportion of spawning at night; changes in physical structure of the otoliths causing problems in age determinations; an increased incidence of females with ovaries full of unspawned eggs in the fall; a consistent and relatively high level of the proportions of spent females in the fall since 1992.

In the evaluation of resource status, seven partially overlapping series of indicators were combined in a mathematical model to provide relative estimates of yearclass strength (Chapter 8). The indicators used in the model were:

1) aerial survey index 1982-97
2) purse seine catch rate index 1981-96
3) trap catch rate index 1981-93
4) groundfish 3L fall bycatch 1985-94
5) groundfish 2J3K fall bycatch 1985-94
6) Russian 2J3K fall commercial catch rate index 1972-91
7) egg deposition index 1990-97

The aerial survey and egg deposition index provided the only information on the 1995 yearclass and the 1997 mature biomass in this formulation of the mathematical model. The 1997 aerial survey index was lower than the 1996 estimate. It was the fourth highest in the series and higher than all but one (1987) of the estimates from the 1980's. Egg densities in Bellevue Beach were the second highest in the series (highest in 1993). Catch rate data from purse seines and traps for 1997 were not considered to be indicative of stock status because the fishery was very contracted both spatially and temporally. A change in the gear in the fall groundfish survey in Div. 2J3KL in 1995 has effectively produced a new series which is too short to use.

Results from the model (Fig. 1) indicate that the 1983, 1986 and 1990 yearclasses were strong. Yearclasses since 1992 also appear strong but the standard errors were so large that the relative abundance of these yearclasses is statistically indistinguishable from both large and less abundant yearclasses.

A second mathematical model (Chapter 8) using results from surveys for larvae and one-year-olds produced a recruitment index (Fig. 2). The indicators used in the model were:

1) oceanic 0-group index 1991-97
2) sediment larval index 1990-97
3) emergent larval index 1990-96
4) Conception Bay sediment larval abundance 1987-93
5) oceanic age 1 index 1992-97

This recruitment index shows trends in yearclasses up to 1993 that are similar to trends in the cohort index. After 1993, the largest difference between these two indices occurs for the 1994 yearclass which in the recruitment index is relatively weak. The 1995, 1996, and 1997 yearclasses appear strong with the 1996 yearclass as strong as any in the series. Although the estimates of yearclass strength exhibit considerable variation, the statistical uncertainties are large.

A third (Chapter 8) mathematical model (using the same seven series of indicators as the cohort model and which includes an assumption that recruitment does not change) provided trends in mature biomass (Fig. 3). The trends indicate that biomass was relatively high in the late 1980's and in the more recent years in the 1990's, consistent with the presence of strong yearclasses. However, standard errors are large and biomasses from the mid-1980's to the present are not statistically different.

The assessment of the capelin stock described above is more optimistic than the results from an opinion survey of capelin fixed gear fishermen. Most respondents considered capelin abundance to have decreased from 1996. This survey has been conducted for four years and in each year, fishers indicated that the abundance of capelin has been lower than when they first started fishing capelin.

Sources of Uncertainty

Many sources of uncertainty have been cited in previous stock status reports. These included the large-scale changes in distribution, the irreconciled divergence between low offshore acoustic estimates and inshore indices in the 1990's, difficulties in ageing capelin in the 1990's compared to earlier years and the large statistical uncertainties from the mathematical model. The mathematical models used assume that a number of things are constant over time; for example, maturity schedules, survival rates and for the biomass model, yearclass strengths. The effects of violations of these assumptions have not been examined.

There is particular concern about whether the individual indices are now providing reliable indicators of stock status. During the 1980's, catch rates and other indices showed similar annual patterns. However, catch rates may now be poor indicators of stock status. Fishing effort has declined in recent years, due in part to monitoring for quality and fishing only when the fish meet market requirements. This results in catch rates which probably cannot be compared to the 1980's and may not reflect stock status. Both the aerial survey and egg deposition studies which provide fishery-independent indices, have been reduced in geographical coverage and/or intensity. The aerial survey now covers only the transects in the inner parts of Trinity and Conception Bays. The only beach study area is Bellevue Beach compared to six study beaches (three in each of Div. 3L and 3K) in the original study. There are two major concerns with the 1997 aerial and beach surveys: 1) they are so limited in geographical coverage compared to the overall stock area that the results may not reflect status of the whole stock, and 2) there are indications from the opinion survey that abundance may be changing at different rates within the stock area, for example, within the bays versus near headlands. If this is the case, the limited geographical coverage by the aerial and beach survey may not detect these changes. While the offshore surveys for early life stages (primarily 0- and 1-group) are continuing, acoustic surveys for older juveniles and adults have been discontinued. Scientific investigations have been reduced to such an extent that it may not be possible to assess the status of capelin stocks.

There is also concern over the divergence between the assessment using the mathematical model and the opinions of fixed gear fishermen, particularly the contradiction in comparisons between the 1990's and earlier periods. A longer timeseries and further evaluation are necessary to determine whether the opinion survey can be used as a stock status indicator but this evaluation will be very difficult without other sources of data, which as noted, may be compromised by reduced coverage.

Outlook for 1998

The 1994 and 1995 yearclasses are expected to be major contributors to the 1998 spawning stock. The results from this and previous assessments on the relative strength of the 1994 yearclass are contradictory. The recruitment index indicates the 1994 yearclass is relatively weak while the cohort index indicates this yearclass is relatively strong. The 1995 yearclass is stronger than the 1994 yearclass from both the recruitment and cohort indices. The recruitment index, which incorporates several observations of the strength of this yearclass, indicates that it is about average strength (1987-97 yearclasses). If the conservative estimates of yearclass strength for the 1994 and 1995 yearclasses as derived from the recruitment index are considered, the 1998 mature biomass would be expected to be no better than average, when compared to biomasses of the 1990's.

There have been many problems and uncertainties in assessing the capelin stocks in recent years related in part perhaps to changing behaviour during unusual oceanographic conditions, as well as reduced directed scientific research. It is unlikely that future assessments will be improved at the current level of research activity.

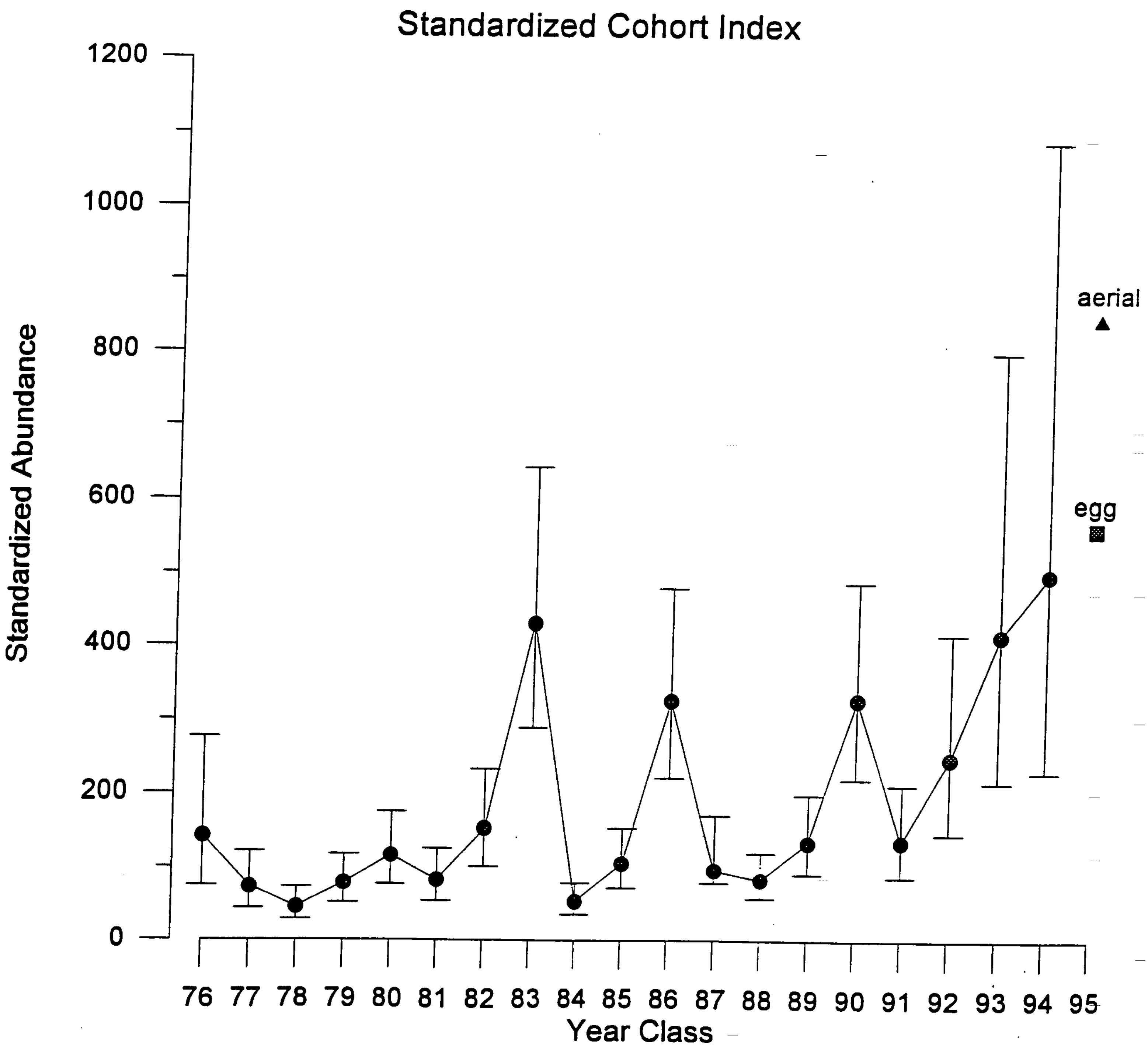

Fig. 1. Standardized cohort index derived from the multiplicative model.

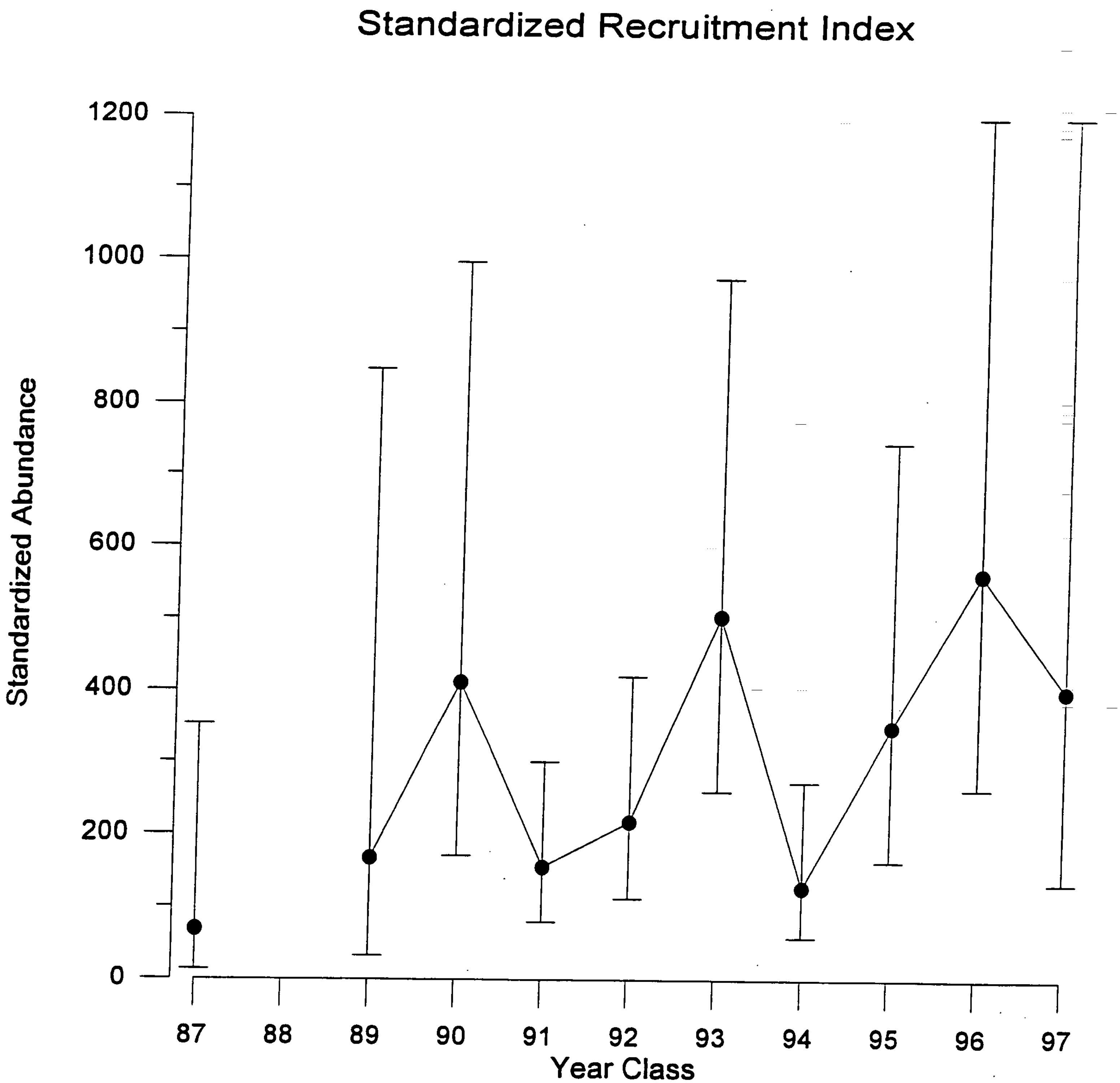

Fig. 2. Standardized recruitment index derived from the multiplicative model.

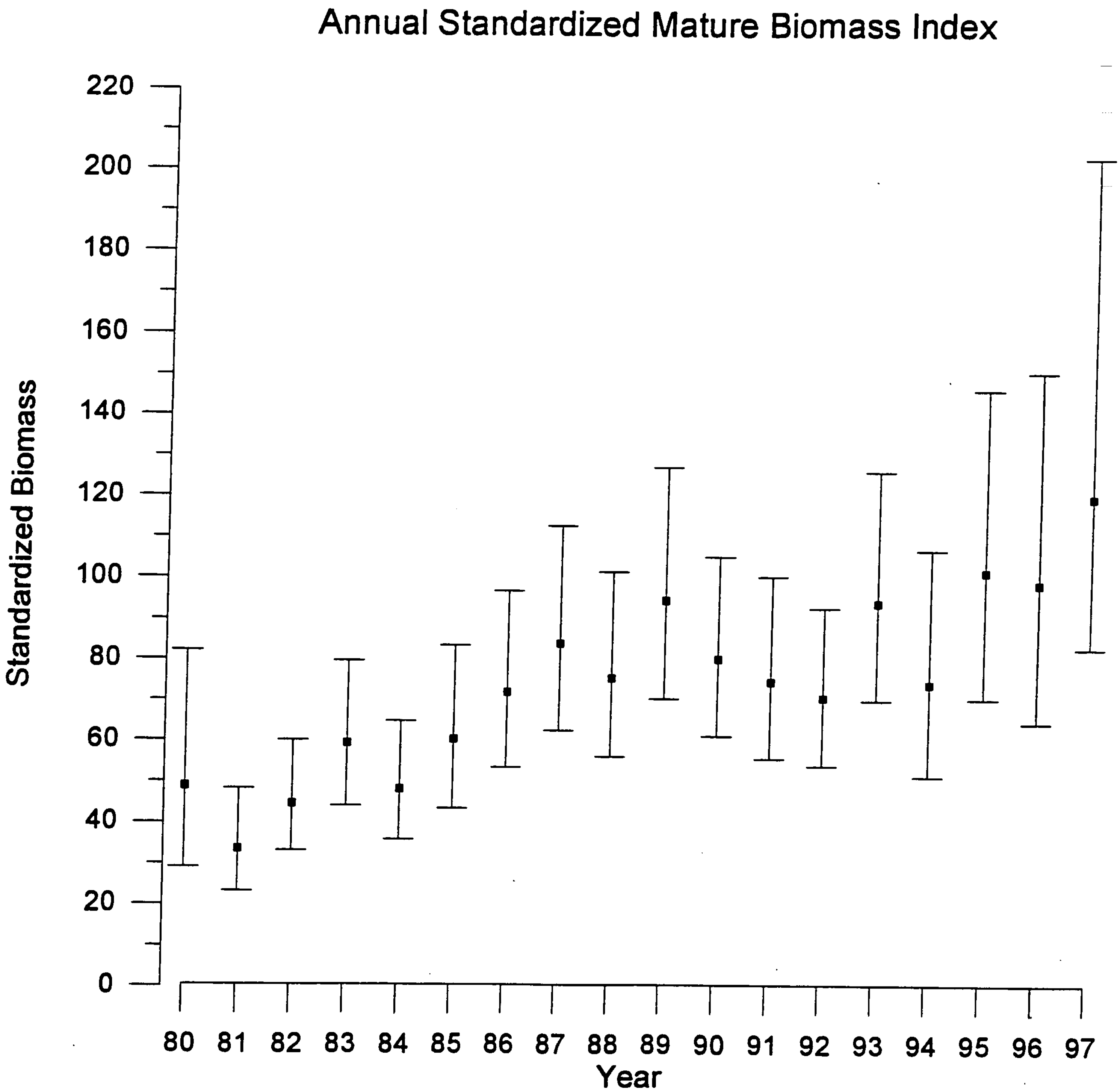

Fig. 3. Standardized mature biomass index derived from the multiplicative model.

Appendix 1

List of Participants

Name	Affiliation
Anderson, J.	Ocean Ecology
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Chardine, J.	CWS
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Dalley, E.	Ocean Ecology
Eustace, P.	PSSMM
Evans, G.	PSSMM
Lilly, G.	Groundfish
Mayne, B.	Resource Management
Miller, D.	PSSMM
Montevecchi, W.	M.U.N.
Nakashima, B.	PSSMM
Redmond, Greg	Ocean Ecology
Slaney, B.	PSSMM
Stansbury, D. (Chair)	Groundfish
Wheeler, J.	PSSMM
Winters, G.	PSSMM

Results of a Telephone Survey of 1997 Fixed Gear Capelin Licence Holders

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St. John's NF A1C 5X1

Introduction

A questionnaire was used to quantitatively evaluate biological and fishery-related information obtained from capelin (Mallotus villosus) fishermen in 1997. The questions were developed to supplement information collected by the research logbook and beach sampling programmes and to quantify to some extent the impressions of fishermen on the status of the capelin stock in Div. 3KL. All questions were the same as in previous surveys with some exceptions. Two questions related to the cessation of spawning (Nakashima 1997: Ques. 12a and 12b) were dropped from the 1997 survey. Previously these questions produced a high level of unknown responses because respondents tended not to notice or recall the end of spawning (eg. Nakashima 1995, 1996, 1997). The 1997 survey includes for the first time a question on the size of female capelin in the spawning population (see Appendix A).

Methods

The survey population size of 1830 (3L:799, 3K:1031) was defined as all capelin fixed gear (traps and beach seines) fishermen licensed to fish capelin in NAFO Div. 3L and 3K in 1997. A list of names and telephone numbers was provided by the Resource Management Division, Fisheries and Habitat Management Branch, DFO. Employing a simple random sampling design and an expected response rate of 85% a sample population with 219 names was chosen to achieve a ±7% margin of error with 95% confidence intervals (Gower and Kelly 1993). The sampling statistics do not apply to the comments presented in Table 1. Unlike previous years this analysis excluded questionnaires from Div. 3Ps. The survey was conducted by telephone interview.

Telephone interviews commenced October 6, 1997 and were completed on November 16, 1997. Interviewers were unable to contact 30 individuals on the licensing list which were included in the sample population. Of these 9 could not be contacted despite five attempts to do so, 4 had no telephone in service (disconnected, wrong number, no telephone number), 3 were out of the province during the survey, 4 declined to participate, 8 did not fish, and 2 persons were deceased. The 189 completed questionnaires represent an 86% response rate which was slightly higher than the 85% expected.

Comparisons to earlier years are based on a reanalysis of the pre 1997 database using only the information from Div. 3KL. Past reports generated statistics for Div. 3KLPs (Nakashima 1995, 1996, 1997).

Results and Discussion

Abundance Questions

Three questions (Appendix A) comparing abundance of capelin in 1997 to previous years were asked in the survey. Most respondents indicated that capelin abundance in 1997 in their area was low (Fig. 2) with a mean response equal to 3.8. This is lower than 5.4 in 1996 and comparable to 3.4 in 1995. The abundance of capelin in 1996 was estimated to be 4.7 by respondents of this survey which was slightly lower than the 5.4 estimate from the 1996 survey (Fig. 3). Unlike the last two years (Nakashima 1996, 1997) the perception of relative abundance the previous year declined with time. When given three options in question 3 (Appendix A) respondents clearly indicated that capelin abundance in 1997 was lower than when they first started to fish capelin (Fig. 4). This response has held firm for all four surveys. Generally most respondents considered capelin abundance to be low and to have decreased from 1996.

Spawning Questions

Questions 4-13 (Appendix A) relate to spawning. According to respondents capelin in 1997 occupied a small proportion of the available spawning beaches (Fig. 5). The number of respondents reporting 'no spawning' has increased from 1996. The responses in the 1-5 beaches category is similar to 1996 (Nakashima 1997), however most responses were at the low end of the range. Capelin spawned on less or the same number of beaches in 1997 compared to 1996 (Fig. 6). The intensity of spawning was lower in 1997 than in 1996 (Fig. 7) with a mean spawning intensity of 4.1 compared to 6.5 in 1996 and 3.8 in 1995. Spawning intensity in 1997 compared to 1996 was considered to be lower or the same (Fig. 8). Egg densities at Bellevue Beach were similar in 1996 and 1997 (Nakashima et al. 1998) while the total school area estimated by the aerial survey in 1997 was lower than the estimate for 1996 (Nakashima 1998). Respondents felt spawning on beaches in 1997 was lower than in 1996.

Compared to 1996 (Nakashima 1997) capelin exhibited less off-beach spawning behaviour in 1997 and more than reported for 1995 (Fig. 9). Non-responses remain high at over 30%. The historical view of capelin spawning off beaches has changed somewhat among the three most recent surveys (Fig. 10). The 96 persons who responded in the affirmative to question 8 were asked to give reasons why capelin may have spawned in deeper water in 1997 (Appendix A: question 9). The most frequent response was better water temperatures in deeper water (51%). Other possibilities suggested were the presence of predators (eg. humans, seagulls) driving capelin away from beaches (13%), low capelin abundance (3%), cold water (1%), no cod to drive capelin ashore (1%), and rough water inshore (1%). Approximately 14% said capelin in their area always spawned in deep water which has remained consistent for all years surveyed. The remaining 16% gave no response.

Spawning times were again delayed compared to the 1980s. The distribution of times is similar to 1995 and marginally later than 1996. Of those answering question 11a who recalled when spawning began in 1997 the majority suggested late June to late July with most respondents favouring early to mid July (Fig. 11). Almost 28% observed no spawning in 1997, a similar proportion in 1995. Comparing the start of the spawning season in 1997 to 1996 in question 11b most respondents who expressed a time indicated that it was the same (Fig. 12). Fifty-nine of 189 respondents were unable to make a comparison. Compared to when fishers first started fishing capelin there has been an overwhelming majority which felt that spawning in 1994-97 has been later (Fig. 13). Spawning began in mid-July at Bellevue Beach, Trinity Bay in 1997 (Nakashima et al. 1998) which is within the range reported in this survey.

The general size of females in 1997 was small (45%) or average (29%) with few reports of large females (Fig. 14). These observations are consistent with the low mean lengths observed in samples collected in 1997 (Carscadden and Evans 1998).

Questions on the Fishery

Almost all licenced respondents (98%) intended to fish capelin in 1997 and 49% actually set out fishing gear. Of the 92 respondents who fished in 1997, 45 used one trap, 17 used two traps, 2 fished more than 2 traps, 10 used trap(s) and a beach seine, and 28 used a beach seine. Over 55% who fished had no landings in 1997 (Fig. 15) and average reported landings were 26,300 lbs (11,930 kg). The majority reported discards of less than 25,000 lbs (11,340 kg) (Fig. 16). Combining estimates of landings and discards by telephone respondents the average catch in 1997 was 32,520 kg (71,700 lbs) (Fig. 17). In comparison the average catch from logbook estimates (53,000 kg, Nakashima and Slaney 1998) was higher than the telephone survey results. Most of the discarded capelin were released alive (Fig. 18). The reasons for discarding were small fish (33%), redfeed (20%), capelin caught during the monitoring period (15%), low percentage of females (13%), spent fish (6%), over ripe females(4%), catch in excess of vessel capacity (4%), problems with buyers and selling capelin (2%), mixed with herring (2%), and capelin caught after the season was closed (2%). Logbook results support the importance of redfeed, small fish and low percentage of females but also include boat quotas as a significant factor (Nakashima and Slaney 1998). Discarding in 1997 was lower than in previous years (Fig. 19). In contrast trap logbooks report one of the highest discarding rates (Nakashima and Slaney 1998). Of those who fished 55% reported bycatches of a few pounds to several thousand pounds. The most frequent bycatch species based on estimated weight were cod (60%), herring (31%), small cod (7%), flatfish (1%), and less than 0.5% for each of squid, salmon, and rock cod. Of these 88% were released alive.

Questions on Climate and Ocean Conditions

The sample population was asked question 24 (Appendix A) pertaining to general weather and oceanic conditions during the summer of 1997. Wind conditions in the summer of 1997 were considered calm by 3% of the population, light or favourable by 46%, moderate by 39%, and windy by 12%. Air temperatures were reported to be cold (5%) or cool (35%), average (38%), or warm (22%). The summer was mainly overcast (46%) or half sunny and half overcast (40%). Only 14% said it was mainly sunny. Ice was not a concern in 1997 with only 7% reporting moderate or heavy ice. Fishers reported cold (18%) or cool (19%) water temperatures, average conditions (37%), and warm temperatures (26%) which covered a wide range. Overall weather conditions were considered to be average (32%) or favourable (50%) for fishing throughout the region.

Comments by Respondents

At the end of the telephone interview each of the 189 respondents were solicited for comments. The range of topics covered most aspects of capelin biology and the fishery and also on other fisheries. The comments relative to capelin have been summarized in Table 1.

Demographics of the Sample Population

All respondents were asked questions 25-28 to characterize the sample population of fixed gear fishers and to be able to relate in subsequent analyses responses to areas fished and experience in the fishery. The distribution of responses to question 25 suggests a change in the number of years of involvement in the capelin fishery (Fig. 20). In 1997 the entry years of respondents were mainly 1982 and between 1984 and 1989. The low number of new entrants in the 1990s is expected in recent years. Fishing vessel lengths varied from 17 to 55 feet with 87% less than 36 feet (Fig. 21). Estimated vessel capacity for capelin was less than 30,000 lbs (13,600 kg) for 75% of the fishing fleet involved in the fixed gear capelin fishery (Fig. 22). Most licensed fixed gear capelin fishers are in the 45 to 55 age range followed closely by the 35 to 44 range (Fig. 23). The average age was 45 years. Average vessel capacity (17000 lbs or 7700 kg) and vessel length (29 ft) of the fleet and the age structure of the licence-holders (Fig. 23) are comparable to previous surveys. The highest proportion of respondents were from Notre Dame Bay with the fewest fishers in the sample population from the Southern Shore and St. Mary's Bay (Fig. 24). The distribution of responses from Div. 3KL in the sample population is similar to previous surveys.

Summary

Results from the telephone survey of fixed gear capelin fishermen provided observations on beach spawning, local capelin abundance, fishing activities, and summer weather conditions. In 1997 most respondents indicated that capelin spawned slightly later, spawned on fewer beaches at a lower intensity, and spawned subtidally away from beaches more so than in the 1980s. Most licenced fishers intended to fish in 1997 but only 50% actually put their gear in the water. The commercial fixed-gear fishing activity occurred in Div. 3K or on the Southern Shore and in St. Mary's Bay. In the other bays the only source of fixed gear fishing activity was from individuals who participated in the monitoring programme. The weather was generally considered favourable for being out on the water and water temperatures were considered warmer than normal. Overall respondents felt capelin abundance and spawning on beaches in 1997 was less than observed in 1996 and much lower than in the 1980s. The results of this telephone survey

represent the opinions of the survey population at the time the survey was conducted with a ±7% margin of error 19 times out of 20.

Acknowledgements

Morris Clark and Barry Slaney conducted the telephone interviews. Our appreciation to the individuals who took the time to share their knowledge with us. M. Y. Rees assisted in the preparation of the manuscript.

References

Carscadden, J., and G. T. Evans. 1998. Predicting mean lengths of female capelin in SA2 + Div. 3KL. pp. 72-78. In: Anon. Capelin in SA2 + Div. 3KL. DFO Atl. Fish. Res. Doc. 98/63.

Gower, A., and K. Kelly. MS 1993. How big should the sample be? Social Survey Methods Division, Statistics Canada. 14p. (Mimeo).

Nakashima, B. S. 1995. Results of a telephone survey of 1994 fixed gear capelin licence holders. pp. 4-24. In: Anon. Capelin in SA2 + Div. 3KL. DFO Atl. Fish. Res. Doc. 95/70.

1996. Results of a telephone survey of 1995 fixed gear capelin licence holders. pp. 4-26. In: Anon. Capelin in SA2 + Div. 3KL. DFO Atl. Fish. Res. Doc. 96/90.

1997. Results of a telephone survey of 1996 fixed gear capelin licence holders. pp. 28-41. In: Anon. Capelin in SA2 + Div. 3KL. CSAS Atl. Fish. Res. 97/29.

1998. Results of the 1997 aerial survey of capelin (*Mallotus villosus*) schools. pp. 50-61. In: Anon. Capelin in SA2 + Div. 3KL. CSAS Atl. Fish. Res. Doc. 98/63.

Nakashima, B. S., and B. W. Slaney. 1998. The 1997 inshore capelin (*Mallotus villosus*) fishery in NAFO Div. 3KL. pp. 38-49. In: Anon. Capelin in SA2 + Div. 3KL. CSAS Atl. Fish. Res. Doc. 98/63.

Nakashima, B. S., G. H. Winters, and B. W. Slaney. 1998. Spawning, egg densities, and pre-emergent larvae from Bellevue Beach, Trinity Bay in 1997. pp. 62-71. In: Anon. Capelin in SA2 + Div. 3KL. CSAS Res. Doc. 98/63.

Appendix A

SURVEY QUESTIONNAIRE OF FIXED GEAR CAPELIN LICENCE HOLDERS

Questions on Abundance:

1. Using a scale of 1 to 10 with 1 being the lowest and 10 the highest how abundant (i.e. numbers of fish) were capelin in your area this year?

2. Using a scale of 1 to 10 with 1 being the lowest and 10 the highest how abundant (i.e. numbers of fish) were capelin in your area last year?

3. How would you describe the abundance of capelin this year compared to when you first started fishing capelin?

Questions on Spawning:

4. Approximately on how many beaches in your area do capelin usually spawn?

5. Approximately on how many beaches did capelin spawn this year?

   If 'none' or 'don't know' go to Ques. 8

6. How many beaches did capelin spawn on this year compared to last year?

7a. On a scale of 1 to 10 with 1 being low and 10 being high how intense was capelin spawning in your area this year?

7b. What was the intensity of capelin spawning this year compared to last year?

8. Did capelin spawn off beaches in your area in deeper water?

   If yes go to Ques. 9
   If 'no' or 'don't know' go to Ques. 10
   If no spawning on beaches or in deep water go to Ques. 14

9. Why do you think capelin spawned in deeper water this year?

10. How often since you started fishing have you observed capelin spawning off beaches in deeper water?

11a. When did capelin first spawn in your area this year?

11b. Did spawning start at the same time this year as last year?

12. What was the overall size of female capelin this year?

13. How does the timing of capelin spawning (beginning and end) this year compare to when you first started fishing capelin?

Questions on the Fishery.

14. Did you intend to fish for capelin this year?

    If 'yes' continue, if 'no' go to Ques. 24

14b. Did you set your fishing gear or go out and search for capelin this year?

    If 'yes' continue, if 'no' go to Ques. 24

15a. What type of fishing gear did you use?

    If a 'trap' go to Ques. 15b if other gear types go to Ques. 15d

15b. How many traps did you fish?

15c. How much capelin does your trap(s) hold when full?

15d. Did you always fish this gear type or have you fished other types in the past?

    If fished other gear types what were they?

16. Approximately how much capelin did you and your crew land this year?

17. Approximately how much capelin (live or dead) did you and your crew discard (i.e. did not land or sell)?

    If discarding >0 continue, if discarding is '0' go to Ques. 21

18. What percent of the discarded capelin do you think survived?

19. Why were capelin discarded? Please give reasons in order of importance.

20. How does the amount discarded this year compare to all the other years you've fished capelin?

21. While fishing capelin did you and your crew catch any other species (i.e. by catch)?

    If 'yes' continue, if 'no' go to Ques. 24

22. What species (three maximum) were they and approximately how many (weight) of each?

23. What was the condition of the by catch when released?

Questions on Climate/Ocean Conditions:

24. Weather plays an important role in the biology of capelin. Please describe the local weather and sea conditions in your area during capelin spawning season (usually June/July). Winds-force and direction, air temperature, sun or overcast, ice, water temperature

General Information:

25. In what year did you first start fishing capelin commercially?

26. What is the length and capacity (maximum weight of capelin it can carry) of your vessel?

27a. Have you always fished for capelin in the same location?

If 'no' continue, if 'yes' go to Ques. 28

27b. Where else have you fished for capelin?

28. How old are you?

Table 1. Summary of comments pertinent to capelin or the capelin fishery.

Comment	Number of responses	Percent response
No capelin/scarce	25	13.2
Lots outside and after quota closed	1	0.5
Lots/lots but never came to land	6	3.2
Not much and small	3	1.6
Good size and abundant	1	0.5
Fair amount/abundant and small	3	1.6
Small	5	2.7
Bay stocks of large capelin gone, small offshore ones left	1	0.5
Good size	1	0.5
Capelin around long time	1	0.5
Capelin deep not come to land	2	1.1
Cold summer/water, no capelin	2	1.1
Bad weather	1	1.5
Seals got everything/capelin	3	1.6
Caught/destroyed by seiners/longliners	4	2.1
Dumping destroying capelin	3	1.6
Fishery should be closed	23	12.2
Cod closed; capelin should be closed	14	7.4
Should not be destroyed for nothing/low price	9	4.8
Low abundance, close fishery	1	0.5
Closed to let capelin grow	1	0.5
Leave alone for a while	2	1.1
Closed until know more about capelin	1	0.5
Open if stocks are there	2	1.1
No monitoring, just open	9	4.8
Need better monitoring	1	0.5
IQ system	3	1.6
Need bigger quota	1	0.5
Should not allow fishing in other areas	1	0.5
Ban capelin traps which destroy young cod	1	0.5
Opened too early	3	1.6
Opened too late	1	0.5
Used to go and look, now wait for opening date	1	0.5
Buyers not interested in buying	1	0.5
No comments	52	27.5

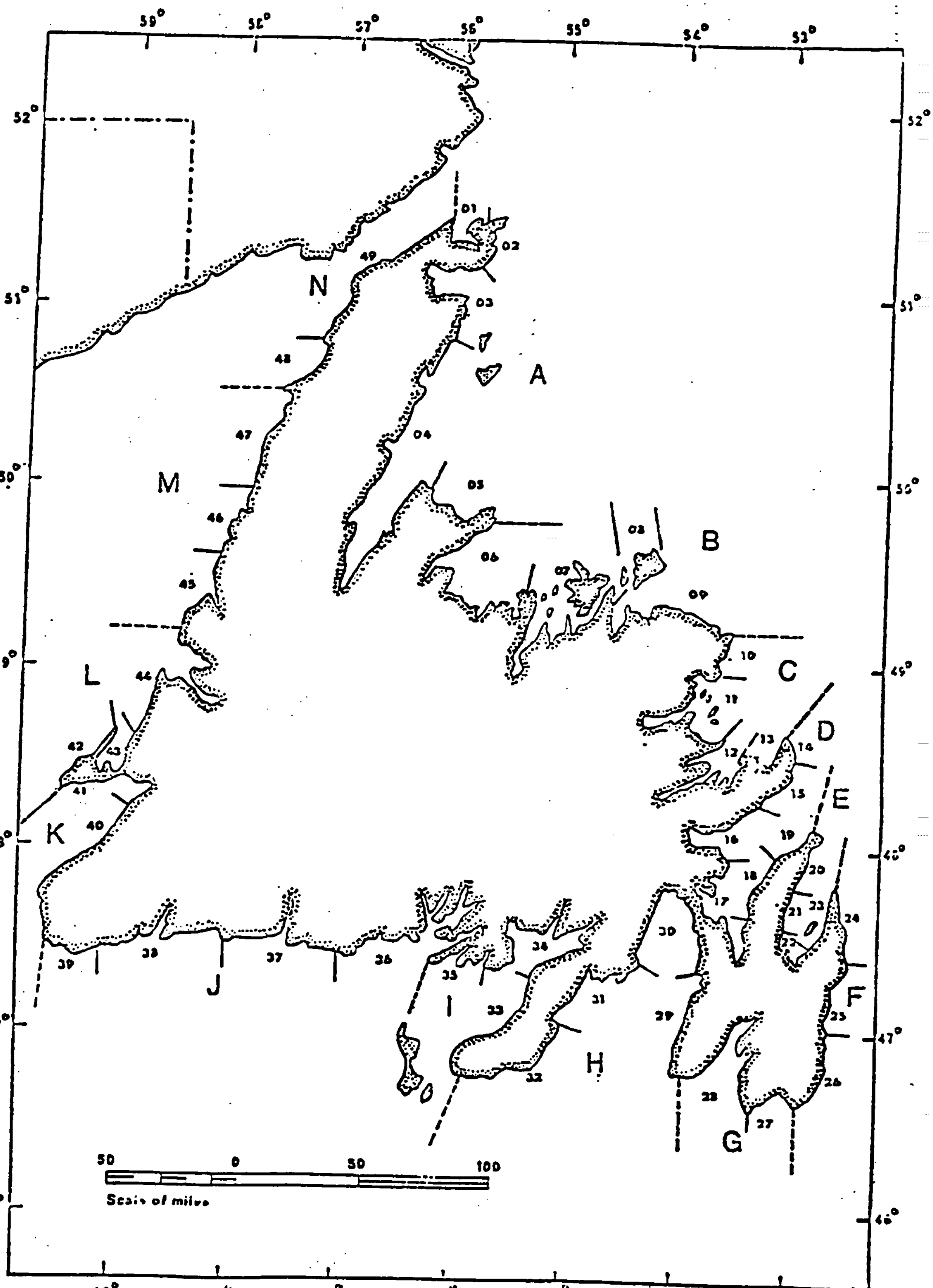

Fig. 1. Statistical areas (A = White Bay, B = Notre Dame Bay, C = Bonavista Bay, D = Trinity Bay, E = Conception Bay, F = Southern Shore, and G = St. Mary's Bay) for the Newfoundland Region.

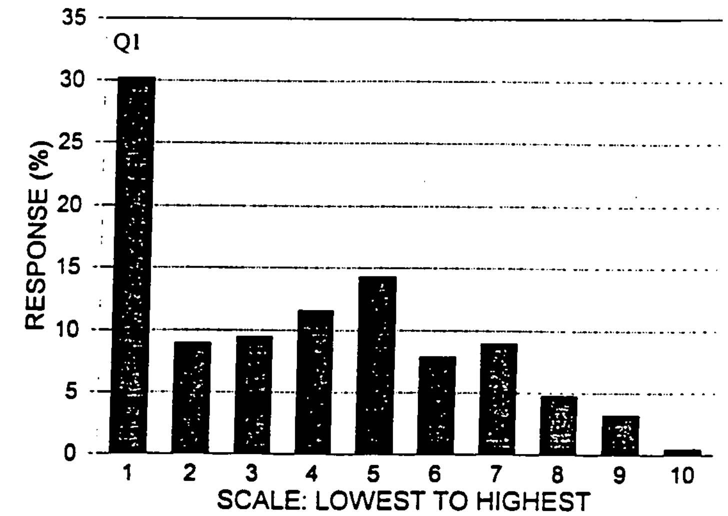

Fig. 2. Response to question 1 on the abundance of capelin in 1997.

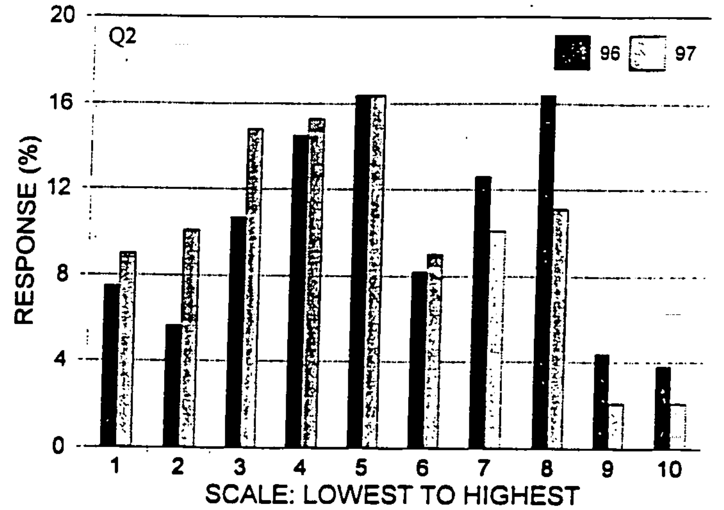

Fig. 3. Impression of capelin abundance in 1996 from the 1996 (Nakashima 1997) and 1997 surveys.

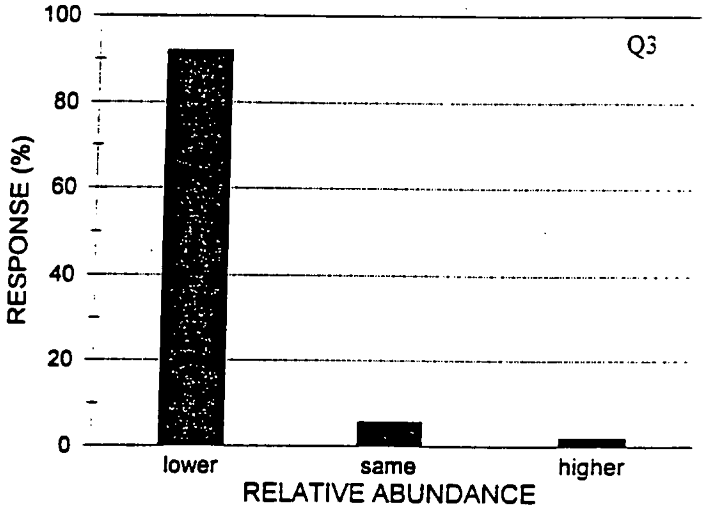

Fig. 4. Response to question 3 concerning abundance in 1997 compared to first started fishing. No answer given (na).

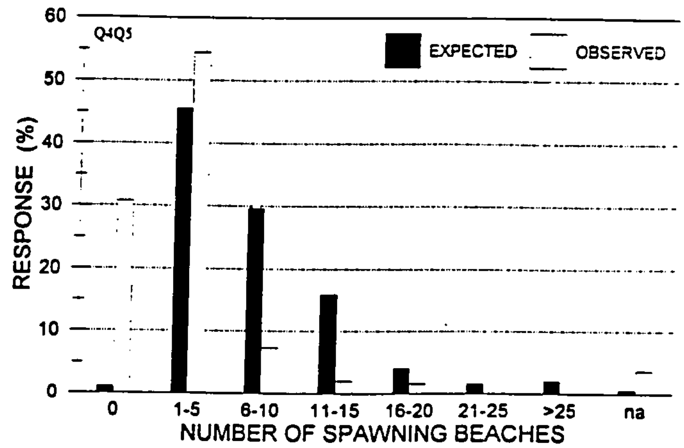

Fig. 5. Comparison of the number of beaches capelin spawned on in 1997 to the available beaches. No answer given (na).

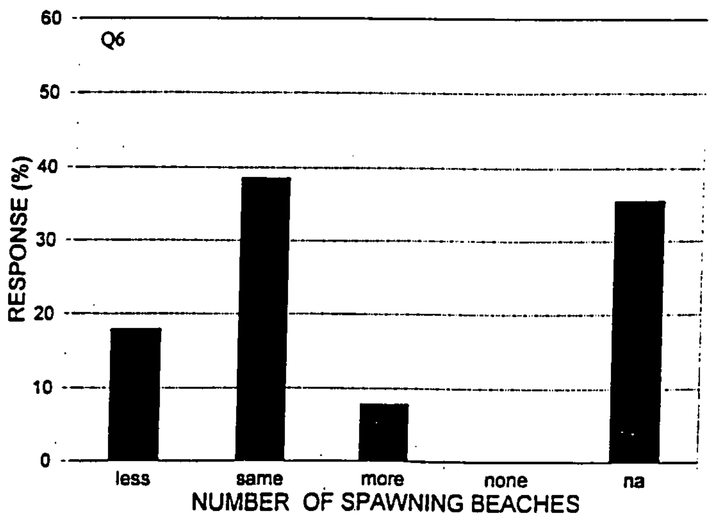

Fig. 6. Response to question 6 concerning the relative number of spawning beaches occupied in 1997 compared to 1996. No answer given (na).

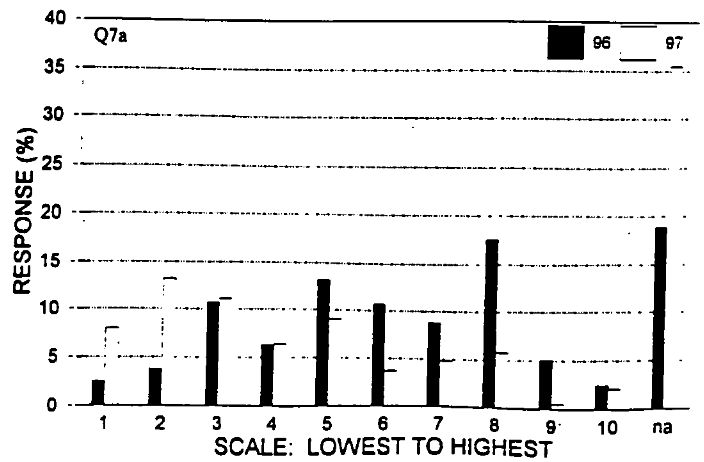

Fig. 7. Response to question 7a comparing the intensity of spawning on an increasing scale of 1 to 10 in 1996 and 1997. No answer given (na).

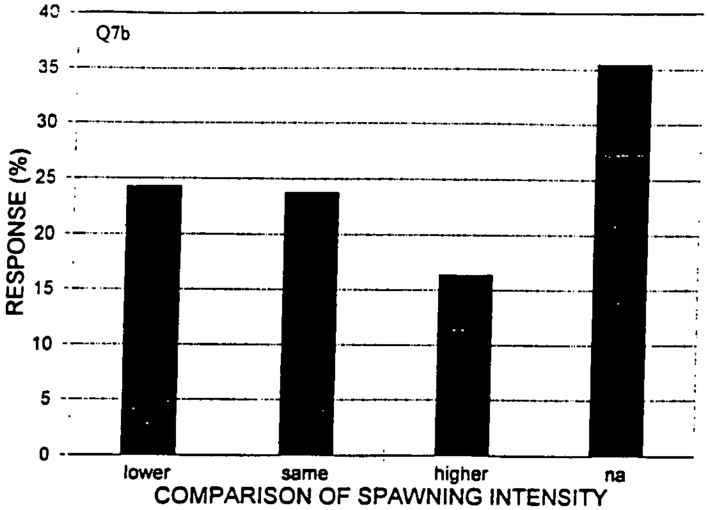

Fig. 8. Response to question 7b comparing the spawning intensity in 1997 relative to 1996. No answer given (na).

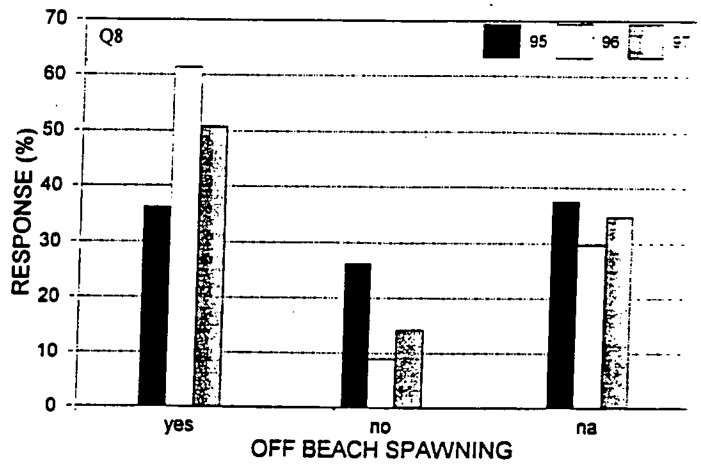

Fig. 9. To what extent did off beach spawning occur in 1995 (Nakashima 1996), in 1996 (Nakashima 1997) and in 1997. No answer given (na).

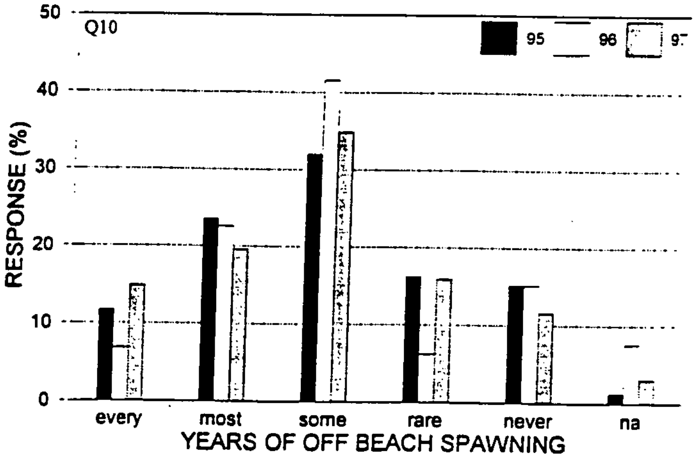

Fig. 10. The prevalence of off beach spawning reported in the 1995, 1996 and 1997 surveys. No answer given (na).

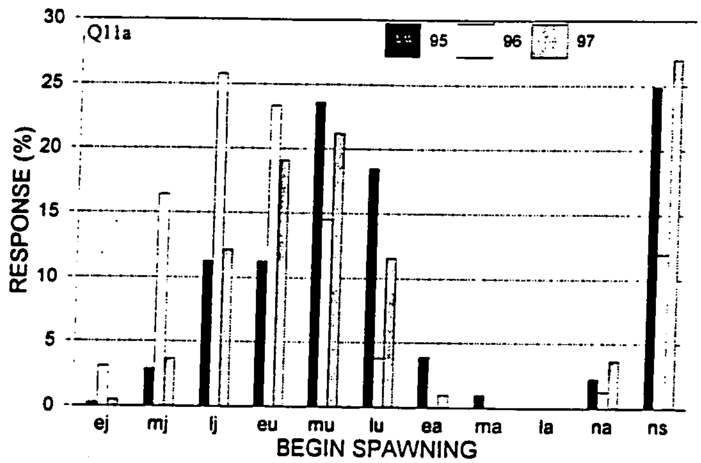

Fig. 11. The time when capelin began spawning in 1995 (Nakashima 1996), 1996 (Nakashima 1997) and 1997. Spawning times are early June = ej, mid June = mj, late June = lj, early July = eu, mid July = mu, late July = lu, early August = ea, mid August = ma, and late August = la. No answer given (na) and no spawning (ns).

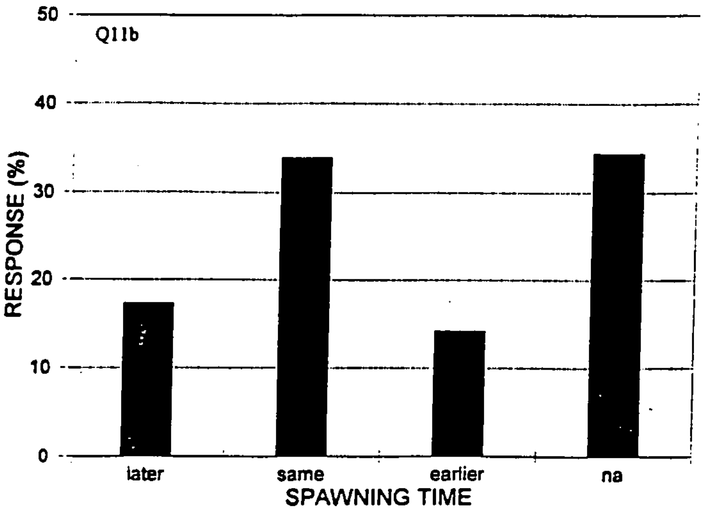

Fig. 12. The start of spawning in 1997 compared to 1996 in response to question 11b. No answer given (na).

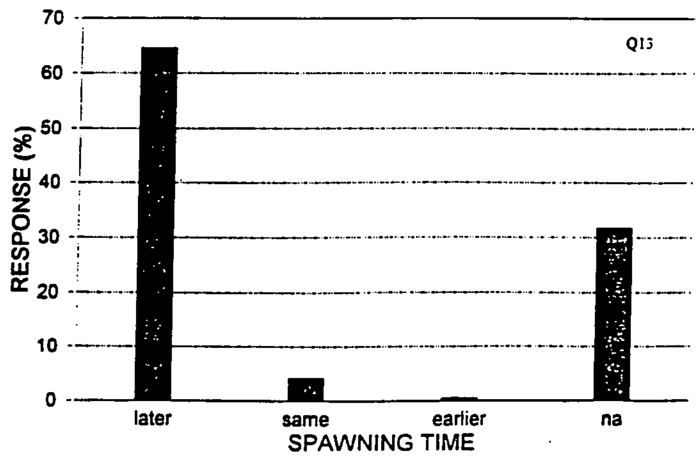

Fig. 13. Comparison of spawning times in 1997 to when respondents first fished capelin. No answer given (na).

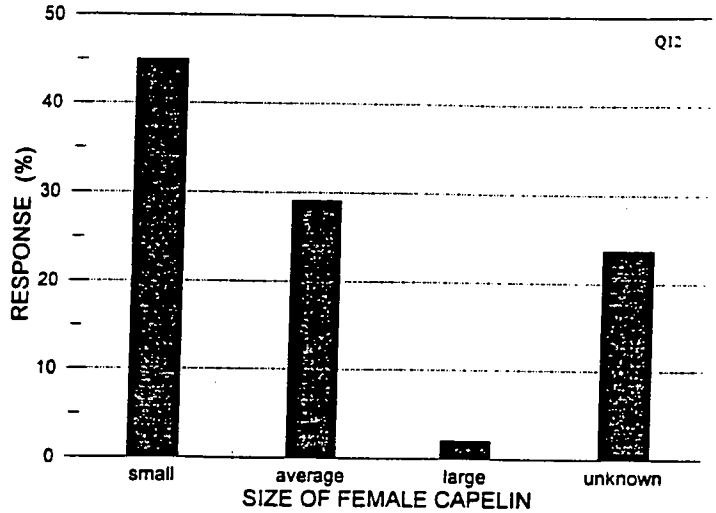

Fig. 14. Sizes of capelin observed in 1997.

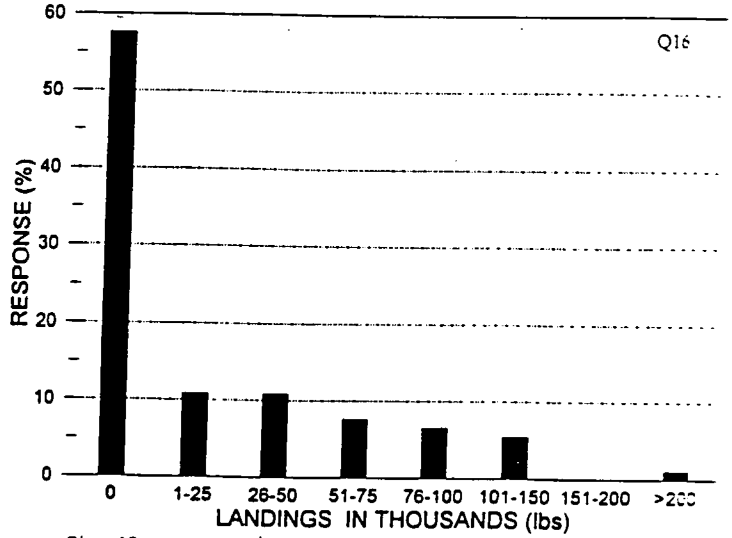

Fig. 15. Estimated landings in 1997 by respondents of question 16.

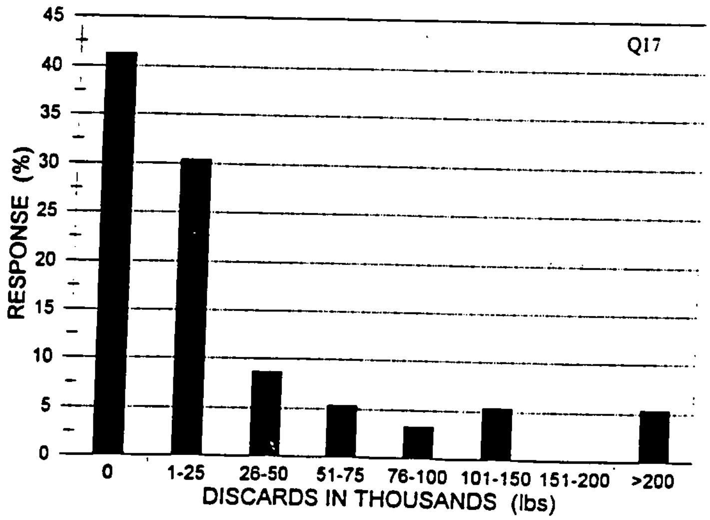

Fig. 16. Estimated discards in 1997 by respondents of question 17.

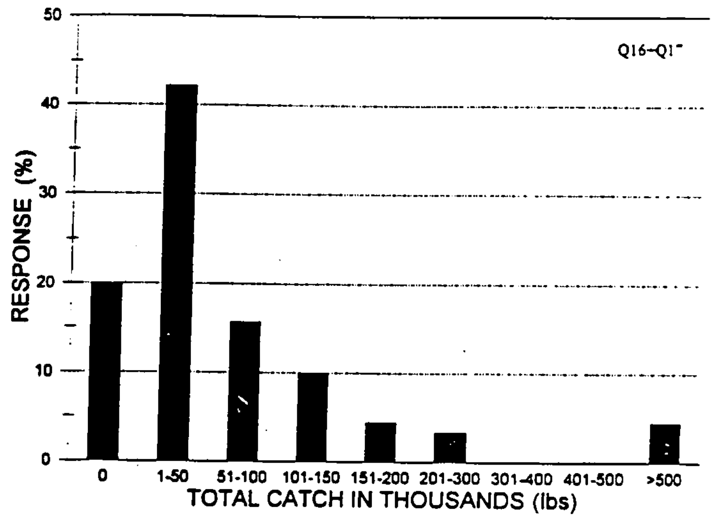

Fig. 17. Estimated total catch in 1997 combining landings and discards.

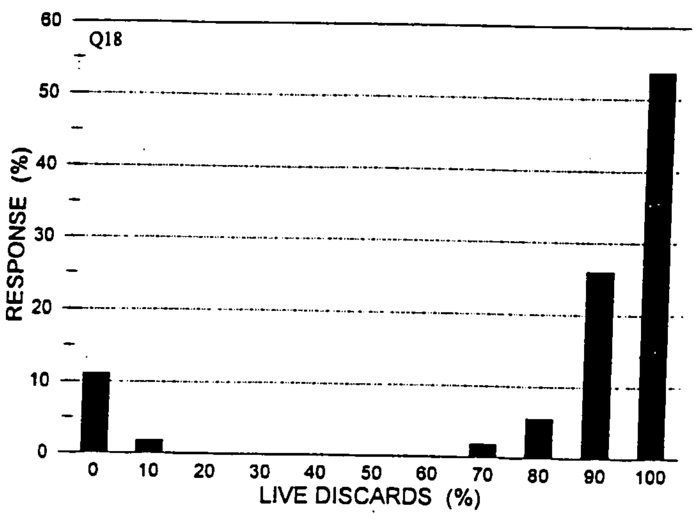

Fig. 18. Estimated survival of discarded capelin by respondents of question 18.

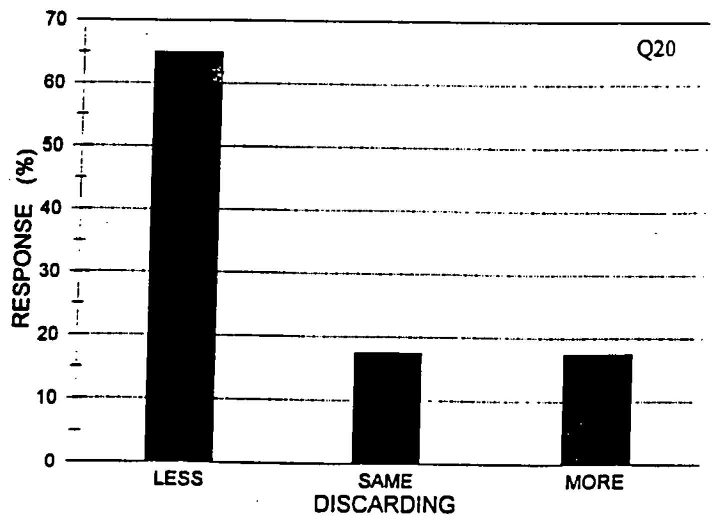

Fig. 19. Comparison of amount of discarding in 1997 compared to earlier years in response to question 20.

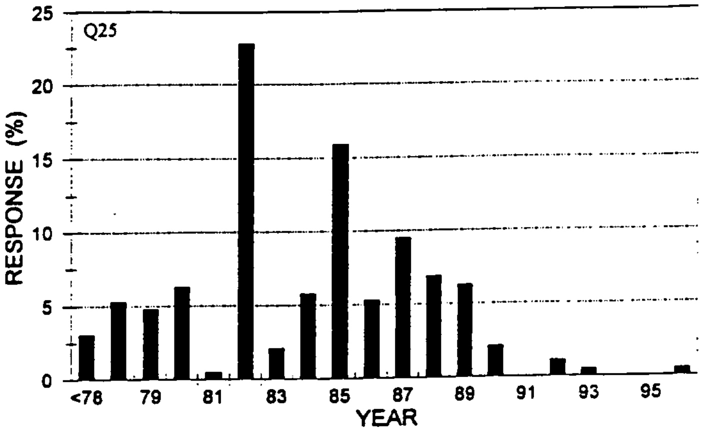

Fig. 20. Experience in the inshore capelin fishery.

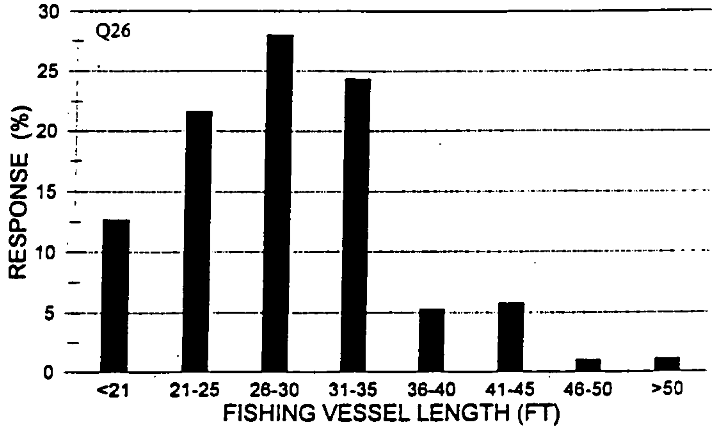

Fig. 21. Lengths of fishing vessels involved in the fixed gear fishery.

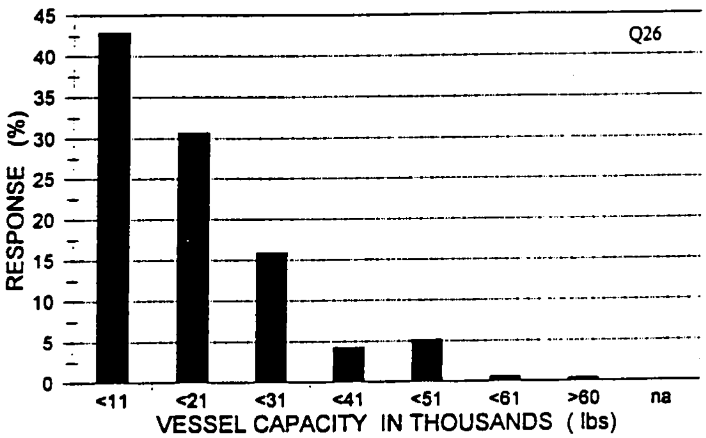

Fig. 22. Estimated fishing vessel capacity for capelin. No answer given (na).

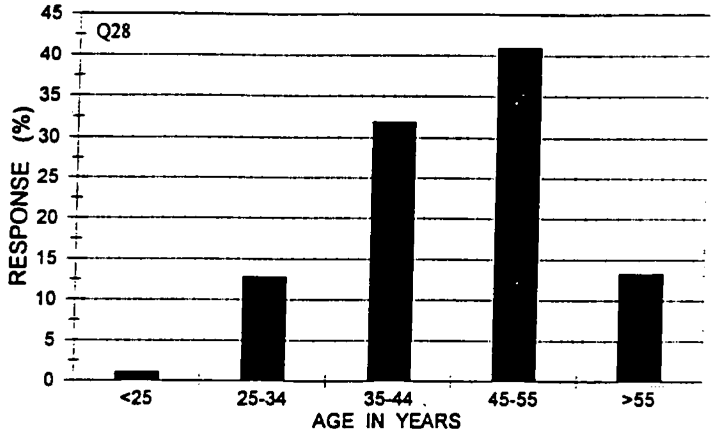

Fig. 23. Age range of capelin fishers in 1997.

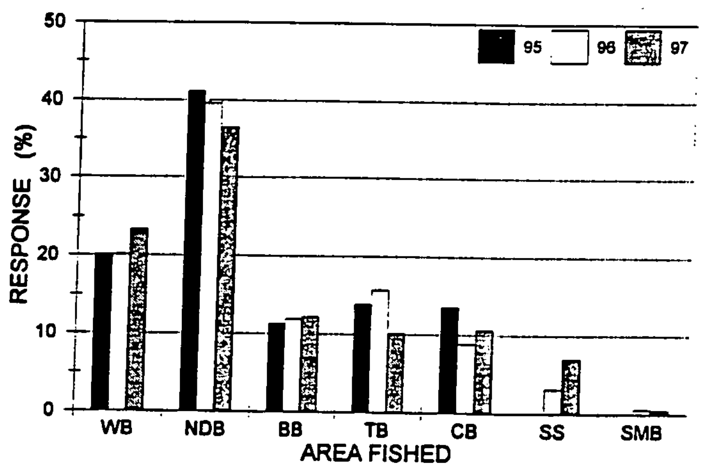

Fig. 24. Distribution of respondents among fishing areas (WB = White Bay, Notre Dame Bay = NDB, BB = Bonavista Bay, TB = Trinity Bay, CB = Conception Bay, SS = Southern Shore, SMB = Trepassey and St. Mary's Bay) for the 1995-97 telephone surveys.

The 1997 Inshore Capelin (Mallotus villosus) Fishery in NAFO Div. 3KL

by

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Introduction

Reported landings in 1997 were 9,069 t (Table 1, Fig. 1) in Div. 2J3KL compared to a quota allocation of 33,280 t (Appendix A). Research logbooks were used to estimate catch and effort for mobile and fixed gear fisheries.

Materials and Methods

Capelin landings are extracted from this year's Table M-18, Policy and Economics Branch. The results are preliminary. Fixed gear landings were not hailed by community. Consequently when Table M-18 is updated with the location data the distribution of landings may change.

Research logbooks were mailed to 43 purse seine and 149 fixed gear licensed fishers residing in Div. 3KL. Four trap logbooks were completed by fishers who were involved in the monitoring program, however these results are not presented here.

Results and Discussion

The Inshore Fishery

The inshore fishery in Div. 3KL is normally prosecuted by purse seines, capelin traps, and beach seines and has been regulated by quota management since 1982. Quotas by area and gear type established for 1997 are presented in Appendix A. Monitoring programs in all areas were set up to open the fishery when fish conformed to criteria defined in the 1997 Capelin Management Plan. The presence of small females in the catch (more than 50 females/kg) was the main reason areas opened or closed in 1997. Areas were opened to fishing for short periods, some less than 12 hours, during July (Appendix B). Fixed-gear fisheries in Conception Bay, Trinity Bay, Bonavista Bay, and parts of White Bay and Notre Dame Bay did not open in 1997. The reported landings for 1997 (Table 1) were less than 1996 and one of the lowest in the series (Fig. 1, Table 1).

Research Logbooks

The return rate of completed logbooks was lower than in previous years (Table 2) despite our efforts to personally contact each logbook fisher in May. Discounting those who did not fish in 1997, 30% of fixed gear and 66% of mobile gear fishers returned research logbooks. Two logbooks were returned but the information was insufficient to code into the database. Three fished (one mobile and two fixed gear) but did not send in a logbook. Four fixed gear fishers had no landings and did not fill in their logbooks. Several reasons for the low return rate are possible. In most of Div. 3L the fixed-gear fishery never opened and the mobile fishery was opened for less than a day in many bays(Appendix B). The inshore capelin fishery in 1997 was a frustrating fishery similar to others in the 1990s. Uncertainty over fishery openings, problems with small size females, and low prices contributed to the frustration. The information we did receive was of high quality.

The main reasons for discarding capelin were variable. The ones mentioned most often were low percentage of females, small size fish, redfeed, and boat quotas (Table 3). In White Bay capelin were discarded from traps mostly because of boat quotas (55%) and low percentage of females (21%). The reasons for trap discards in the 'miscellaneous' category were catches after the quota was taken and herring mixed in with capelin. In Notre Dame Bay small fish was the problem (100%). On the Southern Shore redfeed(92%) was the major problem. In White Bay and Notre Dame Bay redfeed (86-87%) was the reason purse seine catches were released. Discarding by seiners in Bonavista Bay was due mainly to small females (49%). The miscellaneous category was capelin let go from large purse seine catches. Low percentage of females (67%) and small females (33%) were reported in Conception Bay. In St. Mary's Bay boat quotas (29%), redfeed (27%), and small females (17%) caused problems. Releasing capelin because of damage to the purse seine was in the miscellaneous category.

Discarding as a percentage of reported landings varied among areas for traps (Table 4: 4% to all discards) and for purse seines (Table 5: 5 to 233%). The overall discarding rate of 75% for traps was comparable to the highest rate in 1987 and the rate of 44% for purse seines was higher than 1996 and similar to 1990. The reported discards include 68.8 t given away by purse seiners to other boats. According to the logbook reports 100 % of trap and 90% of purse seine discards were released alive at sea. In the present analysis (Tables 3-7) discards are defined as capelin caught but not landed by the fishers who caught them and includes capelin released alive and those dumped as dead fish.

Fishing effort for traps and for purse seines was the lowest since data have been collected. Traps averaged 3.8 fishing days and were hauled 9.0 times (Table 6). Purse seines searched for 3.4 days and made 7.1 sets (Table 7). Three purse seiners had no catches. The trap logbook activity is from the White Bay area with a few trap logbooks returned from Notre Dame Bay and the Southern Shore (Table 4). Purse seine logbook data were available from all areas with much of the information from White Bay, Notre Dame Bay, and St. Mary's Bay.

Catch/effort (CPUE) estimates were available since 1981 for traps and for purse seines (Tables 6 and 7). The 1997 trap CPUE of 10.7 t/day was the highest in the series and the estimate of 4.6 t/haul was the third highest in that series (Table 6). The 1997 purse seine CPUE of 23.5 t/day was the highest in the series and the CPUE of 11.1 t/set was similar to estimates in 1986-87 (Table 7).

Conclusions

Discarding varied among areas and gear types. Discarding from traps was 75% and 44% from purse seines. Both were high, however most were reported as released live at sea. The main reasons for releasing capelin were low percentage of females, redfeed, boat quotas, and small females. The 1997 trap and purse seine CPUEs were the highest in the C/D series and among the higher ones in the C/S series. We suspect that fishing in recent years is very different than in the 1980s. Effort has steadily declined from the early 1980s (Fig. 2, 3). Trap fishing days and purse seine searching time is low in the 1990s primarily due to monitoring initiatives put in place to reduce discarding of unmarketable capelin. The effect on fishing effort has been to concentrate the effort only when capelin are highly available and to reduce fishing time dramatically. In fact Winters (1994) proposed the integrated trap catch rate series used in the multiplicative model to compensate for the reduced fishing season in the 1990s. However the reduction especially in recent years is so severe that no method has been proposed to utilize the 1997 catch rate data as indicators of stock abundance.

Acknowledgments

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References

Nakashima, B. S. 1995. The inshore capelin (Mallotus villosus) fishery in NAFO Div. 3KL in 1994. pp. 25-46. In: Anon. Capelin in SA2 + Div. 3KL. DFO Atl. Fish. Res. Doc. 95/70.

Nakashima, B. S., and G. H. Winters. 1997. Egg and larval production from Bellevue Beach, Trinity Bay in 1996. pp. 168-188. In: Anon. Capelin in SA2 + Div. 3KL. CSAS Res. Doc. 97/29.

Winters, G. H. 1994. Reanalysis of inshore abundance indices. pp. 35-57. In: Anon. Capelin in SA2 + Div. 3KL. DFO Atl. Fish. Res. Doc. 94/18.

Table 1. Inshore capelin landings (t) by fishing gear (vessels <21 m in length) by area (White Bay = WB, Notre Dame Bay = NDB, Bonavista Bay = BB, Trinity Bay = TB, Conception Bay = CB, Southern Shore = SS, St. Mary's and Trepassey Bays = SMB) and by NAFO Division.

Year	Div.	Area	Purse seine	Beach seine	Trap	Dipnet	Total
1988	**2J**		**0**	**2**	**0**		**2**
		WB	3309	517	6751		10577
		NDB	6414	3213	6636		16263
	3K		**9723**	**3730**	**13387**		**26840**
		BB	3689	157	3918		7764
		TB	4380	164	15418		19962
		CB	6965	210	10585		17760
		SS	220	33	3194		3447
		SMB	3687	228	605		4520
	3L		**18941**	**792**	**33720**		**53453**
1989	**2J**		**0**	**3**	**304**		**307**
		WB	3276	643	9513		13432
		NDB	3235	2793	7938		13966
	3K		**6511**	**3436**	**17451**		**27398**
		BB	2800	111	4426		7337
		TB	4822	172	14845		19839
		CB	8643	75	8579		17297
		SS	225	10	3048		3283
		SMB	3327	1	643		3971
	3L		**19817**	**369**	**31541**		**51727**
1990	**2J**		**0**	**1**	**0**		**1**
		WB	4507	318	11820		16645
		NDB	5782	3403	9294		18479
	3K		**10289**	**3721**	**21114**		**35124**
		BB	3186	90	5619		8895
		TB	4790	108	11723		16621
		CB	6470	41	11381		17892
		SS	31	45	2897		2973
		SMB	610	0	1016		1626
	3L		**15087**	**284**	**32636**		**48007**
1991	**2J**		**0**	**1**	**0**		**1**
		WB	239	227	12045		12511
		NDB	426	2709	4291		7426
	3K		**665**	**2937**	**16336**		**19937**
		BB	3066	70	3180		6316
		TB	4450	154	6474		11078
		CB	1889	20	2925		4834
		SS	0	7	0		7
		SMB	69	0	3		72
	3L		**9474**	**251**	**12582**		**22307**
1992	**2J**		**0**	**0**	**0**		**0**
		WB	2995	126	7602		10723
		NDB	2819	1113	1695		5627
	3K		**5814**	**1239**	**9297**		**16350**
		BB	977	28	60		1065
		TB	69	26	53		148
		CB	411	57	160		628
		SS	0	5	21		26
		SMB	25	3	26		54
	3L		**1482**	**119**	**320**		**1921**

Table 1. Continued ...

Year	Div.	Area	Purse seine	Beach seine	Trap	Dipnet	Total
1993	**2J**		**0**	**1**	**0**		**1**
		WB	1583	197	5108		6888
		NDB	1447	2503	2323		6273
	3K		**3030**	**2700**	**7431**		**13161**
		BB	1734	92	1920		3746
		TB	1989	365	4568		6922
		CB	4712	50	3377		8139
		SS	57	31	1480		1568
		SMB	2102	4	404		2510
	3L		**10594**	**542**	**11749**		**22885**
1994*	**2J**		**0**	**0**	**0**		**0**
		WB	0	20	0		20
		NDB	23	23	1		47
	3K		**23**	**43**	**1**		**67**
		BB	0	2	0		2
		TB	23	54	4		81
		CB	0	4	10		14
		SS	0	16	722		738
		SMB	0	3	55		58
	3L		**23**	**79**	**791**		**893**
1995*	**2J**		**0**	**0**	**0**	**0**	**0**
		WB	0	2	0	0	2
		NDB	0	25	1	2	28
	3K		**0**	**27**	**1**	**2**	**30**
		BB	0	35	0	5	40
		TB	0	16	1	4	21
		CB	0	19	2	1	22
		SS	0	9	0	0	9
		SMB	0	6	0	0	6
	3L		**0**	**85**	**3**	**10**	**98**
1996*	**2J**		**15**	**0**	**7**	**0**	**22**
	WB	1278	1	3462	0	4741	
		NDB	1258	1121	1772	0	4151
	3K		**2551**	**1122**	**5241**	**0**	**8914**
		BB	1204	9	1942	0	3155
		TB	1906	31	2934	1	4872
		CB	3242	14	3774	0	7030
		SS	8	0	90	0	98
		SMB	1129	16	535	0	1680
	3L		**7489**	**70**	**9275**	**1**	**16835**
1997*	**2J**		**0**	**0**	**0**		**0**
		WB**					
		NDB**					
	3K		**3973**	**0**	**1522**		**5495**
		BB	455	0	0		455
		TB	459	0	17		476
		CB	634	0	0		634
		SS	0	0	141		141
		SMB	1865	0	3		868
	3L		**3413**	**0**	**161**		**3574**

* provisional

** unable to breakdown landings by bay at this time

Table 2. The distribution of research logbooks in 1997.

NAFO Div.	Gear type	No. of fishers	No. returned	No. never fished	No logbook
3K	Mobile	17	12	1	4
	Fixed	52	20	11	21
3L	Mobile	26	16	1	9
	Fixed	97	3	62	32

Table 3. Percent contribution by weight of reasons for discarding capelin in 1997. This analysis excludes capelin given to other fishers.

Area	Redfeed	Low % females	Small females	Males picked out	Females spawned out	Boat quota/ quota filled	Misc.	Not given
Traps:								
White Bay	9	21	4	0	0	55	11	0
Notre Dame Bay	0	0	100	0	0	0	0	0
Bonavista Bay	0	0	0	0	0	0	0	0
Trinity Bay	0	0	0	0	0	0	0	0
Conception Bay	0	0	0	0	0	0	0	0
Southern Shore	92	0	8	0	0	0	0	0
St. Mary's Bay	0	0	0	0	0	0	0	0
Purse seine:								
White Bay	86	4	1	0	0	9	0	0
Notre Dame Bay	87	0	4	0	0	4	5	0
Bonavista Bay	15	0	49	0	0	0	37	0
Trinity Bay	0	0	0	0	0	0	100	0
Conception Bay	0	67	33	0	0	0	0	0
St. Mary's Bay	27	0	17	0	0	29	27	0

Table 4. Capelin landings (t), discards (t), and catch/effort from research logbook records for capelin traps in Div. 3KL in 1997.

Area	No. fishers	No. traps	Landings	Discard logbook	Bycatch		No. days fished (D)	No. times hauled (H)	C = Landings + discards	
					Cod	Herring			C/D	C/H
White Bay	14	18	494.6	130.9	+	6.4	69.5	169	9.0	3.7
Notre Dame Bay	1	1	21.7	0.9	+	0	1.2	6	18.8	3.8
Bonavista Bay	0	0	-	-	-	-	-	-	-	-
Trinity Bay	0	0	-	-	-	-	-	-	-	-
Conception Bay	0	0	-	-	-	-	-	-	-	-
Southern Shore	2	3	0	252.9	+	+	13.4	23	18.9	11.0
St. Mary's Bay	0	0	-	-	-	-	-	-	-	-

Table 5. Capelin landings (t), discards (t), bycatch (t), and catch/effort compiled from research logbooks for purse seines in Div. 3KL in 1997.

Area	No. of fishers	Landings by logbook	Discards by logbook*	No. days fished	No. sets made	C = landings + discards	
						C/D	C/S
White Bay	9	352.8	127.1	18	48	26.7	10.0
Notre Dame Bay	18	406.5	120.7	29	61	18.2	8.6
Bonavista Bay	7	85.0	197.8	7	17	40.4	16.6
Trinity Bay	5	134.7	6.8	5	8	28.3	17.7
Conception Bay	13	163.2	122.5	13	21	22.0	13.6
Southern Shore	0	-	-	-	-	-	-
St. Mary's Bay	12	347.6	73.8	19	37	22.2	11.4

* includes capelin given to other fishers

Table 6. Capelin landings (t), discards (t), bycatch (t), and catch/effort from research logbook records for capelin traps in Div. 3KL, 1981-93, 1996-97. Data available from Div. 3L only for 1981 and 1982.

Year	No. fishers	No. traps	Landings	Discard logbook	Bycatch		No. days fished (D)	No. times hauled (H)	C = Landings + discards	
					Cod	Herring			C/D	C/H
1981	35	41	1281.0	417.7	6.4	0	577	680	2.9	2.5
1982	60	81	4366.5	605.2	58.5	0	1630	1996	3.1	2.5
1983	50	71	3051.2	1338.0	30.1	38.5	1277	1460	3.4	3.0
1984	67	89	4172.5	634.1	45.1	0.4	1615	2442	3.0	2.0
1985	60	80	3011.3	1850.1	34.2	0.2	1108	1508	4.4	3.2
1986	64	91	5056.4	1436.4	18.0	0.5	1567	2095	4.8	3.6
1987	68	93	3150.6	2437.5	11.5	+	622	1104	9.0	5.1
1988	86	125	6792.6	1500.4	35.9	1.1	1353	2415	6.1	3.4
1989	102	154	6275.8	2188.1	55.5	0.2	1314	2431	6.4	3.5
1990	106	167	5538.1	2986.6	10.7	1.9	1041	1825	9.2	5.3
1991	59	76	2793.0	1187.5	16.7	1.5	860	1325	5.9	3.8
1992	28	34	1225.8	567.1	1.5	5.7	297	666	6.0	2.7
1993	59	78	2261.1	297.0	20.7	37.0	400	863	6.4	3.0
1996	52	68	1719.4	930.8	79.2	3.6	274	692	9.7	3.8
1997	17	22	516.3	384.7	5.5	6.6	84.1	198	10.7	4.6

Table 7. Capelin landings (t), discards (t), and catch/effort from research logbook records for purse seines in Div. 3KL, 1981-93, 1996-97.

Year	No. fishers	Landings	Discards logbook	No. days fished (D)	No. sets made (S)	C = landings + discards	
						C/D	C/S
1981	23	2705.3	810.4	376	707	9.4	5.0
1982	61	11541.9	2484.8	859	1670	16.3	8.4
1983	48	6439.0	4551.3	626	1155	17.6	9.5
1984	46	8185.5	1517.2	679	1305	14.3	7.4
1985	35	4191.0	2314.3	396	696	16.4	9.3
1986	36	8654.5	2745.2	605	991	18.8	11.5
1987	29	2100.5	869.1	169	267	17.6	11.1
1988	41	8282.7	1247.1	476	927	20.0	10.3
1989	46	7463.5	1687.1	421	863	21.7	10.6
1990	32	5081.4	2327.4	344	630	21.5	11.8
1991	9	699.0	413.7	74	95	15.0	11.7
1992	17	1719.8	254.0	95	146	20.8	13.5
1993	21	2448.7	291.5	169	292	16.2	9.4
1996	23	1327.9	396.6	101	181	17.1	9.5
1997	27	1489.8	648.7	91	192	23.5	11.1

Appendix A

1997 Capelin Allocations

NAFO Area	Coastal area	Quotas (tonnes) Fixed gear	Purse seine	Total
2J	Labrador	150	-	150
3K	White Bay	4475	1500	5975
	Notre Dame Bay	3925	1500	5425
Totals - 3K		8400	3000	11400
3L	Bonavista Bay	2245	1425	3670
	Trinity Bay	4490	1870	6360
	Conception Bay	3710	3370	7080
	Southern Shore	2300	190	2490
	St. Mary's Bay	450	1680	2130
Totals - 3L		13195	8535	21730

1997 Capelin Quotas - Fixed Gear Sub-divisions

Area	Sub-division	Quota
White Bay	Cape Bauld to Fischot Island	965
	Fischot Island to Cape Fox	325
	Cape Fox to Hampden, inclusive	1274
	Bottom of Bay to Cape St. John	1911
Notre Dame Bay	Cape St. John to North Head	1105
	North Head to Dog Bay Point	2300
	Dog Bay Point to Cape Freels	520
Southern Shore	Cape St. Francis to Long Point	600
	Long Point to Cape Neddick	400
	Cape Neddick to Cape Pine	1300

Appendix B

1997 Opening and Closing Dates

Mobile Gear

St. Mary's Bay - July 6-8

Conception Bay - July 23

Trinity Bay - July 29

Bonavista Bay - July 23

Notre Dame Bay - July 11-12

White Bay - July 8-11

Fixed Gear

St. Mary's Bay - July 7

Southern Shore:
- Cape St. Francis to Long Point - July 6-August 8
- Long Point to Cape Neddick - no opening
- Cape Neddick to Cape Pine - July 7-August 8

Conception Bay - no opening

Trinity Bay - no opening

Bonavista Bay - no opening

Notre Dame Bay:
- Cape St. John to North Head - July 18-20
- North Head to Dog Bay Point - July 18-26
- Dog Bay Point to Cape Freels - no opening

White Bay:
- Cape Bauld to Fischot Island - July 12-August 8
- Fischot Island to Cape Fox - no opening
- Cape Fox to Hampden - July 9-11
- Hampden to Cape St. John - July 10-13, July 18-19

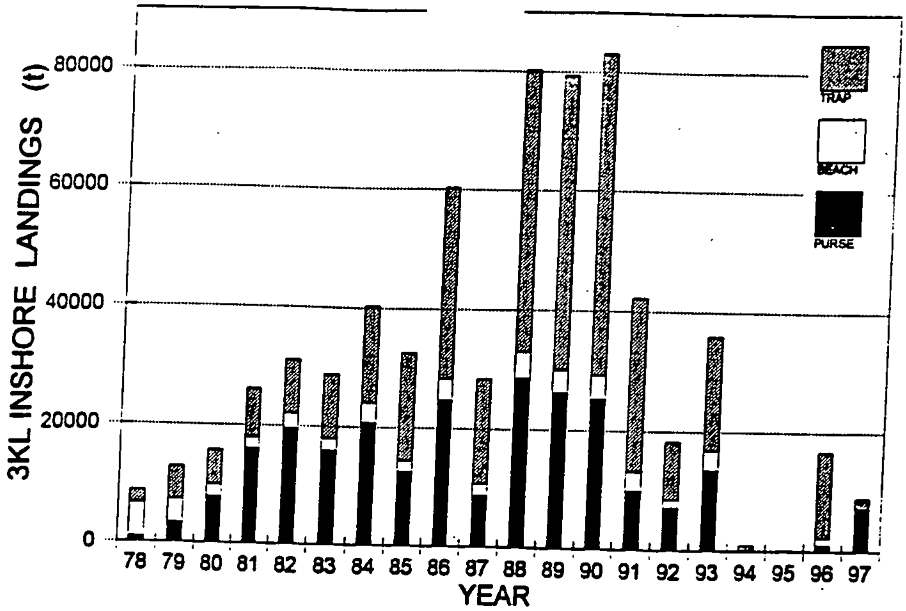

Fig. 1. Inshore capelin landings (t) in Div. 3KL.

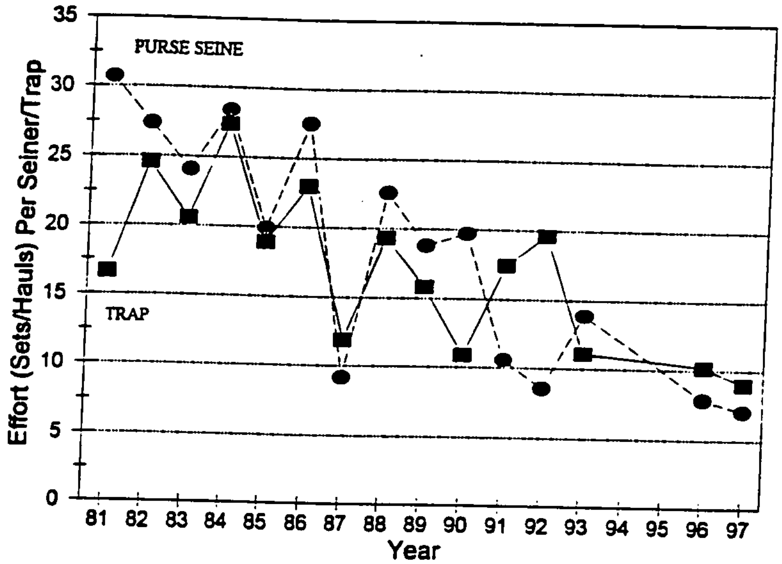

Fig. 2. Trends in average fishing effort for trap hauls (■) and purse seine sets (●).

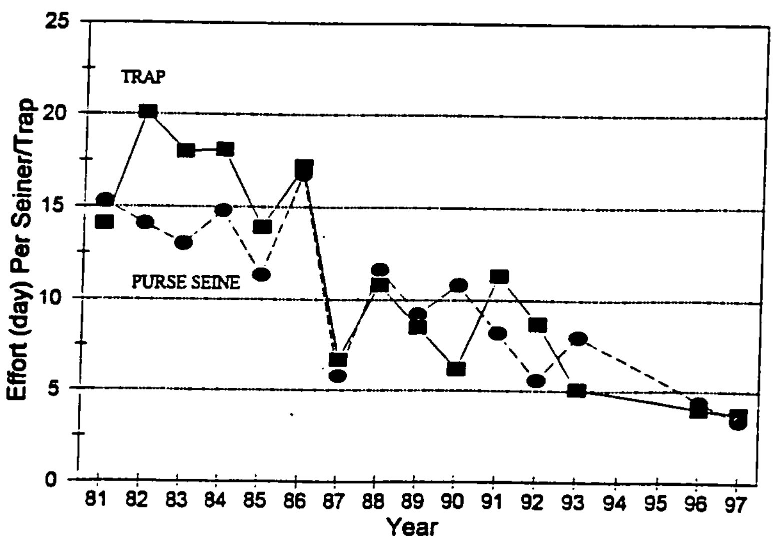

Fig. 3. Trends in average fishing effort for trap fishing days (■) and purse seine searching days (●).

Chapter 3

Results of the 1997 Aerial Survey of Capelin (Mallotus villosus) Schools

by

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Introduction

Area estimates of capelin (Mallotus villosus) schools conducted since 1982 have been used as an index of inshore abundance of mature capelin in NAFO Div. 3L (eg. Nakashima 1996). From 1982 to 1989 school areas were measured from aerial photographs (Nakashima 1990). From 1990 to 1996 school areas were estimated from digital imagery data collected with the Compact Airborne Spectrographic Imager (CASI) (Borstad et al. 1992, Nakashima 1997). In 1997 imagery was collected for the first time using a video camera. Data were collected in 1997 to begin to examine the validity of the assumed relationship between school area and density. This report presents the results of the 1997 CASI aerial survey and preliminary results of the aerial/acoustic experiment.

Materials and Methods

Instrument Operation

A SONY CCD-TR500 video camera was used to collect the imagery. The video camera is equiped with a 10x power zoom lens with f=5.4 to 54 mm. The position of the zoom lens was fixed before the camera was mounted inside the aircraft. A nine-inch portable TV was used to monitor the data as it was being recorded on hi8 tape. In many cases viewing schools on videotape was a better means of identification and interpretation than examining still digital images. The movement and/or changing shape of schools was a useful way to confirm the presence of fish schools.

Area Calibration

Three fixed objects were identified at widely dispersed locations along the two transects. The surface area of the three targets was measured (219,847 and 1340 m2) and for every flight at least one target was recorded at the video camera settings and altitudes flown to collect that flight's data.

Survey Method

Particulars of previous aerial surveys including aircraft type, equipment used, survey time, and altitudes flown are listed in Table 1. The optimal altitude for video surveys was 610 m (3000') which was largely governed by the resolution of the videocamera. Flights were limited to early morning and early evening hours similar to conditions imposed by aerial photography. At this altitude maintaining a flight line was more problematic on poor weather days due to turbulence and to local fog conditions. The survey covered two transects as often as possible; the inside of Trinity Bay from Masters Head to Hopeall Head and the inside of Conception Bay from Bryant's Cove to Portugal Cove (Fig. 1). The logistics of covering three transects frequently while developing the video technique and funding prospects resulted in dropping the outside portion of Conception Bay between Harbour Grace Islands and Bay de Verde in 1997. A comparison of school area estimates with and without this transect indicated that for most years there is a consistent change (Fig. 2). Two exceptions are 1986 and 1989 when the estimate from the outside transect of Conception Bay made substantial contributions to the overall estimate (Fig. 2). The loss of this transect means the survey is covering a smaller portion of the coastal habitat occupied by mature capelin schools and most of the effort is directed at the inner portions of the two bays.

As with aerial photography and CASI an experienced observer identified potential schools along the transect. If there was any doubt as to the presence or absence of a school imagery was collected and examined later. If the schools were not observed on the monitor then the line was rerun. The altitude and location were recorded directly onto the videotape by a microphone linked to the intercom system of the aircraft and written on field sheets.

Analytical Methods

Video data were digitized and transferred to a PC-based image processor for classification and analysis as PCI image files. All potential schools on video tape were identified by the field observer and imaging operator/analyst. The ability to resolve schools fron the background was not as clear as with CASI imagery. With the CASI the bands used to collect imagery can be programmed according to local conditions (eg. Borstad et al. 1992, Nakashima 1997). This was not possible with the commercial video camera. When this problem arose it was overcome by manually tracing the school perimeters. Some electrical interference appeared as 'striping' on some images which disrupted the automatic mode of area calculation. This was corrected in a similar manner.

The same algorithm used to estimate school areas from CASI digital survey data was used to estimate the number of pixels per school on digitized video imagery. Pixel numbers per school were converted to area taking into account pixel size estimated from the calibration sites and altitudes flown. For each transect flown, the mean and median surface areas of capelin schools, the total number of schools, and the total surface area of all schools observed along a transect were estimated.

The school surface area index for each year per transect was estimated by summing the highest total school surface area observed on each transect. I assumed that the peak in school surface area was indicative of inshore abundance for each transect for that year (Nakashima 1985). Survey times reported in Table 1 are the total flying hours and best estimates of the actual time spent per transect are in Tables 2 and 3.

Aerial/Acoustic Experiment

Approximately 5 hours spread out over 5 days were used to collect aerial/acoustic data of schools in the Bellevue-Chance Cove area. Using hand held marine VHF units the aircraft and acoustic vessel coordinated runs over the same capelin schools. In some instances multiple estimates of surface area were made of the same school.

Results and Discussion

In 1997, the aerial survey provided frequent coverage of Conception Bay and Trinity Bay. Complete coverage in Trinity Bay occurred nine times (Table 2a) and six times in Conception Bay (Table 2b). On three occasions (July 14, 18, 22) flights in the morning and afternoon were required for full coverage. In Trinity Bay the transect had to be surveyed over two days (July 13-14) because of fog moving into the area on July 13. The total number of hours flown in 1997 was one of the highest since the surveys began. The frequent coverage in 1997 can be attributed to good flying conditions and coverage of two transects instead of three. Eleven days (June 29-30, July 1-2, 4-5, 11, 15-16, 20-21) were not flown because of poor weather or rough sea conditions.

In Trinity Bay the highest school area estimate was observed on July 13-14, similar to 1994-96 (Table 2). This time also corresponds to the peak period (July 11-21) of egg deposition on Bellevue Beach (Fig. 3) (Nakashima et al. 1998). In Conception Bay the highest total school area was also observed on July 14 (Table 3). For daily estimates prior to 1991 see Nakashima (1995). The peak estimate in Trinity Bay was similar to the estimate in 1987 and for Conception Bay the 1997 estimate of the inside transect was higher than the long-term geometric mean of

127,940 m^2 which excludes the 1991 estimate (Table 4, Fig. 4). Concentrating on frequent coverage of two transects instead of three has succeeded in higher coverage (Tables 2, 3).

Several assumptions are required when using this methodology. Schools can only be detected close to shore in shallow water. Schools in deep water remain unobserved from the air. By surveying frequently during the spawning season I assume that all fish will eventually be detected as they move closer to beaches to spawn. Even though all schools may be recorded and measured, by choosing a single estimate of total school area per bay I assume all schools arrive at the same time as a single spawning peak. This is not true (eg. Nakashima et al. 1998). I am unaware of any reliable method to discount multiple estimates of the same fish.

Using school area as a relative abundance index assumes density/abundance of a school is related to its surface area. Misund et al. (1992) have shown that herring, sprat, and saithe biomasses are correlated to school area and to school volume. Multiple runs over the same school tended to yield consistent estimates of school area (Table 5). The same data also demonstrate the potential variation in a short period of time (see school 2 in Table 5). Further experients are planned to define the nature of the area vs volume relationship for spawning aggregations of capelin.

Acknowledgments

Special thanks to Gene Ploughman of Thorburn Aviation for providing the Cessna 185 at short notice and outfitting it for the video camera setup. The experience of Cal Blackwood, the pilot, in surveying the coastline for capelin was invaluable. Digitization and school area measurements were conducted by Borstad Associates Ltd., Sidney, B.C. M. Y. Rees assisted in the preparation of the manuscript. The next step is to have acoustic diversity estimates of these schools.

References

Borstad, G. A., D. A. Hill, R. C. Kerr, and B. Nakashima. 1992. Direct digital remote sensing of herring schools. Int. J. Rem. Sensing 13: 2191-2198.

Misund, O. A., A. Aglen, A. K. Beltestad, and J. Dalen. 1992. Relationship between the geometric dimensions and biomass of schools. ICES J. Mar. Sci. 49: 305-315.

Nakashima, B. S. 1985. The design and application of aerial surveys to estimate inshore distribution and relative abundance of capelin. NAFO SCR Doc. 85/84, Ser. No. N1058. 11 p.

1990. Capelin school surface area index for NAFO Div. 3L during the 1989 spawning season. NAFO SCR Doc. 90/59, Ser. No. N1780. 6 p.

1997. Results of the 1996 aerial survey of capelin (Mallotus villosus) schools. pp. 63-73. In: Anon. Capelin in SA2 + Div. 3KL. DFO Atl. Fish. Res. Doc. 97/29.

Nakashima, B. S., and G. H. Winters. 1996. Results from monitoring capelin spawning beaches on the northeast coast of Newfoundland in 1995. pp. 131-143. In: Anon. DFO Atl. Fish. Res. Doc. 96/90.

Nakashima, B. S., G. H. Winters, and B. W. Slaney. 1998. Spawning, egg deposition, and pre-emergent larvae from Bellevue Beach in 1997. pp. 62-71. In: Anon. DFO Atl. Fish. Res. Doc. 98/63.

Table 1. Summary of aerial surveys.

Year	Aircraft	Camera	Survey period	Altitude (m)	Flight time (hrs)
1982	Piper Aztec	RC 10	Jun 18-Jul 5	150-160	?
1983	Aero-Commander RC 10	Wild	Jun 19-Jul 9	460	25.9
1984	Cessna 310 RC 10	Wild	Jun 17-Jul 7	460	38.5
1985	Aero-Commander 500 B	Wild RC 10	Jun 18-Jul 3	290-610	28.6
1986	Aero-Commander 500 B	Wild RC 10	Jun 19-Jul 5	380-580	13.4
1987	Piper Aztec RMK	Zeiss	Jun 16-Jul 3	460	37.0
1988	Piper Navajo Piper Aztec	Zeiss RMK	Jun 15-Jul 5	305-490	33.0
1989	Piper Navajo RMK	Zeiss	Jun 16-27 Jun 30-Jul 4	435-730	26.0
1990	Piper Aztec RMK CASI	Zeiss	Jun 17-Jul 6	570-1260	27.0
1991	Piper Navajo	CASI	Jun 21-25 Jul 3-17	1220	27.3
1992	Cessna 185	CASI	Jun 21-Jul 14	275-1280	34.6
1993	De Havilland Beaver	CASI	Jun 30-Jul 16 Jul 19-22 Jul 26-28	365-1220	46.2
1994	De Havilland Beaver	CASI	Jul 2, 7-19 Jul 24-27 Aug 2-4	1220	43.8
1995	De Havilland Beaver	CASI	Jul 5-21, Jul 27-29	915-1340	42.4
1996	de Havilland Beaver	CASI	Jun 25-Jul 9, Jul 13-16	1060-1260	22.6
1997	Cessna 185	SONY CCD-TR500 HANDYCAM	Jun 29-Jul 24	610-975	41.7

Table 2. Schooling data for the inside part of Trinity Bay from Masters Head to Hopeall.

Date		No. of schools	Surface total area (m²)	School size (m²) Mean	SD	Median	Survey time (hr)
1991	Jun 23	0	0				1.6
	Jun 24	0	0				1.1
	Jul 5	139	170681	1228	1827	535	2.5
	Jul 14	54	64598	1196	1894	567	1.4
	Jul 16	33	93680	2839	5562	800	1.3
1992	Jun 25	29	40836	1408	1591	1078	1.4
	Jun 29	71	97424	1372	1510	679	1.4
	Jul 6	70	97565	1394	4273	267	2.3
	Jul 8	124	173219	1397	3862	370	2.7
	Jul 13	50	67889	1358	4008	263	1.7
1993	Jul 3	27	CASI data unavailable				1.5
	Jul 12	31	30502	1006	1747[a]	515	1.3
	Jul 14	14	58786	4199	2847	3976	1.1
	Jul 21	22	9760	451	611[a]	260	0.9
1994	Jul 2	0	0				0.3
	Jul 7	14	4311	308	408	220	1.1
	Jul 9	39	65179	1671	2081	846	1.6
	Jul 13	79	522964	6620	18249	577	1.8
	Jul 15	77	539207	7003	24606	706	1.6
	Jul 17	66	377255	5716	18303	1221	1.5
	Jul 19	57	296029	5193	19751	511	1.6
	Aug 2	9	16240	1804	1577	1115	1.0
1995	Jul 8		Transect coverage incomplete				1.0
	Jul 11	39	80225	2057	2575	1045	2.4
	Jul 13	73	(150198)[b]	2058	4700	503	2.7
	Jul 15	184	330010	1794	4751	514	2.5
	Jul 18	59	62737	1063	2955	318	1.1
	Jul 29	8	4460	558	444	492	1.0
1996	Jun 25	28	CASI unavailable				0.8
	Jul 8	119	478888	4024	14210	1000	2.0
	Jul 13	109	562977	5165	11268	1519	2.3
	Jul 15	50	98292	1966	2230	1382	2.8
1997	Jul 6	71	93393	1315	2398	424	1.4
	Jul 7	97	213060	2196	8131	388	1.1
	Jul 8	118	309246	2621	10044	313	1.8
	Jul 10	68	234180	3444	9862	625	1.4
	Jul 12	91	383255	4212	16694	484	1.3
	Jul 13/14	84	384610	4637	9026	1004	1.6
	Jul 17	88	310544	3529	16242	487	1.7
	Jul 19	39	165912	4254	4197	2853	1.0
	Jul 22	73	119727	1640	2611	713	1.3

[a] calculation excludes capelin in traps; [b] underestimate due to corrupted data files

Table 3. Schooling data for the inside of Conception Bay from Harbour Grace Islands to Portugal Cove.

Date		No. of schools	Surface total area (m^2)	School size (m^2) Mean	SD	Median	Survey time (hr)
1991	Jul 8		Few schools observed - no CASI data				1.1
	Jul 11	56	15577	278	359	124	1.2
	Jul 17	8	8453	1057	531	875	1.1
1992	Jun 24	8	4772	597	328	468	0.9
	Jun 27	7	11726	1675	3478	133	0.4
	Jul 5	12	24263	2708	2880	2143	1.1
	Jul 6	23	10775	468	620	272	1.7
	Jul 9	30	45748	1525	1865	792	1.3
	Jul 13	63	148629	2359	3294	981	1.0
	Jul 14	143	350988	2454	6098	751	2.6
1993	Jul 2	16	CASI data unavailable				1.9
	Jul 4	45	CASI data unavailable				2.3
	Jul 11	60	102645	1867	4904[a]	440	2.0
	Jul 13	53	44184	910	1247[a]	455	1.7
	Jul 15	18	9670	551	681[a]	323	1.7
	Jul 20	73	69246	984	1357[a]	385	2.5
	Jul 21	72	98938	1390	3678	309	1.9
	Jul 27	69	198968	2884	5960	587	1.6
	Jul 28	35	41844	1196	1521	546	1.2
1994	Jul 2	5	CASI data unavailable				0.5
	Jul 7	9	11368	1263	1614	378	1.6
	Jul 9-10	16	79949	4997	10291	1609	1.8
	Jul 12-13	67	98926	1476	2607	333	1.7
	Jul 14	13	17110	1316	1624	416	1.3
	Jul 15	8	8678	1085	1089	868	0.7
	Jul 16	23	40575	1764	4753	576	1.0
	Jul 18	35	61500	1757	2294	1176	1.6
	Jul 26	0	0				0.9
	Aug 3	0	0				
1995	Jul 5	18	12242	680	813	337	1.1
	Jul 8	47	180070	3831	8506	1051	2.9
	Jul 12	5	717	143	59	120	1.5
	Jul 15	13	56285	4330	5147	1389	1.5
	Jul 21	75	51352	685	1161	284	2.8
	Jul 28	65	64918	999	2539	272	1.8
1996	Jun 25	12	CASI unavailable				0.8
	Jul 8-9	120	196509	1605	2829[a]	742	1.7
	Jul 13	8	12533	1567	1368	1002	1.6
1997	Jul 3	1	772	772	-	772	1.3
	Jul 7	0	0				1.0
	Jul 9	4	1572	393	204	429	1.1
	Jul 12	69	134150	1944	2470	898	1.5
	Jul 14	93	159485	1715	3298	341	1.7
	Jul 18	56	58898	1052	1888	518	1.7
	Jul 22	11	28296	2572	2718	1250	1.3

[a] calculation excludes capelin in traps

Table 4. School surface area (m^2) estimates for Trinity Bay and Conception Bay.

Year	Trinity Bay	Inner Conception Bay	Outer Conception Bay
1982	62,397	151,214	6,577
1983	199,373	97,595	51,838
1984	43,245	63,891	65,956
1985	195,659	43,228	69,166
1986	95,898	31,574	132,455
1987	399,026	205,846	184,307
1988	112,863	201,642	87,534
1989	84,349	187,311	266,878
1990	141,122	128,743	88,759
1991	(170,681)[a]	(15,577)[a]	(6,374)[a]
1992	173,219	350,988	225,838
1993	58,786[b]	198,968	77,202
1994	539,207	98,926	28,339
1995	330,010	180,070	126,670
1996	562,977	196,509	77,650
1997	384,610	159,485	

[a] The survey in 1991 was over before inshore spawning had begun.
[b] Underestimate-spawning in August was missed.

Table 5. Estimates of school areas of Bellevue Beach, Trinity Bay from the aerial/acoustic experiment.

School identity	Date	Time	Area (m^2)	Perimeter (m)
1	8-7-97	10:27:09	597	103
2	12-7-97	9:37:59	3045	209
	12-7-97	9:42:14	3828	217
	12-7-97	9:44:53	3201	200
	12-7-97	9:46:56	5642 (3939)[a]	440 (230)[a]
3	12-7-97	10:08:19	2316	176
4	17-7-97	10:37:56	2775	324
5	17-7-97	10:43:19	1717	175
6	23-7-97	11:20:26	5619	281
7	23-7-97	11:27:55	3379	254
		11:30:41	3663	279
8	23-7-97	11:38:14	49717	2453
9	23-7-97	11:40:38	79673	2747
10	23-7-97	11:44:19	49216	1777
11	24-7-97	11:10:47	908	122
	24-7-97	11:15:24	933	205

[a] assumes school shape similar to previous 3 estimates of same school

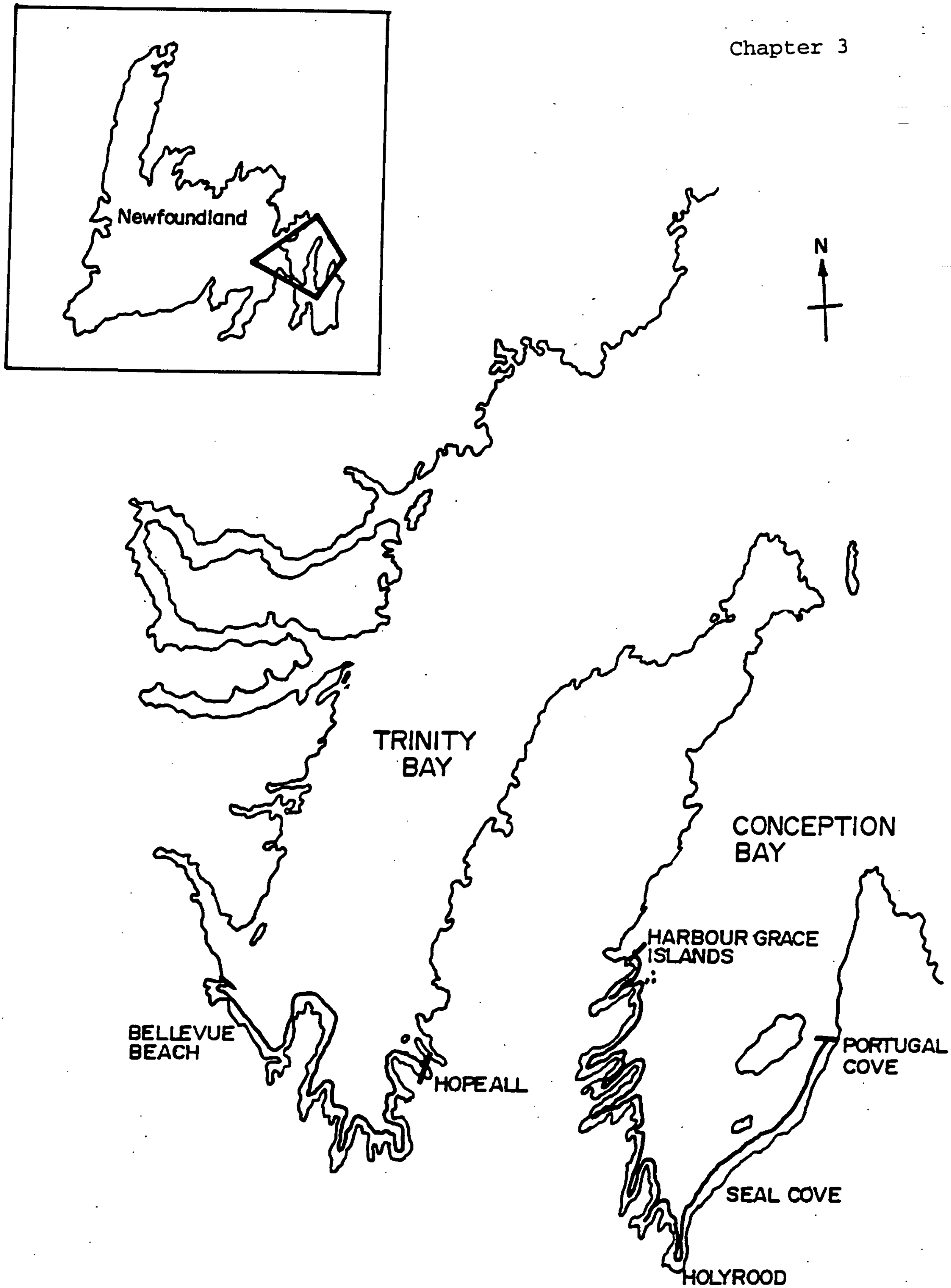

Fig. 1. Transects flown during the aerial survey.

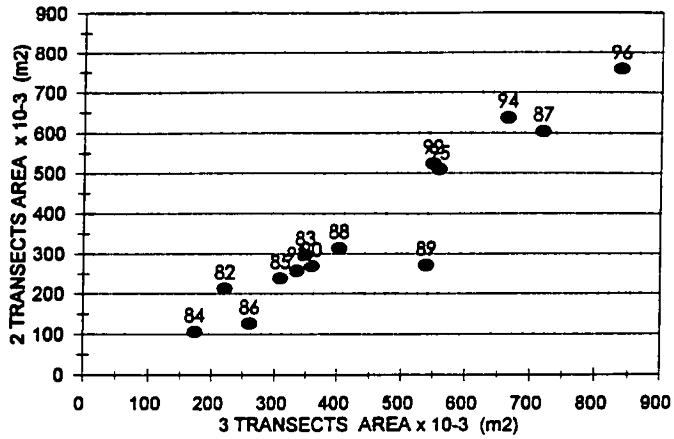

Fig. 2. Comparison of annual estimates with two transects (excludes the outside transect of Conception Bay) and with three transects.

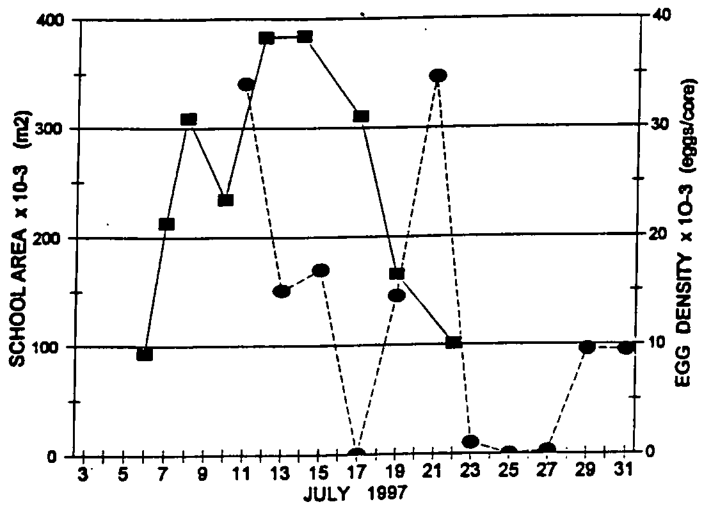

Fig. 3. Daily pattern of school areas in Trinity Bay (■) and egg deposition at Bellevue Beach (●) in July 1997.

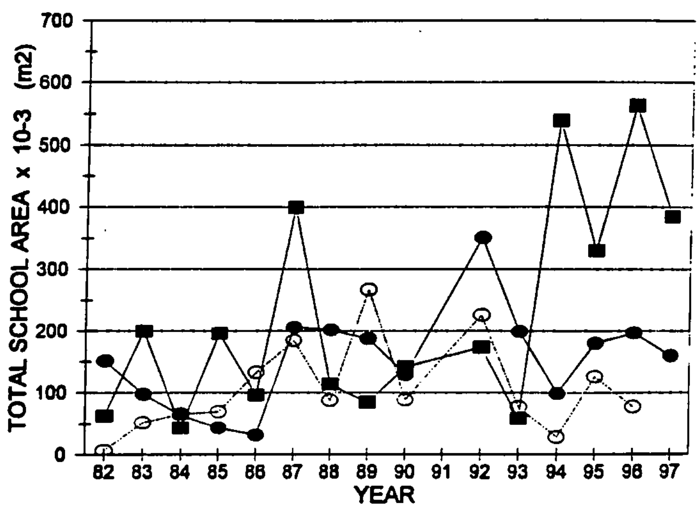

Fig. 4. Trends in school surface area indices for Trinity Bay (■), inner Conception Bay (●), and outer Conception Bay (O).

Chapter 4

Spawning, Egg Densities, and Pre-emergent Larvae from Bellevue Beach, Trinity Bay in 1997

by

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Introduction

In 1990 we began to monitor spawning times, egg deposition and development, larval emergence and various environmental variables (eg. sunlight hours, wind direction and speed, air temperature, water temperature, precipitation, beach sediment temperatures, beach disturbance) on two capelin spawning beaches located at Arnold's Cove in Div. 3Ps and at Bellevue Beach in Div. 3L (Fig. 1). The number of sites was expanded in 1991 to include five additional beaches at Chapels Cove, Eastport, Cape Freels, Twillingate, and Hampden in Div. 3KL (Fig. 1). In 1995 Chapels Cove and Bellevue Beach were sampled. Since 1996 Bellevue Beach has been the only monitored site. In this report we present information on age compositions, fish lengths, spawning times, egg densities, and pre-emergent larval estimates in 1997 from Bellevue Beach located in Div. 3L.

Materials and Methods

Adult Samples

Random samples of 25 males and 25 females were collected whenever significant spawning had taken place. Random samples were also collected from a monitoring capelin trap located nearby at Rantem. Fish were measured for length and weight and otoliths removed for age determination.

Egg and Larval Sampling

During low tide conditions egg samples in beach sediments were collected once every 48 hrs until eggs were no longer on the beach (<500 eggs per sample). Nine samples subdivided into three samples per tidal zone (low tide, mid tide, high tide) were collected each time. A steel sediment corer (6.5 cm internal diameter) was used to extract each sample as described in Nakashima and Slaney (1993). Samples were preserved in 4% formalin and seawater solution buffered with sodium borate. To separate eggs from sediments, samples were immersed in 2% KOH solution for 24 hrs. To estimate pre-emergent larvae in beach cores larvae were sorted from eggs and counted. To estimate egg abundance, eggs were counted by subsampling with a whirling vessel (Nakashima 1987).

At each sampling site at least 50 eggs were placed in Stockard's Solution (Bonnet 1939) to fix and clear the eggs. Stages I-II (eggs from fertilization to the formation of the blastula) accounts for egg development up to the first 36 hrs at 7.2°C (Fridgeirsson 1976).

Trapezoidal Integration and Normalization

Total annual production of eggs and pre-emergent larvae were estimated by interpolating between point estimates applying trapezoidal integration. The seasonal estimate is:

$$\Sigma\ t_n - t_{n-1})\ ½\ [X(t_n) + X(t_{n-1})]$$

where t is the julian day, n is the number of sampling days, and X(t) is the number of eggs or larvae on day t.

To address variation in sample size between years annual estimates for a given beach were normalized to the mean value of each series.

Egg and Larval Densities

The ratio of Stage I-II eggs to total eggs in the Stockard's sample was used to estimate the number of Stage I-II eggs occurring in each beach core sample assuming that these eggs had been deposited recently on the beach. The daily average density of stages I-II eggs in all cores per tidal zone on a given beach was then estimated. An average beach density was assumed to be the mean of the three tidal zones. Total egg density of stages I-II eggs per unit area was estimated using the trapezoidal integration method.

The daily average density of pre-emergent larvae in all cores per tidal zone was estimated. An average density was assumed to be the mean of the three tidal zones. Total pre-emergent larval density was estimated using the trapezoidal integration method, as well.

Sampling of newly-emerged larvae was not conducted in 1997. Larval emergence data from previous collections are reported in Nakashima and Winters (1997).

Chapter 4

Results and Discussion

Age Composition

Age compositions of spawning fish from 1990 to 1997 were dominated by age 3 fish in all years except in 1991 and 1992 when age 4's were most abundant (Table 1, Fig. 2). Our age composition data show that the 1997 spawning population consisted mainly of the 1994 yearclass (49%) followed by the 1993 yearclass (32%). The proportion of age 2 fish is considerably higher for females than for males. The 1995 yearclass as age 2 represented 10% of the overall mature population spawning in the vicinity of Bellevue Beach (Table 1).

Spawning Time

The extent and timing of the spawning period in 1997 was similar to 1995 and later than in 1996 (Table 2).

Egg Density

Four modes assumed to represent spawning runs were observed on Bellevue Beach in early July, mid-July, late July, and early August (Fig. 3). Egg densities on Bellevue Beach was the second highest since 1990 (Table 2). The annual mean of the normalized values show that egg densities in 1997 were lower than 1993, the highest estimate in the series, and slightly higher than 1996 (Table3). This implies for this area the mature biomass was similar in the last two years.

Pre-emergent Larval Estimates

The majority of pre-emergent larvae observed in beach sediments at Bellevue Beach in 1997 occurred between Aug.7-13 (Fig. 4). The density of pre-emergent larvae was comparable to 1995 and lower than in 1990 and 1993 (Table 2). The annual mean of the normalized estimates indicates that overall pre-emergent larval densities in 1997 were the fourth highest since 1990 (Table 3). This implies that the 1997 year class is of average strength for the 1990s; stronger than the 1991 year-class and weaker than the 1992.

Emergent Larvae

Data are no longer being collected on emerging larvae. Thus the recruitment index from the multiplicative analysis has one less index to consider.

Acknowledgements

Pelagic Fish Section staff and summer students collected the field data. Core samples were processed by D. Joy, D. Bannister, P. Lundrigan, and S. Flynn. R. Clarke from Chance Cove collected capelin samples throughout the spawning season. M. Y. Rees assisted in the preparation of the manuscript.

References

Bonnet, D. D. 1939. Mortality of the cod egg in relation to temperature. Biol. Bull. 76: 428-441.

Fridgeirsson, E. 1976. Observations on spawning behaviour and embryonic development of the Icelandic capelin. Rit. Fiskideildar 5: 1-24.

Nakashima, B. S. 1987. Regional and temporal variations in fecundity of capelin in Newfoundland waters. Trans. Am. Fish. Soc. 116: 864-873.

Nakashima, B. S., and B. W. Slaney. 1993. Capelin (Mallotus villosus) egg deposition on fifteen spawning beaches in Conception Bay, Newfoundland in 1992. DFO Atl. Fish. Res. Doc. 93/7. 11 p.

Nakashima, B. S., and G. H. Winters. 1997. Egg and larval production from Bellevue Beach, Trinity Bay in 1996. pp. 74-83. In: Anon. Capelin in SA2 + Div. 3KL. DFO Atl. Fish. Res. Doc. 97/29.

Table 1. Age composition by numbers for mature capelin in Div. 3KL combined. In 1990 only females from Div. 3L were sampled. Since 1995 samples are from Div. 3L.

Sex	Year	Age 2	3	4	5	6	Sample size
M	1991	4.0	34.6	52.4	8.8	0.2	1081
	1992	2.8	25.5	60.4	11.1	0.2	788
	1993	1.5	64.7	30.6	3.2	0	886
	1994	7.8	55.0	32.4	4.5	0.2	675
	1995	6.7	53.6	28.0	11.2	0.5	375
	1996	4.4	67.5	26.5	1.3	0.3	371
	1997	5.3	48.5	37.7	8.0	0.6	324
F	1990	4.8	49.8	42.2	3.2	0	249
	1991	4.8	37.5	41.0	15.9	0.8	805
	1992	8.9	34.9	47.3	8.8	0.1	740
	1993	9.2	69.3	18.0	3.0	0.5	890
	1994	16.9	49.6	25.3	7.9	0.3	657
	1995	22.6	55.6	14.7	7.2	0	279
	1996	14.2	61.3	21.8	2.1	0.7	339
	1997	14.5	49.4	26.2	9.3	0.6	324
Combined	1991	4.4	35.8	47.6	11.8	0.4	
	1992	5.7	30.0	54.1	10.0	0.2	
	1993	5.4	67.0	24.2	3.1	0.2	
	1994	12.2	52.3	28.9	6.4	0.2	
	1995	13.5	54.4	22.3	9.5	0.3	
	1996	9.0	64.6	24.3	1.6	0.5	
	1997	9.9	48.9	31.9	8.6	0.6	

Table 2. Annual estimates derived from trapezoidal integration of egg deposition and pre-emergent larvae in beach sediments and the range of spawning dates for capelin spawning beaches in Div. 3KL.

Year	Chapel Cove (3L)	Bellevue Beach (3L)	Eastport (3L)	Cape Freels (3K)	Twillingate (3K)	Hampden (3K)	Range
Egg deposition Stages I-II eggs ('000 eggs/core)							
1990	-	92.2	-	-	-	-	
1991	60.5	242.2	153.6	147.5	138.4	71.2	
1992	173.5	261.7	248.9	73.0	38.5	61.9	
1993	59.9	337.6	195.4	306.0	132.7	349.5	
1994	72.6	192.5	1.9	0	1.1	102.1	
1995	145.2[a]	153.8	-	-	-	-	
1996	-	243.3	-	-	-	-	
1997	-	263.5	-	-	-	-	
$\bar{x}$	102.3	223.4	150.0	131.6	77.7	146.2	
Pre-emergent larvae in beach sediments ('000 larvae/core)							
1990	-	26.2	-	-	-	-	
1991	0.9	9.0	3.6	14.8	17.6	2.7	
1992	6.8	18.3	14.8	3.4	9.1	20.2	
1993	12.0	27.1[b]	6.4	2.3	23.5[b]	29.4[b]	
1994	2.6	17.4	0.6	0	1.8	4.0	
1995	2.6	20.9	-	-	-	-	
1996	-	15.2	-	-	-	-	
1997	-	21.5	-	-	-	-	
$\bar{x}$	5.0	19.5	6.4	5.1	13.0	14.1	
Spawning dates (Julian Day)							
1990	-	175-207	-	-	-	-	175-207
1991	192-219	185-234	178-214	209-230	210-226	188-232	178-234
1992	205-230	185-232	187-204	205-230	190-210	192-224	185-232
1993	190-218	182-242	197-220	198-229	190-233	188-249	182-249
1994	186-195	180-217	199-210	-	207-209	173-235	173-235
1995	188-205	192-218	-	-	-	-	188-218
1996	-	178-215	-	-	-	-	178-215
1997	-	191-220	-	-	-	-	191-220

a Adjusted to account for sampling missing the initial spawning. Unadjusted estimate is 42.3
b Adjusted to account for sampling ending before eggs had hatched. Unadjusted estimates were 17.2, 14.2, 16.3 respectively

Table 3. Normalized estimates of egg deposition and pre-emergent larvae.

Year	Chapel Cove (3L)	Bellevue Beach (3L)	Eastport (3L)	Cape Freels (3K)	Twillingate (3K)	Hampden (3K)	Mean
	Site						
Egg deposition Stages I-II eggs ('000 eggs/core)							
1990	-	0.41	-	-	-	-	0.41
1991	0.59	1.08	1.02	1.12	1.78	0.49	1.01
1992	1.70	1.17	1.66	0.55	0.50	0.42	1.00
1993	0.59	1.51	1.30	2.33	1.71	2.39	1.64
1994	0.71	0.86	0.01	0	0.01	0.70	0.38
1995	1.42	0.69	-	-	-	-	1.06
1996	-	1.09	-	-	-	-	1.09
1997	-	1.18	-	-	-	-	1.18
Pre-emergent larvae in beach sediments ('000 larvae/core)							
1990	-	1.34	-	-	-	-	1.34
1991	0.18	0.46	0.56	2.90	1.35	0.19	0.94
1992	1.36	0.94	2.31	0.67	0.70	1.43	1.24
1993	2.40	1.39	1.00	0.45	1.81	2.09	1.52
1994	0.52	0.89	0.09	0	0.14	0.28	0.32
1995	0.52	1.07	-	-	-	-	0.80
1996	-	0.78	-	-	-	-	0.78
1997	-	1.10	-	-	-	-	1.10

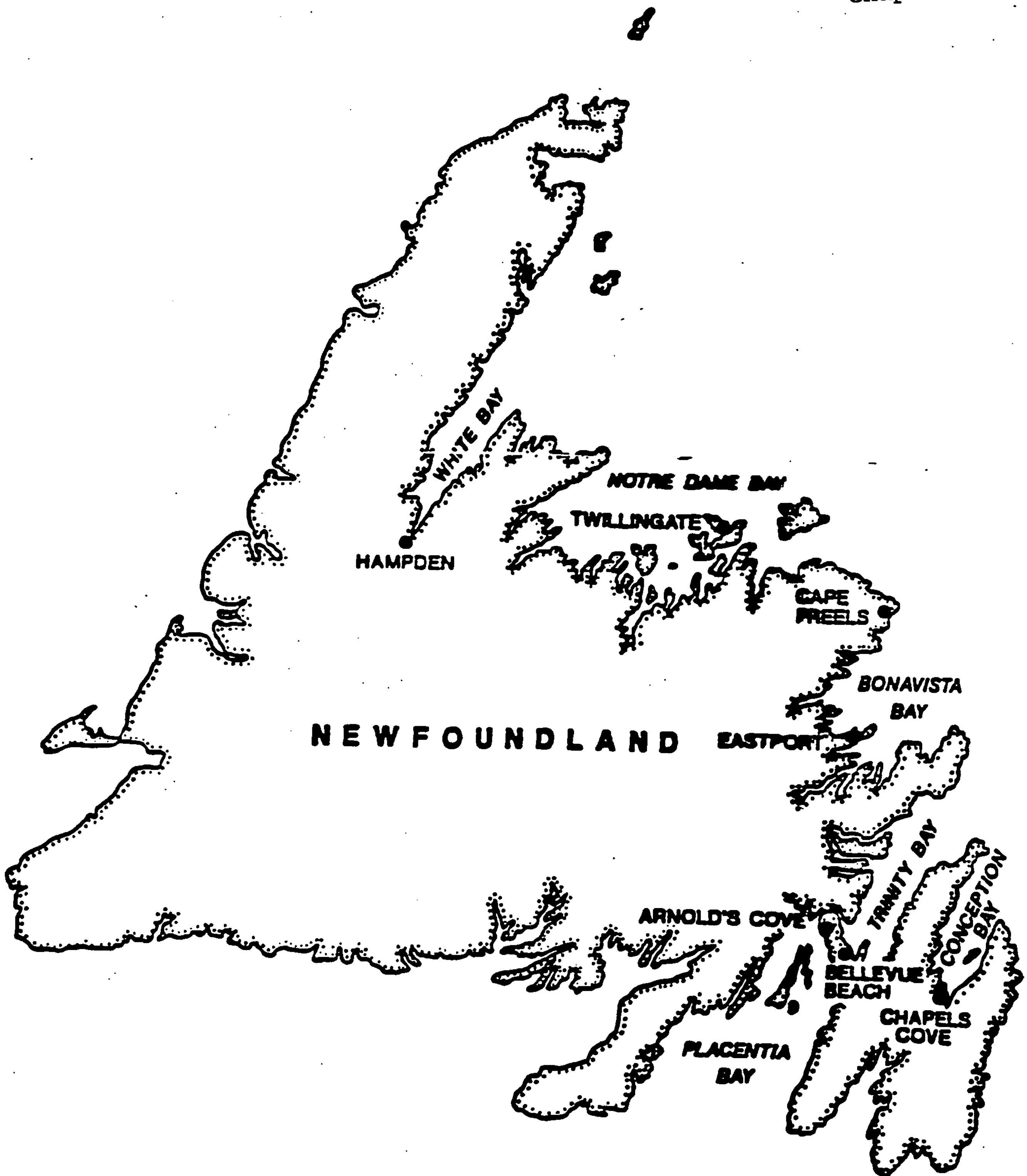

Fig. 1. Sampling sites.

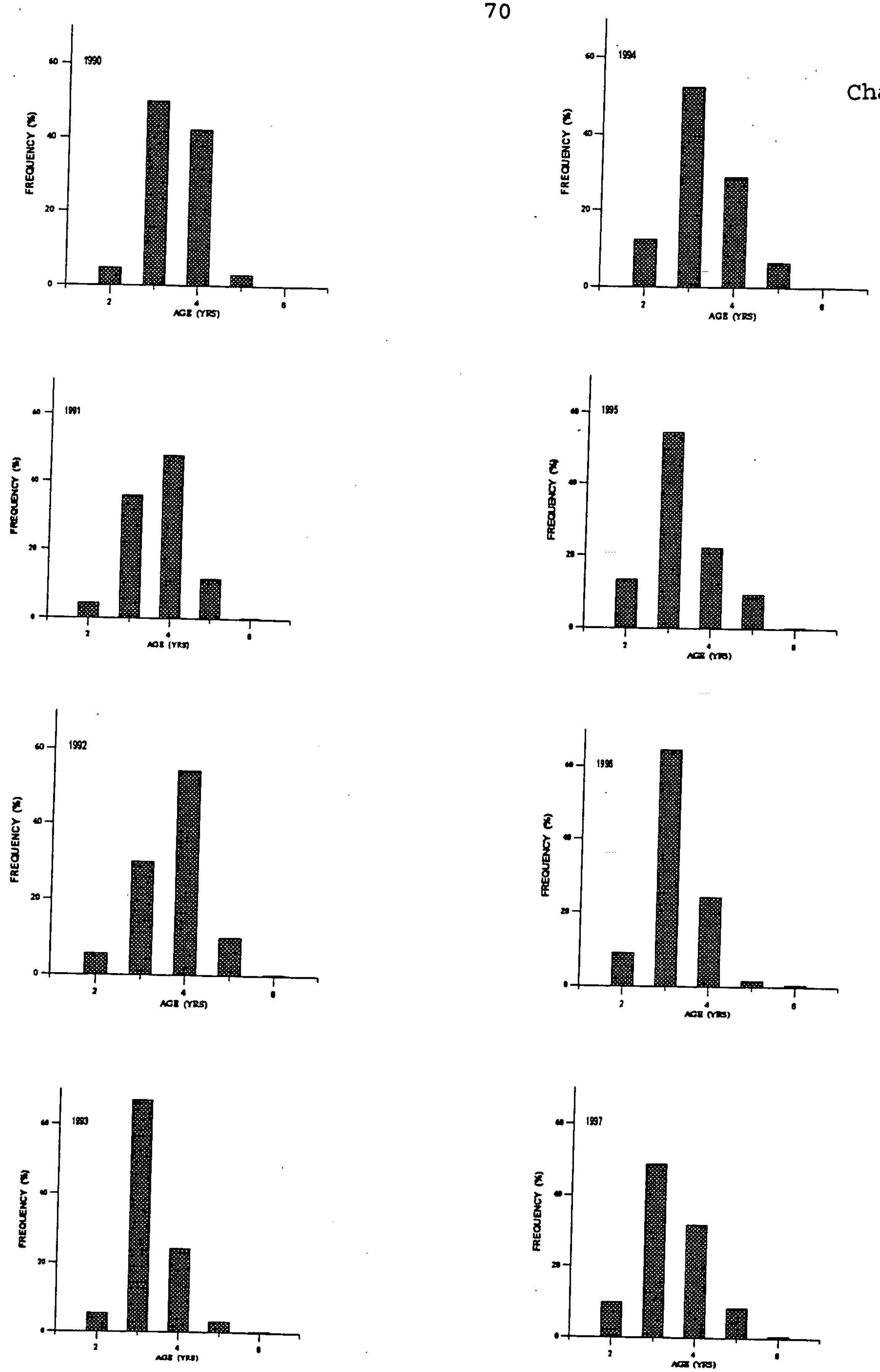

Fig. 2. Age compositions 1990-97.

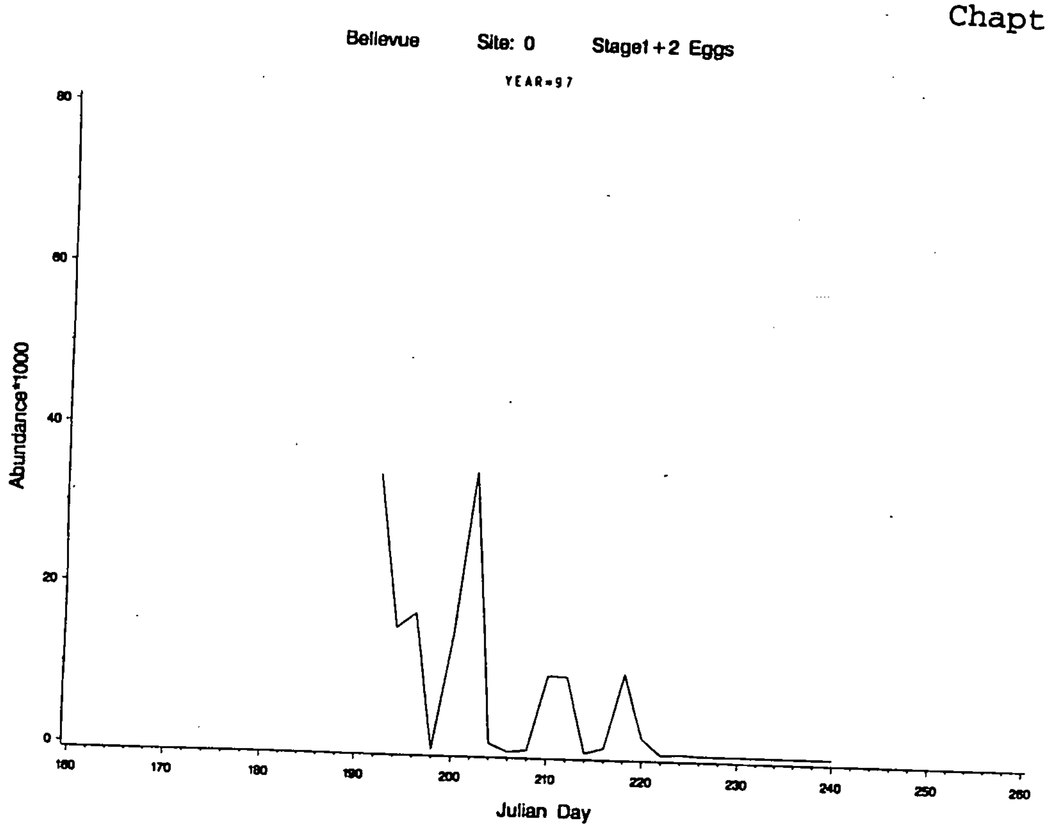

Fig. 3. Seasonal pattern in egg deposition in Bellevue Beach in 1997.

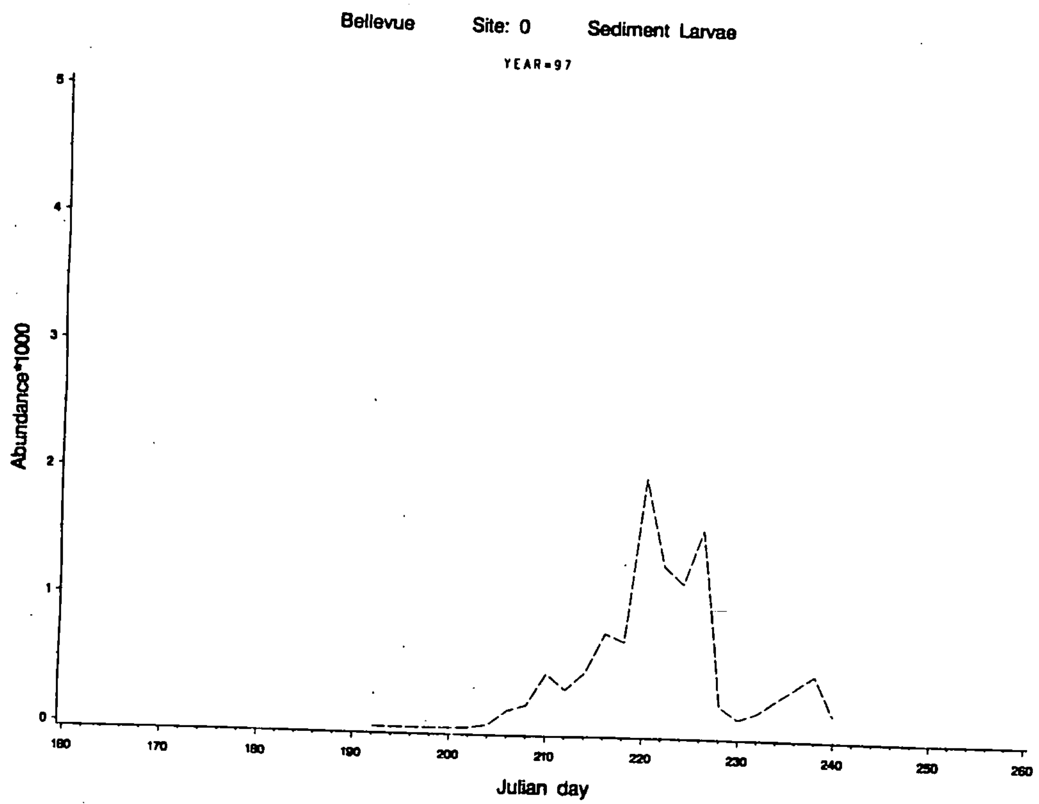

Fig. 4. Seasonal pattern of pre-emergent larvae in beach sediment from Bellevue Beach in 1997.

Predicting Mean Lengths of Female Capelin in SA2 + Div. 3KL

by

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Introduction

In recent assessments, the positive relationships between mean lengths of maturing capelin from offshore surveys and the mean lengths of spawning capelin the following year have been used as basis to predict mean lengths of mature capelin during the assessment year (Carscadden 1995, 1996, 1997). In this paper, we examine the prediction made during the 1997 assessment (Carscadden 1997) and provide an analysis which provides guidance for the 1998 spawning period. Because of the difficulties in reading capelin otoliths in recent years and because females are of primary interest to the fishing industry, the analysis concentrates on mean population length of females.

The 1997 Analysis and Prediction

Two relationships were used in last years assessment to predict mean lengths of females in 1997:

1) Mean lengths of immature females in spring acoustic surveys were positively correlated with mean lengths of mature females in the spawning stock the following year (i.e. approximately 13-14 months later). Since an acoustic survey had been conducted in 1996, the mean lengths of immature females in this survey were used to predict mean lengths of mature females in 1997. This calculation indicated that for all ages combined, the mean lengths of females in 1997 (166 mm) would be comparable to the 1981-90 mean (166 mm) and larger than the 1991-96 mean lengths (151 mm).

2) A positive relationship between maturing capelin from the fall period and mature capelin the following spring provided the basis for predicting the mean length in 1997. This relationship indicated that the mean length in 1997 (161 mm) would be smaller than the 1981-90 mean length (166 mm) but larger than the 1991-96 mean length (151 mm).

In fact, the mean lengths of female capelin in 1997 from both monitoring and commercial samples indicated that the mean length was much smaller than had been predicted from the relationships described above. The mean length from the fall of 1996 (149 mm) was only slightly different from the mean lengths observed inshore in 1997 (monitoring = 148 mm, commercial = 150 mm) (Fig. 1).

Why was the 1997 predicted mean length underestimated? There are several factors that might have contributed to the failed prediction in 1997.

1) The samples collected from the inshore in 1997 did not represent the spawning population. This is unlikely to be a significant problem since samples were analyzed from all parts of the stock area (Table 1). Furthermore, the 1998 fishery was poor or in many cases did not open because of small females, consistent with small mean fish lengths presented here.

2) The fall offshore sampling was inadequate. Was there a component that was smaller in mean length that was missed by the Campelen gear in the fall of 1996? As previously mentioned the mean lengths in the fall of 1996 and inshore in 1997 were nearly the same, implying poor sampling and/or no growth. This raises the question of the adequacy of the Campelen gear to provide a representative sample of capelin. It is presently used as a bottom-trawl gear and capelin are bycatch. In this analysis, the original relationship used capelin collected from midwater trawl from fall acoustic surveys on the x-axis. For Figure 1, all years labeled 1981-94 are taken from midwater trawl. The 1995 point (fall of 1995) of 141 mm is derived from samples derived from Campelen and IYGPT combined from a special acoustic survey (Carscadden 1997). Carscadden (1997) compared mean lengths from different sources in the fall to that observed in the spring (fall 1995/spring 1996) and concluded that the mean lengths from bycatch of capelin in the groundfish survey using Campelen gear could be useful in predicting mean lengths inshore the following year. Data were available for only one year (fall 1995/spring 1996) when this comparison was made.

3) The use of capelin bycatch from the groundfish survey as the mean length for prediction may be introducing a bias because of survey timing. During the years when the fall acoustic survey was conducted, it was always completed before the groundfish survey. Although the fall acoustic survey is now discontinued (last fall survey 1994) the fall groundfish survey still is conducted at about the same time, often not finishing until after the middle of December. Capelin are thought to be feeding and growing during the fall and thus, using the mean length of capelin from the 1997 groundfish survey in the same manner as the mean length of capelin collected earlier in the season in previous years may be inappropriate. This could introduce a bias upwards in the mean lengths from Campelen gear in groundfish surveys. In other words, mean lengths from the groundfish surveys using Campelen gear in the relationship in Figure 1 might predict

larger sizes the following year than mean lengths predicted from mean lengths collected earlier in the fall.

4) The growth between the fall of one year and spring the following year may have been different between the 1980's and 1990's. This is evident in Figure 1 where the points labeled 81-89 inclusive are clustered separately from the points labeled 90-97. This possible difference in fall-to-spring growth between the two time periods is consistent with other changes in capelin biology in the 1990's such as distribution (Frank et al. 1996), spawning time and mean lengths (Carscadden et al. 1997).

Predicted Mean Lengths of Females in 1998

The only source of samples from the fall in 1997 is the bycatch in the 2J3KL groundfish survey using Campelen gear. In 1997, lengths were recorded from all capelin taken as bycatch. This differs from previous years since samples were retained from only large catches. Information from the fall bycatch is given in Table 2. The overall mean length of maturing female capelin in the fall of 1997 was 144 mm compared to the mean length in 1996 of 149 mm.

Past observations have shown that a certain range of increments in length between the fall and the following spawning season can be expected. The range is large enough that one would be unwilling to predict the increment. There is evidence that the increment decreases as the starting length increases. There is evidence that the increment was less in the 1990's than in the 1980's, for unknown reasons.

Following the non-parametric methods of Evans and Rice (1988) we present a probability distribution for the mean length in 1998, based on the mean length of 144 mm measured in the fall of 1997. In fact, we present two such distributions: one if the increments of 1990's prevail, another (higher) if the system reverts to the increments of the 1980's. For reference we also illustrate the position of lengths corresponding to the approximate 50 and 40 counts (Fig. 2). The positions of the 50 and 40 counts are approximate. They are derived from length-weight regressions for females during the spawning season and the weights of these females (from which counts are derived) are variable at this time because of rapid maturation. However, they do offer guidance in evaluating the probable size of females in 1998. If growth increments resemble those observed in the 1990's, there is about a 60% probability that the average count will be 50 or less. On the other hand, if growth is more typical of the 1980's, there is a 100% probability that counts will average 50 or less. Under these growth conditions, there is about a 70% probability that the average count will be 40 or less.

These graphs describe only the variation in increments observed since 1981 and cannot rule out accidents as yet unobserved. The analysis is based on pooled data from the stock area and consequently, it is not possible to account for differences that may occur between geographical areas and between spawning runs.

References

Carscadden, J. 1995. Mean lengths and age compositions of capelin, offshore and inshore. p. 193-215. In: Anon. Capelin in SA2 + Div. 3KL. DFO Atl. Fish. Res. Doc. 95/70, 338 p.

1996. Expected mean lengths of mature female capelin during 1996. p. 200-208. In: Anon. Capelin in SA2 + Div. 3KL. DFO Atl. Fish. Res. Doc. 96/90, 269 p.

1997. Predicting mean lengths of capelin. p. 148-158. In: Anon. Capelin in SA2 + Div. 3KL. DFO CSAS Res. Doc. 97/29, 188 p.

Carscadden, J., B. S. Nakashima, and K. T. Frank. 1997. Effects of fish length and temperature on the timing of peak spawning in capelin (Mallotus villosus). Can. J. Fish. Aquat. Sci. 54: 781-787.

Evans, G. T., and J. C. Rice. 1998. Predicting recruitment from stock size without the mediation of a functional relation. J. Cons. Int. Explor. Mer 44: 111-122.

Frank, K. T., J. E. Carscadden, J. E. Simon. 1996. Recent excursions of capelin (Mallotus villosus) to the Scotian Shelf and Flemish Cap during anomalous hydrographic conditions. Can. J. Fish. Aquat. Sci. 53: 1473-1486.

Table 1. Number of capelin measured inshore in 1997 from monitoring and commercial activities, by quota area. Number of females/number of males.

Location	Monitoring	Commercial
St. Mary's Bay	179/21	285/115
Southern Shore		835/767
Conception Bay	177/423	433/567
Trinity Bay	1290/585	611/389
Bonavista Bay	289/311	554/446
Notre Dame Bay	219/181	1826/1574
White Bay		1873/693

Table 2. Number and average lengths of maturing females from the 1997 fall groundfish survey in Div. 2J3KL, Campelen trawl.

NAFO Division	Mean length (mm) (N)
2J	151 (1057)
3K	148 (4119)
3L	133 (2448)
Overall mean	144

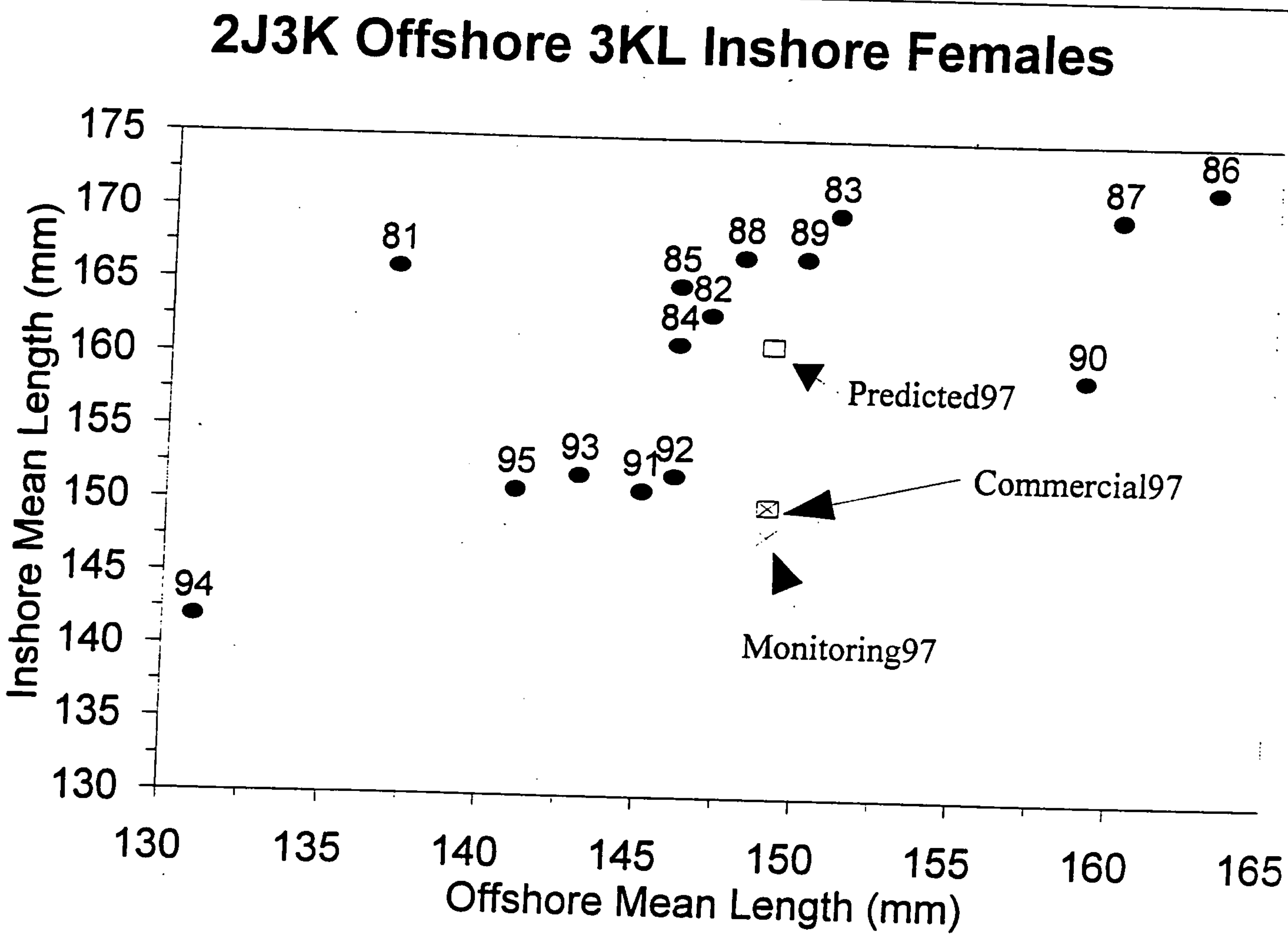

Fig. 1. Relationship between man lengths of female capelin, from fall offshore acoustic surveys and from inshore one year later. The 1997 mean length predicted from mean length of females in the fall groundfish survey in 1996 and the observed mean lengths from 1997 commercial and monitoring samples are also shown.

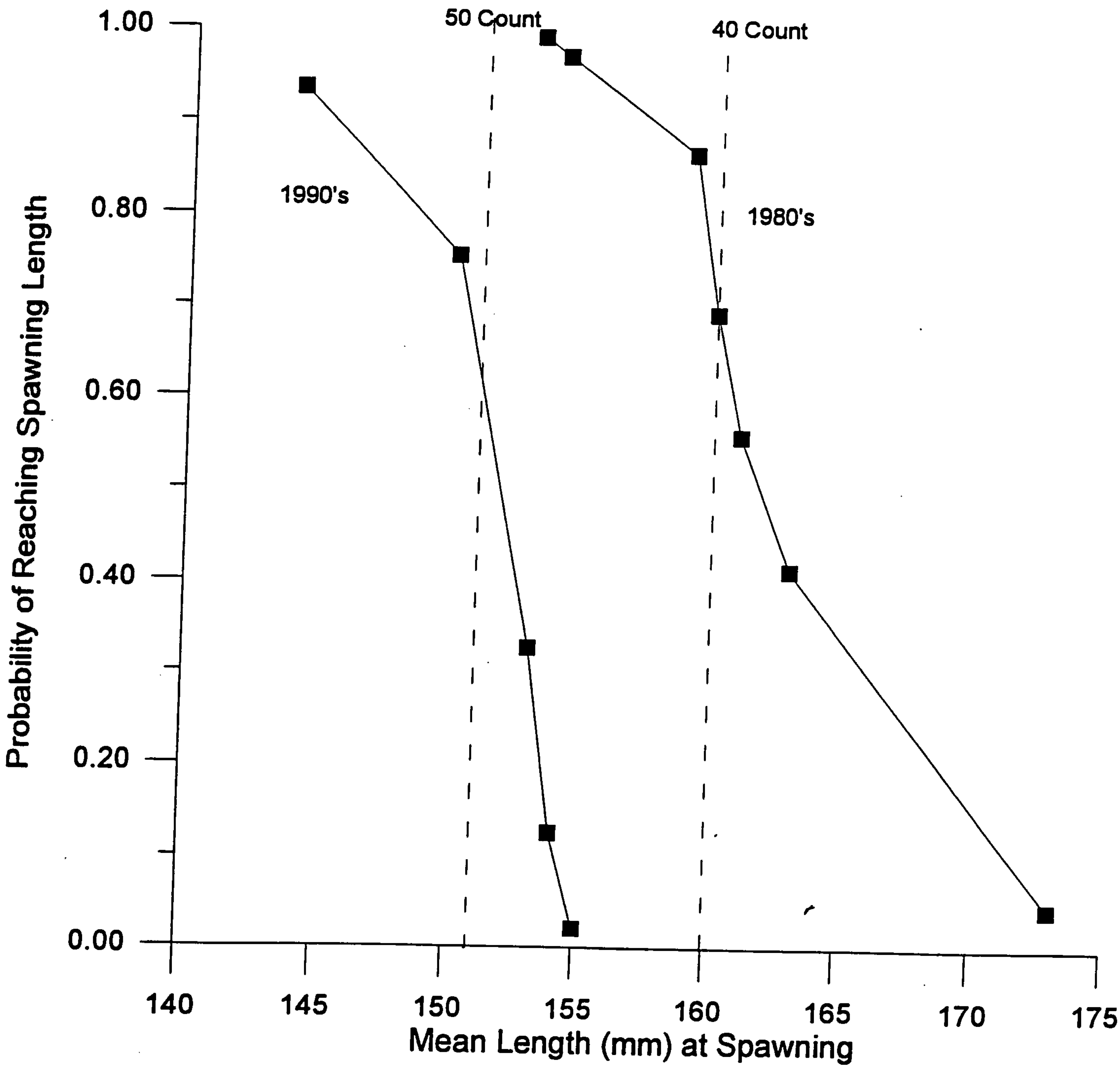

Fig. 2. Probabilities of reaching particular spawning lengths using data from the 1980's and 1990's. The dotted lines identify the approximate mean lengths of 50 and 40 count (numbers of females per kg) capelin.

By-catches of capelin during spring and autumn bottom-trawl surveys in Divisions 2J3KL in 1997

by

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Introduction

Capelin (Mallotus villosus) are frequently caught during bottom-trawl surveys directed toward demersal fish off southern Labrador and eastern Newfoundland. The distribution and magnitude of capelin catches from the surveys in Divisions 2J, 3K and 3L during the autumns of 1978-96 and the springs of 1972-96 have been compared with geographic coverage by acoustic surveys for capelin to help determine whether coverage by the acoustic surveys has been adequate (Carscadden et al. 1989, Carscadden et al. 1990, Miller and Lilly 1991, Lilly 1992, 1994a, 1995ab, 1996, 1997, Lilly and Davis 1993) and to provide supporting data on changes in capelin distribution (Lilly and Davis 1993, Lilly 1994b, Lilly 1995c). There has also been interest in exploring the extent to which the frequency of occurrence of capelin in bottom-trawl catches might provide an index of capelin abundance. This chapter provides information on the distribution and frequency of occurrence of capelin, and estimates of capelin biomass, based on catches during the trawl surveys in spring and autumn 1997. In addition, the average capelin weight is calculated for each set and presented in a geographic plot to provide information on the distribution of small and large capelin.

Materials and Methods

Surveys in Divisions 2J3KL in autumn

Capelin were caught during random-stratified bottom-trawl surveys designed to assess the biomass of demersal fish during October-December 1978-97 (Table 1). All surveys in Divisions 2J and 3K in 1978-94 were conducted with the 74 m stern trawler 'Gadus Atlantica'. Surveys in Division 3L in 1981-83 and 1985-94 were conducted with the 51 m side trawler 'A. T. Cameron' (1981-82) and the sister 50 m stern trawlers 'Wilfred Templeman' (1983, 1985, 1987-94) and 'Alfred Needler' (1986). There were no autumn surveys in Division 3L in 1978-80 and 1984. The 'Gadus Atlantica', 'Wilfred Templeman' and 'Alfred Needler' deployed an Engel 145 Hi-Lift trawl, whereas the 'A. T. Cameron' deployed a Yankee 41-5 trawl. In all instances, a 29 mm meshliner was inserted in the codend. Tows were made at 3.5 knots for 30 min at each fishing station, and catches from the few tows of duration other than 30 min were appropriately adjusted. The variability in ships and bottom-trawls (McCallum and Walsh 1997) may have resulted in differences in catching efficiency, but this possibility has not been examined for capelin. Additional details regarding areas and locations of strata, and changes in survey pattern, are provided by Doubleday (1981), Lilly and Davis (1993), Bishop (1994) and Lilly et al. (1998). The most notable change in survey coverage was the addition of depths between 100 and 200 m in northwestern Division 3K (St. Anthony Shelf and Grey Islands Shelf) in 1984 and subsequent years. Fishing in all Divisions and years was conducted on a 24-h basis.

The survey in autumn 1995 differed from that in previous years in several respects (Brodie 1996). The 'Gadus Atlantica' was replaced by the 63 m stern trawler 'Teleost', the Engel 145 Hi-Lift trawl was replaced with a Campelen 1800 shrimp trawl with rockhopper foot gear, tows were made at 3.0 knots for 15 min instead of 3.5 knots for 30 min, and the 'Wilfred Templeman' fished north of Division 3L for the first time in the time-series. The survey in 1996 was similar to that in 1995. However, in 2J3K the survey started and finished relatively early. In addition, the survey was extended to depths of 1500 m and new strata were added in the inshore (9 strata in Division 3K and 16 in Division 3L). The survey in 1997 was similar to that in 1996, except that some of the new inshore strata were modified and one stratum was added. The offshore strata of Division 3K were surveyed during October 18-November 28, which is near the usual time, but the inshore strata were occupied much later (December 17-19).

Surveys in Divisions 3LNO in spring

Capelin were caught during random-stratified bottom-trawl surveys of Divisions 3LNO during April-June 1971-97, excluding 1983 (Table 2). Surveys were conducted with the 51 m side trawler 'A. T. Cameron' (1971-82) and the sister 50 m stern trawlers 'Wilfred Templeman' (1985-97) and 'Alfred Needler' (1984). The 'A. T. Cameron' deployed a Yankee 41-5 trawl, and the 'Wilfred Templeman' and 'Alfred Needler' deployed an Engel 145 Hi-Lift trawl until 1995. In all instances, a 29 mm mesh liner was inserted in the codend. Tows were made at 3.5 knots for 30 min at each fishing station, and catches from the few tows of duration other than 30 min were appropriately adjusted. No adjustments were made for possible between-vessel differences in catching efficiency. Starting in spring 1996, the Engel 145 Hi-Lift trawl was replaced with the Campelen 1800 shrimp trawl with rockhopper foot gear and tows were made at 3.0 knots for 15 min.

Most surveys in the 1970's and 1980's were conducted in May (Fig. 1). The 1971 survey was conducted entirely in June, and the 1981 survey was conducted primarily in April. The 1985 survey was part of special seasonal surveying, and was conducted by three consecutive trips of the 'Wilfred Templeman' over a period of 40 d. From the late 1980's to the mid-1990's the median date of fishing shifted from mid-May to mid-June.

Average weight of capelin

The average weight of the capelin caught in each fishing tow was calculated from the total weight and number recorded for that set. That is, information on the actual weights of individual fish was not used. To reduce the potential impact of measurement error, analyses were limited to those sets in which the catch consisted of at least 50 individuals weighing at least 1 kg. As described by Lilly (1997), there was a loss of heavier mean weights during the 1990's compared with earlier years and the proportion of sets with small mean weights increased with the introduction of the Campelen trawl in 1995. For displaying the geographic distribution of average weight, the weights were subjectively and arbitrarily binned into three groups: <10.5, 10.5-17.5, and >17.5 g.

Distributions

The distribution of capelin is presented in expanding symbol plots, as opposed to contour plots generated from modelling of the catches, in order to provide visual information on the spatial distribution of fishing stations, among-station variability in catch of capelin, and the relationship between capelin catches and bathymetry.

Estimation of frequency of occurrence of capelin

The frequency of occurrence of capelin in the bottom-trawl catches is simply the number of occurrences expressed as a percentage of the number of sets. The number of sets assigned to each stratum was approximately equal to stratum area except during the autumn surveys of 1991-94, when a proportionally higher number of sets was assigned to certain strata in which the variance of the cod catch had been high for some years previous. To adjust for variation in the number of sets per unit area, an adjusted percentage occurrence was calculated as

$$O_{ad} = \frac{\sum_{h=1}^{m} \left(\frac{100(nc_h)}{n_h} \right) A_h}{\sum_{h=1}^{m} A_h}$$

where nc_h is the number of sets in which capelin were caught in stratum h, n_h is the number of sets in stratum h, A_h is the area of stratum h, and m is the number of strata fished.

Estimation of capelin biomass and numbers

The biomass of capelin in each stratum was estimated as

$$W_h = \frac{A_h \sum_{i=1}^{n_h} W_{hi}}{an_h}$$

where W_{hi} is the weight (kg) of capelin in set i (i = 1, 2, ..., n_h) in stratum h, and a is the area sampled by a standard tow. The biomass in each Division was obtained by summing over strata. Population abundance was estimated in the same way. The abundance of capelin was not estimated for spring surveys in Division 3L because the number of capelin in the catch was not always recorded, especially in some years in the 1970's.

Results

Capelin in Divisions 2J3KL during autumn

Distribution

In Divisions 2J3K during the autumn of 1997, capelin were recorded at 62% of the 236 fishing stations conducted at depths of 750 m or less (Table 3). This percentage is the highest since the surveys started in 1978, but is only a little higher than in 1995. Catches (median = 2.0 kg; 95th percentile = 20 kg) were a little larger than in 1996 but smaller than in 1995 (Table 3). Very few capelin were caught on Hamilton and Belle Isle Banks and near the coast off southern Labrador. Catches off northeastern Newfoundland (northwestern Division 3K) were the largest seen in many years (Fig. 2). Large catches were also obtained in central and southern Funk Island Deep. Capelin were also caught in most of the inshore sets. All of the large catches in the offshore occurred within the area covered by the acoustic survey in 1994, but the large catches in the inshore would have been shoreward of an acoustic survey, if one had been run using the survey blocks employed in 1994. In general, the distribution in 1997 was similar to that in 1995-96 (Fig. 3) and in 1991-94 (Lilly 1992, 1994a, 1995a; Lilly and Davis 1993), except that the capelin in Division 3K seemed less concentrated to the south and east.

In Division 3L, capelin were recorded at 66% of the 141 stations (Table 4). This is the second highest value since the introduction of the Engels trawl. Catches (median = 1.1 kg; 95th percentile = 17 kg) were larger than in 1996 but smaller than in 1995 (Table 4). Capelin were caught mainly in northern and northeastern Division 3L (Fig. 2). There were only a few small catches on the plateau of Grand Bank. Catches in the new inshore strata tended to be larger toward the outer regions of the bays. The distribution in 1997 was similar to that in 1996 (Fig. 3), except that in 1997 there were more large catches in northern Division 3L and catches off the southern Avalon Peninsula were smaller. Both 1996 and 1997 differed from 1995 (Fig. 3) when more capelin were caught in the Avalon Channel and on the northeastern slope of Grand Bank, especially in the area of the Sackville Spur.

Average capelin weight

There were consistent patterns in the geographic distribution of capelin average weights in 1995-97 (Fig. 4). Most catches in Division 2J were dominated by large average weights. Many of the sets on the coastal shelf off northeastern Newfoundland in Division 3K were dominated by medium average weights whereas those to the east in Funk Island Deep were dominated by large average weights. On the southern part of the Northeast Newfoundland Shelf (near the 3K/3L boundary) most sets had medium capelin average weights, and on northern Grand Bank in depths less than 300 m almost all sets had small capelin average weights. Some sets with capelin average weights of intermediate value occurred on the northeastern slope of Grand Bank. This was most notable in 1995, especially in the area of the Sackville Spur.

Frequency of occurrence

As reported by Lilly (1995a), the adjustment of the frequency of occurrence, to take into account the allocation of a relatively large number of sets to certain strata in 1991-94, did not substantially change the estimate of the frequency of occurrence, except in Division 3L in 1992 (Table 5; Fig. 5). In Division 2J3K, the adjusted frequency of occurrence increased, with irregular fluctuations, from 20-35% in the early 1980's to 40-50% in the 1990's. With the introduction of the Campelen trawl in 1995, the frequency of occurrence rose to the highest level in the time-series. The value declined in 1996 but increased again in 1997 to the second highest level in the time-series (unadjusted, 62%; adjusted, 65%). In Division 3L, the frequency of occurrence fluctuated more widely than in Divisions 2J3K. Low values of about 20% in 1990-91 were followed by high values of about 50% in 1992-93 and a decline to an intermediate level of about 40% in 1994. The value in 1995 was the highest in the time-series. The value declined in 1996 but increased again in 1997 to the second highest in the time-series (unadjusted, 66%; adjusted, 69%).

Estimates of abundance and biomass

The minimum trawlable abundance and biomass were extremely low in 1978, relatively high in 1979-81, and fluctuated without trend from 1982 to 1994 (Fig. 6). The high levels in Division 2J in 1978-81 were due almost entirely to a few very large catches on the plateau of Hamilton Bank (Carscadden et al. 1989). The estimates increased dramatically with the introduction of the Campelen trawl in 1995 (Fig. 7). Estimates declined in 1996 but increased again in 1997 to the second highest in the time-series. Biomass estimates, in thousands of tonnes, were as follows since the introduction of the Campelen trawl:

Year	2J	3K	2L	Total
1995	2.4	42.6	22.6	67.6
1996	0.3	16.7	12.3	29.3
1997	2.6	22.4	17.6	42.6

Capelin in Divisions 3LNO during spring

Distribution

In Division 3L during the spring of 1997, capelin were recorded at 77% of the 122 fishing stations conducted at depths of 750 m or less (Table 6). This was a little higher than in 1996 and close to the maximum level recorded (80% in 1986). Catches were smaller than in 1996 (95th percentile = 17 kg; maximum = 40 kg). The distribution was extensive, but catches greater than 25 kg were taken only in the north and on the northeastern slope (Fig. 8). Catches were nil or very small in the northeast at depths greater than 300 m and on the eastern side of the plateau of the bank. The broad distribution of moderate to large catches in Division 3L in 1996-97 is very different from observations in 1991-95, but similar to distributions observed in the mid to late 1980's. One notable difference from earlier years, such as 1986 and 1987, is the high frequency of occurrence of large catches in northern Division 3L.

In Divisions 3N and 3O the frequency of occurrence of capelin was by far the highest in the time-series (Table 2). Most catches were small (Fig. 8) but the largest catch in the whole survey (194 kg) was taken on the Tail of the Bank (42°59'N, 49°54'W).

During the period 1985-90, the majority of large capelin catches (i.e. catches of at least 50 individuals and 1 kg) were dominated by large capelin (Lilly 1997; Fig. 9). Catches dominated by small capelin were recorded mainly in eastern Division 3L. During the 1991-95 period, when very few large catches were recorded, many of the sets toward the northeastern edge of the bank were dominated by small fish.

With the introduction of the Campelen trawl in 1996, the number of sets with information on average capelin weight increased dramatically. In 1996 many catches in Division 3L had high average capelin weights but catches with medium weights were numerous, especially in the Avalon Channel and south of the Avalon Peninsula. In 1997 the majority of the catches had medium capelin weights. The number of sets with high average weights was much reduced.

Frequency of occurrence

The frequency of occurrence of capelin in sets at depths <750 m (unadjusted, 77%; adjusted 81%) was higher than levels in 1991-95 but similar to the level in 1996 and to levels found in 4 of the 5 years in the period 1986-90 (Table 7; Fig. 10).

Estimates of biomass

The biomass estimated from areal expansion of mean catch per tow was 20 thousand tons (Table 7; Fig. 11). This is a large decline from the biomass of 95 thousand tons estimated from the 1996 survey and is less than the biomass of 34 thousand tons recorded in 1986 when the Engels trawl was used.

Discussion

Capelin in Division 2J3KL in the autumn

The autumn distribution of capelin in Divisions 2J and 3K changed in the early 1990's. In years prior to 1991 most of the capelin in Divisions 2J and 3K were concentrated either in Division 2J or in central Division 3K, but after about 1991 most of the capelin caught during the bottom-trawl surveys or found in stomachs of cod caught during those surveys came from southeastern Division 3K (Lilly 1995a,c). In 1997 the distribution was still concentrated toward the southeast but with some indication of a return to the west. The geographic distribution of mean capelin weights is in agreement with previous studies that showed that the large capelin were mainly toward the north and that small capelin were mainly toward the south, especially on the northern slope of Grand Bank.

In 1997 both the frequency of occurrence and minimum trawlable biomass of capelin were intermediate between values from the 1995 and 1996 surveys.

Capelin in Division 3LNO in the spring

The extensive distribution and moderate to large catches of capelin in Division 3L in the springs of 1996 and 1997 contrast markedly with the very small catches in 1991-95. Part of the increase may be attributed to the change to the Campelen trawl in 1996. However, the Engels trawl was capable of making substantial catches of capelin in years prior to 1991, so the increase in 1996 may also reflect increased abundance in the survey area at the time of the survey.

There is a notable contrast between the autumn surveys and the spring surveys with respect to the increase in trawlable biomass of capelin attending the change to the Campelen trawl. In the autumn series the biomass estimates in 1995-97 were about an order of magnitude greater than estimates in the mid-1980's. The extent of the increase in the spring series is less clear because of the considerable difference between the estimates in 1996 and 1997. However, the estimate in 1997 was not larger than several estimates in the 1970's and 1980's. This might indicate that the quantity of capelin in Division 3L at the time of the survey in 1997 was substantially lower than the quantity present at the time of several of the surveys in the 1970's and 1980's.

Bottom-trawl catches as indices of capelin status

The frequency of occurrence of capelin in bottom-trawl catches and the minimum trawlable biomass calculated from those catches have been presented for both the autumn survey series in Divisions 2J3KL and the spring survey series in Division 3L. The extent to which either of these metrics may serve as an index of capelin abundance or biomass is not known. It is useful to consider the question in two steps: (1) how well do the frequency of occurrence and the estimate of biomass reflect the quantity of capelin in the trawl survey area at the time of the survey and

(2) how does the latter reflect the total abundance or biomass of the capelin stock? With respect to part (1), Lilly (1995b) found that both the frequency of occurrence and the trawlable biomass calculated for the spring series in Division 3L were positively (but not significantly) related to the biomass of capelin estimated from the spring acoustic surveys. The lack of significance may be due in part to poor overlap in time and space between the acoustic survey and the bottom-trawl survey. More information is needed on the relationship between catches in a bottom trawl and the density and behaviour of capelin in the immediate vicinity as measured and observed with hydroacoustics. It is possible that a large catch of capelin in a bottom trawl indicates a high density of capelin near the bottom, especially since large catches are frequently taken close together, often in sequential sets. However, large catches could occur when the survey encounters capelin in relatively shallow water. For example, large catches of capelin on Hamilton Bank in 1979-1981 (Carscadden et al. 1989) contributed to high estimates of trawlable biomass at a time when Soviet and Canadian acoustic surveys indicated that the abundance of the SA2 + Div. 3K capelin stock was low (Lilly 1994b). It is also possible that changes in the behaviour of capelin may change their vulnerability to a bottom trawl. For example, if capelin tend to stay near the bottom in both night and day, instead of migrating upward at night as has often been observed, then they may be captured more frequently and in greater quantities. Shackell et al. (1994b) reported that the capelin found during the acoustic survey of Division 3L in spring 1992 were relatively deep and did not surface at night as in previous years. Such behaviour might result in an upward bias in the frequency of occurrence and the estimate of biomass.

The second part of the question relates to the distribution of the capelin at the time of the bottom-trawl survey. Frank et al. (1996) reported that capelin increased in abundance outside their normal range during periods of anomalously low sea temperatures. They speculated that these changes in distribution, particularly the appearance of capelin on the Flemish Cap, could explain, in part, the dramatic decline in estimates of capelin abundance from spring acoustic surveys beginning in 1991. Such large-scale migrations to areas outside Divisions 2J3KL could affect bycatches in both the spring and autumn bottom-trawl surveys. Bycatches in the spring survey might also be affected by changes in the timing of the capelin migration relative to the timing of the survey. Both the timing of the capelin migration into southern Division 3L and the timing of their spawning on beaches of eastern Newfoundland are variable and related in part to changes in water temperature (Shackell et al. 1994a, Nakashima 1996, Carscadden et al. 1997). In addition, the time of the spring bottom-trawl survey in Division 3L has become retarded by about one month in recent years compared with the 1980's. This delay in the survey might increase the degree of spatial overlap with capelin if the capelin migration is also delayed, but the degree of overlap cannot be assessed.

References

Bishop, C. A. 1994. Revisions and additions to stratification schemes used during research vessel surveys in NAFO Subareas 2 and 3. NAFO SCR Doc. 94/43, Serial No. N2413. 23p.

Brodie, W. 1996. A description of the 1995 fall groundfish survey in Division 2J3KLNO. NAFO SCR Doc. 96/27, Serial No. N2700. 7 p.

Carscadden, J., D. S. Miller, and G. R. Lilly. 1989. Capelin in SA2 + Div. 3K: results from offshore research. CAFSAC Res. Doc. 89/78. 44 p.

Carscadden, J., B. S. Nakashima, and K. T. Frank. 1997. Effects of fish length and temperature on the timing of peak spawning in capelin (Mallotus villosus). Can. J. Fish. Aquat. Sci. 54: 781-787.

Carscadden, J., B. Nakashima, R. Harnum, and G. Lilly. 1990. Capelin in SA 2 and Div. 3K. CAFSAC Res. Doc. 90/7. 28 p.

Doubleday, W. G. 1981. Manual on groundfish surveys in the Northwest Atlantic. NAFO Sci. Coun. Studies 2: 7-55.

Frank, K. T., J. E. Carscadden, and J. E. Simon. 1996. Recent excursions of capelin (Mallotus villosus) to the Scotian Shelf and Flemish Cap during anomalous hydrographic conditions. Can. J. Fish. Aquat. Sci. 53: 1473-1486.

Lilly, G. R. 1992. By-catches of capelin in Canadian bottom-trawl surveys from northern Labrador to the southern Grand Bank (Div. 2GHJ3KLNO) in autumn 1991. NAFO SCR Doc. 92/8, Serial No. N2041. 7 p.

1994a. By-catches of capelin in bottom-trawl surveys, p. 99-107. In: J. Carscadden [ed.] Capelin in SA2 + Div. 3KL. DFO Atl. Fish. Res. Doc. 94/18.

1994b. Predation by Atlantic cod on capelin on the southern Labrador and Northeast Newfoundland shelves during a period of changing spatial distributions. ICES mar. Sci. Symp. 198: 600-611.

1995a. By-catches of capelin during autumn bottom trawl surveys in Divisions 2J3KLNO, with emphasis on 1994, p. 93-109. In: Anon. [ed.] Capelin in SA2 + Div. 3KL. DFO Atl. Fish. Res. Doc. 95/70.

1995b. By-catches of capelin during spring bottom-trawl surveys in Divisions 3LNO, p. 110-132. In: Anon. [ed.] Capelin in SA2 + Div. 3KL. DFO Atl. Fish. Res. Doc. 95/70.

1995c. Did the feeding level of the cod off southern Labrador and eastern Newfoundland decline in the 1990s? DFO Atl. Fish. Res. Doc. 95/74. 25 p.

1996. By-catches of capelin and Arctic cod during bottom trawl surveys in NAFO Divisions 2J3KL, p. 218-242. In: Anon. [ed.] Capelin in SA2 + Div. 3KL. DFO Atl. Fish. Res. Doc. 96/90.

1997. By-catches of capelin during spring and autumn bottom-trawl surveys in Divisions 2J3KL in 1996. In: Capelin in SA2 + Div. 3KL. *Edited by* Anon. CSAS Res. Doc. 97/29. pp. 91-124.

Lilly, G. R., and D. J. Davis. 1993. Changes in the distribution of capelin in Divisions 2J, 3K and 3L in the autumns of recent years, as inferred from bottom-trawl by-catches and cod stomach examinations. NAFO SCR Doc. 93/54, Serial No. N2237. 14 p.

Lilly, G. R., P. A. Shelton, J. Brattey, N. Cadigan, E. F. Murphy, D. E. Stansbury, M. B. Davis, and M. J. Morgan. 1998. An assessment of the cod stock in NAFO Divisions 2J + 3KL. DFO CSAS Sec. Res. Doc. 98/15. 102 p.

McCallum, B. R., and S. J. Walsh. 1997. Groundfish survey trawls used at the Northwest Atlantic Fisheries Centre, 1971 to present. NAFO Sci. Coun. Studies 29: 93-104.

Miller, D. S., and G. R. Lilly. 1991. Observations and studies on SA2 + Div. 3K capelin in 1990. CAFSAC Res. Doc. 91/11. 30 p.

Nakashima, B. S. 1996. The relationship between oceanographic conditions in the 1990s and changes in spawning behaviour, growth and early life history of capelin (Mallotus villosus). NAFO Sci. Coun. Studies 24: 55-68.

Shackell, N. L., J. E. Carscadden, and D. S. Miller. 1994a. Migration of pre-spawning capelin (Mallotus villosus) as related to temperature on the northern Grand Bank, Newfoundland. ICES J. mar. Sci. 51: 107-114.

1994b. Diel vertical migration of capelin (Mallotus villosus) and its effect on acoustic estimates of density. ICES C.M.1994/Mini:5. 18 p.

Table 1. Selected data for bottom-trawl surveys in Divisions 2J3KL in the autumns of 1977-1997. AN = ALFRED NEEDLER, ATC = A. T. CAMERON, GA = GADUS ATLANTICA, TE = TELEOST, WT = WILFRED TEMPLEMAN.

Year	Div.	Ship/Trip	Sampling dates (d/mo.-d/mo.)	Number of stations occupied		Phase 1 stations with cod		Phase 1 stations with capelin	
				Phase 1	Phase 2	No.	%	No.	%
1977	2J3K	GA 3	11/11-02/12	127		96	76	7	6
1978	2J3K	GA 15	04/11-27/11	125		122	98	2	2
1979	2J3K	GA 29	15/11-04/12	124		121	98	42	34
1980	2J3K	GA 44	22/11-08/12	134		129	96	25	19
1981	2J3K	GA 58,59	14/11-13/12	224		182	81	53	24
	3L	ATC 323,325	03/10-18/11	97		87	90	13	13
1982	2J3K	GA 71,72	30/10-08/12	303		251	83	97	32
	3L	ATC 333,334	30/10-06/12	121		113	93	43	36
1983	2J3K	GA 86-88	28/10-07/12	255		220	86	57	22
	3L	WT 7-9	13/10-14/11	126		122	97	44	35
1984	2J3K	GA 101-103	27/10-05/12	262		219	84	67	26
1985	2J3K	GA 116-118	23/10-02/12	311		251	81	127	41
	3L	WT 37-39	09/10-18/11	232		189	82	80	34
1986	2J3K	GA 131-133	03/11-11/12	215		185	86	52	24
	3L	AN 72	13/11-30/11	142		119	84	38	27
1987	2J3K	GA 145-147	29/10-08/12	288		252	88	94	33
	3L	WT 65	15/10-01/11	165		149	90	38	23
1988	2J3K	GA 159-161	04/11-13/12	239		209	87	84	35
	3L	WT 78	26/10-13/11	189		167	88	85	45
1989	2J3K	GA 174-176	02/11-19/12	276	48	228	83	134	49
	3L	WT 87	12/10-31/10	174	21	134	77	72	41
1990	2J3K	GA 190-192	03/11-19/12	243	68	178	73	83	34
	3L	WT 101	18/10-18/11	161	27	140	87	31	19

Table 1. (Cont'd.)

Year	Div.	Ship/Trip	Sampling dates (d/mo.-d/mo.)	Number of stations occupied		Phase 1 stations with cod		Phase 1 stations with capelin	
				Phase 1	Phase 2	No.	%	No.	%
1991	2J3K	GA 208-210	06/11-17/12	313		229	73	117	37
	3L	WT 114,115	08/11-02/12	219		168	77	45	21
1992	2J3K	GA 224-226	29/10-09/12	319		209	66	153	48
	3L	WT 129,130	05/11-29/11	215		146	68	80	37
1993	2J3K	GA 236-238	30/10-06/12	263		137	52	98	37
	3L	WT 145,146	12/11-04/12	153		94	61	76	50
1994	2J3K	GA 250-252	09/11-19/12	255		81	32	108	42
	3L	WT 161,162	08/11-07/12	200		68	34	83	42
1995	2J3K	TE 20-23 WT 180, 181	28/11-25/01	215		155	72	116	54
	3L	TE 23 WT 176, 178, 179	03/10-25/01	166		69	42	117	71
1996	2J3K	TE 39-41 WT 198	22/10-26/11	291		180	62	139	48
	3L	TE 41 WT 196-198	09/10-05/12	210		75	36	97	46
1997	2J3K	TE 54-57 WT 217	19/10-19/12	292		158	54	164	56
	3L	TE 57-58 WT 213-217	23/10-20/12	205		98	48	119	58

Table 2. Selected data for bottom-trawl surveys in Divisions 3LNØ in the springs of 1971-1997.

Year	Div.	Ship/Trip	Sampling Dates (d/mo.-d/mo.)	No. of stations occupied	Stations with cod		Stations with capelin	
					No.	%	No.	%
1971	3L	ATC 187	03/06-18/06	60	55	92	25	42
	3NØ	ATC 187	09/06-13/06	25	23	92	7	28
1972	3L	ATC 199	12/05-18/05	38	38	100	16	42
	3NØ	ATC 199	04/05-12/05	45	44	98	6	13
1973	3L	ATC 208, 209	07/04-06/05	33	27	82	3	9
	3NØ	ATC 207-209	22/03-04/05	96	80	83	17	18
1974	3L	ATC 222	07/05-21/05	70	57	81	17	24
	3NØ	ATC 222	08/05-13/05	37	30	81	3	8
1975	3L	ATC 233	09/05-25/05	55	47	86	39	71
	3NØ	ATC 233	15/05-24/05	58	45	78	24	41
1976	3L	ATC 246	23/04-03/05	64	60	94	30	47
	3NØ	ATC 245	02/04-13/04	78	58	74	4	5
1977	3L	ATC 262	04/05-18/05	102	92	90	36	35
	3NØ	ATC 263	26/05-07/06	88	77	88	12	14
1978	3L	ATC 276	06/05-17/05	95	86	91	8	8
	3NØ	ATC 276, 277	14/05-07/06	92	78	85	5	5
1979	3L	ATC 290	17/05-04/06	141	134	95	42	30
	3NØ	ATC 289, 291	02/04-25/06	172	133	77	21	12
1980	3L	ATC 304, 305	10/05-02/06	115	113	98	20	17
	3NØ	ATC 303, 304	11/04-11/05	140	109	78	4	3
1981	3L	ATC 317, 318	06/04-07/05	81	67	83	28	35
	3NØ	ATC 318, 319	04/05-22/05	77	67	87	10	13
1982	3L	ATC 329	06/05-17/05	103	93	90	44	43
	3NØ	ATC 327, 328	27/03-26/04	138	119	86	20	15
1984	3L	AN 28	17/05-21/05	37	37	100	18	49
	3NØ	AN 27	28/04-08/05	117	86	74	15	13
1985	3L	WT 28-30	17/04-26/05	221	198	90	94	43
	3NØ	WT 29 AN 43	11/04-05/05	178	134	75	33	19

Table 2. Continued ...

Year	Div.	Ship/Trip	Sampling Dates (d/mo.-d/mo.)	No. of stations occupied	Stations with cod		Stations with capelin	
					No.	%	No.	%
1986	3L	WT 48	07/05-25/05	211	203	96	169	80
	3NØ	WT 47	18/04-04/05	203	160	79	21	10
1987	3L	WT 59, 60	14/05-01/06	181	169	93	53	29
	3NØ	WT 58, 59	23/04-14/05	190	168	88	56	29
1988	3L	WT 70, 71	05/05-24/05	154	142	92	108	70
	3NØ	WT 70	21/04-05/05	161	132	82	28	17
1989	3L	WT 82,83	06/05-28/05	205	189	92	157	77
	3NØ	WT 82	20/04-06/05	195	155	80	47	24
1990	3L	WT 96	18/05-04/06	156	137	88	108	69
	3NØ	WT 94-96	22/04-01/06	178	146	82	59	33
1991	3L	WT 106, 107	11/05-29/05	143	89	62	69	48
	3NØ	WT 105, 106	19/04-11/05	209	128	61	44	21
1992	3L	WT 120-122	13/05-07/06	178	51	29	92	52
	3NØ	WT 119, 120	22/04-13/05	185	90	49	54	29
1993	3L	WT 137, 138	18/05-10/06	181	55	30	93	51
	3NØ	WT 136, 137	27/04-18/05	166	77	46	67	40
1994	3L	WT 153, 154	22/05-10/06	160	18	11	75	47
	3NO	WT 152, 153	30/04-22/05	157	44	28	48	31
1995	3L	WT 169, 170	27/05-14/06	151	19	13	78	52
	3NO	WT 168, 169	03/05-27/05	174	51	29	42	24
1996	3L	WT 189-191	30/05-27/06	189	82	43	138	73
	3NO	WT 188, 189	07/05-30/05	168	100	60	91	54
1997	3L	WT 206-208	04/06-26/06	158	40	25	122	77
	3NO	WT 204-206	30/04-04/06	152	80	53	118	78

Table 3. Statistics for by-catches of capelin during bottom-trawl surveys in NAFO Divisions 2J3K during the autumns of 1978 to 1997.

Year	Number[a] of stations	Stations with capelin		Percentiles of capelin[b] catches (kg)			
		No.	%	50	75	95	Max.
1978	125	2	2	0.03			<<1
1979	124	42	34	0.09	0.3	9	185
1980	134	25	19	0.50	1.8	149	172
1981	214	53	25	0.30	1.0	234	345
1982	291	97	33	0.20	0.5	3	18
1983	248	58	23	0.10	0.3	2	24
1984	251	67	27	0.15	0.4	2	3
1985	297	127	43	0.12	0.4	3	10
1986	209	50	24	0.18	0.8	12	24
1987	276	94	34	0.20	1.0	18	117
1988	233	84	36	0.15	0.8	3	39
1989	273[c]	134	49	0.12	0.3	2	32
1990	232[c]	82	35	0.09	0.3	1	11
1991[d]	302	117	39	0.14	0.5	4	68
1992[d]	308	151	49	0.10	0.3	3	15
1993[d]	245	98	40	0.14	0.5	6	9
1994[d]	237	108	46	0.50	1.9	10	30
1995[e]	194	116	60	2.31	8.3	56	332
1996[e]	234	122	52	0.99	3.3	21	53
1997[e]	236	146	62	1.96	6.7	20	49

a Stations in depths >750 m are not included. Stations in strata 618 and 619 on the coastal shelf off northern Newfoundland are included, but stations in strata 608-616 in the inshore area of 3K are not included. Strata 618 and 619 were not fished prior to 1984, and strata 608-616 were added in 1996.

b Percentiles are calculated for those stations in which capelin were recorded in the catch.

c Only stations from first-stage sampling are included.

d Surveys in 1991-94 are not directly comparable to those in other years, because the number of fishing stations assigned to each stratum was not roughly proportional to stratum area.

e Survey was conducted with a Campelen 1800 shrimp trawl. Earlier surveys were conducted with an Engel 145 Hi-Lift trawl.

Table 4. Statistics for by-catches of capelin during bottom-trawl surveys in NAFO Division 3L during the autumns of 1985 to 1997.

Year	Number[a] of stations	Stations with capelin		Percentiles of capelin[b] catches (kg)			
		No.	%	50	75	95	Max.
1985	232	80	35	0.33	0.8	6	16
1986	142	38	27	0.11	0.4	2	6
1987	165	38	23	0.10	0.5	2	4
1988	189	85	45	0.20	0.8	7	21
1989	174[c]	72	41	0.20	0.4	7	30
1990	161[c]	31	19	0.10	0.5	11	17
1991[d]	219	45	21	0.11	0.5	7	10
1992[d]	215	80	37	0.12	0.4	2	6
1993[d]	153	76	50	0.13	0.4	3	16
1994[d]	200	83	42	0.10	0.3	1	2
1995[e]	162	117	72	1.26	6.3	29	70
1996[e]	148	78	53	0.48	3.9	17	92
1997[e]	141	93	66	1.09	4.1	19	47

[a] Stations in depths >750 m are not included. Stations in strata 784-799, which were added in the inshore area in 1996,and stratum 800, which was added in 1997, are not included.

[b] Percentiles are calculated for those stations in which capelin were recorded in the catch.

[c] Only stations from first-stage sampling are included.

[d] Surveys in 1991-94 are not directly comparable to those in other years, because the number of fishing stations assigned to each stratum was not roughly proportional to stratum area.

[e] Survey was conducted with a Campelen 1800 shrimp trawl. Earlier surveys were conducted with an Engels 145 Hi-Lift trawl.

Table 5. The frequency of occurrence of capelin in catches during the autumn bottom-trawl surveys in Divisions 2J3K and Division 3L in 1978-1997. Division 3L was not surveyed in 1978-1980 and 1984. Only sets in 750 m or less are included. Sets in the inshore strata of Divisions 3K and 3L are deleted. The method of adjustment is described in the text. For 1989 and 1990, the unadjusted value includes only sets from phase 1, whereas the adjusted value includes sets from phases 1 and 2. The tows in Division 3L in 1981-1983 were conducted with a Yankee 41-5 bottom trawl. All other tows prior to 1995 were conducted with an Engel 145 Hi-Lift bottom trawl. Tows in 1995-97 were conducted with a Campelen 1800 shrimp trawl.

Year	2J3K unadj.	2J3K adj.	3L unadj.	3L adj.
1978	1.6	1.3		
1979	33.9	35.0		
1980	18.7	18.4		
1981	24.8	26.4	13.4	14.1
1982	33.3	33.6	35.5	28.8
1983	23.4	24.8	34.9	30.6
1984	26.7	26.4		
1985	42.8	43.7	34.5	34.3
1986	23.9	26.1	26.8	27.0
1987	34.1	35.3	23.0	26.6
1988	36.1	36.9	45.0	45.5
1989	49.1	48.8	41.4	39.8
1990	35.3	35.2	19.3	21.0
1991	38.7	43.3	20.5	22.9
1992	49.0	53.0	37.2	52.1
1993	40.0	47.4	49.7	52.8
1994	45.6	46.7	41.5	38.7
1995	59.8	66.2	72.2	76.1
1996	52.1	54.2	52.7	56.6
1997	61.9	65.1	66.0	69.4

Table 6. Statistics for by-catches of capelin during bottom-trawl surveys in NAFO Div. 3L during the springs of 1971 to 1997.

Year	Ship[a] and trip number	Number[b] of stations	Stations with capelin		Percentiles of capelin catches[c] (kg)			
			No.	%	50	75	95	Max.
1971	ATC 187	60	25	42	4.54	14.3	135	181
1972	ATC 199	38	16	42	1.24	4.5	9	9
1973	ATC 208,209	33	3	9	0.14	21.8	22	22
1974	ATC 222	70	17	24	1.13	9.3	58	58
1975	ATC 233	55	39	71	0.91	6.2	145	544
1976	ATC 246	64	30	47	1.86	6.0	17	18
1977	ATC 262	102	36	35	0.89	4.5	119	255
1978	ATC 276	95	8	8	0.07	0.3	<1	<1
1979	ATC 290	141	42	30	0.80	8.4	137	227
1980	ATC 304,305	115	20	17	0.48	1.6	12	13
1981	ATC 317,318	81	28	35	1.00	2.4	18	20
1982	ATC 329	103	44	43	0.50	2.9	27	48
1983								
1984	AN 28	37	18	49	3.25	11.5	190	190
1985	WT 28-30	221	94	43	0.30	1.4	8	24
1986	WT 48	211	169	80	2.00	6.0	72	483
1987	WT 59,60	181	53	29	4.50	17.0	69	167
1988	WT 70,71	154	108	70	0.30	1.7	12	33
1989	WT 82,83	205	157	77	0.80	2.1	18	32
1990	WT 96	156	108	69	0.98	3.2	52	175
1991	WT 106,107	143	69	48	0.14	0.5	5	24
1992	WT 120-122	178	92	52	0.04	0.1	1	4
1993	WT 137,138	181	93	51	0.09	0.4	5	26
1994	WT 153,154	152	74	49	0.11	0.3	2	4
1995	WT 169,170	151	78	52	0.08	0.3	6	12
1996	WT 189-191	189	138	73	3.92	15.1	78	625
1997	WT 206-208	158	122	77	1.37	5.5	17	40

[a] ATC = A. T. Cameron, AN = Alfred Needler, WT = Wilfred Templeman

[b] Stations in depths >750 m are not included.

[c] Percentiles are calculated for those stations in which capelin were recorded in the catch.

Table 7. The frequency of occurrence and trawlable biomass of capelin in Division 3L in the springs of 1977-1997, as estimated from bottom trawl surveys. There was no bottom-trawl survey in 1983, and the survey in 1984 was incomplete. Tows were made with a Yankee 41-5 trawl in 1977-1982, an Engel 145 Hi-Lift trawl in 1985-95, and a Campelen 1600 trawl in 1996-1997.

	Frequency of occurrence (%)		Biomass ('000 tons)
Year	Unadj.	Adj.	Bottom trawl survey
1977	35.3	38.2	18.246
1978	8.4	5.9	0.025
1979	29.8	31.7	15.441
1980	17.4	15.6	0.492
1981	34.6	28.5	2.045
1982	42.7	47.9	6.005
1983			
1984			
1985	42.5	41.0	1.874
1986	80.1	79.7	33.864
1987	29.3	32.1	12.919
1988	70.1	69.8	4.007
1989	76.6	78.0	6.250
1990	69.2	71.5	15.546
1991	48.3	52.1	1.398
1992	51.7	54.1	0.259
1993	51.4	53.1	1.436
1994	48.7	48.6	0.432
1995	51.7	55.8	1.103
1996	73.0	77.7	94.695
1997	77.2	81.3	19.970

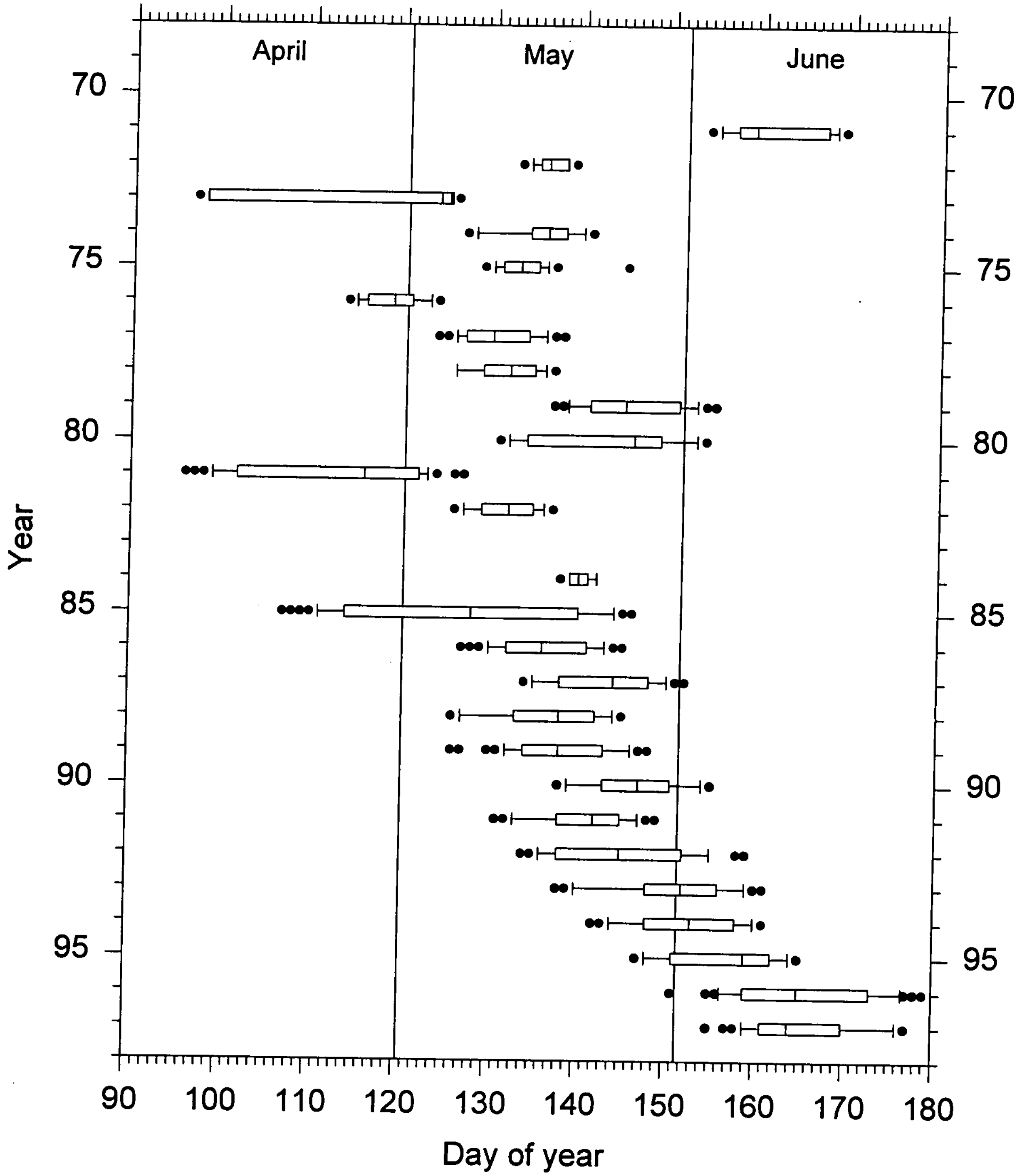


Fig. 1. Dates of fishing during stratified-random bottom-trawl surveys in Division 3L in 1971-1997. The box plot for each year illustrates the 10th, 25th, 50th, 75th and 90th percentiles, and all dates beyond the 10th and 90th percentiles.

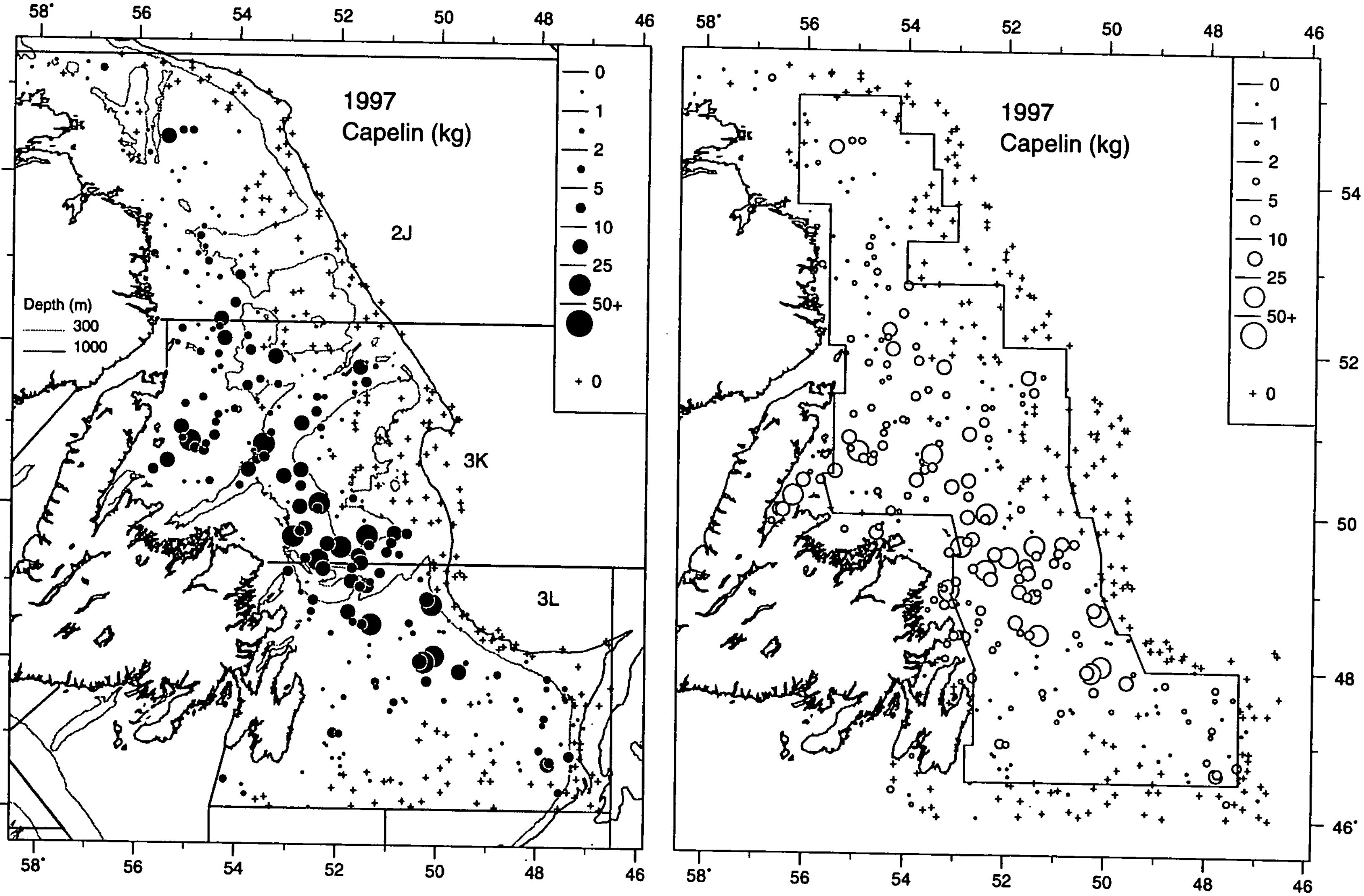


Fig. 2. Capelin catches (kg/15 min tow) during random-stratified bottom-trawl surveys in Divisions 2J3KL during autumn 1997. The left panel shows the 300 and 1000m isobaths. The right panel shows the boundary of the acoustic survey in 1994. Inshore stations are illustrated in the right panel only.

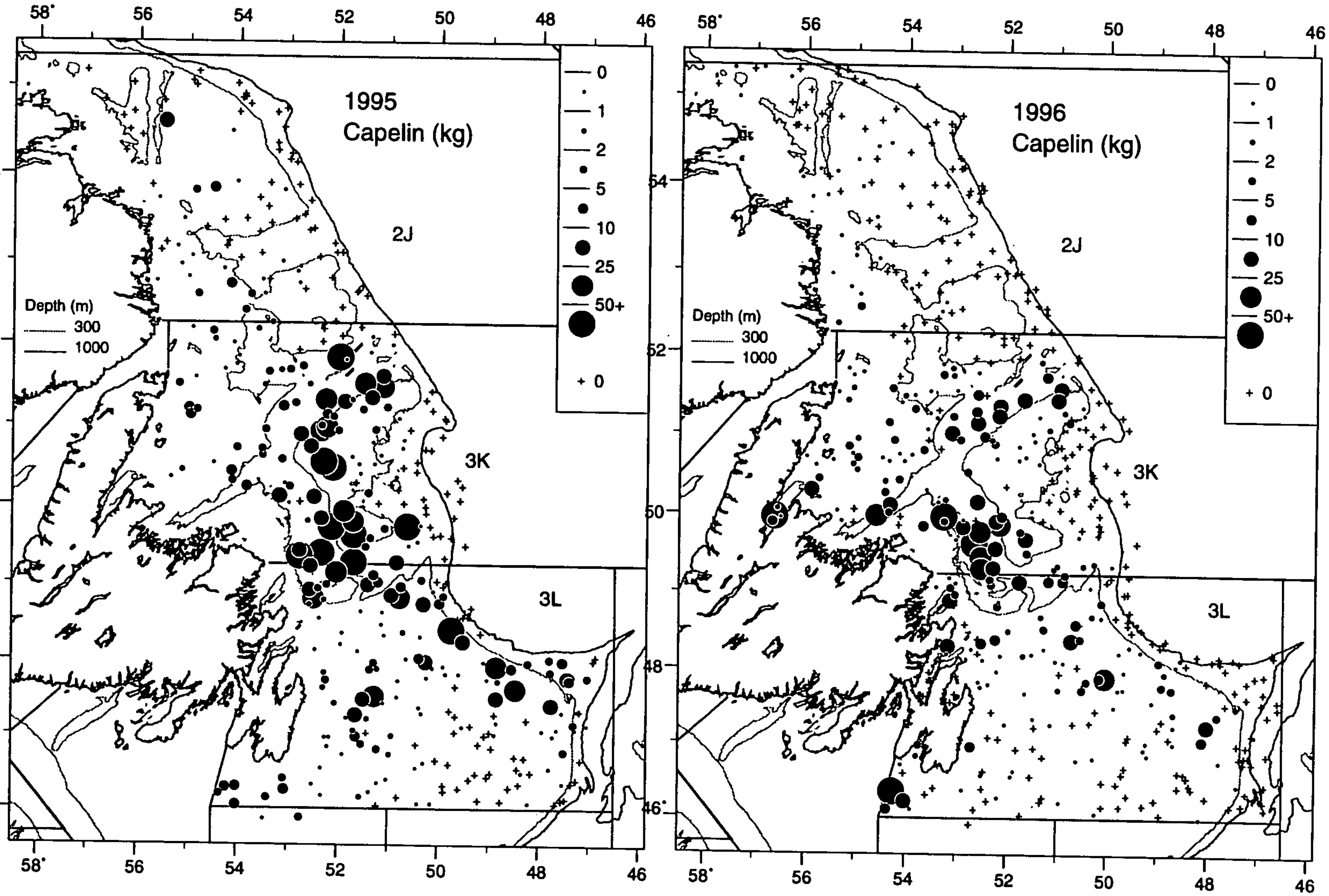


Fig. 3. Capelin catches (kg/15 min tow) during random-stratified bottom-trawl surveys in Divisions 2J3KL during the autumns of 1995 and 1996.

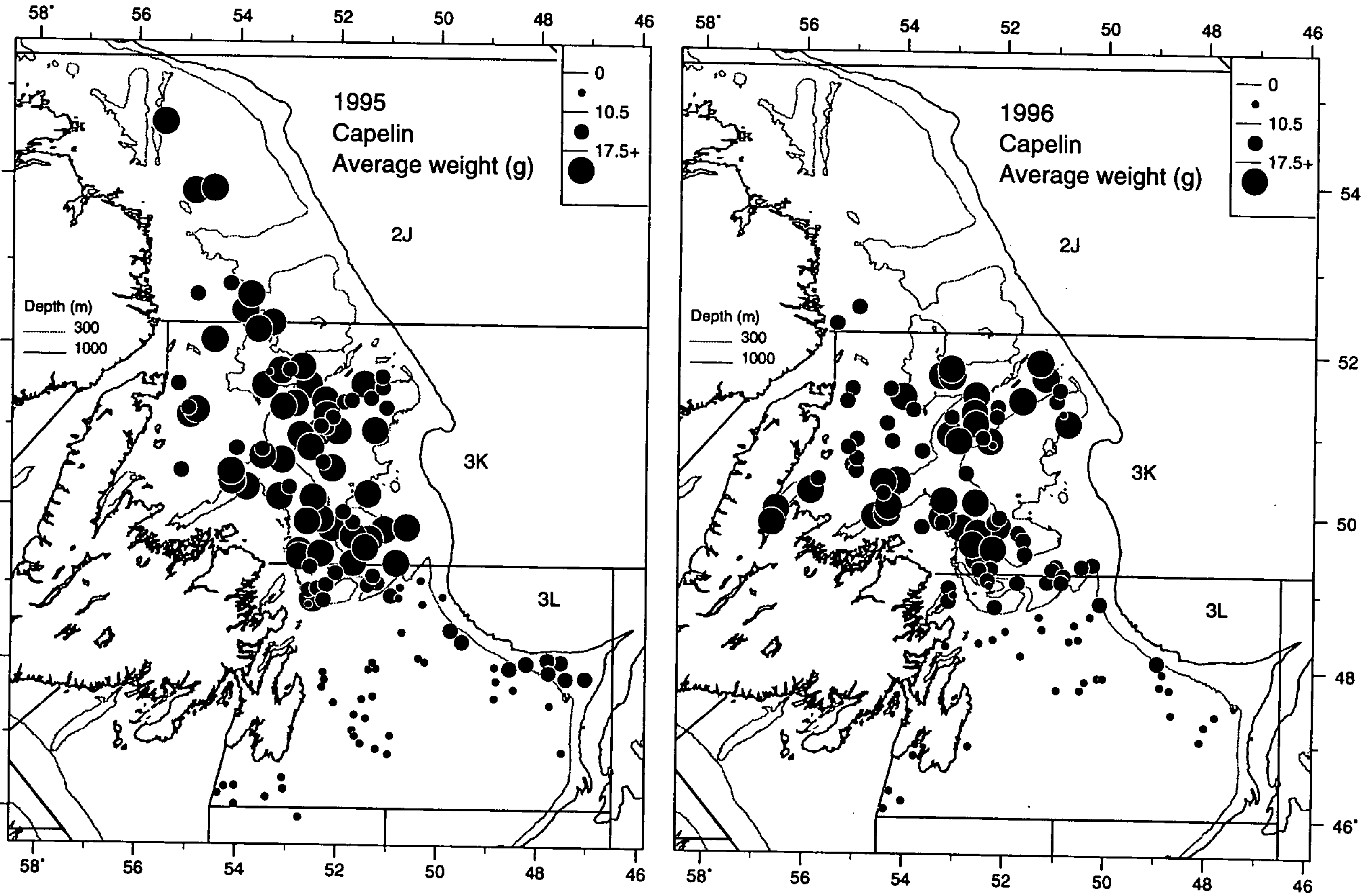


Fig. 4. Average weight of capelin in catches of at least 1 kg and 50 individuals during random-stratified bottom-trawl surveys in Divisions 2J3KL during the autumns of 1995-1997.

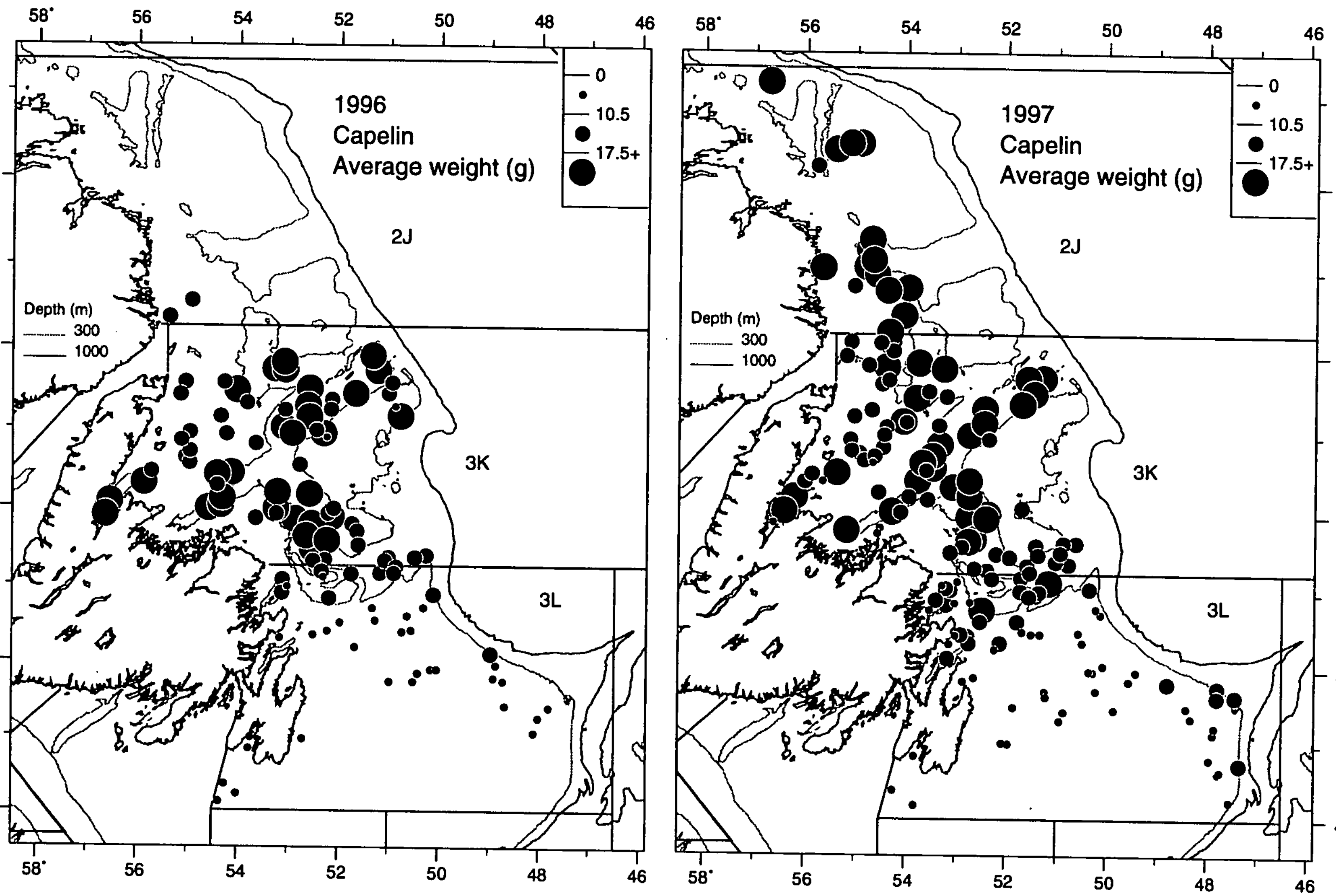

1996
Capelin
Average weight (g)
0
10.5
17.5+
2J
3K
3L
Depth (m)
300
1000
58°
56
54
52
50
48
46
46°
1997
Capelin
Average weight (g)
0
10.5
17.5+
2J
3K
3L
Depth (m)
300
1000

Fig. 4 (cont'd).

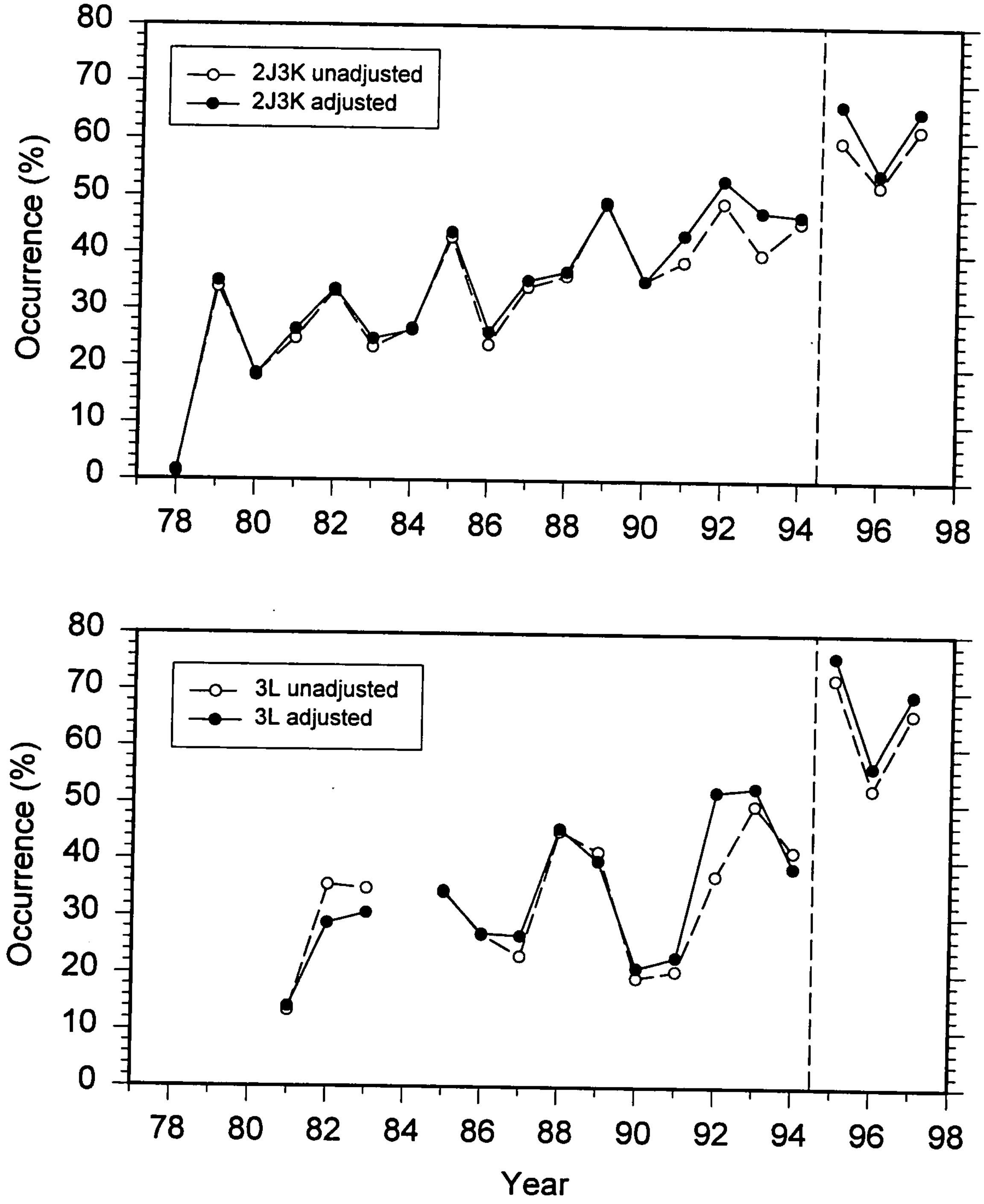


Fig. 5. The frequency of occurrence of capelin in catches during the autumn bottom-trawl surveys in Division 2J3K (upper panel) and Division 3L (lower panel) in 1978-1997. Division 3L was not surveyed in 1978-1980 and 1984. A Yankee 41-5 trawl was used in Division 3L in 1981-1983. An Engel 145 Hi-Lift trawl was used in Division 3L in 1985-1994 and in Division 2J3K in 1978-1994. A Campelen 1800 shrimp trawl was used in all Divisions in 1995-1997.

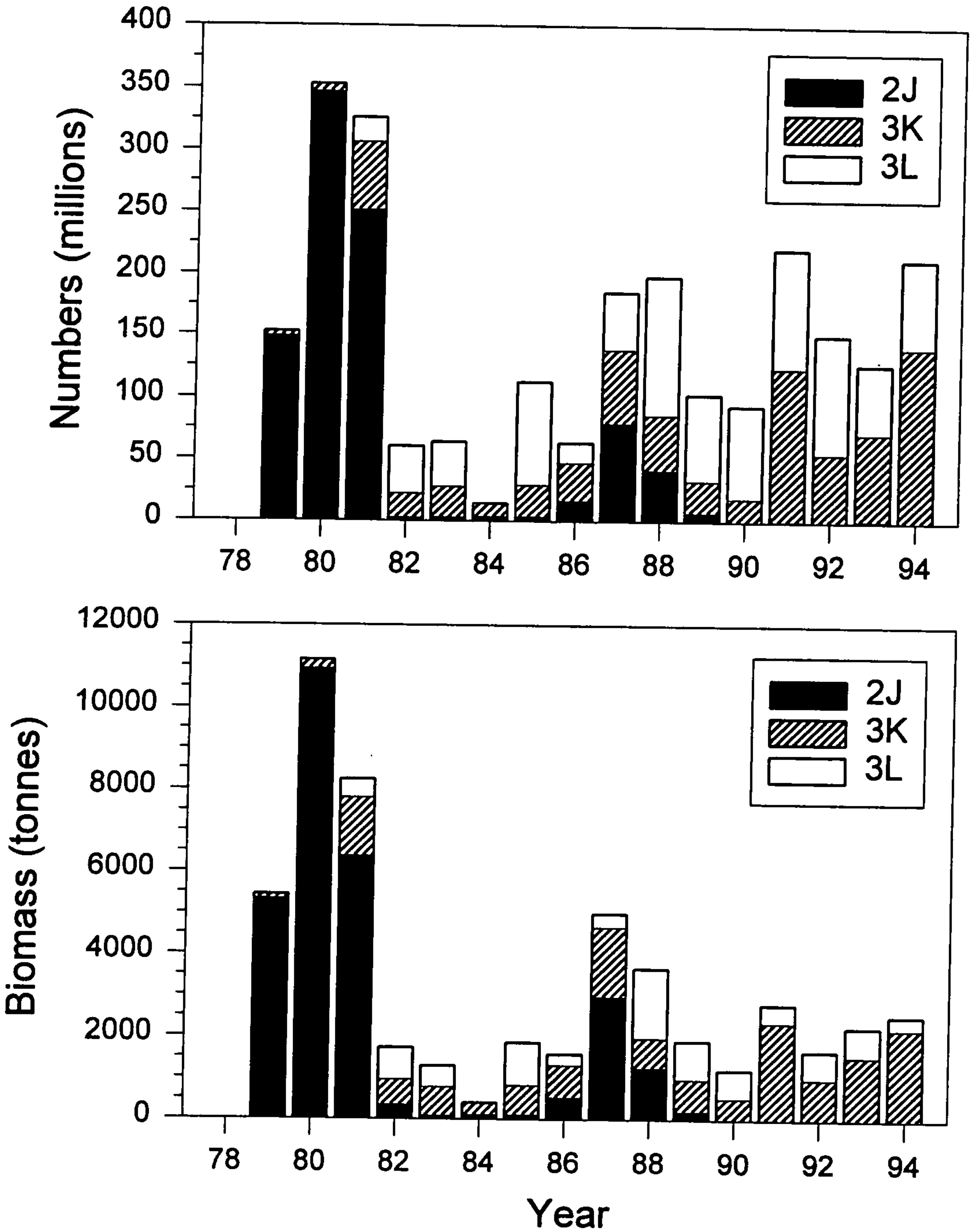


Fig. 6. Abundance and biomass of capelin by year and Division, estimated from areal expansion of stratified mean catch per tow during autumn surveys, for the years 1978-1994. There was a survey in Divisions 2J3K in 1978, but the estimated levels were too small to be distinguishable from the axis. Division 3L was not surveyed in 1978-1980 and 1984.

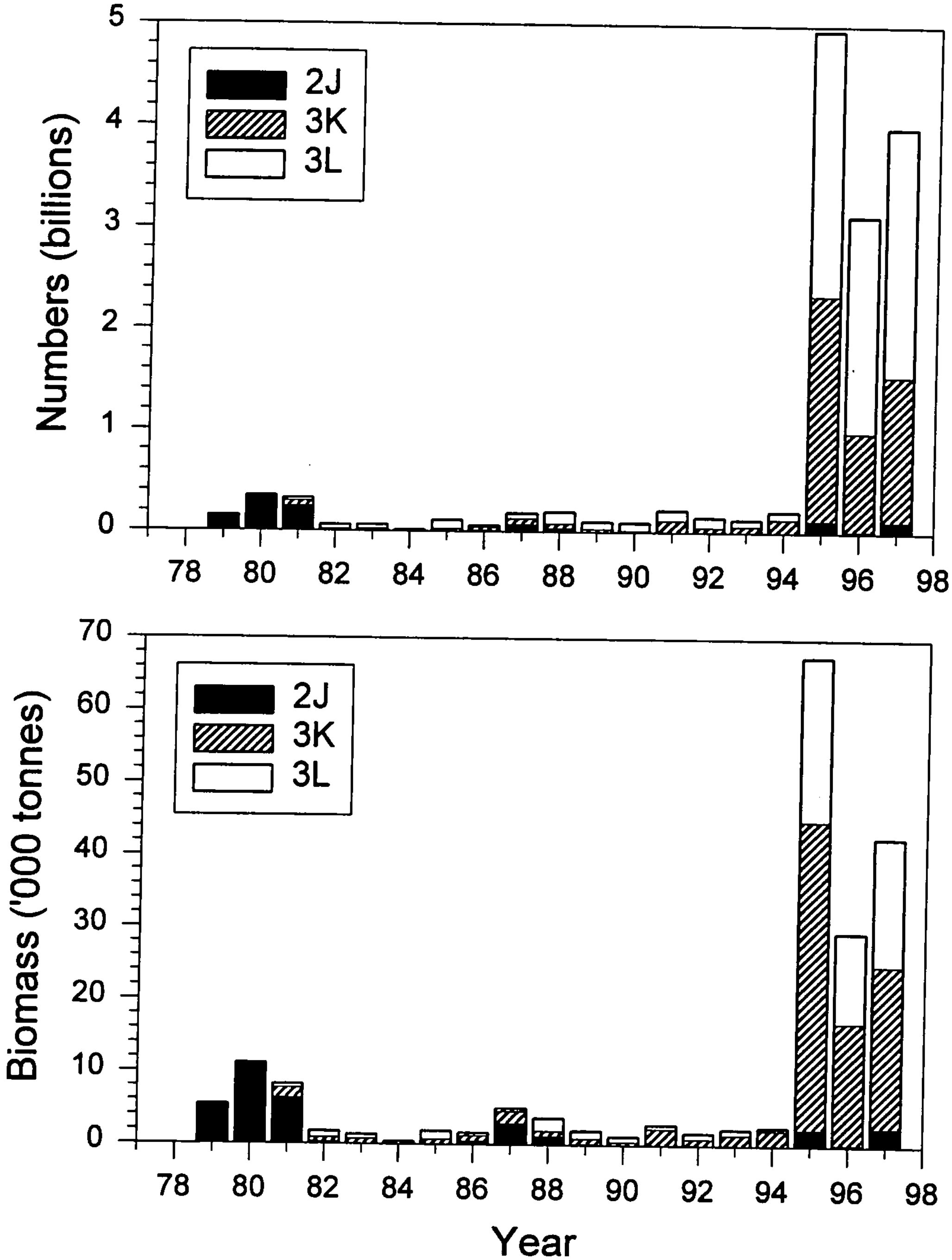


Fig. 7. Abundance and biomass of capelin by year and Division, estimated from areal expansion of stratified mean catch per tow during autumn surveys, for the years 1978-1997. There was a survey in Divisions 2J3K in 1978, but the estimated levels were too small to be distinguishable from the axis. Division 3L was not surveyed in 1978-1980 and 1984. A Campelen 1800 shrimp trawl was introduced in 1995.

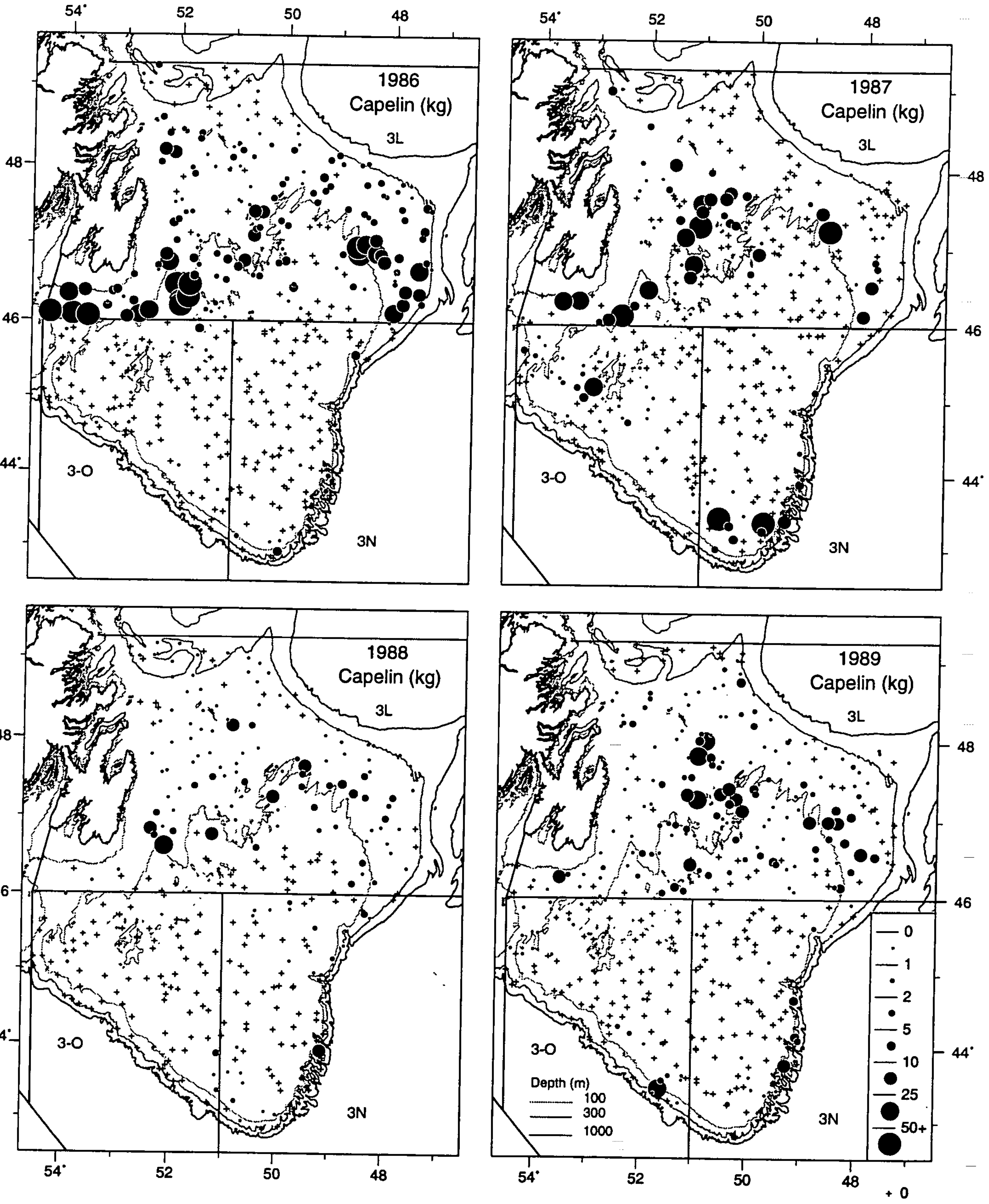
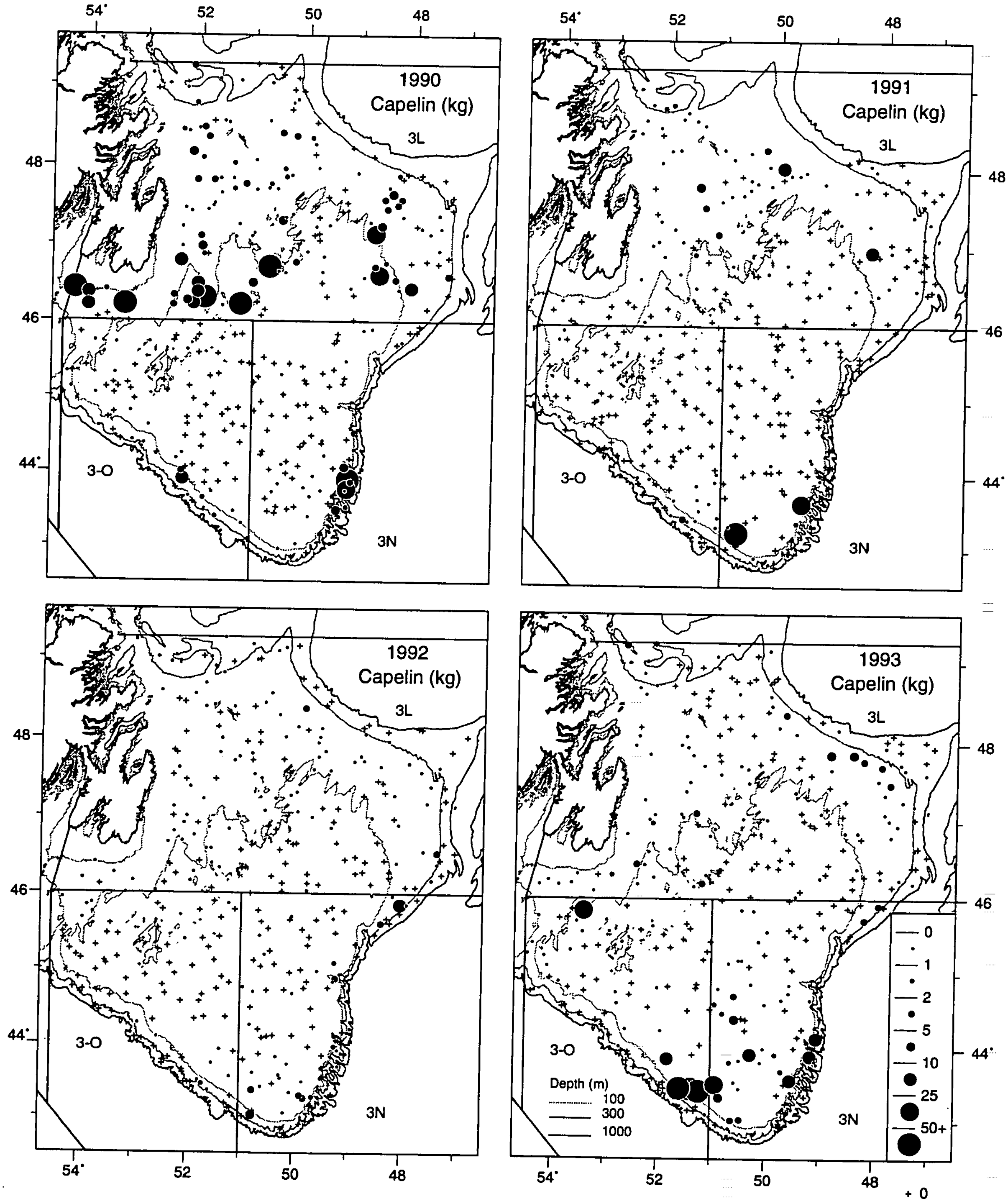


Fig. 8. Capelin catches during stratified-random bottom-trawl surveys in Divisions 3LNO during the springs of 1986-1997. Data from 1986-1995 are kg/30 min tow with the Engels trawl and data from 1996-1997 are kg/15 min tow with the Campelen trawl. For plots of distributions in 1971-1985, see Lilly (1995b).



1990
Capelin (kg)
1991
Capelin (kg)
1992
Capelin (kg)
1993
Capelin (kg)
3L
3-O
3N
54°
52
50
48
46
44°
Depth (m)
100
300
1000
0
1
2
5
10
25
50+
+ 0

Fig. 8. (cont'd)

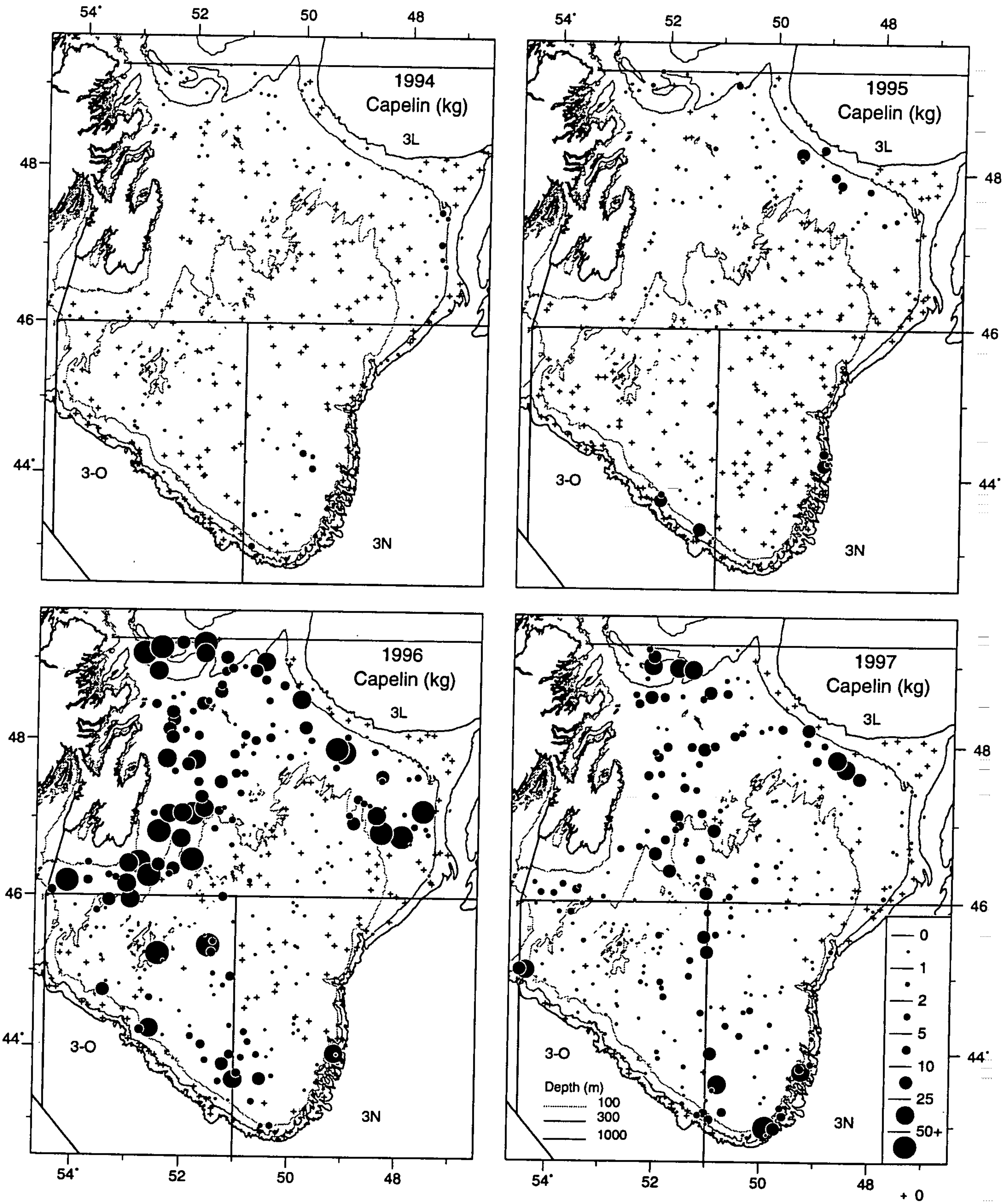

1994
Capelin (kg)
1995
Capelin (kg)
1996
Capelin (kg)
1997
Capelin (kg)
3L
3N
3-O
54°
52
50
48
48
46
44°
Depth (m)
100
300
1000
0
1
2
5
10
25
50+
+ 0

Fig. 8. (cont'd)

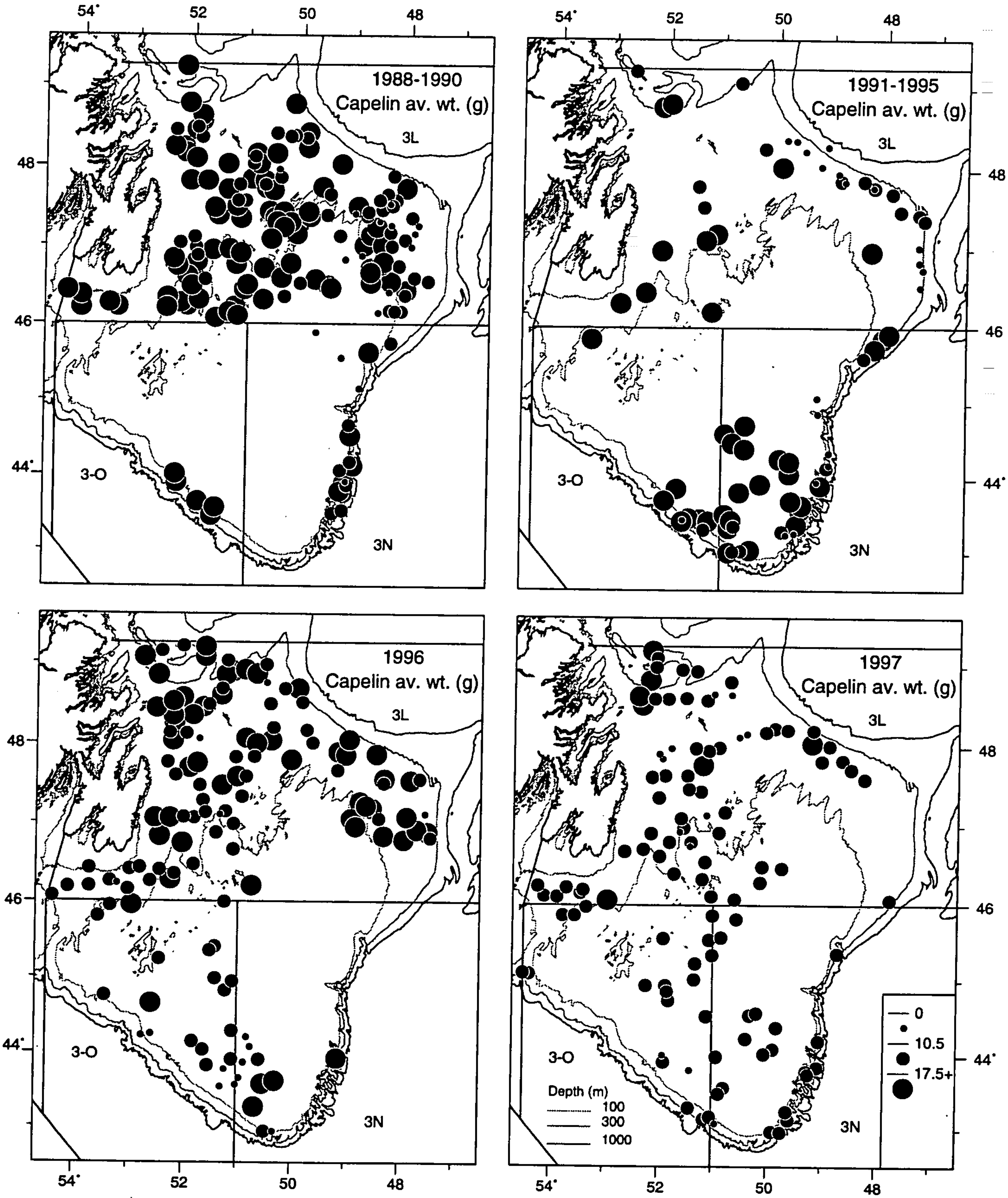


Fig. 9. Average mean weight of capelin in catches of at least 1 kg and 50 individuals during random-stratified bottom-trawl surveys in Divisions 3LNO in the springs of 1988-1990, 1991-1995, 1996 and 1997. Catches in 1988-1995 were from the Engels trawl and catches in 1996 and 1997 were from the Campelen trawl.

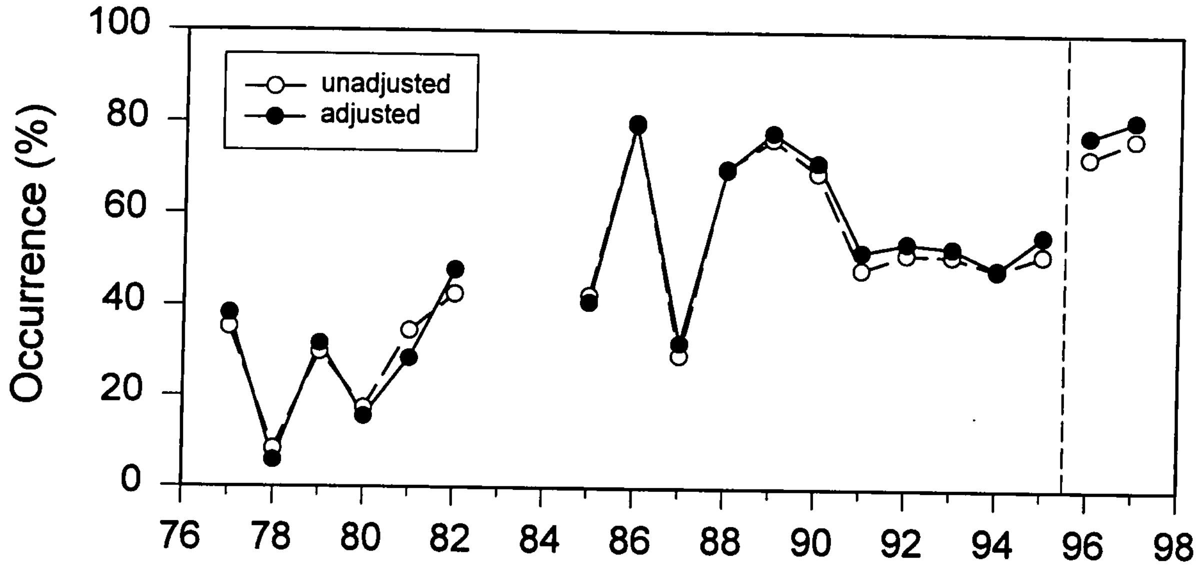


Fig. 10. The frequency of occurrence of capelin in catches during spring bottom-trawl surveys in Division 3L in 1977-1997. There was no survey in 1983 and coverage was inadequate in 1971-1976 and 1984. A Yankee 41-5 trawl was used until 1982, an Engels 145 Hi-Lift trawl was used in 1985-1995, and a Campelen 1600 shrimp trawl was used in 1996-1997.

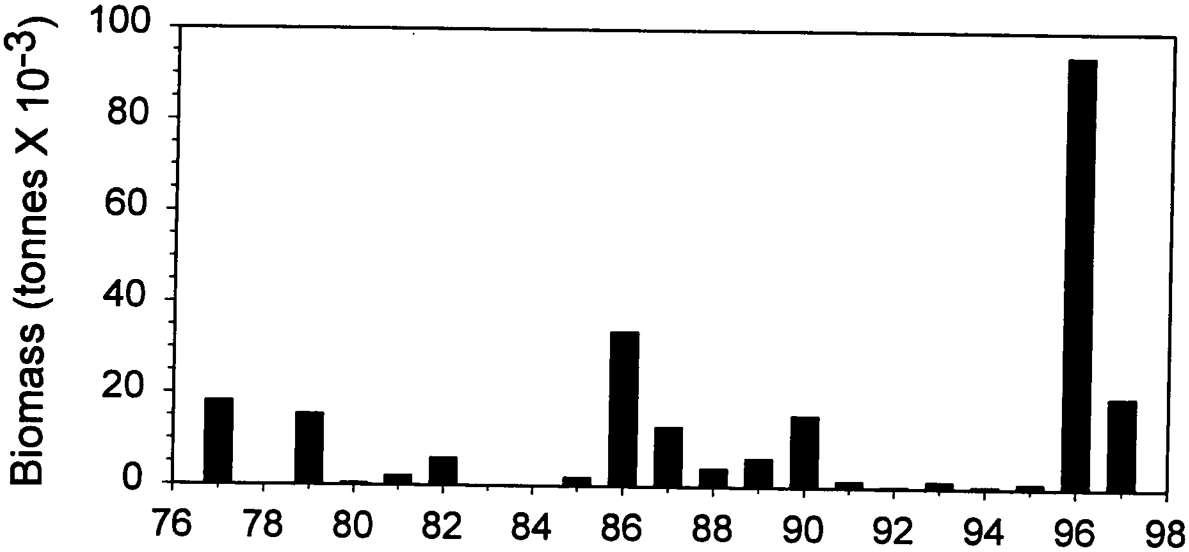


Fig. 11. The biomass of capelin as estimated from areal expansion of stratified mean catch per tow during spring bottom-trawl surveys in Division 3L in 1977-1997. There was no survey in 1983 and coverage was inadequate in 1971-1976 and 1984. A Yankee 41-5 trawl was used until 1982, an Engels 145 Hi-Lift trawl was used in 1985-1995, and a Campelen 1600 shrimp trawl was used in 1996-1997.

Year-Class Strength of Northwest Atlantic Capelin (2J3KLNO) Estimated from Pelagic Juvenile Fish Surveys in the Newfoundland Region, 1991-97

by

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Introduction

Research trawl surveys to estimate the year-class strength of capelin within NAFO Divisions 2J3KLNO have been carried out since 1991 (Anderson and Dalley 1995, 1996, 1997). Two gear types are used to sample 3 groups of capelin in the upper water column; the larval stage (0-Group; 3-50 mm), one year old (1-Group, 50-119 mm), and two year old capelin (2-Group, ≥120 mm). The survey in 1997 was carried out at the end of August, beginning of September, timed to sample pelagic juvenile cod before they settle to the bottom, and larval capelin released from beach and bottom sediments following spawning.

The purpose of this paper is to report on capelin catches from the 1997 survey, and to compare these results to the previous surveys. We examine year-class strength estimates of capelin for three ages, 0-2 years, from the 1997 survey and compare these estimates to previous years. Two different ways of indexing year-class strength, based on mean annual densities (number m^{-3}) and a Weighted Index Area method which incorporates spatial distribution as well as density. It should be noted that mean annual density comparisons include all years 1991-97 whereas the Weighted Index Area method includes only the more recent years (1994-97) when a larger geographic area was surveyed using two ships. In addition, we present information on size of capelin for these different ages, and information on their geographic distributions. Results from previous surveys are available in Anderson and Dalley (1995, 1996, 1997).

Results and Discussion

Survey

The survey was conducted earlier in 1997 than 1994 and 1996 by approximately 8 days and by approximately 24 days compared to 1995. These surveys were approximately six weeks earlier than the surveys carried out in 1991-93 (Table 1). In 1997, 148 stations were occupied sampling with the bongo and IYGPT samplers. These stations covered the inshore areas along the northeast coast of Newfoundland and six offshore areas over the Northeast Newfoundland Shelf and on the Grand Banks (Fig. 1). Survey stations in the outer most areas along the shelfbreak were not occupied due to time constraints.

Larval Capelin (0-Group)

The larval capelin represent an estimate of the 1997 year-class abundance. Adjusted larval capelin abundance (0-group) in 1997 ranked second for all areas, non-zero catches and ranked fifth for common area, null catches, for the 1991-1997 time series (Table 2, Fig. 2). The difference between indices appears to result from the high number of null catches in the 1997 survey within the common area, which indicates that capelin were not as widely dispersed during the time of the survey. Capelin year-class abundance estimates based on the Weighted Index Area method indicates that it was greater than, or equal to, the 1995 year-class which were both greater than the 1994 year-class (Table 3, Fig. 3). A comparison of year-class indices over the four common years for 2J3KLNO were:

➢ Rankings of Year-Class Strength:

Index	*Ranking*
All Areas, Non-Zero Catches	1996>>1997>1995>1994
Common Area, Zero Catches	1996>>1995>1997>1994
Weighted Index Area	1996>>1997≥1995>1994

Larvae were distributed abundantly along the northeast coast (Fig. 7). None were observed off southern Labrador, as in previous years. There was no indication of spawning on the Southern Grand Bank (3NO) based on the absence of larvae.

1-Group Capelin

Abundance of 1996 year-class at age one was the highest in the 1991-96 year-class time series, based on mean density for all non-zero catches and for the 1994-96 year-classes based on the Weighted Index Area method (Fig. 4 and 5). Year-class ranking at age one is estimated to be: 1996 > 1993 = 1995 > 1994 > 1991 ≥ 1992.

One year old capelin were observed within the northeast coastal bays and offshore on northern Grand Bank (Fig. 8). A few age one capelin were observed off southern Labrador and on the Northeast Newfoundland Shelf. Only incidental occurrence of capelin was observed on the southern Grand Bank.

2^+-Group Capelin

Abundance of the 2^+ age group of capelin was lowest in 1995 and highest in 1997. Assuming these capelin were primarily age two, then year-class strength ranks as: 1995 >1994 > 1992 > 1993 (Fig. 6). However, we now believe that this size class of fish may contain significant numbers of age three fish and 4-5 year old fish as well as two year olds. Therefore, until the size distribution is disagregated into specific age classes it is difficult to interpret these data with respect to year-class abundance.

The distribution of 2^+ capelin was very similar to that of the one year olds (Fig. 9).

Size of Capelin

Mean length of capelin in the bongos was 10.0 mm (10-19 mm), which was very similar to mean lengths of 8.9-10.7 mm, 1994-96. This mean length is larger than expected given the early survey date and reports that spawning was still occurring July and August (B. Nakashima, pers. comm.). The mean length of capelin released from spawning habitat is approximately 3-5 mm. Therefore, these larvae would average approximately 20 days age, with a range of 14-28 days based on growth rates of 0.25-0.35 mm d^{-1}.

Some (43) large 0-group capelin were captured in the IYGPT trawl, with a mean length 35.3 mm (24-49 mm) (Fig. 10). These larger capelin were mostly captured in the White Bay area and did not represent a significant number of capelin.

Mean length of age one capelin in 1997 (i.e. the 1996 year-class) was 88.1 mm (50-119 mm, Fig. 10). This mean length was similar to the 1995 and 1992 year-classes, smaller than the 1994 year-class and bigger than the 1990 and 1991 year-classes. The ranking of mean length of capelin measured at age one has persisted to age two for the 1993-95 year-classes, where the rank of mean lengths at ages one and two are: 1994 > 1995 > 1993 (Fig. 11).

Year-Class Strength Ages 0-2 Years

The ranking of year-class strength from age 0 (larvae) to ages 1 has remained constant for the 1991-95 year-classes, with the exception of the age 0 estimate in 1994 (Fig. 12). The 1994 estimate of abundance at age 0 has previously been regarded as biased low due to the late release in 1994. The ranking of year-class strength for the 1994 and 1995 year-classes has remained the same from ages 0 and 1 to age 2^+. Year-class strength for the 1993 year-class was similar to the 1995 year-class at ages 0 and 1 but was much lower for the 1993 year-class at age 2^+. As outlined above, the 2^+ estimate is a composite of more than one age class and cannot be regarded as representing one particular year-class until the age composition among lengths has been determined.

Inshore/Offshore Abundance

Inshore larval abundance has been higher during 1994-1997 than offshore, except in 1995 when abundance was similar. Inshore abundance of 1-group capelin has been higher during 1994-97, except in 1995 when offshore abundance was higher. Inshore abundance of 2^+-group capelin was higher in 1994 and 1996, lower in 1995 and similar in 1997, compared to the offshore.

Geographic Distributions of Larval Sizes

Larvae were bigger in the north (Bonavista Bay to White Bay, mean range 10.8-11.3 mm) than in the south (Trinity Bay to St. Mary's Bay, mean range 8.2-9.9 mm). The larger larvae caught in IYGPT (i.e. 95%) were in the north, from Bonavista Bay to White Bay (35.1-47.7 mm), but these larvae were also smaller offshore on the ISS (27.8 mm). The distribution of lengths indicates two significant periods of larval release in the north: one early, approximately 94 days before the survey, during the 3rd week of May; and a second late release period, approximately 1st week of August. For the second release period, size indicates larvae were older and spawned earlier in the north, from Bonavista Bay to White Bay (-20 days old), and then in St. Mary's Bay to Trinity Bay (-14 days old).

References

Anderson, J. T., and E. L. Dalley. 1995. Distribution and abundances of pre-recruit capelin (Mallotus villosus) in the Newfoundland Region, 1991-94. In: Capelin in SA2 + Div. 3L. Chapter 9. DFO Atl. Fish. Res. Doc. 95/70. p. 133-145.

Anderson, J. T., and E. L. Dalley. 1996. Distribution and abundances of pre-recruit capelin (Mallotus villosus) in the Newfoundland Region, 1994 and 1995. In: Capelin in SA2 + Div. 3L. Chapter 14. DFO Atl. Fish. Res. Doc. 96/90. p. 185-199.

Anderson, J. T., and E. L. Dalley. 1997. Distribution and abundances of pre-recruit capelin (Mallotus villosus) in the Newfoundland Region, 1991-96. In: Capelin in SA2 + Div. 3L. Chapter 7. DFO CSAS Res. Doc. 97/29. p. 125-147.

Table 1. Summary of Pelagic Juvenile Fish Surveys, 1991-1997, carried out in the Northwest Atlantic, as a single ship survey, 1991-1993, and as a two ship survey, 1994-1996. DAW–Dawson; TEM–Wilfred Templeman; GAD–Gadus Atlantica; TEL–Teleost; DoY - Day of the calendar year; Bongo - 0.61 m bongo sampler; Tucker Trawl - 4.5 m^2 Tucker trawl; IYGPT - International Young Gadoids Pelagic Trawl $\sim$ 90 m^2; the numbers listed under each gear type indicate the number of survey stations sampled each year.

Year	Ship	Dates	Bongo	Tucker	IYGPT
1991	DAW046	11 Oct–22 Oct	57	86	0
1992	TEM127	30 Sep–15 Oct	54	35	32
1993	TEM143	25 Oct–10 Nov	87	0	87
1994	TEM157/GAD247	22 Aug–3 Sep	99	0	99
1995	TEM75/TEL018	5 Sep–22 Sep	139	0	139
1996	TEM193/TEL034	19 Aug–6 Sep	147	0	147
1997	TEM210/TEL050	11 Aug–29 Sep	148	0	148

Table 2. Abundance estimates (number m^{-3}) of larval capelin based on arithmetic averages for the largest common area sampled across all years, 1991-1996, and for all non-zero stations sampled each year. Abundances are adjusted to a common date each year (see text for details). Zero Catches - the number of stations sampled within the largest common area where no larval capelin were captured.

Year-Class	Common Area	All Areas Non-Zero Catches	Null Catches Common Area
1991	218.2	233.7	10
1992	306.7	261.6	2
1993	461.1	449.7	6
1994	139.5	225.8	15
1995	327.6	483.2	12
1996	987.9	1416.2	18
1997	270.4	672.7	22

Table 3. Abundance indices for Northwest Atlantic capelin (NAFO Divisions 2J3KLNO) based on the two-ship surveys, 1994 - 1997, using the Weighted Index Area method for non-transformed data (number $10^3 m^{-3}$). The shaded areas represent the Index Areas used in the abundance estimates. SUM - summed Weighted Index Area estimates for Inshore and Offshore separately. TOTAL - summed Weighted Index Area estimates for Inshore and Offshore areas combined. See Figure 1 for location of Inshore and Offshore areas as well as the Index Area definitions. 0-Group - larval capelin; 1-Group - one year old capelin; 2-Group - two year old capelin.

	Sampling Year 1994			Sampling Year 1995			Sampling Year 1996			Sampling Year 1997		
Area	0-Group	1-Group	2-Group	0-Group	1-Group	2-Group	0-Group	1-Group	2-Group	0-Group	1-Group	2-Group
Inshore												
CB	22.72	6330.47	141.57	66.58	9.61	0.81	192.46	1.21	0.61	51.48	43.85	1.99
TB	12.88	854.32	19.15	36.70	23.25	0.42	142.76	82.39	15.66	46.42	4764.71	682.46
BB	12.57	2927.28	0.54	18.04	6.42	2.07	114.44	8579.40	662.36	41.30	4320.54	21.32
NDB	36.72	74.59	2.71	19.45	452.30	10.11	100.43	2.14	0.66	25.34	4.84	0.91
WB	41.70	23.75	0.15	15.64	3.30	6.24	154.19	0.42	1.71	56.69	2424.25	1.39
SUM	126.59	10210.4	164.12	156.41	494.88	19.65	704.28	8665.56	681.00	221.23	11558.2	708.07
Offshore												
HB												
ISN				0.86	0.30	14.06	0.00	0.20	0.20	0.00	34.23	67.62
ISS	28.47	21.40	0.00	44.13	14.88	5.17	220.78	0.42	9.17	108.64	0.90	85.89
BIBI	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.20	0.00
BIBO												
FIBI				4.15	8.75	3.41	3.61	92.39	0.98	0.00	3.13	21.52
FIBO	0.00	4.64	0.00									
NGB	9.72	4136.70	32.72	126.40	755.35	108.37	79.98	1115.11	23.99	12.43	7546.21	524.56
SA	8.80	258.55	50.54				18.29	9.48	0.53	24.23	1228.40	0.53
SGB	0.05	127.52	1.33	1.00	132.88	3.13	0.00	0.00	0.00	0.28	0.43	1.53
NOSE							0.00	199.83	0.44	0.00	51.05	1.92
TAIL												
SGBO												
WD												
SUM	38.24	4285.62	34.05	171.53	903.11	116.67	300.76	1115.53	33.16	121.35	7547.74	611.98
TOTAL	164.83	14496.0	198.17	327.94	1397.99	136.32	1005.04	9781.09	714.16	342.58	19105.9	1320.05

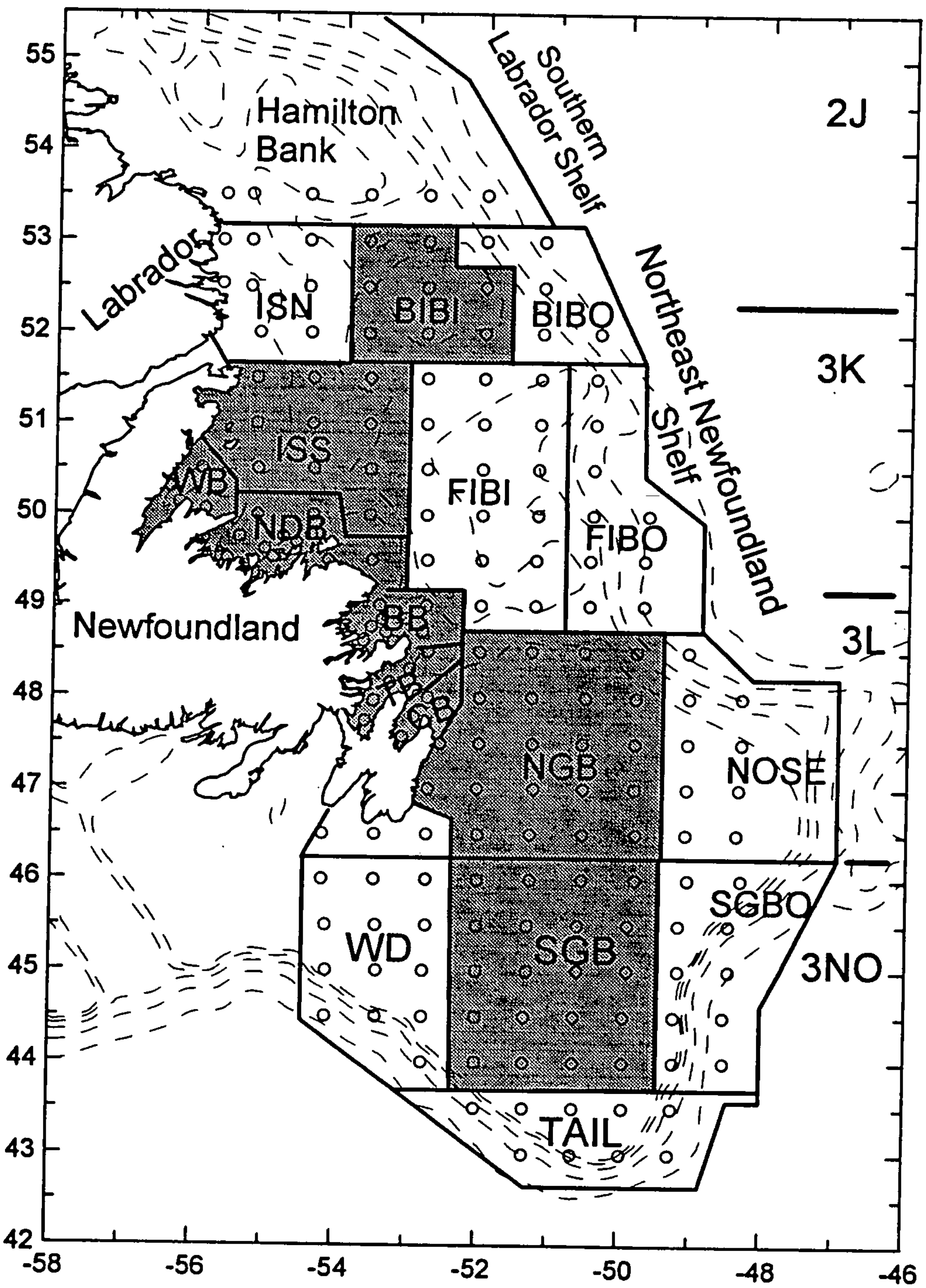

Figure 1. Pelagic Juvenile Fish Survey area, showing sampling locations (indicated by 'o') and Index Areas. The shaded areas represent the Index Areas used in the calculation of annual abundance indices. See text for explanation of areas.

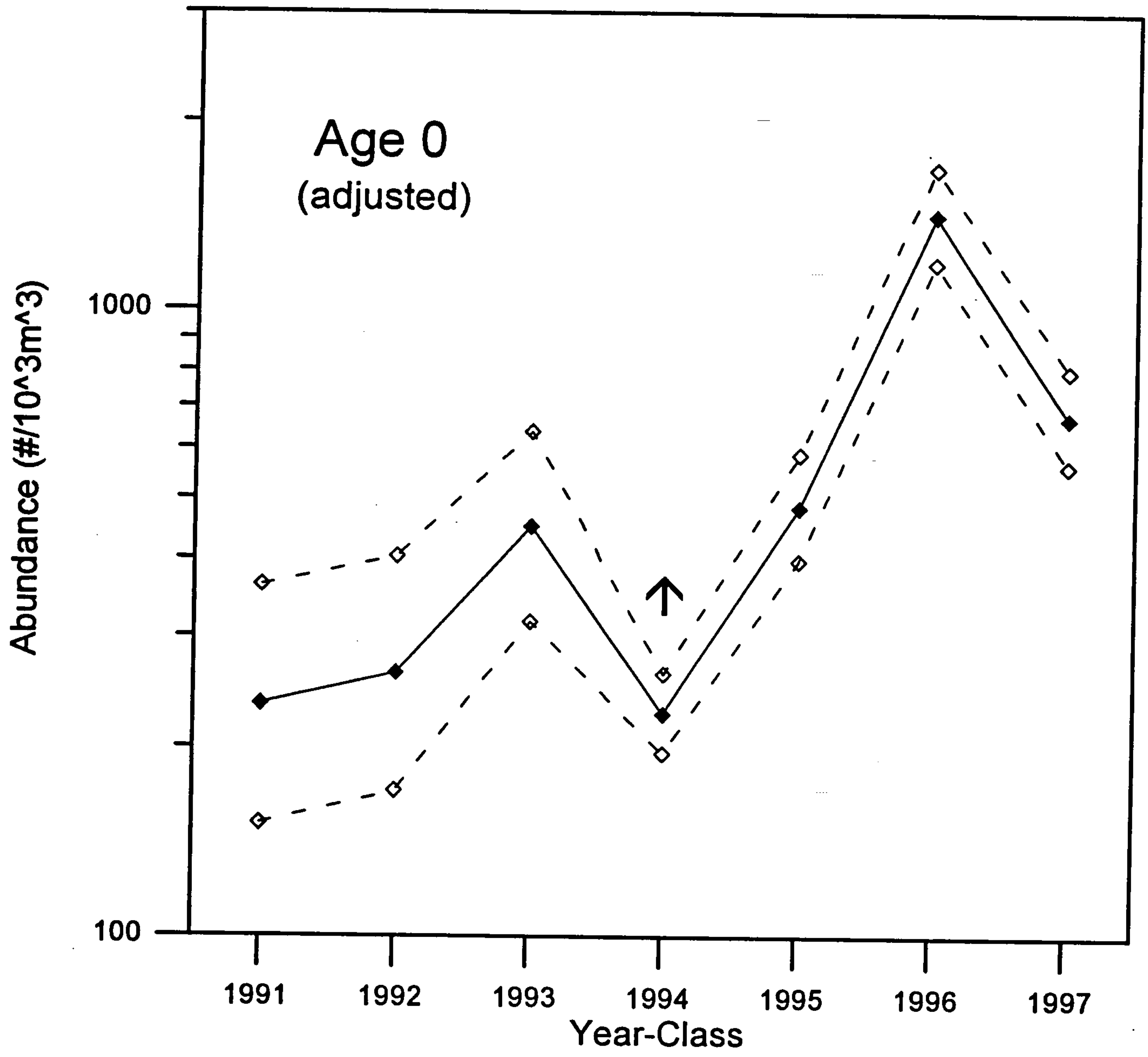

Figure 2. Larval abundance estimated each year from the means of all non-zero catches. The estimates have been adjusted for differences in survey times. The closed triangles represent the mean estimates and the open triangles represent minimum and maximum estimates of adjusted values.

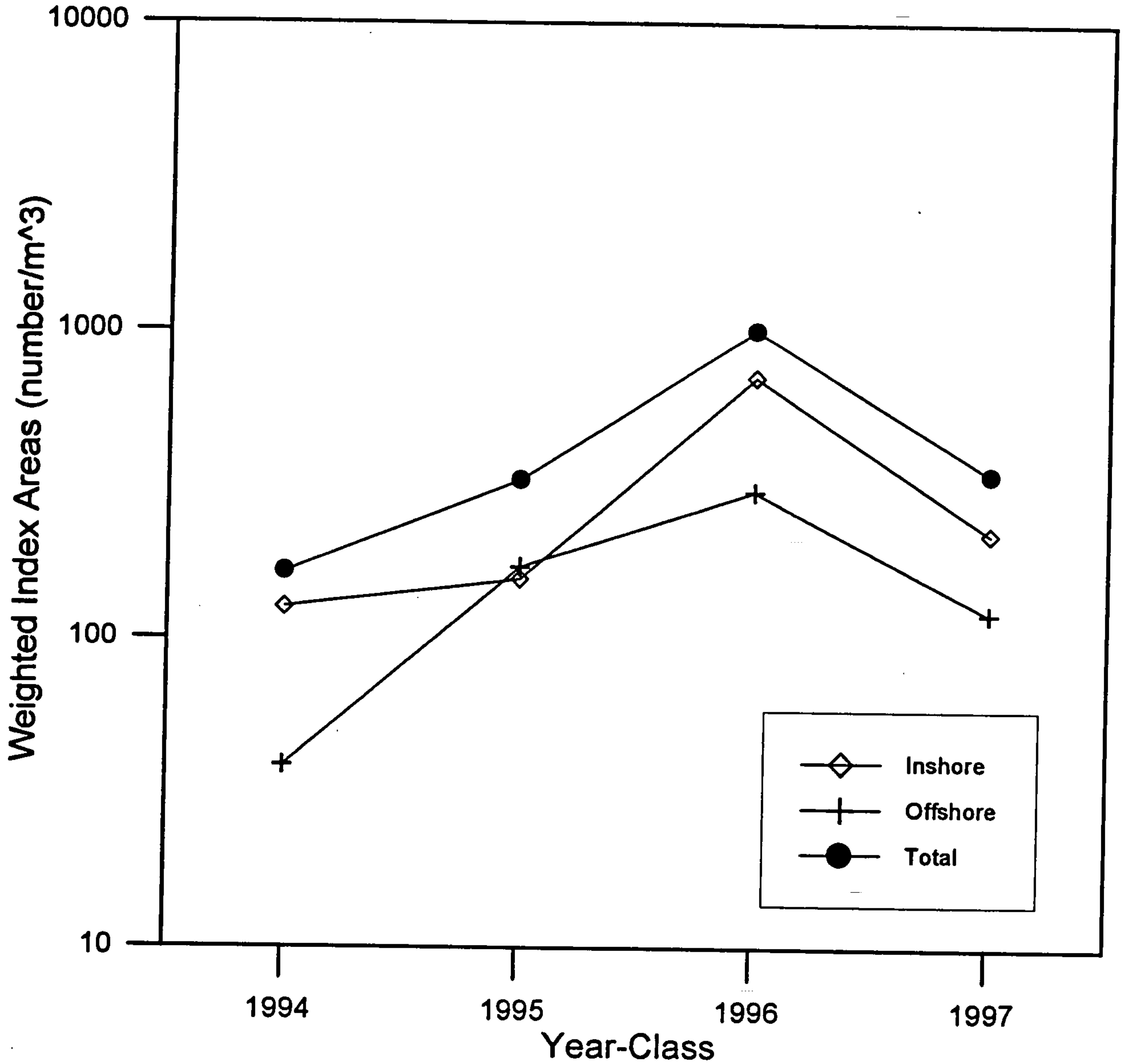

Figure 3. Year-class estimate based on the Weighted Index Area method for larval (0-group) capelin, 1994-1997 year-classes.

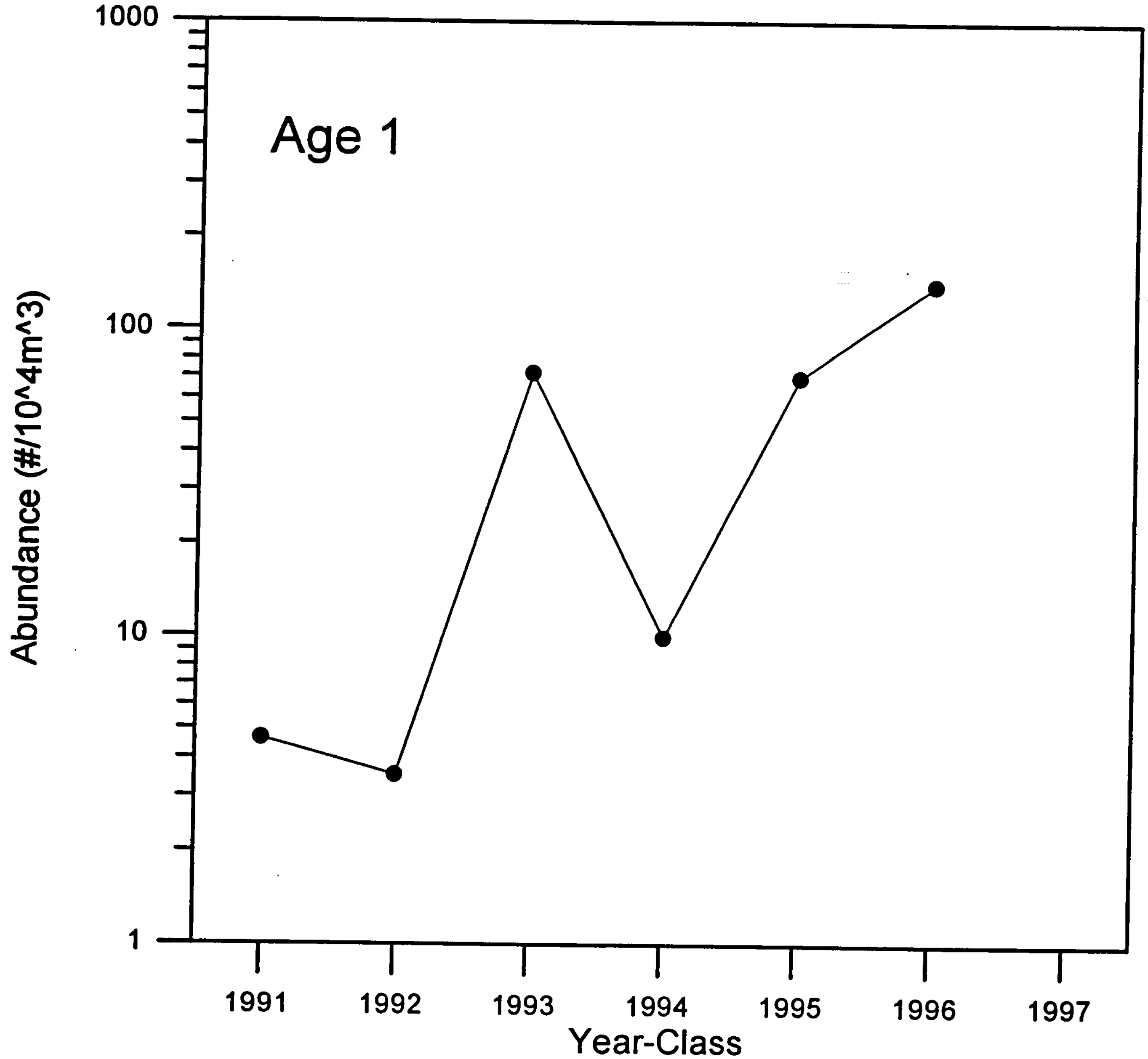

Figure 4. One year old capelin abundance estimated each year from the means of all non-zero catches.

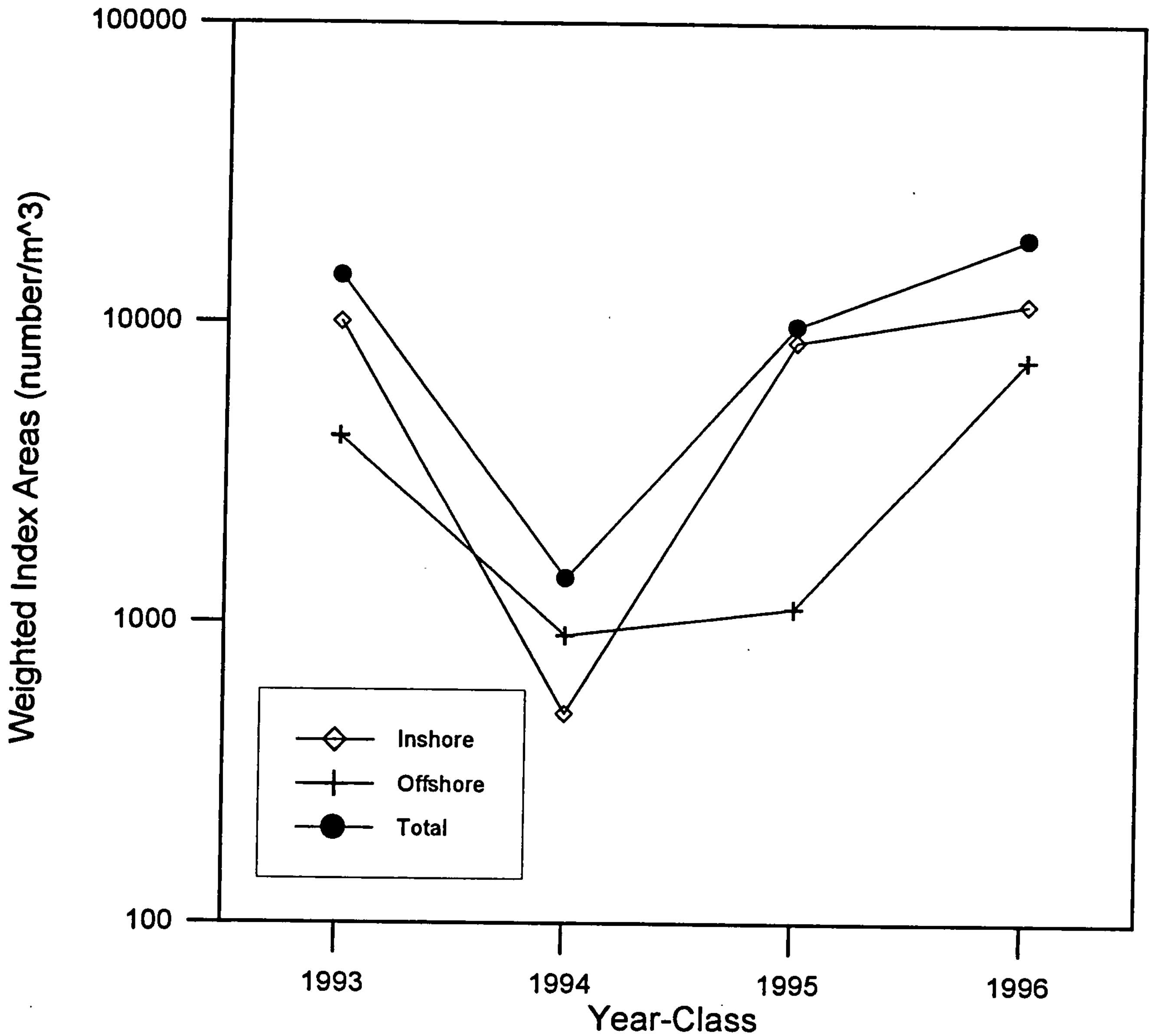

Figure 5. Year-class estimate based on the Weighted Index Area method for one year old (1-group) capelin, 1993-1996 year-classes.

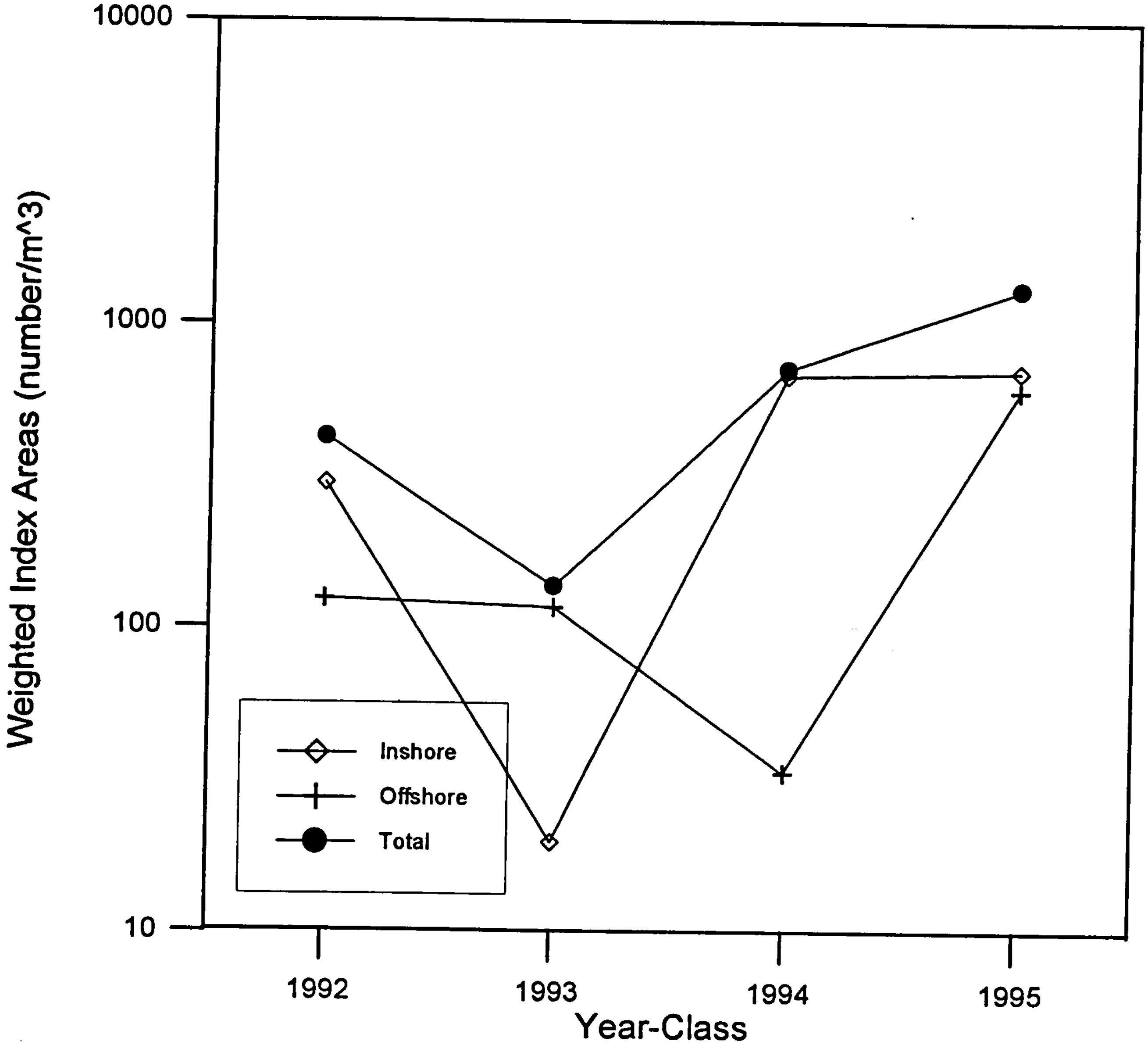

Figure 6. Year-class estimate based on the Weighted Index Area method for two year old (2+-group) capelin, 1992-1995 year-classes.

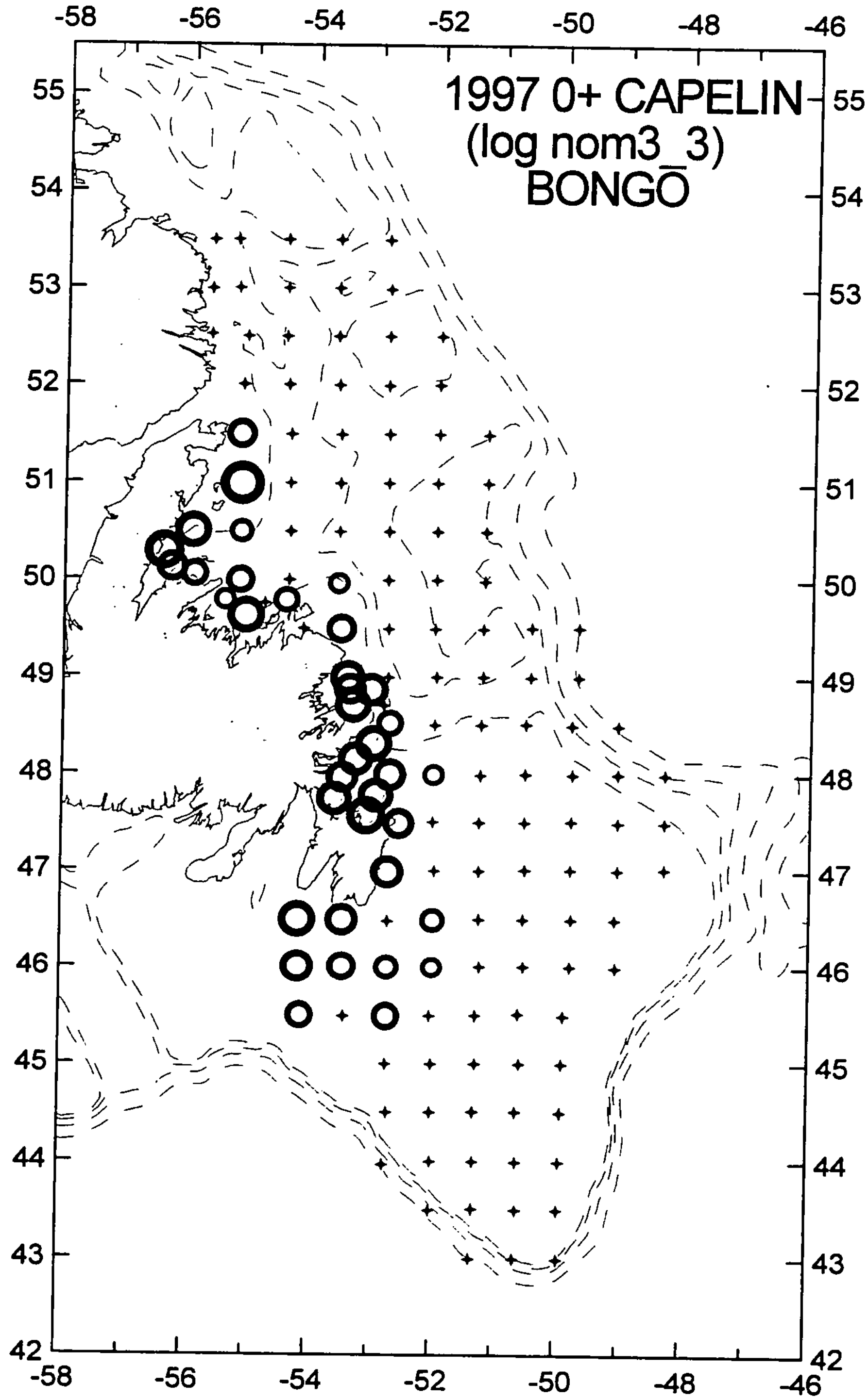

Figure 7. Distribution of larval capelin sampled by the bongo sampler in 1997. Abundance (log_10 number/m^3) at each location is represented by an expanding symbol. Crosses (+) represent stations where capelin were not caught.

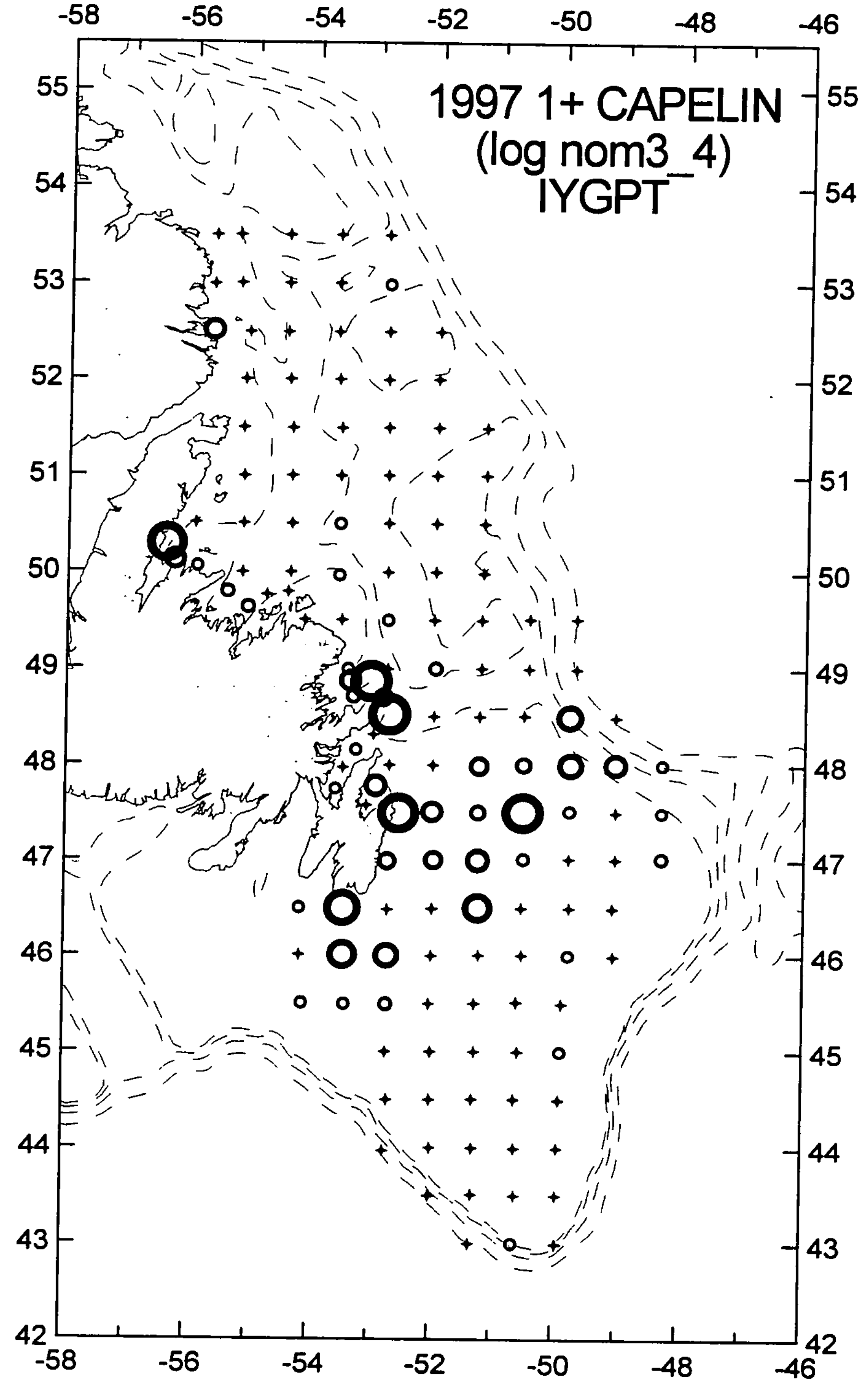

Figure 8. Distribution of one year old capelin sampled by the IYGPT trawl in 1997. Abundance (log_10 number/m^4) at each location is represented by expanding symbols. Crosses (+) indicate stations where capelin were not caught.

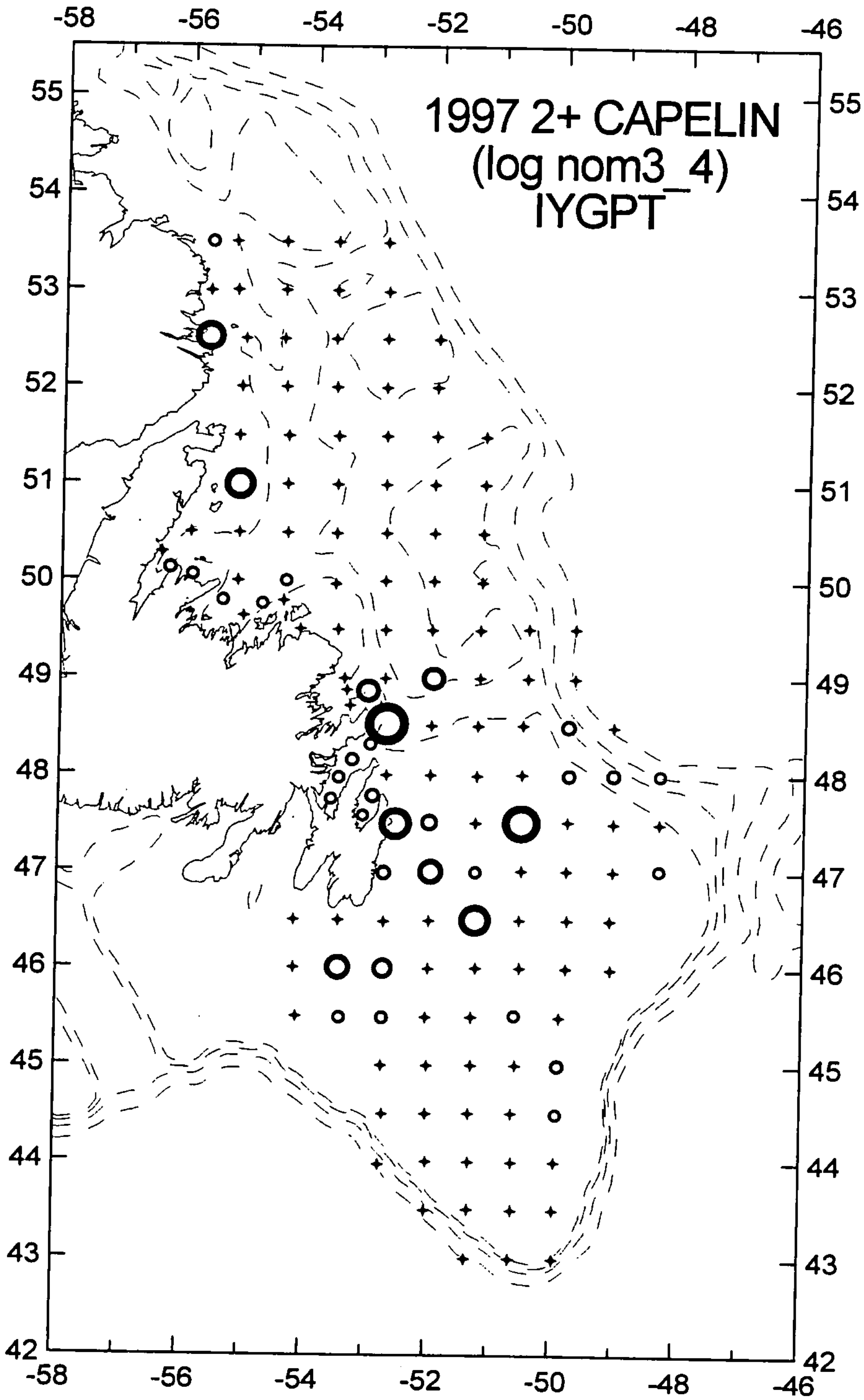

Figure 9. Distribution of two year old capelin sampled by the IYGPT trawl in 1997. Abundance (log_10 number/m^4) at each location is represented by expanding symbols. Crosses (+) represent stations where capelin were not caught.

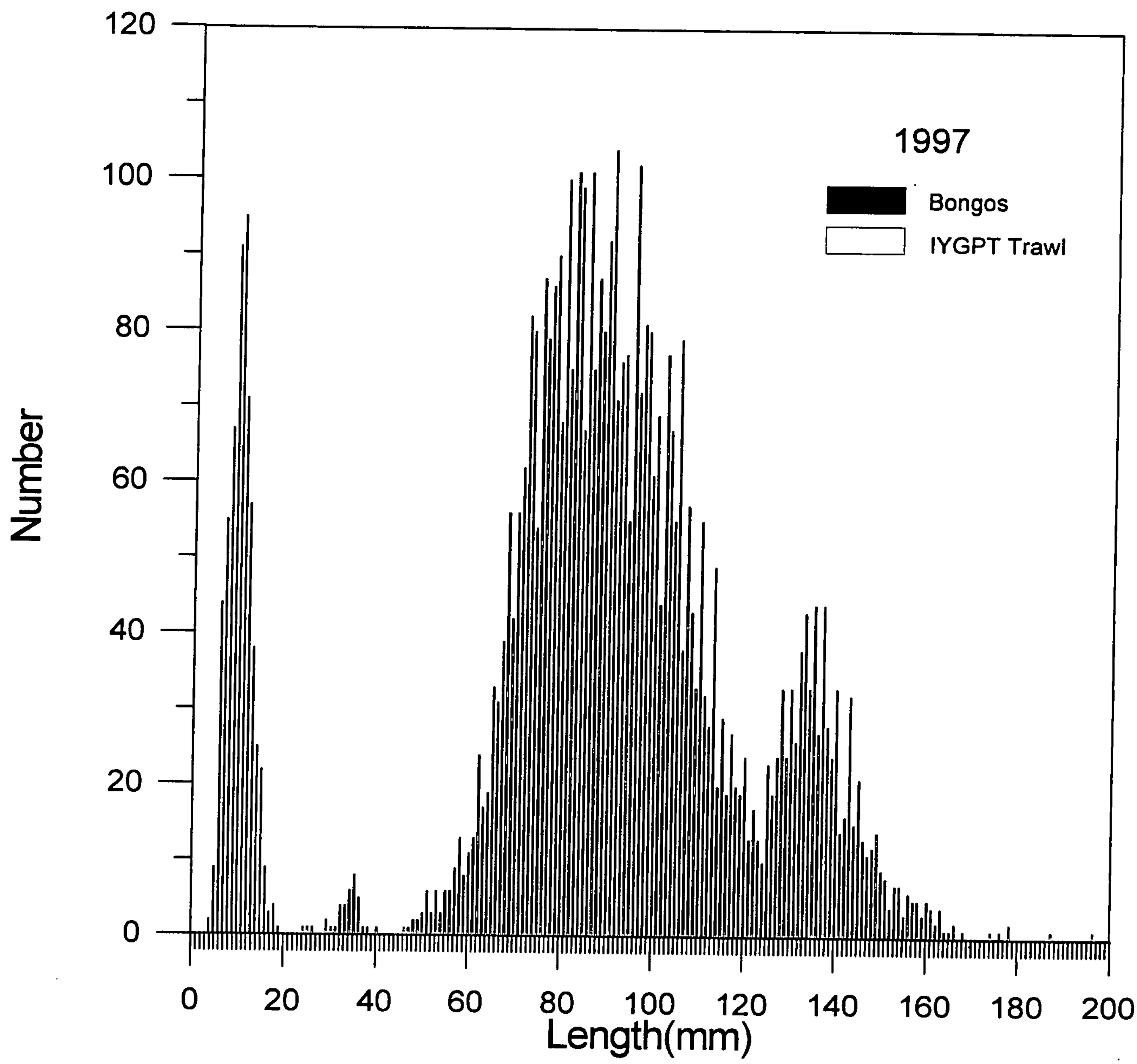

Figure 10. Length (mm) frequency distribution of capelin sampled by the bongo and IYGPT samplers in 1997.

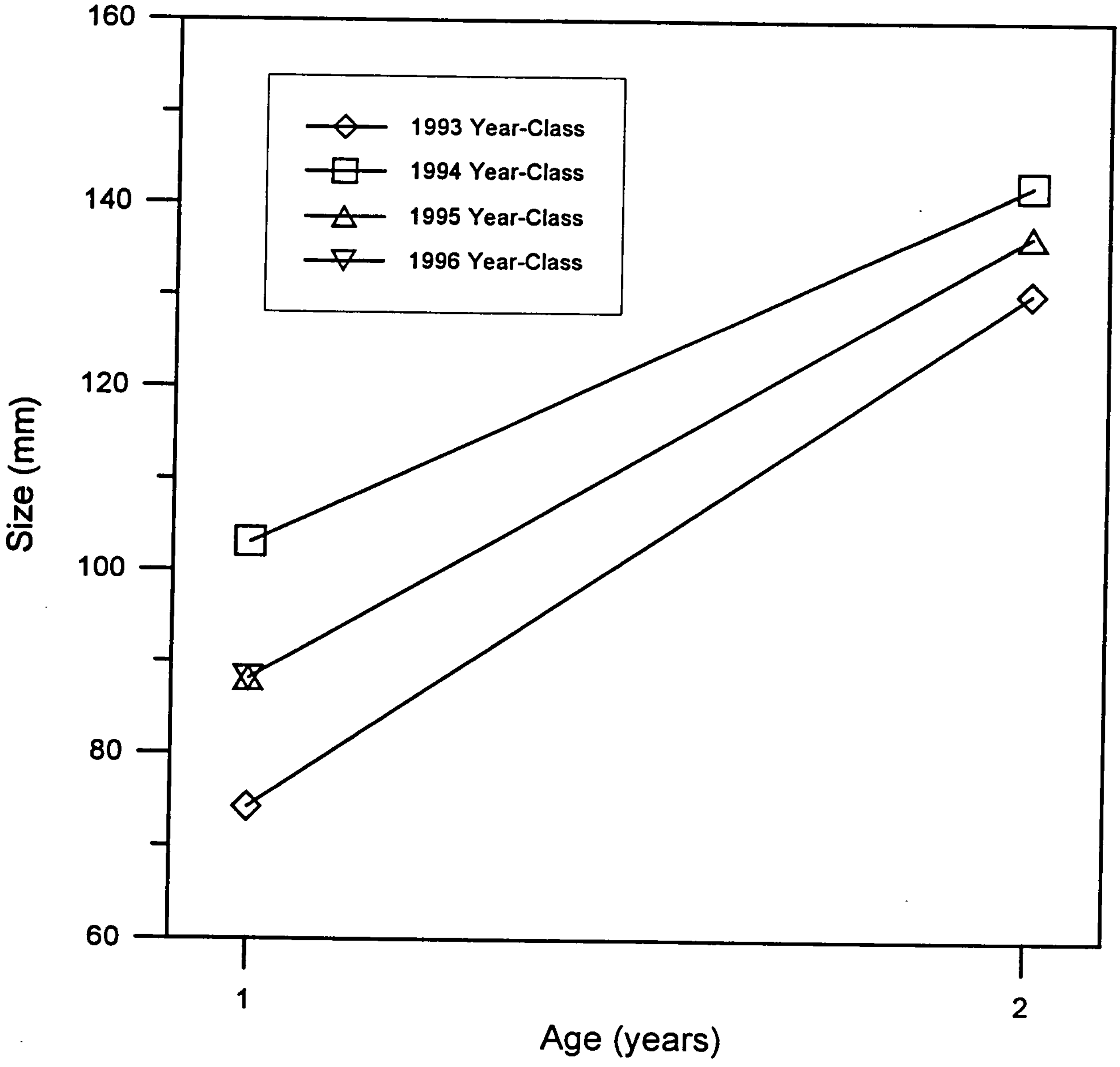

Figure 11. Mean length (mm) of one and two year old capelin for the 1993-1996 year-classes. Note that the 1996 year-class is only available for one year old capelin at this time.

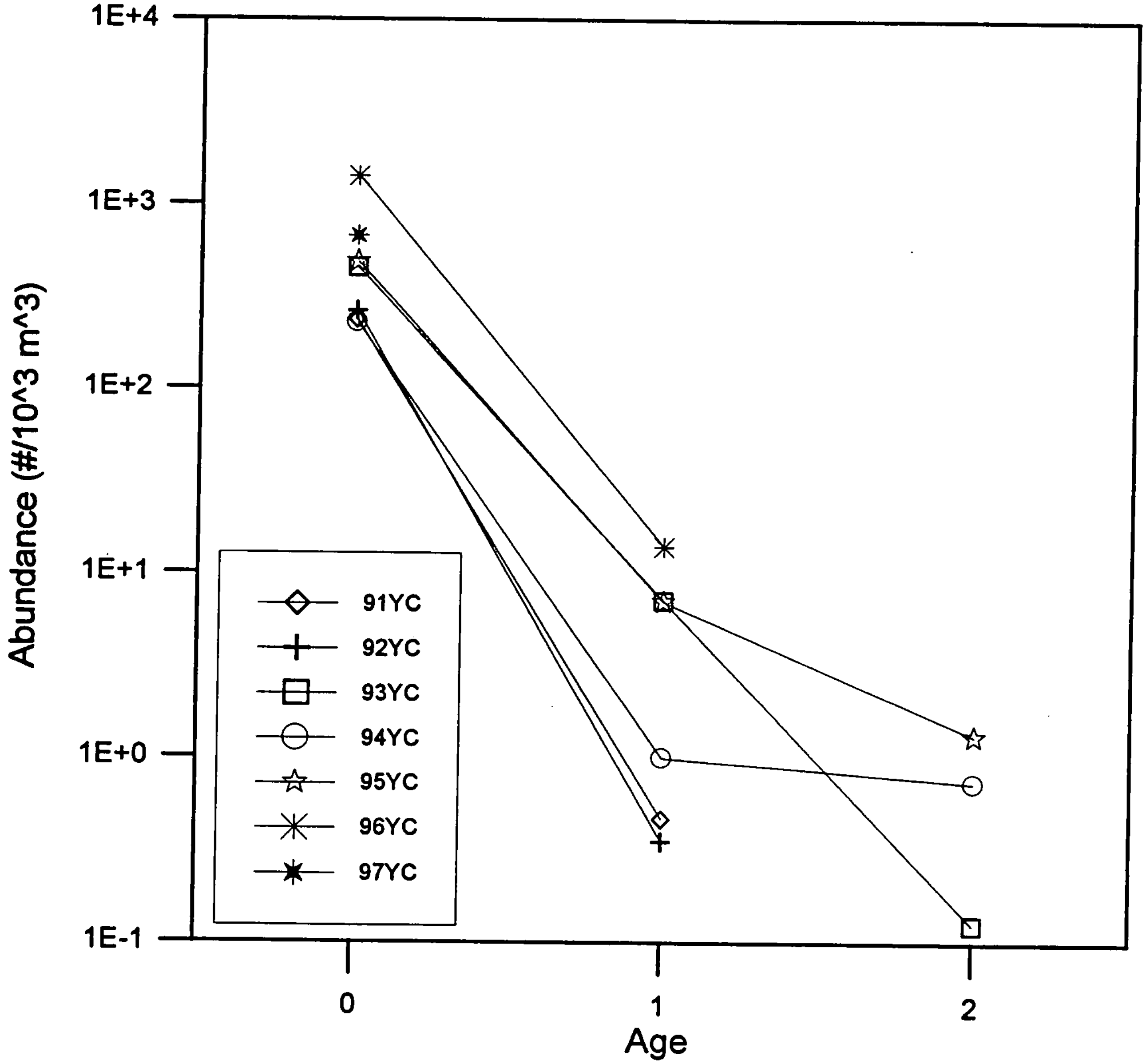

Figure 12. Abundance of capelin measured at age 0, 1 and 2+ years for the 1991-1997 year-classes. Abundance is plotted on a log10 scale.

Relative Multiplicative Trends in Biomass, Cohort Abundance, and Recruitment of Capelin (Mallotus villosus)

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Introduction

The multiplicative model provides an objective framework for analytical integration of abundance indices from a variety of sources (see Myers et al. 1993). This approach is particularly attractive for extraction of the yearclass effect because multiple estimates from several abundance indices can be integrated across a life-span (i.e. if there are five abundance indices which measure yearclass strength over four age-groups, then each cohort will have 20 estimates as a basis for its standardized measure of strength). The multiplicative approach was applied to capelin for the first time in the 1995 assessment (Anon. 1995).

For the 1998 assessment the multiplicative model was used to develop standardized indices of biomass, cohort strength, and early recruitment.

Methods

The multiplicative cohort model assumes that the various types of abundance indices to be integrated retain their relativity throughout the time series, i.e. each index remains proportional to population abundance (and therefore each other) so that gaps and missing values can be filled in through standardization into a combined index. If indices of yearclass strength show divergent trends, however, the resulting interaction creates difficulties in the interpretation of the standardized index. Divergent indices cannot be proportional to population abundance and choices were made in the past to reject some of them (see Winters 1996). Incompatibility in trends can be examined through comparison of statistical coherence in the form of regression plots and consideration of residual patterns.

The multiplicative model took the form:

$$N_{ijkt} = I.C_k.S_j{*}A_j.\in$$

where I = intercept
C_k = cohort effect
S_j = survey effect for j = 1 ... 7
A_j = age effect for i = 0 ... 5
$\in$ = residuals from fitted model
and N_{ijkt} = number at age i from survey j belonging to cohort k to what is in year t

All variables were log-transformed (i.e. multiplicative model becomes an additive model) and the estimated cohort strengths were obtained after exponentiation.

To develop standardized biomass and cohort indices for the 1998 assessment a multiplicative model (see Winters 1995) was applied to seven indices which were accepted as the basis for the 1996 assessment, i.e. catch rates from purse seines and traps, the aerial survey index, egg deposition, the Russian 2J3K CPUE, and Canadian 2J3K and 3L fall bycatch indices from offshore groundfish surveys. Where possible indices were updated to include 1997 estimates.

To develop a standardized recruitment index the multiplicative model was applied to four 0-group indices as discussed by Winters et al. (1996) and an age 1 index first included last year (Nakashima and Winters 1997).

Results and Discussion

I. Biomass and Cohort Indices

The above multiplicative model was applied to the following indices as a basis for the 1998 assessment of capelin (Appendix A, B):

1. aerial survey index 1982-97, excluding 1991;
2. egg deposition index 1990-97;
3. purse seine catch rate index 1981-93, 1996;
4. integrated trap catch rate index 1981-93;
5. groundfish 3L fall bycatch 1985-94;
6. groundfish 2J3K fall bycatch 1985-94;
7. Russian 2J3K fall commercial catch rate index 1972-91.

(a) Aerial survey index

The aerial survey in 1997 covered two transects instead of three, having dropped the outside transect of Conception Bay (Nakashima 1998). We considered adopting a new aerial survey index which would use only the two transects covered in 1997 or an index based on a multiplicative analysis of the three transects. Although not significant, $p = 0.05$, the latter was preferred because it made use of all the available data. The 1997 estimate was partitioned using the age composition derived for Bellevue Beach spawners. The index assumes that the overall trend observed in the two bays is indicative of the whole stock area.

(b) Egg deposition index

Egg deposition (stages I-II, integrated for each beach) has been estimated since 1990 for several beaches on the northeast coast (Nakashima et al. 1998). Since 1996 only Bellevue Beach has been surveyed. To estimate the number of females we divided egg deposition by the mean female weight in gm. The estimate was then partitioned for the cohort model using the female age composition from biological samples collected at Bellevue Beach. The egg deposition time series was first adopted as an index in the 1996 assessment (Winters 1996) and serves as an indirect measure of spawner escapement. A concern raised last year by Nakashima and

Winters (1997) is the reduction in the number of sampling sites from six in 1991-94 to two in 1995 and one in 1996-97. Retention of the index in the analysis assumes that observations at Bellevue Beach are indicative of the overall trend in beach spawning for Div. 3KL.

(c) Purse seine index

Data were available to estimate a purse seine catch rate (catch per fishing day) index for the 1997 mobile fishery. Details concerning the purse seine fishery in 1997 are in Nakashima and Slaney (1998). The purse seine catch rate index was not used in the standardized biomass model and in the standardized cohort model this year. The reduced effort and nature of the fishery raised concerns about evaluating the relevance of the current catch rate to those in the early part of the series.

(d) Integrated trap index

Data were unavailable from the research logbook survey to estimate an integrated trap index for 1997. The monitoring program to determine area openings and marketing constraints have changed fishing practices. Also catch rates for trap fishery were only available from a small portion of the stock area (Southern Shore, Notre Dame Bay, and White Bay) with most of the data coming from the White Bay area (Nakashima and Slaney 1998). No acceptable method was put forth to adjust the 1997 estimate and make it compatible with estimates earlier in the time series. Consequently the 1997 estimate was not used in the analysis.

(e) Offshore indices

These include the Russian 2J3K CPUE series and the 2J3K and 3L bycatch (%) of capelin in the fall 2J3KL groundfish survey (see Lilly 1995). The Russian 2J3K CPUE series ended in 1991. The two fall groundfish bycatch indices ended in 1994 when the survey fishing gear was changed from an Engels 145 high-lift trawl to a Campelen 1800 shrimp trawl.

The standardized annual biomass index is shown in Figure 2 and the statistical output in Table 2. The wide standard errors in the standardized biomass plot suggest no detectable change since at least 1987, however the general trend suggests an increase since 1994. Standardized cohort abundances are shown in Figure 3 and the statistical output is presented in Table 3. The 1995 yearclass estimates at age 2 from the both the aerial survey and the egg deposition study show this yearclass is relatively strong. However, these estimates are based on two estimates at age 2 and should be considered very preliminary. As the yearclass ages and more estimates are made the relative strength of the 1995 cohort will be better estimated.

II. Recruitment Indices

The multiplicative model was applied to the following indices to develop a composite recruitment index (Appendix C):

1. Conception Bay sediment larval index 1987, 1989-93;
2. Div. 3KL beach sediment larval index 1990-97;
3. Div. 3KL emergent larval index 1990-96;
4. Offshore Div. 3KL 0-group index 1991-97;
5. Offshore Div. 3KL age 1 index 1992-97.

(a) Inshore indices

The inshore indices were based on very early estimates of 0-group fish. Sediment larvae are newly hatched capelin larvae resident in beach sediments for 1-5 days. When larvae are released from beach sediments into the water column they are then termed emergent larvae. Sediment larvae were estimated from 15 Conception Bay beaches in 1987 and 1989-93 (Winters et al. 1996) and from 1-6 beaches along the northeast coast since 1990 (Nakashima et al 1998). Emergent larvae were also enumerated at northeast coast beaches from 1990-96 (Nakashima and Winters 1997) but not in 1997. Both beach indices are derived as normalized annual estimates.

(b) Offshore indices

An 0-group index and an age 1 index from annual offshore surveys conducted in August-September since 1991 (Anderson and Dalley 1998) were incorporated into the multiplicative recruitment model. 0-group capelin are collected by bongos and age 1 capelin are collected using an IGYPT trawl at the same stations during the offshore O-group survey (Anderson and Dalley 1998).

The 0-group indices were evaluated and used first as a recruitment index in 1996 (Winters et al 1996). Because of the short time series for all the indices this analysis was kept separate from the cohort model. The age 1 offshore series was incorporated for the first time in the multiplicative analysis at last year's assessment (Nakashima and Winters 1997). The standardized annual recruitment index is shown in Figure 3 and the statistical output is in Table 4. Standard errors overlap between adjacent data points.

Summary

The relative biomass trend from the multiplicative analysis suggesting that abundance in recent years (Fig. 1) is high relative to the early 1980s is different from the observation by fixed gear fishermen (Nakashima and Clark 1998) that capelin abundance in the 1990s is lower than the 1980s.

The standardized recruitment index (Fig. 2) appears to predict cohort strength for the 1987 and 1989 to 1993 yearclasses reasonably well (Fig. 3). The recruitment index depicts the 1994 cohort lower than the 1993, whereas the cohort abundance index shows the 1994 yearclass larger than the 1993. The 1994 estimate in the cohort analysis is based on the presence of mature age 2 in 1996 and age 3 fish in 1997. With estimates of the 1994 yearclass at age 4 in 1998 we will be in a better position to evaluate the relative strength of this yearclass. However, understanding the basis of the discrepancy may take longer. Based on the multiplicative analysis, the 1995 yearclass is relatively strong and will dominate the 1998 spawning biomass (Fig. 2, 3). The 1996 yearclass is relatively strong in the recruitment series (Fig. 3). Depending on what fraction matures, age 2 capelin of the 1996 yearclass could be relatively abundant in 1998.

Besides the problems and assumptions associated with each of the indices in this analysis, there are other assumptions which have not been evaluated but may be important to interpreting the model results. All indices are given equal weight. Constant mortality rates and maturity rates from year to year are implied, however departures from this and their effects are unknown. In the cohort model each index does not use an independently derived age composition. The biomass model assumes the age composition of the stock is the same in all years. The results of the multiplicative analysis must be considered with caution in light of these and other assumptions whose effects have not been evaluated.

References

Anon. 1995. Capelin in SA2 + Div. 3KL. DFO Atl. Fish. Res. Doc. 95/70.

Anderson, J. and E. Dalley. 1998. Year-class strength of Northwest Capelin (2J3KLNO) estimated from pelagic juvenile fish surveys in the Newfoundland Region, 1991-97. pp. 114-133. In: Anon. Capelin in SA2 + Div. 3KL. CSAS Res. Doc. 98/63.

Lilly, G. R. 1995. Bycatches of capelin during autumn bottom trawl surveys in Divisions 2J3KLNO with emphasis on 1994. pp. 110-132. In: Anon. Capelin in SA2 + Div. 3KL. DFO Atl. Fish. Res. Doc. 95/70.

Myers, R. A., K. F. Drinkwater, N. J. Barrowman, and J. W. Baird. 1993. Salinity and recruitment of Atlantic cod (Gadus morhua) in the Newfoundland region. Can. J. Fish. Aquat. Sci. 50: 1599-1609.

Nakashima, B. S. 1998. Results of the 1997 aerial survey of capelin (Mallotus villosus) schools. pp. 50-61. In: Anon. Capelin in SA2 + Div. 3KL. CSAS Res. Doc. 98/63.

Nakashima, B. S. and M. C. Clark. 1998. Results of a telephone survey of 1997 fixed gear cpaelin licence holders. pp. 23-37. In: Anon. Capelin in SA2 + Div. 3KL. CSAS Res. Doc. 98/63.

Nakashima, B. S. and B. W. Slaney. 1998. The 1997 inshore capelin (Mallotus villosus) fishery in NAFO Div. 3KL. pp. 38-49. In: Anon. Capelin in SA2 + Div. 3KL. CSAS Res. Doc. 98/63.

Nakashima, B. S. and G. H. Winters. 1997. Multiplicative trends of biomass, cohort abundance, and recruitment of capelin (Mallotus villosus). pp. 168-188. In: Anon. Capelin in SA2 + Div. 3KL. CSAS Res. Doc. 97/29.

Nakashima, B. S., G. H. Winters, and B. W. Slaney. 1998. Spawning, egg densities, and pre-emergent larvae from Bellevue Beach, Trinity Bay in 1997. pp. 62-71. In: Anon. Capelin in SA2 + Div. 3KL. CSAS Res. Doc. 98/63.

Winters, G. H. 1995. A multiplicative approach to capelin abundance indices. pp. 270-297. In: Anon. Capelin in SA2 + Div. 3KL. DFO Atl. Fish. Res. Doc. 95/70.

1996. Further considerations of the age-structured multiplicative abundance model. pp. 81-108. In: Anon. Capelin in SA2 + Div. 3KL. DFO Atl. Fish. Res. Doc. 96/90.

Winters, G. H., B. S. Nakashima, J. T. Anderson, and E. L. Dalley. 1996. The case for 0-group measures of capelin recruitment. pp. 109-126. In: Anon. Capelin in SA2 + Div. 3KL. DFO Atl. Fish. Res. Doc. 96/90.

Table 1. Statistical output of the multiplicative analysis used to estimate a standardized aerial survey index. Reference categories were year 1997 and the inside transect of Conception Bay.

Source	DF	Sum of squares	Mean square	F-value	Pr > F
Model	16	16.24	1.01	1.86	0.08
Error	27	14.74	0.55		
Corrected total	43	30.98			
	Root MSE		0.74		
	Dep. mean		4.79		
	C.V.		15.41		
	R-square		0.52		

Table 2. Statistical output of the multiplicative analysis used to estimate standardized annual biomass. Reference categories were year 1997 and the egg deposition index.

Source	DF	Sum of squares	Mean square	F-value	Pr > F
Model	29	48.71	1.68	13.11	0.0001
Error	68	8.72	0.13		
Corrected total	97	57.43			
	Root MSE		0.36		
	Dep. mean		4.22		
	C.V.		8.48		
	R-square		0.85		

Table 3. Statistical output of the multiplicative analysis used to estimate standardized yearclass strengths. Reference categories were yearclass 1995 and age 5 of the trap catch rates.

Source	DF	Sum of squares	Mean square	F-value	Pr > F
Model	53	1097.70	20.71	29.82	0.0001
Error	269	186.86	0.69		
Corrected total	322	1284.56			
	Root MSE		0.83		
	Dep. mean		4.90		
	C.V.		17.02		
	R-square		0.85		

Table 4. Statistical output of the multiplicative model used to estimate a standardized recruitment index. Reference categories were year 1997 and the offshore age I survey.

Source	DF	Sum of squares	Mean square	F-value	Pr > F
Model	13	84.04	6.46	11.87	0.0001
Error	20	10.89	0.54		
Corrected total	33	94.93			
	Root MSE		0.74		
	Dep. mean		5.59		
	C.V.		13.21		
	R-square		0.89		

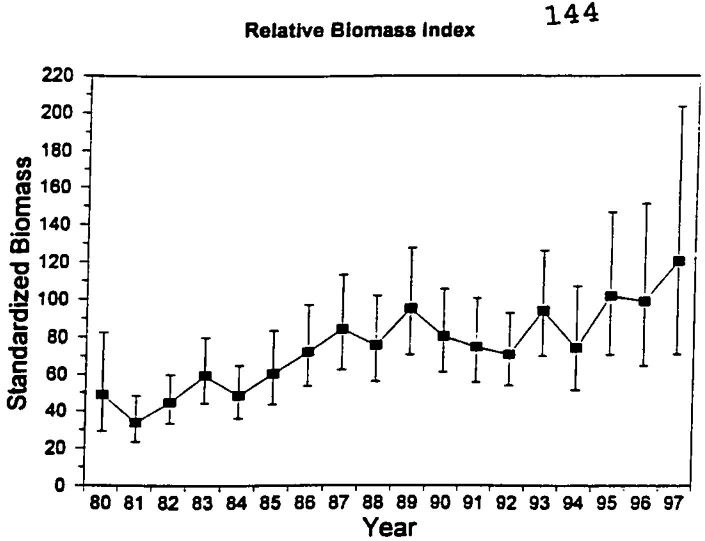

Fig. 1. Standardized estimates of annual biomass of capelin with 2 standard errors.

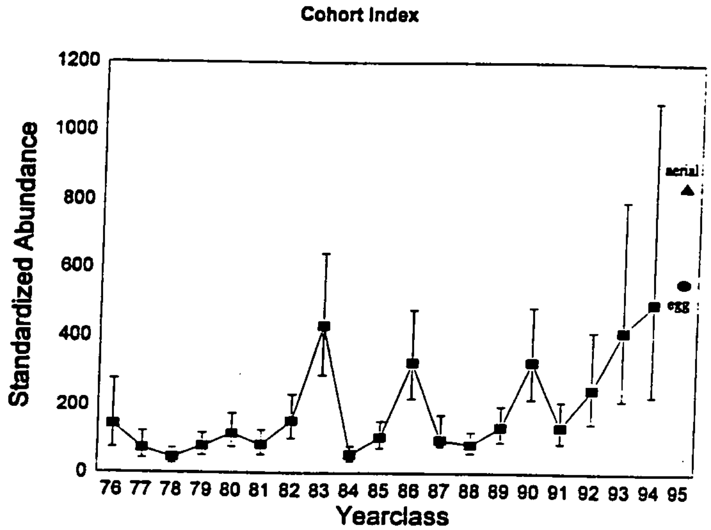

Fig. 2. Standardized estimates of cohort abundance of capelin with 2 standard errors. The individual estimates of the 1996 cohort from the aerial survey and the egg deposition study are depicted as shown.

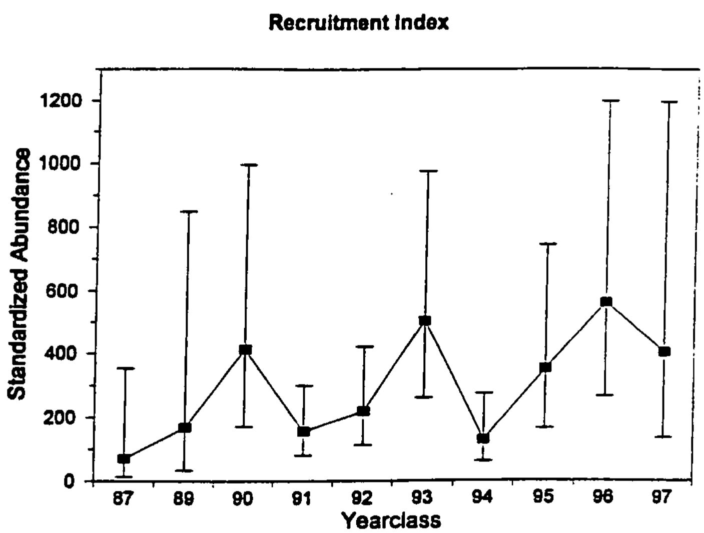

Fig. 3. Standardized estimates of recruitment abundance of immature capelin with 2 standard errors.

Appendix A. Indices used in the standardized biomass model.

Year	Russian 2J3KL fall CPUE	Groundfish 2J3K fall bycatch	Groundfish 3L fall bycatch	Purse seine 3KL	Integ. trap 3KL	Aerial survey 3L	Egg deposition 3KL
1973	28						
1974	33						
1975	46						
1976	65						
1977	53						
1978	41						
1979	23						
1980	13	34					
1981	46	19		94	75		
1982	37	26	14	163	70	42	
1983	32	34	29	176	64	107	
1984	53	25	31	143	60	60	
1985	42	27	-	164	89	89	
1986	70	44	35	188	149	78	
1987	61	26	27	176	155	263	
1988	77	35	27	200	121	134	
1989	60	37	46	217	148	172	
1990	61	49	40	215	167	125	41
1991	13	35	21	150	153	-	101
1992		43	23	208	132	255	100
1993		53	52	162	146	103	164
1994		47	53	-		122	38
1995		47	39	-		209	106
1996				171		218	109
1997						206	118

Appendix B. Indices used in the standardized cohort abundance model.

	Year	Age 0	1	2	3	4	5
Aerial survey index							
	1982	-	-	55	939	125	36
	1983	-	-	44	1783	1095	47
	1984	-	-	32	712	885	79
	1985	-	-	354	1775	582	143
	1986	-	-	23	1438	803	56
	1987	-	-	332	1456	4521	339
	1988	-	-	515	2247	527	500
	1989	-	-	24	3637	1011	52
	1990	-	-	54	1524	1987	54
	1991	-	-	-	-	-	-
	1992	-	-	505	2660	4798	887
	1993	-	-	226	2803	1013	130
	1994	-	-	625	2678	1480	328
	1995	-	-	1297	5227	2143	913
	1996	-	-	768	5514	2074	137
	1997	-	-	944	4662	3041	820
Egg deposition index (normalized)							
	1990	-	-	79	821	696	53
	1991	-	-	207	1620	1772	687
	1992	-	-	482	1889	2561	476
	1993	-	-	877	6609	1717	286
	1994	-	-	347	1019	520	162
	1995	-	-	1607	3955	1046	512
	1996	-	-	812	3504	1246	120
	1997	-	-	943	3213	1704	605
Purse seine catch rate index							
	1981	-	-	1	123	124	112
	1982	-	-	3	395	58	18
	1983	-	-	14	341	210	9
	1984	-	-	4	158	248	20
	1985	-	-	64	386	143	54
	1986	-	-	1	441	215	16
	1987	-	-	14	120	643	47
	1988	-	-	42	358	107	111
	1989	-	-	3	510	163	8
	1990	-	-	10	304	413	10
	1991	-	-	50	315	219	36
	1992	-	-	150	705	89	5
	1993	-	-	42	590	42	1
	1994	-	-	-	-	-	-
	1995	-	-	-	-	-	-
	1996	-	-	217	500	35	1

Appendix B. Continued ...

	Year	Age 0	1	2	3	4	5
Trap catch rate index (integrated)							
	1981	-	-	1	941	943	831
	1982	-	-	16	1908	237	95
	1983	-	-	67	1202	719	26
	1984	-	-	30	766	1095	93
	1985	-	-	334	1998	731	245
	1986	-	-	10	3013	1674	155
	1987	-	-	124	697	3216	243
	1988	-	-	323	2271	634	615
	1989	-	-	38	3447	1083	122
	1990	-	-	55	2198	3200	83
	1991	-	-	723	3180	2248	365
	1992	-	-	730	4056	648	55
	1993	-	-	665	4902	413	12
Groundfish 3L fall bycatch index							
	1985	-	44	220	28	-	-
	1986	-	-	-	-	-	-
	1987	-	-	-	-	-	-
	1988	-	45	261	5	-	-
	1989	-	57	140	71	-	-
	1990	-	-	-	-	-	-
	1991	-	352	56	12	-	-
	1992	-	99	466	2	-	-
	1993	-	154	125	66	-	-
Groundfish 2J3K fall bycatch index							
	1980	-	-	34	31	7	-
	1981	-	-	77	26	5	-
	1982	-	-	31	97	6	-
	1983	-	-	-	-	-	-
	1984	-	-	-	-	-	-
	1985	-	-	-	-	-	-
	1986	-	-	-	-	-	-
	1987	-	-	39	23	41	-
	1988	-	-	131	37	2	-
	1989	-	-	-	-	-	-
	1990	-	-	-	-	-	-
	1991	-	-	166	49	2	-
	1992	-	-	248	29	1	-
	1993	-	-	128	87	9	-
	1994	-	-	173	20	3	-

Appendix B. Continued ...

Year	Age 0	1	2	3	4	5
Russian 2J3K fall commercial catch rate index						
1972	-	-	33	181	59	8
1973	-	-	83	99	132	16
1974	-	-	92	223	80	56
1975	-	-	400	179	53	12
1976	-	-	46	437	36	5
1977	-	-	12	124	248	26
1978	-	-	38	71	97	14
1979	-	-	105	14	3	4
1980	-	-	206	185	49	7
1981	-	-	248	49	15	13
1982	-	-	247	61	5	1
1983	-	-	215	256	39	3
1984	-	-	262	77	39	5
1985	-	-	464	200	19	10
1986	-	-	128	419	50	4
1987	-	-	340	150	248	27
1988	-	-	430	112	14	33
1989	-	-	248	332	26	2
1990	-	-	208	281	95	3
1991	-	-	104	18	0	0

Appendix C. Indices used in the standardized recruitment model.

		Age	
	Year	0	1
Conception Bay sediment larval index	1987	61	-
	1988	-	-
	1989	147	-
	1990	285	-
	1991	99	-
	1992	340	-
	1993	432	-
NCSP sediment larval index (normalized)	1990	134	-
	1991	94	-
	1992	124	-
	1993	152	-
	1994	32	-
	1995	80	-
	1996	78	-
	1997	110	
NCSP emergent larval index (normalized)	1990	151	-
	1991	89	-
	1992	126	-
	1993	152	-
	1994	43	-
	1995	63	-
	1996	67	-
	1997	110	-
Offshore 0-group index	1991	2337	-
	1992	2616	-
	1993	4497	-
	1994	2258	-
	1995	4832	-
	1996	15578	-
	1997	6727	-
Offshore age I index	1992	-	46
	1993	-	35
	1994	-	723
	1995	-	99
	1996	-	700
	1997	-	1399

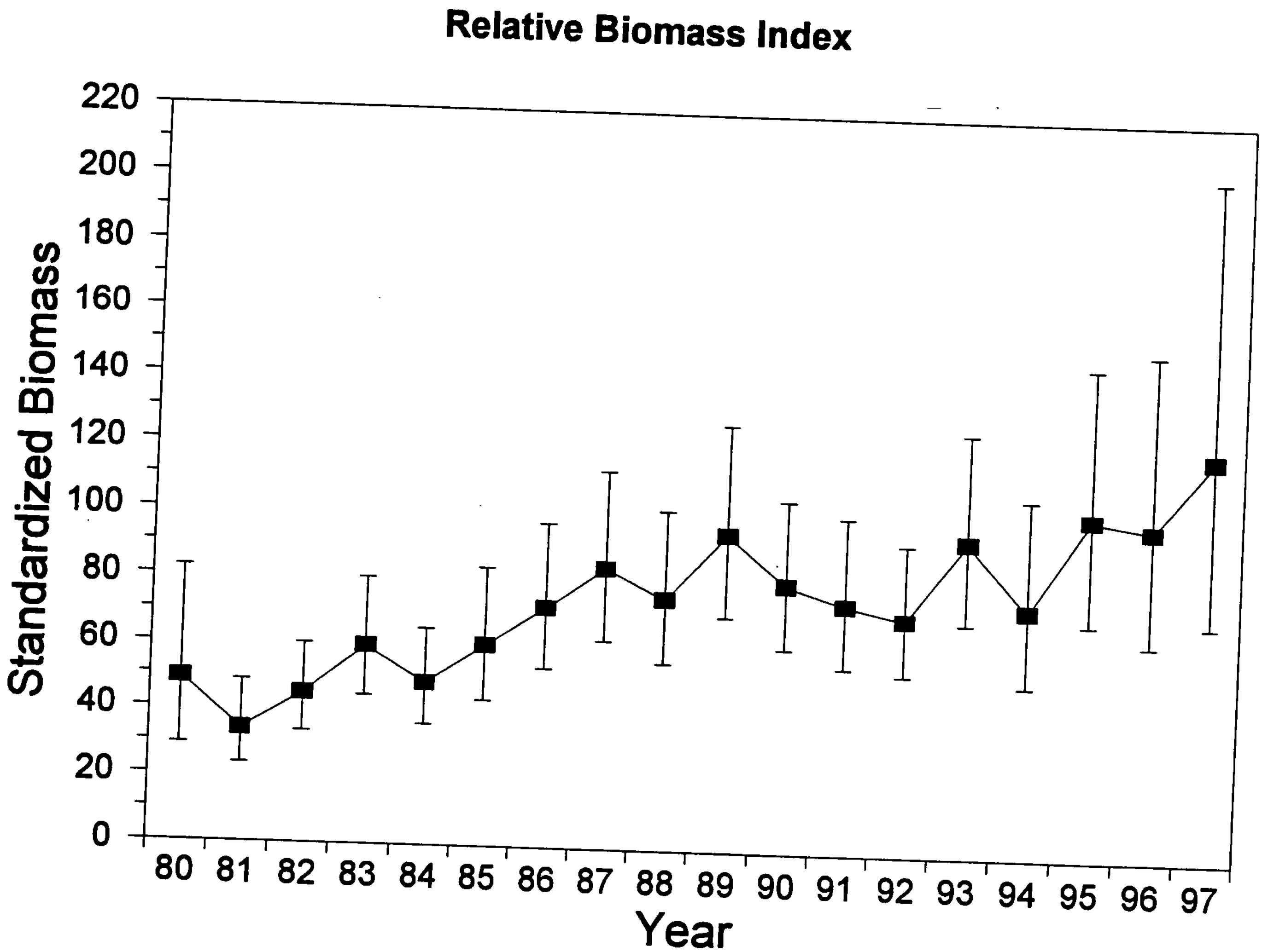

Fig. 1. Standardized estimates of annual biomass of capelin with 2 standard errors.

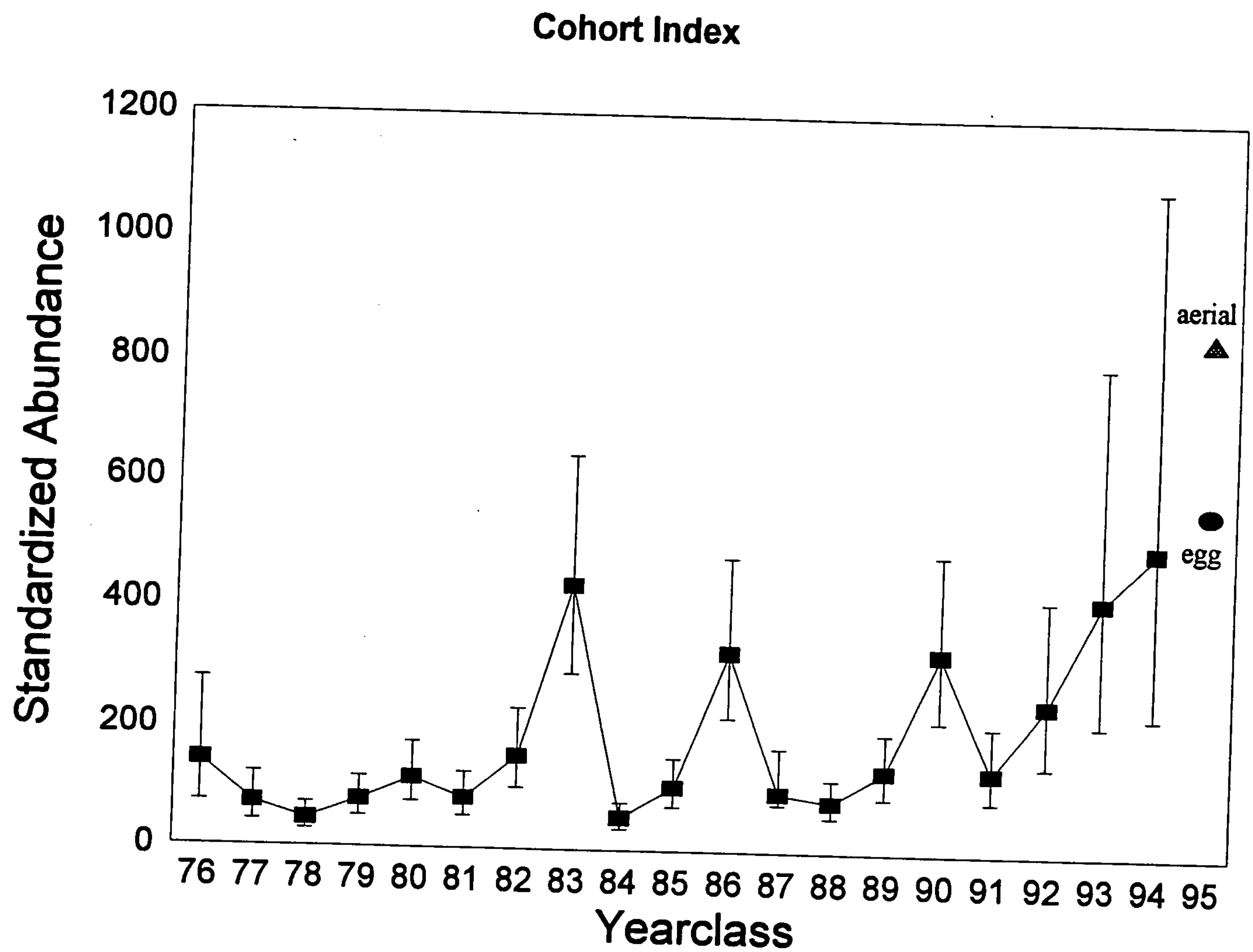

Fig. 2. Standardized estimates of cohort abundance of capelin with 2 standard errors. The individual estimates of the 1996 cohort from the aerial survey and the egg deposition study are depicted as shown.

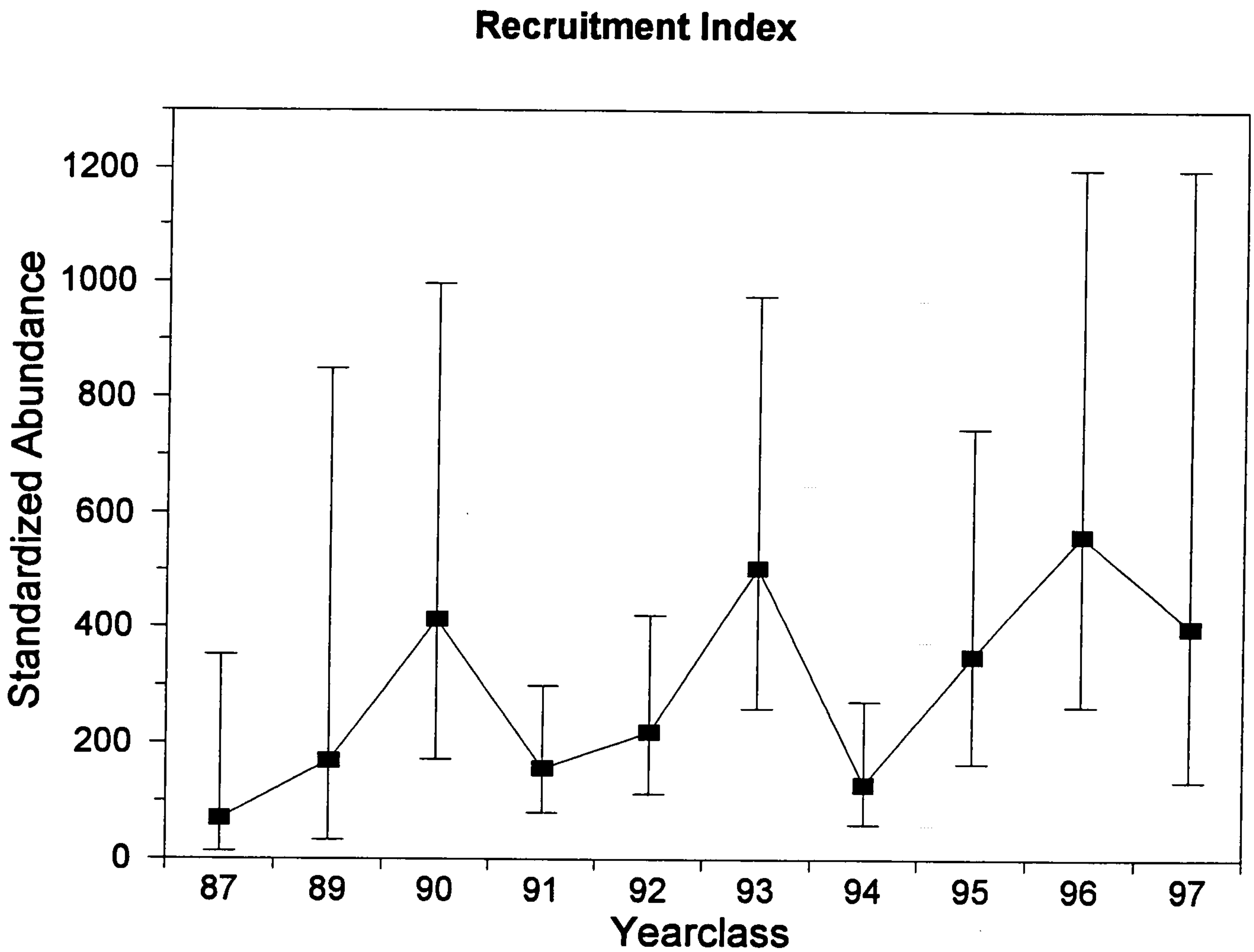

Fig. 3. Standardized estimates of recruitment abundance of immature capelin with 2 standard errors.