Department of Fisheries and Oceans
Canadian Stock Assessment Secretariat
Research Document 97/29

Ministère des pêches et océans
Secrétariat canadien pour l'évaluation des stocks
Document de recherche 97/29

Not to be cited without
permission of the authors[1]

Ne pas citer sans
autorisation des auteurs[1]

Capelin in SA2 + Div. 3KL

Science Branch
Department of Fisheries and Oceans
P. O. Box 5667
St. John's NF A1C 5X1

[1] This series documents the scientific basis for the evaluation of fisheries resources in Canada. As such, it addresses the issues of the day in the time frames required and the documents it contains are not intended as definitive statements on the subjects addressed but rather as progress reports on ongoing investigations.

Research documents are produced in the official language in which they are provided to the Secretariat.

[1] La présente série documente les bases scientifiques des évaluations des ressources halieutiques du Canada. Elle traite des problèmes courants selon les échéanciers dictés. Les documents qu'elle contient ne doivent pas être considérés comme des énoncés définitifs sur les sujets traités, mais plutôt comme des rapports d'étape sur les études en cours.

Les documents de recherche sont publiés dans la langue officielle utilisée dans le manuscrit envoyé au secrétariat.

Table of Contents

Abstract

This document contains a number of discrete research results which were considered during the 1997 assessment of capelin in SA2 + Div. 3KL. These results are arranged in ten chapters. In addition, a meeting report, cross-referenced by chapter, is provided. The data available included the results of studies on inshore capelin, acoustic survey results, bycatches of capelin in groundfish surveys, analyses of capelin lengths, repeat spawning and a synthesis paper.

Résumé

Le présent document contient divers résultats de recherches distinctes qui ont été examinés au moment de l'évaluation de 1997 du capelan de SA2 et des divisions 3KL. Les résultats sont présentés sous forme de dix chapitres. On y trouve aussi un rapport des rencontres avec renvois aux chapitres. Les données présentées ont trait aux résultats des études du capelan côtier et des relevés acoustiques, aux prises accessoires de capelans au moment des relevés du poisson de fond, aux analyses de longueur, aux géniteurs ayant déjà frayé et à un document de synthèse.

Capelin in SA2 + Div. 3KL

1) Introduction

A capelin assessment committee met several times during March and April 1997 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 the 1980's were restricted by quota and ranged between 5,000 to 31,000 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 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. Monitoring programmes were in place to open the fishery when fish conformed to criteria (other than size) defined in the management plan. Preliminary landings in SA2 + Div. 3K were 7,600 t compared to the quota of 9,585 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 (Fig. 1). 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 the monitoring programme in 1996 were similar to that in Div. 3K. Preliminary landings in Div. 3L were 15,900 t compared to a quota of 18,285 t.

Area	1990	1991	1992	1993	1994	1995	1996
SA2 + Div. 3K							
Offshore							
TAC	71	57	0	0	0	0	-
Nominal Catch	57	0.5	0	0	0	0	-
Inshore							
TAC	29	29	17	11.4	11.5	11.5,	9.7
Nominal Catch	33	20	18	13a	<.1a	.1a	8a
Div. 3L							
Inshore							
TAC	56	56	19.3	21	21	22	18.3
Nominal Catch	48	22	3	23a	1a	1a	16a
SA2 + Div. 3KL							
Total nominal catch	138	42.5	21	36	1	1	24

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 fishers. 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.

The original survey was modified slightly in both 1995 and 1996. For the 1996 survey, the survey population size was defined as all capelin fixed gear (traps and beach seines) fishers licensed to fish capelin in NAFO Div. 3Ps, 3L, and 3K in 1996 (n = 1943). Employing a simple random sampling design and an expected response rate of 85% a sample population with 212 names was chosen to achieve a 7% margin of error with 95% confidence intervals. Telephone interviews were completed between September 12, 1996 and December 1, 1996. The 178 completed questionnaires represented an 84% response rate compared to the 85% expected.

Most respondents indicated that capelin abundance in 1996 was average (mean response = 5.2 on a scale of one to ten). The abundance of capelin in 1995 was estimated to be low by respondents in both the 1995 and 1996 surveys, however, the perception of relative abundance in 1995 improved slightly between the two surveys. Most respondents indicated capelin abundance in 1996 was lower than when they had first started to fish capelin. Most respondents considered capelin abundance to be increasing.

Respondents indicated that spawning on beaches in 1996 was high and more intense than in 1995 but lower than in earlier years, that spawning was late but close to 'normal', and that spawning in deep water away from beaches was more than in 1995 and more prevalent than in previous years. Capelin spawned on more or the same number of beaches in 1996 than in 1995 but in 1996, occupied a small proportion of the available spawning beaches.

Most licenced fishers intended to fish in 1996. The weather was generally considered favourable for being out on the water and water temperatures were considered warmer than normal.

4) Inshore Data

i) Sampling (Chapter 2)

Commercial samples were available for all gear types throughout Div. 3KL. The 1996 spawning biomass in numbers was dominated by the 1993 yearclass (64.4%), the 1994 yearclass (29.9%), and the 1992 yearclass (5.6%).

ii) Aerial Survey (Chapter 3)

In 1996, the aerial survey coverage was the lowest since 1991 due to a combination of poor weather conditions and technical problems with the instrumentation.

In Conception Bay, the highest total for both transects occurred on July 8, the same date as 1995. Spawning was known to have occurred in Conception Bay during late June and early July but due to weather and instrument problems, school areas could not be estimated. In Trinity Bay, the highest school area estimated was observed on July 13, similar to 1994-95. This time also corresponded to the peak period of egg deposition on Bellevue Beach. The total school surface area for both bays combined was the third highest in the series. The estimate in Trinity Bay was the highest since 1982 and the estimate in Conception Bay was higher than the long-term geometric mean.

iii) Egg and Larvae Study (Chapter 4)

Egg deposition and larval abundance studies were conducted at Bellevue Beach, Trinity Bay. The number of study sites in Div. 3KL has changed over time with 1 beach in 1990, 6 beaches during 1991-94, 2 sites in 1995 and 1 in 1996. Bellevue Beach has been a study site throughout the period.

When comparing data from Bellevue Beach only, egg deposition was the third highest after 1993 and 1992. When comparing all beaches, egg deposition on Bellevue Beach was the third highest.

Survival at Bellevue Beach in 1996 appears to have been low. The annual means of the normalized estimates indicates that overall pre-emergent and emergent larval densities in 1996 were less than all years except 1991.

Age compositions of spawning fish from 1990 to 1996 indicate that age 3 fish dominated in all years except in 1991 and 1992 when age 4 predominated.

Three spawnings were observed on Bellevue Beach in late June-early July, mid July and late July. The overall extent of the spawning period in 1996 was similar to 1995 but spawning began earlier.

iv) Research Logbooks (Chapter 2)

During 1994 and 1995, the fishery was nearly non-existent and as a result, research logbooks and catch rate data were not available. However, a fishery occurred in 1996 and catch rates for purse seines and traps could be extracted from research logbooks.

For purse seiners, logbooks from 23 fishers were returned. Reasons for discarding from purse seines varied from bay to bay, although small females were cited as a reason in every bay except Conception Bay. The catch rate (catch/day including landings and discards) was 17.1 t/day approximately equal to the 1981-96 average.

Logbooks were received from 52 trap fishers in 1996. Low proportions of females and small females were most often mentioned as the reasons for discarding. Approximately 74 t of cod were discarded, the second highest amount (highest = 100 t) in the series (1981-96). The catch rate for 1996 was 9.7 t/day, the highest in the series or 3.8 t/haul, the third largest in the series. In previous assessments, estimates of integrated trap catch rates, based on catch per haul, had been used. This integrated catch rate had been calculated to account for differences in duration of the spawning season from year to year. This procedure again was discussed because of the change in fishing pattern in 1996 as a result of the monitoring program. This monitoring program was most extensive in 1996 and conceivably could have had an effect on the estimates of catch rate. Under this monitoring, a few fishermen in local areas fished prior to the season opening and checked their catches for market suitability. Only when fish met predetermined market criteria did the fishery open and it was closed if catches failed to meet the criteria before the quota was reached. There was a concern that this management procedure could have biased the catch rate estimates.

There was also concern that the previous calculations to estimate an integrated trap catch rate and correct for differences in duration of the spawning runs was inappropriate. However, this could not be addressed in detail during the meeting. Given these concerns and the necessity of re-addressing them in greater detail, the Committee decided not to include the 1996 catch rate estimates in the multiplicative model.

It was concluded that the 1996 value for purse seines could be used in the multiplicative model. Although they are mobile gears which are considered less sensitive to changes in stock abundance than fixed gears, purse seine catch rates have generally followed the same pattern as trap catch rates. Furthermore, because they are mobile they are not as sensitive to differences in duration of the spawning season.

5) Offshore Data

i) Acoustic Surveys (Chapter 5)

The biomass estimates from offshore acoustic surveys have been very low since the 1990 fall survey. Starting in 1993, survey effort was concentrated in the fall period and in 1995, only special acoustic studies were conducted i.e. no survey. During the 1980's, a spring survey had shown the most promise of estimating the abundance of recruiting yearclasses. However, the spring survey often encountered ice in Div. 3L and in all years the entire stock area could not be surveyed because of ice cover. Nevertheless, because of the earlier success of the spring survey and the most recent low estimates in the fall, it was decided to conduct the capelin acoustic survey during the spring in 1996.

This survey was conducted from the research vessel TELEOST during May 14-29, 1996. The survey design and area was similar to that of the 1993 and 1994 fall survey in Div. 3L but extended to the north only to latitude 50o in southern Div. 3K. The largest concentrations were found in northern Div. 3L and southern Div. 3K. The total biomass was estimated at 64,000 t, the lowest estimate of the series. Ages 2 and 3 accounted for about 31,000 t each.

ii) 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 early 1990's.

The survey in autumn 1995 differed from that in previous years in several respects. The GADUS ATLANTICA was replaced by the TELEOST, the Engels 145 high-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 Div. 3L for the first time in the time-series. The survey in 1996 was similar to that in 1995. However, in Div. 2J3K the survey started and finished relatively early. In addition, the survey was extended to depths of 1,500 m and new strata were added in the inshore (9 strata in Div. 3K and 16 in Div. 3L).

During the offshore portion of the fall groundfish survey, very few capelin were caught in Div. 2J. Most catches occurred in Div. 3K with some catches along the northeast portion of the Grand Bank (Div. 3L) and south of the Avalon Peninsula. The offshore distribution was generally similar to the 1991-95 results. Largest inshore catches occurred in White, Bonavista and Trinity Bays.

During the 1995 assessment the Committee examined the frequency of occurrence of capelin in bottom trawls and minimum trawlable biomass estimates of capelin from the same data as potential indices of abundance, and incorporated the frequency of occurrence into the multiplicative model (i.e. all years up to and including 1994). The frequency of occurrence in the 1995 survey was highest to date in both Div. 2J3K and Div. 3L. However, during the 1996 assessment, the Committee felt that this was probably due to the change in the trawl used during the survey, and decided not to incorporate the trawl bycatch data into the multiplicative model. The biomass estimates in Div. 2J3K and Div. 3L were approximately an order of magnitude greater than those recorded during previous years.

The 1996 and 1995 estimates are directly comparable. The frequency of occurrence for both Div. 2J3K and Div. 3L declined in 1996. Both total numbers of capelin and minimum trawlable biomass declined in all areas in 1996.

Capelin bycatches during the spring Div. 3L bottom trawl surveys had not been included in the multiplicative model, however, they had been examined in the past to give some indication of the distribution and relative abundance of capelin on the northern Grand Bank in spring. The change in trawl gear reported above for the autumn surveys did not occur until 1996 for the spring survey. Thus, results for 1996 for Div. 3L cannot be compared directly to previous years. In 1996, capelin occurred in 73% of the sets. Capelin were distributed along the northeastern and northern Grand Banks, throughout the Avalon Channel and south of the Avalon Peninsula. There were occasional catches throughout Div. 3O and a few catches in Div. 3N.

iii) Catches in 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 stage (0-group; 3-50 mm), one year old (50-120 mm), and two year old capelin (2+, >120 mm). The survey 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.

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

Estimates of abundance at age 0 showed the following rankings from strongest to weakest: 1996; 1995 and 1993 approximately equal; 1992, 1991 and 1994 approximately equal. The strong 1996 yearclass differs from the results of the strength of this yearclass as larvae in the beach survey which ranked it as weak. At age 1, the 1995 and 1993 yearclasses were equal and strongest, followed by the 1994, 1991 and 1992 yearclasses.

In Div. 3KL age 0 capelin were distributed in the bays and in stations closest to land in 1996. Capelin were completely absent from tows in Div. 2J and the southern Grand Banks (Div. 3NO). Few capelin larger than 20 mm were taken. The smaller size and generally shoreward distribution compared to 1995 might reflect a later hatch date in 1996.

Age 1 capelin from IYGPT tows were mainly distributed in southern Div. 3K and northern Div. 3L in 1996. Visual examination of the distribution plots suggested that the age 1 capelin were more extensively distributed in both 1995 and 1994 than in 1996.

Average size of the 1994 yearclass at ages 1 and 2 was larger than the 1993 yearclass at the same ages.

6) Information on Capelin Predators

The 1996 breeding season for Black-legged Kittiwakes in southeast Newfoundland was markedly different from the previous six seasons (since 1990), and resembled the "normal" seasons of 1969 and 1970. Eggs were laid about three weeks earlier in 1996 than during the period 1990-95. Timing of breeding is related to environmental conditions in the spring and likely to the condition of the female before egg-laying. Clutch size and breeding success was significantly higher in 1996 than in 1990-95. The normal modal clutch size of two eggs was achieved in 1996 and surveys late in the fledging period indicated that most nests in Witless Bay contained one or two chicks. In the period 1990-95 most nests surveyed at the same time of year contained no chicks. Female condition before egg laying and breeding success are likely affected by availability of food. Although the precise food habits of kittiwakes in Newfoundland is unclear at present, it is suspected that early in the season they eat mainly crustacea such as amphipods and euphausids, while later during chick rearing they feed mainly on capelin. The results from 1996 suggest that food such as capelin was much more available to surface feeders such as kittiwakes than in 1990-95.

The breeding success of kittiwakes at Cape St. Mary's and

Baccalieu Island was better than at Witless Bay in 1996 and this may be due to more predation by gulls in the Witless Bay area. It was previously noted that increased predation by gulls during 1990-95 may have been due to the lack of prey for gulls near the surface (like kittiwakes, gulls are surface feeders) as well as the lack of offal due to fish plant closures.

Recent studies of the diets of common murres nesting on Gannett Island, offshore from Cartwright, Labrador indicated that capelin formed only about 15% of the diet in 1996 compared to 76% in 1982-83. Common murres are pursuit divers and dietary generalist, but capelin has been shown to be a predominant prey in the Newfoundland diet. Although capelin appeared to be less important in the common murre diet in 1996, breeding success was good.

A recent study of puffin feeding estimated that the puffin population would consume about 12,000 t of capelin during the breeding season. Common murres would consume about 9,000 t in the Witless Bay area only. Estimates for year-round consumption by these species and other seabirds is not presently available.

Information on the temporal variability in the diet of anadromous Arctic charr in the inshore zone of the Nain stock complex was available from 1982 to 1995. The contribution of capelin varied from 58% to 83% from the 1982-84 period through to the 1988-90 period. Since 1991, capelin have been virtually absent from the diet of charr, contributing less than 10% during 1991-93 and 5% in 1994-95. The decline in capelin has been balanced by corresponding increases in amphipods and sculpins. The decline in capelin in the diets of charr and common murres off Labrador is consistent with the lack of capelin in acoustic surveys and bycatch in groundfish surveys.

Estimates of consumption of capelin by harp and hood seals were also available, using the estimated 1996 seal population and diet samples collected in 1982, 1986 and 1990-94. Harp seals were estimated to have consumed about 806,000 t of capelin in Div. 2J3KL and 319,000 t in the Northern Gulf of St. Lawrence. In contrast, hoods were estimated to have consumed 3,000 t of capelin in 2J3KL, 26 t in the Northern Gulf and 325 t on Flemish Cap. Consumption estimates for seals were also available for Atlantic cod, Arctic cod, herring, redfish and Greenland halibut. Next to capelin, Arctic cod was the next highest consumption estimate; harp seals were estimated to have consumed 600,000 t of Arctic cod in Div. 2J3KL. These estimates are highly dependent upon the assumed seasonal distribution of the seals. If harp seals are feeding in nearshore waters more often than assumed (45%), the amount of capelin consumed would be less. Conversely, more feeding in the offshore would result in greater consumption.

7) Other Studies:

i) Mean Lengths of Capelin in 1997 (Chapter 8)

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. Fish lengths in fall 1995 were small and it was predicted that fish lengths in 1996 would be small and unlikely to achieve the sizes observed during the 1980's. Results from the 1996 fishery indicated that this to be the case. The data from the bycatch in the fall groundfish survey (Campelen gear) appeared to predict the mean lengths in 1996 reasonably well.

In this 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 length of females from the 1996 acoustic survey indicated that capelin in 1997 would be larger than the early 1990's.

In all of the relationships tested, water temperature was also added to the regression. In most cases, the r2 values increased. However, in some instances, temperature could not be used in predictions because they were not available while in others, where temperatures were available, the predicted mean lengths did not differ appreciably from predictions using mean lengths alone.

ii) Incidence of Repeat Spawning (Chapter 9)

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. Results from a detailed study of female gonads spanning two years (1995 and 1996) were presented at this meeting.

Based on a combination of microscopy of gonads, examination of residual eggs and thickening of ovarian wall, 20% and 60% of fish examined from the fall of 1995 and 1996 respectively were recovering. When comparing results from a histological technique with the visual examination currently used, the present method consistently underestimates the proportions recovering, except for the older fish where all were recovering. There was a general trend to increasing proportions of recovering fish with age. The lower proportion recovering in 1995 probably reflected the younger age composition in the 1995 sample.

8) Multiplicative Model (Chapter 10)

In the two previous assessments, a multiplicative model was used to provide standardized estimates of abundance for each cohort. In this assessment, this approach was again used. Standardized estimates of annual and cohort abundance were derived from the multiplicative model applied to the following indices:

1) aerial survey index 1982-96
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 1990-96

These are the same seven series that were used in the 1996 assessment. Data for all formulations of the multiplicative model are found in Appendices II and III.

The aerial survey, the egg deposition index and purse seine catch rate provided the only information on the 1994 yearclass and the 1996 mature biomass in these formulations of the mathematical model. The aerial survey index was the highest in the series, the egg deposition was the second highest in the series and the purse seine catch rate was approximately equal to the average. A calibrated trap catch rate index for 1996 was not used because changes in management practices resulted in fishing patterns and trap catch rates which were not comparable to previous years.

Results from the model indicate that the 1983 and 1986 yearclasses were strong as were the 1990 to 1992 yearclasses (Fig. 1). The 1993 yearclass appears strong although the 95% confidence intervals are large. Estimates of the 1994 yearclass from the three data sources exhibit a wide range and therefore there is great uncertainty about the abundance of this yearclass from this analysis. However, even the lowest estimate (from the egg deposition index) would suggest that this yearclass is not weak.

A separate mathematical model using the same indices as above provided trends in mature biomass (Fig. 2). The mature biomass was high in the mid to late 1980's and from 1992 to

1996. These periods of high abundance can be attributed to the presence of strong yearclasses in the population, namely the 1983 and 1986 yearclasses in the 1980's and several yearclasses in the 1990's (Fig. 1).

Another formulation of the multiplicative model used several indices from early life history studies (Fig. 3). The indices used were (1) oceanic 0-group indices (1991-96), (2) NCSP sediment larval abundance (1990-96), (3) NCSP emergent larval abundance (1990-96), (4) Conception Bay sediment larvae (1987-92), and (5) oceanic age 1 index (1992-96). The patterns of relative yearclass strength from this model and the cohort model are in good agreement for all yearclasses up to and including the 1993 yearclass. The relative strength of the 1994 yearclass is lower than the other estimates from the cohort model. The estimates for the 1995 and 1996 yearclasses from this formulation of the model are the only estimates available.

Stock Status in 1996

The results of the multiplicative model indicate that the 1996 capelin stock biomass was slightly higher than 1995 and the highest since 1980. This high biomass occurred because the estimates of relative yearclass strength indicated that yearclasses in the 1990's have been above average. Three indices were used to evaluate stock status in 1996, in contrast to two in 1995. The aerial survey index was the highest in the series (1992-96), the egg deposition index was the second highest in the series (1990-96), and the purse seine catch rate was approximately equal to the average (1981-96). The aerial survey has maintained its geographical coverage throughout the series while the egg deposition survey was reduced to one beach in 1996, in contrast to two beaches in 1995 and six beaches between 1991 and 1994.

Stock status has been difficult to determine in recent years because of the divergence between inshore indices and offshore acoustic surveys. This divergence continued in 1996 with a low spring acoustic offshore estimate and high inshore indices. This divergence has not been resolved. The acoustic survey, planned for spring 1997, has been cancelled and no other surveys are planned. Information on distribution patterns indicated that capelin were still scarce in Div. 2J.

Outlook for 1997

The 1993 and 1994 yearclasses are expected to be major contributors to the 1997 spawning stock. The results from this assessment show that the 1993 yearclass is strong. The estimates for the 1994 yearclass span a wide range, however, even the lowest estimate would indicate that it is approximately the same strength as the 1991 yearclass and therefore, larger than many yearclasses in the timeseries. No absolute estimates of these yearclasses presently are available. However, during 1982-89, catches in Div. 3L averaged only 4.3% of the mature biomass projected from the 3L acoustic survey. This corresponds to an annual average catch in Div. 3L of 35,000 t. During the same period, inshore catches averaged 12,000 t in SA2 + Div. 3K. Based on these comparisons and the estimated strength of the 1993 and 1994 yearclasses relative to those in the 1980's, the TAC of about 28,000 t in SA2 + Div. 3KL in the tentative management plan would be less than 10% of the expected mature biomass in 1997.

Mean female size in the 1996 fishery was approximately equal to that predicted from mean size observed in fall surveys in 1995. The mean size of mature females in 1996 was smaller than that observed during the 1980's but larger than that observed during the early 1990's. Based on historical trends in size of both immature females in the previous spring and maturing females in the previous fall with size inshore the following year, capelin in the 1997 spawning stock will be comparable in size to the historical mean and larger than those of the 1991-96 period.

Research Recommendations

1. Evidence presented during the assessment indicates that the multispecies 0-group pelagic surveys are providing an early indication of relative yearclass strengths. This survey should be continued.

2. Recent information indicates that there have been changes in distribution and abundance of Arctic cod. These changes should be documented. In addition, the feeding of Arctic cod should be investigated, particularly with respect to predation on capelin and potential competition with capelin.

3. The multiplicative model should be investigated regarding its appropriateness for combining diverse indices and regarding weighting methods. (Revised from 1996 meeting.)

4. The telephone survey is viewed as one of the best of its type in eastern Canadian fisheries. It should be continued and improved with a long-term goal of developing and verifying an index of abundance.

5. Acoustic data on mature capelin schools near Bellevue Beach were collected during the aerial survey. Preliminary data were presented during the assessment meeting but are not included as a chapter. However, the preliminary results wre encouraging and it is recommended that these studies should be continued in 1997 to relate density estimates with area of schools.

6. The importance of bottom trawl surveys for obtaining reliable data on capelin abundance should be assessed and appropriate sampling schemes established.

7. The uncertainty in the strength of the 1994 yearclass is due to the difficulty in age interpretation in recent years. Resolution of the ageing problem is critical to future assessment of cohort strength.

8. It was agreed that new information on the proportion of iteroparous females showed potential for estimating capelin survival. Annual variability was evident in the short data series and the possibility of collecting additional data should be addressed.

9. There was concern that the 1996 trap catch rate was biased by the monitoring program. This possibility requires further detailed examination. In addition, the integrated catch rate estimation may not be achieving its purpose, namely accounting for differences in the duration of the spawning season. This too requires further investigation possibly through simulations.

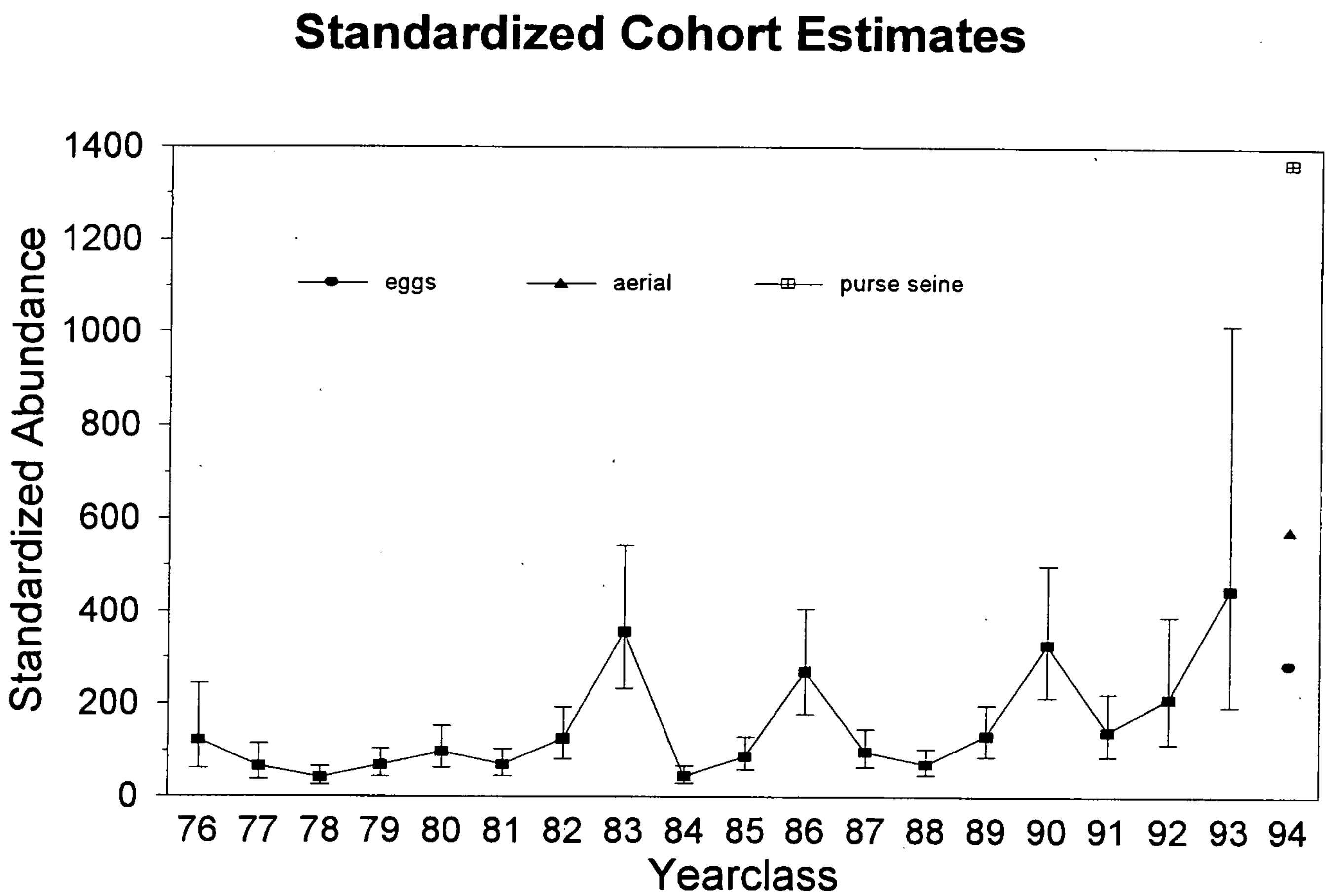


Fig. 1. Standardized abundance and 95% confidence intervals of capelin yearclass from the multiplicative model. Estimates for the 1994 yearclass derived from three different sources are plotted separately to illustrate the range of estimates.

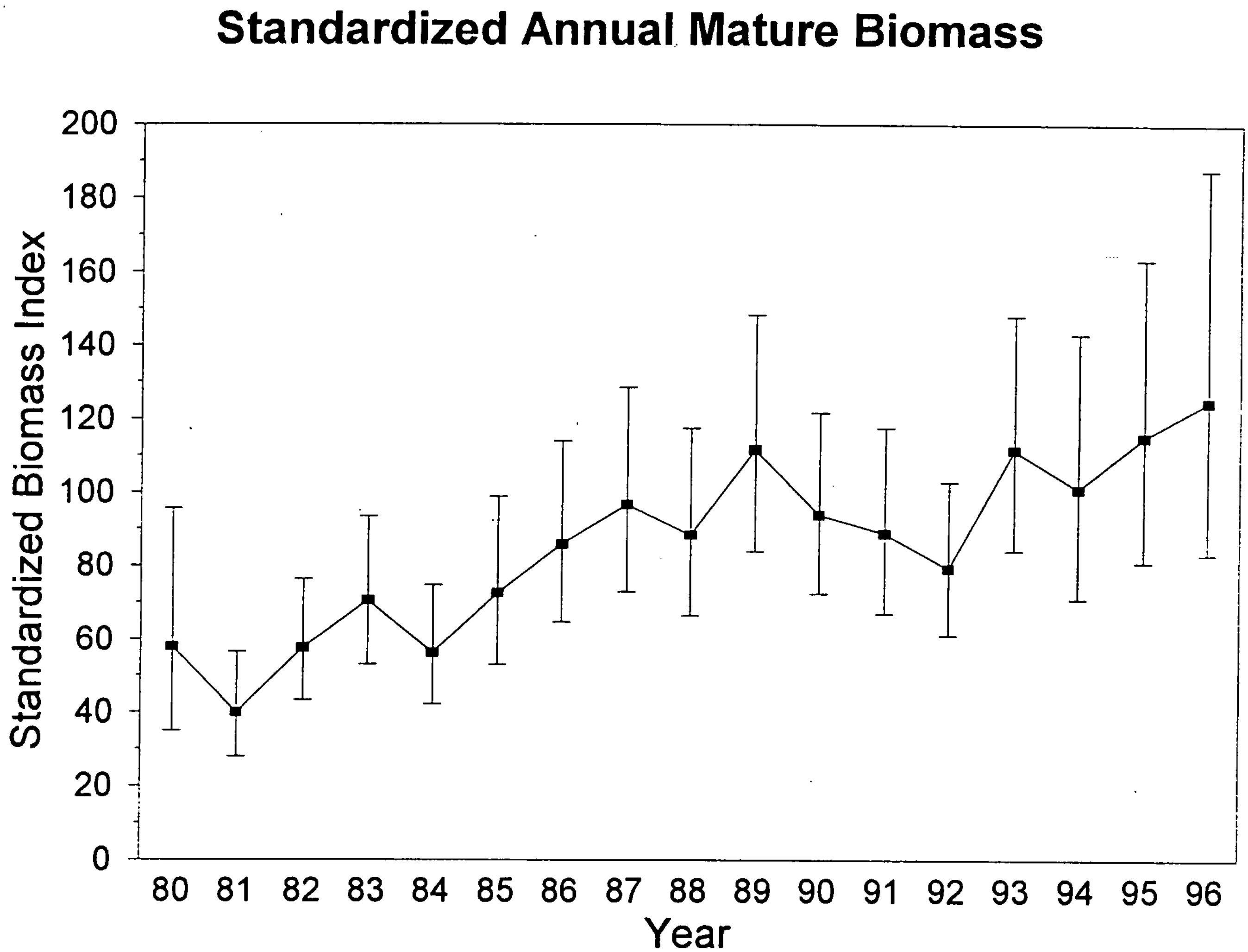


Fig. 2. Standardized annual mature biomass indices and 95% confidence intervals from the multiplicative model.

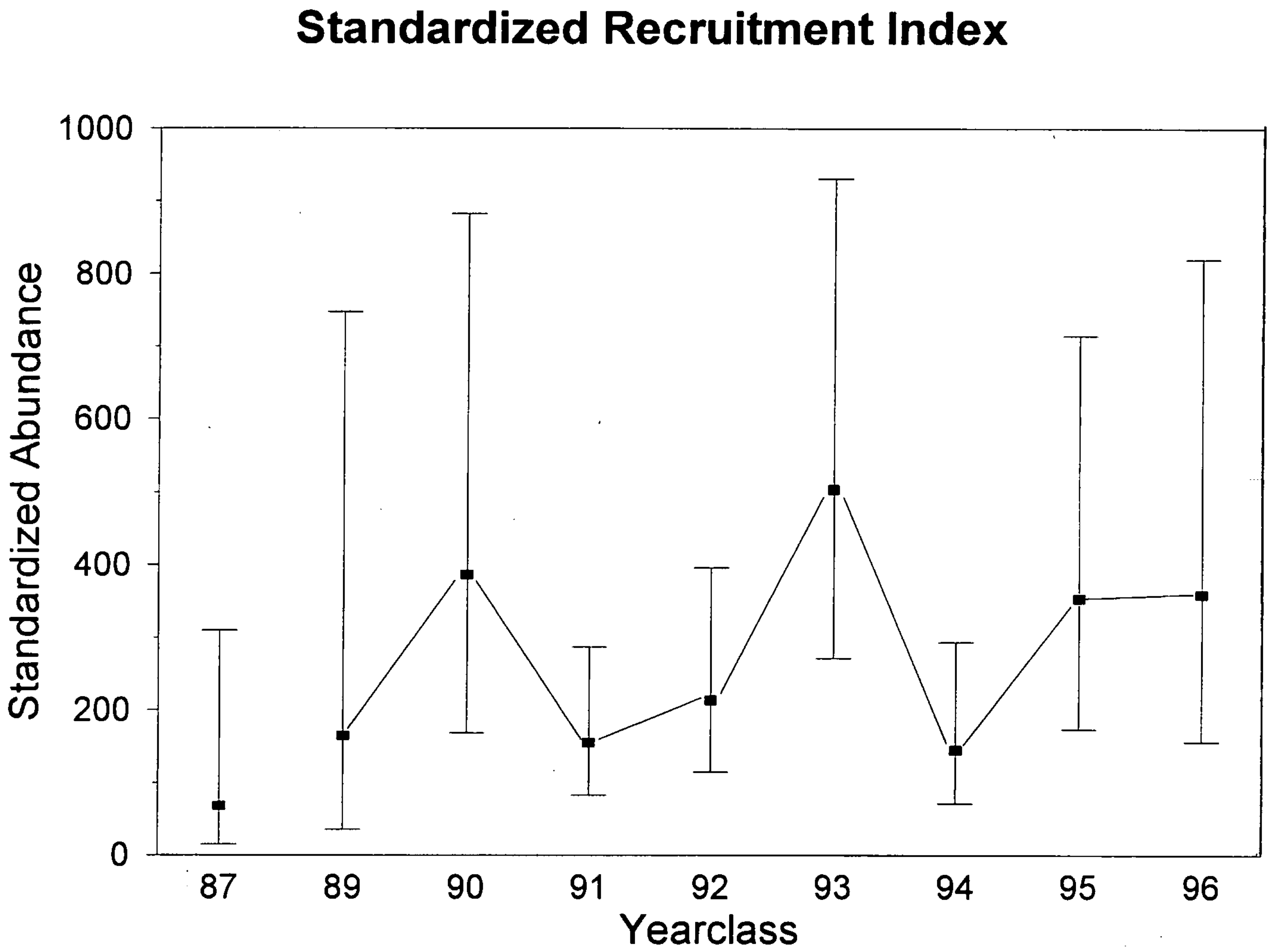


Fig. 3. Standardized abundance and 95% confidence intervals of capelin yearclasses from the multiplicative model, using indices from early life history studies.

Appendix I.

List of participants

Name	Affiliation
Anderson, J.	Ocean Ecol.
Burton, M.	M.U.N.
Bryant, R.	M.U.N.
Carscadden, J.	PFSS
Chardine, J.	CWS
Clark, M.	PFSS
Coombs, R.	Prov. Fisheries
Dalley, E.	Ocean Ecol.
Eustace, P.	PFSS
Evans, G.	PFSS
Flynn, S.	M.U.N.
Lilly, G.	GF
Miller, D.	PFSS
Montevecchi, W.	M.U.N.
Nakashima, B.	PFSS
Parsons, D. (Chair)	PFSS
Rice, J.	CSAS, Ottawa
Rivard, D.	Science, Ottawa
Slaney, B.	PFSS
Stenson, G.	Ocean Ecol.
Wheeler, J.	PFSS
Winters, G.	PFSS

Appendix II. Indices used in the multiplicative analyses.

	Year	Age					
		0	1	2	3	4	5
<u>Standardized Cohort Model</u>							
Aerial survey index							
	1982	-	-	31	522	69	20
	1983	-	-	15	621	381	16
	1984	-	-	10	217	270	24
	1985	-	-	130	654	215	53
	1986	-	-	8	507	283	20
	1987	-	-	97	423	1310	98
	1988	-	-	165	717	168	160
	1989	-	-	8	1212	336	18
	1990	-	-	17	466	608	17
	1991	-	-	-	-	-	-
	1992	-	-	238	926	1265	231
	1993	-	-	86	973	363	46
	1994	-	-	432	1586	810	189
	1995	-	-	369	1487	609	260
	1996	-	-	338	2428	914	60
Egg deposition index (normalized)							
	1990	-	-	81	840	711	54
	1991	-	-	240	1875	2050	795
	1992	-	-	523	2049	2777	517
	1993	-	-	867	6534	1697	283
	1994	-	-	354	1040	531	166
	1995	-	-	1634	4020	1063	521
	1996	-	-	859	3708	1320	126
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 II. Continued ...

		Age					
	Year	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 II. Continued ...

	Age					
Year	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
<u>Standardized Recruitment Model</u>						
Conception Bay sediment larval index						
1987	61	-	-	-	-	-
1988	-	-	-	-	-	-
1989	147	-	-	-	-	-
1990	285	-	-	-	-	-
1991	99	-	-	-	-	-
1992	340	-	-	-	-	-
1993	432	-	-	-	-	-
NCSP sediment larval index (normalized)						
1990	136	-	-	-	-	-
1991	94	-	-	-	-	-
1992	113	-	-	-	-	-
1993	153	-	-	-	-	-
1994	51	-	-	-	-	-
1995	81	-	-	-	-	-
1996	79	-	-	-	-	-

Appendix II. Continued ...

	Year	Age 0	1	2	3	4	5
NCSP emergent larval index (normalized)							
	1990	151	-	-	-	-	-
	1991	89	-	-	-	-	-
	1992	126	-	-	-	-	-
	1993	152	-	-	-	-	-
	1994	43	-	-	-	-	-
	1995	63	-	-	-	-	-
	1996	67	-	-	-	-	-
Offshore 0-group index							
	1991	2337	-	-	-	-	-
	1992	2616	-	-	-	-	-
	1993	4497	-	-	-	-	-
	1994	2258	-	-	-	-	-
	1995	4832	-	-	-	-	-
	1996	15578	-	-	-	-	-
Offshore age I index							
	1992	-	46	-	-	-	-
	1993	-	35	-	-	-	-
	1994	-	711	-	-	-	-
	1995	-	99	-	-	-	-
	1996	-	700	-	-	-	-

Appendix III. 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	220	
1983	32	34	29	176	64	348	
1984	53	25	31	143	60	173	
1985	42	27	-	164	89	308	
1986	70	44	35	188	149	260	
1987	61	26	27	176	155	718	
1988	77	35	27	200	121	402	
1989	60	37	46	217	148	539	
1990	61	49	40	215	167	359	42
1991	13	35	21	150	153	-	102
1992		43	23	208	132	548	101
1993		53	52	162	146	335	165
1994		47	53	-		663	39
1995		47	39	-		557	107
1996				171		837	112

Results of a Telephone Survey of 1996 Fixed Gear Capelin Licence Holders

by

B. S. Nakashima
Science Branch
Department of Fisheries and Oceans
P. O. Box 5667
St. John's NF A1C 5X1

Introduction

A questionnaire modified slightly from the one in 1995 (Nakashima 1996) was used to quantitatively evaluate biological and fishery-related information obtained from capelin fishers in 1996. Questions on cod bycatches and opinions on a capelin fishery for next year were not included in this survey. The questions were developed to supplement information collected by the research logbook and beach sampling programmes and to provide background data on characteristics of the survey population of capelin fishers.

Methods

The survey population size of 1943 was defined as all capelin fixed gear (traps and beach seines) fishers licensed to fish capelin in NAFO Div. 3Ps, 3L, and 3K in 1996. This was 65 more licences than the 1878 licences issued in 1995 (Nakashima 1996). 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% (Nakashima 1996) a sample population with 212 names was chosen to achieve a ±7% margin of error with 95% confidence intervals (Gower and Kelly 1993). Similar to 1994-95 the survey was conducted by telephone interviews.

Telephone interviews commenced September 12, 1996 and were completed on December 1, 1996. The survey was conducted earlier than in 1995. Interviewers were unable to contact 34 individuals on the licensing list which were included in the sample population. Of these 16 could not be contacted despite 5 or more attempts to do so, 9 had no telephone in service (disconnected, wrong number, no telephone number), 2 were out of the province during the survey, 6 declined to participate, and 1 person was retired. The 178 completed questionnaires represent an 84% response rate which was slightly lower than the 85% expected.

The Div. 3KLPs survey area was subdivided into 9 areas corresponding to the statistical areas for the Newfoundland Region (Fig. 1).

Results and Discussion

Abundance Questions

Three questions (Appendix A) comparing abundance of capelin in 1996 to previous years were asked in the survey. Most respondents indicated that capelin abundance in 1996 in their area was average (Fig. 2) with a mean response equal to 5.2 to question 1 (Appendix A). The abundance of capelin in 1995 was estimated to be low by respondents in both the 1995 and 1996 surveys, however, the perception of relative abundance in 1995 improved slightly between the two surveys (Fig. 3). Similar to last year (Nakashima 1996) opinion on relative abundance improved with time. When given three options in question 3 (Appendix A) respondents clearly indicated that capelin abundance in 1996 was lower than when they had first started to fish capelin (Fig. 4). Generally most respondents considered capelin abundance to be increasing.

Spawning Questions

Respondents of questions 4-13 (Appendix A) related to spawning generally indicated that spawning on beaches in 1996 was higher and more intense than in 1995 but lower than in earlier years, that spawning was late but close to 'normal', and that spawning in deep water away from beaches was more than in 1995 and more prevalent than in previous years. According to respondents capelin in 1996 occupied a small proportion of the available spawning beaches (Fig. 5). Continuing a trend observed in 1995 the number of respondents reporting no spawning has declined in 1996 and the responses in the 1-5 beaches category is substantially higher than in 1994 (Nakashima 1996). Capelin spawned on more or the same number of beaches in 1996 than in 1995 (Fig. 6). The intensity of spawning was higher in 1996 than in the previous two years (Fig. 7) with a mean intensity of spawning of 5.7 compared to 3.7 in 1995. Spawning intensity in 1996 compared to 1995 was considered to be higher (Fig. 8). These results support the estimates of higher egg densities at Bellevue Beach in 1996 compared to 1995 (Nakashima and Winters 1997).

Compared to 1994-95 (Nakashima 1995, 1996) capelin exhibited more off-beach spawning behaviour in deeper water in 1996 (Fig. 9). The historical view of capelin spawning off beaches has changed somewhat among the three surveys (Fig. 10). Only the 104 persons who responded in the affirmative to question 8 were asked to give reasons why capelin may have spawned in deeper water in 1996 (Appendix A: question 9). The most frequent response was better water temperatures in deeper water (41%). Other possibilities suggested were the presence of predators (eg. humans, seagulls) driving them away from beaches (11%), unsuitable beach habitat including nearby pollution (5%), weather or wind conditions (4%), beaches full of eggs (3%), a later, smaller run (2%), no cod to drive capelin ashore (1%), low abundance (1%), and tide not right (1%). Approximately 14% said capelin in their area always spawned in deep water and 18% did not have an opinion.

Spawning times were again delayed compared to the 1980s but closer to 'normal' compared to the rest of the 1990s. Of those answering question 11a who recalled when spawning began in 1996 the majority suggested mid June to mid July with most responses favouring late June to early July (Fig. 11). Comparing the start of the spawning season in 1996 to 1995 in question 11b most respondents who expressed a time indicated that it was earlier or the same (Fig. 12). There was a large percentage of non-responses in the three surveys. When asked to indicate the end of the 1996 spawning season the number of non-responses to question 12a dropped dramatically in 1996 compared to the previous two surveys (Fig. 13). The results suggest that spawning in 1996 ended between late July and late August (Fig. 13). Answers to question 12b suggested that the end of spawning was similar in 1995 and 1996 for at least 25% of the sample population (Fig. 14). A significant proportion were unable to make a comparison. Compared to when fishers first started fishing capelin there was general agreement that spawning in 1994-96 has been later, however more respondents are noticing a shift back to historical spawning times (Fig. 15). Spawning times at Bellevue Beach in Trinity Bay in 1996 (Nakashima and Winters 1997) were comparable to the ranges reported in this survey. The results suggest a gradual return to 'normal' spawning times since 1991 (Nakashima 1994).

Questions on the Fishery

Almost all licenced respondents (96%) intended to fish capelin in 1996 and 75% actually set out fishing gear. Of the 132 respondents who fished in 1996, 53 used one trap, 36 used two traps, 7 fished more than 2 traps, 13 used one trap and one beach seine, 2 had 2 traps set and used a beach seine, and 21 used a beach seine. Over 70% who fished landed less than 50,000 lbs (Fig. 16), the average reported landings were 50,424 lbs (22,872 kg). For discarding the majority reported less than 25,000 lbs (11,040 kg) discarded (Fig. 17). Combining landings and discards the average catch in 1996 was 99,045 lbs (44,927 kg). The interviews suggest almost all capelin were discarded live (Fig. 18). The major reasons for discarding were low percentage of females (40%), small fish (15%), problem with buyers and selling capelin (12%), redfeed (10%), mixed with other species (9%), caught after the season closed (10%), and spent fish (2%). There was no consistent response to question 20 comparing discarding in 1996 to previous years (Fig. 19). Of those who fished 75% reported bycatches of a few pounds to several thousand pounds. The most frequent bycatch species were cod (91%), salmon (14%), herring (11%), squid (1%), and flatfish (1%) for those who indicated having a bycatch. Of these most were released alive (94%).

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 1996. Wind conditions in the summer of 1996 were considered light or favourable by 74% of the population, moderate by 3%, and windy by 6%. Other respondents noted that it was windy for a specific month, either June (8%) or July (9%), and good weather the rest of the summer. Air temperatures were reported to be warmer than normal (89%) while a few indicated it was normal (9%) or colder than usual (2%). Similarly 86% observed that the summer was mainly sunny, 6% felt the number of sunny and overcast days were even, and 7% recalled more overcast days. Of the latter group, half of the respondents indicated it was overcast during the capelin run then sunny the rest of the summer. Ice was not a concern in 1996 in all areas (98%) and several fishers indicated how unusual the lack of spring ice was. Most fishers (75%) reported warmer than normal water temperatures or the same temperatures as usual (23%). Only a few thought it was colder than average (2%). Overall weather conditions were favourable for fishing throughout the region.

Characteristics of the Sample Population

All respondents were asked questions 25-28 to help characterize the sample population of fixed gear fishers and to be able to relate in a 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 1996 the entry years of respondents were spread out between 1978 and 1988. The low number of new entrants in the 1990s is common to all three surveys. Fishing vessel lengths varied from 17-55 feet with the majority less than 36 feet (Fig. 21). Estimated vessel capacity for capelin was less than 30,000 lbs (13,608 kg) for over 85% of the fishing fleet involved in the fixed gear capelin fishery (Fig. 22). Most licensed fixed gear capelin fishers are in the 45-55 age range followed closely by the 35-44 range (Fig. 23). The responses to question 26 are comparable in all three surveys. The highest proportion of respondents were from Notre Dame Bay with a few fishers in the sample population from the Southern Shore and St. Mary's Bay and none from Fortune Bay (Fig. 24). The distribution of responses from Div. 3KLPs in the sample population is similar to and therefore representative of the survey population of licences in 1996.

Summary

Results from the telephone survey of fixed gear capelin fishers provided observations on beach spawning, local capelin abundance, fishing activities, and summer weather conditions. In 1996 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. However, spawning times are earlier and intensities have increased compared to 1994-95. Most licenced fishers intended to fish in 1996. 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 1996 was higher than in 1995 but lower than in previous years. 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.

The general characteristics of the capelin fixed gear licence population have remained consistent between the three surveys except for a change towards fewer years in the capelin fishery and an increase in the proportion of licence holders from Notre Dame Bay.

Acknowledgements

Morris Clark and Barry Slaney conducted the telephone interviews. Our appreciation to the individuals who gave of their time to share their knowledge for this report. M. Y. Rees assisted in the preparation of the manuscript.

References

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

Nakashima, B. S. 1994. The relationship between oceanographic condition in the 1990's and changes in spawning behaviour, growth, and early life history of capelin (Mallotus villosus). NAFO SCR Doc. 94/74, Ser. No. N2453. 18 p.

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. 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. 96/90.

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. CSAS Res. Doc. 97/29.

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 (ie numbers of fish) were capelin in your area in 1996?

2. Using a scale of 1 to 10 with 1 being the lowest and 10 the highest how abundant (ie numbers of fish) were capelin in your area in 1995?

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 in 1996?

   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 in 1996?

7b. What was the intensity of capelin spawning in 1996 compared to 1995?

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 in 1996?

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 in 1996?

11b. Did spawning start at the same time in 1996 as in 1995?

12a. When did capelin finish spawning in your area in 1996?

12b. Did spawning finish at the same time in 1996 as in 1995?

13. How does the timing of capelin spawning (beginning and end) in 1996 compare to when you first started fishing capelin?

Questions on the Fishery.

14. Did you intend to fish for capelin in 1996?

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

14b. Did you set your fishing gear or go out and search for capelin in 1996?

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

15a. What type of fishing gear did you use in 1996?

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

15b. How many traps did you fish in 1996?

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 in 1996?

17. Approximately how much capelin (live or dead) did you and your crew discard (ie did not land or sell) in 1996?

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 in 1996 compare to all the other years you've fished capelin?

21. While fishing capelin did you and your crew catch any other species (ie 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?

29. If there is a capelin fishery in 1997 would you consider keeping a diary of your fishing activities in a capelin research logbook if asked?

30. Thank you for your patience and your time. Are there any comments you wish to make on the questionnaire itself or any comments in general?

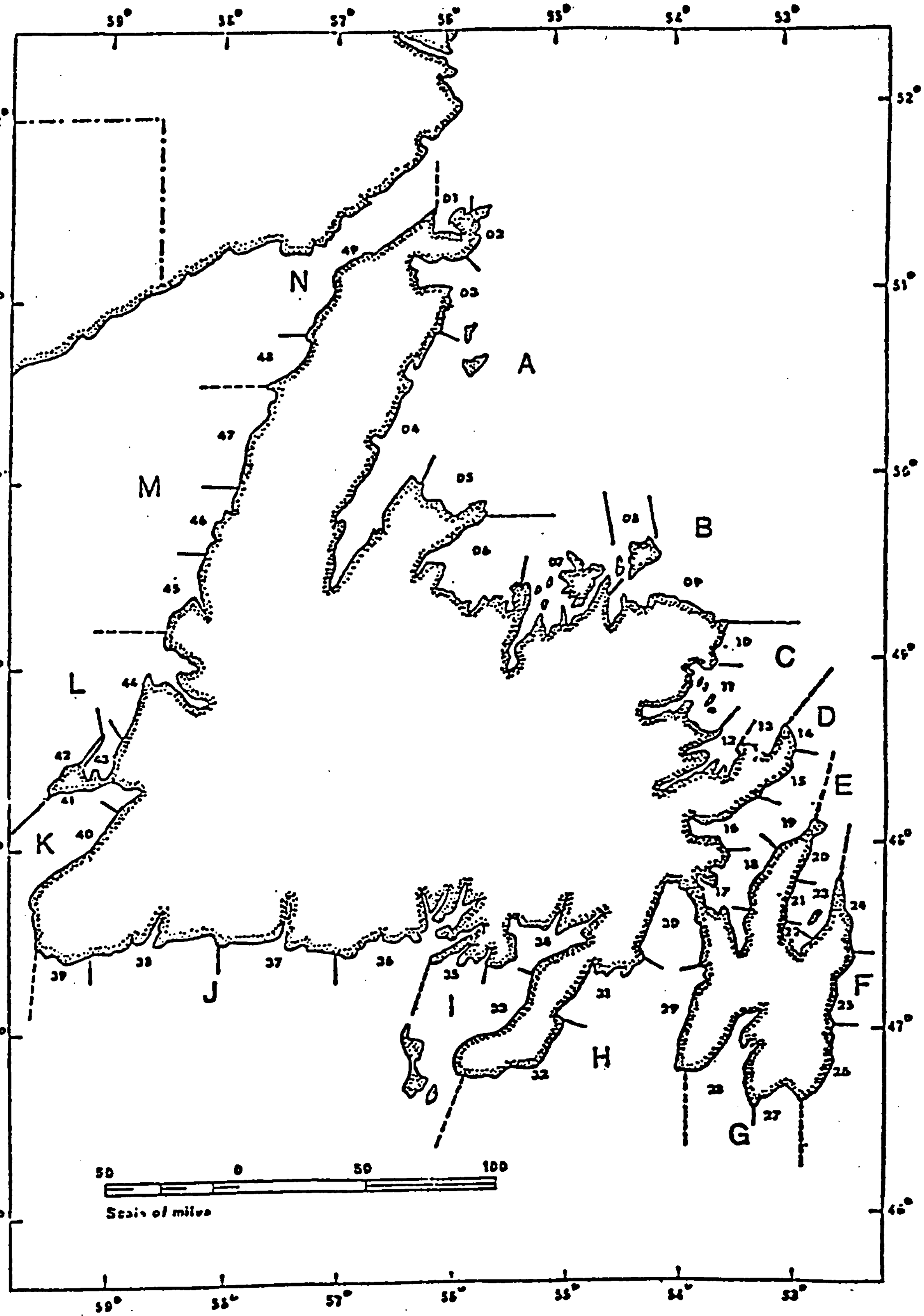


Fig. 1. Statistical areas (A = White Bay, B = Notre Dame Bay, C = Bonavista Bay, D = Trinity Bay, E = Conception Bay, F = Southern Shore, G = St. Mary's Bay, H = Placentia Bay, and I = Fortune Bay) for the Newfoundland Region.

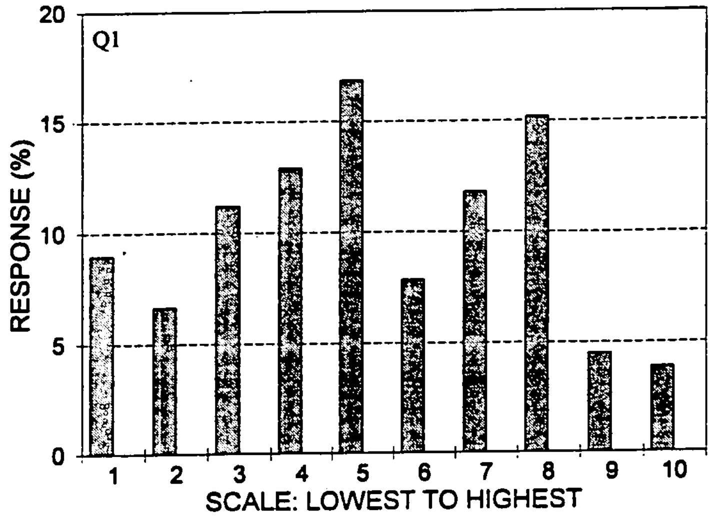


Fig. 2. Response to question 1 on the abundance of capelin in 1996.

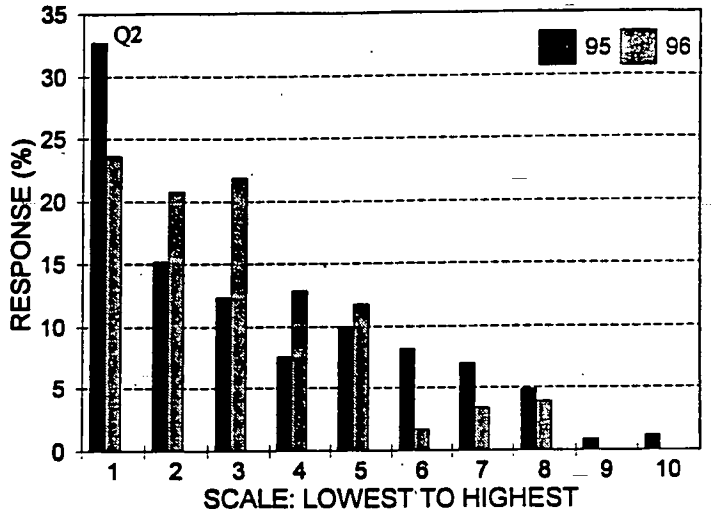


Fig. 3. Impression of capelin abundance in 1995 from the 1995 (Nakashima 1996) and 1996 surveys.

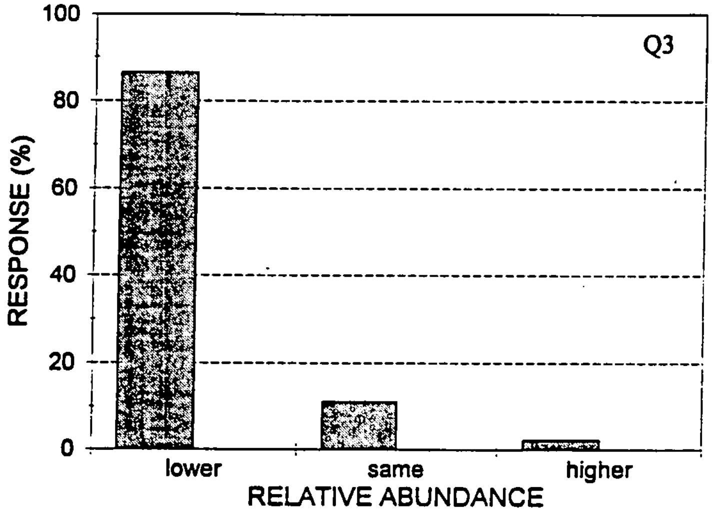


Fig. 4. Response to question 3 concerning abundance in 1996 compared to first started fishing. No answer given (na).

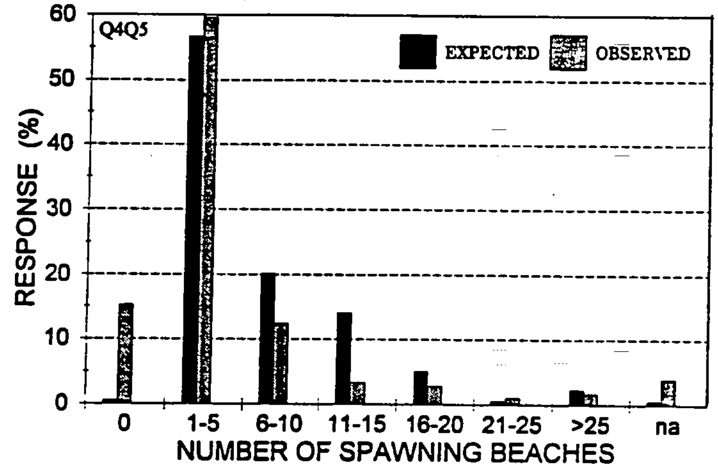


Fig. 5. Comparison of the number of beaches capelin spawned on in 1996 to the available beaches. No answer given (na).

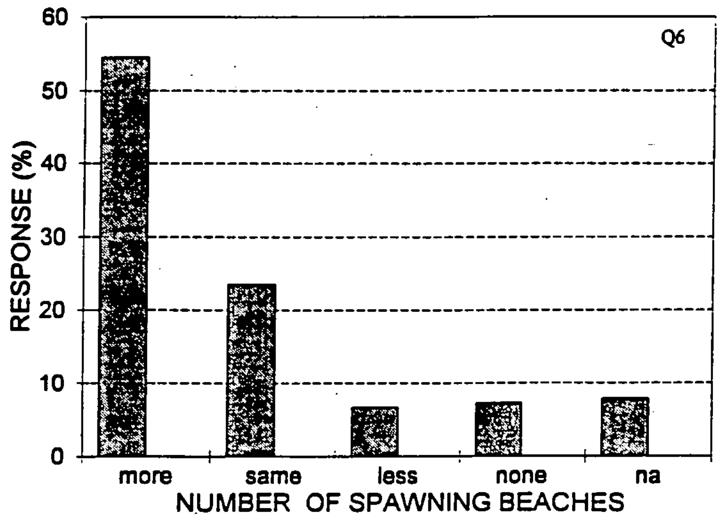


Fig. 6. Response to question 6 concerning the relative number of spawning beaches occupied in 1996 compared to 1995. No answer given (na).

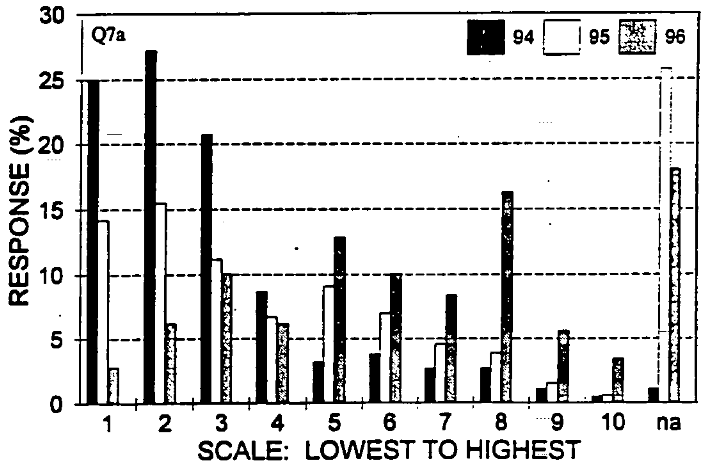


Fig. 7. Response to question 7a describing the intensity of spawning on an increasing scale of 1 to 10. No answer given (na).

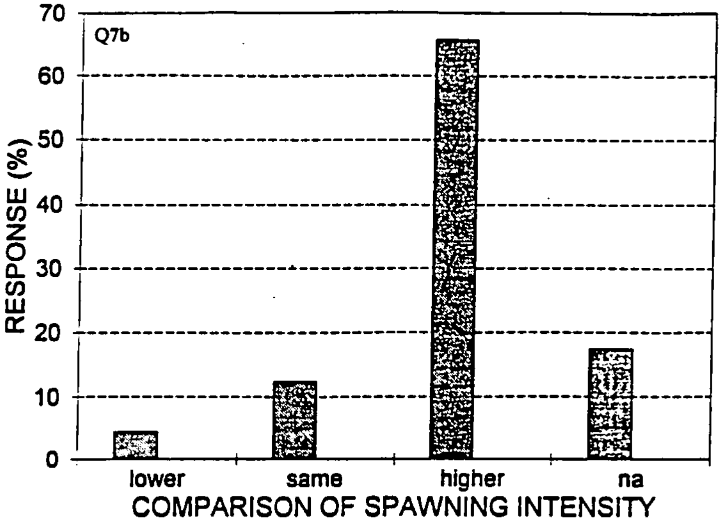


Fig. 8. Response to question 7b comparing the spawning intensity in 1996 relative to 1995. No answer given (na).

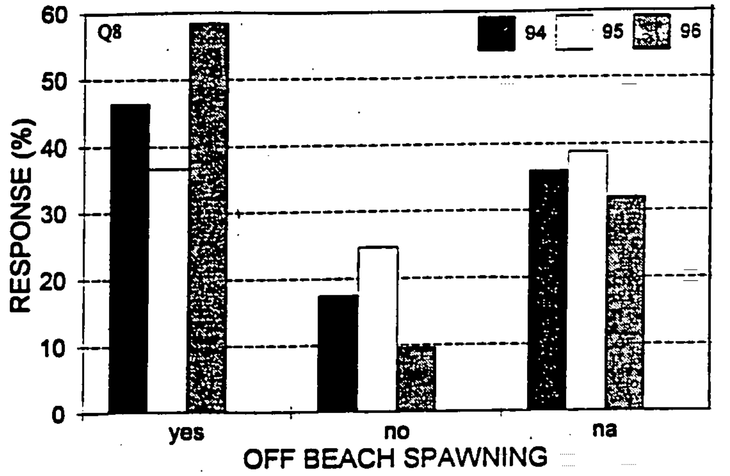


Fig. 9. Did off beach spawning occur in 1994 (Nakashima 1995), in 1995 (Nakashima 1996), and in 1996? No answer given (na).

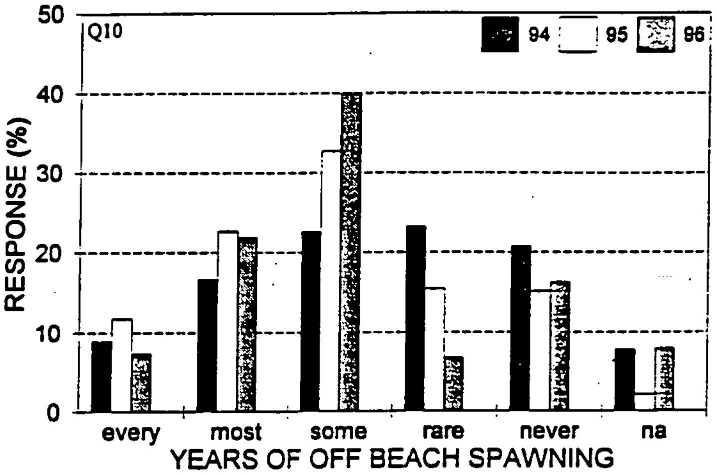


Fig. 10. The prevalence of off beach spawning from the 1994, 1995 and 1996 surveys. No answer given (na).

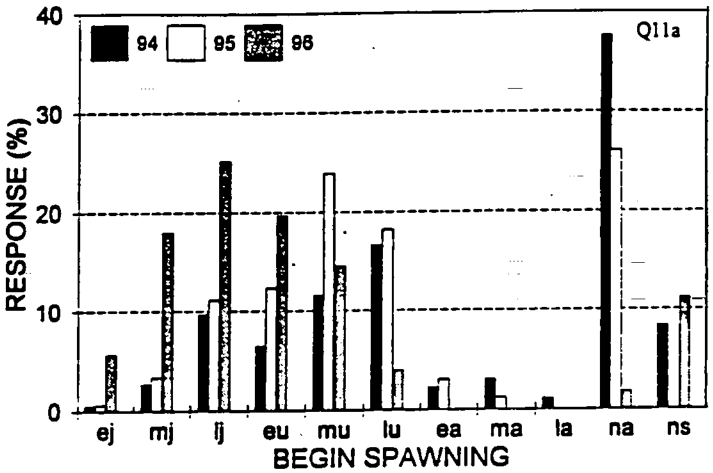


Fig. 11. The time when capelin began spawning in 1994 (Nakashima 1995), 1995 (Nakashima 1996), and 1996. Spawning times are early June = ej, mid June = mj, late June = lj, early July = eu, mid July = mu, late July = lu, early August = ea, mid August = ma, and late August = la. No answer given (na) and no spawning (ns).

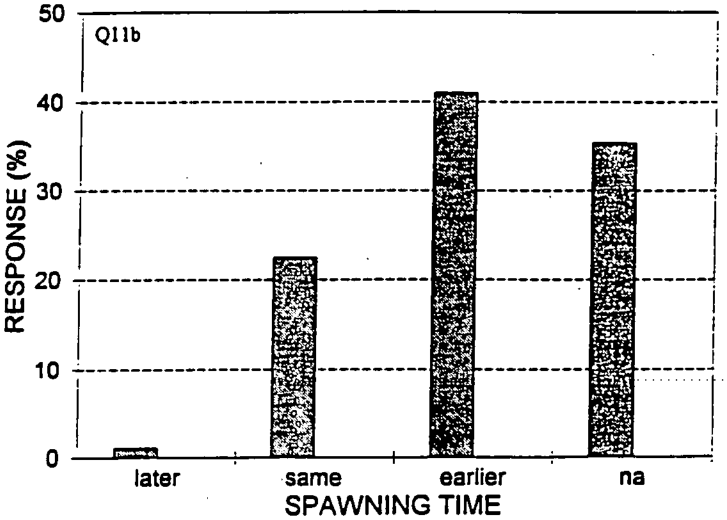


Fig. 12. The start of spawning in 1996 compared to 1995 in response to question 11b. No answer given (na).

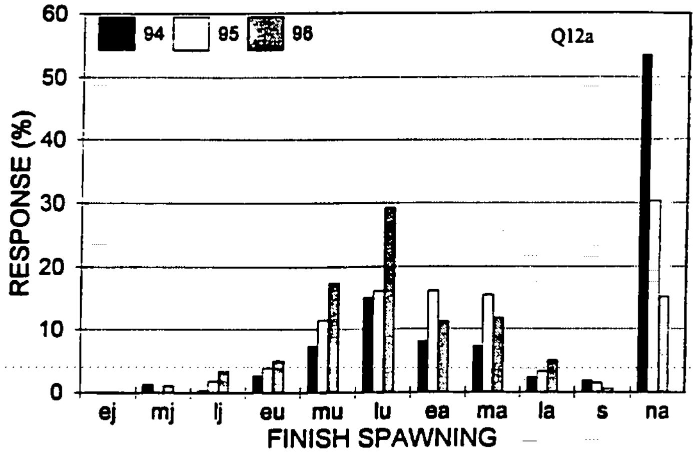


Fig. 13. The time when spawning ceased in 1994 (Nakashima 1995), 1995 (Nakashima 1996), and 1996. Spawning times are mid June = mj, late June = lj, early July = eu, mid July = mu, late July = lu, early August = ea, mid August = ma, late August = la, and September = s. No answer given (na).

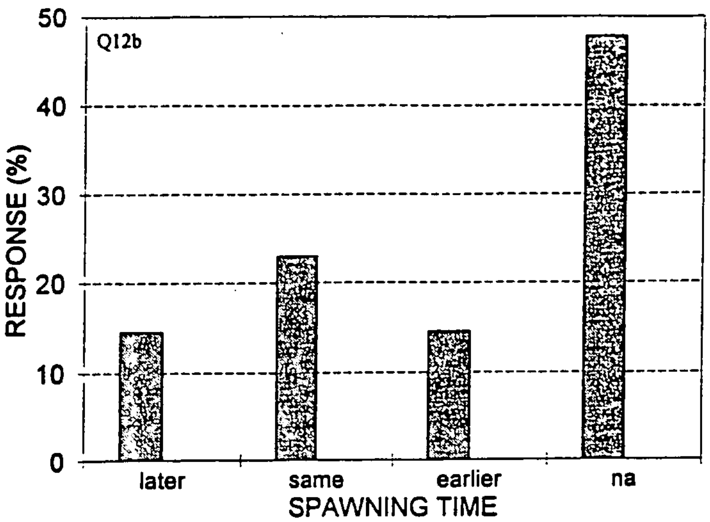


Fig. 14. The cessation of spawning in 1996 compared to 1995 in response to question 12b. No answer given (na).

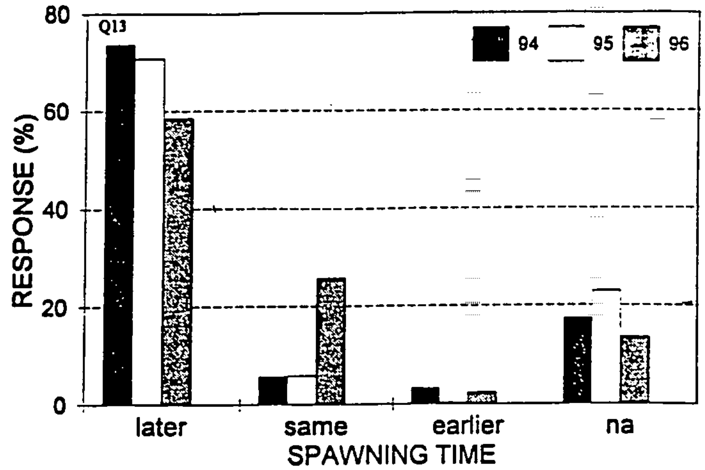


Fig. 15. Comparison of spawning times in 1994 (Nakashima 1995), 1995 (Nakashima 1996), and 1996 to when first started fishing. No answer given (na).

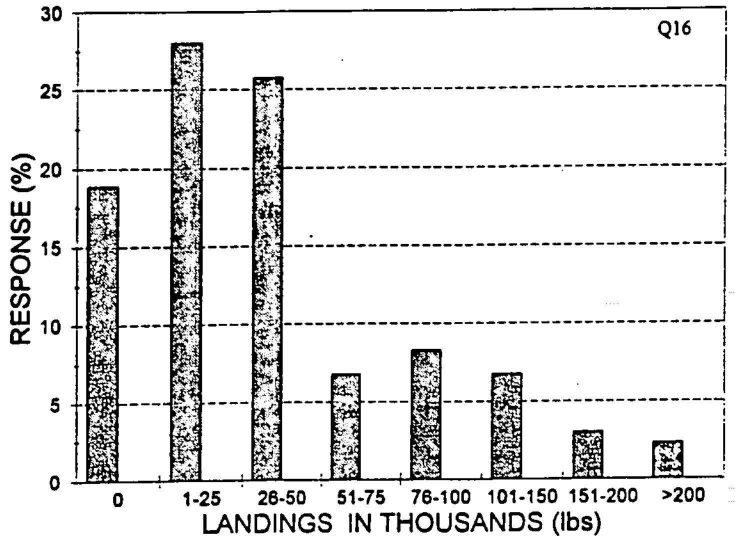


Fig. 16. Estimated landings in 1996 by respondents of question 16.

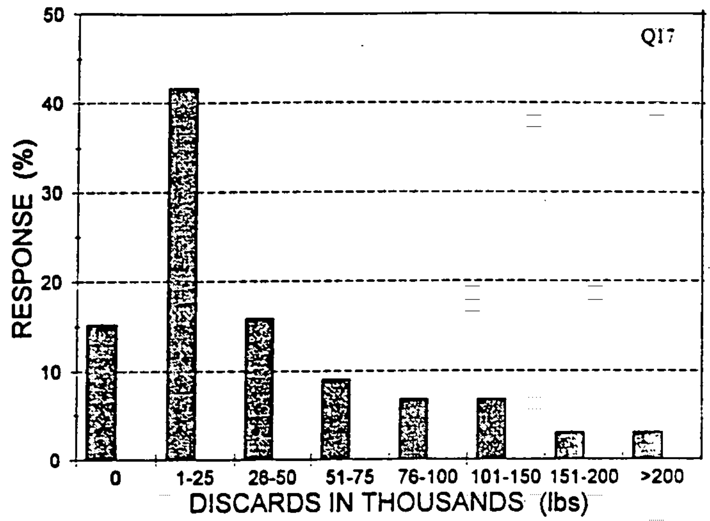


Fig. 17. Estimated discards in 1996 by respondents of question 17.

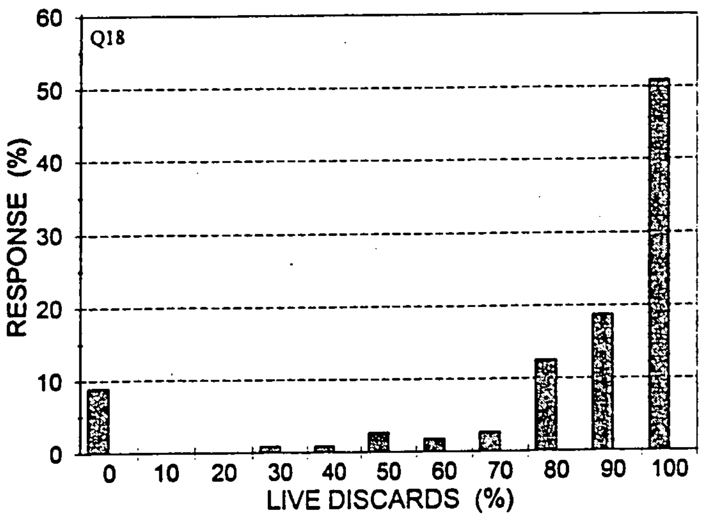


Fig. 18. Estimated survival of discarded capelin by respondent of question 18.

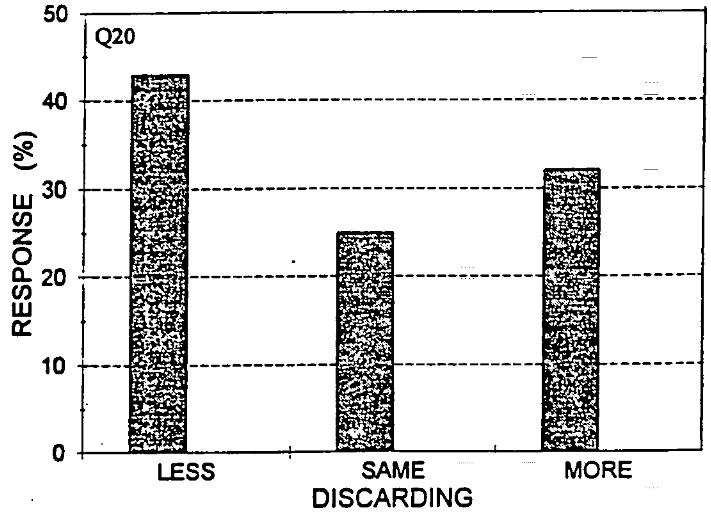


Fig. 19. Comparison of amount of discarding in 1996 compared to earlier years in response to question 20.

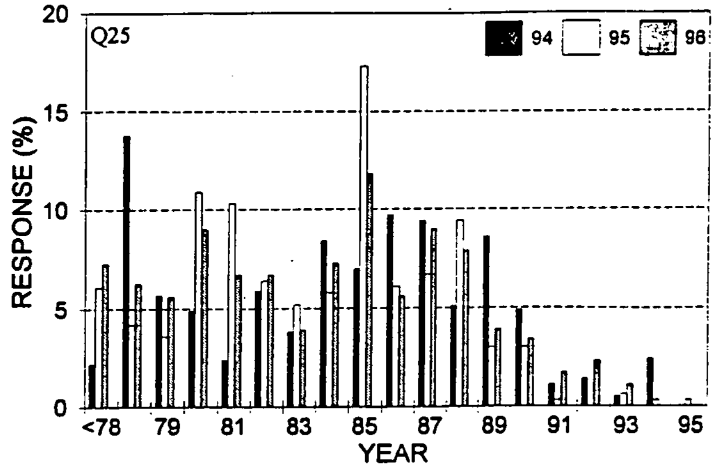


Fig. 20. Experience in the inshore capelin fishery.

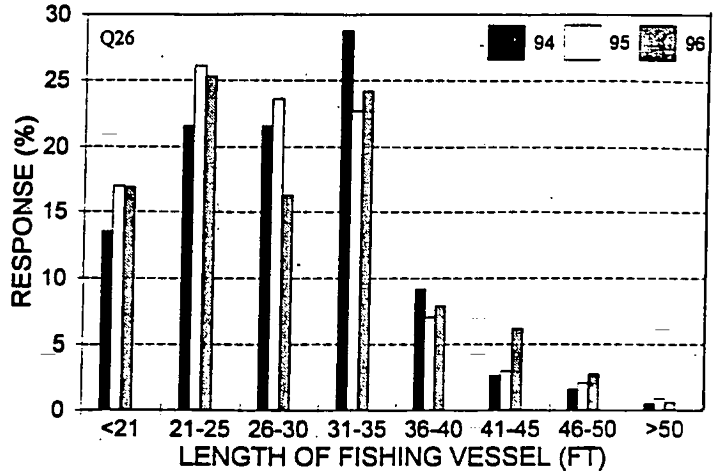


Fig. 21. Lengths of fishing vessels involved in the fixed gear fishery.

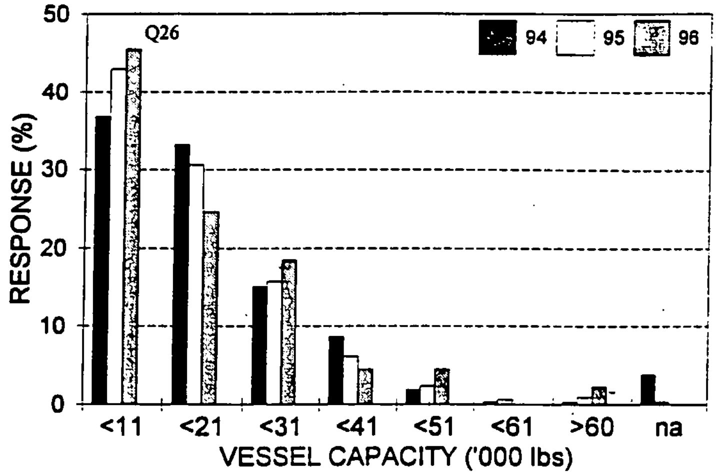


Fig. 22. Fishing vessel capacity for capelin. No answer given (na).

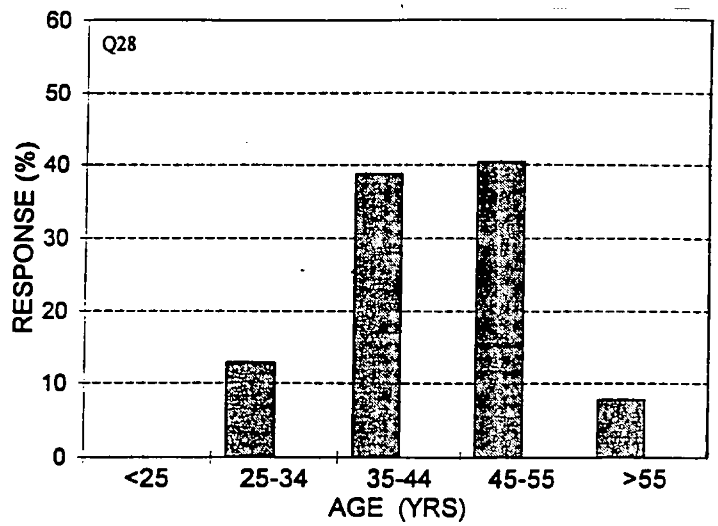


Fig. 23. Age range of capelin fishers in 1996.

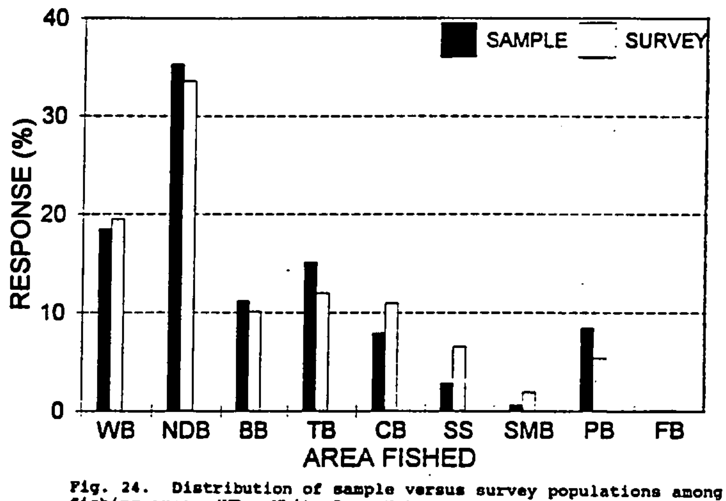


Fig. 24. Distribution of sample versus survey populations among fishing areas (WB = White Bay, Notre Dame Bay = NDB, BB = Bonavista Bay, TB = Trinity Bay, CB = Conception Bay, SS = Southern Shore, SMB = Trepassey and St. Mary's Bay, PB = Placentia Bay, FB = Fortune Bay).

The Inshore Fishery for Capelin (*Mallotus villosus*) in NAFO Div. 3KL in 1996

by

B. S. Nakashima
Science Branch
Department of Fisheries and Oceans
P. O. Box 5667
St. John's NF A1C 5X1

Introduction

Reported landings in 1996 were 23,556 t in Div. 2J3KL compared to a market-based quota allocation of 27,995 t (Table 1, Fig. 1). Samples from the commercial fishery provided biological information on the mature portion of the stock in 1996. Research logbooks were used to estimate catch and effort for mobile and fixed gear fisheries.

Materials and Methods

Commercial samples were collected by fishers and other reliable collectors. From each sample, length, sex, and maturity stage were measured on 200 fish and a stratified sample of 2 otoliths per sex per 1/2 cm length was taken for ageing.

Age compositions for Div. 3KL and mean lengths and weights for Div. 3K and 3L separately were estimated from commercial data. Samples were weighted by the landings per gear type (Table 1).

Research logbooks were mailed to 41 purse seine and 143 fixed gear licensed fishers residing in Div. 3KL. A few trap logbooks were completed by fishers who were involved in the monitoring programme. 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 1996 are presented in Appendix A. Monitoring programmes in all areas were set up to open the fishery when fish conformed to criteria defined in the 1996 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 1996. Areas were open to fishing for short periods during late June to early July (Appendix B). The reported landings for 1996 in Table 1 were higher than the previous two years but lower than the average (Fig. 1).

Biological Sampling

In 1996 73 commercial samples were processed throughout Div. 3KL (Table 2). The mean number of otolith pairs per sample was less in Div. 3K than in Div. 3L (Table 2).

The 1996 spawning biomass in numbers was dominated by the 1993 year-class as three-year-olds followed by the 1994 year-class as two-year-olds and the 1992 yearclass as four-year-olds (Table 3). These age compositions differ from those derived from beach samples (Nakashima and Winters 1997).

In Div. 3K the mean length at age 2 is higher than in 1995 (Fig. 2). For ages 3 and 4 there has been a slight increase in the mean length from 1995 to 1996 (Fig. 2). For all ages combined the mean length has increased but is still lower than in the 1980s.

In Div. 3L the mean lengths at age 2 have shown an increase between 1993 and 1996 (Fig. 3). For ages 3 and 4, mean lengths have shown little or no variation since 1992 (Fig. 3). For all ages combined, the decline seemed more severe during 1991 and 1992 followed by a small recovery but remains lower than in the 1980s (Fig. 3).

Age 2 females have contributed more to the spawning biomass than age 2 males especially since 1991 (Table 3). In most years, Div. 3L two-year-old females were smaller than Div. 3K females. This is true since 1991 when age 2 fish appear to have contributed more to the spawning stock and to the decline in overall mean size (all ages combined) of females in the population.

The sample mean weights are given in Table 4. For Div. 3K the sample mean weights-at-age are only available since 1984. Similar to length-at-age trends the weights-at-age have declined since 1991 for ages 3 and 4 but not for age 2 fish. The weights-at-age from research samples in 1996 indicate an increase between 1995 and 1996 for all ages in Div. 3K and an increase for ages 3 and 4 in Div. 3L.

Research Logbooks

The return rate of completed logbooks was lower than in previous years (Table 5). Discounting those who did not fish in 1996, 50% of fixed gear and 66% of mobile gear fishers returned research logbooks. Several reasons for the low return rate are possible. The inshore capelin fishery in 1996 was the first active fishery since 1993. Reminders to record information were sent in May, 1996 however this was inadequate. Many of the research logbook fishers had not been contacted in person for at least three years. Uncertainty over the fishery opening and problems with small size females in 1994-95 also contributed. The short season of a few days was another factor. To obtain a higher return rate we must reinstate frequent personal contact with fishers. Despite the response rate the information from the logbooks were of high quality and allowed us to examine catch and effort for the 1996 commercial fishery.

The main reasons for discarding capelin were low percentage of females and small size females in the catches (Table 6). In Notre Dame, Bonavista, Trinity, and St. Mary's Bays capelin were discarded from traps mostly because of low percentage of females (50-86%). The main reason for trap discards in the 'miscellaneous' category was bycatches of cod with capelin. For Conception Bay and the Southern Shore small females (54-100%) were the major problem. The level of redfeed was significant for traps and purse seines in White Bay. In most areas small females (47-93%) were the reason purse seine catches were released. Discarding in Conception Bay was due to plant quotas (62%) and to redfeed levels (38%).

Discarding as a percentage of reported landings varied among areas for traps (Table 7: 8-98%) and for purse seines (Table 8: 4-91%). The overall discarding rate of 54% for traps was the highest since 1987 and the rate of 30% for purse seines was higher than 1992 and 1993. The reported discards includes 49.1 t given away to other trap boats and 8.6 t given away to another seiner. According to the logbook reports 98 % of trap and 92% of purse seine discards were released alive at sea. This compares favourably with the response from the telephone survey (Nakashima 1997). In the present analysis (Tables 6-10) discards are defined as capelin caught but not landed by the fishers who caught them and includes both live and dead fish.

The average fishing effort for traps and purse seines was the lowest since data have been collected. Traps averaged 4.0 fishing days and were hauled 10.2 times (Table 9). Purse seines searched for 4.4 days and made 7.9 sets (Table 10). Few trap logbooks were returned from Notre Dame Bay, Southern Shore, and St. Mary's Bay.

The latter two have smaller fisher populations than found in Notre Dame Bay. Purse seine logbook data were highest in Trinity Bay and low elsewhere.

Catch/effort (CPUE) estimates were available since 1981 for traps and for purse seines (Tables 9 and 10). The 1996 trap CPUE of 9.7 t/day was the highest in the series and the 1996 estimate of 3.8 t/haul was comparable to 1991 and one of the highest in the series (Table 9). The 1996 purse seine CPUE of 17.1 t/day was comparable to the series average of 17.4 t/day from 1981-93 and the 1996 CPUE of 9.5 t/set was close to the series average of 10.0 t/day (Table 10).

Conclusions

An inshore commercial fishery occurred for the first time since 1993. The results from commercial sampling suggest that the spawning biomass in 1996 was comprised of age 2 and age 3 fish only, that the size at age of age 2 fish are higher than recent years, and ages 3 and 4 fish were small and indicative of poor growth in the early 1990s.

The 1996 trap CPUE was one of the highest in the series and the purse seine CPUE was similar to the series mean however fishing effort was the lowest since 1981. Trap days and purse seine searching time was less than 5 days in 1996. Discarding varied among areas and gear types. Discarding from traps was 54% and from purse seines it was 30%. Both were higher than in 1993. The main reasons for releasing capelin were low percentage of females and small females which were the same as expressed in the telephone survey (Nakashima 1997). The estimated landings of research logbook trap fishers was 33 t which was higher than the reported landings of 23 t by fixed gear fishers (trap and beach seine) in the telephone survey (Nakashima 1997). Total catch between the two surveys was 51 t for the research logbook survey and 45 t from the telephone survey (Nakashima 1997).

Acknowledgements

The inshore commercial sampling programme was organized by P. J. Williams. Samples were processed by the technical staff of the Pelagic Fish Section. Otoliths were aged by P. G. Eustace. M. Y. Rees assisted in the preparation of the manuscript.

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.

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

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.

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
1987	**2J**		**0**	**4**	**0**		**4**
		WB	619	193	2719		3531
		NDB	1948	1539	1948		5435
	3K		**2567**	**1732**	**4667**		**8966**
		BB	2154	76	2179		4409
		TB	1982	88	6973		9043
		CB	1382	79	3127		4588
		SS	106	32	631		769
		SMB	673	0	0		673
	3L		**6297**	**275**	**12910**		**19482**
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**

Table 1. Continued ...

Year	Div.	Area	Purse seine	Beach seine	Trap	Dipnet	Total
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**
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		**0**	**0**	**7**	**0**	**7**
		WB	844	1	2764	0	3609
		NDB	1212	1085	1700	0	3997
	3K		**2056**	**1086**	**4464**	**0**	**7606**
		BB	1178	0	1825	0	3003
		TB	1896	31	3001	1	4929
		CB	3189	14	3067	0	6270
		SS	8	0	81	0	89
		SMB	1101	16	535	0	1652
	3L		**7372**	**61**	**8509**	**1**	**15943**

* provisional

Table 2. Summary of inshore commercial samples processed and aged from 1996 in Div. 3KL.

Gear type	No. of LSM/strat. samples	No. of otoliths aged (N)	Mean no. otoliths ± SD per sample
Div. 3K			
Purse seine	9	261	29.0 ± 3.5
Capelin trap	17	475	27.9 ± 5.1
Beach seine	7	197	28.1 ± 2.7
TOTAL	33	933	
Div. 3L			
Purse seine	14	465	33.2 ± 2.9
Capelin trap	24	715	29.8 ± 3.3
Beach seine	2	58	29.0 ± 1.4
TOTAL	40	1238	

Table 3. Age compositions (%) of capelin from the inshore commercial capelin fishery, Div. 3KL. Data available from Div. 3L only in 1979-81.

Year/Sex	Age 2	3	4	5	6
Males					
1979	0	47.6	36.3	15.1	0.9
1980	0	39.0	57.8	2.9	0.3
1981	0	28.3	40.2	29.7	1.9
1982	+	90.5	8.7	0.7	+
1983	0.3	60.8	38.5	0.3	0
1984	0.3	36.0	62.9	0.8	0
1985	4.9	65.4	27.9	1.7	+
1986	0.2	56.7	42.5	0.5	0
1987	0.2	11.4	86.8	1.5	0
1988	3.7	70.2	23.1	3.0	0
1989	0.3	76.8	22.8	0.1	0
1990	0.4	33.6	65.7	0.2	0
1991	9.2	47.8	41.6	1.4	+
1992	7.9	81.4	10.5	0.2	0
1993	5.9	88.4	5.6	0.1	0
1994[a]	23.8	56.7	19.5	0	0
1995[b]	34.7	63.4	1.9	0	0
1996	25.0	73.4	1.5	0	0
Females					
1979	0.8	59.1	25.4	11.3	3.4
1980	0.3	41.1	58.3	0.2	0.1
1981	+	38.7	31.4	28.9	1.1
1982	1.5	77.9	12.4	6.4	1.8
1983	5.8	58.8	33.4	2.0	+
1984	2.6	41.0	48.0	8.1	0.3
1985	13.4	57.3	18.5	10.3	0.5
1986	0.2	65.5	29.5	3.7	1.1
1987	4.8	19.1	67.1	8.5	0.4
1988	11.6	51.8	12.1	23.0	1.5
1989	1.3	70.7	23.4	2.0	2.6
1990	1.4	44.1	51.9	2.5	+
1991	12.6	49.5	29.4	8.4	0.1
1992	17.6	67.8	12.9	1.7	+
1993	10.4	82.1	7.3	0.2	+
1994[a]	33.4	43.1	19.7	3.8	0
1995[b]	55.8	37.3	6.4	0.4	0.1
1996	33.3	58.1	8.5	0.2	0
Sexes combined					
1979	0.2	50.3	33.8	14.2	1.5
1980	0.2	40.4	58.1	1.1	0.2
1981	0	34.6	34.7	29.2	1.4
1982	0.7	84.6	10.5	3.4	0.8
1983	3.3	59.7	35.7	1.3	+
1984	1.5	38.6	55.2	4.5	0.2
1985	10.1	60.4	22.1	7.0	0.4
1986	0.2	62.1	34.5	2.5	0.7
1987	2.9	15.9	75.5	5.5	0.2
1988	8.4	59.1	16.5	15.1	0.9
1989	0.8	73.5	23.1	1.2	1.4
1990	1.0	39.7	57.8	1.5	+
1991	11.1	48.8	34.5	5.5	0.1
1992	13.3	73.9	11.8	1.0	+
1993	8.5	84.8	6.6	0.1	+
1994[a]	31.1	46.3	19.7	2.9	0
1995[b]	43.7	52.3	3.8	0.2	0
1996	29.9	64.4	5.6	0.1	0

[a] low sample numbers (N = 11) and from a small area
[b] research samples, no commercial samples collected

Table 4. Mean weights-at-age (gm) from commercial samples in Div. 3K and Div. 3L, sexes combined.

Year	Age 2	3	4	5	6	All
Div. 3K						
1984	14.7	30.5	37.0	34.5	32.3	35.0
1985	15.3	26.3	34.1	31.7	33.6	29.2
1986	11.3	27.4	34.4	32.9	35.3	30.1
1987	17.0	30.7	37.9	34.8	35.8	36.8
1988	17.2	31.2	42.6	36.4	38.9	34.1
1989	14.5	31.3	38.2	36.9	38.8	33.2
1990	16.4	26.1	32.6	31.3		30.2
1991	18.9	23.1	27.2	26.4	31.7	24.8
1992	15.7	25.0	27.4	26.7	37.5	24.6
1993	20.1	24.5	29.4	30.5		29.2
1994	18.1	29.9	32.9	30.4		30.5
1995*	15.2	23.1	25.3	29.5	31.3	20.9
1996	22.7	25.6	25.4	27.0	27.7	25.2
Div. 3L						
1981	7.8	22.3	29.8	32.3	36.4	28.1
1982	12.6	32.5	37.0	37.2	39.9	33.0
1983	13.9	27.7	33.8	34.0	27.6	29.1
1984	13.9	27.6	34.7	30.5	33.6	31.3
1985	12.0	25.4	35.9	32.6	33.1	26.7
1986	18.0	26.2	34.2	33.7	36.8	29.1
1987	14.2	27.4	36.3	33.5	38.1	33.1
1988	14.3	29.9	39.6	36.4	38.8	30.7
1989	14.5	29.3	36.5	36.6	37.9	30.8
1990	16.0	25.4	32.7	32.1	37.1	29.2
1991	12.6	21.2	29.2	27.8	35.7	22.6
1992	12.9	18.7	25.2	25.0		17.1
1993	15.0	24.1	25.7	27.8	28.5	23.5
1994	16.8	23.8	27.7	28.1		22.4
1995*	18.3	25.2	24.2	25.9		21.8
1996	19.8	24.3	24.4	30.9		22.6

* from research samples only

Table 5. The distribution of research logbooks in 1996.

NAFO Div.	Gear type	No. of fishers	No. returned	No. never fished	No logbook
3K	Mobile	18	9	6	3
	Fixed	46	15	10	21
3L	Mobile	23	14	0	9
	Fixed	97	45	12	40

Table 6. Percent contribution by weight of reasons for discarding capelin in 1996. This analysis excludes capelin given to other fishers.

Area	Redfeed	Low % females	Small females	Males picked out	Females spawned out	No market/ quota filled	Misc.	Not given
Traps:								
White Bay	43	30	23	+	0	4	+	0
Notre Dame Bay	0	86	+	0	0	0	14	0
Bonavista Bay	3	50	18	0	2	3	24	0
Trinity Bay	6	75	8	0	0	0	11	0
Conception Bay	0	5	54	0	21	15	4	0
Southern Shore	0	0	100	0	0	0	0	0
St. Mary's Bay	0	96	0	0	0	0	0	4
Purse seine:								
White Bay	75	0	25	0	0	0	0	0
Notre Dame Bay	0	32	47	0	12	0	9	0
Bonavista Bay	0	0	54	0	0	36	10	0
Trinity Bay	0	0	85	0	0	15	0	0
Conception Bay	38	0	0	0	0	62	0	0
St. Mary's Bay	0	0	93	0	0	0	7	0

Table 7. Capelin landings (t), discards (t), and catch/effort from research logbook records for capelin traps in Div. 3KL in 1996.

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	10	13	440.0	388.2	7.0	+	104.2	201	7.9	4.1
Notre Dame Bay	2	2	20.2	1.6	0.7	0	6.6	20	3.3	1.1
Bonavista Bay	12	15	451.1	246.9	47.7	+	55.2	162	12.6	4.3
Trinity Bay	12	18	349.7	81.4	18.5	3.6	56.1	193	7.7	2.2
Conception Bay	12	16	384.1	67.8	+	0	32.8	82	13.8	5.5
Southern Shore	1	1	0	72.3	+	0	7.4	12	9.8	6.0
St. Mary's Bay	3	3	74.3	72.6	0	0	12.1	22	12.1	6.7

Table 8. Capelin landings (t), discards (t), bycatch (t), and catch/effort compiled from research logbooks for purse seines in Div. 3KL in 1996.

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	5	189.4	172.4	22	34	16.4	10.6
Notre Dame Bay	9	198.2	67.7	17	31	15.6	8.6
Bonavista Bay	3	118.8	46.3	4	17	41.3	9.7
Trinity Bay	15	170.4	67.6	24	40	9.9	6.0
Conception Bay	8	470.0	18.1	21	39	23.2	12.5
Southern Shore	0	-	-	-	-	-	-
St. Mary's Bay	6	181.1	24.5	13	20	15.8	10.3

* includes capelin given to other fishers

Table 9. Capelin landings (t), discards (t), bycatch (t), and catch/effort from research logbook records for capelin traps in Div. 3KL, 1981-93, 1996. 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	5.8	0	577	680	2.9	2.5
1982	60	81	4366.5	605.2	60.4	0	1630	1996	3.1	2.5
1983	50	71	3051.2	1338.0	23.6	32.8	1277	1460	3.4	3.0
1984	67	89	4172.5	634.1	48.3	1.8	1615	2442	3.0	2.0
1985	60	80	3011.3	1850.1	31.0	0.1	1108	1508	4.4	3.2
1986	64	91	5056.4	1436.4	17.8	0.4	1567	2095	4.8	3.6
1987	68	93	3150.6	2437.5	11.8	0	622	1104	9.0	5.1
1988	86	125	6792.6	1500.4	28.0	0.2	1353	2415	6.1	3.4
1989	102	154	6275.8	2188.1	53.0	+	1314	2431	6.4	3.5
1990	106	167	5538.1	2986.6	100.4	0.7	1041	1825	9.2	5.3
1991	59	76	2793.0	1187.5	23.7	1.4	860	1325	5.9	3.8
1992	28	34	1225.8	567.1	1.5	5.76	297	666	6.0	2.7
1993	59	78	2261.1	297.0	52.3	10.7	400	863	6.4	3.0
1996	52	68	1719.4	930.8	73.9	3.6	274	692	9.7	3.8

Table 10. Capelin landings (t), discards (t), and catch/effort from research logbook records for purse seines in Div. 3KL, 1981-93, 1996.

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

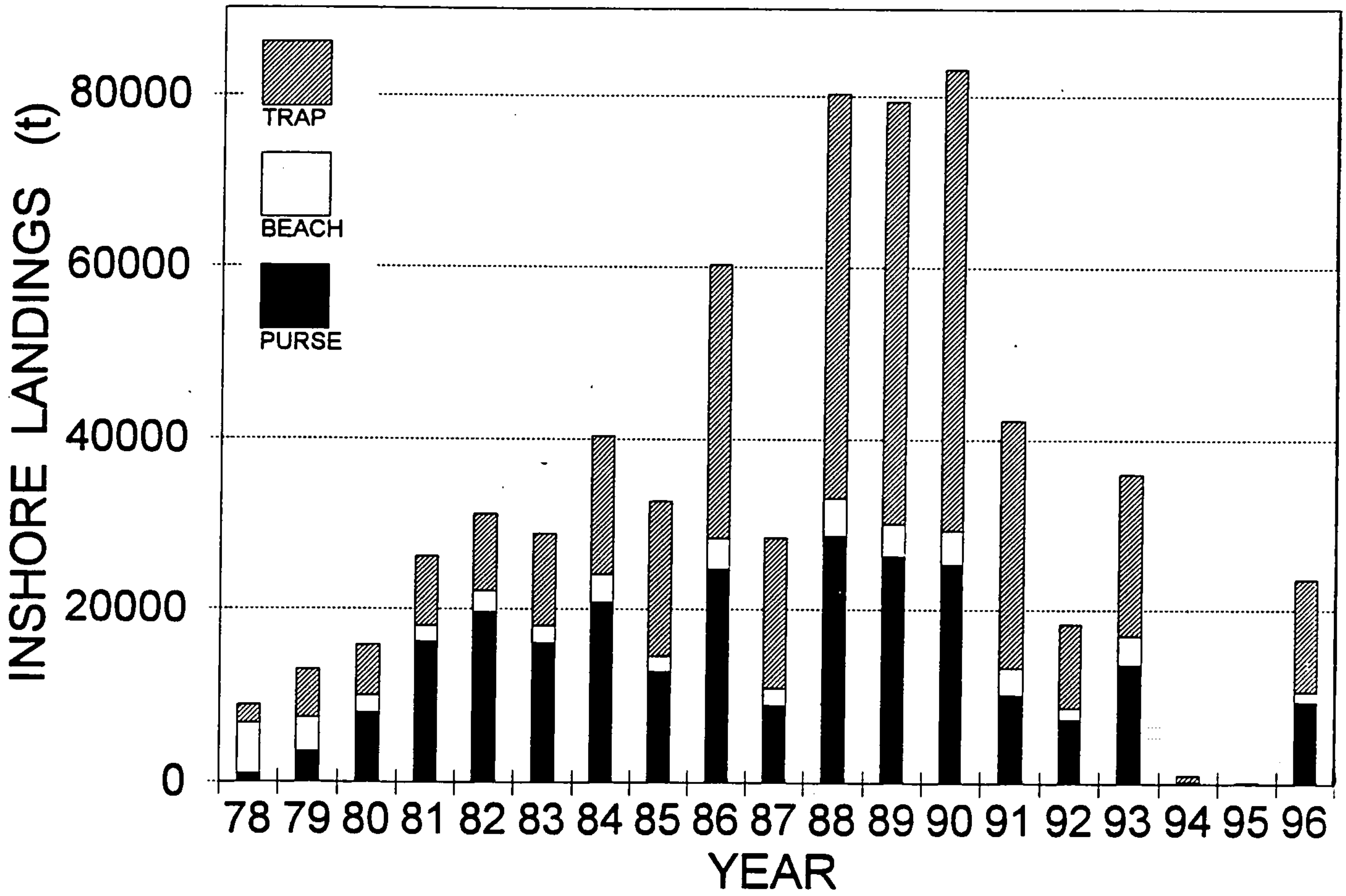


Fig. 1. Inshore capelin landings (t) in Div. 3KL.

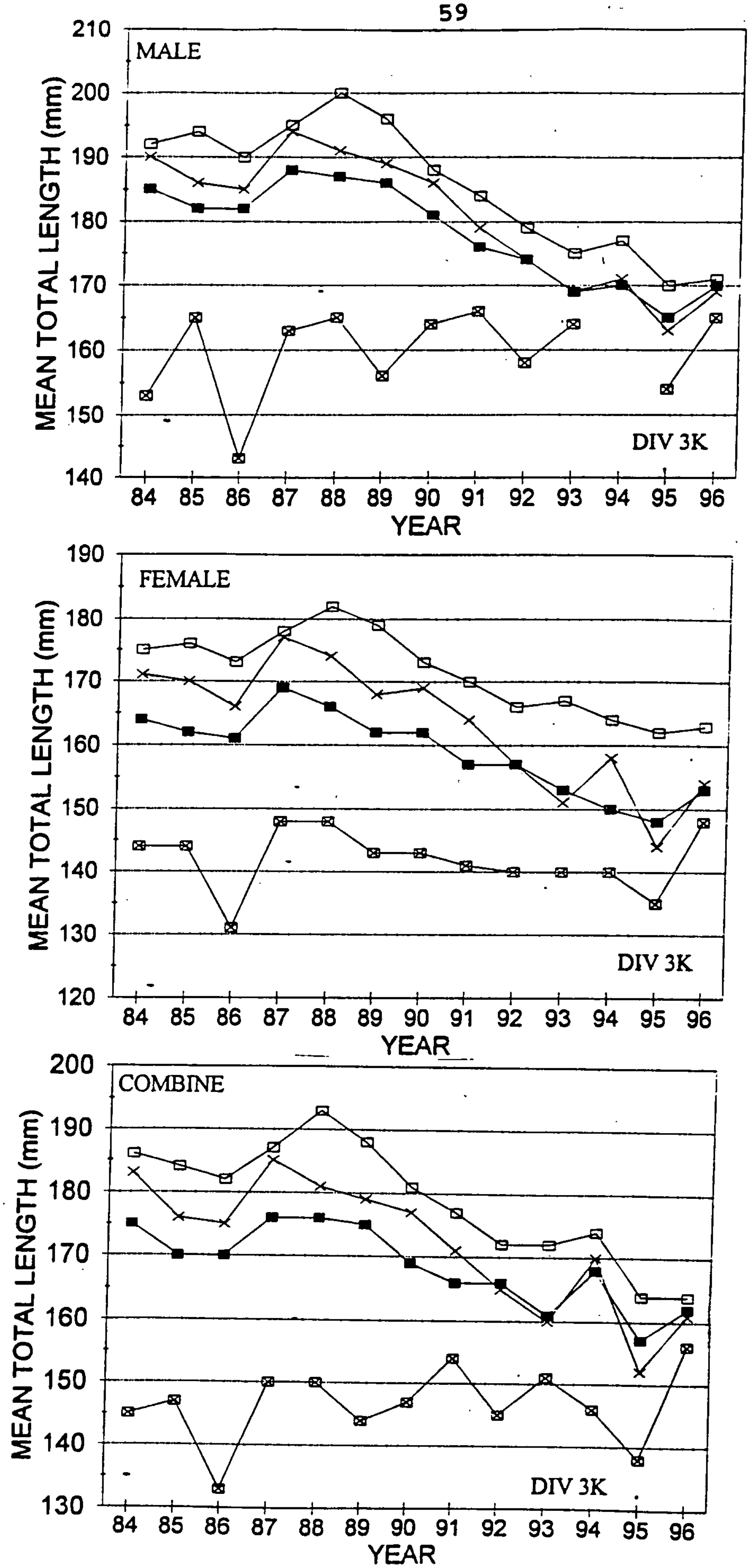


Fig. 2. Mean total length-at-age for age 2 (⊠), age 3 (■), age 4 (□), and all ages (X) for males, females, and sexes combined in Div. 3K.

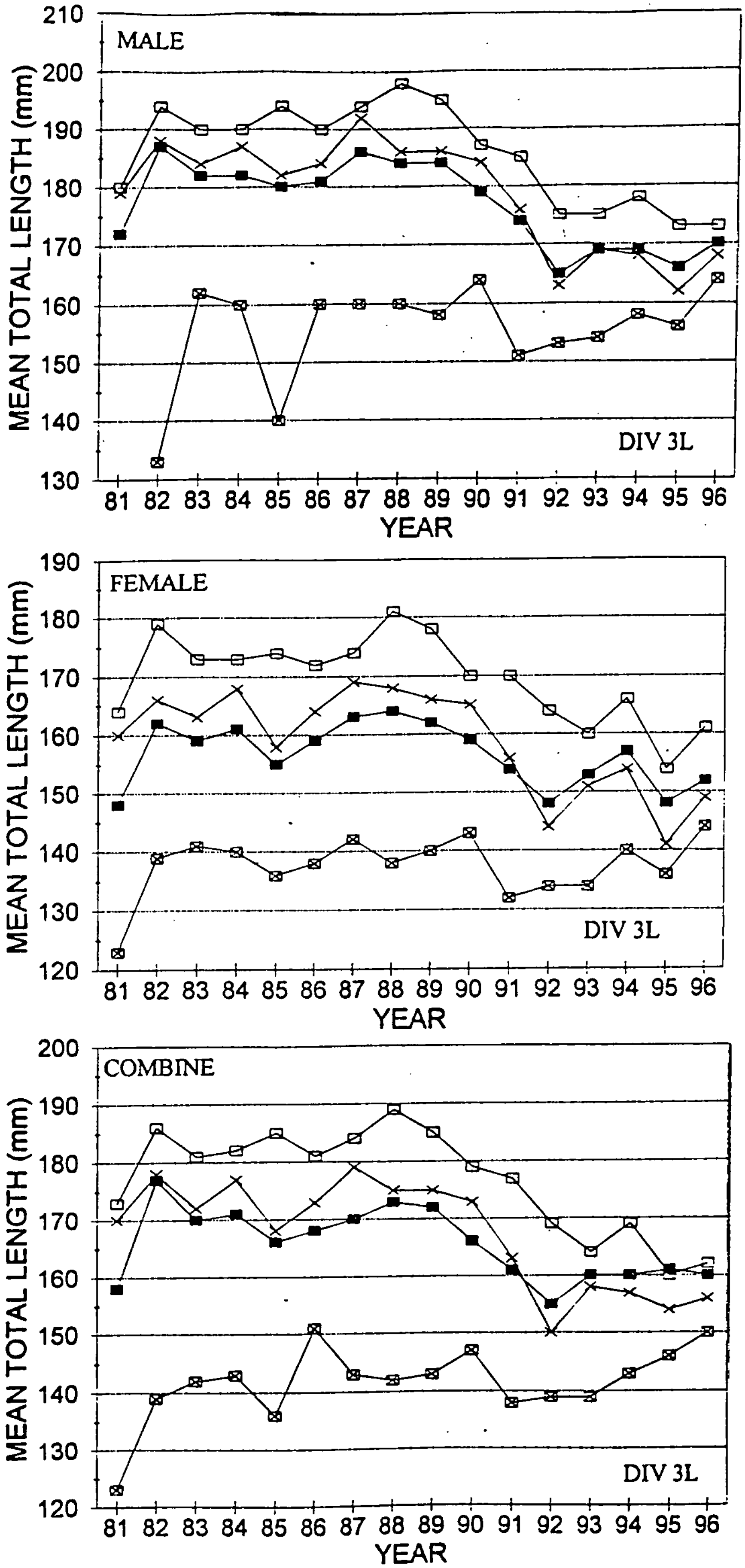


Fig. 3. Mean total length-at-age for age 2 (⊠), age 3 (■), age 4 (□), and all ages (X) for males, females, and sexes combined in Div. 3L.

Appendix A

1996 Capelin Allocations

NAFO Area	Coastal Area	Quotas (tonnes) Fixed Gear	Purse Seine	Total
2J	Labrador	125	....	125
3K	White Bay	3,765	1,260	5,025
	Notre Dame Bay	3,300	1,260	4,560
	Totals - 3K	7,065	2,520	9,585
3L	Bonavista Bay	1,890	1,200	3,090
	Trinity Bay	3,775	1,575	5,350
	Conception Bay	3,120	2,835	5,955
	Southern Shore	1,935	160	2,095
	St. Mary's Bay	380	1,415	1,795
	Totals - 3L	11,100	7,185	18,285

1996 Capelin Quotas - Fixed Gear Sub-divisions

Area	Sub-division	Quota
White Bay	Cape Bauld to Fischot Island	810
	Fischot Island to Cape Fox	275
	Cape Fox to Hampden, inclusive	1,070
	Bottom of Bay to Cape St. John	1,610
Notre Dame Bay	Cape St. John to North Head	930
	North Head to Dog Bay Point	1,935
	Dog Bay Point to Cape Freels	435
Southern Shore	Cape St. Francis to Long Point	505
	Long Point to Cape Neddick	335
	Cape Neddick to Cape Pine	1,095

Appendix B

1996 Opening and Closing Dates

<u>Mobile Gear</u>

St. Mary's Bay - June 26-27, July 1-4

Conception Bay - July 3-5

Trinity Bay - July 1-2

Bonavista Bay - July 5-6

Notre Dame Bay - June 24-25, July 10-11

White Bay - June 24-25, June 28-July 8

<u>Fixed Gear</u>

St. Mary's Bay - June 28-29

Southern Shore:
- Cape St. Francis to Long Point - July 1-12
- Long Point to Cape Neddick - July 4-12
- Cape Neddick to Cape Pine - June 29-July 12

Conception Bay - July 6-8

Trinity Bay - July 1-4

Bonavista Bay - July 4-8

Notre Dame Bay:
- Cape St. John to Dog Bay Point - June 24-25
- Cape St. John to North Head - July 2-5
- North Head to Dog Bay Point - July 3-16
- Dog Bay Point to Cape Freels - July 8-11

White Bay:
- Fischot Island to Cape Fox - July 2-9
- Cape Fox to Hampden - June 28-July 6
- Hampden to Cape St. John - June 25-26, June 28-July 5

Results of the 1996 Aerial Survey of Capelin (Mallotus villosus) Schools

by

B. S. Nakashima
Science Branch
Department of Fisheries and Oceans
P. O. Box 5667
St. John's NF A1C 5X1

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). Since 1990 school areas have been estimated from digital imagery data collected with the Compact Airborne Spectrographic Imager (CASI). The digital images collected using the CASI and processed by image classification techniques are generally easier to interpret than aerial photographs (Nakashima et al. 1989, Borstad et al. 1990, Borstad et al. 1992). This report presents the results of the 1996 CASI aerial survey.

Materials and Methods

Instrument Operation

The CASI is an imaging spectrometer which uses a two dimensional (612 x 288) charge couple device (CCD) and a diffraction grating to collect image and spectral data. The CASI operates in the range of 423-946 nm. A 512 pixel width spatial image is formed in "pushbroom" fashion by reading out the cross track information as the aircraft moves forward. The remaining elements are used to obtain dark and electronic offset reference values. Integration times are a function of ambient light levels, aircraft speed, altitude, and band selections.

In spatial or imaging mode the CASI operates like other pushbroom imagers except that band widths, positions and number are programmable during the flight. High spatial resolution imagery is collected in several spectral bands which can be programmed as narrow as 1.8 nm or wider. Different spectral band widths were used for overcast days and for sunny days:

Light condition	Band widths			
	1	2	3	4
Overcast	450-510	525-591	640-691	735-755
Sunny	476-501	525-590	651-671	744-755

These bands selections have been used since 1993.

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 CASI surveys was 1220 m to obtain a swath width comparable to aerial photographs taken at 457 m. The survey time was divided into two segments (Table 1) to allow four days in mid-July in case more schools arrived nearshore. The survey covered three transects as often as possible; the inside of Trinity Bay from Masters Head to Hopeall Head, the outside of Conception Bay from Bay de Verde to Harbour Grace Islands, and the inside of Conception Bay from Bryant's Cove to Portugal Cove (Fig. 1).

During each flight capelin schools were detected by experienced spotters prior to digital recording of the area. If there was any doubt as to the presence of schools imagery was collected and examined later.

Analytical Methods

CASI imagery data were transferred to a PC-based image processor for classification and analysis. Data were calibrated and set up as PCI image files. An algorithm, first tested in 1989 to estimate school areas from the digital survey data (Borstad et al. 1990), was used to analyze the data. Schools on the imagery were identified by an experienced observer. 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 was estimated by summing the highest total school surface area observed on each of the three transects. 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 best estimates of the true survey time.

Results and Discussion

In 1996, the aerial survey provided infrequent coverage of both Conception Bay transects and Trinity Bay. Flights were made in Trinity Bay three times (Table 2a), along the outside transect of Conception Bay two times (Table 2b), and the inside of Conception Bay two times (Table 2c). The number of hours flown in 1996 was the lowest since 1991. Nine days (June 27-28, July 1-7) were not flown because of poor weather conditions. Technical problems with the instrument resulted in no digital data collections on June 25-26 and 29-30.

In Trinity Bay the highest school area estimate was observed on July 13, similar to 1994-95 (Table 2a). This time also corresponds to the peak period (July 9-13) of egg deposition on Bellevue Beach (Fig. 1) (Nakashima and Winters, unpub. data). In Conception Bay the highest total for both transects occurred on July 8 (Tables 2b, c) which was the same as in 1995. However due to weather and instrument problems we were unable to estimate school areas during the late June-early July period when spawning occurred in Conception Bay. Estimates then may have been higher than for July 8. For daily estimates prior to 1991 see Nakashima (1995). The total school surface area for 1996, taken from the highest estimates in Conception and Trinity Bays, was 837,136 m^2 which is the highest in the series (Table 3, Fig. 2). The estimate in Trinity Bay was the highest since 1982 and the total school area estimate in Conception Bay was higher than the long-term geometric mean of 230,378 m^2 excluding the 1991 estimate (Table 3, Fig. 2).

Several assumptions are made 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 be detected as they move close to the 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 always true (eg. Nakashima and Winters 1996). Using school area as a relative abundance index assumes density is related to surface area. Misund et al. (1992) have shown that herring, sprat, and saithe biomasses are correlated to school area and to school volume. No data exist to test this assumption for capelin however a study began in 1996 to investigate the relationship between school colour and acoustic density (D. S. Miller, pers. comm.).

Acknowledgments

The CASI data were collected by Geomatic Technologies Incorporated, St. John's, Nfld. School counts and area measurements were completed by Borstad Associates Ltd., Sidney, B.C. I am especially grateful to R. Linehan for assistance during the flights. M. Y. Rees assisted in the preparation of the manuscript.

References

Borstad, G. A., D. A. Hill, R. C. Kerr, and L. R. Armstrong. 1990. Development of a digital survey technique for operational aerial surveys of spawning capelin. Contract No. XA988-00115-(021) for the Dept. Fisheries and Oceans. 46 p.

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.

1995. Results of the 1994 CASI aerial survey of capelin (Mallotus villosus) schools. pp. 47-62. In: Capelin in SA2 + Div. 3KL. Anon. DFO Atl. Fish. Res. Doc. 95/70.

1996. Results of the 1995 CASI aerial survey of capelin (Mallotus villosus) schools. pp. 50-60. In: Capelin in SA2 + Div. 3KL. Anon. DFO Atl. Fish. Res. Doc. 96/90.

Nakashima, B. S., G. A. Borstad, D. A. Hill, and R. C. Kerr. 1989. Remote sensing of fish schools: early results from a digital imaging spectrometer. pp. 2044-2047. In: Proc. of IGARSS '89, 12th. Canadian Symposium on Remote Sensing, Vancouver, B.C., July 10-14, 1989.

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.

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	Wild RC 10	Jun 19-Jul 9	460	25.9
1984	Cessna 310	Wild RC 10	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	Zeiss RMK	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	Zeiss RMK	Jun 16-27 Jun 30-Jul 4	435-730	26.0
1990	Piper Aztec	Zeiss RMK CASI	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

Table 2a. 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)			Survey time (hr)
				Mean	SD	Median	
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

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

Table 2b. Schooling data for the outside of Conception Bay from Bay de Verde to Harbour Grace Islands.

Date		No. of schools	Surface total area (m^2)	School size (m^2) Mean	SD	Median	Survey time (hr)
1991	Jun 23	0	0				0.5
	Jun 24	0	0				1.1
	Jul 14	11	6374	579	2789	520	0.6
1992	Jun 30	5	27150	5430	4668	2629	0.5
	Jul 5	32	49308	1541	3383	558	1.5
	Jul 9	45	135723	3016	6069	883	1.9
	Jul 13	72	225838	3137	5026	1101	1.6
1993	Jul 2	6	CASI data unavailable				0.7
	Jul 4	13	CASI data unavailable				1.3
	Jul 11	30	30130	1560	4118[a]	239	0.9
	Jul 13	61	77202	1746	6014[a]	299	1.5
	Jul 15	54	32321	621	803[a]	239	1.5
	Jul 21	26	23598	908	1536[a]	1041	0.8
	Jul 27	20	8095	405	271	276	1.0
	Jul 28	21	27540	1311	1225	783	1.0
1994	Jul 2	2	CASI data unavailable				0.3
	Jul 8	17	27299	1606	2249	643	1.2
	Jul 10	16	11500	719	596	595	0.8
	Jul 12	19	25046	1318	2427	746	1.0
	Jul 16	16	28339	1771	1774	1223	0.9
	Jul 18	1	2449	2449	1	2449	0.4
1995	Jul 7	37	47371	1280	2791	573	1.4
	Jul 9	9	18917	2102	2174	1381	1.2
	Jul 13	19	126070	6635	12020	3282	1.0
	Jul 21	31	41566	1341	1981	536	1.7
1996	Jul 9	65	77650	1138	1494[a]	543	1.2
	Jul 16	3	1283	428	415	220	1.2

[a] calculation excludes capelin in traps

Table 2c. Schooling data for the inside of Conception Bay from Harbour Grace Islands to Portugal Cove.

	Date	No. of schools	Surface total area (m²)	School size (m²)			Survey time (hr)
				Mean	SD	Median	
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

[a] calculation excludes capelin in traps

Table 3. School surface area (m^2) index for Trinity Bay, Conception Bay, and the total of the two bays.

Year	Trinity Bay	Conception Bay	Total
1982	62,397	157,791	220,188
1983	199,373	149,433	348,806
1984	43,245	129,847	173,092
1985	195,659	112,394	308,053
1986	95,898	164,029	259,927
1987	399,026	318,506	717,532
1988	112,863	289,176	402,039
1989	84,349	454,189	538,538
1990	141,122	217,502	358,624
1991	(170,681)*	(21,951)*	(192,632)*
1992	173,219	374,467	547,686
1993	58,786**	276,170	334,956
1994	539,207	123,972	663,179
1995	330,010	227,441	557,451
1996	562,977	274,159	837,136

* The survey in 1991 was over before inshore spawning had begun.
** Underestimate-spawning in August was missed.

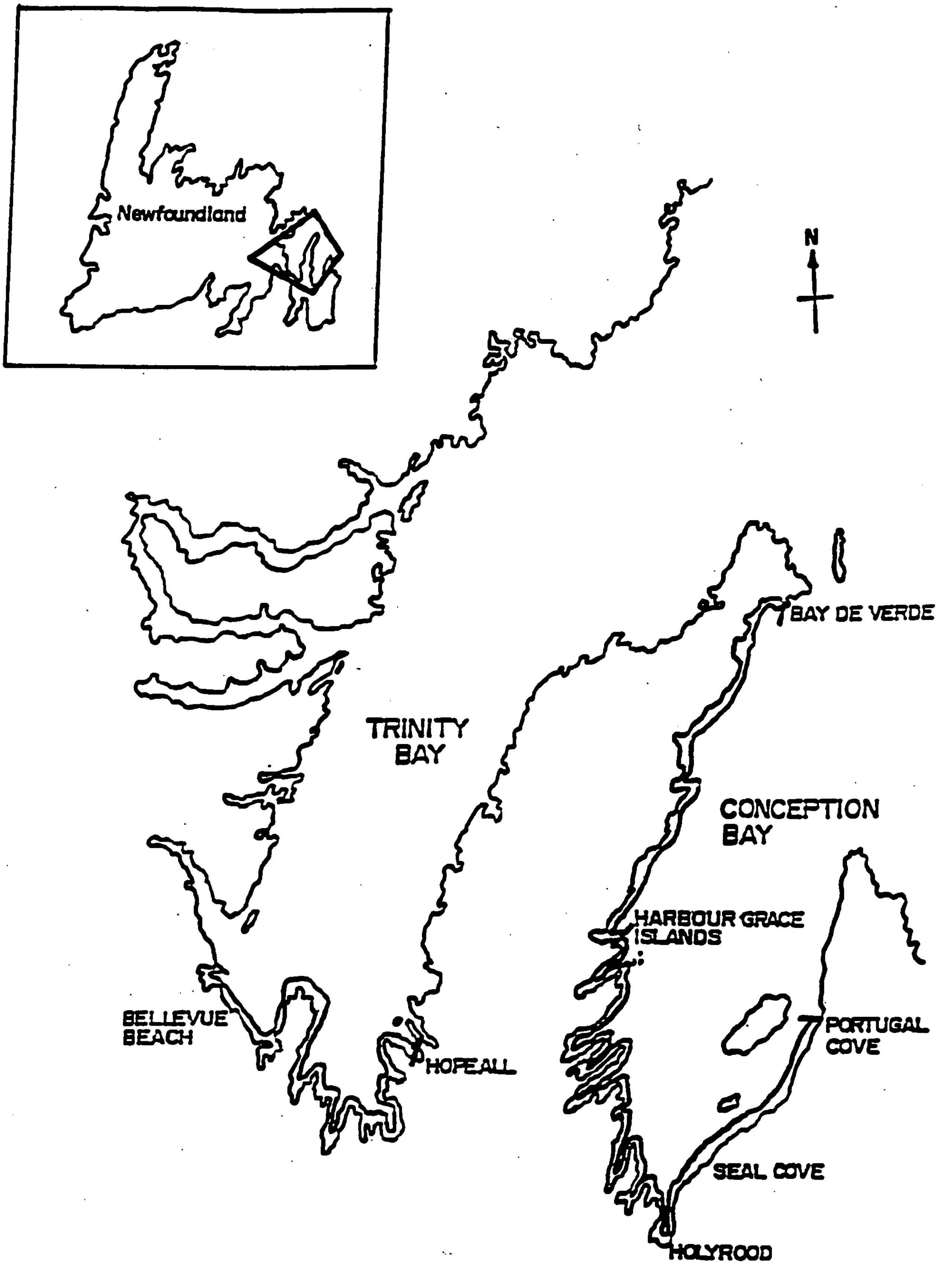


Fig. 1. Transects flown during the aerial survey.

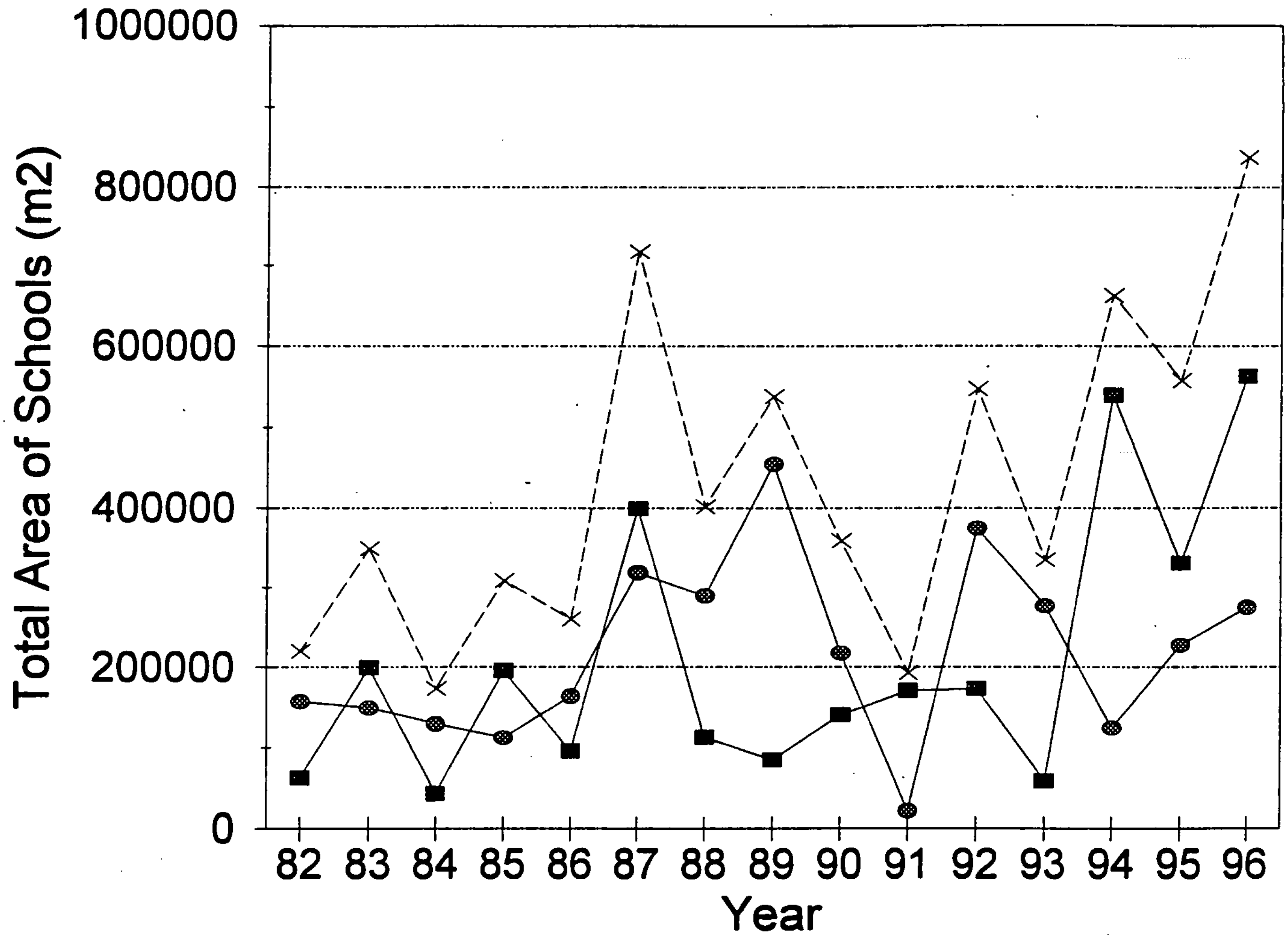


Fig. 2. Trends in school surface area index for Trinity Bay (■), Conception Bay (□), and combined (x).

Egg and Larval Production from Bellevue Beach, Trinity Bay in 1996

by

B. S. Nakashima and G. H. Winters
Science Branch
Department of Fisheries and Oceans
P. O. Box 5667
St. John's NF A1C 5X1

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). The number of sites was reduced in 1995 to Chapels Cove and Bellevue Beach. In this report we present information on age compositions, fish lengths, spawning times, egg deposition, and larval estimates in 1996 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. 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 every time substantial spawning had occurred and 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 24-36 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 at least 50 eggs were placed in Stockard's Solution (Bonnet 1939) to fix and clear the eggs. Stages I-II which include eggs from fertilization to the formation of the blastula accounts for egg development up to the first 36 hrs at 7.2°C according to Fridgeirsson (1976).

Newly emerging larvae were collected in the intertidal zone at high tide water conditions generally twice a day. A 165 Tm plankton net was towed for 40 m parallel to the beach, rinsed, and the contents preserved in 4% formalin and seawater solution buffered with sodium borate. Two tows were conducted each time. Both samples were counted if the sample size had at least 5000 larvae otherwise one sample was processed. Larvae were categorized into 'good' and 'bad' condition larvae based on visual inspection. Larval density was expressed as larvae per m^3.

Trapezoidal Integration and Normalization

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

$$\Sigma\ (t_n - t_{n-1})\ \tfrac{1}{2}\ [X(t_n) + X(t_{n-1})]$$

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 larval production per unit area was estimated using the trapezoidal integration method.

The daily average density of emergent larvae was assumed to be the mean of the two high tide estimates. Total larval density per m^3 was then estimated using the trapezoidal integration method. In Table 2 of Nakashima and Winters (1996) the estimates for emergent larvae were in numbers per tow and have been corrected in this report.

Results and Discussion

Age Composition

Age compositions of spawning fish from 1990 to 1996 indicate that age 3 fish dominated in all years except in 1991 and 1992 when age 4 had the highest proportion (Table 1). Our age composition data show that the spawning population consisted mainly of the 1993 yearclass followed by the 1992 yearclass. The 1994 yearclass represented 9% of the overall mature population (Table 1). The commercial sampling data also show that the 1993 yearclass was dominant in the fishery, however the 1994 yearclass was next in abundance (30%) and the 1992 yearclass was scarce (6%) (Nakashima 1997). Samples collected in 1996 were from Bellevue Beach only.

Spawning Time

The extent of the spawning period in 1996 was similar to 1995, however, spawning began earlier than in 1995 (Table 2).

Egg Density

Three spawnings were observed on Bellevue Beach in late June-early July, mid-July, and late July (Fig. 2). Egg deposition on Bellevue Beach was the third highest since 1990 and comparable to 1991 (Table 2, 3). The annual mean of the normalized values show that egg deposition in 1996 was lower than in 1993 and comparable to 1991, 1992 and 1995 (Table 3).

Larval Estimates

Survival at Bellevue Beach was low (Table 2) with most larvae emerging from the beach sediments in late July (Fig. 3). The annual mean of the normalized estimates indicates that overall pre-emergent and emergent larval densities in 1996 were less than all years except 1991 (Table 3). The larval emergence observed at Bellevue Beach in 1996 suggests that the 1996 yearclass is one of the weakest yearclasses produced there since 1990 (Table 3).

Acknowledgements

Pelagic staff were instrumental in collecting and organizing the data. The samples were processed by R. Linehan, D. Mercer, D. Joy, and J. Mitchell. 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.

1997. The inshore fishery for capelin (Mallotus villosus) in NAFO Div. 3KL in 1996. pp. 42-61. In: Anon. Capelin in SA2 + Div. 3KL. CSAS Res. Doc. 97/29.

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. 1996. Results from monitoring capelin spawning beaches on the northeast coast of Newfoundland in 1995. pp. 131-143. In: Anon. Capelin in SA2 + Div. 3KL. DFO Atl. Fish. Res. Doc. 96/90.

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

Sex	Year	Age 2	3	4	5	6
M	1991	4.0	34.6	52.4	8.8	0.2
	1992	2.8	25.5	60.4	11.1	0.2
	1993	1.5	64.7	30.6	3.2	0
	1994	7.8	55.0	32.4	4.5	0.2
	1995	6.7	53.6	28.0	11.2	0.5
	1996	4.4	67.5	26.5	1.3	0.3
F	1990	4.8	49.8	42.2	3.2	0
	1991	4.8	37.5	41.0	15.9	0.8
	1992	8.9	34.9	47.3	8.8	0.1
	1993	9.2	69.3	18.0	3.0	0.5
	1994	16.9	49.6	25.3	7.9	0.3
	1995	22.6	55.6	14.7	7.2	0
	1996	14.2	61.3	21.8	2.1	0.7
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

Table 2. Annual estimates derived from trapezoidal integration of egg deposition, pre-emergent larvae in beach sediments, and larval emergence, and range of spawning dates for capelin spawning times on 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	-	-	-	-	
X̄	102.3	217.6	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	-	-	-	-	
X̄	5.0	19.2	6.4	5.1	13.0	14.1	
Emergent larvae ('000 larvae/m^3)							
1990	-	212.1	-	-	-	-	
1991	35.8	60.5	48.8	54.7	25.6	4.9	
1992	8.3	192.5	137.8	38.7	69.3	35.3	
1993	19.2	175.3[c]	24.7	48.3	93.6[c]	178.2[c]	
1994	25.9	109.8	2.3	0	3.7	15.0	
1995	4.8	140.1	-	-	-	-	
1996	-	93.6	-	-	-	-	
X̄	18.4	140.6	53.4	35.4	48.1	58.4	
'Good condition' emergent larvae ('000 larvae/m^3)							
1990	-	117.4	-	-	-	-	
1991	25.9	43.9	44.0	40.3	24.5	4.3	
1992	8.2	183.9	113.9	34.2	48.1	34.5	
1993	17.5	171.6[d]	18.6	39.3	91.1[d]	171.0[d]	
1994	24.6	85.8	2.2	0	3.5	14.9	
1995	9.5	124.9	-	-	-	-	
1996	-	85.7	-	-	-	-	
X̄	16.1	116.2	44.7	28.5	41.8	56.2	
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

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

c Adjusted to account for sampling ending before larvae had emerged from sediments. Unadjusted estimates were 111.0, 56.7, and 99.0 respectively

d Adjusted to account for sampling ending before larvae had emerged. Unadjusted were 108.6, 55.2, and 95.0 respectively

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

Year	Site						Mean
	Chapel Cove (3L)	Bellevue Beach (3L)	Eastport (3L)	Cape Freels (3K)	Twillingate (3K)	Hampden (3K)	
Egg deposition Stages I-II eggs ('000 eggs/core)							
1990	-	0.42	-	-	-	-	0.42
1991	0.59	1.11	1.02	1.12	1.78	0.49	1.02
1992	1.70	1.20	1.66	0.55	0.50	0.42	1.01
1993	0.59	1.55	1.30	2.33	1.71	2.39	1.65
1994	0.71	0.88	0.01	0	0.01	0.70	0.39
1995	1.42	0.71	-	-	-	-	1.07
1996	-	1.12	-	-	-	-	1.12
Pre-emergent larvae in beach sediments ('000 larvae/core)							
1990	-	1.36	-	-	-	-	1.36
1991	0.18	0.47	0.56	2.90	1.35	0.19	0.94
1992	1.36	0.95	2.31	0.67	0.70	1.43	1.13
1993	2.40	1.41	1.00	0.45	1.81	2.09	1.53
1994	0.52	0.91	0.09	0	0.14	0.28	0.51
1995	0.52	1.09	-	-	-	-	0.81
1996	-	0.79	-	-	-	-	0.79
Emergent larvae ('000 larvae/m^3)							
1990	-	1.51	-	-	-	-	1.51
1991	1.84	0.43	0.91	1.54	0.53	0.08	0.89
1992	0.45	1.37	2.58	1.09	1.44	0.60	1.26
1993	1.04	1.25	0.46	1.36	1.95	3.05	1.52
1994	1.41	0.78	0.05	0	0.08	0.26	0.43
1995	0.26	1.00	-	-	-	-	0.63
1996	-	0.67	-	-	-	-	0.67
'Good condition' emergent larvae ('000 larvae/m^3)							
1990	-	1.01	-	-	-	-	1.01
1991	1.61	0.38	0.98	1.41	0.59	0.08	0.84
1992	0.51	1.58	2.55	1.20	1.15	0.61	1.27
1993	1.09	1.48	0.42	1.38	2.18	3.04	1.60
1994	1.53	0.74	0.05	0	0.08	0.27	0.45
1995	0.28	1.07	-	-	-	-	0.68
1996	-	0.74	-	-	-	-	0.74

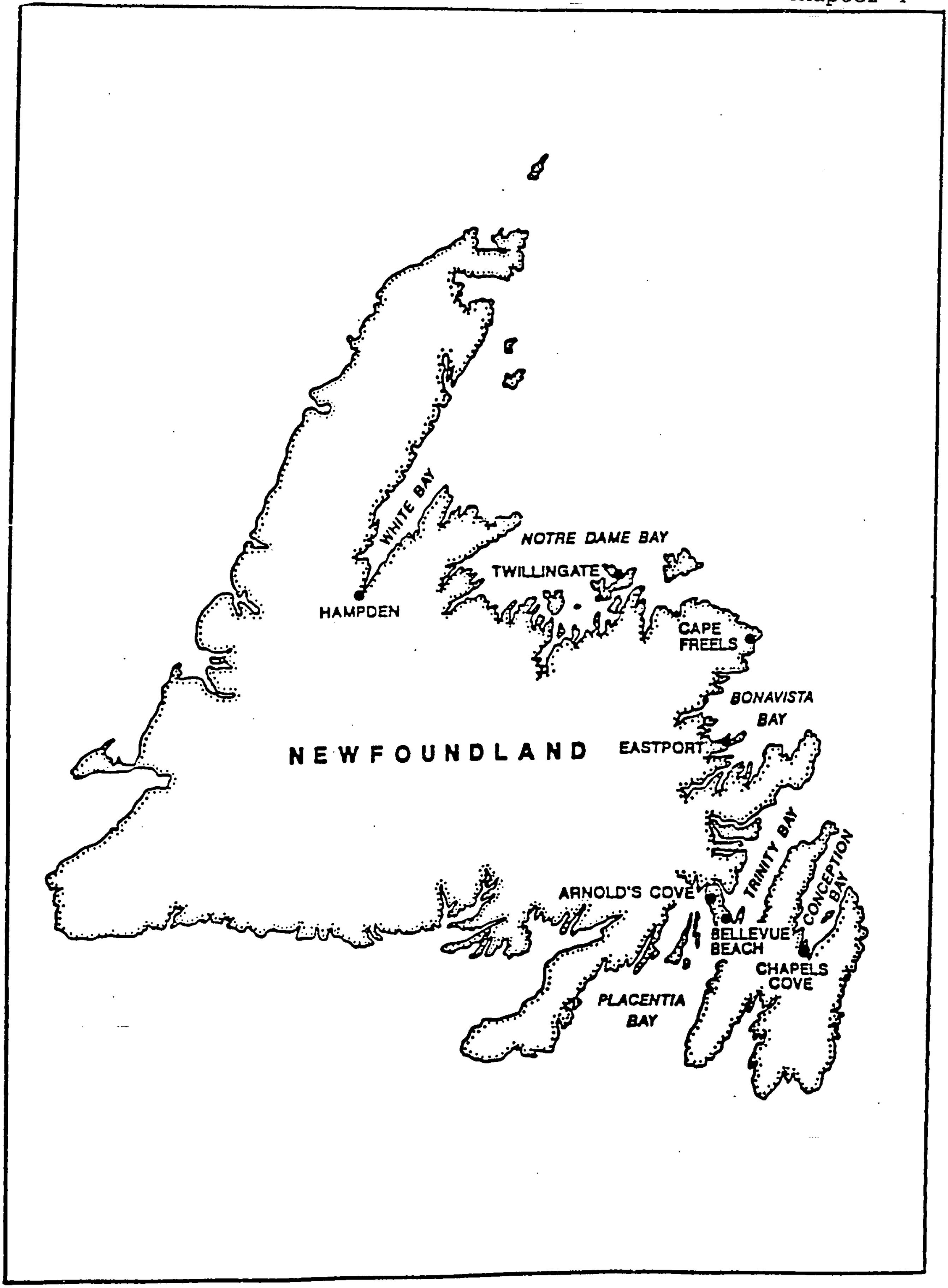


Fig. 1. Sampling sites.

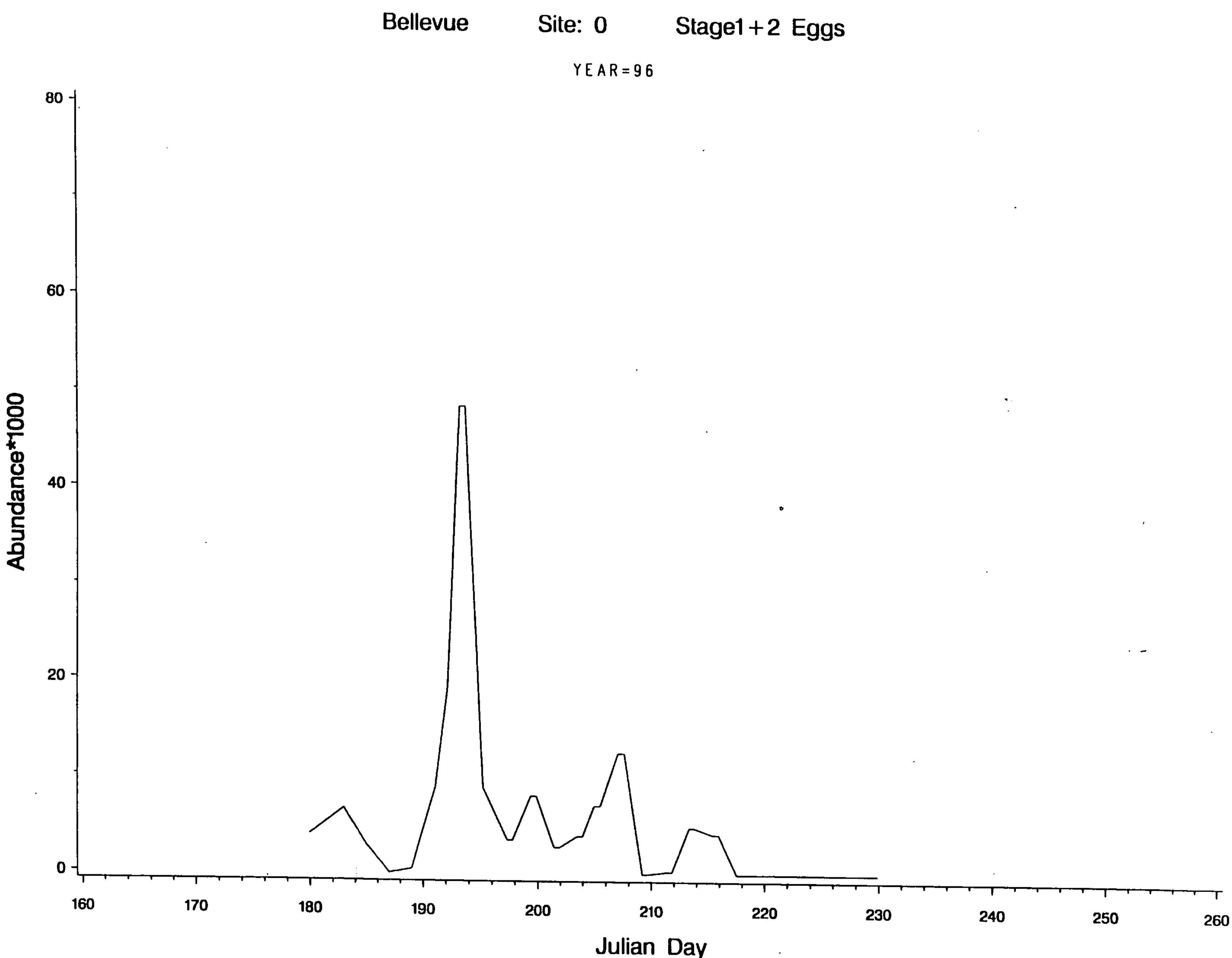
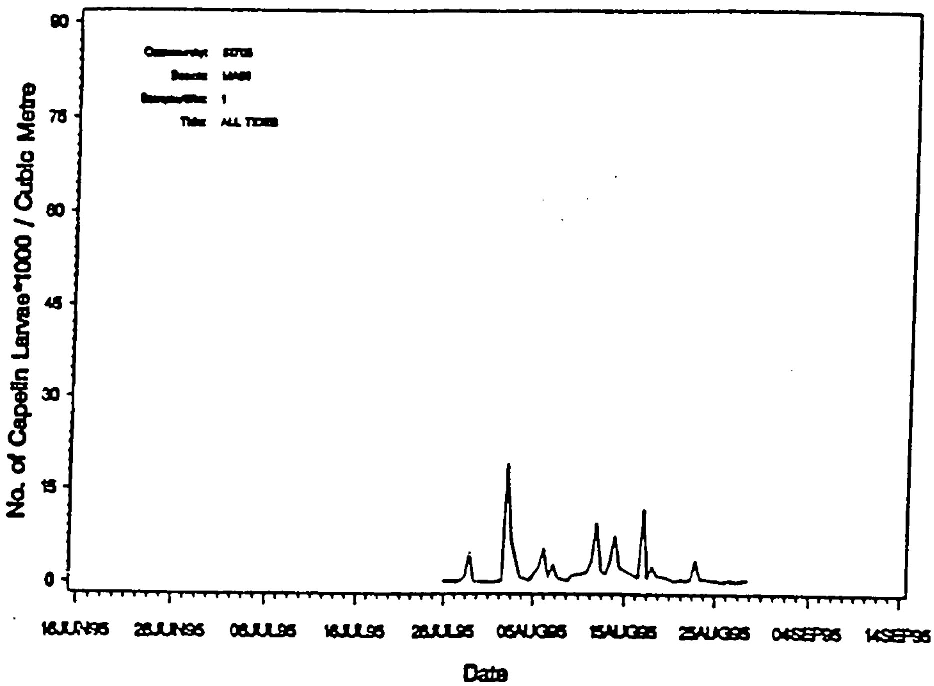


Fig. 2. Seasonal pattern in egg deposition on Bellevue Beach in 1996.

BELLEVUE 95



BELLEVUE 1996

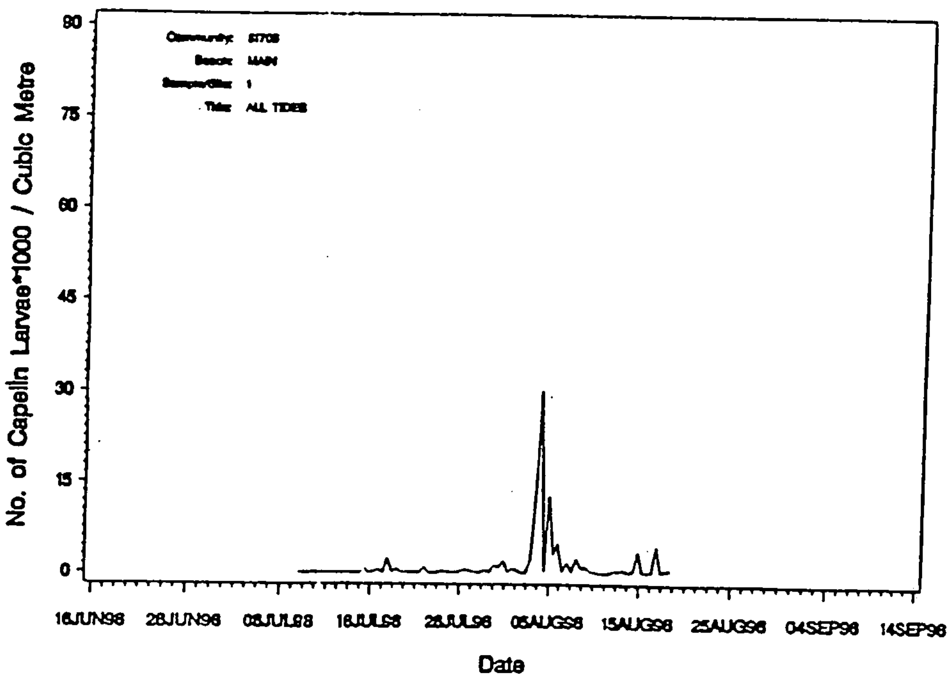


Fig. 3. Seasonal pattern in larval emergence from Bellevue Beach, 1995 and 1996.

Results from an acoustic survey for capelin (*Mallotus villosus*) in NAFO Divisions 3KL in the spring of 1996

by

D. S. Miller
Science Branch
Department of Fisheries and Oceans
P.O. Box 5667
St. John's, Newfoundland A1C-5X1

Abstract

This paper documents the results of an acoustic survey for capelin in NAFO Divisions 3KL during the spring of 1996. The survey is part of a series of annual acoustic surveys of the Division 2J3K and 3L stock that began in 1981 that have been used as the basis for setting the fishery TAC. Capelin biomass for the entire Division 3KL offshore area was estimated at 63,990 metric tons. A survey of the central part of Trinity Bay was also carried out and capelin biomass was estimated at 22,180 tons.

Introduction

From 1981 to 1992, east coast Newfoundland and Labrador capelin stocks have been surveyed acoustically by a spring (April-May) survey of Division 3L and an autumn (October-November) survey of Division 2J3K. In 1993 and 1994, these surveys were combined into a combined 2J3KL survey covering the all the area covered by the separate surveys of the 1981-1992 period (Miller 1994, 1995). Estimates of stock biomass from acoustic surveys declined dramatically in 1990 for the Division 2J3K survey and in 1991 for the Division 3L survey. In 1996, it was decided to change the survey time from the autumn back to May as historically the survey during this time period has shown the best record of predicting inshore abundance of spawning three year old capelin in the following year.

Concentrations of capelin were reported in Trinity Bay during an inshore cod acoustic survey prior to the offshore capelin acoustic survey and a break was taken from the offshore capelin survey during May 23-24 to attempt to locate and quantify any capelin concentrations within Trinity Bay.

Methodology

The survey was conducted from the research vessel *Teleost* during the period May 14-29, 1996. A 38 kHz sounder system was used comprised of a Biosonics ES2000 receiver and a Instruments Inc. S14 transmitter. A 38 kHz dual beam transducer was used in single beam mode and was mounted in a towed body that was deployed at a depth of about eight meters, astern and abeam of the starboard side of the vessel. The acoustic system was calibrated at the beginning of the survey. Calibration parameters used were as follows:

Combined source level/ receive sensitivity:	65.10dB
Fixed receiver gain:	6.90 dB
TVG gain:	20 log R
Attenuation coefficient:	0.00936 dB/m
Pulse length:	0.8 millisecs
Bandwidth:	2.5 kHz
Average beam pattern:	-28.18 dB
Target strength:	-34 dB/kg

The survey design and area was similar to that of the 1993 and 1994 fall surveys but only extended in the north to latitude 50° in southern Division 3K (Figure 1). The survey was interrupted for one day to conduct an exploratory survey of Trinity Bay to investigate reports of capelin concentrations found on a cod acoustic survey prior to this survey. The Trinity Bay strata and transects are shown in Figure 2.

Fishing sets were made on an opportunistic basis throughout the survey. It was attempted to have at least one set for each twelve hour watch and at least one set for each transect. For those midwater trawl sets that contained capelin, a random sample of 200 capelin was obtained for length, sex, and maturity observations and a stratified age sample was selected from each length/sex/maturity sample. Length composition and an age/length key was constructed for each stratum from the samples obtained in that stratum.

Results

Figure 1. Shows an outline of the offshore strata that were surveyed along with symbols proportional to estimated capelin density for each 2.8 km. segment of transect. Fishing set locations are also shown. The largest concentrations of capelin were found in northern Division 3L and southern Division 3K. Figure 2. shows similar data for the Trinity Bay segment with acoustic data aggregated in 1.4 km. segments. Capelin were most abundant in deep water in the centre of the bay.

Table 1. provides the biomass estimate and acoustic estimation parameters for

each stratum from the survey. Table 2. provides the acoustic parameters and the biological sampling of capelin for each transect in the survey. Acoustic data and catches from midwater trawl sets in stratum A indicated that capelin were not abundant in this area. Tables 3. and 4. provide the acoustic estimate broken down by age groups into numbers and biomass respectively including the historical series of spring Division 3L surveys.

Table 5. provides a summary of the acoustic results from the Trinity Bay segment on May 23-24.

Acknowledgements

Phil Eustace aged the capelin samples. Barry Slaney and Phil Eustace helped with the data collection at sea. Chris Stevens, Chis Lang and Gary Mason calibrated the acoustic system and provided logistical support for the acoustic equipment during the survey.

References

Miller, D.S. 1994. Results from an acoustic survey for capelin (Mallotus villosus) in NAFO divisions 2J3KL in the autumn of 1993.

Miller, D.S. 1995. Results from an acoustic survey for capelin (Mallotus villosus) in NAFO divisions 2J3KL in the autumn of 1994.

Table 1. Statistics for each strata and total survey for offshore area

Strata	Transects sampled	Number of possible transects	Transect area	Transect area scattering coefficient Mean	S.E.	Strata total backscatter	Biomass per transect (tons) Mean	S.E.	Total biomass (tons)
A	6	120	739.0	8.	3.5	990.	20.7	8.9	2487.
B	3	30	463.6	160.	74.5	4813.	403.0	187.2	12091.
C	3	30	409.3	203.	63.4	6101.	510.8	159.2	15325.
D	3	30	396.3	370.	70.1	11108.	930.1	176.0	27903.
E	3	30	206.1	82.	41.5	2462.	206.1	104.2	6184.
Total	56.	240		106.	3.6	40902.	266.6	9.0	63990.
						.209			.143

Table 2. Backscatter, biomass, and biological sampling for each transect.

Strata	Transect Number	Transect length	Transect area	Area scattering	Total backscattering	Density	Transect biomass	# of sets	Lsms	Ages
A	1	399.0	799.0	.00	2.	.01	5.	1	0	0
	2	399.0	799.0	.00	3.	.01	7.	2	0	0
	3	399.0	799.0	.01	6.	.02	15.	1	0	0
	4	399.0	799.0	.02	11.	.04	29.	2	200	15
	5	399.0	799.0	.00	3.	.01	8.	1	0	0
	6	399.0	799.0	.03	25.	.08	62.	1	200	43
B	1	250.3	463.6	.59	272.	1.47	683.	2	400	108
	2	250.3	463.6	.41	190.	1.03	478.	2	200	54
	3	250.3	463.6	.04	19.	.10	48.	1	130	33
C	1	221.0	409.3	.22	92.	.56	230.	1	200	40
	2	221.0	409.3	.76	311.	1.91	782.	0	0	0
	3	221.0	409.3	.51	207.	1.27	521.	0	0	0
D	1	214.0	396.3	1.22	485.	3.07	1217.	1	200	40
	2	214.0	396.3	.97	383.	2.43	963.	2	200	48
	3	214.0	396.3	.61	243.	1.54	610.	0	0	0
E	1	111.3	206.1	.67	137.	1.67	344.	0	0	0
	2	111.3	206.1	.53	108.	1.32	272.	1	200	58
	3	111.3	206.1	.00	1.	.01	2.	1	0	0

Table 3. Numbers at age (in billions) from NAFO Division 3L acoustic surveys.

Survey date	Cruise	1	2	3	4	5+	Total
May 14-31, 1996	T29	0.1	3.0	1.7	0.1	0.0	4.9
	Trinity Bay	0.1	1.1	0.5	<0.1	0.0	1.7
May 6-26, 1992	G215	5.7	19.0	6.5	0.7	<0.1	31.9
May 7-26, 1991	G200	18.7	7.7	3.2	0.5	<0.1	30.1
May 9-27, 1990	G181	18.9	353.2	169.0	55.6	1.9	598.6
May 11-29, 1989	G166	3.4	314.8	96.2	11.0	1.4	426.8
May 14-June 1, 1988	G151	13.6	380.4	65.7	9.7	16.8	486.2
May 14-June 2, 1987	G137	0.3	88.1	18.3	38.9	4.0	149.6
May 14-June 1, 1986	G124	0.0	59.4	158.1	21.3	1.0	239.8
May 10-28, 1985	G109	0.2	369.5	80.5	3.8	2.3	456.3
April 29-May 14, 1984	G93	0.1	21.0	6.2	3.1	0.5	30.8
April 29-May 9, 1983	G77	<0.1	3.4	1.9	0.8	0.1	6.2
April 3-20, 1982	G64	<0.1	9.7	16.2	2.4	0.9	29.2

Table 4. Biomass at age (in thousands of tons) from NAFO Division 3L acoustic surveys.

Survey date	Cruise	1	2	3	4	5+	Total
May 14-31, 1996	T29	<1	31	31	2	0	64
	Trinity Bay	<1	13	9	<1	0	22
May 6-26, 1992	G215	2	74	111	18	1	206
May 7-26, 1991	G200	7	40	56	12	1	116
May 9-27, 1990	G181	6	2507	2862	1517	66	6958
May 11-29, 1989	G166	2	1776	1643	358	50	3829
May 14-June 1, 1988	G151	10	1953	1604	380	604	4551
May 14-June 2, 1987	G137	<1	640	436	1358	142	2576
May 14-June 1, 1986	G124	0	411	2653	600	33	3697
May 10-28, 1985	G109	<1	1992	1253	107	74	3426
April 29-May 14, 1984	G93	<1	129	121	88	15	353
April 29-May 9, 1983	G77	<1	25	35	22	2	84
April 3-20, 1982	G64	<1	49	327	61	29	466

Table 5. Acoustic results for Trinity Bay transects

Transect No.	Length (km)	Density (g/sq.m)
1	97.5	27.6
2	16.9	1.0
3	29.8	49.3
4	31.1	19.8
5	29.4	5.2
6	30.1	15.2

Weighted mean	23.0 g/sq.m.
Total area	966 sq. km.
Biomass	22,218 metric tons

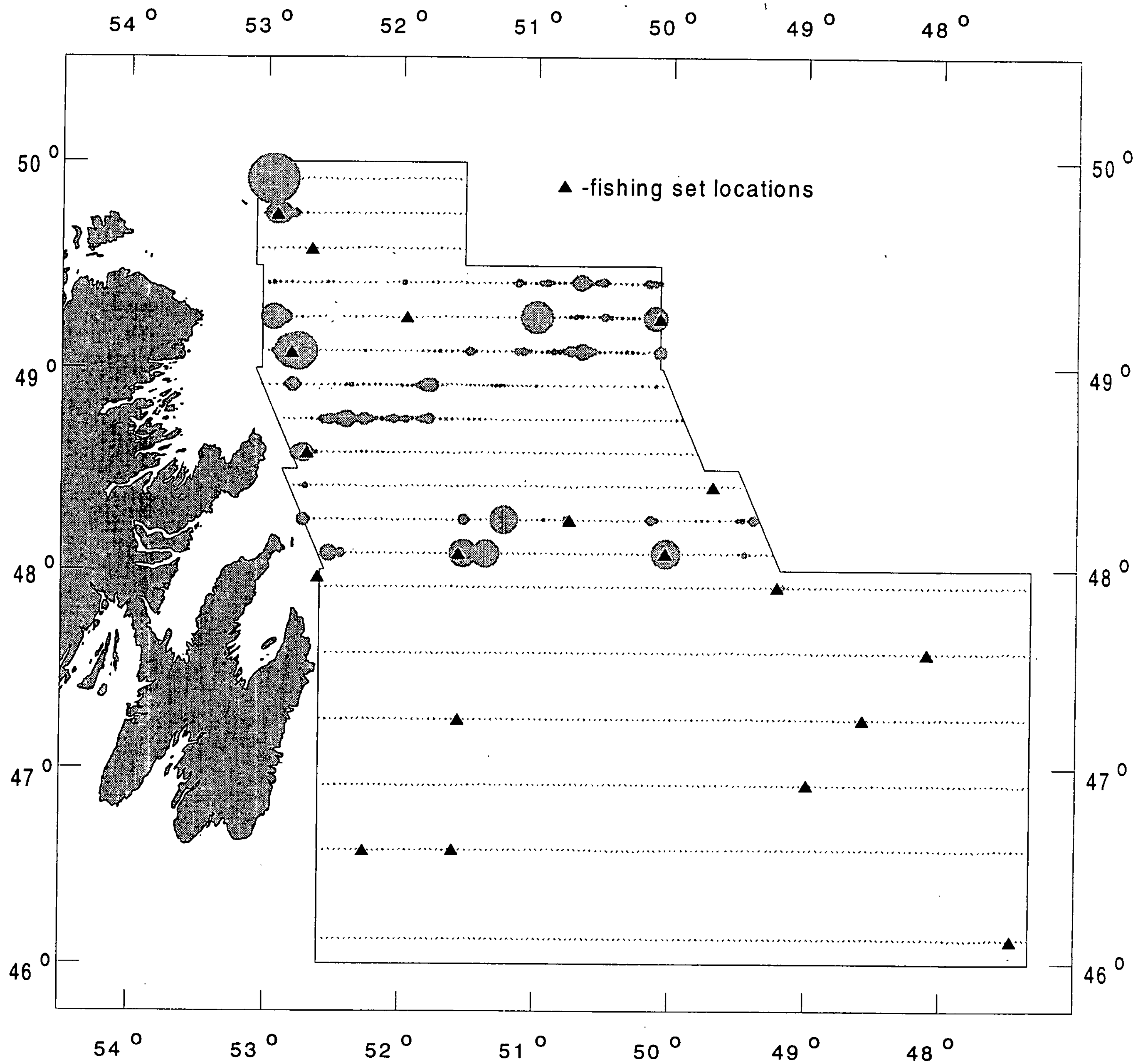


Figure 1. Offshore strata and capelin distribution - May 1996

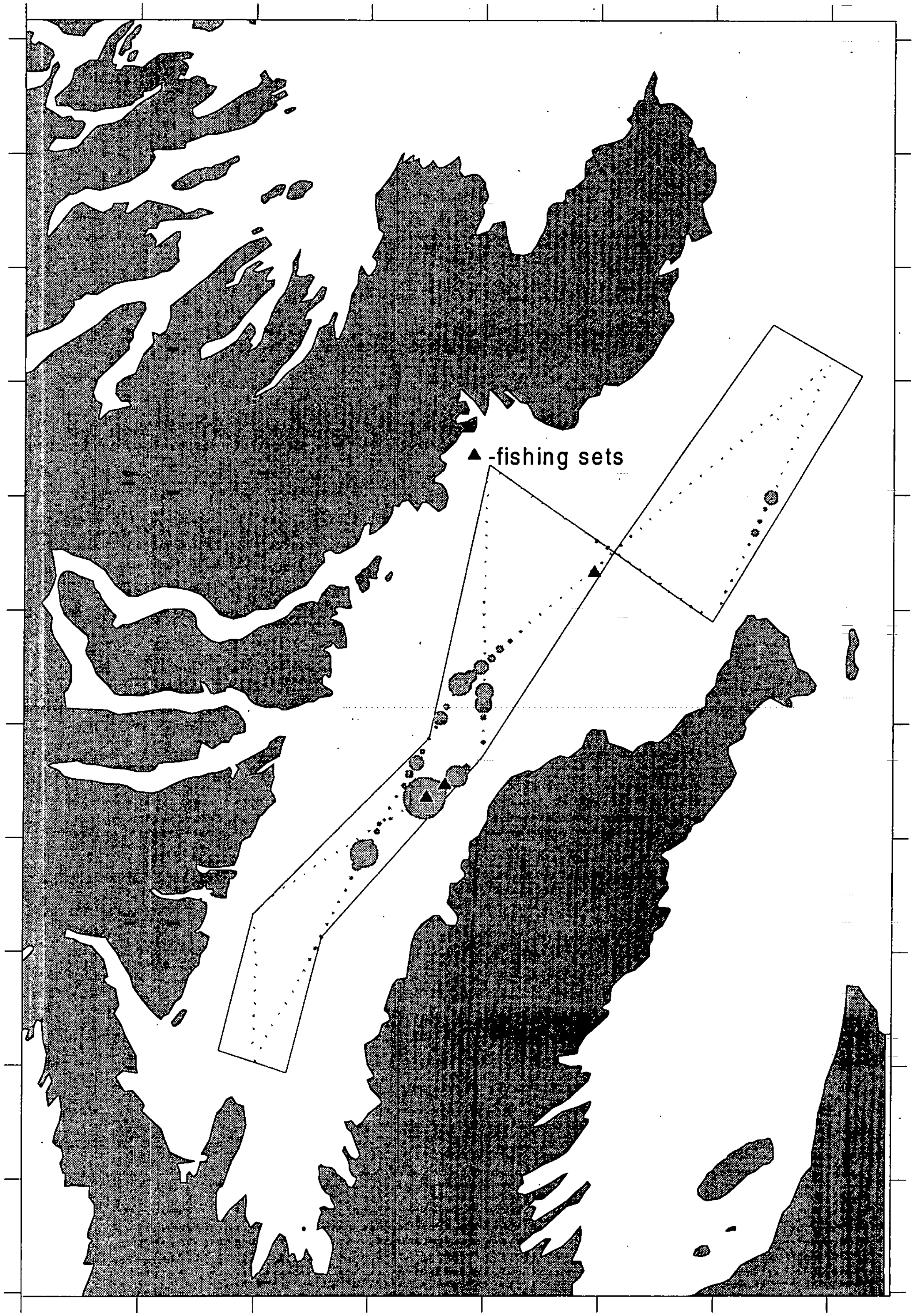


Figure 2. Trinity Bay segment - Teleost 29 May 1996

Chapter 6

By-catches of capelin during spring and autumn bottom-trawl surveys in Divisions 2J3KL in 1996

by

G. R. Lilly
Science Branch
Department of Fisheries and Oceans
P. O. Box 5667
St. John's NF A1C 5X1

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 1978-1995 and the springs of 1972-1995 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; Lilly and Davis 1993) and to provide supporting data on changes in capelin distribution (Lilly and Davis 1993; Lilly 1994b). 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 1996. 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 1978-1996 (Table 1). All surveys in Divisions 2J and 3K in 1978-1994 were conducted with the 74 m stern trawler 'Gadus Atlantica'. Surveys in Division 3L in 1981-1983 and 1985-1994 were conducted with the 51 m side trawler 'A. T. Cameron' (1981-1982) and the sister 50 m stern trawlers 'Wilfred Templeman' (1983, 1985, 1987-1994) and 'Alfred Needler' (1986). There were no autumn surveys in Division 3L in 1978-1980 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 1996) 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 Shelton et al. (1996). 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 (Table 1) 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 (Table 1) 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).

Surveys in Divisions 3LNO in spring

Capelin were caught during random-stratified bottom-trawl surveys of Divisions 3LNO during April-June 1971-1996, excluding 1983 (Table 2). Surveys were conducted with the 51 m side trawler 'A. T. Cameron' (1971-1982) and the sister 50 m stern trawlers 'Wilfred Templeman' (1985-1996) 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 Division 3L 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. The median dates of fishing in 1993, 1994, 1995 and 1996 (June 1, June 3, June 8 and June 13 respectively) were the latest since 1971.

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.

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. The number of sets meeting these criteria in the autumn surveys increased greatly with the introduction of the Campelen trawl in 1995.

Period	Total number of sets for each period
1978-1989	152
1990-1994	127
1995	132
1996	111

The frequency distribution of average weights is illustrated for the periods 1978-1989, 1990-1994, 1995 and 1996 in Fig. 2. Average weights at the ends of the distribution (< about 3 g and > about 39 g) are suspect. There was a loss of heavier mean weights during the 1990s compared with the earlier years. In addition, the proportion of sets with small mean weights increased in 1995 and 1996. In the spring 3L data series, there was a similar loss of heavier mean weights in the 1990s compared with earlier years (not illustrated). 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.

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 1991-1994, 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 1970s.

Results

Capelin in Division 2J3KL during autumn

Distribution

In Division 2J3K during the autumn of 1996, capelin were recorded at 52% of the 234 fishing stations conducted at depths of 750 m or less (Table 3). This percentage is lower than in 1995 but higher than that recorded in any year prior to the introduction of the Campelen trawl. Catches (95th percentile = 21 kg; maximum = 53 kg) were smaller than in 1995 (Table 3). Very few capelin were caught on Hamilton and Belle Isle Banks and near the coast off southern Labrador and northeastern Newfoundland (Division 2J and western Division 3K) (Fig. 3). Largest catches were concentrated in the northern and southern portions of Funk Island Bank and Funk Island Deep. Catches in the new inshore strata ranged from nil to greater than 50 kg. All of the large catches in the offshore of Divisions 2J and 3K 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 1996 was similar to that observed in 1995 (Fig. 4) and similar to the distributions observed in 1991-1994 (Lilly 1992, 1994a, 1995a; Lilly and Davis 1993).

In Division 3L, capelin were recorded at 53% of the 148 stations (Table 4). This is considerably lower than the 72% recorded in 1995, and only a little above values reported in some of the years in the period 1985-1994. Catches (95th percentile = 17 kg; maximum = 92 kg) were generally smaller than in 1995 but larger than in 1985-1994 (Table 4). Capelin were caught in northern and northeastern Division 3L and south of the Avalon Peninsula (Fig. 3). There were only a few small catches on the plateau of Grand Bank. Catches in the new inshore strata ranged from nil to greater than 50 kg. The large catches in the inshore and south of the Avalon Peninsula would have been outside of an acoustic survey, if one had been run using the survey blocks employed in 1994. The distribution in 1996 was similar to that in 1995 (Fig. 4), except that in 1995 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

During the 1978-1989 period, most large catches of capelin in Divisions 2J and 3K were dominated by large fish (Fig. 5). Only two sets, both near Cape Bauld, were dominated by small fish. In Division 3L, sets dominated by large fish and sets dominated by small fish were intermixed. During 1990-1994, most large catches were in southern and eastern Division 3K. Average weight varied from intermediate to large in Divisions 2J and 3K. Catches dominated by small fish occurred only in Division 3L.

With the introduction of the Campelen trawl in 1995, the number of catches dominated by small fish increased considerably (Fig. 6). These sets occurred primarily in Division 3L. In 1995-1996, the boundary between a region dominated by medium-large capelin mean weights and a region dominated by small capelin mean weights seemed to occur within Division 3L near the 300 m isobath at the junction between the Northeast Newfoundland Shelf and the northern slope of Grand Bank. However, some sets with capelin mean weights of intermediate value occurred south of this boundary on the northeastern slope of Grand Bank. This was more 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 1991-1994, did not substantially change the estimate of the frequency of occurrence, except in Division 3L in 1992 (Table 5; Fig. 7). In Division 2J3K, the adjusted frequency of occurrence increased, with irregular fluctuations, from 20-35% in the early 1980s to 40-50% in the 1990s. With the introduction of the Campelen trawl in 1995, the frequency of occurrence rose to the highest level in the time-series. The value in 1996 (unadjusted, 52%; adjusted, 54%) was less than that in 1995, but still slightly higher than in 1992, the year with the highest value prior to the introduction of the Campelen trawl. In Division 3L, the values fluctuated more widely than in Divisions 2J3K. Low values of about 20% in 1990-1991 were followed by high values of about 50% in 1992-1993 and a decline to an intermediate level of about 40% in 1994. The value in 1995 was by far the highest in the time-series. The value in 1996 (unadjusted, 53%; adjusted, 57%) was much less than that in 1995 and close to the values in 1992-1993.

Estimates of abundance and biomass

The minimum trawlable abundance and biomass were extremely low in 1978, relatively high in 1979-1981, and fluctuated without trend from 1982 to 1994 (Fig. 8). The high levels in Division 2J in 1978-1981 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. 9). Values in 1996 were less than half those in 1995. Biomasses, in thousands of tonnes, were as follows:

	2J	3K	3L	Total
1995	2.4	42.6	22.6	67.6
1996	0.3	16.7	12.3	29.3

Capelin in Division 3LNO during spring

Distribution

In Division 3L during the spring of 1996, capelin were recorded at 73% of the 189 fishing stations conducted at depths of 750 m or less (Table 6). This was much higher than in 1991-1995, but similar to levels in most years during the period 1986-1990. Catches were relatively large (95th percentile = 78 kg; maximum =

625 kg). The distribution was extensive, ranging in an arc from the Nose of the bank, along the northeastern slope to the Division 3K/3L boundary, and southward through the Avalon Channel to the area south of the Avalon Peninsula (Fig. 10). Catches were nil or very small in the northeast at depths greater than 300 m and on the plateau of the bank. There were also catches in both 3N and 3O. The broad distribution of large catches in Division 3L is very different from observations in 1991-1995, but similar to distributions observed in the mid to late 1980s. One notable difference from earlier years, such as 1986 and 1987, is the high frequency of occurrence of large catches in northern Division 3L.

Average capelin weight

During the period 1985-1990, the majority of large capelin catches (ie. catches of at least 50 individuals and 1 kg) were dominated by large capelin (Fig. 11). Catches dominated by small capelin were recorded mainly in eastern Division 3L. During the 1991-1995 period, very few large catches were recorded. Many of the sets toward the northeastern edge of the bank were dominated by small fish.

In 1996, with the introduction of the Campelen trawl, one may have anticipated an increase in the proportion of sets dominated by small capelin. Although a number of such sets were recorded on the southern Grand Bank, there were very few in Division 3L, and these were scattered throughout the Division. Most catches in the Avalon Channel and south of the Avalon Peninsula had moderate mean weights.

Frequency of occurrence

The frequency of occurrence in depths <750 m (unadjusted, 73%; adjusted 78%) was higher than levels in 1991-1995 but similar to levels found in 4 of the 5 years in the period 1986-1990 (Table 7; Fig. 12).

Estimates of biomass

The biomass estimated from areal expansion of mean catch per tow was 94.7 thousand tons (Table 7; Fig. 13). This contrasts markedly with the very low estimates of about 1 thousand tons in the period 1991-1995, and is almost 3 times as large as the highest previous estimate (33.9 thousand tons in 1986).

Discussion

Capelin in Division 2J3KL in the autumn

During the autumn survey, the largest catches of capelin were obtained on the northern and southern portions of Funk Island Bank and Funk Island Deep and along the northeastern slope of Grand

Bank. A few moderate to large catches were taken in the extreme southeastern portion of Division 3L south of the Avalon Peninsula. Catches were nil or very small on Hamilton and Belle Isle Banks, near the shelf break in Division 3K and on the plateau of Grand Bank. This distribution is similar to that seen in 1991-1995, and contrasts with years prior to 1991 when the capelin in Division 2J3K were concentrated either in Division 2J or in central Division 3K (Lilly 1995a,c). The distribution was less extensive in 1996 than in 1995, and both the frequency of occurrence of capelin and the estimate of capelin biomass declined in 1996 compared with 1995. It is not known if this is a reflection of a lower quantity of capelin in 1996. The catches might have been influenced by the earlier timing of the 1996 survey compared with the 1995 survey. There may also be differences in capelin distribution and behaviour.

Capelin in Division 3LNO in the spring

The extensive distribution and large catches of capelin in Division 3L in the spring of 1996 contrast markedly with the very small catches in 1991-1995. Part of the increase in 1996 may be attributed to the change to the Campelen trawl. However, the increase was 90-fold, and 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. However, this would not be in agreement with results from the acoustic survey, which recorded the lowest biomass since spring acoustic surveys began in Division 3L (see chapter by Miller).

It is possible that capelin migrated into Division 3L in the period between May 14-29, when the acoustic survey was conducted, and May 30 - June 27, when the bottom-trawl survey was conducted. The acoustic survey found capelin in Division 3K just north of the 3K/3L boundary, so capelin may have migrated in from the north. It is also possible that capelin migrated into Division 3L from Division 3Ps to the west, Divisions 3NO to the south, or the Flemish Cap to the east, where capelin have been found in recent years (Frank et al. 1996). Several of the large catches on the Nose of the bank consisted of capelin with large average size, supporting the possibility that some of the capelin entered the survey area from the east or southeast.

It is also possible that there was no major migration of capelin into the survey area in the period between the acoustic survey and the bottom-trawl survey. A relatively small quantity of capelin may have been present close to the bottom, where it might not be readily detectable by the acoustic system but might be highly available to the bottom-trawl.

Impact of the change in the survey trawl

The change from the Engel 145 Hi-Lift trawl to the Campelen 1600 shrimp trawl with rockhopper footgear has dramatically increased the catch of small fish, as quantified for cod and several species of flatfish during comparative fishing trials (Warren 1996). Capelin was not included in the comparative fishing, but it is clear from a comparison of catches before and after the change that the Campelen trawl catches capelin in a higher proportion of the sets (ie. yields a higher frequency of occurrence), has larger individual catches, and seems to catch more small capelin, as deduced from the larger proportion of sets dominated by small capelin. This superior performance of the Campelen trawl gives rise to optimism that the bottom trawl survey will provide more reliable information than in the past regarding the distribution, relative abundance and relative year-class strength of capelin, from both the autumn survey in Divisions 2J3KL and the spring survey in Divisions 3LNO.

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

Doubleday, W. G. (ed.) 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.

Lilly, G. R. 1994a. By-catches of capelin in bottom-trawl surveys, p. 99-107. In J. Carscadden [ed.] Capelin in SA2 + Div. 3KL. DFO Atlantic Fisheries Research Document 94/18.

Lilly, G. R. 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.

Lilly, G. R. 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 Atlantic Fisheries Research Document 95/70.

Lilly, G. R. 1995b. By-catches of capelin during spring bottom-trawl surveys in Divisions 3LNO, p. 110-122. In Anon. [ed.] Capelin in SA2 + Div. 3KL. DFO Atlantic Fisheries Research Document 95/70.

Lilly, G. R. 1995c. Did the feeding level of the cod off southern Labrador and eastern Newfoundland decline in the 1990s? DFO Atlantic Fisheries Research Document 95/74. 25 p.

Lilly, G. R. 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 Atlantic Fisheries Research Document 96/90.

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.

McCallum, B. R., and S. J. Walsh. 1996. Groundfish survey trawls used at the Northwest Atlantic Fisheries Centre, 1971-present. NAFO SCR Doc. 96/50, Serial No. N2726. 18 p.

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.

Shelton, P. A., D. E. Stansbury, E. F. Murphy, G. R. Lilly, and J. Brattey. 1996. An assessment of the cod stock in NAFO Divisions 2J+3KL. NAFO SCR Doc. 96/62, Serial No. N2738. 56 p. (also DFO Atl. Fish. Res. Doc. 96/80)

Warren, W. G. 1996. Report on the comparative fishing trial between the Gadus Atlantica and Teleost. NAFO SCR Doc. 96/28, Serial No. N2701. 16 p.

Table 1. Selected data for bottom-trawl surveys in Divisions 2J3KL in the autumns of 1977-1996. 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	112		119	81	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	Number of stations occupied: Phase 2	Phase 1 stations with cod: No.	Phase 1 stations with cod: %	Phase 1 stations with capelin: No.	Phase 1 stations with capelin: %
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	12/11-01/12	153		91	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	31	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

Table 2. Selected data for bottom-trawl surveys in Divisions 3LNØ in the springs of 1971-1996.

Year	Div.	Ship/Trip	Sampling Dates (d/mo.-d/mo.)	Number 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

Table 2. (Cont'd)

Year	Div.	Ship/Trip	Sampling Dates (d/mo.-d/mo.)	Number of Stations Occupied	Stations with cod No.	Stations with cod %	Stations with capelin No.	Stations with capelin %
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
	3NO	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
	3NO	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
	3NO	WT 29 AN 43	11/04-05/05	178	134	75	33	19
1986	3L	WT 48	07/05-25/05	211	203	96	169	80
	3NO	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
	3NO	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
	3NO	WT 70	21/04-05/05	161	132	82	28	17

Table 2. (Cont'd)

Year	Div.	Ship/Trip	Sampling Dates (d/mo.-d/mo.)	Number of Stations Occupied	Stations with cod No.	Stations with cod %	Stations with capelin No.	Stations with capelin %
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

Table 3. Statistics for by-catches of capelin during bottom-trawl surveys in NAFO Divisions 2J3K during the autumns of 1978 to 1996.

Year	Number of stations	Stations with capelin		Percentiles of capelin 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	16
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	0.3	12	24
1987	276	94	34	0.20	1.0	18	117
1988	233	84	36	0.15	0.8	3	39
1989	273	134	49	0.12	0.3	2	32
1990	232	82	35	0.09	0.3	1	11
1991	302	117	39	0.14	0.5	4	68
1992	308	151	49	0.10	0.3	3	15
1993	245	98	40	0.14	0.5	6	9
1994	237	108	46	0.50	1.9	10	30
1995	194	116	60	2.31	5.3	56	332
1996	234	122	52	0.99	1.3	21	53

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.

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

Only stations from first-stage sampling are included.

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.

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 1996.

Year	Number of stations	Stations with capelin		Percentiles of capelin 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	72	41	0.20	0.4	7	30
1990	161	31	19	0.10	0.5	11	17
1991	219	45	21	0.11	0.5	7	10
1992	215	80	37	0.12	0.4	2	6
1993	153	76	59	0.13	0.4	3	16
1994	200	83	42	0.10	0.3	1	2
1995	162	117	72	1.26	6.3	29	70
1996	148	78	53	0.48	3.9	17	92

Stations in depths >750 m are not included. Stations in strata 784-799, which were added in the inshore area in 1996, are not included.

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

Only stations from first-stage sampling are included.

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.

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 1978-1995. Division 3L was not surveyed in 1978-1980 and 1984. Only sets in 750 m or less are included. 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 and 1996 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	22.0
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	54.4	52.7	56.6

Table 6. Statistics for by-catches of capelin during bottom-trawl surveys in NAFO Div. 3L during the springs of 1971 to 1996.

Year	Ship[a] and trip number	Number[b] of stations	Stations with capelin		Percentiles of capelin[c] catches (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

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 1977-1996, 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 Yanke 41-5 trawl in 1977-1982, an Engel 145 Hi-Lift trawl in 1985-1995, and a Campelen 1600 trawl in 1996.

Year	Frequency of occurrence (%)		Biomass ('000 tons)
	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

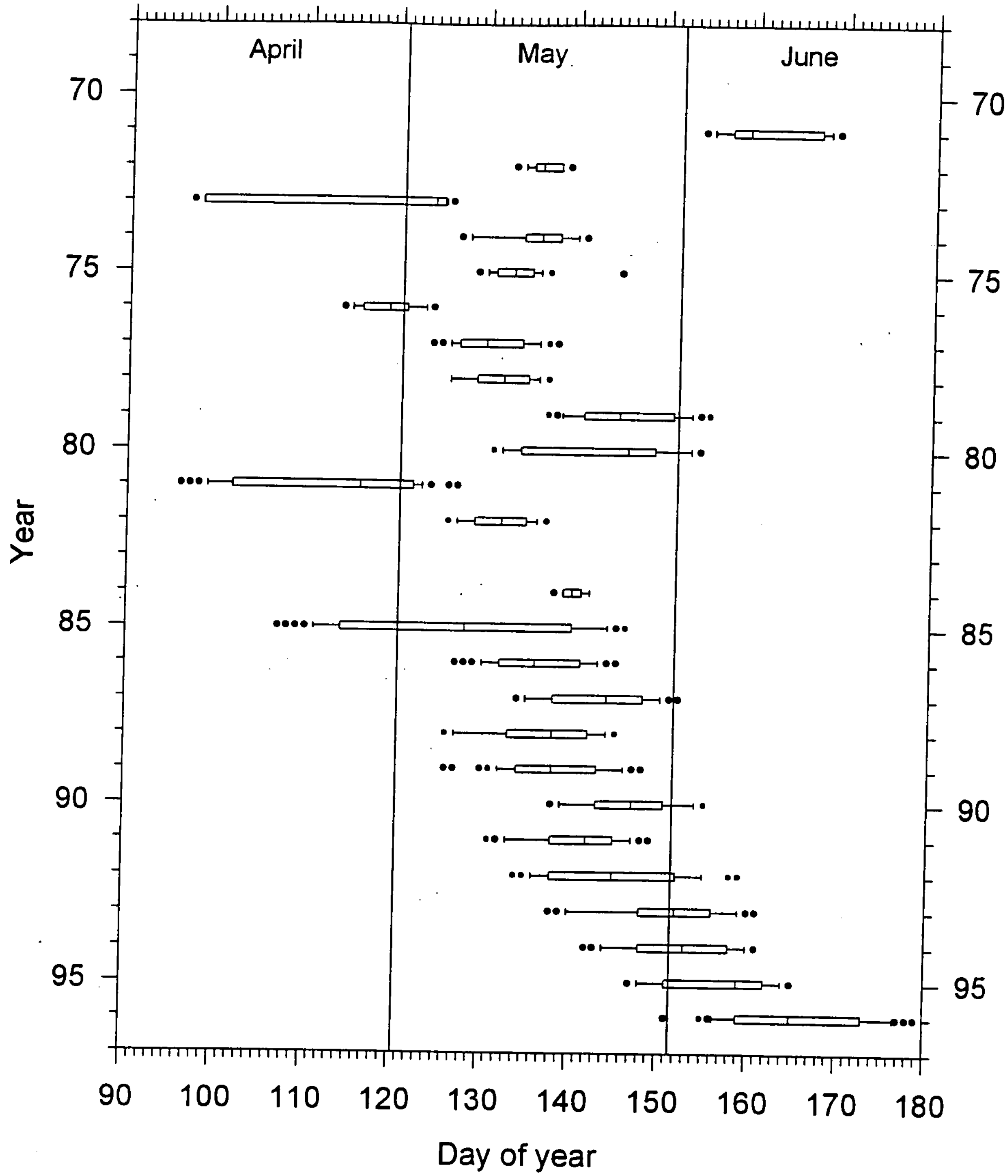


Fig. 1. Dates of fishing during stratified-random bottom-trawl surveys in Division 3L in 1971-1996. The box plot for each year illustrates the 10th, 25th, 50th, 75th and 90th percentiles, and all dates beyond the 10th and 90th percentiles.

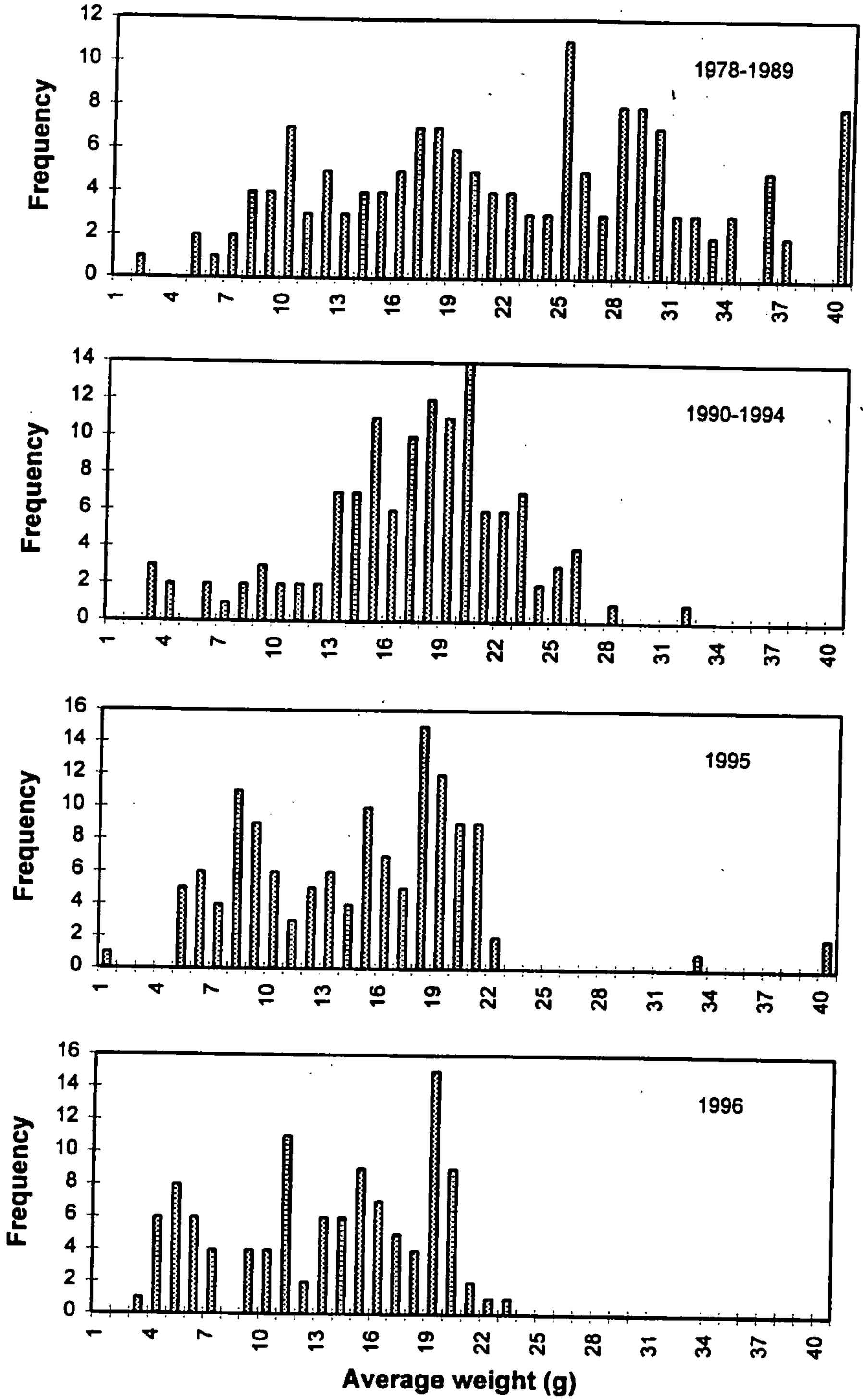


Fig. 2. Frequency distribution of average capelin weight (g) in tows made during autumn surveys in Divisions 2J3KL in 1978-1989, 1990-1994, 1995 and 1996. Only catches of at least 1 kg and 50 individuals are included.

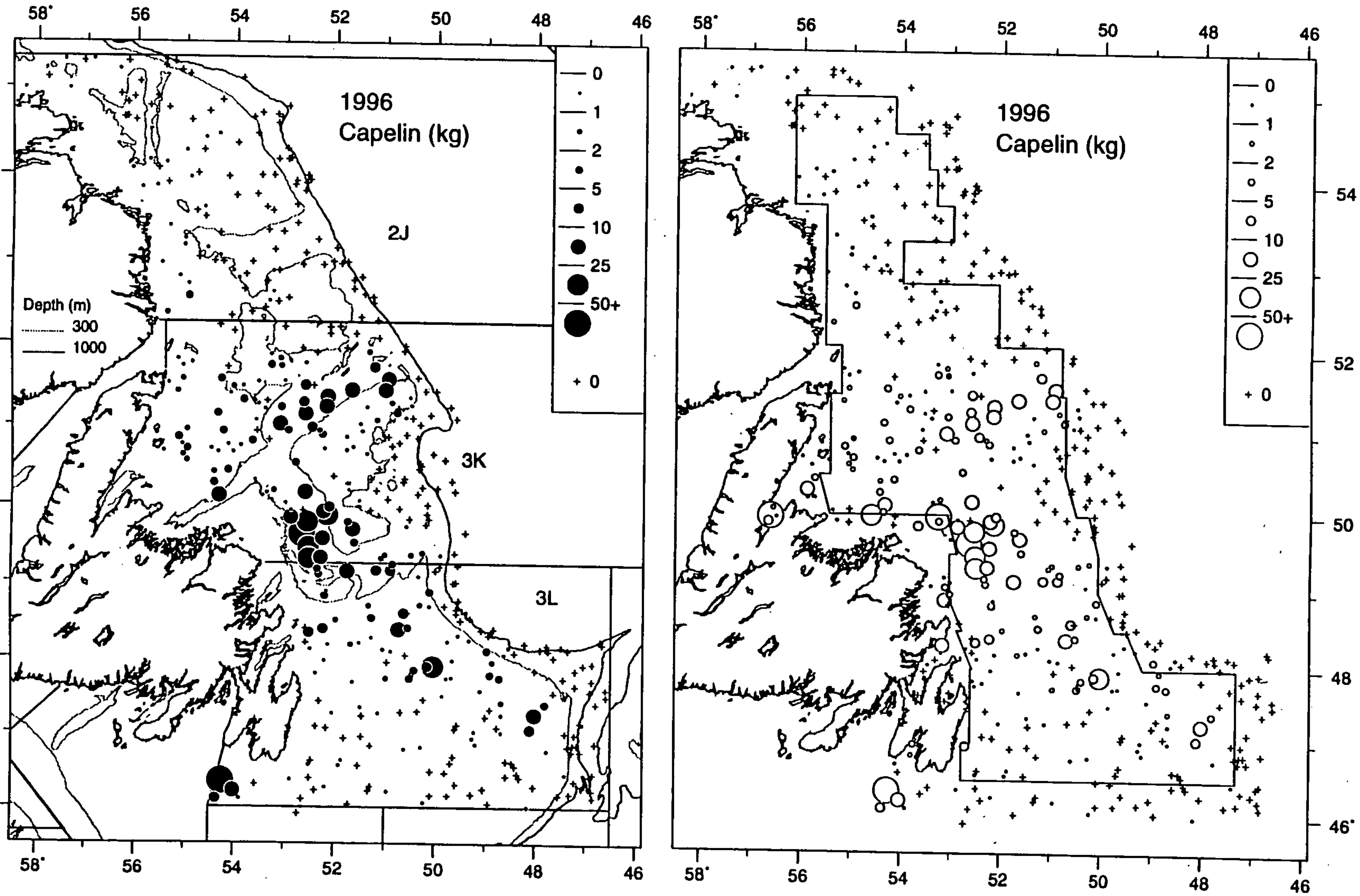


Fig. 3. Capelin catches (kg/15 min tow) during random-stratified bottom-trawl surveys in Divisions 2J3KL during autumn 1996. The left panel shows the 300 and 1000m isobaths. The right panel shows the boundary of the acoustic survey in 1994. Inshore stations are illustrated in the right panel only.

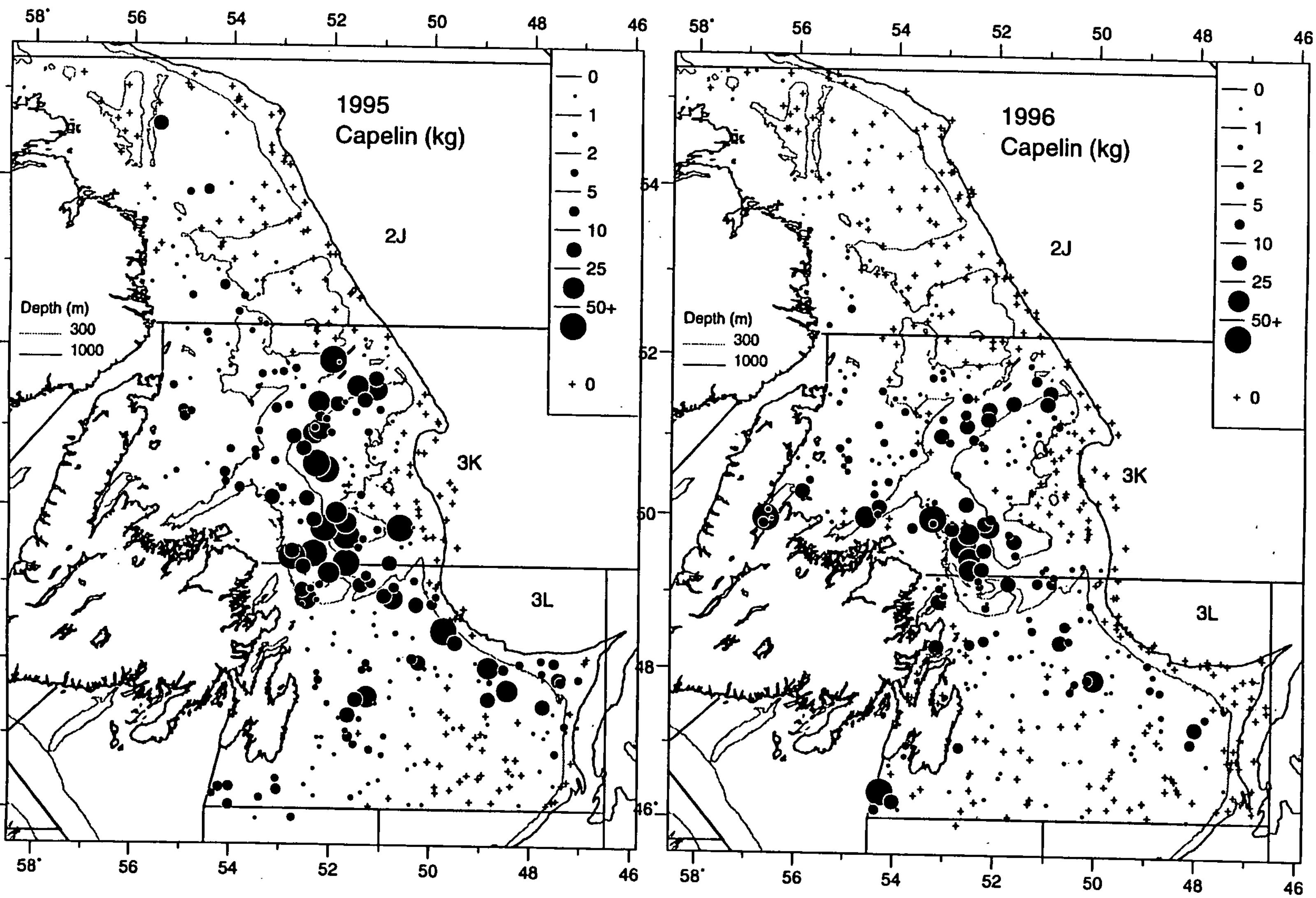


Fig. 4. Capelin catches (kg/15 min tow) during random-stratified bottom-trawl surveys in Divisions 2J3KL during the autumns of 1995 and 1996.

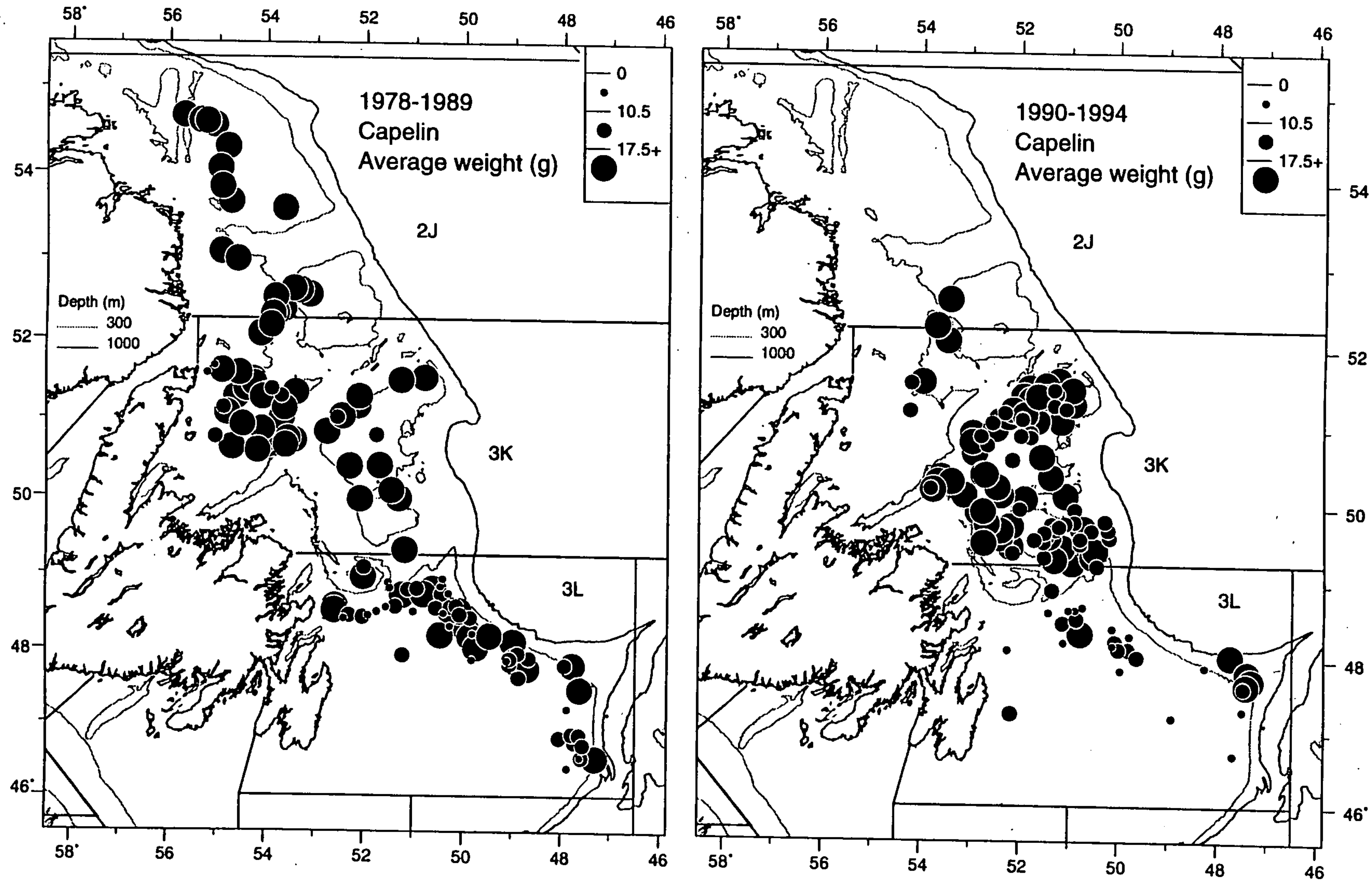


Fig. 5. Average weight of capelin in catches of at least 1 kg and 50 individuals in two periods (1978-1989 and 1990-1994) before the introduction of the Campelen trawl.

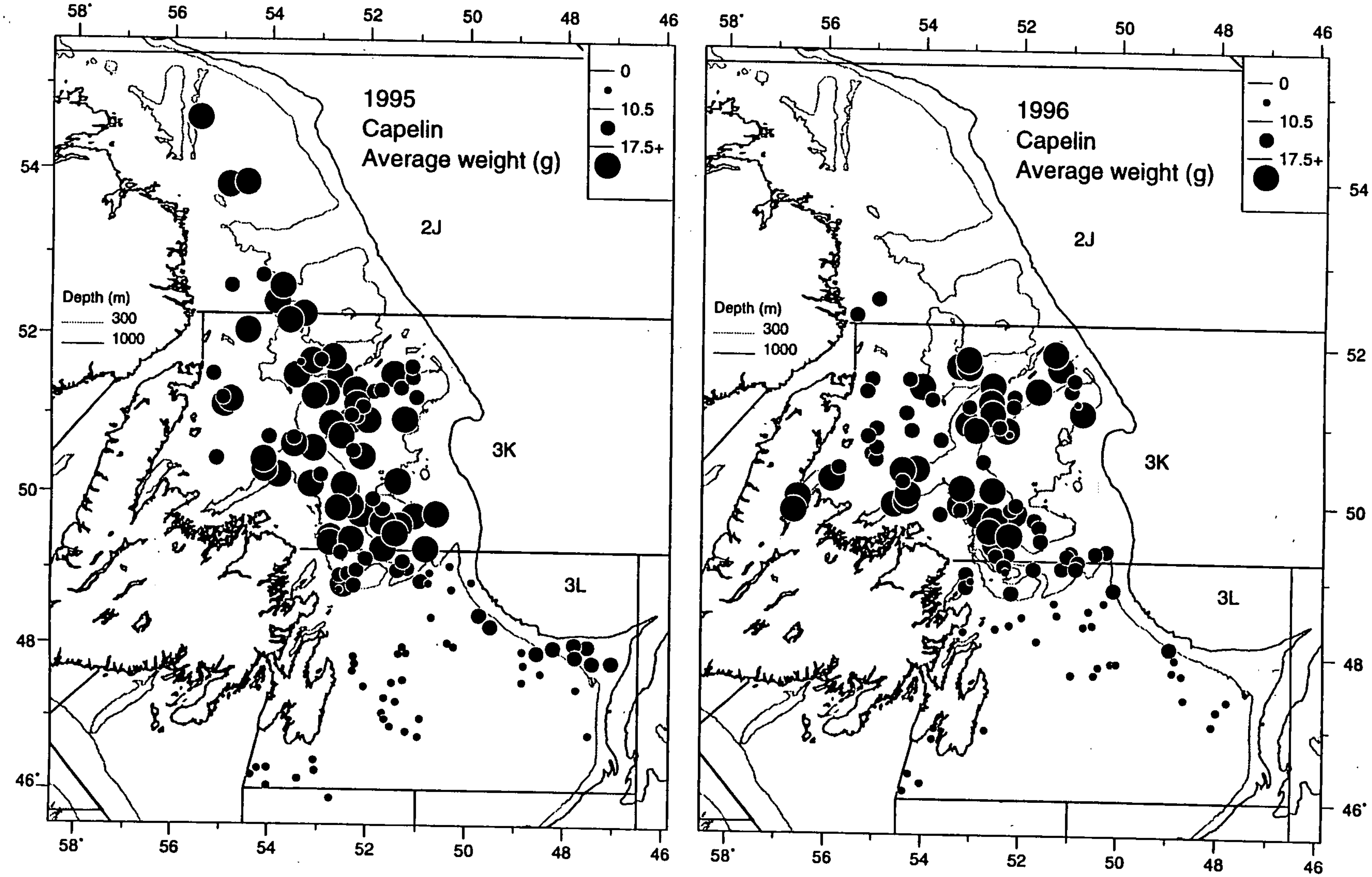


Fig. 6. Average weight of capelin in catches of at least 1 kg and 50 individuals in two years (1995 and 1996) following the introduction of the Campelen trawl.

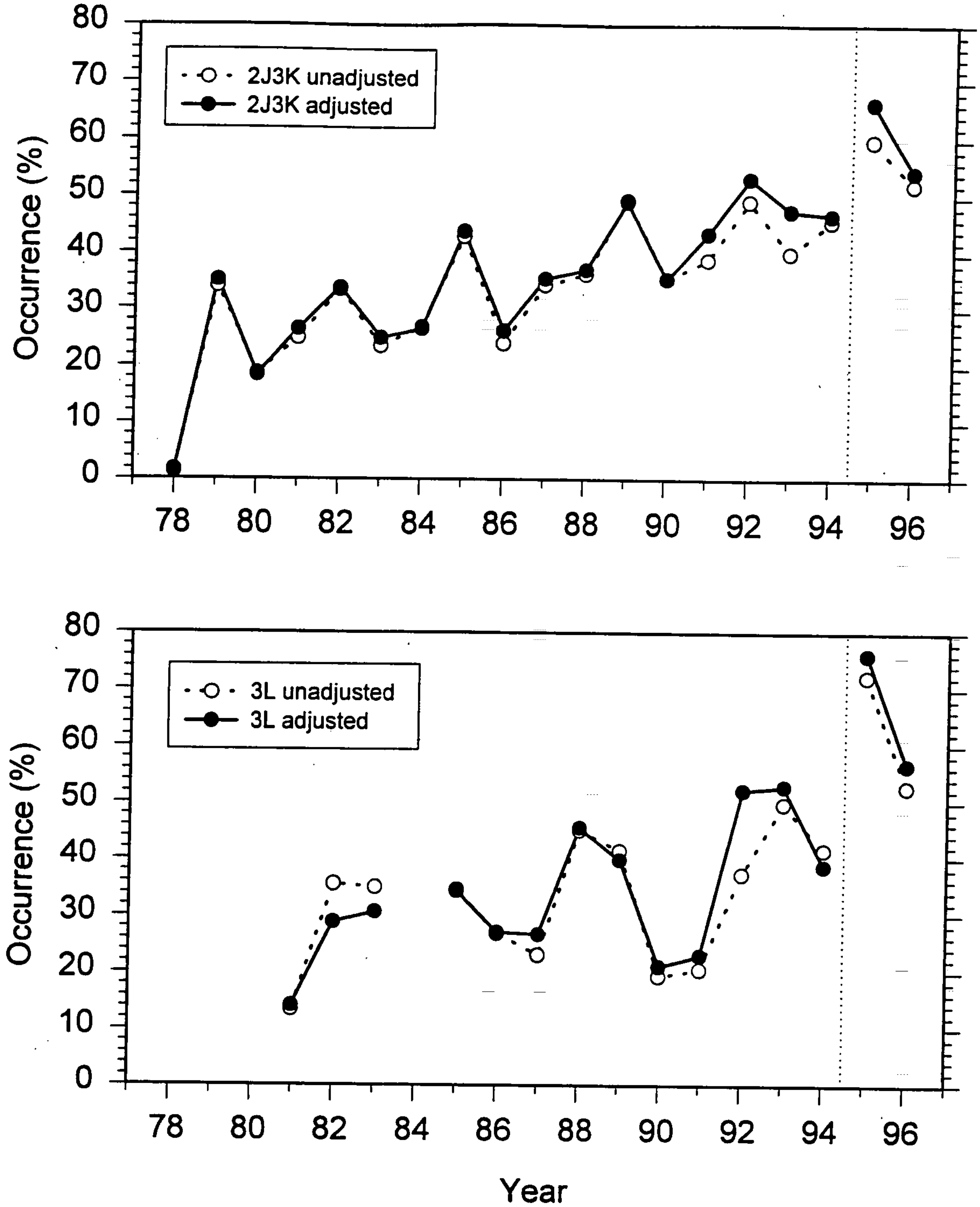


Fig. 7. The frequency of occurrence of capelin in catches during the autumn bottom-trawl surveys in Divisions 2J3K (upper panel) and Division 3L (lower panel) in 1978-1996. Division 3L was not surveyed in 1978-1980 and 1984. In 1995, the survey gear was changed to a Campelen 1800 shrimp trawl from the Engel 145 Hi-Lift trawl used in 2J3K and 3L (1985-1994). A Yankee 41-5 trawl was used in Division 3L in 1981-1983.

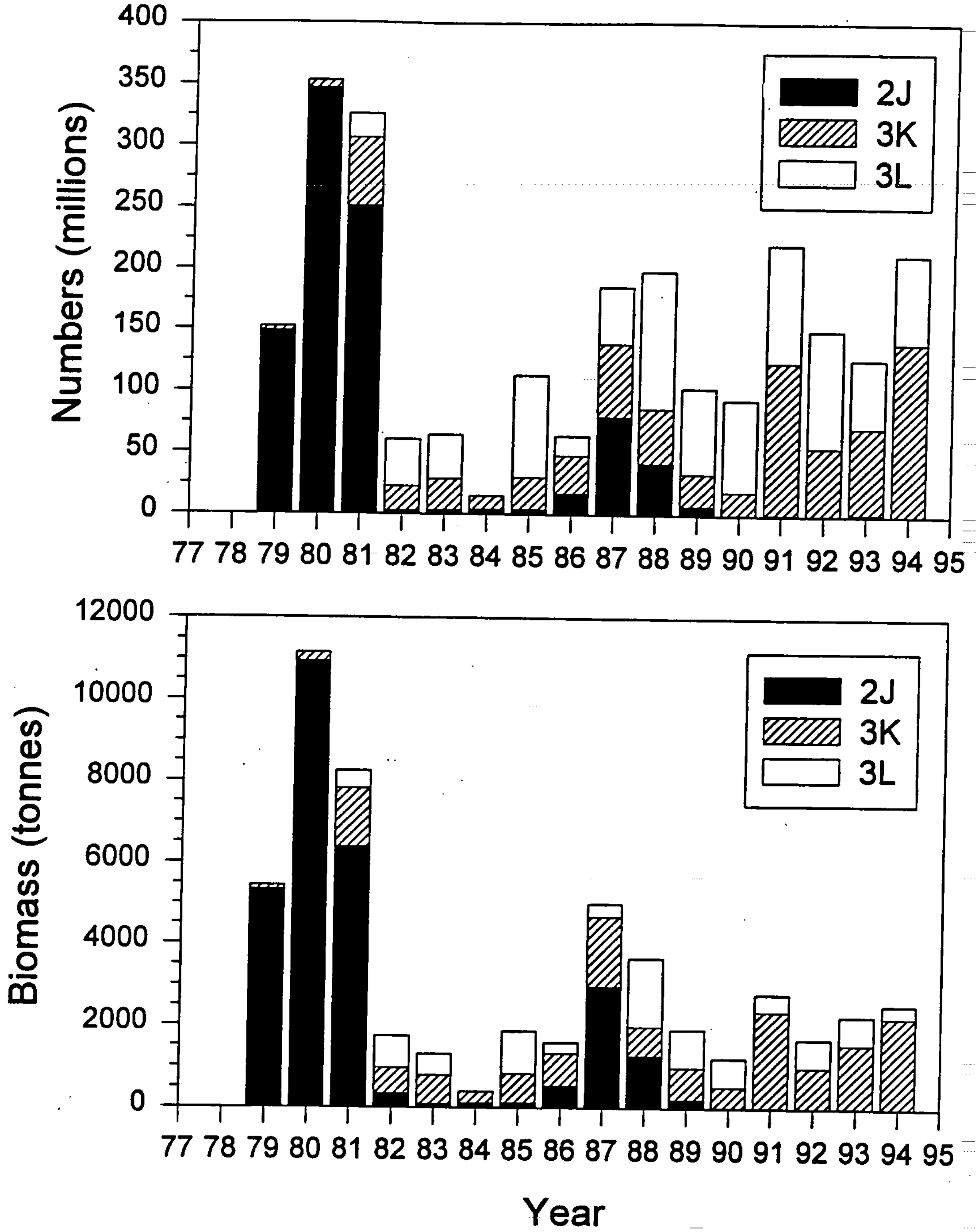


Fig. 8. Abundance and biomass of capelin by year and Division, estimated from areal expansion of stratified mean catch per tow during autumn surveys, for the years 1978-1994. There was a survey in 2J3K in 1978, but the estimated levels were very low. Division 3L was not surveyed in 1978-1980 and 1984.

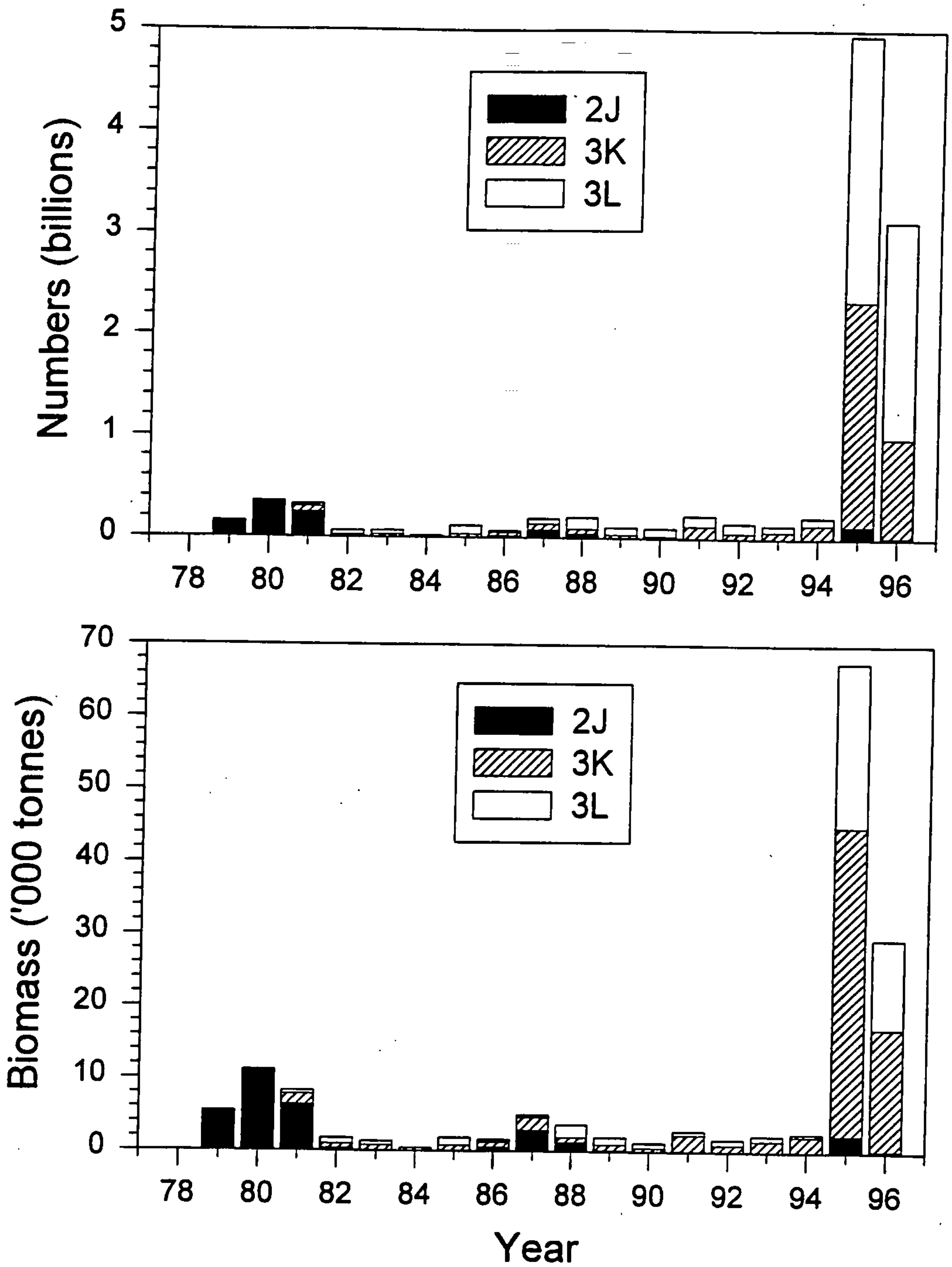


Fig. 9. Abundance and biomass of capelin by year and Division, estimated from areal expansion of stratified mean catch per tow during autumn surveys, for the years 1978-1996. There was a survey in 2J3K in 1978, but the estimated levels were very low. Division 3L was not surveyed in 1978-1980 and 1984. A Campelen 1800 shrimp trawl was introduced in 1995.

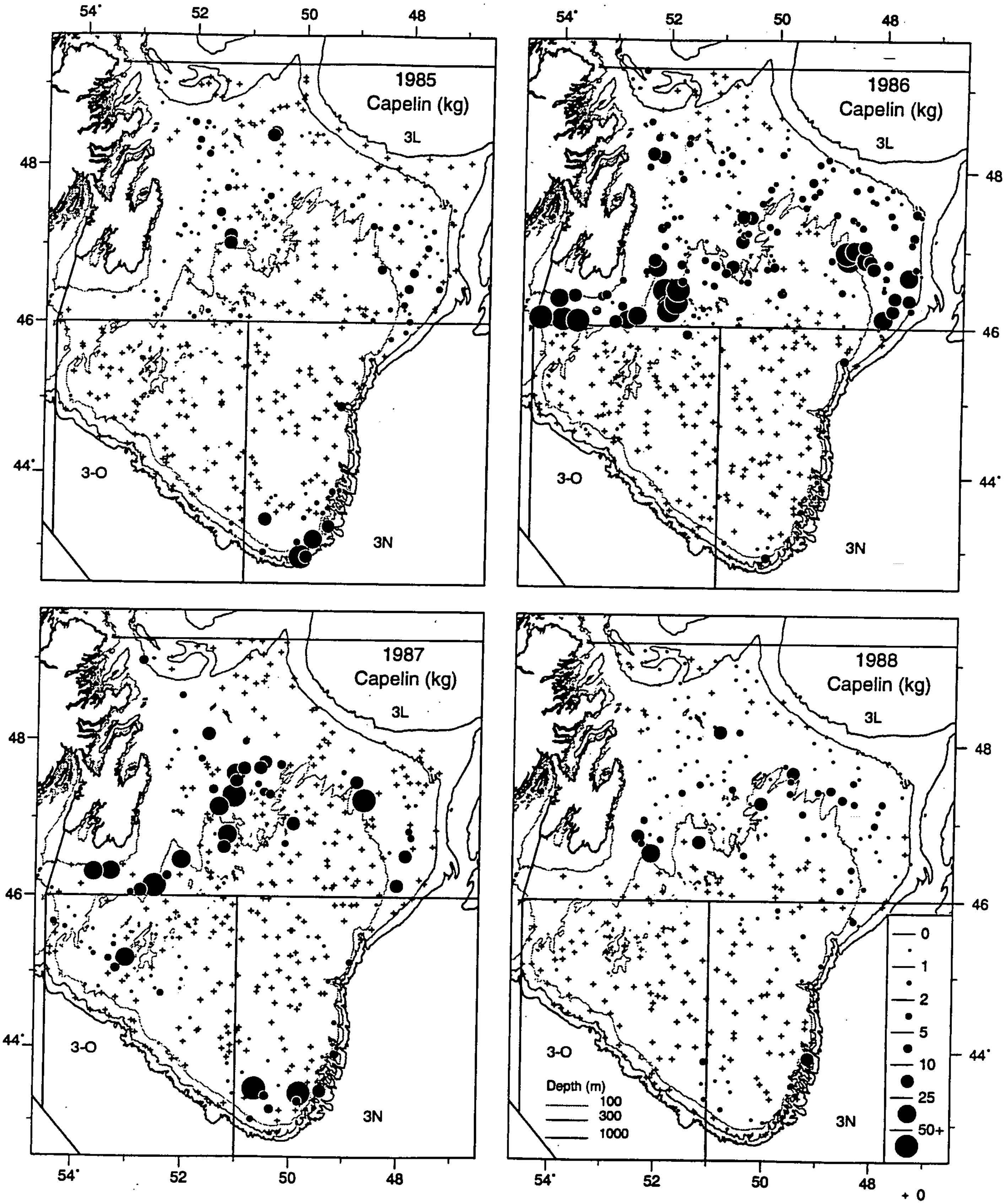


Fig. 10. Capelin catches during stratified-random bottom-trawl surveys in Divisions 3LNO in the springs of 1985-1996. For plots of distributions in 1971-1984, see Lilly (1995b).

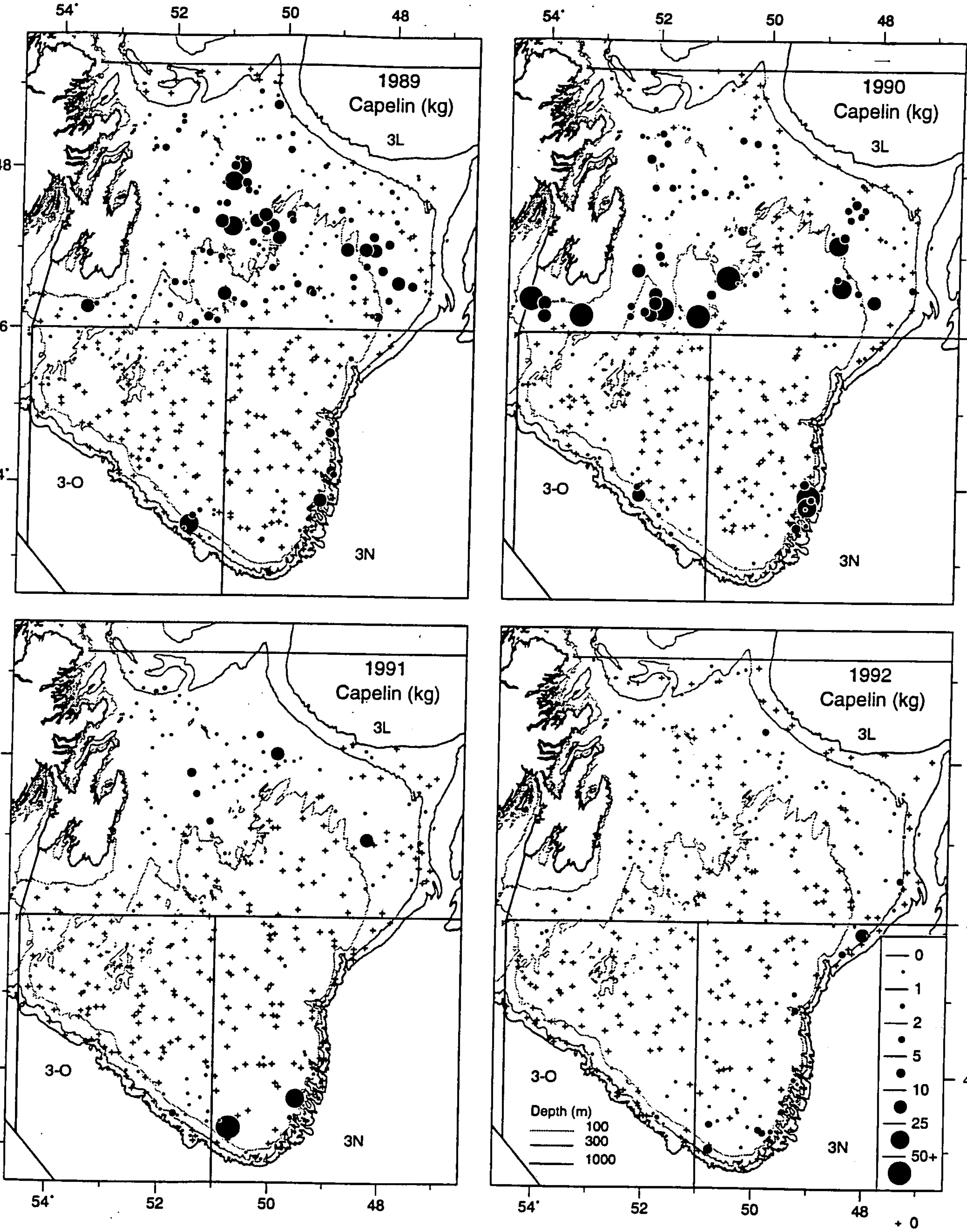

1989
Capelin (kg)
1990
Capelin (kg)
1991
Capelin (kg)
1992
Capelin (kg)
3L
3-O
3N
54°
52
50
48
48
46
44°
Depth (m)
100
300
1000
0
1
2
5
10
25
50+
+ 0

Fig. 10. (cont'd)

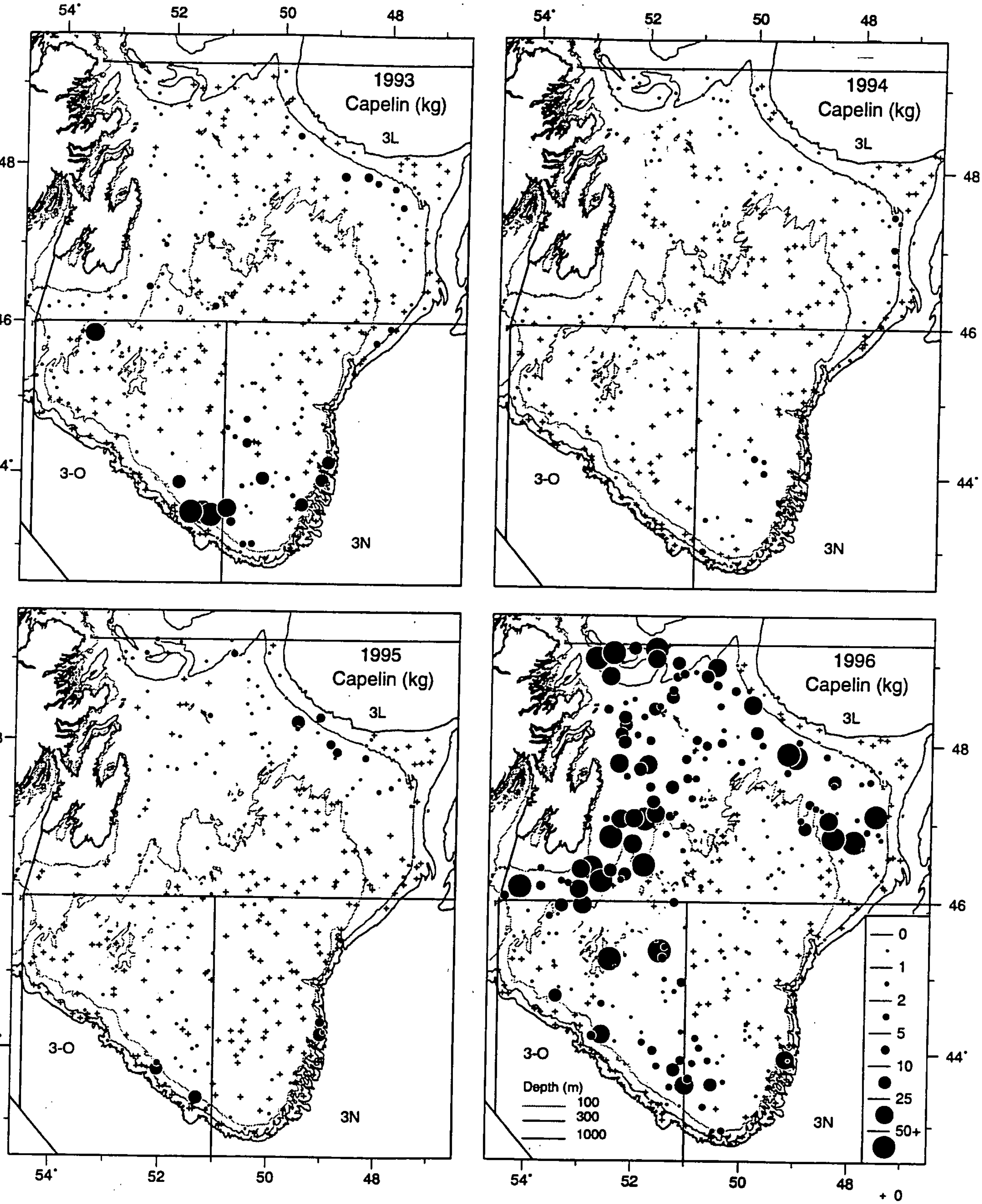

1993
Capelin (kg)
1994
Capelin (kg)
1995
Capelin (kg)
1996
Capelin (kg)
3L
3-O
3N
Depth (m)
100
300
1000
0
1
2
5
10
25
50+
+ 0
54°
52
50
48
46
44°

Fig. 10. (cont'd)

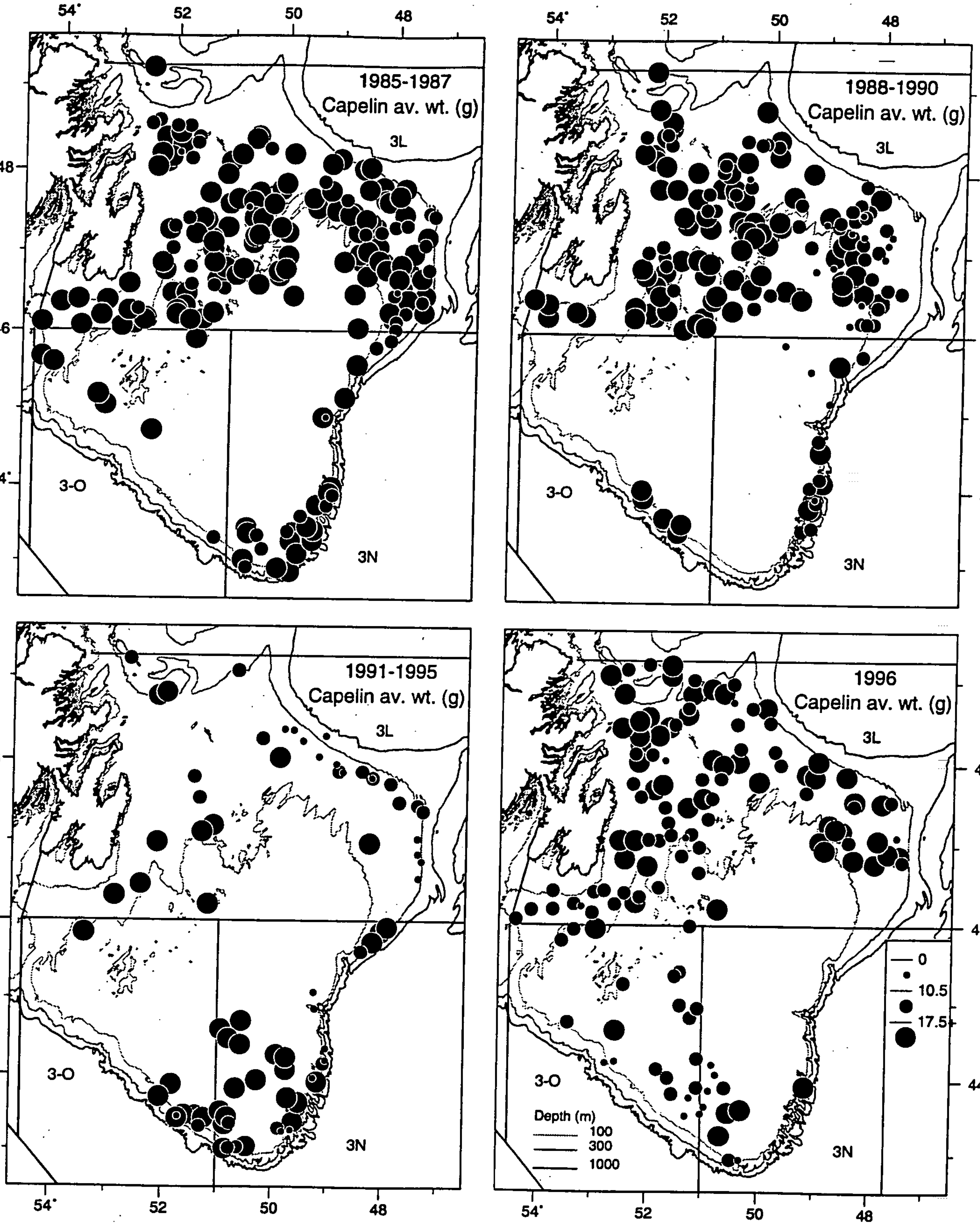


Fig. 11. Average weight of capelin in catches of at least 1 kg and 50 individuals in 1985-1987, 1988-1990, 1991-1995 and 1996. The Campelen trawl was first used in 1996.

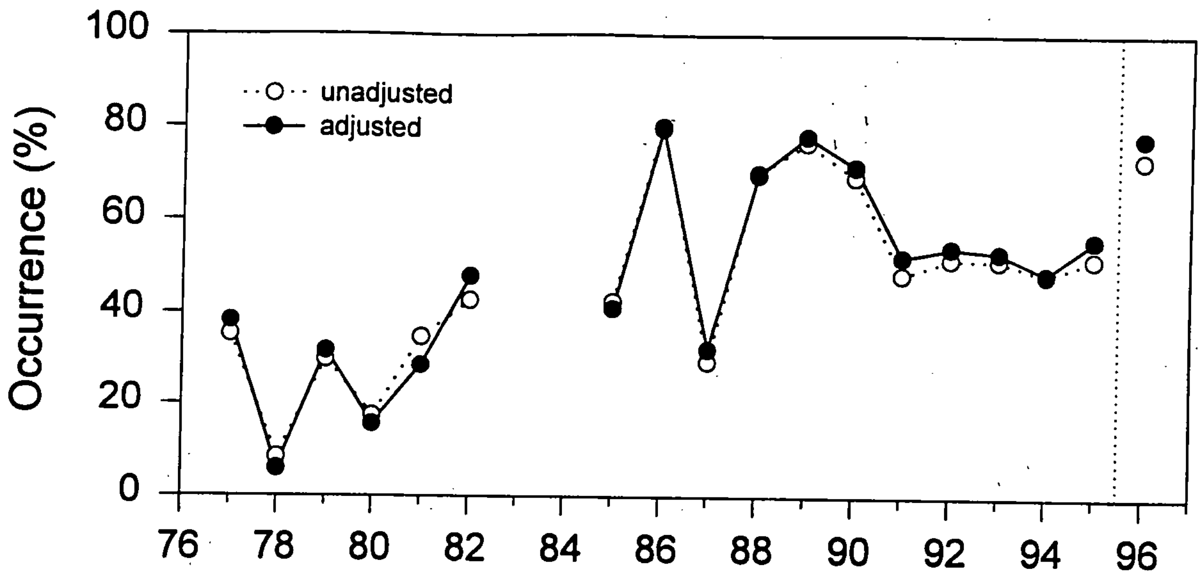


Fig. 12. The frequency of occurrence of capelin in catches during spring bottom-trawl surveys in Division 3L in 1977-1996. There was no survey in 1983 and coverage was inadequate in 1971-1976 and 1984. A Yankee 41-5 trawl was used until 1982, an Engels 145 Hi-Lift trawl was used in 1985-1995, and a Campelen 1600 shrimp trawl was introduced in 1996.

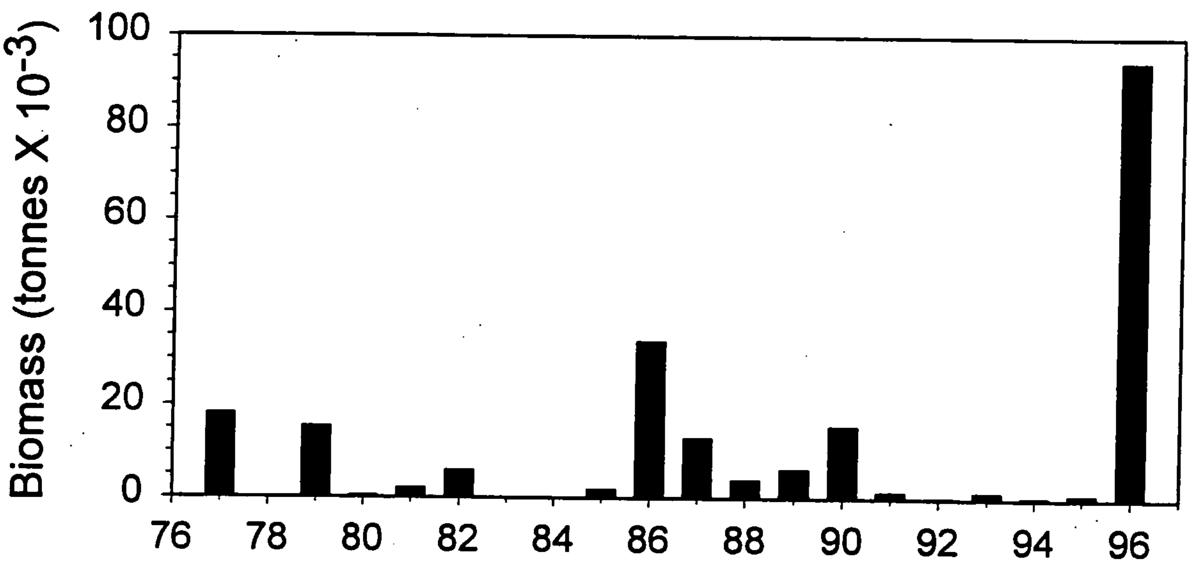


Fig. 13. The biomass of capelin as estimated from areal expansion of stratified mean catch per tow during spring bottom-trawl surveys in Division 3L in 1977-1996. There was no survey in 1983 and coverage was inadequate in 1971-1976 and 1984. A Yankee 41-5 trawl was used until 1982, an Engels 145 Hi-Lift trawl was used in 1985-1995, and a Campelen 1600 shrimp trawl was introduced in 1996.

Distributions and Abundances of Pre-Recruit Capelin (*Mallotus villosus*) in the Northwest Atlantic (NAFO Divisions 2J3KLNO), 1991-1996

by

John T. Anderson and Edgar L. Dalley

Department of Fisheries and Oceans
Science Branch
P. O. Box 5667
St. John's, NF
A1C 5X1

Introduction

A research program to develop a multi-species, pre-recruit survey was carried out during 1991-1993, 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 Divisions 2J3KLNO, including both inshore and offshore areas (Figure 1). Two gear types are used to sample capelin in the upper water column, for the larval stage (0-Group; 3-50 mm), one year old (1-Group, 50-120 mm), and two year old capelin (2-Group, > 120 mm). The survey is 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 their spring and summer spawning.

The purpose of this paper is to report on the results of capelin from the 1996 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 1996 survey and compare these estimates to previous years. We explored two different ways of indexing year-class strength, based on mean annual density (number m^{-3}) as well as an Weighted Index Area method which incorporates spatial distribution as well as density. In addition, we present information on size of capelin for these different ages, and information on their geographic distributions in 1996, and compare these to previous survey results.

Methods

The survey design is based on a random stratified grid, where stations are spaced 54 km apart (Figure 1). At each station a CTD is profiled 0-500 m, or less depending on depth, to measure temperature, salinity, density and fluorescence. This is followed by a double oblique bongo tow to 100 m depth, and finally by a 30 minute IYGPT (International Young Gadoids Pelagic Trawl) tow which samples the 20-60 m depth stratum. Details of the methods used and the sample processing procedures are outlined in Anderson and Dalley (1995).

Beginning in 1996, insufficient resources were available to process the entire bongo samples. Therefore, an at-sea subsampling procedure was used to estimate the abundance of capelin larvae. One side of the bongo sampler was made up to two liters volume. From this volume, homogeneous 50 ml aliquots were subsampled until either 30 capelin larvae had been identified, measured for length and enumerated under a microscope or 20% of the sample had been processed. Total abundance was estimated based on the proportion of the sample processed. In the laboratory, 10% of all samples were selected and fully processed for quality assurance of the subsampling procedure. These samples were stratified among the two survey ships and the two sea-watches aboard each ship.

The survey was carried out from August 19 to September 6, 1996. This was identical to the survey time in 1994 and about two weeks earlier than the survey in 1995. These survey times are approximately 5-6 weeks earlier than the surveys carried out 1991-1993 (Table 1).

An abundance index was calculated based on the mean number of capelin sampled each year, as abundance per cubic meter. This was done for both the total area sampled, excluding null sets, and for the largest common area sampled across all years, 1991-1996, including null sets. For 0-group (larval) capelin it was necessary to adjust abundances due to the relatively high mortality rates experienced by larvae and the significant differences in survey times, 1991-93 versus 1994-96. Adjusted abundance estimates were calculated based on an estimated mean age for each survey and assumed mortality rates of 0.03 to 0.05 d^{-1} (Winters et al. 1996). Age is based on an assumed growth rate each year of 0.35 mm d^{-1} (Frank and Carscadden 1989, J. Anderson unpubl. data), the mean size of 0-group capelin and a larval release size of 4 mm. Therefore, abundance was adjusted to a total abundance estimated at the time of release from beach sediments. Abundance for 1-group and 2-group capelin was only done for the 1994-96 survey years based on IYGPT samples and no adjustment for mortality is necessary.

An area weighted abundance index was developed based on a number of selected areas, following the method of Randa (1982). The Index Areas were chosen to represent different regions for inshore and offshore locations (Figure 1). The index is dependent on all stations being sampled within each area for a given year. When two or more areas have been sampled, an area weighted overall index of abundance can be derived. The basic index for a unit area is calculated as,

$$I_j = \overline{X}_j \cdot p_j$$

where, I_j is the index of abundance for area j, $\overline{X}_j$ is the geometric mean abundance ($\log_e$ number $10^4 m^{-3}$) and p_j is the proportion of non-zero catches. The geometric mean abundance is calculated for each Index Area as,

$$\overline{X_j} = \frac{1}{N_{lj}} \cdot \sum_{i=1}^{N_{lj}} \cdot ln(X_{ij})$$

where N_{lj} is the number of non-zero catches and the variance of $\overline{X_j}$ is calculated as,

$$S_j^2 = \frac{1}{N_{lj} - a} \cdot \sum_{i=1}^{N_{lj}} \cdot (ln(X_{ij}) - \overline{X}_j)$$

where a is the number of zero catches. Finally the Index Area is weighted by the size of each area as,

$$P_j = a_j \cdot I_j$$

where a_j is area of each Index Area (km^2).

An overall index for several commonly sampled areas can be estimated as the sum of the weighted Index Area values

$$SUM_{P_j} = \sum_{j=1}^{k} P_j$$

where k is the total number of commonly sampled Index Areas.

Estimates of year-class strength based on mean abundances do not account for differences in geographic distributions among years. For example, a high mean abundance for a relatively small geographic distribution may represent a smaller population of fish than a low mean abundance with a broad geographic distribution. The Weighted Index Area method attempts to account for differences in geographic distributions of capelin each year. We estimated the abundances of 0, 1 and 2 year old capelin from the 1994-1995 surveys only, where two ships were used to cover the entire geographic distributions of the capelin. We calculated indices for inshore, offshore and total areas for the largest common set of survey Index Areas, where the total represents a sum of the inshore and offshore indices each year for both normal and $\log_e$ transformed data.

The division of samples from the IYGPT into one year old (1-group) and two year old (2-group) capelin from the 1996 survey was based on the length frequency distributions and the ageing of samples from 1994 and 1995 (Anderson and Dalley 1996). One year old capelin were classified as > 50 mm and ≤ 120 mm, and two year old capelin as > 120 mm.

Results

Year-Class Strength–Mean Abundances Method

At the larval (0-group) stage, the 1996 year-class was the most abundant observed since our surveys began in 1991 (Table 2, Figure 2). Comparison of adjusted densities for the period 1991-1996 indicate that year-class strength has increased by a factor of six, from the lowest estimates in 1991 to the highest in 1996. While 1994 was estimated to be the lowest of the time series, it was considered that larval capelin were underestimated by the 1994 survey due to continued release of larvae after the survey was conducted (Anderson and Dalley 1996, Winters et al. 1996). Therefore, we would consider the 1991 and 1992 year-classes to be relatively low compared to the 1993 and 1995 year-classes, while the 1996 year-class was the highest of the time series. The 1994 year-class may have been intermediate in strength between the 1991-92 and the 1993-95 year-classes at the larval stage, based on the larval index.

Year-class strength estimates for the larval stage for the period 1991-1996 were based two different calculations. Mean abundances (number $10^3 m^{-3}$) were estimated for the largest common area sampled over these six years, including zero values, and mean abundances were estimated for all stations sampled where catches were non-zero. The advantage of the common area sampled method is that any differences in geographic distributions are removed. However, this estimate may introduce some degree of bias due to the later survey times in 1991-1993. These capelin were larger, indicating that they were both older and had experienced a longer time to disperse. This would tend to result in fewer zero catches compared to 1994-96 when capelin were both younger and less dispersed to the offshore. The effect of fewer zero catches would be to bias the 1991-1993 estimates upwards. Estimates of year-class strength based on abundances from all non-zero stations would remove the effect of dispersal differences between the 1991-93 and the 1994-96 surveys. It is possible a geographic bias might be introduced by this method, where the 1994-96 surveys sampled both north and south of the 1991-93 surveys. However, there is no indication in our data that there were any significant differences in the spawning distributions among these years, 1991-96. In other words, capelin spawned along the northeast coast of Newfoundland each year, and the 1991-93 surveys appeared to capture most of the distributions of capelin larvae.

The only difference in our estimates of year-class strength ranking, based on these two methods for the larval data, was the ranking of the 1993 and 1995 year-classes (Table 2). Based on the common area estimate, the 1993 year-class ranked higher than the 1995 year-class. However, the number of zero stations was six versus twelve for 1993 and 1995 survey years, respectively (Table 2), and larvae averaged 5 mm larger in 1993. Therefore, the year-class estimates based on the mean abundances for all non-zero stations sampled each year may be a better index. Overall, however, both methods estimate the largest and smallest year-classes the same.

Year-class strength was estimated for one year old capelin (1-group) for the 1991-1995 year-classes based on mean abundances in the IYGPT for all non-zero stations sampled during the 1992-1996 surveys. No adjustments were made for differences in survey times or geographical distributions. This index indicates that the 1991 and 1992 year-classes were the lowest, followed by the 1994 year-class, while the 1993 and 1995 year-classes were highest, and not different from each other (Figure 2). There were 1.5–2 orders of magnitude difference between the lowest year-classes

(1991-92) and the highest (1993-95). These estimates also demonstrate there is a consistent ranking in year-class strength between the larval (0-group) and age one (1-group) abundances, indicating that year-class strength established by the larval stage persisted through to age one (Figure 3).

Year-Class Strength–Weighted Index Areas

The Weighted Index Area method indicates increasing year-class strength at the larval (0-group) stage for the period 1994-1996, using both normal and $\log_e$ transformed data (Tables 3 and 4; Figure 4). Both indices indicate the increase from 1994 to 1996 was approximately one order of magnitude. Abundance estimates for the inshore areas were higher than the offshore areas in all but one instance, when abundances in 1995 for the normal data were approximately equal for inshore and offshore areas.

For one year old capelin (1-group), the Weighted Index Area method estimated that year-class strength ranked as 1993>1995>1994 for both normal and $\log_e$ transformed data (Figure 5; Tables 3 and 4). In both 1994 and 1996 one year old capelin were more abundant within the inshore area, whereas in 1995 capelin were more abundant offshore. Higher abundance inshore is notable, as this area is represented by only 27 stations, whereas the offshore areas used in the index is represented by 60 stations covering twice the area. Therefore, in two of the three years sampled there were more capelin inshore than offshore. If we regard the inshore and offshore areas separately then our ranking of year-class strength changes: inshore 1993>1995>1994; offshore 1993>1994>1995 (Figure 5).

For two year old capelin (2-group), there was a difference in the ranking of year-class strength based on the different data used to calculate the Weighted Index Area values. For normal data, year-class ranking was 1994>1992>1993, whereas for the $\log_e$ transformed data it was 1992>1993=1994 (Figure 6; Tables 3 and 4). Two year old capelin were more abundant within the inshore area than offshore in 1994 and 1996, which was similar to one year old capelin. As with one year old capelin, our ranking of year-class strength for age two capelin changes between inshore and offshore areas. However, the ranking also changes with the estimation method. The only consistent result is that the 1993 year-class never ranked higher than the 1992 and 1994 year-classes at age two.

Distributions

Larval (0-group) capelin were distributed throughout the inshore areas from the Northern Peninsula to the southern Avalon Peninsula (Figure 7). Larval capelin were also distributed onto the adjacent shelf, as in 1994 and 1995 (Anderson and Dalley 1996). Highest abundances occurred in White Bay, Notre Dame Bay and Conception Bay.

One year old capelin were distributed throughout the inshore from White Bay to St. Mary's Bay as well as on the southern part of the Northeast Newfoundland Shelf and the northern Grand Bank (Figure 8). Highest abundances occurred in Bonavista Bay and on the adjacent shelf. One year old capelin were noticeably absent from the northern part of the survey, and on the southern Grand Bank. Geographically, this distribution was similar to that of one year old capelin in 1995 but less extensive than that in 1994 (Anderson and Dalley 1996).

The distribution of two year old capelin in 1996 was similar to the one year old (Figure 9). Highest abundances occurred off Bonavista Bay and the north slope of the Grand Bank. Two year old capelin occurred throughout much of the inshore area along the northeast coast of Newfoundland and over the northern Grand Bank, but were absent from much of the northeast Newfoundland Shelf and the southern Grand Bank. This distribution is similar to that of two year old capelin in the 1995 survey, but was less extensive geographically (Anderson and Dalley 1996). The distribution of two year old capelin in the 1994 survey was largely restricted to Conception Bay, the coastal waters around the Avalon Peninsula and one small area on the northern Grand Bank (op. cit.).

Lengths

Larval capelin averaged 9.9 mm in length in 1996 with one dominant mode from 9-13 mm (Figure 10). This was comparable to average lengths of 8.9 mm in 1994 and 10.7 mm in 1995 (Anderson and Dalley 1996). One and two year old capelin caught in the IYGPT ranged from 53-174 mm with one mode around 84-98 mm and a second, smaller, mode around 140 mm (Figure 10). In 1996, one year old capelin averaged 88.2 mm and two year old capelin averaged 142.1 mm. The length at age one has varied among year-classes, where 1993<1995<1994 (Figure 11). The 1994 year-class was greater in length than the 1993 year-class at both age one and two years (Figure 11).

Discussion

Year-Class Abundances

Year-class abundance estimated at the larval (0-group) stage predicts the relative abundance at one year of age. For the 1991-1995 year-classes, we estimated the abundance of the 1993 and 1995 year-classes to be relatively large as both larvae and one year old capelin. The 1994 year-class was the lowest estimate at the larval stage during the five year period, but at age one the 1994 year-class ranked higher than either the 1991 or 1992 year-class; although its relative abundance was much less than either the 1993 or 1995 year-classes. The increase in relative abundance of the 1994 year-class at age one is consistent with the belief that this year-class was underestimated at the larval stage due to its relatively late emergence from the beach sediments (Anderson and Dalley 1996, Winters et al. 1996). However, it still appears as a relatively weak year-class in this short time series of data.

Our ranking of year-class abundance at age two indicates that the 1993 year-class was less abundant than either the 1992 or 1994 year-classes. However, estimating year-class strength in our survey for age two capelin may be problematic. Typically, we catch relatively few two year old capelin. Low catches may arise from a patchy distribution in surface waters due to active schooling behaviour in these older fish. Such a patchy distribution may not meet the basic assumptions of our present survey design. In addition, two year old capelin may be distributed much deeper in the water column and not be routinely available to the IYGPT which is towed within the 20-60 m depth range. Examination of these possibilities should be explored.

Population Response–Growth Response

Following low year-class abundance estimates for the 1991 and 1992 year-classes, there appears to have been relatively high production of larval capelin since 1993. In addition, there has also been an increase in the average size of capelin at one year of age. Mean size increased from 73 mm in 1992 to 85 mm in 1993, 103 mm in 1994, dropping to 88 mm in 1995. A larger size measured at age one in 1994, compared to 1993, was still evident at age two (Figure 11). Therefore, it appears that there was a numerical and growth response in the population of capelin that began in 1993. This positive response in capelin can be compared to warmer water temperatures, beginning in 1994 and continuing through to 1996 (Colbourne 1996).

Spawning Areas

Distributions of larval capelin, combined with knowledge of dominant ocean currents and dispersal estimates, can provide some information on the important spawning areas of capelin. In 1996, it appears that capelin spawned successfully along the entire Northeast coast of Newfoundland. There was no evidence of spawning off southern Labrador nor on the Southeast Shoal of the Grand Bank. Absence of capelin in either area could result from larvae not yet released from spawning sediments. On the SE Shoal, larvae 9-17 mm in length were abundant in a survey carried out September 13-18, 1986 (Frank and Carscadden 1989). At a modal length of 12 mm these larvae would have been 23–32 days post-release (assuming a release length of 4 mm and a range of growth rates from 0.25–0.35 mm d^{-1}). However, larvae 4-6 mm were also abundant in this survey, indicating that release from bottom sediments was still ongoing. Therefore, it is possible that a late spawning and release of capelin larvae on the SE Shoal would be missed by our 1996 survey, which ended September 6. However, such a late release would contrast with spawning and release times along the NE coast in 1996, where the dominant length range was 6–13 mm.

Inshore vs Offshore Distributions

It is apparent from these surveys that the inshore area is important to capelin. The relative importance of the inshore area compared to the offshore area for larvae may be a direct function of their age and dispersal from the inshore to offshore area. For one and two year old capelin the abundance of capelin was greater inshore than offshore in two of three years, based on the weighted index area method. These observations appear to be primarily due to the high abundances of one and two year old capelin in Bonavista Bay.

Acknowledgements

A number of people contributed to the successful completion of the 1996 survey. Technical assistance in preparing for and conducting the cruise included Arnold Murphy, Eugene McDonald, Denise Davis, Greg Redmond, Darlene Gillet, and Phil Eustace. Arnold Murphy was responsible for assembly of the considerable amount of electronic gear that are used by the two ships. Denise Davis has been responsible for wrestling with complex data sets being generated and producing the tabulated and graphical results. Greg Redmond and Eugene McDonald were responsible for biological sampling and data quality, including post trip sample processing and verifications. Capelin ageing for 1-5 year old capelin data was provided by Pelagic Section. In particular, we thank the captains and crews of the Wilfred Templeman and Teleost for excellent cooperation and assistance in carrying out our two ship survey for the fourth year.

References

Anderson, J. T., and E. L. Dalley. 1995. Distribution and abundances of pre-recruit capelin (*Mallotus villosus*) in the Newfoundland region, 1994–1994. **In** Capelin in SA2 + Div. 3L. DFO Atl. Fish. Res. Doc. 95/70. P. 185-199.

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. DFO Atl. Fish. Res. Doc. 96/90. P. 185-199.

Colbourne, E. 1996. Environmental conditions on the Newfoundland Shelf, Spring 1996 with reference to the 1961-1990 normal. NAFO SCR Doc. 96/26. Ser. No. N2699. 14 p.

Frank, K. T., and J. E. Carscadden. 1989. Factors affecting recruitment variability of capelin (*Mallotus villosus*) in the Northwest Atlantic. J. Cons. int. Explor. Mer. 45: 146-164.

Randa, K. 1982. Recruitment indices for the Arcto-Norwegian cod for the period 1965-1979 based on the international 0-group fish survey. Coun. Meet. int. Coun. Explor. Sea, 1982 (G:43): 1-22. Mimeo.

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

Table 1. Summary of Pelagic Juvenile Fish Surveys, 1991-1996, carried out in the Northwest Atlantic, as a single ship survey, 1991-1993, and as a two ship survey, 1994-1996. DAW046 - Dawson trip 46; TEM127 - Wilfred Templeman trip 127; TEM143 - Wilfred Templeman trip 143; TEM157 - Wilfred Templeman trip 157; GAD247 - Gadus Atlantica trip 247; TEM175 - Wilfred Templeman trip 175; TEL018 - Teleost trip 18; TEM193 - Wilfred Templeman trip 193; TEL034 - Teleost trip 34; 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

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

Table 3. Abundance indices for Northwest Atlantic capelin (NAFO Divisions 2J3KLNO) based on the two-ship surveys, 1994-1996, 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 areas; TOTAL - summed Weighted Index Area estimates for Inshore and Offshore areas. 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		
Area	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	68.58	9.61	0.81	192.46	1.21	0.61
TB	12.88	854.32	19.15	36.70	23.25	0.42	142.76	82.39	15.68
BB	12.57	2927.28	0.54	18.04	6.42	2.07	114.44	8579.40	662.36
NDB	36.72	74.59	2.71	19.45	452.30	10.11	100.43	2.14	0.66
WB	41.70	23.75	0.15	15.64	3.30	6.24	154.19	0.42	1.71
SUM	126.59	10210.4	164.12	156.41	494.88	19.65	704.28	8665.56	681.00
Offshore									
HB									
ISN				0.86	0.30	14.06	0.00	0.20	0.20
ISS	28.47	21.40	0.00	44.13	14.88	5.17	220.78	0.42	9.17
BIBI	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
BIBO									
FIBI				4.15	8.75	3.41	3.61	92.39	0.98
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
SA	8.80	258.55	50.54				18.29	9.48	0.53
SGB	0.05	127.52	1.33	1.00	132.88	3.13	0.00	0.00	0.00
NOSE							0.00	199.83	0.44
TAIL									
SGBO									
WD									
SUM	38.24	4285.62	34.05	171.53	903.11	116.67	300.76	1115.53	33.16
TOTAL	164.83	14496.0	198.17	327.94	1397.99	136.32	1005.04	9781.09	714.16

Table 4. Abundance indices for Northwest Atlantic capelin (NAFO Divisions 2J3KLNO) based on the two-ship surveys, 1994-1996, using the Weighted Index Area method for transformed data ($\log_e$(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 areas; TOTAL - summed Weighted Index Area estimates for Inshore and Offshore areas. 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		
Area	0-Group	1-Group	2-Group	0-Group	1-Group	2-Group	0-Group	1-Group	2-Group
Inshore									
CB	76.51	18041	550.63	530.26	39.97	8.04	880.81	12.11	6.05
TB	83.45	293.76	191.46	266.8	102.85	4.19	946.21	723.24	35.72
BB	69.96	6400.4	5.44	104.27	47.1	12.94	787.52	15326	276.2
NDB	151.22	132.42	12.87	152.91	392.81	33.06	699.31	12.48	6.46
WB	275.07	114.93	1.5	116.46	18.53	42.9	1087.5	4.22	14.6
SUM	656.21	24983	761.90	1170.7	601.26	101.13	4401.4	16078	339.03
Offshore									
HB									
ISN				8.58	3.03	41.39	0.00	2.01	2.01
ISS	101.32	91.18	0.00	316.98	34.52	27.01	1997.3	4.17	26.63
BIBI	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
BIBO									
FIBI				34.62	49.48	24.41	31.42	216.06	9.14
FIBO	0.00	46.41	0.00						
NGB	23.39	8474.7	171.83	347.3	1931.9	322.92	410.65	933.32	90.34
SA	44.97	1935.2	463.3				143.65	22.3	5.27
SGB	0.53	138.66	12.52	9.58	80.35	25.69	0.00	0.00	0.00
NOSE							0.00	143.54	4.36
TAIL									
SGBO									
WD									
SUM	125.24	8704.5	184.35	673.86	2046.8	375.62	2408	937.49	116.97
TOTAL	781.45	33687	946.25	1844.6	2648.0	476.75	6809.3	17016	456.00

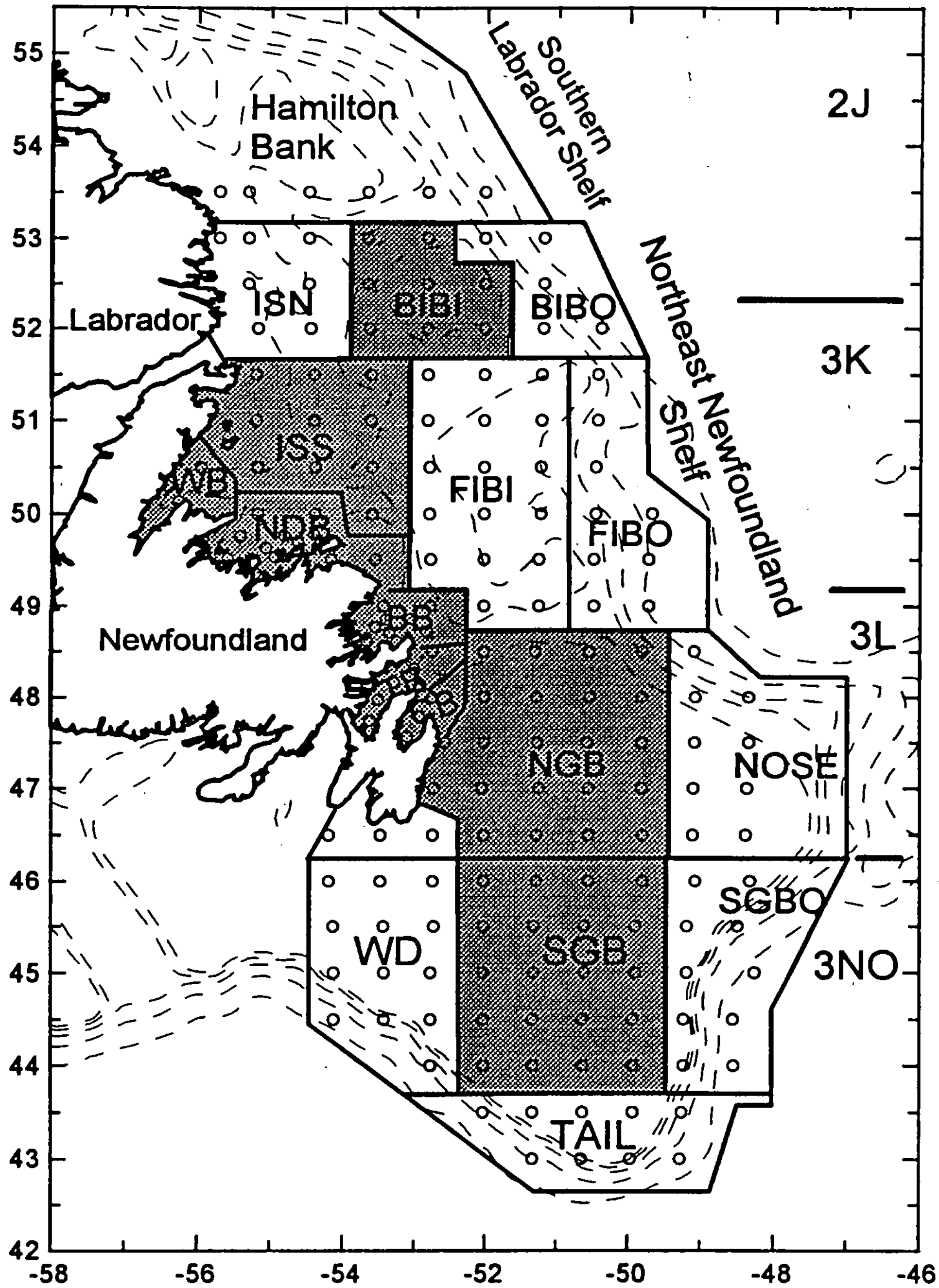


Figure 1. Survey area for Pelagic Juvenile Fish Survey, showing sampling locations (o) and Index Areas. See text for explanation of the Index Areas. The shaded Index Areas represnt those areas used in the estimation of abundance indices.

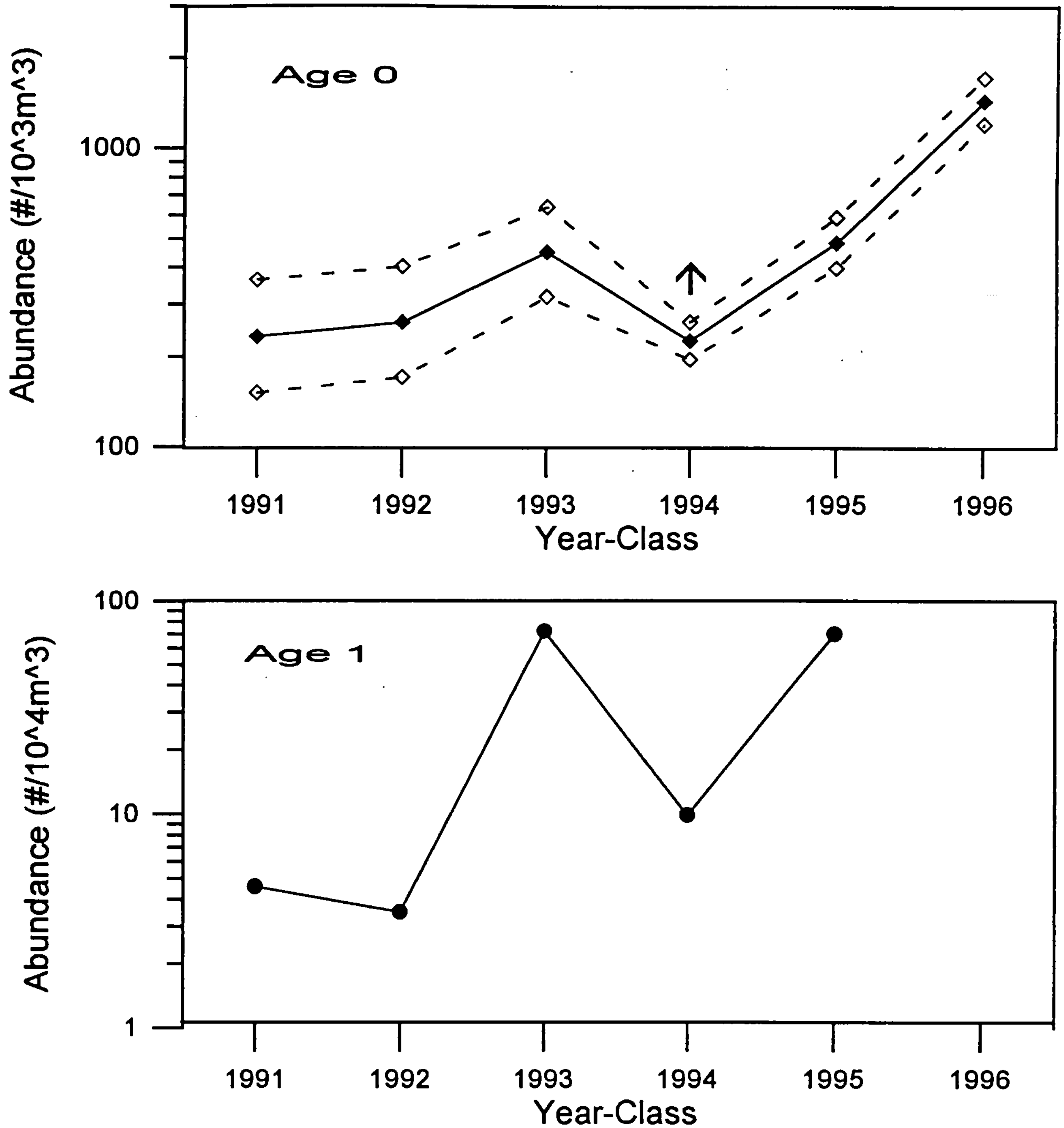


Figure 2. Abundance estimates for larval capelin, based on mean estimates of larval (age 0) and one year old (age 1) capelin each year for all stations were capelin were caught. The open diamonds for Age 0 capelin represent upper and lower standardized estimates based on different mortality assumptions (see text for details).

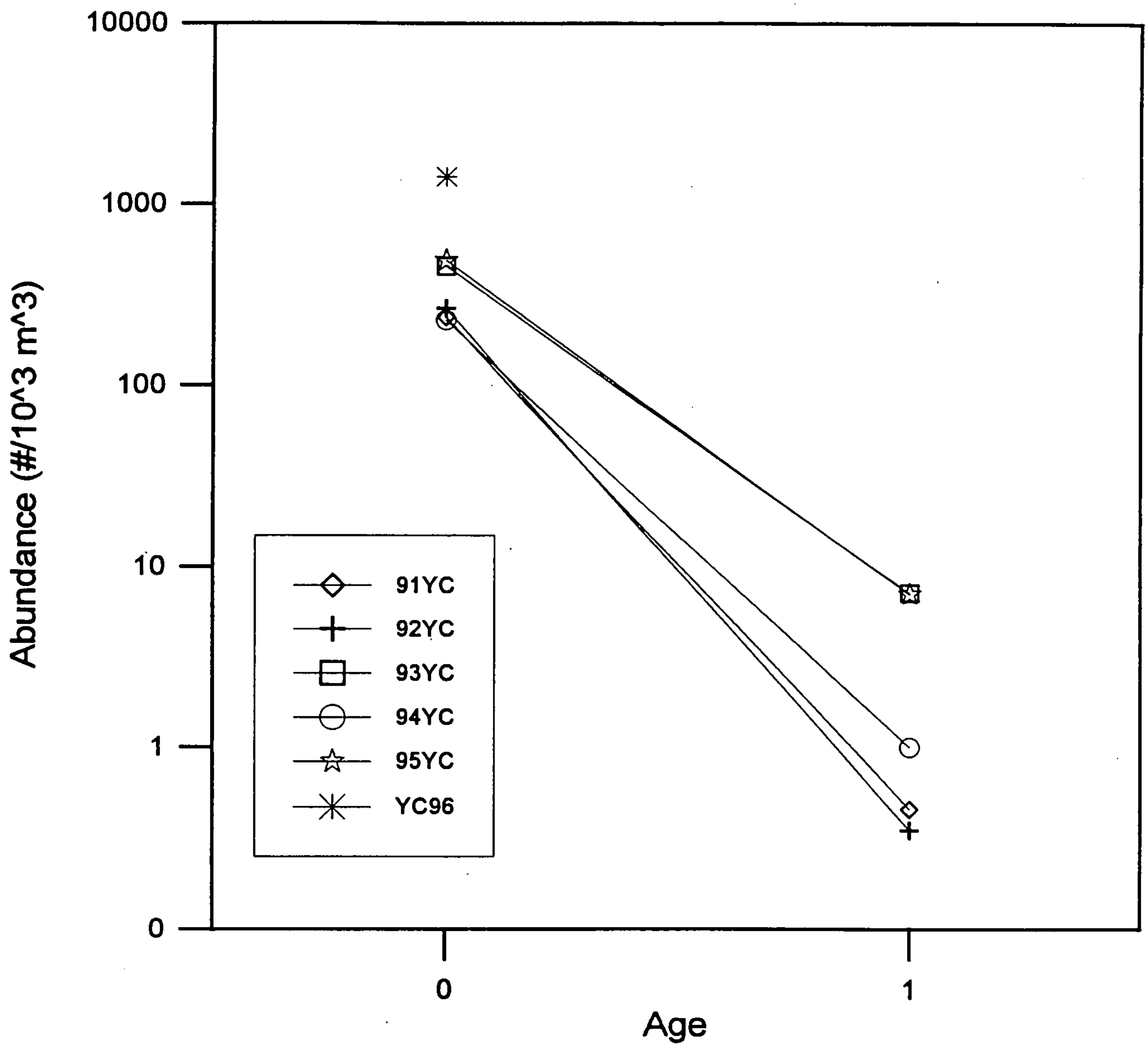


Figure 3. Abundane estimates of larval (age 0) and one year old (age 1) capelin estimated each year. In the legend, YC refers to year-class.

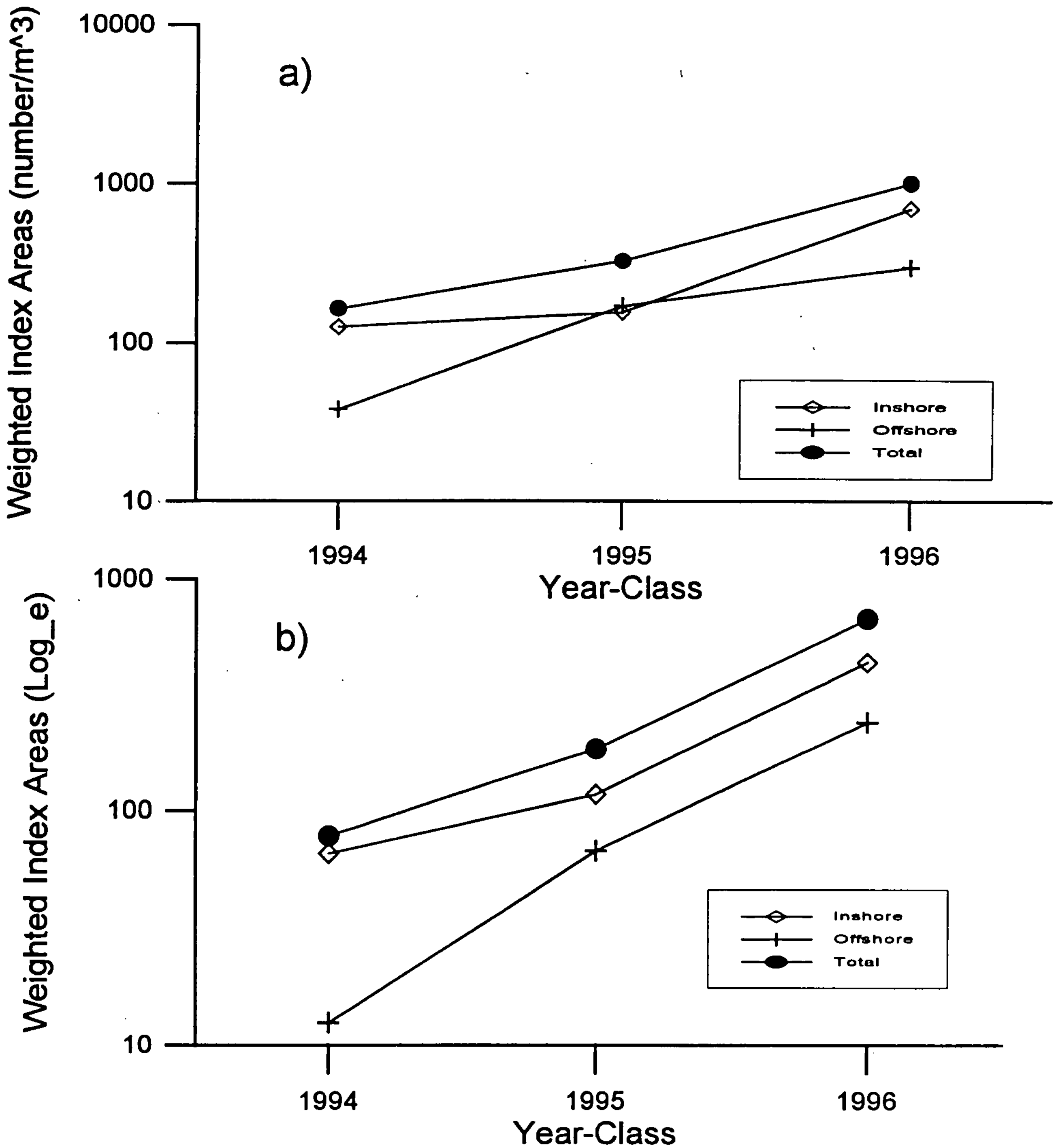


Figure 4. Capelin abundance indices based on the Weighted Index Area method for larval (age 0) capelin, 1994-1996.

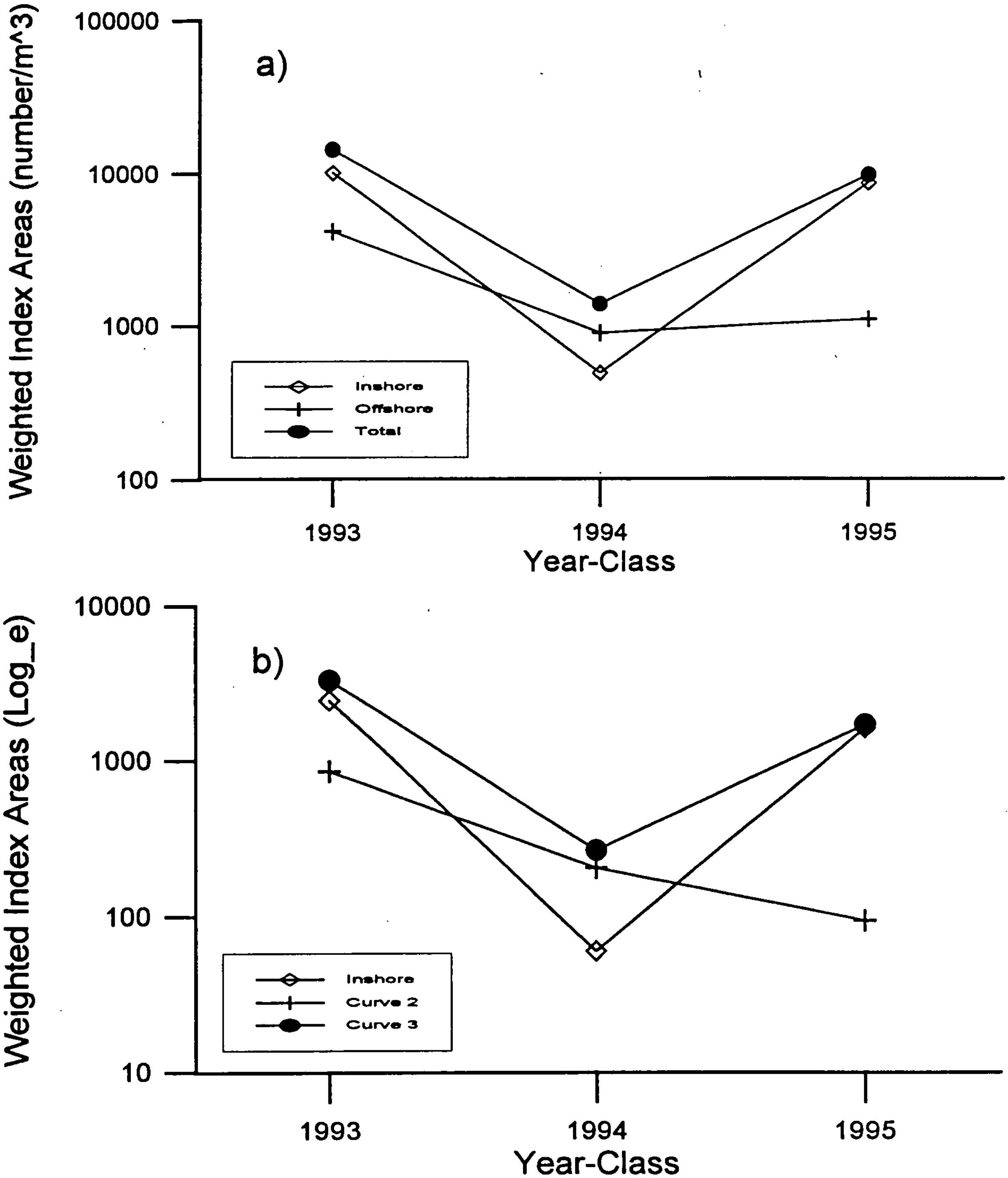


Figure 5. Capelin abundance indices based on the Weighted Index Area methof for one year old (age 1) capelin, 1994-1996.

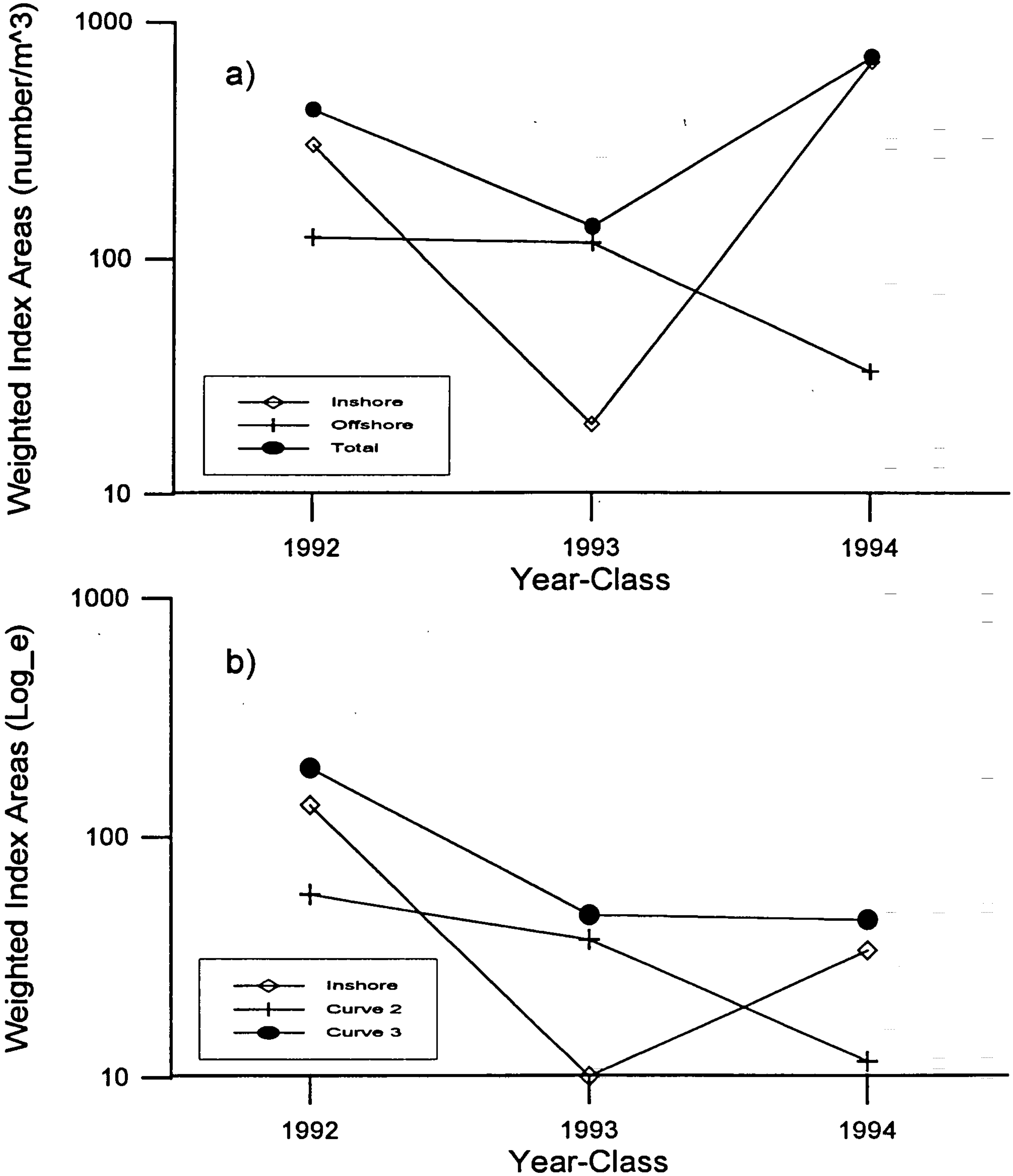


Figure 6. Capelin abunance indices based on the Weighted Index Area method for two year old (age 2) capelin, 1994-1996.

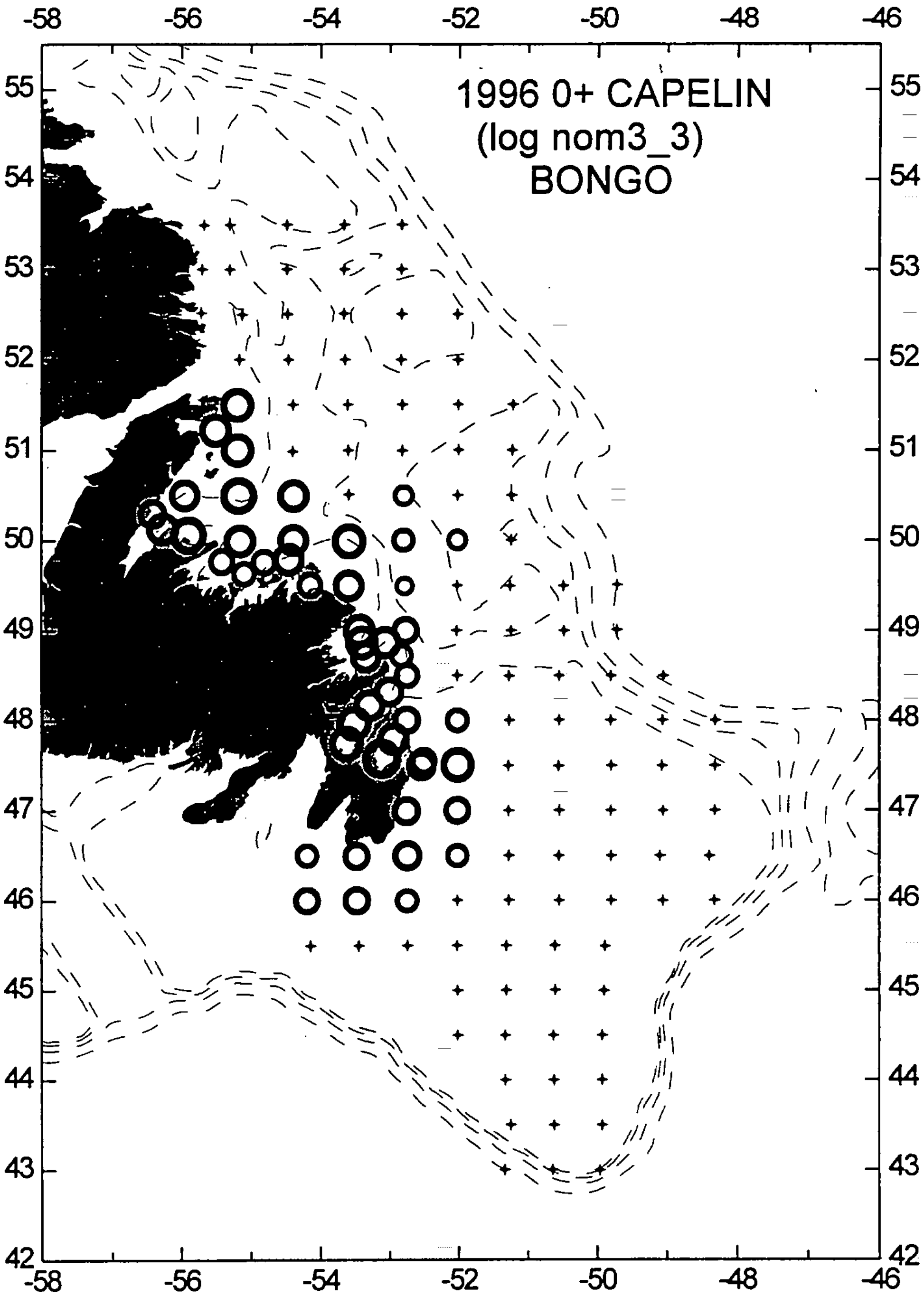


Figure 7. Distribution of larval capelin sampled by the bongo sampler in 1996. Abundance (log_10 number/m^3) at each location is represented by an expanding symbol. Crosses (+) represent stations where capelin were not caught. .

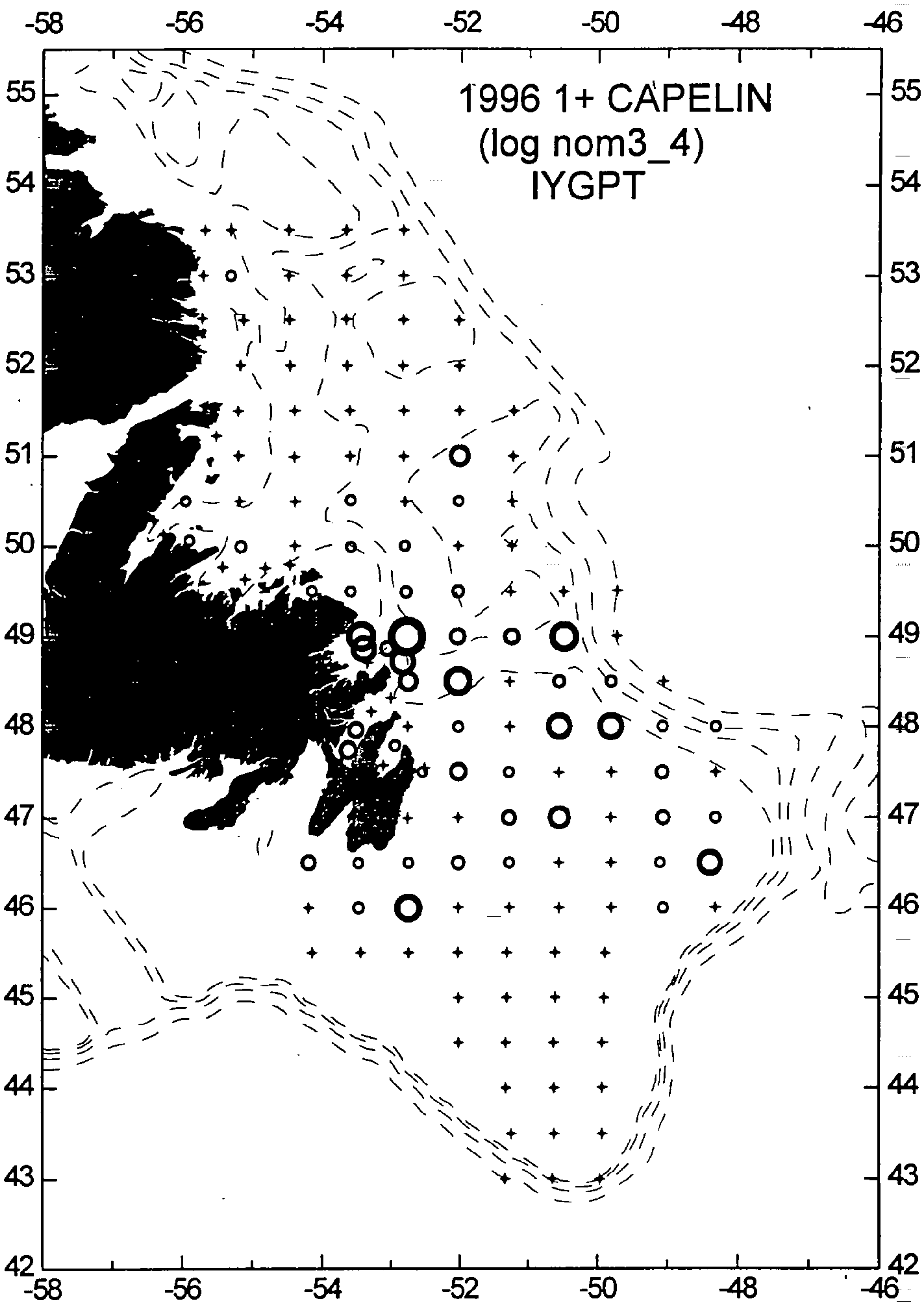


Figure 8. Distribution of one year old capelin sampled by the IYGPT trawl in 1996. Abundance (log_10 number/m^3) at each location is represented by expanding symbols. Crosses (+) indicate stations where capelin were not caught.

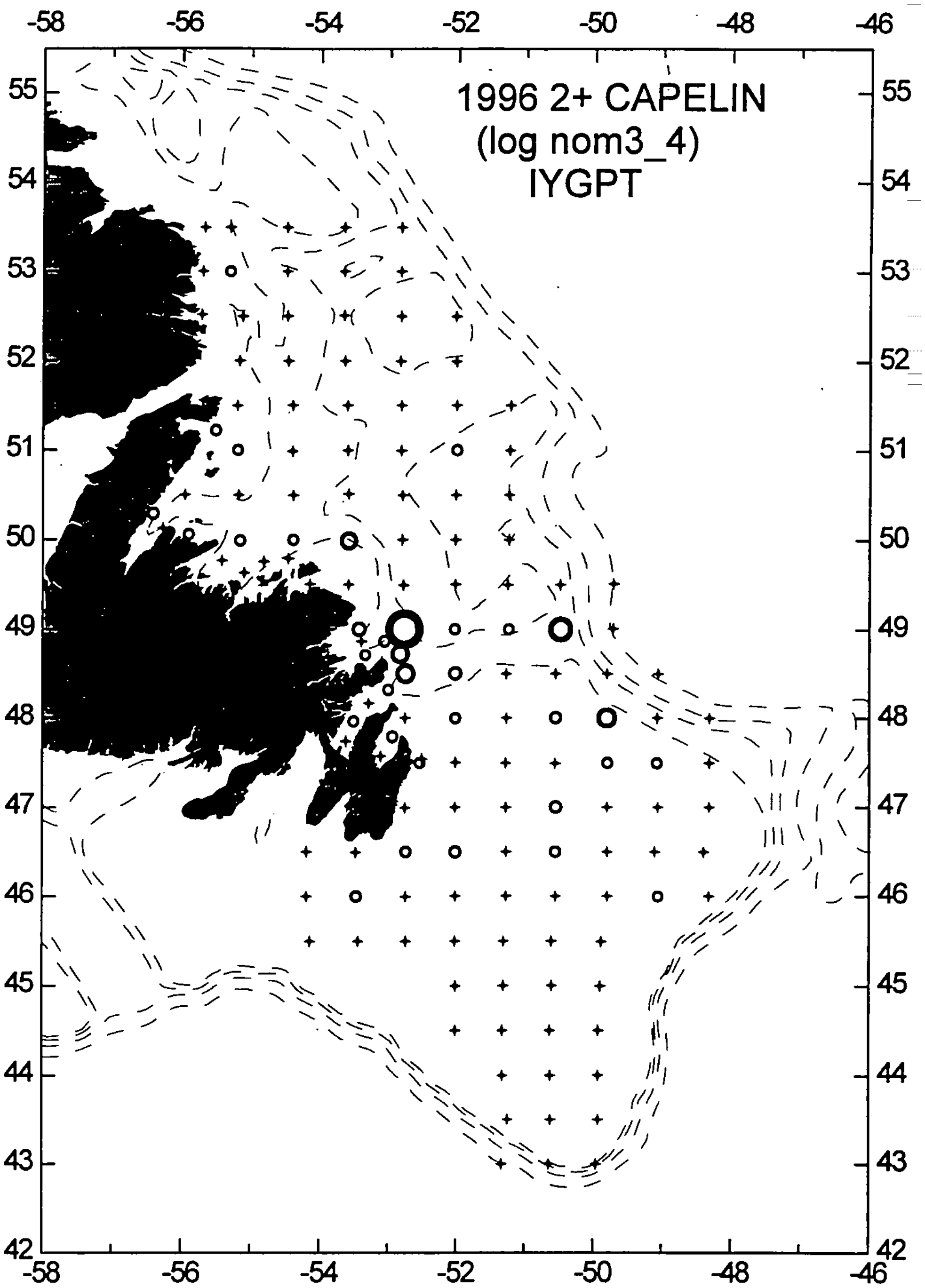


Figure 9. Distribution of two year old capelin sampled by the IYGPT trawl in 1996. Abundance (log_10 number/m^3) at each location is represented by expanding symbols. Crosses (+) represent stations where capelin were not caught.

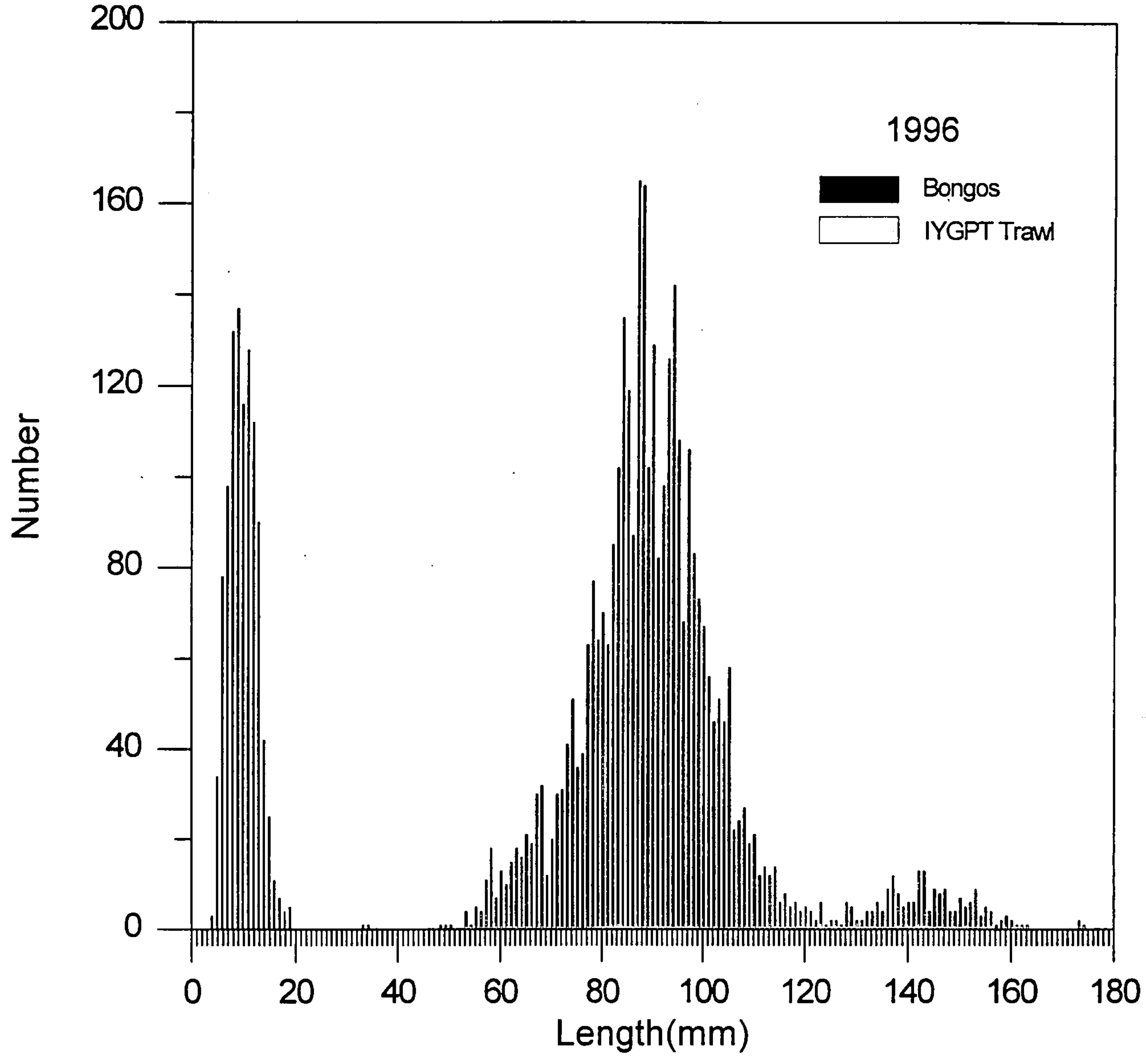


Figure 10. Length (mm) frequency distribution of capelin sampled by the bongo and IYGPT samplers in 1996.

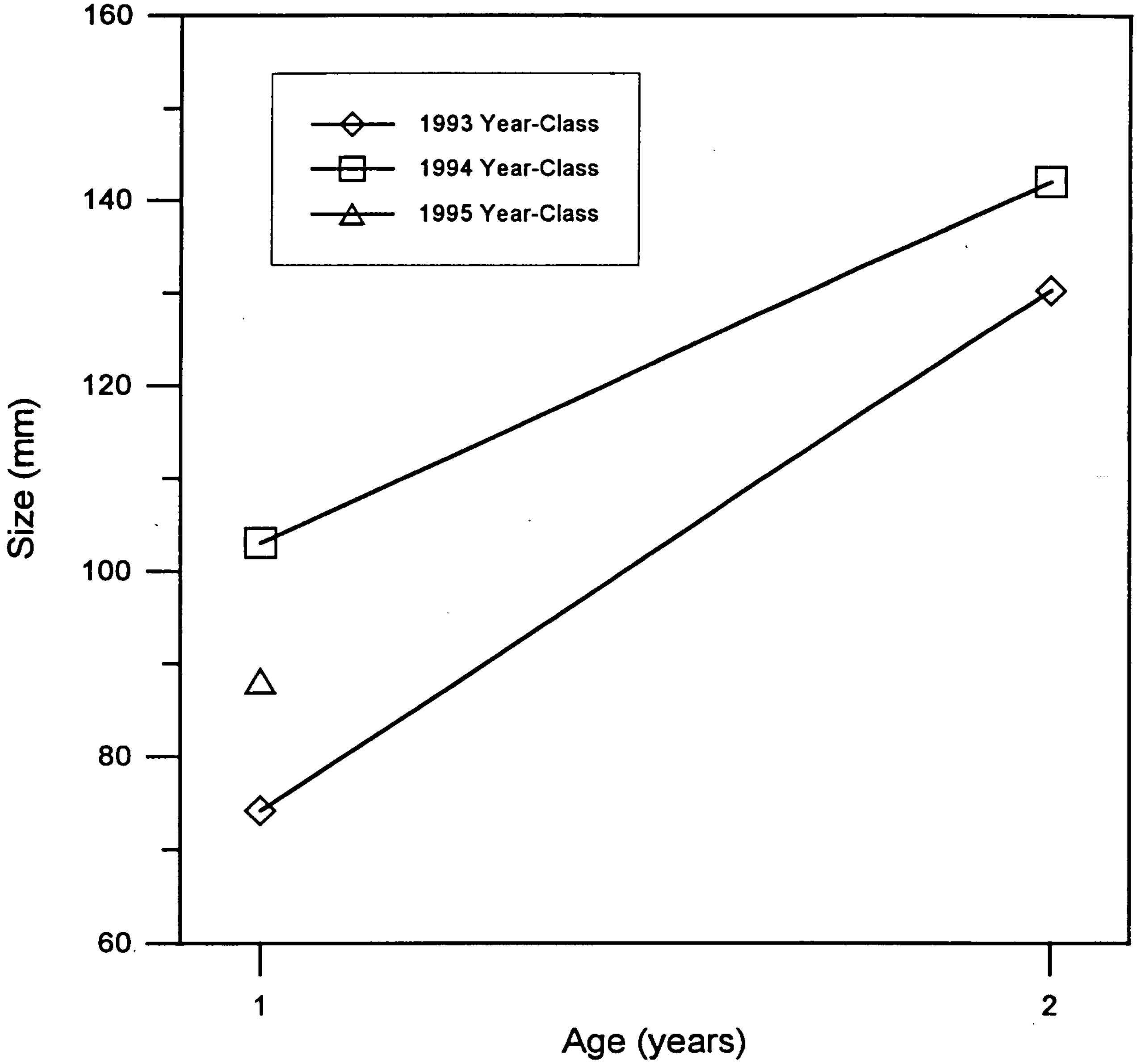


Figure 11. Mean size at age for one and two year old capelin measured in the Pelagic Juvenile Fish Surveys, 1994-1996, for different year-classes.

Predicting Mean Lengths of Capelin

by

J. Carscadden and D. S. Miller
Science Branch
Department of Fisheries and Oceans
P. O. Box 5667
St. John's NF A1C 5X1

Introduction

During the last two assessments, the relationships between mean lengths of capelin from fall offshore acoustic surveys and inshore the following year were evaluated (Carscadden 1995, 1996). These analyses were conducted by sex, by age group and combined age groups. Most relationships were statistically significant but because of the interest in the industry in the size of females, emphasis was placed on these relationships. In these analyses, mean lengths of fish from fall acoustic surveys were calculated from survey blocks where most of the maturing biomass had been detected. Thus, most of the fish would have been maturing although there were likely small numbers of immature fish contributing to the estimates of mean length.

In this paper, this source of bias has now been eliminated by revising the computer program so that the relationships between mean length of maturing fish only, from the fall acoustic surveys and mean lengths of mature fish taken inshore the following year, can now be examined. In addition, we have also examined the relationships between mean lengths of immature fish in the spring acoustic series and the mean lengths of mature fish in the spawning season the following year. In both analyses, we also investigated the influence of temperature on the relationships.

Data Sources

Fall Surveys:

A fall acoustic survey has been conducted annually between 1981 and 1994. The actual area covered each year has differed but generally was enlarged geographically in the late 1980's to answer concerns that fish were not detected due to incomplete coverage. Between 1981 and 1992 (inclusive) areas surveyed occurred in Div. 2J and 3K and during 1993 and 1994, the survey included most of Div. 3L out to the 500 m depth contour to account for the new stock structure of Div. 2J3KL (Nakashima 1992). In this study, mean lengths were calculated by sex, age group and combined sexes and age groups for the entire survey. Data from each set were given equal weight. Mean lengths of maturing capelin in the fall were compared to mean lengths of mature capelin inshore in Div. 3KL the following year.

During 1995, a special acoustic study was conducted in the fall in a restricted area of Div. 3K and data on mean lengths of capelin were available from this study. In addition, the fall groundfish survey using the Campelen trawl has been conducted during 1995 and 1996 and data on mean lengths were also available.

Spring Surveys

Acoustic surveys were conducted in Div. 3L during the spring between 1982 and 1992 (inclusive). During 1993-95, attention was concentrated on the fall surveys but in 1996, the spring survey was again conducted although expanded in area. Thus, in 1996 Div. 3L was the primary survey area with the intent to survey as much of the area north of Div. 3L (Div. 3K) as time and ice cover permitted.

In this analysis, data from the entire survey area were used with each set given equal weight. Mean lengths for each sex, age and sexes and ages combined were estimated for immature fish from the spring surveys. These mean lengths were compared to mean lengths of corresponding cohorts of mature fish taken in the inshore the following year (i.e. approximately 13-14 months later). These comparisons were made using the 1982-92 spring series whereas data from the 1996 survey were used to predict mean lengths in the inshore in 1997.

Inshore

Mean lengths of mature fish taken during the inshore fishery in Div. 3KL were calculated for 1982-96, weighted by catch, except for 1994 and 1995. In these years, the catches were very low and the few samples that are available are not representative of the population. Mean lengths in these years were from capelin collected on spawning beaches in support of egg deposition studies (B. Nakashima, pers. comm.).

Temperature

We used mean monthly temperature averaged over 0-20 m from Station 27. Monthly means were summed (TEMPSUM) over various time periods and used in the comparisons. For comparisons of the fall survey to the next spawning period, we used TEMPSUM from January to May. For comparisons involving the spring survey and the spawning period one year later, we used TEMPSUM June to December (i.e. following the survey), TEMPSUM January to May (i.e. prior to spawning) and TEMPSUM June to May (i.e. in the entire interval between the survey and spawning).

Data Analysis

We used linear regression analyses for the comparisons. Since males are not important in the roe fishery, relationships for males are not considered in this paper. Females are important and these relationships are presented. In addition, we also present the population results, that is, for sexes combined. Because two age-groups tend to dominate the mature stock, our analyses were focused on ages 3 and 4 for the mature fish (ages 2 and 3 the year before), but we also present analyses for all ages combined.

Results and Discussion

Fall Surveys

Scatterplots of the relationships between mean lengths of maturing female fish from the fall acoustic surveys and corresponding age groups in the mature population during the next spawning season are shown in Figure 1. Similar plots for the population (sexes combined) are shown in Figure 2.

The statistics associated with the plots in Figures 1 and 2 are shown in Table 1. Also in Table 1 are the statistics associated with the relationships when temperature is added. The only relationship which is not statistically significant ($p \leq .05$) is age 2 in the fall - age 3 inshore for the population. All other relationships are statistically significant ($p \leq .05$) and in most cases there is an improvement in the relationship when temperature is included.

During last year's assessment we had mean lengths of capelin from two sources, bycatch from the Campelen trawl in the 2J3KL fall groundfish survey and catches of capelin from the Campelen and IYGPT trawls from the special acoustic surveys in 1995 (Carscadden 1996). These values are shown in Table 1 along with revised values (in parenthesis) for only mature fish which were calculated using the revised computer program. Since there was a fishery in 1996, we have estimates of observed mean lengths of females inshore (column labelled "Observed inshore 1996", Table 1). If we substitute the 1996 observed inshore values in the respective regression equations, we can estimate the corresponding fall 1995 mean lengths (in column labelled "from regression fall 1995", Table 1). These values can then be compared to those collected from the two fall 1995 data sources. In these two columns, the values in parentheses are the most appropriate for comparisons since they are derived from maturing fish. (The values not in parenthesis are those that would have been derived during last year's assessment, prior to our ability to use only maturing fish and are included simply because some of these values were used in last year's assessment.) Using only the values in parenthesis, fish taken during the groundfish survey were slightly smaller than those taken during the special acoustics research and showed better agreement with values predicted from the regression. The larger values from the acoustics research may be an artifact of capturing fish from a relatively small geographical area; in contrast, mean lengths from bycatch in the groundfish survey were derived from capelin captured over a much wider area. When all ages were combined, the observed mean lengths in the fall were larger than predicted from the regression. This indicates that if the 1995 observed fall lengths had been used to predict the 1996 inshore lengths, the latter would have larger than that actually observed. Nevertheless, the relationships appear to be useful for prediction and estimates of mean length from the fall groundfish survey (the only source of data for 1996) should be useful in providing direction as to the likely size of the mature fish inshore in 1997.

The last two columns of Table 1, contain the observed mean lengths from the 1996 fall groundfish survey, using the Campelen trawl and the predicted mean lengths of fish inshore in 1997. The predicted values were comparable to those predicted from the spring surveys (Table 2) and larger than those observed in 1996. For females of all ages, the predicted length of 161 mm is the same as the 1981-96 mean, 5 mm shorter than the 1981-90 mean but 10 mm larger than the mean observed during the 1990's.

Spring Surveys

Scatterplots of the relationships between mean lengths of immature female capelin from the spring acoustic survey and the appropriate age groups of the same yearclass in the mature population during the next spawning season are shown in Figure 3. Similar plots for the population (sexes combined) are shown in Figure 4.

The statistics associated with the plots in Figures 3 and 4 are shown in Table 2 along with the statistics associated with the relationships when temperature is added. Of the 24 relationships tested, only five were not statistically significant ($p \leq 0.05$). In most cases, there was an improvement when temperature was in the relationship. In five out of six cases, the highest r^2 occurred when the temperature over the longest time period (June to May) was included.

Using the values of mean lengths of immature capelin from the 1996 spring survey, mean lengths of mature length in 1997 were predicted. We were also able to make predictions including the June-December temperatures. In all cases, the predicted 1997 mean lengths are larger than the 1991-96 mean and in some cases, were comparable to the 1981-90 means. Addition of temperature, June-December, did not result in large changes in predicted mean lengths. The predicted mean lengths differ somewhat from that predicted from the fall surveys. However, the overall conclusion using both datasets is that capelin in 1997 will likely be larger than capelin from the 1991-96 period, at least as large as fish from the overall time period 1981-96 and perhaps as large as fish from the 1981-90 period.

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 females capelin during 1996. p. 200-208. In: Anon. Capelin in SA2 + Div. 3KL. DFO Atl. Fish. Res. Doc. 96/90. 269 p.

Table 1. Statistics of relationships using mean lengths from fall acoustic surveys in Div. 2J3K(L) and inshore one year later, and temperature.

Comparison	Dependent	Independent	r^2	p	Observed inshore 1996	From regression fall 1995	Observed Campelen Groundfish 2J3KL 1995	Observed Campelen/ IGYPT Fall Div. 3K 1995	Campelen observed in 1996	1997 Lengths Predicted from Campelen Div. 2J3K 1996
Females	Age 3, mature	Age 2, mature	.376	.015	152	136	137 (139)	141 (142)	153	166
		Age 2, mature, Tempsum, Jan.-May	.470	.022						
	Age 4, mature	Age 3, mature	.513	.003	161	154	153 (153)	154 (154)	160	169
		Age 3, mature, Tempsum, Jan-May	.540	.009						
	All ages, mature	All ages, mature	.443	.007	151	134	133 (138)	140 (141)	149	161
		All ages, mature, Tempsum, Jan.-May	.527	.011						
Sex combined	Age 3, mature	Age 2, mature	.191	.103	161	137	145 (147)	146 (147)	162	175
		Age 2, mature, Tempsum, Jan.-May	.350	.076						
	Age 4, mature	Age 3, mature	.812	.001	162	155	154 (154)	154 (157)	166	179
		Age 3, mature, Tempsum, Jan.-May	.815	.001						
	All ages, mature	All ages, mature	.333	.024	159	133	139 (145)	145 (146)	152	170
		All ages, mature, Tempsum, Jan.-May	.425	.036						

Table 2. Statistics of relationships using mean lengths from spring acoustic surveys in Div. 3L and inshore one year later, and temperature.

Comparison	Dependent	Independent	r^2	p	Mature 1997 predicted	Dependent		
						Mean (81-96)	Mean (81-90)	Mean (91-96)
Female	Age 3, mature	Age 2, immature	.325	.053	164	157	161	151
		Age 2, immature, Tempsum, June-Dec.	.425	.083	162			
		Age 2, immature, Tempsum, Jan.-May	.528	.034				
		Age 2, immature, Tempsum, June-May	.541	.030				
Female	Age 4, mature	Age 3, immature	.479	.013	167	169	174	161
		Age 3, immature, Tempsum, June-Dec.	.658	.008	169			
		Age 3, immature, Tempsum, Jan.-May	.716	.003				
		Age 3, immature, Tempsum, June-May	.806	.001				
Female	All ages, mature	All ages, immature	.395	.029	166	161	166	151
		All ages, immature, Tempsum, June-Dec.	.557	.026	167			
		All ages, immature, Tempsum, Jan.-May	.480	.053				
		All ages, immature, Tempsum, June-May	.593	.017				
Sexes combined	Age 3, mature	Age 2, immature	.421	.056	174	166	169	160
		Age 2, immature, Tempsum, June-Dec.	.472	.056	173			
		Age 2, immature, Tempsum, Jan.-May	.774	.001				
		Age 2, immature, Tempsum, June-May	.684	.006				
Sexes combined	Age 4, mature	Age 3, immature	.503	.010	173	177	183	167
		Age 3, immature, Tempsum, June-Dec.	.683	.006	176			
		Age 3, immature, Tempsum, Jan.-May	.586	.019				
		Age 3, immature, Tempsum, June-May	.739	.002				
Sexes combined	All ages mature	All ages, immature	.494	.011	176	169	175	160
		All ages, immature, Tempsum, June-Dec.	.617	.013	176			
		All ages, immature, Tempsum, Jan-May	.597	.017				
		All ages, immature, Tempsum, June-May	.684	.006				

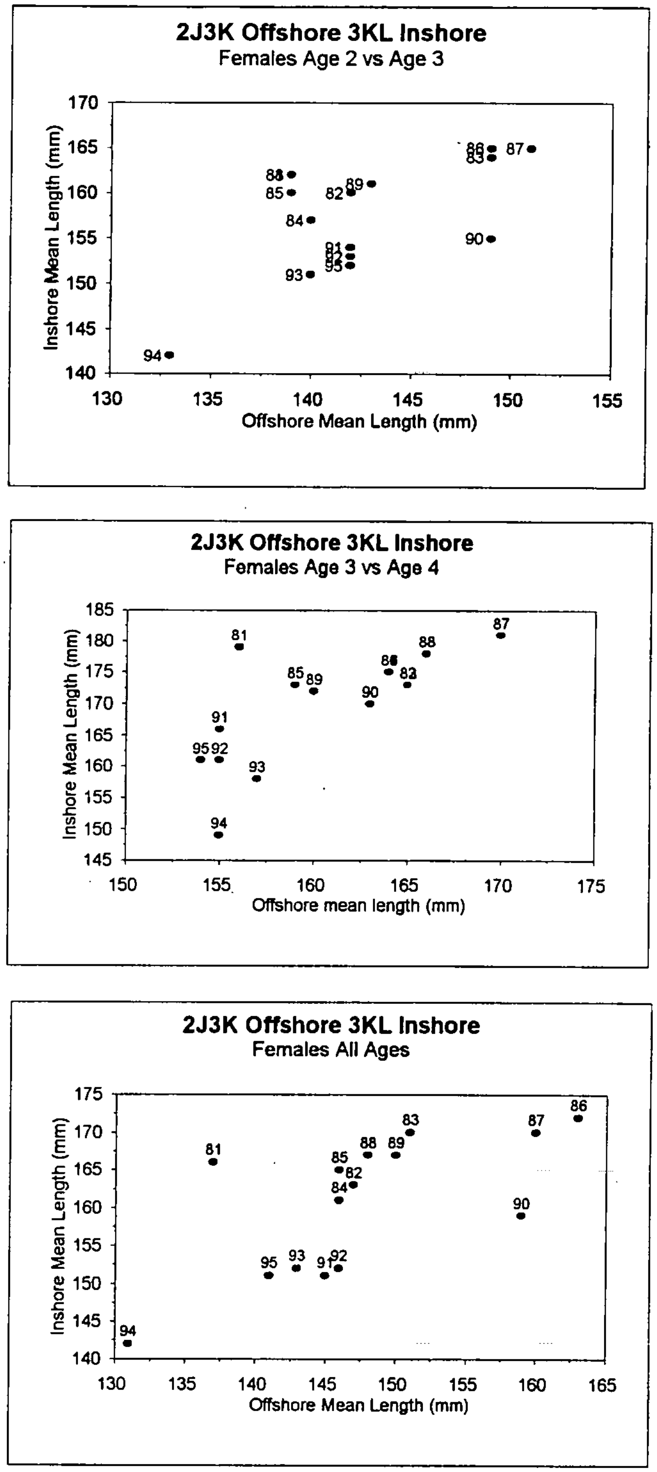


Fig. 1. Relationships between mean lengths of female capelin from fall offshore acoustic surveys and from inshore one year later.

Top panel, age 2 in the acoustic survey on the X-axis and age 3 inshore the following year on the Y-axis.

Middle panel, age 3 in acoustic survey on the X-axis and age 3 inshore the following year on the Y-axis.

Years plotted are years of the acoustic survey.

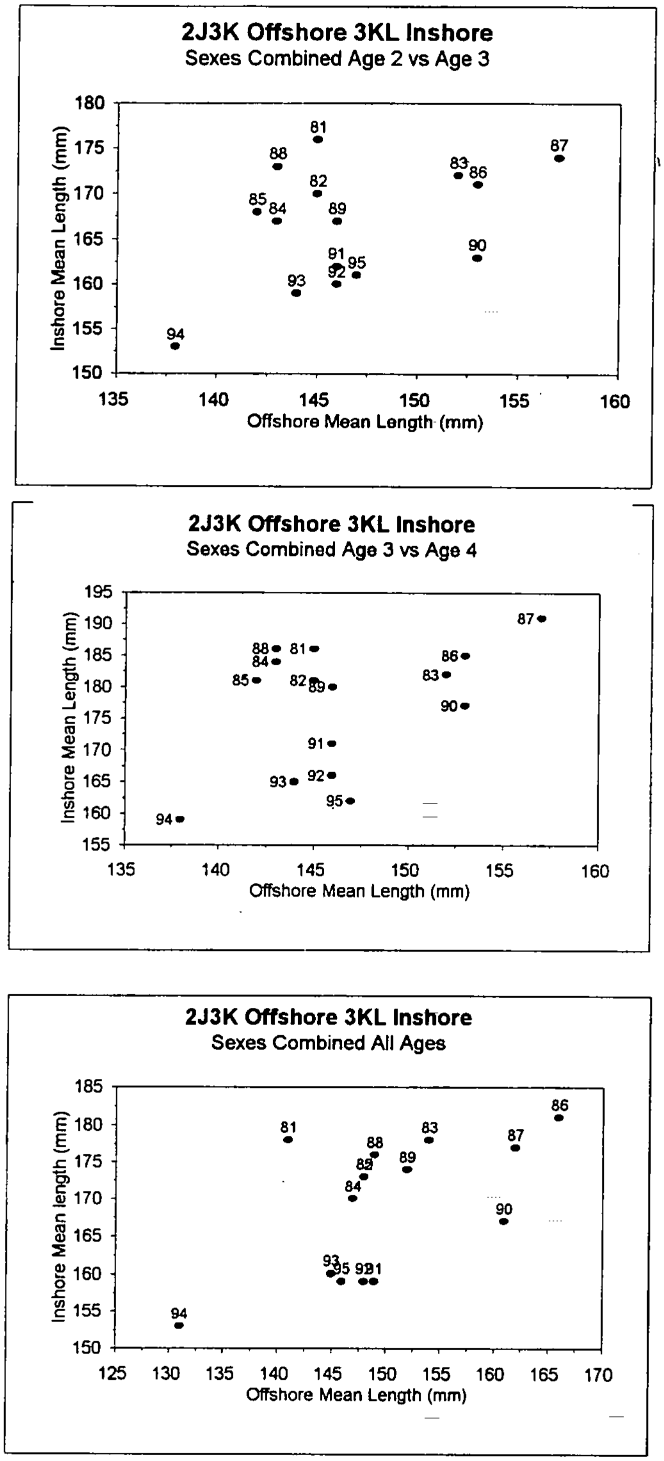


Fig. 2. Relationships between mean lengths of capelin, sexes combined, from fall, offshore acoustic surveys and from inshore one year later.

Top panel, age 2 in the acoustic survey on the X-axis and age 3 inshore the following year on the Y-axis.

Middle panel, age 3 in the fall acoustic survey on the X-axis and age 4 inshore the following year on the Y-axis.

Bottom panel, all ages in the acoustic survey on the X-axis and all ages inshore on the Y-axis.

Years plotted are years of the acoustic survey.

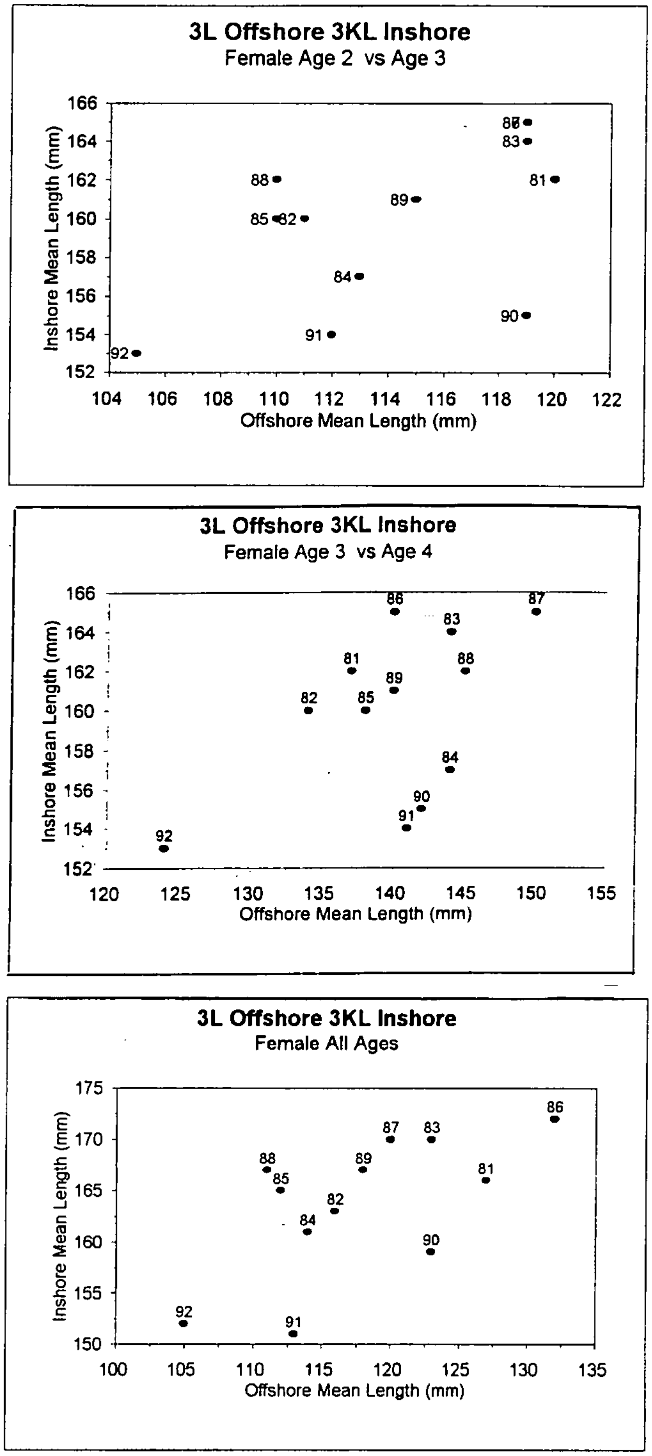


Fig. 3. Relationships between mean lengths of immature female capelin from spring offshore acoustic surveys and mean lengths of mature females inshore one year later.

Top panel, age 2 in the acoustic survey on the X-axis and age 3 inshore the following year on the Y-axis.

Middle panel, age 3 in the acoustic survey on the X-axis and age 4 inshore the following year on the Y-axis.

Bottom panel, all ages in the acoustic survey on the x-axis and all ages inshore on the Y-axis.

Years plotted are years of the acoustic survey.

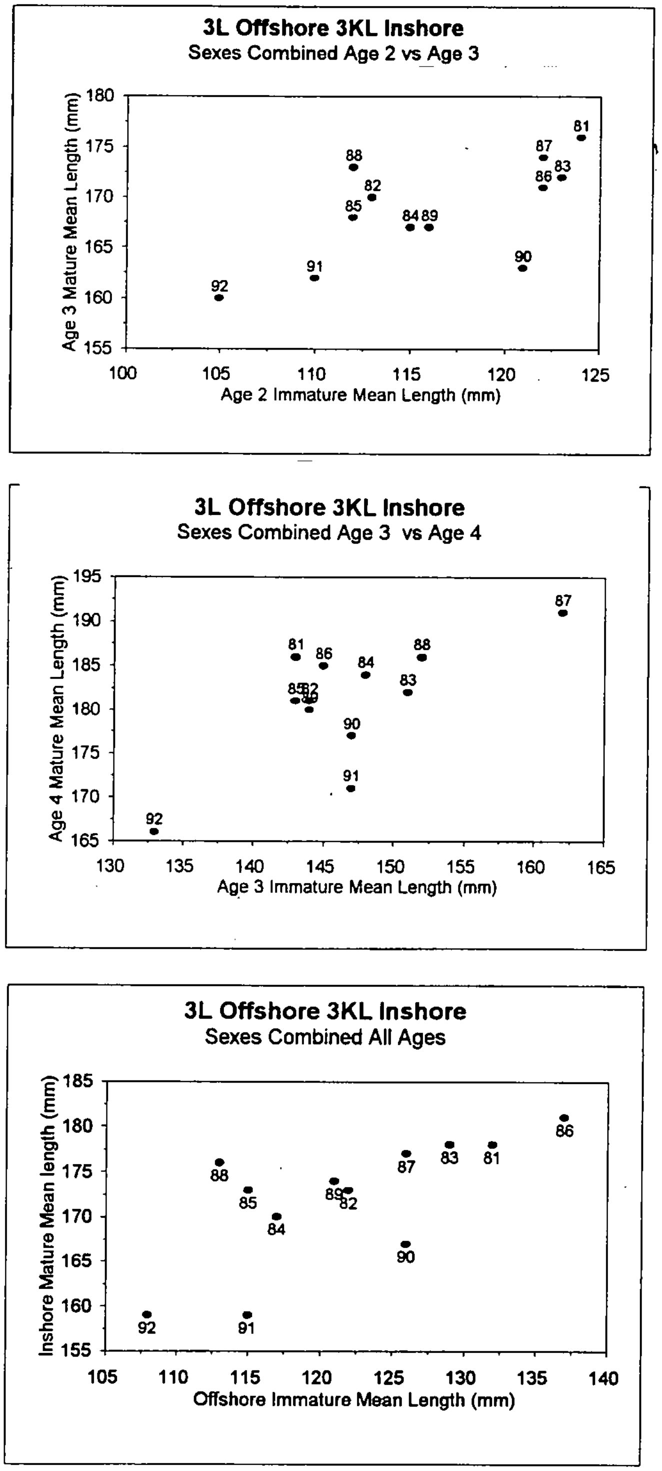


Fig. 4. Relationships between mean lengths of immature capelin, sexes combined, from spring offshore acoustic surveys and mean lengths of mature capelin inshore one year later, sexes combined.
Top panel, age 2 in the acoustic survey on the X-axis and age 3 inshore the following year on the Y-axis.

Middle panel, age 3 in the acoustic survey on the X-axis and age 4 inshore the following year on the Y-axis.

Bottom panel, all ages in the acoustic survey on the X-axis and all ages inshore the following year on the Y-axis.

Year plotted are years of the acoustic survey.

A Comparison of Methods to Estimate the Proportion of Repeat Spawning Female Capelin (*Mallotus villosus*)

by

S. R. Flynn[1], B. S. Nakashima[2], M.P.M. Burton[1]

[1]Department of Biology
Memorial University of Newfoundland, St. John's NF

[2]Science Branch
Department of Fisheries and Oceans
St. John's NF

Introduction

Recovering spawning capelin (*Mallotus villosus*) have been reported off Norway (Forberg 1983), near Iceland (Vilhjálmsson 1994), and in the northwest Atlantic Ocean (Templeman 1948). Templeman (1948) identified several generation of oocytes which represented spawning potential for more than 2 years. Winters (1971) reported that females captured in March had previously spawned based on spawning checks on otoliths. Returns from tagging experiments clearly showed that some males and females were spawning for the second time (Nakashima 1992). Analytical methods were used by Carscadden et al. (1985), Shackell et al. (1993) and Shelton et al. (1993) to estimate percentage survival by following cohorts.

Using a method based on histology developed by Flynn (1996) we examined female capelin in the fall for direct evidence of an earlier spawning. Estimates of the proportion of recovering females in fall offshore samples based on the visual maturity scale used by the Pelagic Fish Section were compared to results from our proposed histological method.

Methods and Materials

Female capelin were collected during the pelagic acoustic survey in 1995 and during the groundfish bottom trawl survey in 1996 from NAFO Div. 3KL:

Vessel trip	Set No.	Date	Location	No. of females
TELEOST 19	5	Oct. 10, 1995	50°18.9'N, 52°28.6'W	27
TELEOST 19	8	Oct. 12, 1995	49°58.0'N, 52°25.4'W	320
TEMPLEMAN 198	84	Nov. 13, 1996	48°57.9'N, 56°36.6'W	150
TELEOST 40	100	Nov. 20, 1996	49°52.8'N, 52°09.4'W	150

All fish were immediately frozen after capture. Only females 12 cm total length or greater were sampled. Using DFO's visual maturity scale fish were assigned maturity stage 6 if residual eggs were present, if the gonad was empty but distended, or if external features were indicative of a recovering female. After macroscopic observations were made to identify residual oocytes from a previous spawning, ovaries were fixed in Bouin's solution. Further observations were made by breaking the ovaries into several pieces and viewing them through a stereoscope at a total magnification of eight times. Macroscopic observations were continued during standard alcohol dehydration of the samples before being embedded in paraffin wax. If residual oocytes were observed at any stage of the preparation procedure the ovaries were embedded but not sectioned. All other ovaries were sectioned at 7 µm, stained with Ehrlich's hematoxylin and alcoholic eosin and examined under light microscopy at 100X and 400X total magnification (Flynn 1996). The presence of residual oocytes, or thickenings of the ovary or its wall were used to identify recovering spawners.

Results and Discussion

The proportion of identified recovering females was twice as high with the microscopic/histological method (1995:20%; 1996: 59%) compared to the visual method (1995:10%; 1996:27%). Most of the repeat spawning fish were identified using residual oocytes from histological sections as the determining feature. Thickening of the ovary or its wall accounted for 3% in 1995 and 8% in 1996.

The variability of the percentage of recovering females in this study may be a function of the difference in the age and size distributions of fish between the two years. Age determination and length measurements indicate that fish in 1995 were younger and shorter than those sampled in 1996 (Fig. 1, 2). Fish captured in 1995 were taken one month earlier than in 1996. The differences may also reflect different environmental conditions. The climatic conditions of the 1990's have been anomalous when compared to historical records and differences in spawning times and size-at-age are significantly correlated to spring water temperatures (Carscadden et al. 1997).

Of the two methods the histological method was the more effective in identifying recovering fish. The visual method consistently underestimated the number of recovering fish, especially for ages 2 and 3 (Fig. 3) which will dominate next year's spawning biomass as ages 3 and 4.

Underestimating the proportion of repeat spawning females has implications on estimates of spawning mortality, stock projections, and how these fisheries should be managed.

Acknowledgments

We thank the scientific staff of TELEOST Trips 19 and 40 and W. TEMPLEMAN Trip No. 198 for collecting the samples. M. Clark and B. Slaney sampled the fish and assigned the maturity stages. P. Eustace aged the fish.

References

Carscadden, J. E., G. H. Winters, and D. S. Miller. 1985. An indirect method of estimating maturation rates of cohorts of capelin (Mallotus villosus). J. Northw. Atl. Fish. Sci. 6: 135-140.

Carscadden, J. E., 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 (in press)

Flynn, S. R. 1996. Gametogenesis in the capelin, Mallotus villosus (Müller). M.Sc. Thesis, Memorial University of Newfoundland, Canada.

Forberg, K. G. 1983. Maturity classification and growth of capelin, Mallotus villosus villosus (M), oocytes. J. Fish. Biol. 22: 485-496.

Nakashima, B. S. 1992. Patterns in coastal migration and stock structure of capelin (Mallotus villosus). Can. J. Fish. Aquat. Sci. 49: 2423-2429.

Shackell, N. L., P. A. Shelton, J. M. Hoenig, and J. E. Carscadden. 1994. Age and sex specific survival of northern Grand Bank capelin (Mallotus villosus). Can. J. Fish. Aquat. Sci. 51: 642-649.

Shelton, P. A., J. E. Carscadden, and J. M. Hoenig. 1993. Risk evaluation of the 10% harvest rate procedure for capelin (Mallotus villosus) in NAFO Division 3L. In: Can. Spec. Publ. Fish. Aquat. Sci. 120 p.

Templeman, W. 1948. The life history of the capelin (Mallotus villosus) in Newfoundland waters. Res. Bull. 17, Nfld. Govt. Lab. 151 p.

Vilhjálmsson, H. 1994. The Icelandic capelin stock: Capelin, Mallotus villosus (Müller) in the Iceland - Greenland - Jan Mayen area. Journal of Marine Research Institute, Reykjavík. Vol. XIII No. 1.

Winters, G. H. 1971. Fecundities of the left and right ovaries of Grand Bank capelin (Mallotus villosus). J. Fish. Res. Bd. Canada 28: 1029-1033.

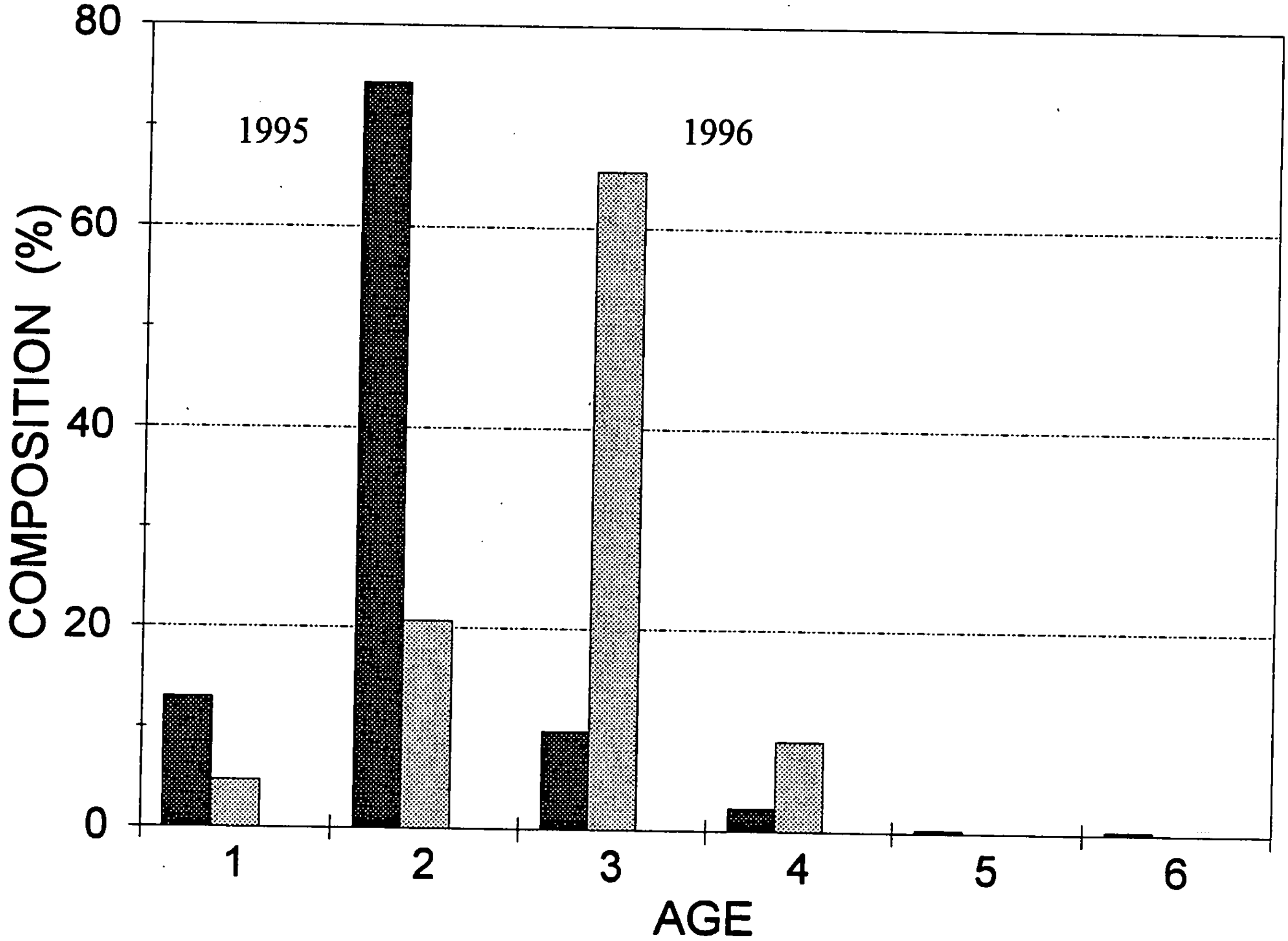


Fig. 1. Age compositions in 1995 (dark) and in 1996 (light).

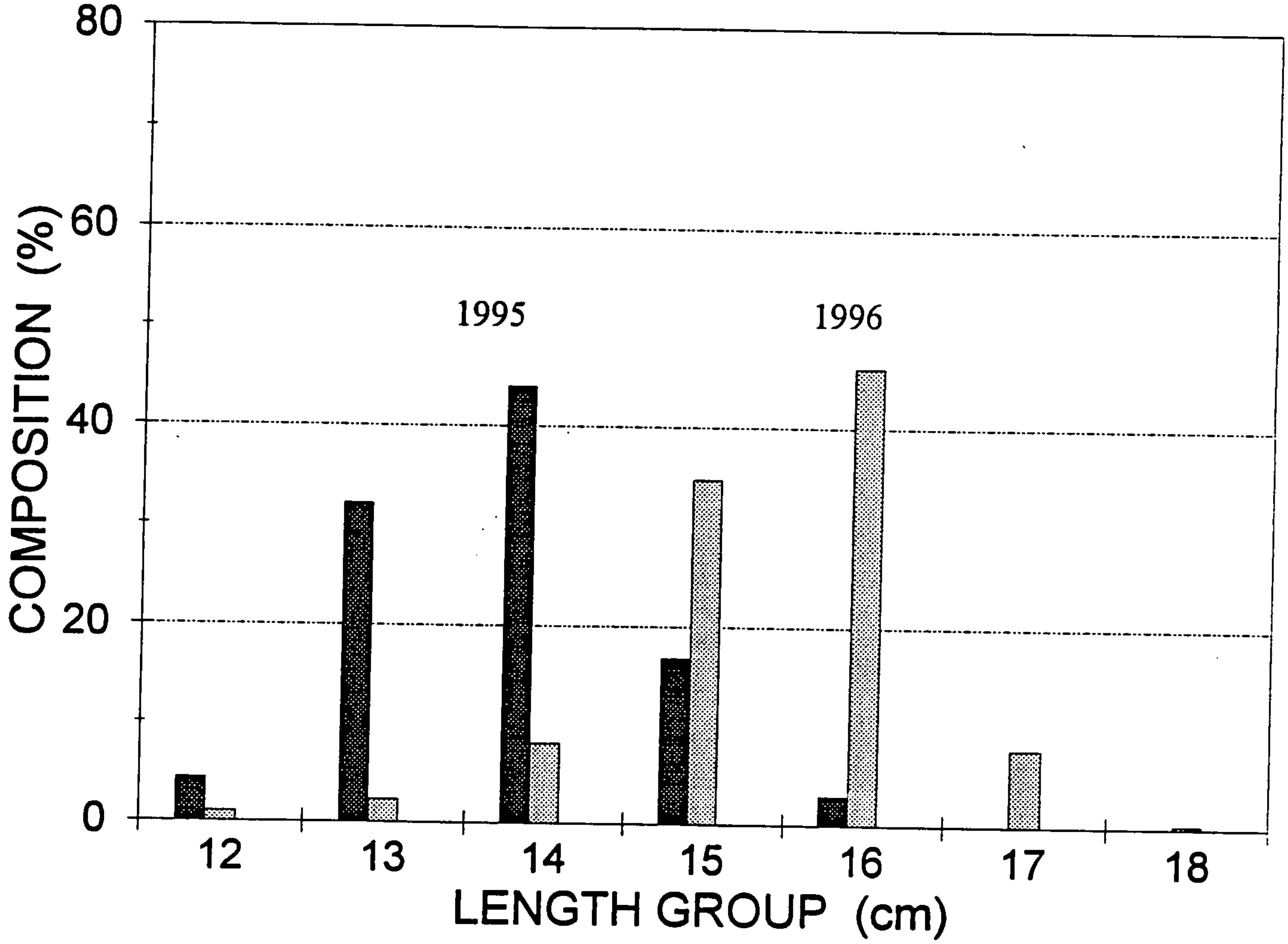


Fig. 2. Length frequencies in 1995 (dark) and in 1996 (light).

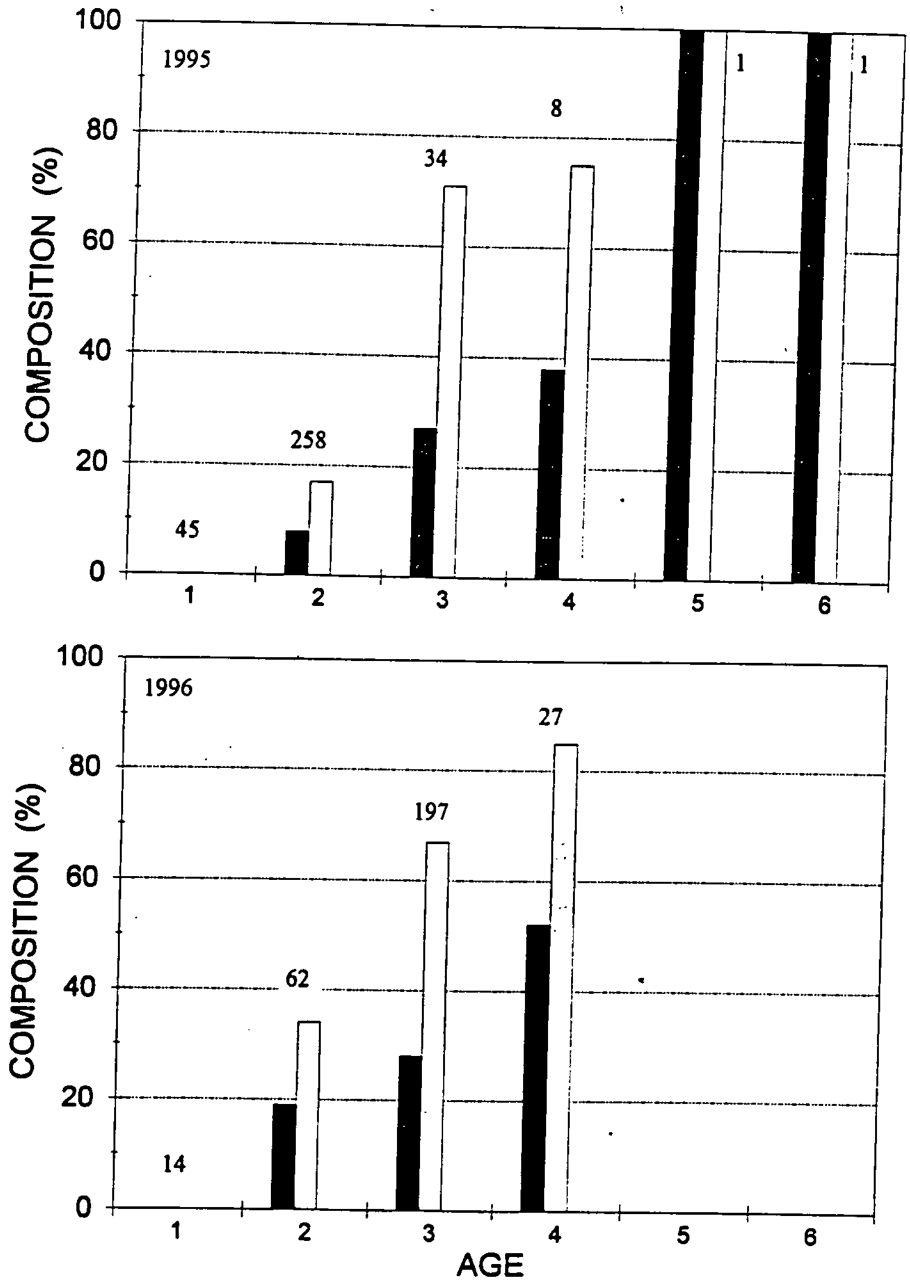


Fig. 3. The proportion of recovering females at age estimated by the visual maturity scale method (dark) and the histological method (light). Sample sizes are above the bars.

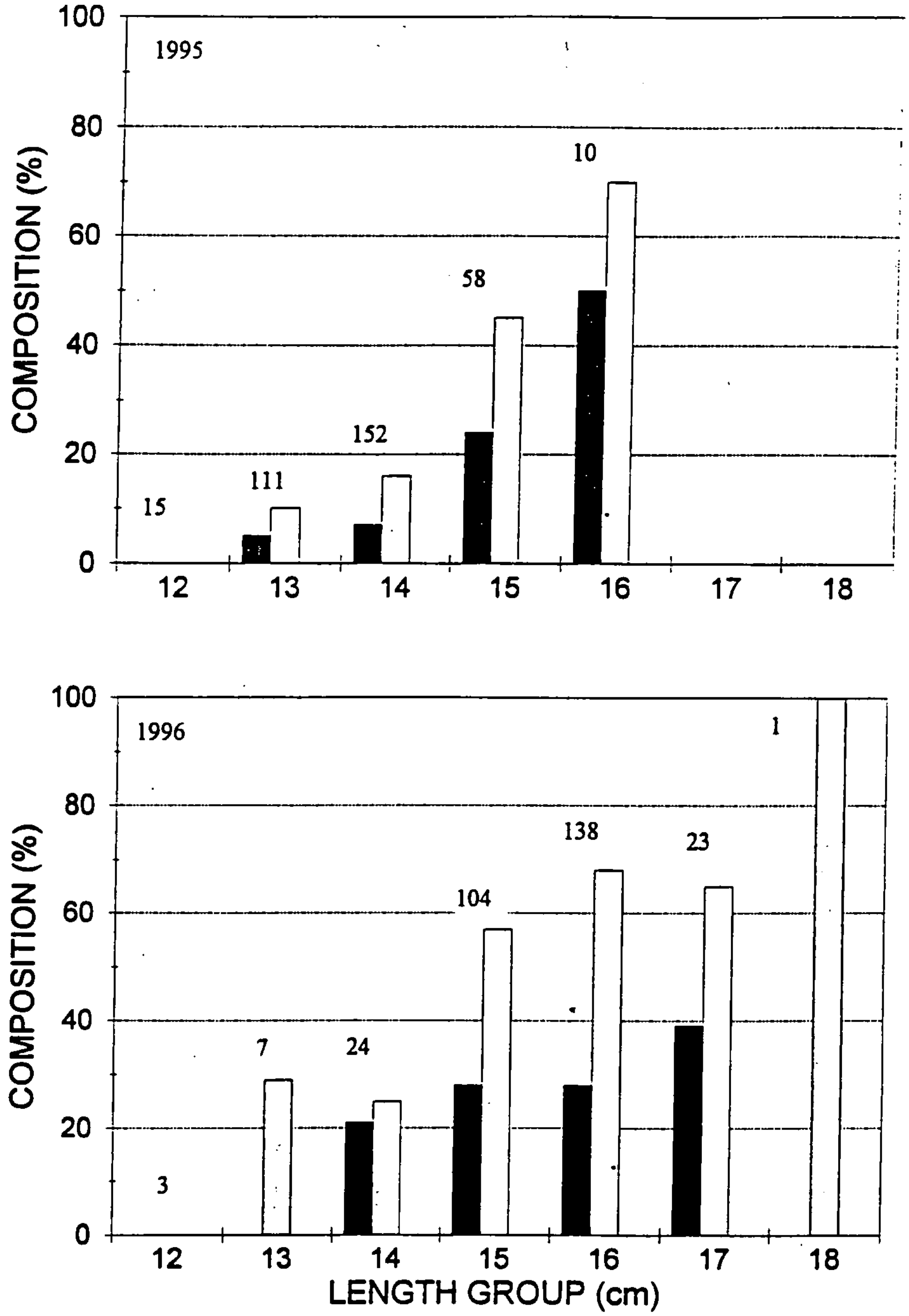


Fig. 4. The proportion of recovering females at length estimated by the visual maturity scale method (dark) and the histological method (light). Sample sizes are above the bars.

Chapter 10

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

by

B. S. Nakashima and G. H. Winters
Science Branch
Department of Fisheries and Oceans
St. John's NF A1C 5X1

Introduction

The multiplicative model provides an objective framework for analytical integration of abundance indices from a variety of sources (eg. 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 1997 assessment the multiplicative model was used to develop standardized indices of biomass, cohort strength, and recruitment.

The Approach

The multiplicative cohort model assumes that the various types of abundance indices to be integrated retain their relativity throughout the time series, i.e. that 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 must be made to reject some of them. 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 1997 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 from inshore surveys, the Russian 2J3K CPUE, and Canadian 2J3K and 3L fall bycatch indices from offshore groundfish surveys. Where possible indices were updated to include 1996 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 included this year (Anderson and Dalley 1997).

Results and Discussion

I. Biomass and Cohort Indices

The above multiplicative model was applied to the following indices as a basis for the 1997 assessment of capelin (Appendix A, B):

1. aerial survey index 1982-96, excluding 1991;
2. egg deposition index 1990-96.
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 estimate in 1996 was the highest in the series (Nakashima 1997b). The 1996 estimate was partitioned using the age composition of Bellevue Beach spawners (Nakashima and Winters 1997).

(b) Egg deposition index

Egg deposition (stages I-II, integrated for each beach) has been estimated since 1990 (Nakashima and Winters 1997) for several beaches on the northeast coast. To estimate the number of females we divided egg deposition by the mean female weight of gm (Nakashima and Winters 1997). The estimate was then partitioned 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 a direct measure of spawner escapement. A potential concern is the reduction in the number of sampling sites from six in 1991-94 to two in 1995 and one in 1996. A plot of the normalized annual egg depositions for Bellevue Beach compared to all beaches indicated that the two series are related (Fig. 1). We therefore concluded that the egg deposition series can be extended into 1996 with Bellevue Beach alone.

(c) Purse seine index

Data were available to develop a purse seine catch rate index for the 1996 fishery. Details concerning the purse seine fishery in 1996 are in Nakashima (1997a). The purse seine catch rate index was used in the standardized biomass model and in the standardized cohort model. For the age-structured analysis the catch rate index was partitioned into ages using age composition from commercial samples.

(d) Integrated trap index

Data were available from the research logbook survey to estimate an integrated trap index for 1996 (Nakashima 1997a). For 1996 the integrated trap index of 73,416 was biased low because of the short fishing season of 18 days was less than 50% of the geometric mean of 38 days for the earlier series 1981-93 excluding 1987 (Table 1). No acceptable method was put forth to adjust the 1996 value to have it comparable with the 1981-93 series. Consequently the 1996 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 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. Despite the wide confidence intervals the standardized biomass plots shows an increasing trend. Standardized cohort abundances are shown in Figure 3 and the statistical output is presented in Table 3. The 1993 yearclass is higher than the strong 1983 yearclass. However, its relative abundance is less than 50% of last year's estimate at age 2 and the confidence interval is much smaller (Winters 1996) now that additional estimates of the yearclass at age 3 are available. The 1994 yearclass has wide confidence intervals which can partly be explained by the difference in the two age compositions used. The commercial age composition for the purse seine index consisted of 30% age 2, whereas the Bellevue Beach age composition applied to the aerial survey and egg deposition indices contained 9% of age 2 fish.

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 1990-96;
3. Div. 3KL emergent larval index 1990-96;
4. Offshore Div. 3KL 0-group index 1991-96;
5. Offshore Div. 3KL age 1 index 1992-96.

(a) Inshore indices

The inshore indices were based on very early estimates of 0-group. 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 and Winters 1997). Emergent larvae were also enumerated at northeast coast beaches since 1990 (Nakashima and Winters 1997). Normalized annual values were used for both indices in the multiplicative model.

(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 1997) were incorporated into the multiplicative recruitment model. The 0-group index was evaluated and used in the model last year (Winters et al 1996). The age 1 index was used for the first time in the 1997 multiplicative model. Age 1 capelin are collected using an IGYPT trawl during the offshore 0-group survey (Anderson and Dalley 1997).

The standardized annual recruitment index is shown in Figure 5 and the statistical output is given in Table 4. Confidence intervals overlap between adjacent data points.

Summary

The standardized recruitment index appears to predict standardized cohort abundance for the 1987 and 1989 to 1993 yearclasses reasonably well (Fig. 6). The recruitment index depicts the 1994 cohort lower than the 1993, whereas the cohort abundance index shows the 1994 yearclass larger than the 1993. For the cohort index the 1994 estimate is based only on the presence of mature age 2 fish in 1996. From the multiplicative trends, the 1993 and 1994 yearclasses are relatively strong and will dominate the 1997 spawning biomass. The recruitment index suggests that the 1995 yearclass will also be relatively strong and depending on what fraction mature, age 2 capelin could be relatively abundant in 1997.

References

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

Anderson, J. and E. Dalley. 1997. Distributions and abundances of pre-recruit capelin (Mallotus villlosus) in the Northwest Atlantic (NAFO Division 2J3KLNO), 1991-96. pp. 125-147. In: Anon. Capelin in SA2 + Div. 3KL. CSAS Res. Doc. 97/29.

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. 1997a. The inshore fishery for capelin (Mallotus villosus) in NAFO Div. 3KL in 1996. pp. 42-61. In: Anon. Capelin in SA2 + Div. 3KL. CSAS Res. Doc. 97/29.

Nakashima, B. S. 1997b. Results of the 1996 aerial survey of capelin (Mallotus villosus) schools. pp. 63-73. In: Anon. Capelin in SA2 + Div. 3KL. CSAS Res. Doc. 97/29.

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. CSAS Res. Doc. 97/29.

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. Mean CPUE (see Nakashima 1997a), duration of fishing season, and integrated trap index for Div. 3KL capelin.

Year	Mean season (CPUE) (kg/haul)	Fishing season (days)	Integrated trap index
1981	2722	32	75,219
1982	2610	31	69,895
1983	3008	30	64,047
1984	2103	36	59,748
1985	3889	30	89,321
1986	4067	40	148,965
1987	6097	(41.5)*	155,474
1988	3139	43	121,063
1989	3279	32	148,680
1990	5116	42	166,636
1991	3247	56	153,159
1992	3699	42	131,724
1993	2753	51	139,031
1996	4102	18	73,416

* strike-shortened season; mean of 1986 and 1988

Table 2. Statistical output of the multiplicative model used to estimate standardized annual biomass. Reference categories were year 1996 and purse seine catch rates.

Source	DF	Sum of squares	Mean square	F-value	Pr > F
Model	28	84.17	3.01	25.39	0.0001
Error	67	7.93	0.12		
Corrected total	95	92.10			
		Root MSE	0.34		
		Dep. mean	4.38		
		C.V.	7.86		
		R-square	0.91		

Table 3. Statistical output of the multiplicative model used to estimate standardized yearclass strengths. Reference categories were yearclass 1994 and age 5 of the trap catch rates.

Source	DF	Sum of squares	Mean square	F-value	Pr > F
Model	52	932.04	17.92	23.28	0.0001
Error	261	200.92	0.77		
Corrected total	313	1132.96			
		Root MSE	0.88		
		Dep. mean	4.70		
		C.V.	18.63		
		R-square	0.82		

Table 4. Statistical output of the multiplicative model used to estimate a standardized recruitment index. Reference categories were year 1996 and the offshore age I survey.

Source	DF	Sum of squares	Mean square	F-value	Pr > F
Model	12	70.30	5.86	12.33	0.001
Error	18	8.55	0.48		
Corrected total	30	78.85			
		Root SE	0.69		
		Dep. mean	5.47		
		C.V.	12.60		
		R-square	0.89		

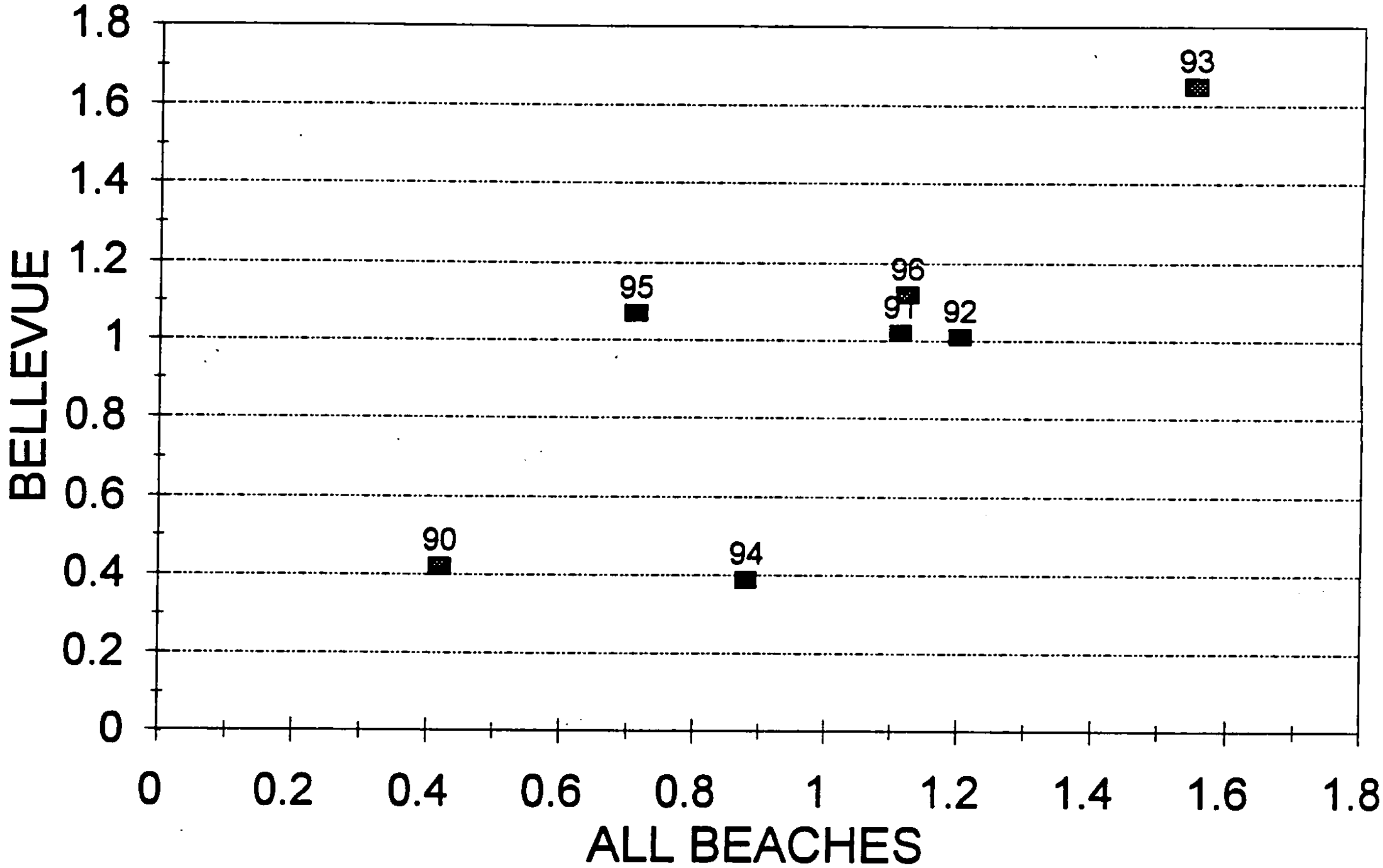


Fig. 1. Comparison of annual normalized egg deposition at Bellevue Beach and for all beaches. In 1990 and 1996 only Bellevue Beach was sampled.

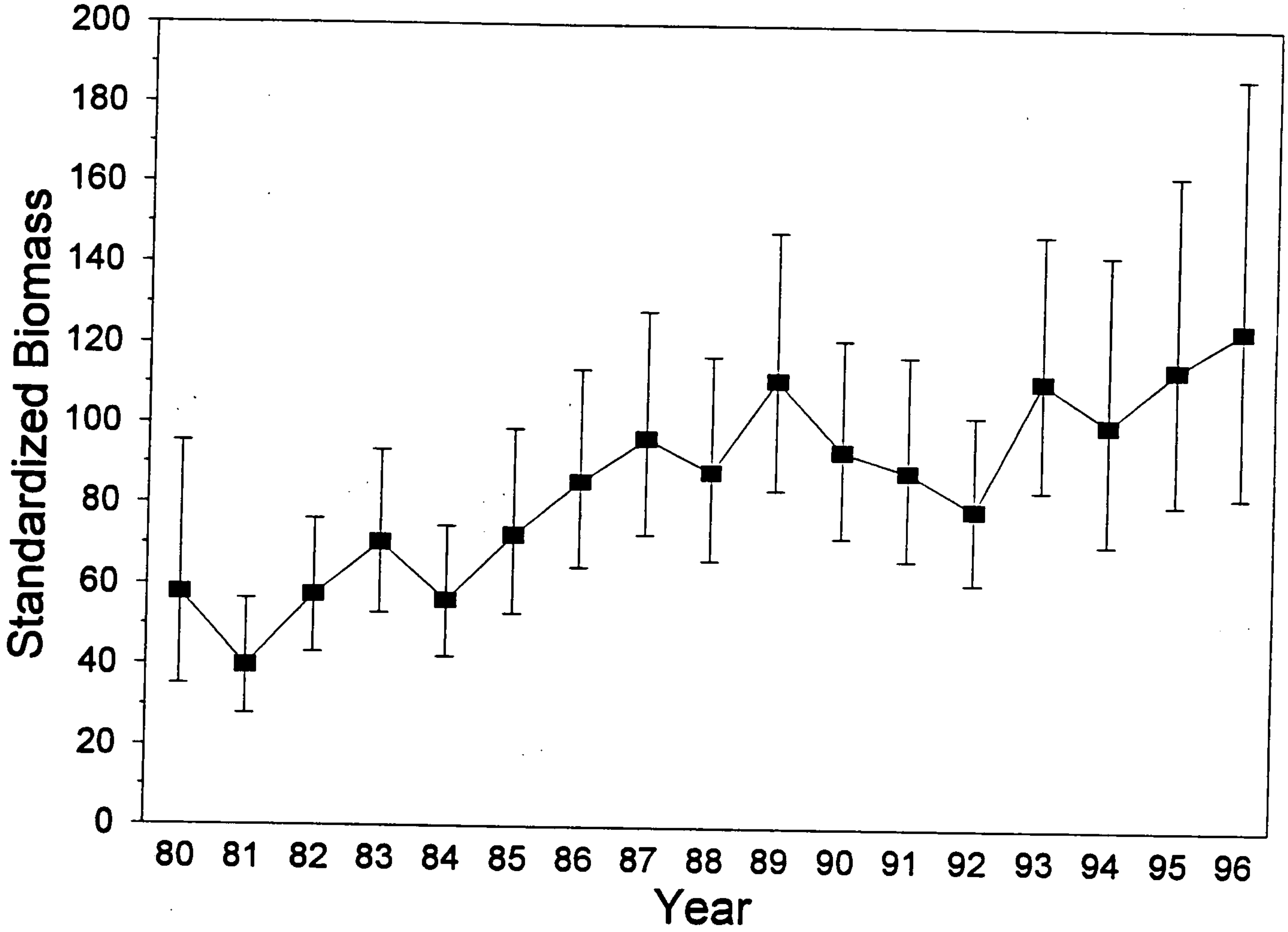


Fig. 2. Standardized estimates of annual biomass of capelin, with 95% confidence intervals.

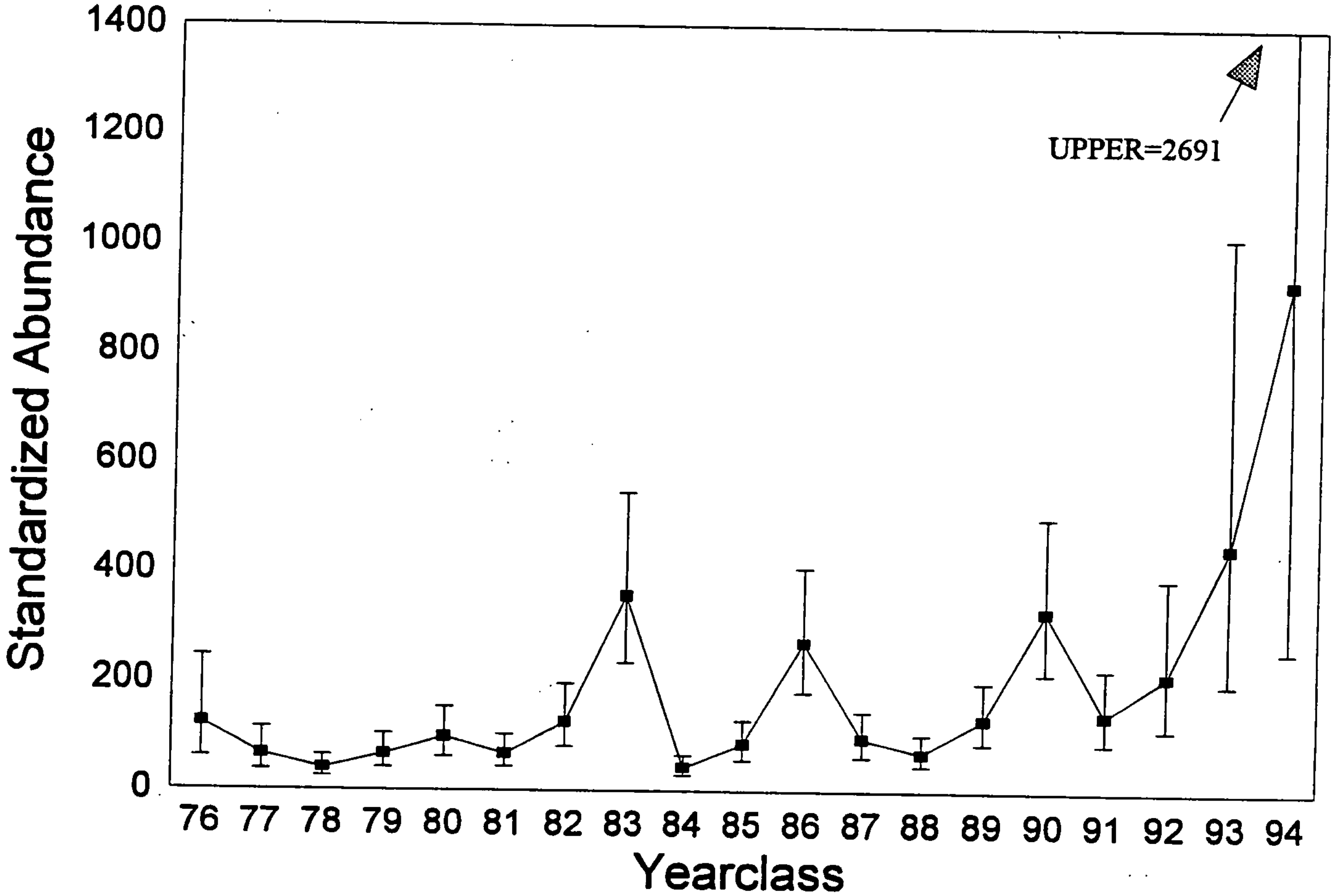


Fig. 3. Standardized estimates of cohort abundance of capelin, with 95% confidence intervals.

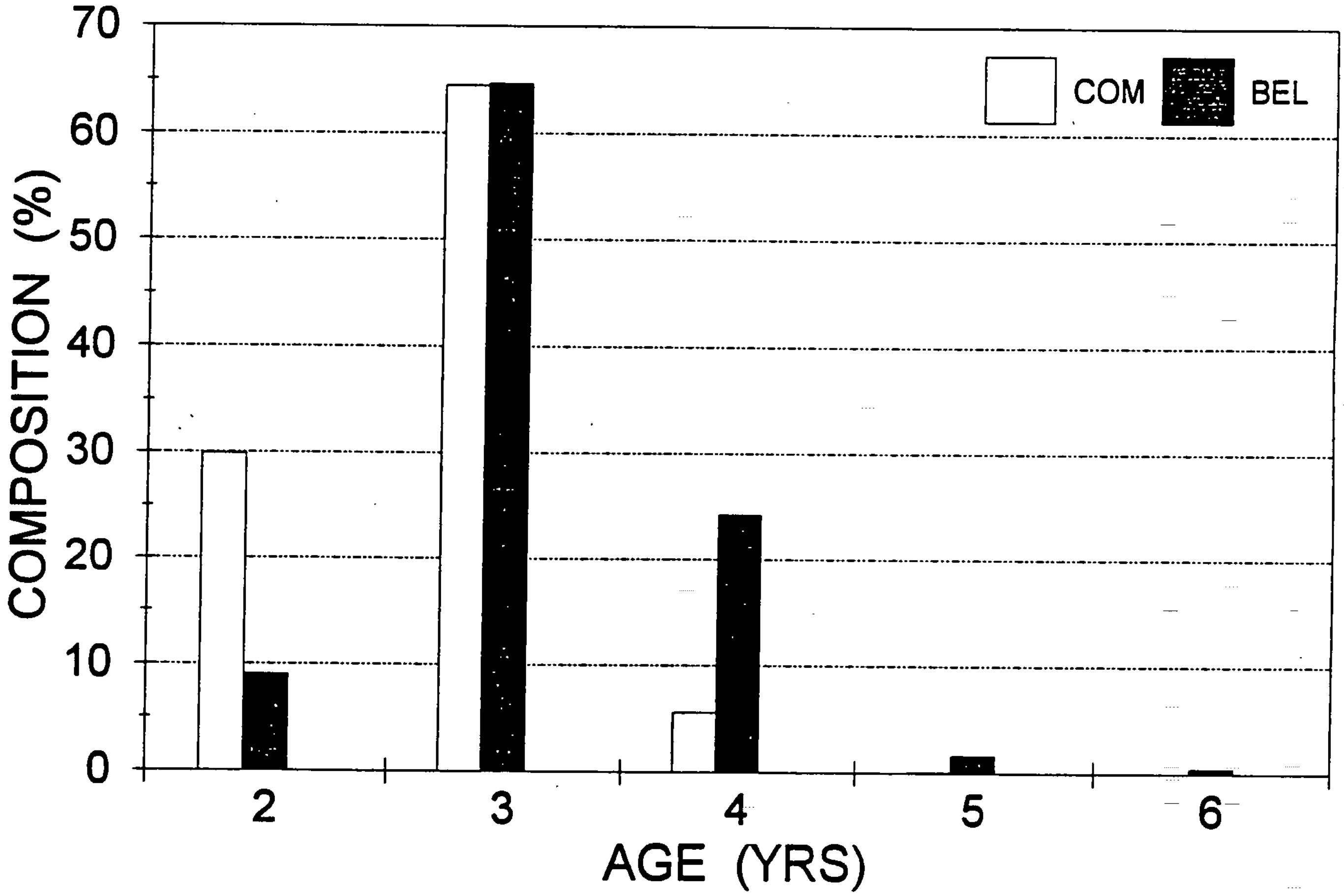


Fig. 4. A comparison of age compositions in 1996 from commercial samples collected in Div. 3KL and from spawning samples collected at Bellevue Beach.

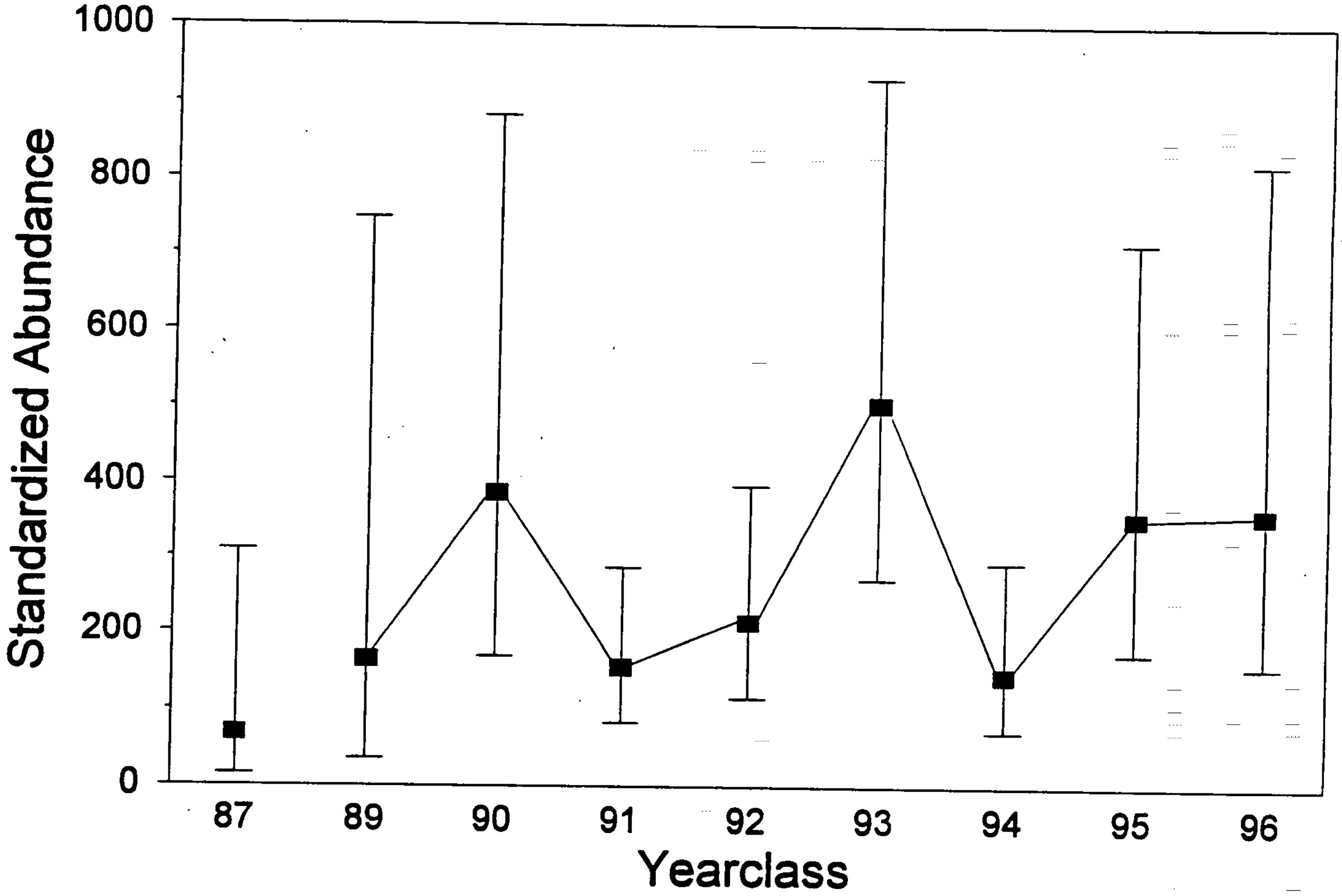


Fig. 5. Standardized estimates of recruitment abundance of capelin with 95% confidence intervals.

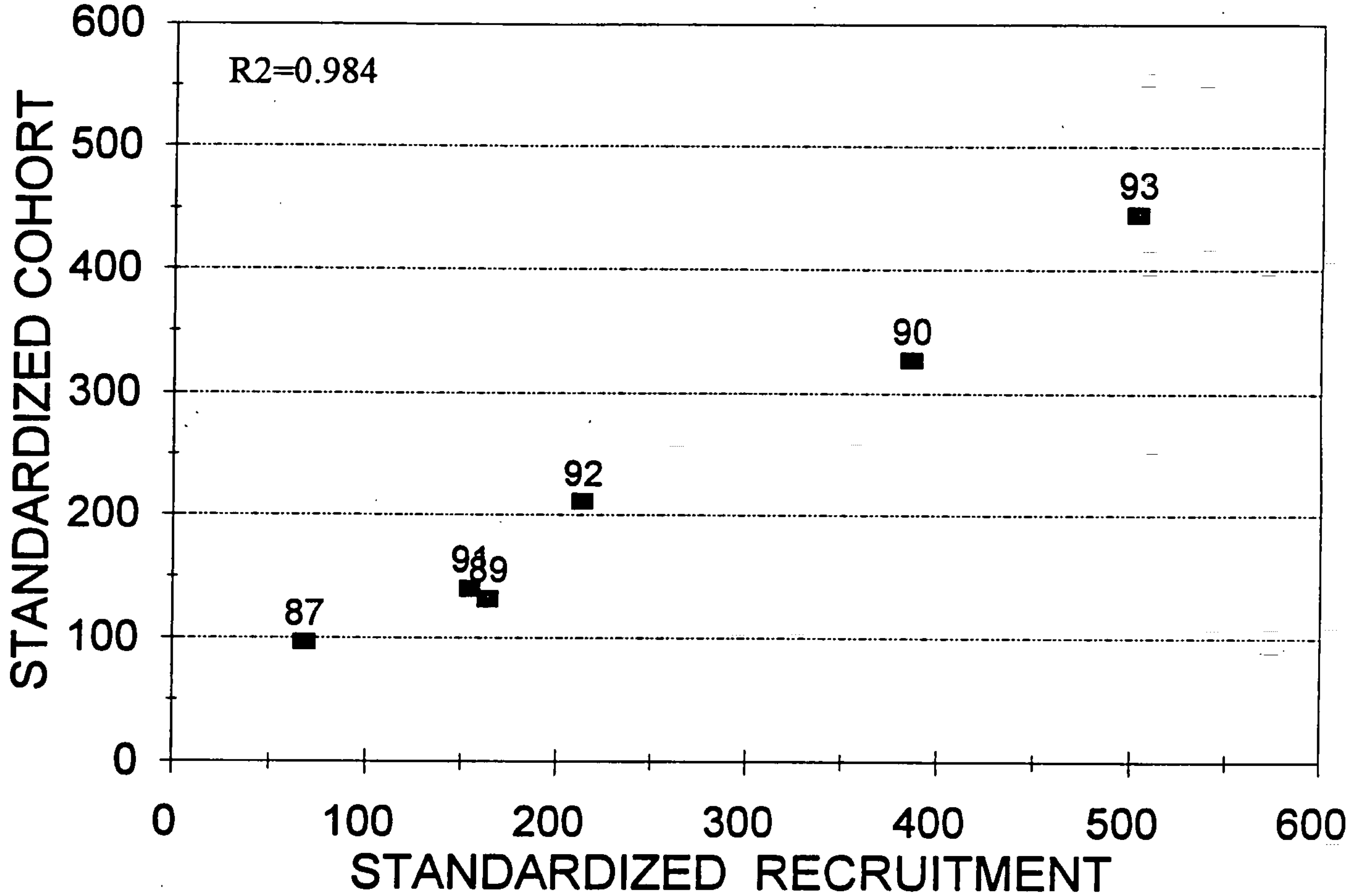


Fig. 6. A comparison of yearclass size estimated by the standardized recruitment index and by the standardized cohort index.

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	220	
1983	32	34	29	176	64	348	
1984	53	25	31	143	60	173	
1985	42	27	-	164	89	308	
1986	70	44	35	188	149	260	
1987	61	26	27	176	155	718	
1988	77	35	27	200	121	402	
1989	60	37	46	217	148	539	
1990	61	49	40	215	167	359	42
1991	13	35	21	150	153	-	102
1992		43	23	208	132	548	101
1993		53	52	162	146	335	165
1994		47	53	-		563	39
1995		47	39	-		557	107
1996				171		837	112

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

	Year	Age 0	1	2	3	4	5
Aerial survey index							
	1982	-	-	31	522	69	20
	1983	-	-	15	621	381	16
	1984	-	-	10	217	270	24
	1985	-	-	130	654	215	53
	1986	-	-	8	507	283	20
	1987	-	-	97	423	1310	98
	1988	-	-	165	717	168	160
	1989	-	-	8	1212	336	19
	1990	-	-	17	466	608	17
	1991	-	-	-	-	-	-
	1992	-	-	238	926	1265	231
	1993	-	-	86	973	363	46
	1994	-	-	432	1586	810	189
	1995	-	-	369	1487	609	260
	1996	-	-	338	2428	914	60
Egg deposition index (normalized)							
	1990	-	-	81	840	711	54
	1991	-	-	240	1875	2050	795
	1992	-	-	523	2049	2777	517
	1993	-	-	867	6534	1697	283
	1994	-	-	354	1040	531	166
	1995	-	-	1634	4020	1063	521
	1996	-	-	859	3708	1320	126
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	821
	1982	-	-	16	1908	237	95
	1983	-	-	67	1202	719	26
	1984	-	-	30	766	1095	92
	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	21	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 ...

	Age					
Year	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	32
1989	-	-	248	332	26	2
1990	-	-	208	281	95	3
1991	-	-	104	18	0	0

Appendix C. Indices used in the standardized recruitment model.

	Year	Age 0	Age 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	136	-
	1991	94	-
	1992	113	-
	1993	153	-
	1994	51	-
	1995	81	-
	1996	79	-
NCSP emergent larval index (normalized)	1990	151	-
	1991	89	-
	1992	126	-
	1993	152	-
	1994	43	-
	1995	63	-
	1996	67	-
Offshore 0-group index	1991	2337	-
	1992	2616	-
	1993	4497	-
	1994	2258	-
	1995	4832	-
	1996	15578	-
Offshore age I index	1992	-	46
	1993	-	35
	1994	-	711
	1995	-	99
	1996	-	700