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Capelin in SA2 + Div. 3KL

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Abstract

This document contains a number of discrete research results which were considered during the 1996 assessment of capelin in SA2 + Div. 3KL. These results are arranged in seventeen 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, predation studies, analyses of capelin distribution, lengths and ageing and several synthesis papers.

Résumé

Ce document présente différents résultats de recherche sur lesquels nous nous sommes penchés lors de l'évaluation 1996 des populations de capelan vivant dans la zone SA2 et la division 3KL. Les résultats ont été regroupés en 17 chapitres. En outre, nous présentons un compte rendu de réunion comprenant des références croisées par chapitre. Ce document se penche notamment sur les résultats d'études sur le capelan vivant dans les eaux côtières et les résultats de relevés acoustiques, sur les prises accessoires de capelan à l'occasion de relevés pour le poisson de fond, sur des études sur la prédation, sur des analyses de la répartition et de la taille des capelans, sur des études de détermination de l'âge des populations, ainsi que sur plusieurs articles de synthèse.

Introduction

This document contains a number of discrete research results which were considered during a March 1995 assessment of capelin in SA2 + Div. 3KL. These results are arranged in seventeen chapters in this research document. In the past, each of these chapters would have formed a separate research document but beginning in 1994, all contributions were arranged into one research document with the aim of simplifying the extensive technical background to the assessment. In a further effort to provide a coherent presentation, a meeting report, cross-referenced by chapter, is provided at the end of this document. A stock status report has been published elsewhere.

The data available for this assessment were extensive and varied. They included the results of studies on inshore capelin, acoustic results, bycatches of capelin in groundfish surveys, predation studies, analyses of capelin distribution, lengths and ageing and several papers synthesizing various datasets.

Results of a Telephone Survey of 1995
Fixed Gear Capelin License Holders

by

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Introduction

A questionnaire modified slightly from the one in 1994 (Nakashima 1995) was used to quantitatively evaluate biological and fishery-related information obtained from capelin fishers in 1995. Questions were developed originally 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 1878 was defined as all capelin fixed gear (traps and beach seines) fishers licensed to fish capelin in NAFO Div. 3Ps, 3L, and 3K in 1995. This was 281 licenses less than the 2159 licenses issued in 1994 (Nakashima 1995). 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 assuming an expected response rate of 82% (Nakashima 1995) a sample population with 382 names was chosen to achieve a ±5% margin of error with 95% confidence intervals (Gower and Kelly 1993). Questions relating to fishing in 1995 were expected to have responses only from those who participated in the monitoring programme. Similar to 1994 the survey was conducted by telephone interviews.

Some questions in the 1994 questionnaire were revised according to suggestions by last year's interviewers to facilitate responses for the 1995 survey. Question 2 in the 1994 survey compared abundance of capelin in 1994 to 1993 but in the 1995 survey respondents were asked to rate their view of capelin abundance in 1994 alone. Questions 11b and 12b were rearranged to compare spawning start and completion times between the year of the survey and the previous year. For question 31 the age ranges were scaled differently to reduce the range of ages per grouping from 15 to 10 years. Questions 34a and 34b on the 1996 capelin fishery

were added to the 1995 survey as a result of the number of comments
made on this topic during the 1994 survey (Nakashima 1995). The
remaining questions are the same in both surveys. The 1995 version
of the questionnaire is shown in Appendix A.

Telephone interviews commenced October 10, 1995 and were
completed on January 4, 1996. The survey was conducted earlier
than in 1994, however the time interval to contact the entire
sample population was longer in 1995. Interviewers were unable to
contact 52 individuals on the licensing list which were included in
the sample population. Of these 22 could not be contacted despite
5 attempts to do so, 18 had no available telephone number
(disconnected, wrong number, no telephone number), 4 were purse
seiners, 3 were not home during the capelin season, 4 declined to
participate, and 1 person was deceased. The 330 completed
questionnaires represent an 86% response rate which was slightly
higher than the 82% expected.

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

<div align="center">Results and Discussion</div>

Abundance Questions

Three questions (Appendix A) comparing abundance of capelin in
1995 to previous years were asked in the survey. Most respondents
indicated that capelin abundance in 1995 in their area was low
(Fig. 2) with an average response equal to 3.4 to question 1
(Appendix A). The abundance of capelin in 1994 was estimated to be
low by respondents in both the 1994 and 1995 surveys (Fig. 3),
however, the perception of relative abundance in 1994 has improved
between the two surveys. When given three options in question 3
(Appendix A) respondents clearly indicated that capelin abundance
in 1995 was lower than when they had first started to fish capelin
(Fig. 4). Generally most respondents considered capelin abundance
in 1995 to be low.

Spawning Questions

Respondents of questions 4-13 (Appendix A) related to spawning
generally indicated that spawning on beaches in 1995 was similar to
or slightly improved from 1994 but much lower than in earlier
years, that spawning continued to be later than 'normal', and that
spawning in deeper water away from beaches was similar to 1994 and
more prevalent than in previous years. The distribution of known
spawning beaches is consistent between the two surveys (Fig. 5).
According to respondents capelin in 1995 only occupied a small
proportion of potential spawning beaches (Fig. 5 and 6). While the
number of beaches where spawning was observed was low in 1995 there

were fewer indications of no spawning and more responses in the 1-5 beaches category compared to 1994 (Fig. 6). Capelin spawned on the same number or fewer beaches in 1994 than in 1995 (Fig. 7). The number of beaches with spawn continues to be perceived as being low as is the intensity of spawning (Fig. 8). The average intensity of spawning in 1995 was 3.7 however responses were not as strongly skewed to the low end as in 1994 (Fig. 8). Spawning intensity in 1995 compared to 1994 was considered the same or higher (Fig. 9). Over 25% of respondents did not answer questions 7a and b which was a much higher non-response rate than in 1994. Many were reluctant to answer because they were not on the water very much in 1995. These results support the estimates of egg density at Bellevue Beach and Chapels Cove in 1995 (Nakashima and Winters 1996).

As in 1994 (Nakashima 1995) there was evidence for capelin exhibiting off beach spawning behaviour in deeper water in 1995 but the incidence was less in 1995 than in 1994 (Fig. 10). The historical view of capelin spawning off beaches has changed somewhat between the two surveys (Fig. 11). Only the 121 persons who responded in the affirmative to question 8 were asked to give reasons why capelin may have spawned in deeper water in 1995 (Appendix A: question 9) . The most frequent response was better water temperatures in deeper water (47%). Other possibilities suggested were the presence of predators (eg. humans, seagulls) driving them away from beaches (5%), unsuitable beach habitat including nearby pollution (3%), no cod to drive capelin ashore (2%), different stock of capelin (2%), a later, smaller run (2%), low abundance (2%), no 'capelin' weather (2%), too rough to spawn (1%), and tide not right (1%). Approximately 16% said capelin in their area always spawned in deeper water and 19% did not know why this occurred in 1995.

Spawning times were again delayed compared to the 1980s and are indicative of the 1990s. Of those answering question 11a who recalled when spawning began in 1995 the majority suggested late June to late July (Fig. 12) with most responses favouring mid to late July. Comparing the start of the spawning season in 1994 to 1995 in question 11b most respondents who expressed a time indicated that it was the same in both years (Fig. 13). There was a large percentage of non-responses in both surveys. When asked to indicate the end of the 1995 spawning season the number of non-responses to question 12a was higher (Fig. 14) than for the start of the season (Fig. 12). Respondents are better able to recall when spawning began than when it finished. The results suggest that spawning in 1995 ended between late July and mid August (Fig. 14). Answers to question 12b suggested that the end of spawning was similar in 1994 and 1995 for at least 25% of the sample population (Fig. 15). 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 and in 1995 has been later (Fig. 16). Nakashima and Winters

(1996) have observed spawning times in Trinity and Conception Bays comparable to the ranges reported in this survey. The results continue a trend of delayed spawning seasons since 1991 (Nakashima 1994).

Questions on the Fishery

Almost all licensed respondents (97%) intended to fish capelin in 1995, however only 7 respondents involved in the capelin fishery monitoring programme actually set their traps. Because no commercial fishery took place in 1995 questions 15-25 were not relevant to 98% of the sample population.

Questions on Climate and Ocean Conditions

The sample population was asked questions 26 and 27 (Appendix A) pertaining to general weather and ocean conditions during the summer of 1995. To be consistent with the 1994 survey answers to question 26 were classified as poor, average/fair, and good/perfect conditions. Based upon the answers given approximately 45% reported good/perfect weather conditions in 1995, 48% thought the weather was average/fair, and 7% indicated poor conditions. Average or fair conditions included east/northeast winds in June changing to west/southwest in the summer, fog or overcast conditions in June, and cool air temperatures in June with warming in the summer. Several respondents indicated that this summer there was good capelin weather in June. Good or perfect weather was mainly described as predominantly west or southwest winds, warm air temperatures, and mainly sunny all summer. These latter conditions are considered ideal for humans as experienced in 1994 but not necessarily conducive to capelin spawning. Ice conditions, frequency of storms, and water temperatures during the summer were the main headings of interest in question 27 (Table 1). Generally ice was gone from Div. 3Ps by the end of May, from Div. 3L in May/June, and from Div. 3K by the end of June. Indications of ice in the summer by 10% of respondents were in reference to the presence of icebergs. There were no (45%) or a few storms (42%) in 1995 with July being mentioned most often in Div. 3LPs and June or August in Div. 3K. Overall 49% of respondents thought water temperatures were normal compared to other years, 23% suggested they were colder, and 25% said warmer (Table 1). Similar to other ocean conditions Div. 3K tended towards colder or average water temperatures while the southern areas reported average or warmer. Average conditions are considered to be cooler in June with warmer temperatures in July and August. Most respondents in the 'warmer' category thought June was cooler than normal but the remainder of the summer was warmer than normal. Those in the 'colder' category emphasized a cold June and until at least mid-July with warming late in July or in August. From the responses to questions 26 and 27 it is clear

that climate and ocean conditions in 1995 displayed a south to
north warming trend.

Characteristics of the Sample Population

All respondents were asked questions 28-31 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 28 suggests a change in the number of years of involvement
in the capelin fishery (Fig. 17). In the 1995 survey over 20% of
respondents began to fish in 1980-81 and a further 40% in 1985-88.
The low number of entrants in the 1990s is common to both surveys.
Most licensed fixed gear capelin fishers are in the 45-55 age range
followed by the 35-44 range (Fig. 18). Despite the change in age
classification between the 1994 (Nakashima 1995) and 1995 surveys
the age distribution of the two sample populations are similar.
Fishing vessel lengths varied from 17-54 feet with the majority
less than 36 feet (Fig. 19). Estimated vessel capacity for capelin
was less than 13,608 kg (30,000 lbs) for over 85% of the fishing
fleet used in the fixed gear capelin fishery (Fig. 20). The
responses to question 29 are comparable in the two surveys. The
highest proportion of respondents were from Notre Dame Bay with no
fishers in the sample population from the Southern Shore,
St. Mary's Bay, and Fortune Bay (Fig. 21). The distribution of
responses from Div. 3KLPs in the sample population is similar to
and therefore representative of the survey population of licenses
in 1995 (Fig. 22).

The 1996 Capelin Fishery

In last year's survey approximately 35% of respondents
commented that the capelin fishery should be closed (Nakashima
1995). Instead of relying on soliciting comments as was done in
the 1994 survey respondents in 1995 were asked if a capelin fishery
should occur in 1996 and to explain why (question 34a,b in
Appendix A). The majority did not support a capelin fishery in
1996. The breakdown was 54% against, 21% in favour, and 24% were
in favour only if certain conditions (mainly larger females and
good abundance) were met. One percent did not have an opinion.

Summary

Results from the telephone survey of fixed gear capelin
fishers provided observations on beach spawning, local capelin
abundance, and summer weather conditions. In 1995 most respondents
indicated that capelin spawned later, spawned on fewer beaches at
a lower intensity, and spawned subtidally away from beaches more so
than in the 1980s. Most licensed fishers intended to fish in 1995
but could not because the fishery did not open. The weather was
generally considered favourable for being out on the water and

water temperatures were considered normal. Overall respondents felt capelin abundance and spawning on beaches in 1995 was higher than in 1994 but lower than in previous years. The results of this telephone survey are representative of the survey population at the time the survey was conducted with a ±5% margin of error 19 times out of 20.

The general characteristics of the capelin fixed gear license population have remained consistent between the two surveys except for a change towards fewer years in the capelin fishery and an increase in the proportion of license holders from Notre Dame Bay in 1995.

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. Rees assisted in the preparation of the manuscript.

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

Nakashima, B. S., and G. H. Winters. 1996. Results from monitoring spawning beaches on the northeast coast of Newfoundland. pp. 131-143. In: Anon. Capelin in SA2 + Div. 3KL. DFO Atl. Fish. Res. 96/90.

Table 1. Responses (%) to question 27 concerning ice, storms, and water temperatures in 1995 by area (PB = Placentia Bay, CB = Conception Bay, TB = Trinity Bay, BB = Bonavista Bay, NDB = Notre Dame Bay, WB = White Bay) and combined for Div. 3KLPs.

Ice conditions	None	in May	in June	in summer
PB	52	48	0	0
CB	26	33	40	0
TB	37	47	16	0
BB	30	45	21	3
NDB	6	17	61	16
WB	0	18	65	18
3KLPs	17	28	45	10

Storm frequency	Calm	Few	Average	Several
PB	52	38	5	5
CB	32	61	0	7
TB	56	37	0	7
BB	33	55	0	12
NDB	46	36	2	16
WB	48	40	0	11
3KLPs	45	42	1	12

Water temperature	Colder	Average	Warmer	No response
PB	14	33	43	10
CB	14	55	29	2
TB	16	46	33	5
BB	26	29	42	3
NDB	27	55	18	0
WB	26	53	16	5
3KLPs	23	49	25	3
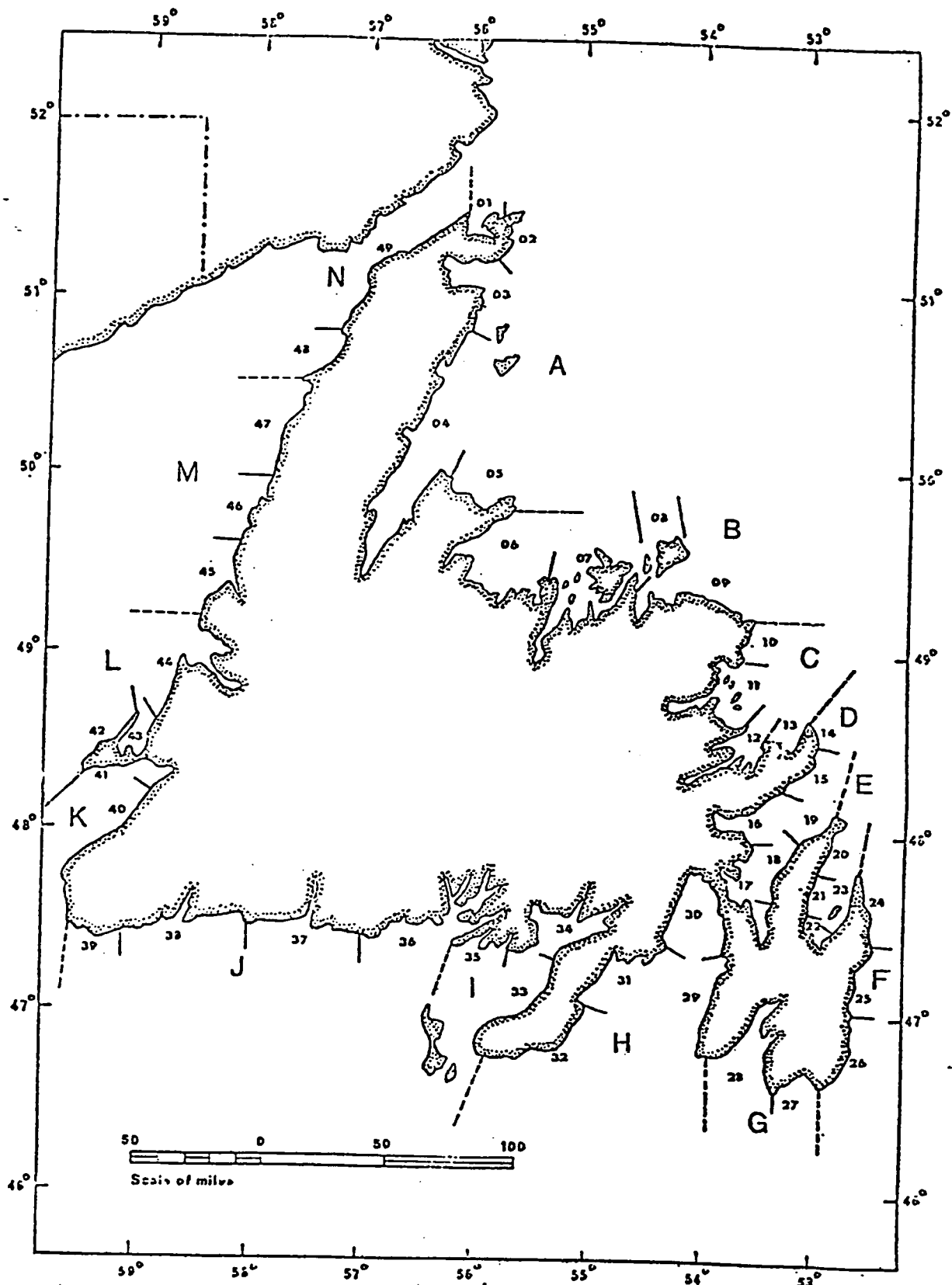
Fig. 1. Statistical areas (A = White Bay, B = Notre Dame Bay, C = Bonavista Bay, D = Trinity Bay, E = Conception Bay, F = Southern Shore, G = St. Mary's Bay, H = Placentia Bay, and I = Fortune Bay) for the Newfoundland Region.
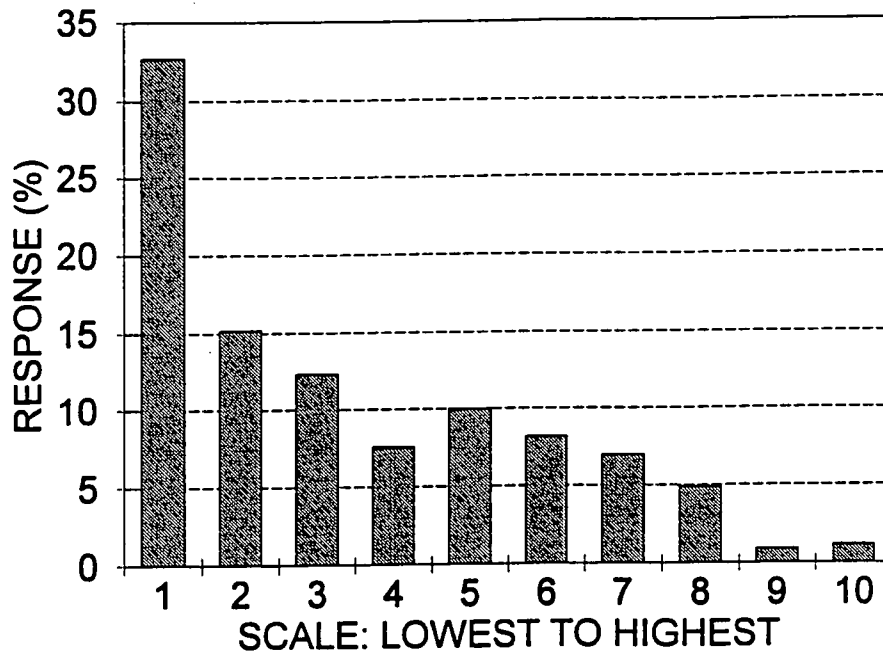
Fig. 2.   Response to question 1 on the abundance of capelin in 1995.
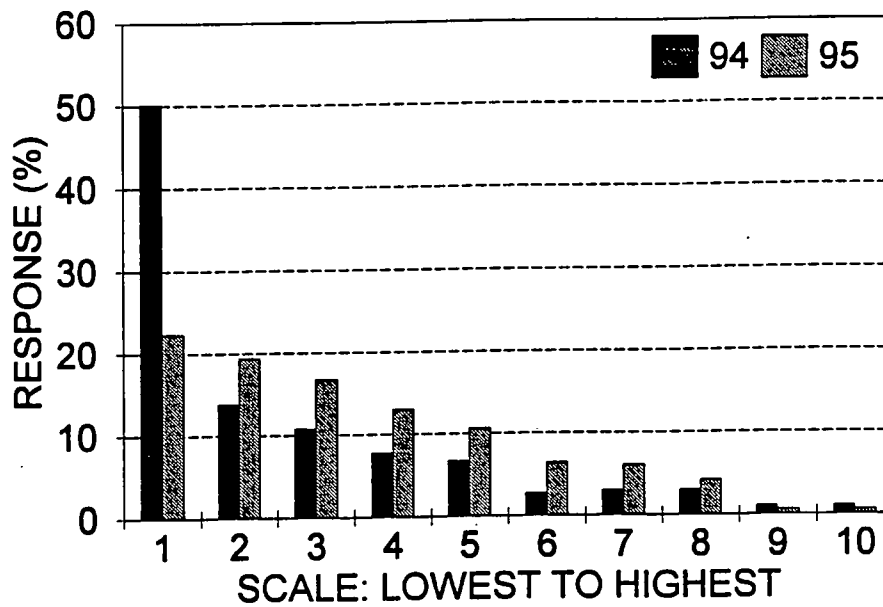
Fig. 3.   Impression of capelin abundance in 1994 from the 1994 (Nakashima 1995) and 1995 surveys.
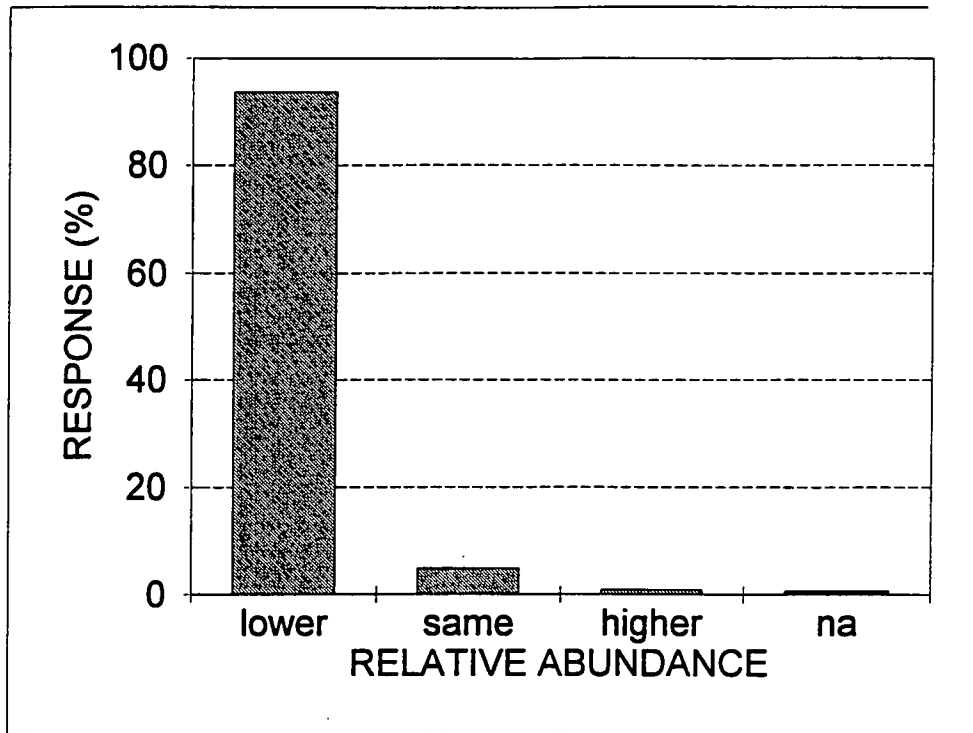
Fig. 4. Response to question 3 concerning abundance in 1995 compared to first started fishing. No answer given (na).
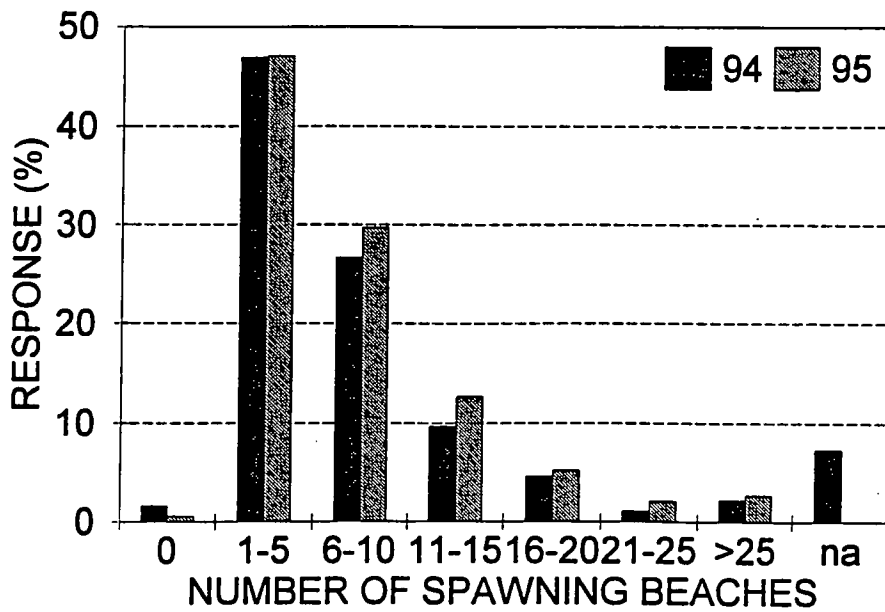
Fig. 5. Response to question 4 concerning the number of capelin spawning beaches. No answer given (na).
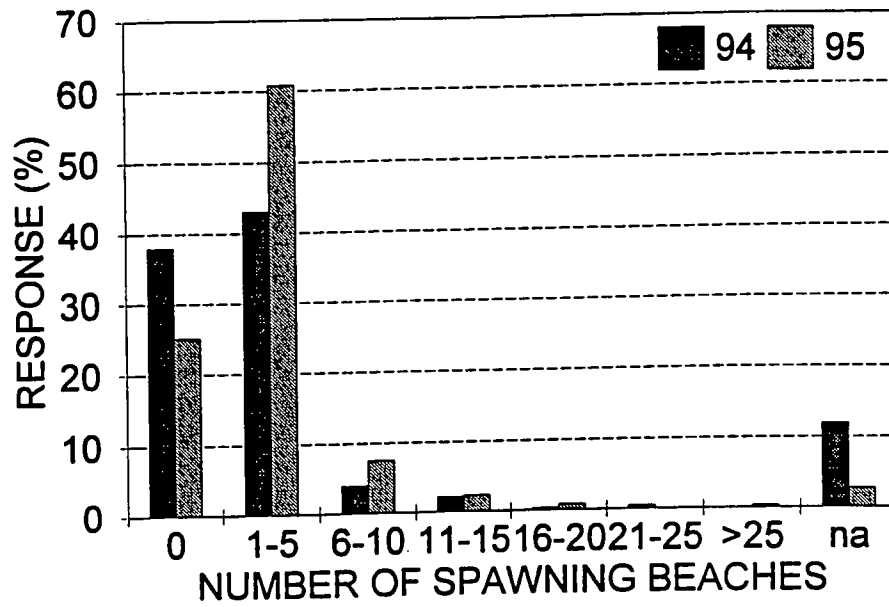
Fig. 6.   Response to question 5 concerning the number of
beaches capelin spawned on in 1994 and in 1995.   No answer
given (na).
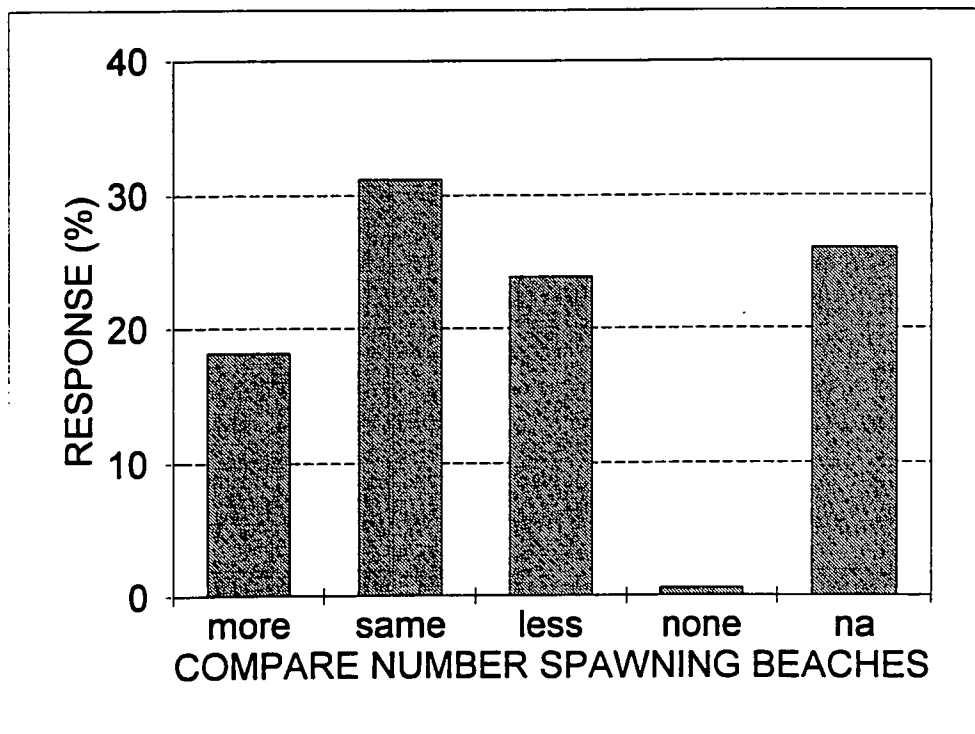
Fig. 7.   Response to question 6 concerning the relative
number of spawning beaches occupied in 1994 compared to
1995.   No answer given (na).
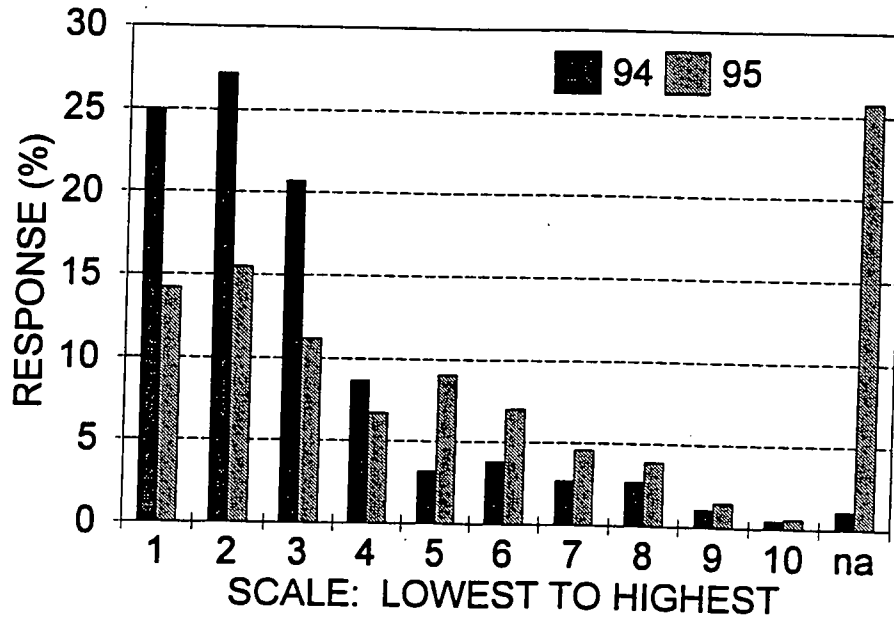
Fig. 8. Response to question 7a describing the intensity of spawning on an increasing scale of 1 to 10. No answer given (na).
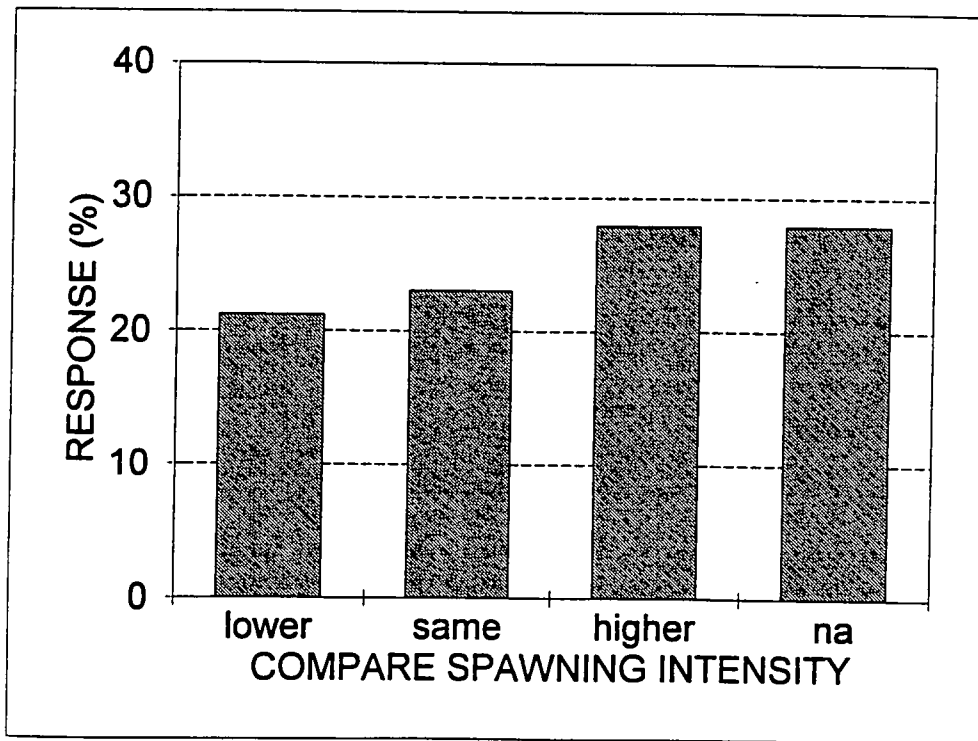
Fig. 9. Response to question 7b comparing the spawning intensity in 1995 relative to 1994. No answer given (na).
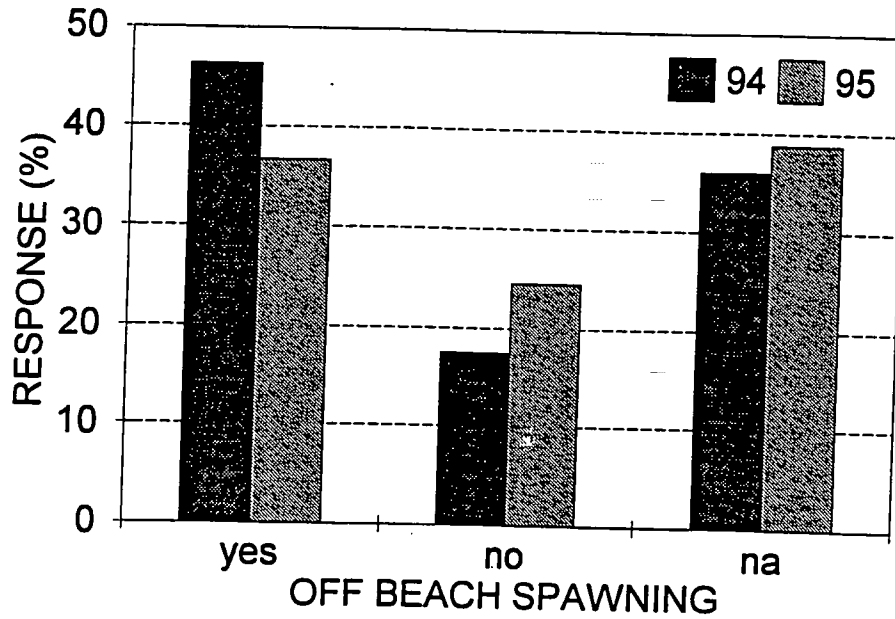
Fig. 10. Did off beach spawning occur in 1994 (from
Nakashima 1995) and in 1995? No answer given (na).
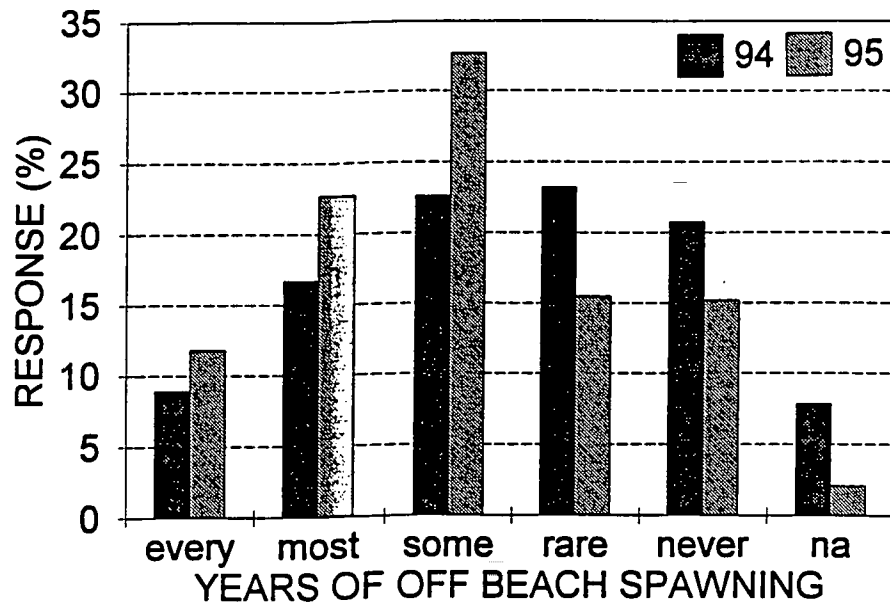
Fig. 11. The prevalence of off beach spawning from the 1994
and 1995 surveys. No answer given (na).
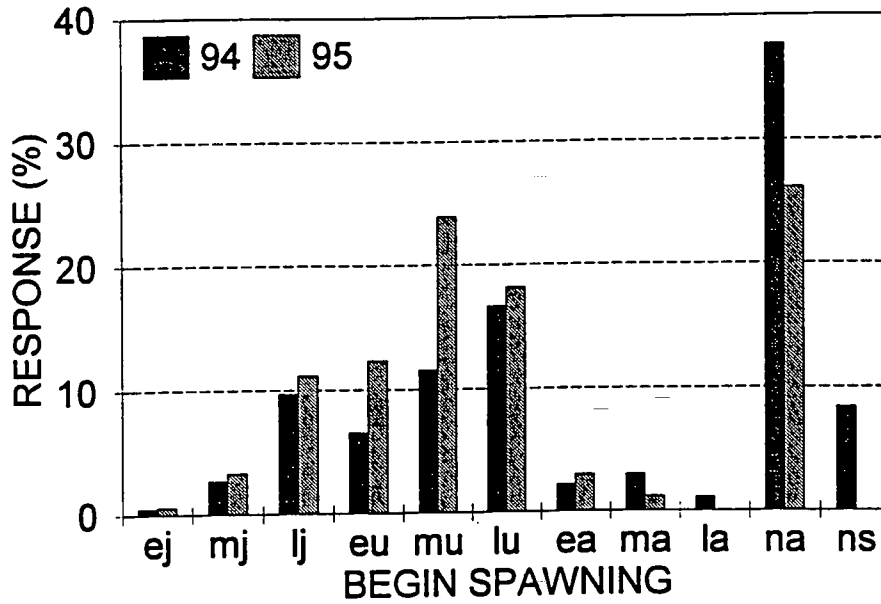
Fig. 12. Range of times when spawning began in 1994 (from Nakashima 1995) and in 1995. Spawning times are early June = ej, mid June = mj, late June = lj, early July = eu, mid July = mu, late July = lu, early August = ea, mid August = ma, and late August = la. No answer given (na) and no spawning (ns).
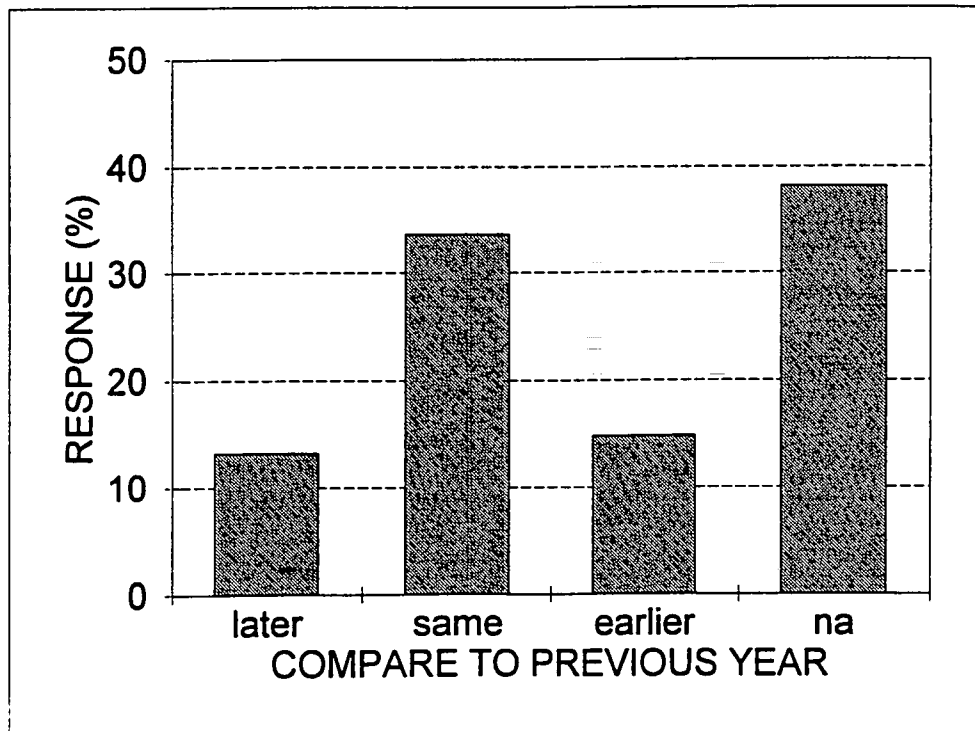
Fig. 13. The start of spawning in 1995 compared to 1994 in response to question 11b. No answer given (na).
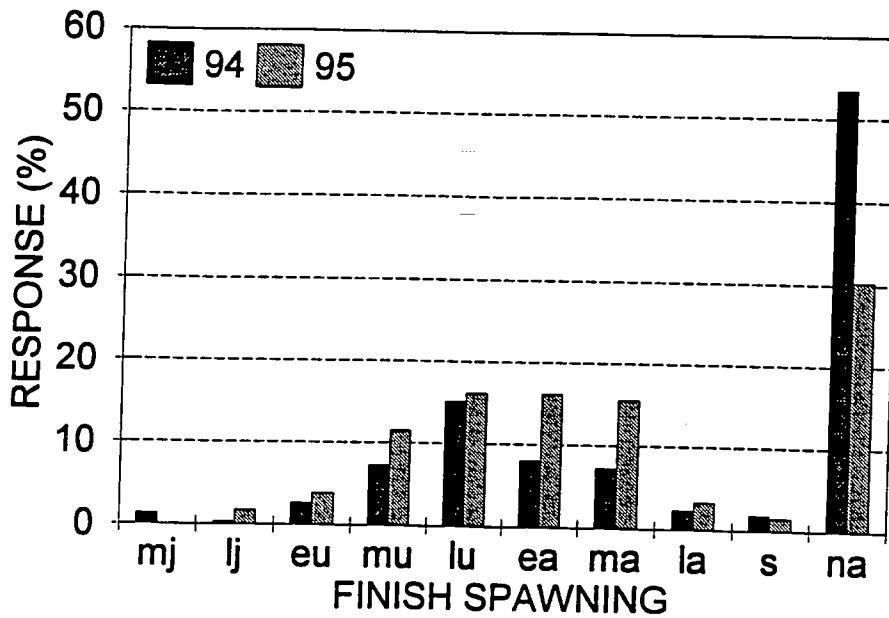
Fig. 14. Range of times when spawning ceased in 1994 (from Nakashima 1995) and in 1995. Spawning times are mid June = mj, late June = lj, early July = eu, mid July = mu, late July = lu, early August = ea, mid August = ma, late August = la, and September = s. No answer given (na).
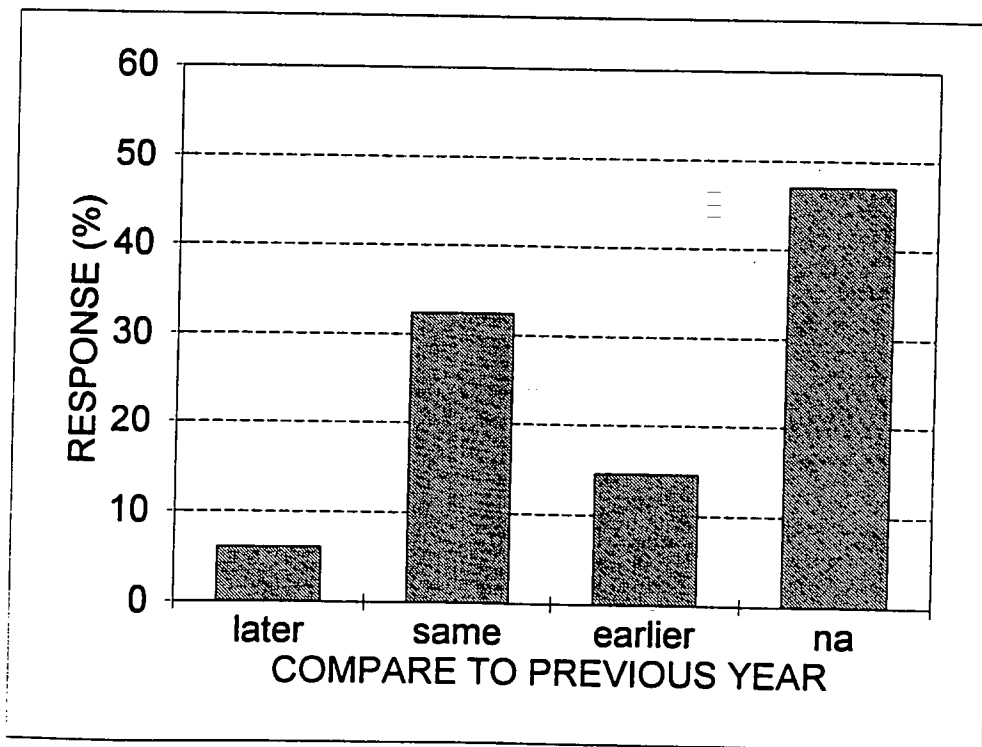
Fig. 15. The cessation of spawning in 1995 compared to 1994 in response to question 12b. No answer given (na).
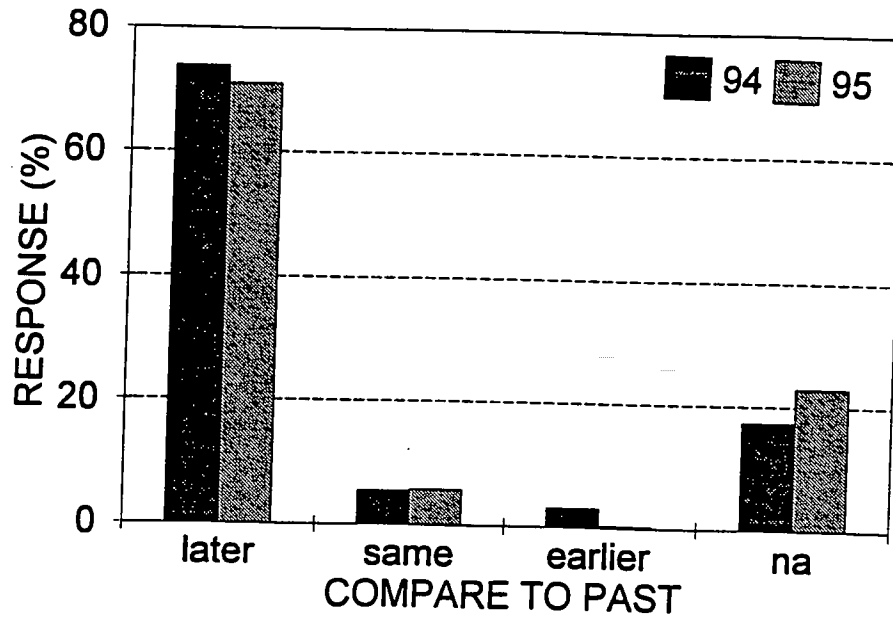
Fig. 16. Comparison of spawning times in 1994 (from Nakashima 1995) and in 1995 to when first started fishing. No answer given (na).
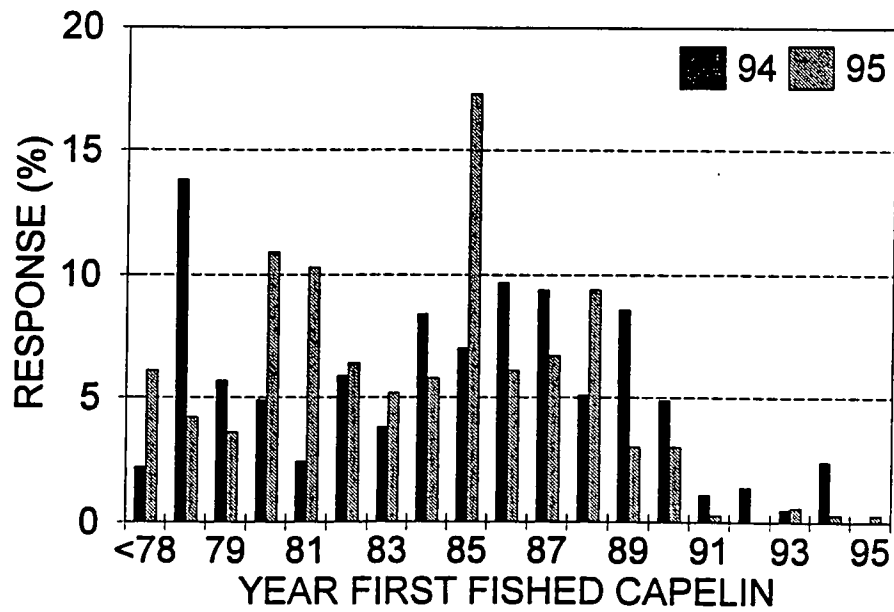
Fig. 17. Experience in the inshore capelin fishery.
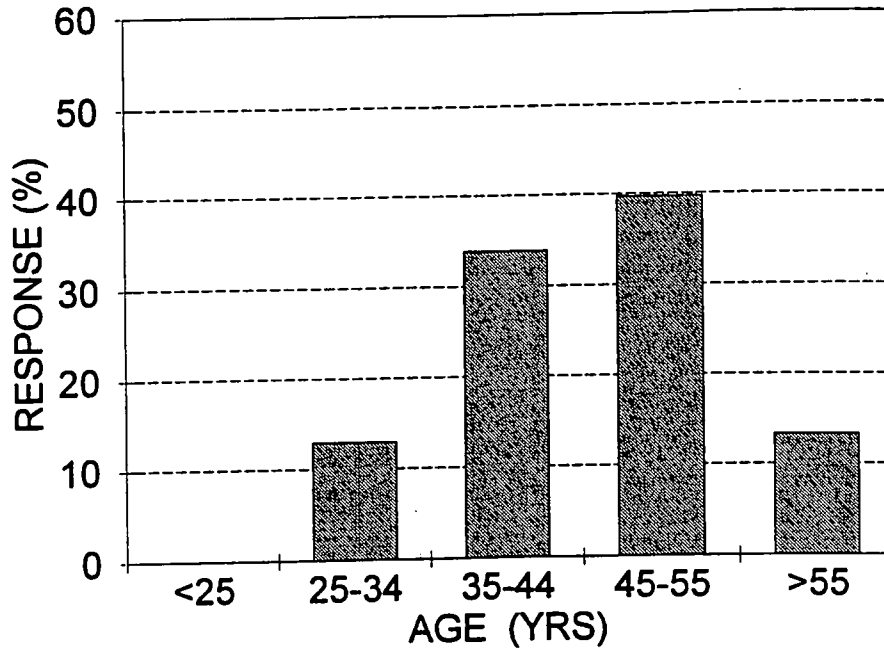
Fig. 18.   Age range of capelin fishers in 1995.
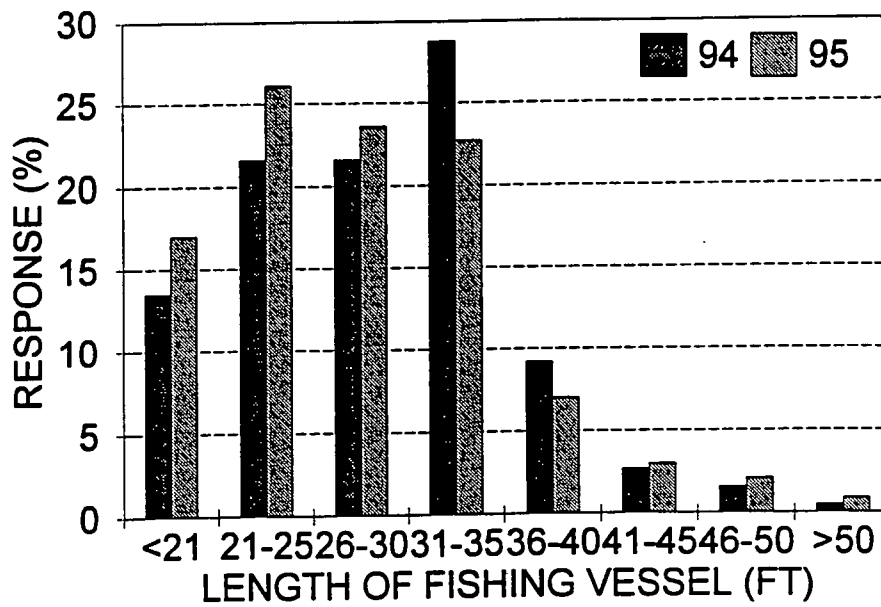
Fig. 19.   Lengths of fishing vessels involved in the fixed
gear fishery.
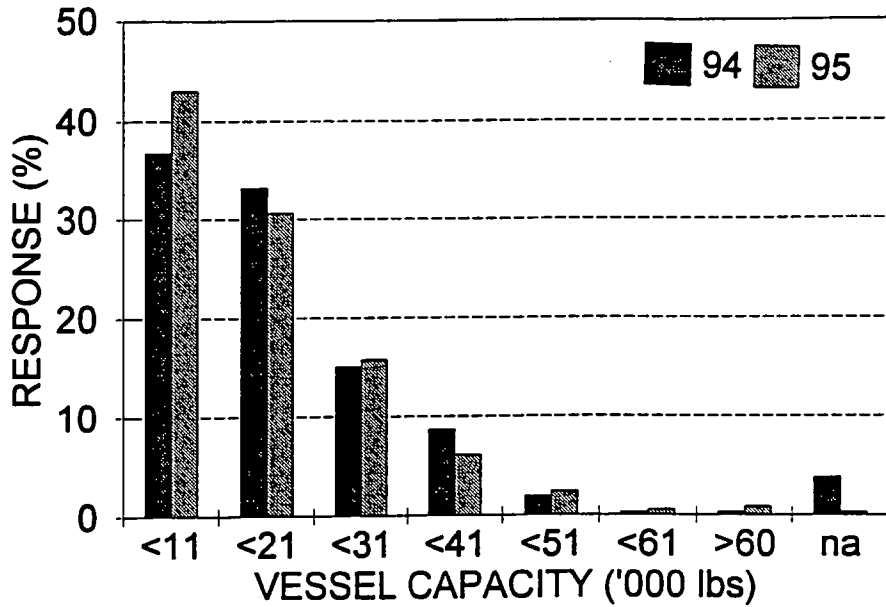
Fig. 20. Fishing vessel capacity for capelin. No answer given (na).
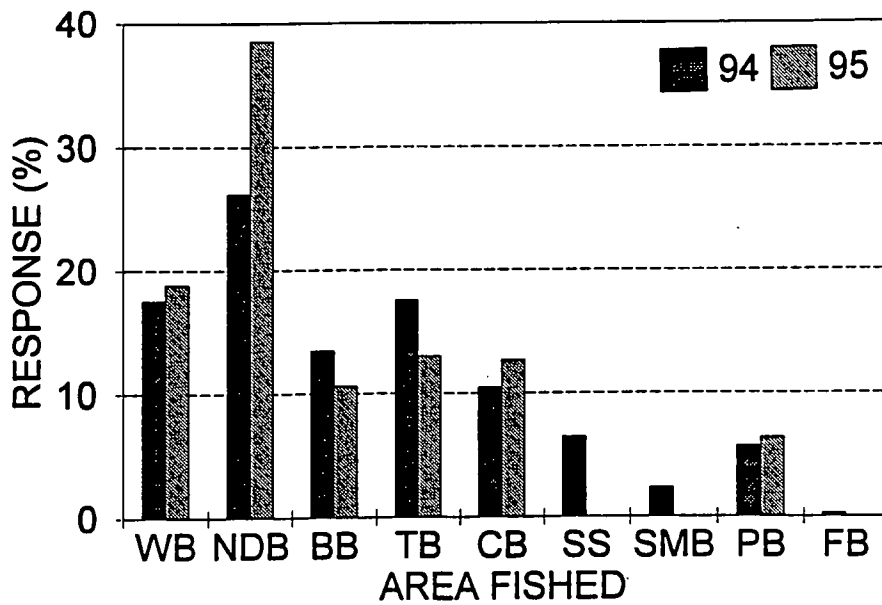
Fig. 21. Distribution of survey respondents among fishing areas (WB = White Bay, Notre Dame Bay = NDB, BB = Bonavista Bay, TB = Trinity Bay, CB = Conception Bay, SS = Southern Shore, SMB = Trepassey and St. Mary's Bay, PB = Placentia Bay, FB = Fortune Bay).
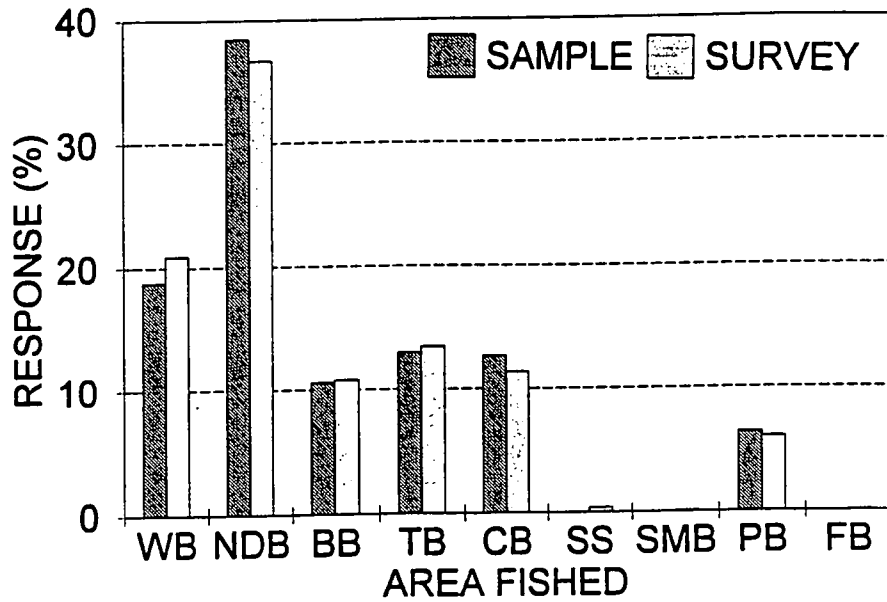
Fig. 22. Representation by area of sample respondents
versus survey population of fixed gear capelin licences in
1995.

Appendix A

SURVEY QUESTIONNAIRE OF FIXED GEAR CAPELIN LICENSE 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 1995?
Ans: 1   2   3   4   5   6   7   8   9   10   ?

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 1994?
Ans: 1   2   3   4   5   6   7   8   9   10   ?

3. How would you describe the abundance of capelin this year compared to when you first started fishing capelin?
Ans: lower   the same   higher   don't know

Questions on Spawning:
4. Approximately on how many beaches in your area do capelin usually spawn?
Ans: none   _____   don't know

5. Approximately on how many beaches did capelin spawn in 1995?
Ans: none   _____   don't know

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

6. Compared to 1995 how many beaches did capelin spawn on in 1994?
Ans: more   same   less   none   don't know

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 1995?
Ans.   1   2   3   4   5   6   7   8   9   10   ?

7b. What was the intensity of capelin spawning in 1995 compared to 1994?
Ans: lower   same   higher   don't know

8. Did capelin spawn off beaches in your area in deeper water?
Ans: yes   no   don't know

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 1995?
Ans:

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

Ans: every yr   most yrs   some times   rarely   never

11a. When did capelin first spawn in your area in 1995?
Ans:

11b. Did spawning start at the same time in 1995 as in 1994?
Ans. later   same   earlier   don't know

12a. When did capelin finish spawning in your area in 1995?
Ans:

12b. Did spawning finish at the same time in 1995 as in 1994?
Ans: later   same   earlier   don't know

13. How does the timing of capelin spawning (beginning and end) in 1995 compare to when you first started fishing capelin?
Ans: later   same   earlier   don't know

Questions on Fishery.
14. Did you intend to fish for capelin in 1995?
Ans: Yes   No

If 'yes' continue if 'no' go to Ques. 26

14b. Did you set your fishing gear or go out and search for capelin in 1995?
Ans. Yes   No

If 'yes' continue if 'no' go to Ques. 26

15a. What type of fishing gear did you use in 1995?
Ans: trap   beach/bar seine   purse seine

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

15b. How many traps did you fish in 1995?
Ans: one   two   more than two

15c. How much capelin does your trap(s) hold (ie maximum amount)?
Ans.

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

16. Approximately how much capelin did you and your crew land in 1995?
Ans:

17. Approximately how much capelin (live or dead) did you and your crew discard (ie did not land or sell) in 1995?
Ans:

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

18. What percent of the discarded capelin do you think survived?
Ans: 0   10   20   30   40   50   60   70   80   90   100

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

20a. How does the amount you discarded in 1995 compare to 1994?
Ans: less   same   more   don't know

20b. How does the amount discarded in 1995 compare to other years you've fished capelin?
Ans: less   same   more   don't know

21. While fishing capelin did you and your crew catch any other species (ie bycatch)?
Ans: yes   no

If 'yes' continue   if 'no' go to Ques. 26

22. What species were they and approximately how many of each?
Ans:

23. What was the condition of the bycatch when released?
Ans: alive   some dead/some alive   dead

24. What effect do you think your bycatch of cod have on cod populations in your area in 1995?
Ans: none   some   significant   very significant   don't know

25. Why do you think so?
Ans.

Questions on Climate/Ocean Conditions:
26. Weather plays an important role in the biology of capelin. While overall weather patterns are similar over the entire island there are instances when local conditions may be different from average conditions. Please describe the local weather in your area during the summer (June to early Sept) of 1995.
Ans:

27. Similar to the weather, ocean/sea conditions can sometimes vary between areas. Please describe the local ocean/sea conditions in your area during this summer (June to early Sept).
Ans:

General Information:
28. In what year did you first start fishing capelin commercially?
Ans:

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

30a. Have you always fished for capelin in the same location?
Ans: Yes   No

If 'no' continue if 'yes' go to Ques. 31

30b. Where else have you fished for capelin?
Ans.

31. How old are you?
Ans: less than 25   25-34   35-44   45-55   over 55

32. Do you wish to receive the results of this survey when the analyses are completed?
Ans: yes   no

33. If there is a capelin fishery in 1996 would you consider keeping a diary of your fishing activities in a capelin research logbook if asked?
Ans: yes   no

34a. In your opinion should there be a capelin fishery in 1996?
Ans: yes   no   depends   don't know

34b. Why do you think there should be/shouldn't be? On what does it depend?

35. 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?

Biological Data on Capelin (Mallotus villosus) from Inshore Areas of NAFO Div. 3KL in 1995

by

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Introduction

Reported landings in 1995 were 140 t in Div. 2J3KL compared to a market-based quota allocation of 32,280 t.   Landings were essentially nonexistent (Table 1, Fig. 1).   Compared to previous years, i.e. before 1994, the lack of a commercial fishery has compromised our information on mature spawners in 1995.

Materials and methods

Commercial samples were unavailable in 1995, however biological samples from monitoring fisheries 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.

Research logbooks were mailed to 44 purse seine and 133 fixed gear licensed fishers residing in Div. 3KL. A few trap logbooks were completed by fishers who were involved in the monitoring programme. These are not presented here.

Age compositions for Div. 3KL and mean lengths and weights for Div. 3K and 3L separately were estimated from trap monitoring and cast net samples. In previous years the samples were weighted by the catch per gear type but in 1995 all samples were given equal weight.

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 1995 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 1995 Capelin Management Plan. The presence of small females in the catch (more than 50 females/kg) was the main reason areas never opened in 1995. Low abundance in some areas was also a factor. The reported landings for 1995 in Table 1 may be from the monitoring programme and from small landings for local products.

Age Composition

In 1995 30 biological samples were processed from monitoring and cast net samples throughout Div. 3KL (Table 2). Div. 3L trap samples were from from Petty Harbour on the Southern Shore and Rantem in Trinity Bay except for one from Bristols Hope in Conception Bay. All Div. 3K trap samples were collected in the White Bay area at Sops Arm, Cat Arm, and Englee. Cast net samples were collected from Conception and Trinity Bays in Div. 3L and one from LaScie in Div. 3K. The mean number of otolith pairs per sample was less in Div. 3K than in Div. 3L (Table 2).

The 1995 spawning biomass in numbers was dominated by the 1992 year-class as three-year-olds (52%) followed by the 1993 year-class as two-year-olds (44%) and the 1991 year-class as four-year-olds (4%) (Table 4). The estimates in Table 4 are from monitoring and trap samples only. Actual estimates differ but the trends in age compositions are comparable between the commercial (Table 3) and non-commercial (Table 4) samples in 1993 and 1994. However, these age compositions differ from those derived from beach samples (Nakashima and Winters 1996).

Mean Lengths and Weights in Div. 3K and Div. 3L

In Div. 3K the mean length at age 2 is variable but with no obvious trend (Fig. 2). For ages 3 and 4 and all ages combined, there has been a general decline in the mean length from 1991-95 except for a small increase in 1994 (Fig. 2).

In Div. 3L the mean lengths at age 2 did not vary much between 1982-95 (Fig. 3). For ages 3 and 4, mean lengths showed only small variations between 1982 and 1988 but have shown a gradual decline since then. 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).

Similar to the precaution about the 1994 data (Nakashima 1995) the mean lengths-at-age in 1995 are predominantly from site-

specific trap monitoring samples and cast nets which may not be comparable to commercial samples.

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 was true since 1991 when age 2 fish made a significant contribution to the spawning stock and contributed to the decline in overall mean size (all ages combined) of females in the population.

The sample mean weights are given in Table 5. 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 1995 indicate a decline between 1994 and 1995 for all ages in Div. 3K and a decline for ages 3 and 4 in Div. 3L. However, under normal circumstances with an active fishery the samples used in 1995 would not have been processed as commercial samples.

Conclusions

For three years now the inshore commercial fishery has been severely curtailed resulting in a paucity of biological and fishery-related information. Biological samples from other sources have been used to continue measuring age compositions, lengths, and weights, however, no comparable catch rate data are available. If the samples can be assumed to represent the spawning population and are comparable to those collected from an active commercial fishery then the results suggest that the spawning biomass in 1995 was comprised of age 2 and age 3 fish only, that size at age of age 2 fish are comparable to earlier years, and age 3 fish in Div. 3K continue to decline while in Div. 3L they are relatively stable since 1993.

Acknowledgements

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    fishery in NAFO Div. 3KL in 1994.   pp 25-46.   <u>In</u>:   Anon.
    Capelin in SA2 + Div. 3KL.   DFO Atl. Fish. Res. Doc. 95/70.

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

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	Total
1986	2J		0	3	0	3
		WB	1675	465	3684	5824
		NDB	2450	2069	1457	5976
	3K		4125	2534	5141	11800
		BB	3307	199	3173	6679
		TB	4018	625	12312	16955
		CB	7497	127	9590	17214
		SS	35	52	1362	1449
		SMB	5772	34	325	6131
	3L		20629	1037	26762	48428
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

Table 1. Continued ...

Year	Div.	Area	Purse seine	Beach seine	Trap	Total
1991	2J		0	1	0	1
		WB	239	227	12045	12511
		NDB	426	2709	4291	7426
	3K		665	2937	16336	19937
		BB	3066	70	3180	6316
		TB	4450	154	6474	11078
		CB	1889	20	2925	4834
		SS	0	7	0	7
		SMB	69	0	3	72
	3L		9474	251	12582	22307
1992	2J		0	0	0	0
		WB	2995	126	7602	10723
		NDB	2819	1113	1695	5627
	3K		5814	1239	9297	16350
		BB	977	28	60	1065
		TB	69	26	53	148
		CB	411	57	160	628
		SS	0	5	21	26
		SMB	25	3	26	54
	3L		1482	119	320	1921
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
		WB	0	2	0	2
		NDB	0	55	0	55
	3K		0	57	0	57
		BB	0	33	0	33
		TB	0	14	1	15
		CB	0	18	2	20
		SS	0	9	0	9
		SMB	0	6	0	6
	3L		0	80	3	83

*   provisional

Table 2. Summary of inshore research samples processed and aged from 1995 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	0	0	
Capelin trap	6	186	31.0 ± 8.2
Cast net	1	26	26
TOTAL	7	212	
Div. 3L			
Purse seine	1	36	36
Capelin trap	10	321	32.1 ± 3.6
Cast net	12	328	27.3 ± 4.3
TOTAL	23	685	

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*	23.8	56.7	19.5	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*	33.4	43.1	19.7	3.8	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*	31.1	46.3	19.7	2.9	0

* low sample numbers (N = 11) and from a small area

Table 4. Age composition (%) of capelin from inshore research samples,
Div. 3KL.

	Age				
Year/Sex	2	3	4	5	6
Males					
1993	5.2	90.8	4.0	0	0
1994	19.5	64.4	15.9	0.2	0
1995	34.7	63.4	1.9	0	0
Females					
1993	15.3	78.1	6.4	0.2	0
1994	43.1	41.5	12.2	3.2	0
1995	55.8	37.3	6.4	0.4	0.1
Sexes Combined					
1993	9.7	85.2	5.1	0.1	0
1994	34.7	49.6	13.5	2.1	0
1995	43.7	52.3	3.8	0.2	0

Table 5. Mean weights-at-age (gm) from commercial samples in Div. 3K and Div. 3L, sexes combined.

| Year	Age					All
	2	3	4	5	6	
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
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

* from research samples only
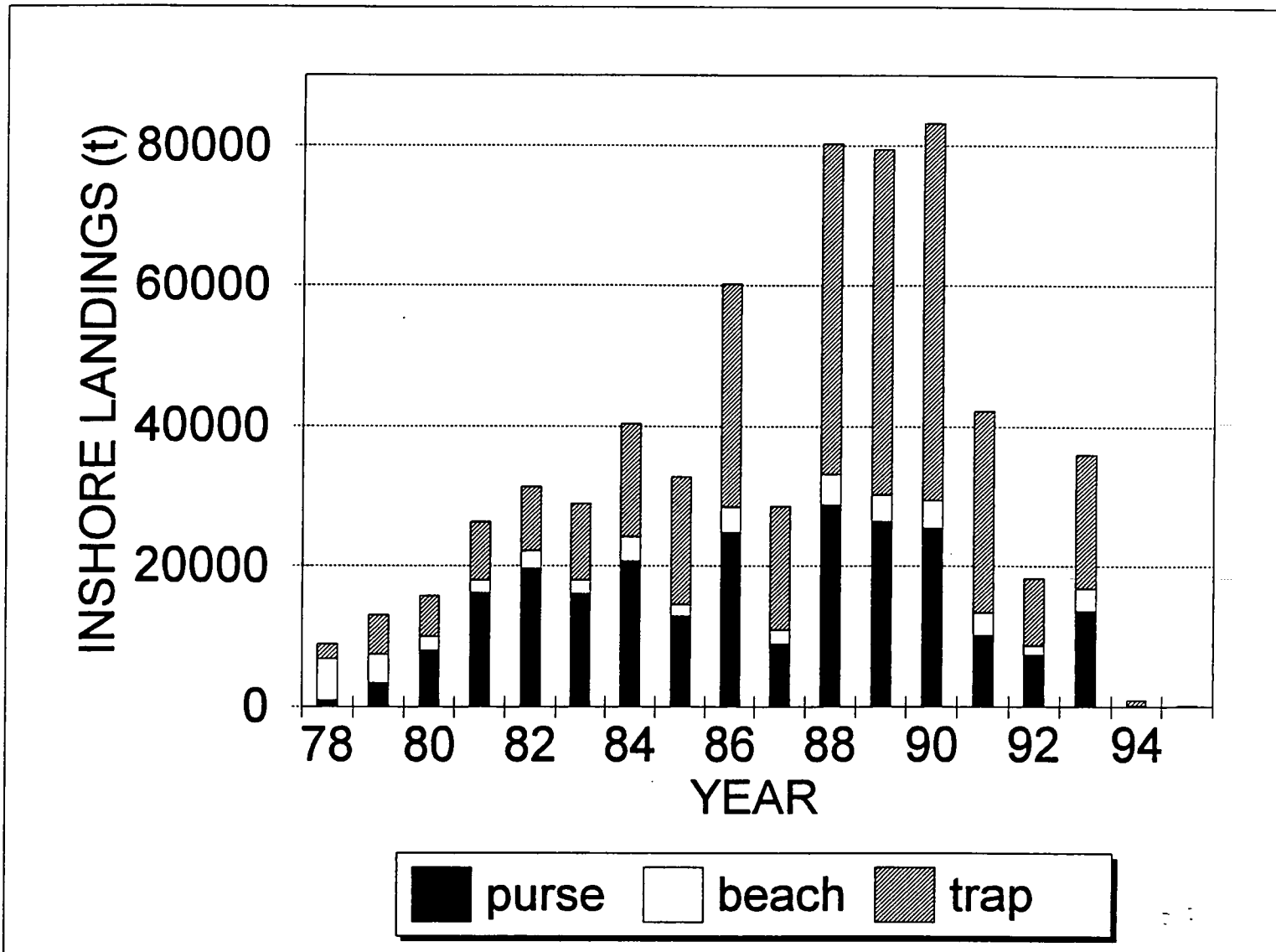
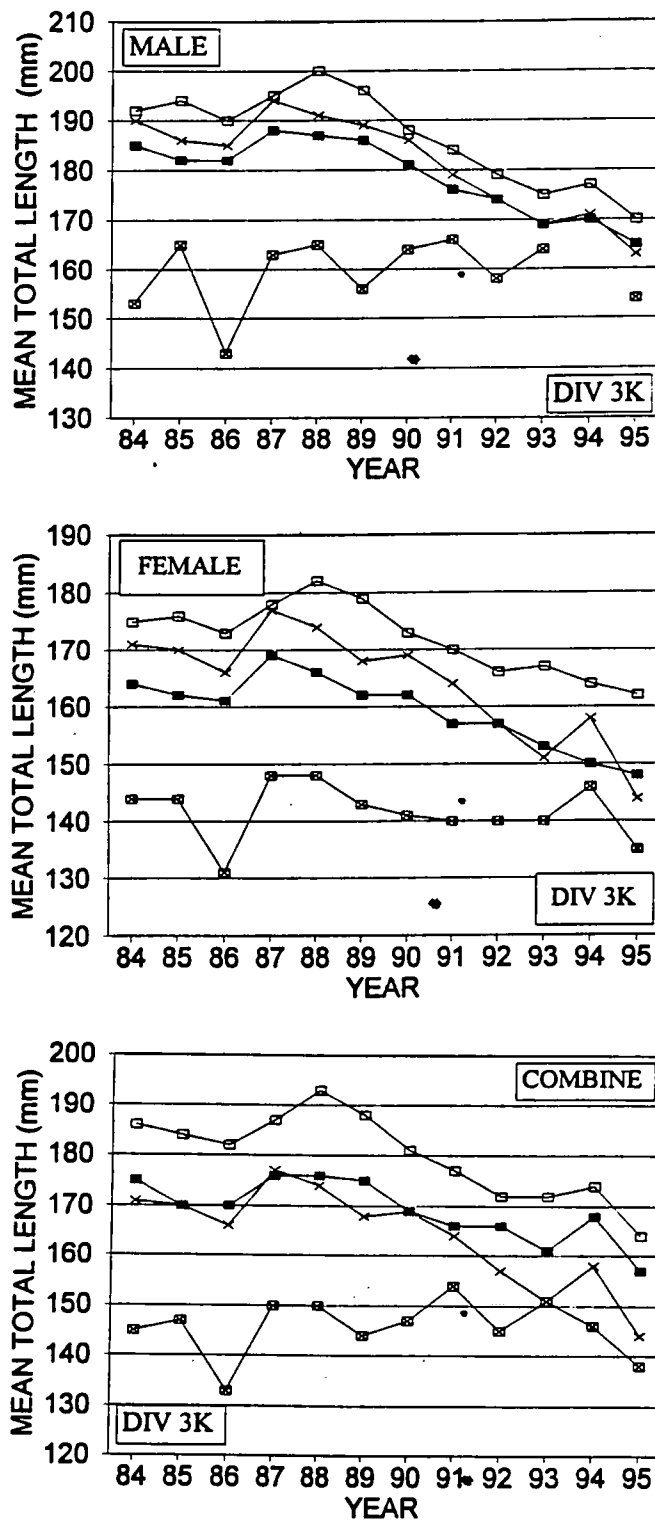Fig. 1.   Inshore capelin (t) in Div. 3KL.

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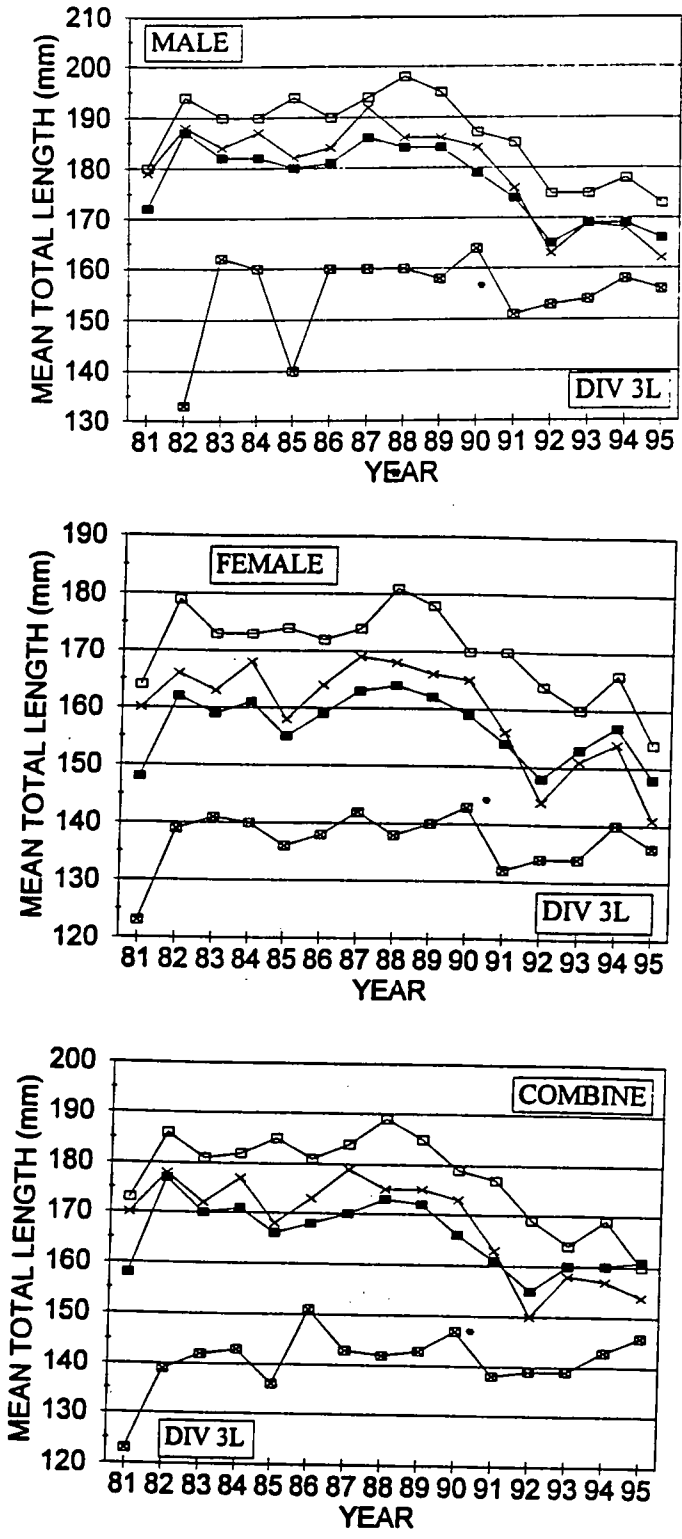
Fig. 3. Mean total length-at-age for age 2 (⊠), age 3 (■), age 4 (□), and all ages (x) for males, females, and sexes combined in Div. 3L.

Appendix A

1995 CAPELIN ALLOCATIONS

NAFO AREA	AREA	FIXED GEAR	PURSE SEINE	TOTAL
2J	LABRADOR	150		150
3K	WHITE BAY (1)	4,475	1,500	5,975
	NOTRE DAME BAY (1)	3,925	1,500	5,425
	TOTAL	8,400	3,000	11,400
3L	BONAVISTA BAY	2,245	1,425	3,670
	TRINITY BAY	4,490	1,870	6,360
	CONCEPTION BAY	3,710	3,370	7,080
	SOUTHERN SHORE (1) (2)	2,300	190	2,490
	ST. MARY'S BAY	450	1,680	2,130
	TOTAL	13,195	8,535	21,730
3Ps	PLACENTIA BAY	1,740	260	2,000
	FORTUNE BAY AND WEST (3)	510	30	540
	TOTAL	2,250	290	2,540
4R3Pn	WEST COAST (1) (4)	4,000	6,000	10,000
	NFLD PROVINCE TOTAL	27,995	17,825	45,820
4ST				1,725
	ATLANTIC COAST TOTAL			47,545

NOTES TO ALLOCATION TABLE:

1. Sub-divisions of the fixed gear quota in White Bay, Notre Dame Bay, Southern Shore and 4R3Pn are detailed on the attached table.

2. Trepassey Bay from Cape Pine to Cape Race is included in the Southern Shore quota area for fixed gear only.

3. The fixed gear quota includes 450 t for an experimental fishery in the Hermitage/Harbour Breton area.

4. The purse seine quota in 4R3Pn is further sub-divided with 3,000 t for vessels over 65 feet and 3,000 t for vessels less than 65 feet.

Appendix A - continued

1995 CAPELIN FIXED GEAR SUB-DIVISIONS

BAY	AREA	QUOTA
WHITE BAY	CAPE BAULD TO FISCHOTT ISLAND	9€.
	FISCHOTT ISLAND TO CAPE FOX	32:
	CAPE FOX TO BOTTOM OF WHITE BAY (INCLUDING HAMPDEN)	1,27٠
	BOTTOM OF WHITE BAY TO CAPE ST. JOHN	1,91٠
NOTRE DAME BAY	CAPE ST. JOHN TO NORTH HEAD	1,1C:
	NORTH HEAD TO DOG BAY POINT	2,3C:
	DOG BAY POINT TO CAPE FREELS	52:
SOUTHERN SHORE	CAPE ST. FRANCIS TO LONG POINT	6C:
	LONG POINT TO CAPE NEDDICK	4C:
	CAPE NEDDICK TO CAPE PINE	1,30:
4R3Pn	SOUTH OF BROOM POINT	64C
	BROOM POINT TO POINT RICHE	44٥
	POINT RICHE TO BIG BROOK	1,43:
	BIG BROOK TO CAPE BAULD	77٥
	LABRADOR	710

Application of the Multiplicative Cohort Model
to Egg Deposition Data from Conception Bay

by

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Introduction

Capelin beaches are known to exhibit annual differences in the abundance of spawn. Beginning in 1987, 15 capelin spawning beaches around Conception Bay were selected for standardized sediment corings. These beaches were sampled on an annual basis until 1993 when the program was terminated (Nakashima and Slaney 1994). Herein we report on the results of applying a multiplicative cohort model to the annual egg deposition estimates desegregated by age.

Methods

The reader is referred to Nakashima and Slaney (1994) for details of beach sampling procedures. In summary, the timing of beach sampling was determined from aerial surveys, phoning monitors near some beaches, and periodic checks by survey teams for evidence of egg deposition. When such evidence indicated that the major spawning had occurred, each beach was cored in the mid-tide zone using a standard steel sediment corer of 6.5 cm internal diameter. The number of cores taken at each site depended on the area and variations in egg deposition which was estimated from linear measurements of the length and width of each egg concentration. Total egg deposition for the mid-tide zone was then estimated for each beach based on egg densities per core times egg concentration area (see Table 3, Nakashima and Slaney 1994).

Sampling times assume that all beaches are sampled after peak spawning and before significant hatching and larval release have occurred. A comparison of the relative proportion of eggs in the eyed versus the early stages (Fig. 1, from Table 2, Nakashima and Slaney 1994) indicates that in certain years (eg. 1988, 1992) sampling occurred much earlier in the incubation cycle than in other years. Taking into account daily egg mortality, these years would therefore be overestimated relative to those years sampled later in the incubation cycle. Since egg stage data were collected at each sampling site the egg abundance data were adjusted for differences in relative (to the incubation cycle) sampling times using the following multiplicative model:

$$\text{Log eggs} = \log \mu + \log \text{year} + \log \text{stage} + \epsilon$$

In this case, egg abundance is a multiplicative effect of year and egg stage effects. The model explained 81% of the variance in egg abundance and the raw versus the standardized estimates of egg abundance are compared in Figure 2. As expected the major adjustment was for 1988 and somewhat less so for 1992. Otherwise, the relative year effects remain unchanged.

The adjusted estimates of egg abundance have been decomposed into numbers at age using annual age compositions and mean weights of female capelin collected throughout the commercial fishing season in Conception Bay by purse seines and traps.

Two-year-olds have been adjusted downwards by a factor of 2.5 for 1991-93 in order to take into account increased selection by commercial gears during this period (Winters 1996).

Results and Conclusions

The cohort effect was extracted using the multiplicative cohort model described in Winters (1995). The model explained 83% of the variance in yearclass abundance based on 28 estimates of 10 yearclasses (1982-91) (Table 1). The standardized estimates of yearclass size are shown in Figure 3 in comparison with the inshore standard (purse seine, trap and aerial). With the exception of the 1982-83 yearclasses, the pattern of yearclass variation is very similar for both series.

This analyses assumes that eggs released in the MT zone can be used as an index of egg deposition for Conception Bay provided the same beaches are always sampled, beaches are surveyed following peak spawning, and that a single spawning peak represents the most abundant portion of the spawning population. In Table 2, the coring period is shown relative to peaks in the two aerial transects in Conception Bay. For all years except 1993 coring followed major peaks in aerial estimates of capelin abundance with an interannual pattern that closely corresponds to the incubation cycle differences noted above (eg. Fig. 1). However, it is obvious from Table 2 that in 1993 a second (and larger) peak in immigrant mature fish occurred towards the end of the beach sampling period. Based on field observations it was felt that a substantial portion of this peak was captured by the beach coring program for most beaches in the inner portion of Conception Bay. However, since only peak egg abundance for each beach (rather than their sum) is included in the above analyses, it is likely that the 1993 egg depositions are underestimated.

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Table 1. Statistical output of the multiplicative model applied to the Conception Bay egg deposition series. The reference categories are the 1991 yearclass and age 5 abundance.

Source	DF	Sum of squares	Mean squares	F-value	PR > F
Model	12	61.48	5.12	5.94	0.0009
Error	15	17.13	0.86		
Corrected total	27	74.42			

Root MSE		0.93
Dep. Mean		3.57
C.V.		25.98
R square		0.83

Table 2. Comparison of peaks in the Conception Bay aerial survey and sediment core sampling times.

Year	Mid-date of core sampling (JD)	Aerial survey peak (JD)		Relative sampling time (days)	
		Inside transect	Outside transect	Inside transect	Outside transect
1987	178	170	167	8	12
1988	181	176	176	5	5
1989	180	167	167	13	13
1990	185	177	177	8	8
1991	208	-	-	-	-
1992	199	195	194	4	5
1993	201	192	194	9	7
		208*	-	-7	-

*   second peak

C.BAY RELATIVE EGG DEVELOPMENT

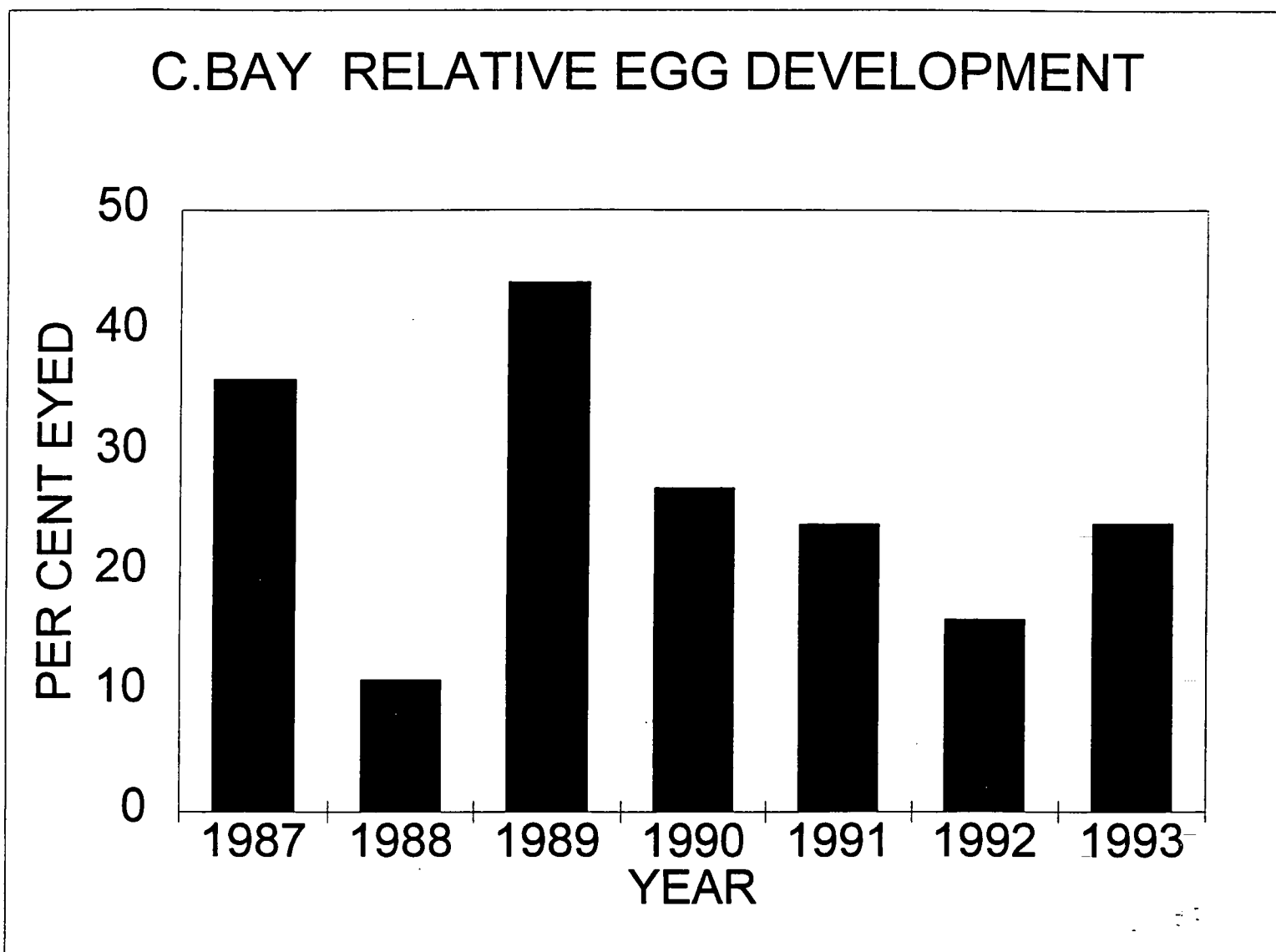Fig. 1.   Relative stage in the incubation cycle of capelin eggs sampled in Conception Bay, 1987-93 (from Nakashima and Slaney 1994).
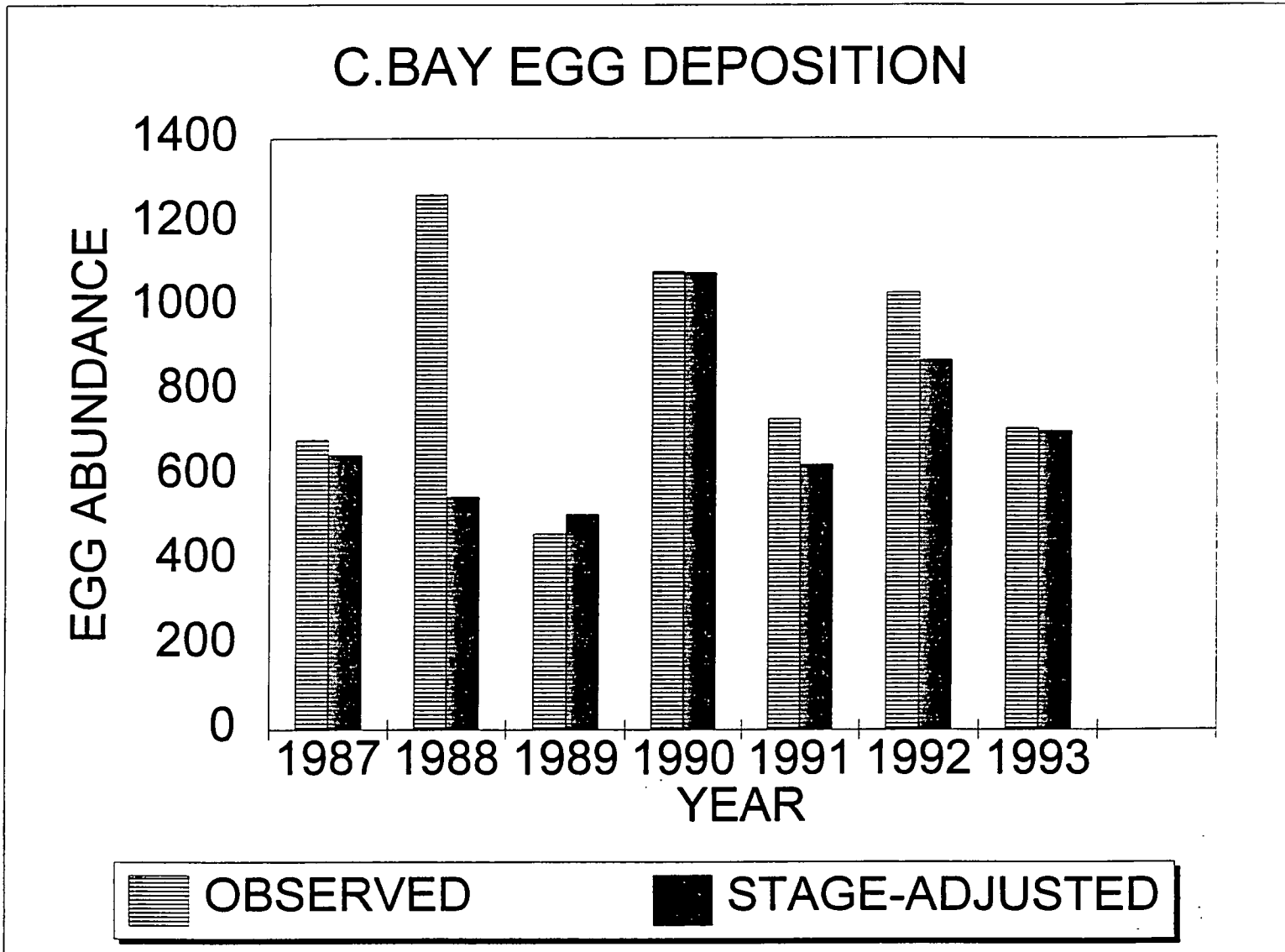
Fig. 2. Comparison of observed egg abundance (no. of eggs x10^{-10}) and egg abundance standardized for interannual variability in stage composition.
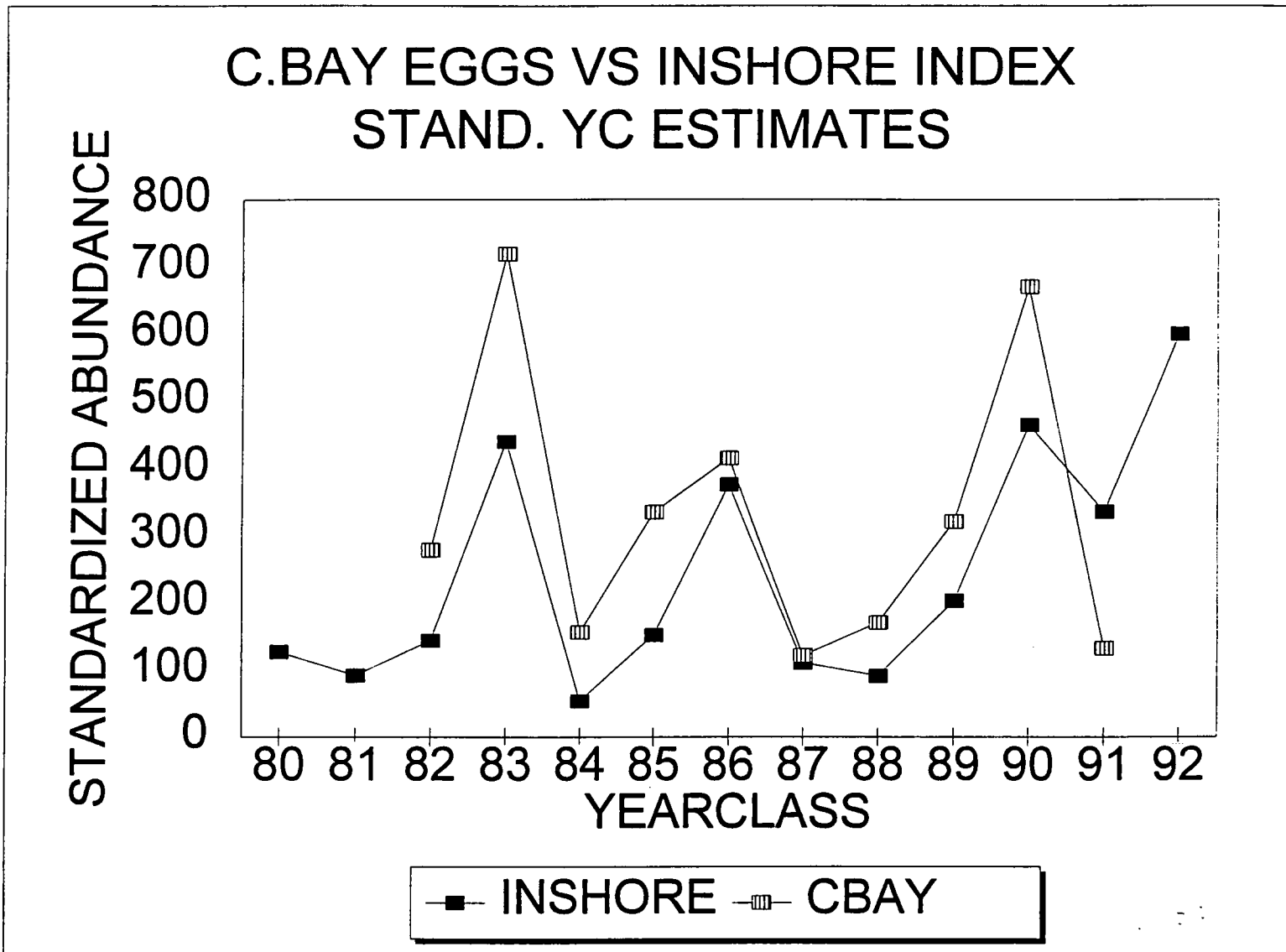
Fig. 3. Comparison of cohort estimates from the Conception Bay
deposition data with those from the inshore standard.

Results of the 1995 CASI Aerial Survey
of Capelin (<u>Mallotus villosus</u>) Schools

by

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Introduction

Area estimates of capelin (<u>Mallotus villosus</u>) schools conducted since 1982 have been used as an index of inshore abundance of mature capelin in NAFO Div. 3L (eg. Nakashima 1995). 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 by 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 1995 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. The spectral resolution of each element is 1.8 nm and the spatial resolution of each element is 1.2 rad. 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 sunny days and for overcast 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. Weather conditions in 1995 were generally favourable
allowing CASI surveys to be flown at 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 three days later
in July in case more schools arrived nearshore. The 1995 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 1995 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 2 are best estimates of the true survey time.

Results and Discussion

In 1995, the aerial survey provided frequent coverage of both Conception Bay transects and Trinity Bay. Flights were made in Trinity Bay six times (Table 2a), along the outside transect of Conception Bay four times (Table 2b), and the inside of Conception Bay six times (Table 2c). The coverage in 1995 was less frequent than in 1994. Five days (July 10, 14, 16, 19, and 20) were not flown because of poor weather conditions. Technical problems with the instrument resulted in incomplete data collections on July 5, 6, and 13.

In Trinity Bay the highest school area estimate was observed on July 15, the same day as in 1994 (Table 2a). In Conception Bay the highest total for both transects occurred on July 7-8 (Tables 2b, c) which was 5 days earlier than in 1994 . For daily estimates prior to 1991 see Nakashima (1995). The total school surface area for 1995 taken from the highest estimates in Conception and Trinity Bays was 557,451 m² which is the third highest in the series (Table 3, Fig. 2). The estimate in Trinity Bay was the the third highest since 1982 and the total school area estimate in Conception Bay was similar to the long-term geometric mean of 208,070 m² excluding the 1991 estimates (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 be detected when they will move close to beaches to spawn. Even though all schools may be recorded and measured, by choosing a single estimate of total school area per bay I assume all schools arrive at the same time as a single spawning peak. This is not always true (eg. Nakashima and Winters 1996). Using school area as a relative abundance index assumes density is related to surface area. No data exists to test this for capelin, however Misund et al. (1992) have shown that herring, sprat, and saithe biomass is correlated to school area and to school volume.

Acknowledgments

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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	152-160	
1983	Aero-Commander	Wild RC 10	Jun 19-Jul 9	457	25.9
1984	Cessna 310	Wild RC 10	Jun 17-Jul 7	457	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	381-579	13.4
1987	Piper Aztec	Zeiss RMK	Jun 16-Jul 3	457	37.0
1988	Piper Navajo Piper Aztec	Zeiss RMK	Jun 15-Jul 5	305-488	33.0
1989	Piper Navajo	Zeiss RMK	Jun 16-27 Jun 30-Jul 4	434-732	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	364-1220	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	914-1341	42.4

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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						1.1
	Jul 29						1.0

[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 (m²)	School size (m²)			Survey time (hr)
				Mean	SD	Median	
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*	239	0.9
	Jul 13	61	77202	1746	6014*	299	1.5
	Jul 15	54	32321	621	803*	239	1.5
	Jul 21	26	23598	908	1536*	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	8					1.2
	Jul 13	19	126070	6635	12020	3282	1.0
	Jul 21	31	41566	1341	1981	536	1.7

* 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 (m^2)	School size (m^2)			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					1.5
Jul 15	13	56285	4330	5147	1389	1.5
Jul 21	75	51352	685	1161	284	2.8
Jul 28						1.8

[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

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

Newfoundland

N

BAY DE VERDE

TRINITY
BAY

CONCEPTION
BAY

HARBOUR GRACE
ISLANDS

PORTUGAL
COVE

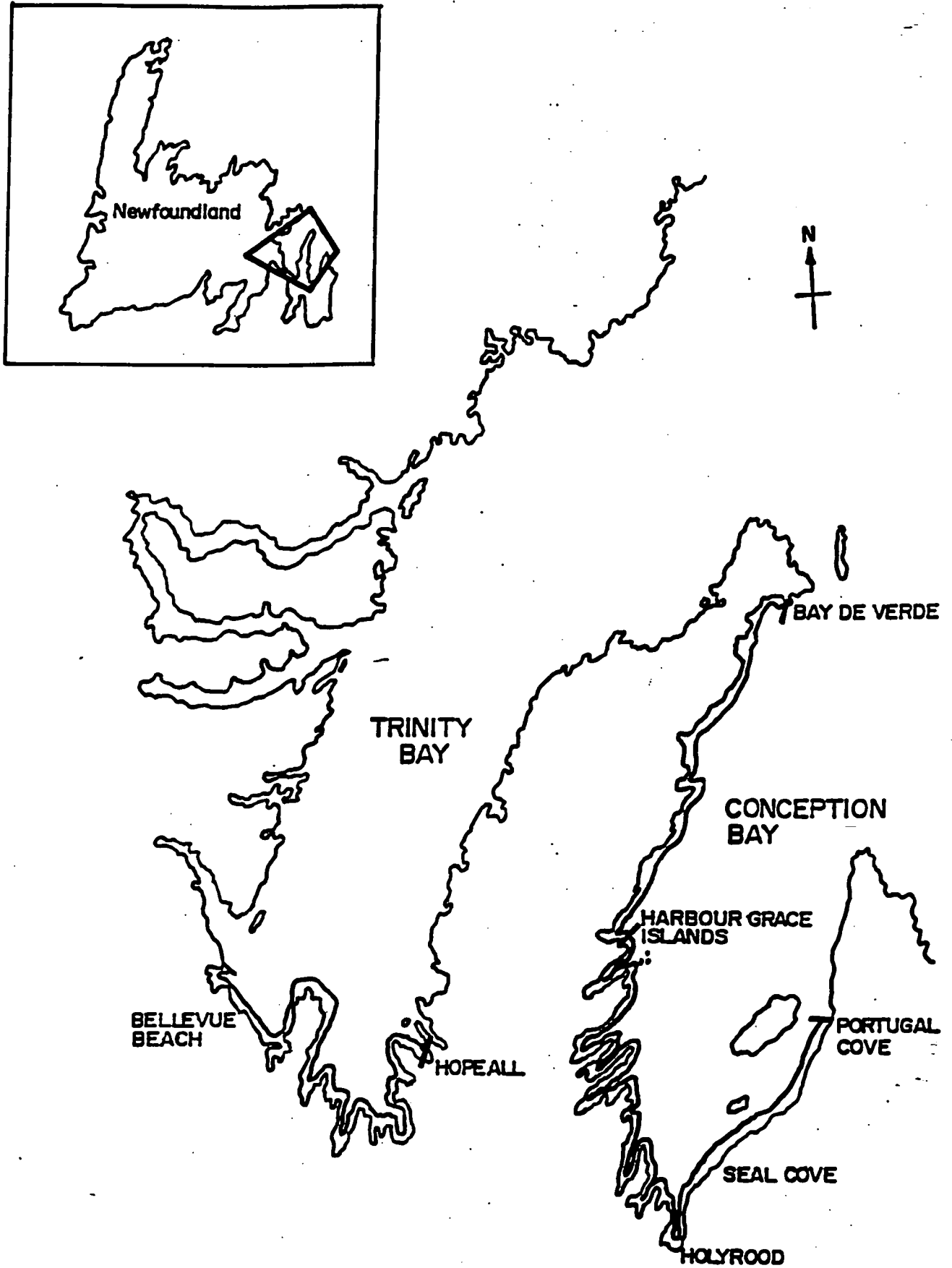BELLEVUE
BEACH

HOPEALL

SEAL COVE

HOLYROOD

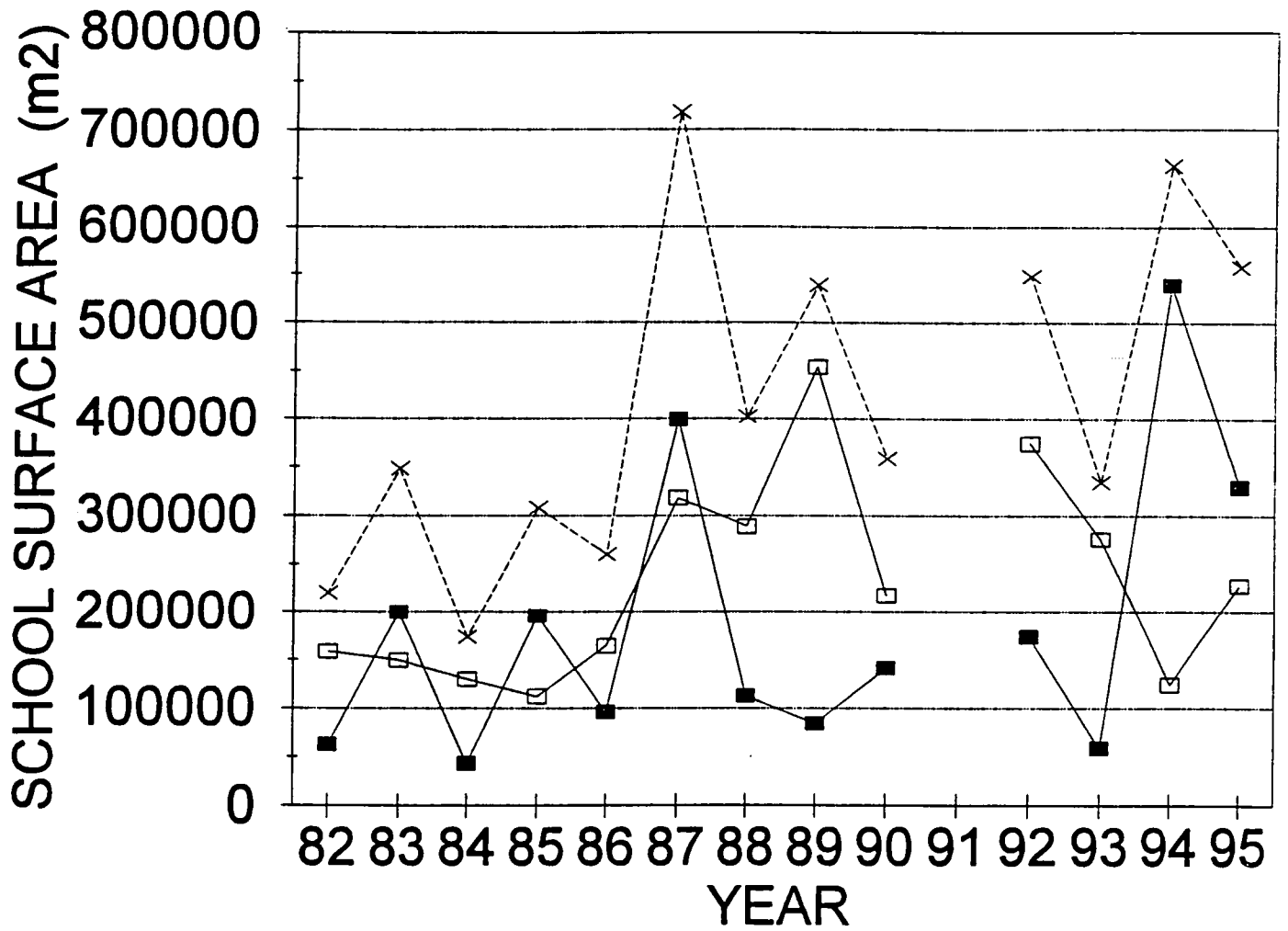Fig. 1.   Transects flown during the aerial survey.

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

Selection Rate of Two-Year-Old Capelin

by

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Introduction

Two-year-old capelin have been appearing in higher proportions in inshore commercial catches in the 1990's relative to their historical contribution to these fisheries in the 1980's. This has been particularly so since 1991 when an extended oceanographic downturn produced poor growth and delayed spawning. Research age compositions from beach-spawning studies, 0-group studies and bycatch compositions indicate that increased recruitment could account for some, but certainly not all of the increased contribution of two-year-olds to commercial catches of traps and purse seines. Analyses of seasonal changes in the mean size of mature capelin during beach spawning demonstrates that the size structure typically present has virtually disappeared during the 1990's, i.e. instead of the expected inverse relationship between size and spawning time (maturation rates of pelagic fish are size-dependent with the smaller fish maturing later) size compositions since 1991 have been mixed throughout the spawning season.

The multiplicative model used to standardize abundance indices assumes that selection-at-age (= q) remains constant for each index. Systematic changes in q will therefore appear as abundance changes unless corrections to q can be made.

Recent analyses of annual variations in spawning times of inshore capelin (Carscadden et al. 1996) show that such variations can be explained by a combination of maturation temperatures (inverse) and mean size (also inverse). Further, time-series studies of annual changes in age-specific sizes of mature capelin (Nakashima 1995) indicates that while older capelin have dramatically declined in size, two-year-olds have maintained their mean sizes. Given the analyses of Carscadden et al. (1996), it can be hypothesized that recent shifts in the spawning times of older capelin (i.e. age 3+) have been more dramatic (because they are affected by both colder temperatures and reduced sizes) than for two-year-olds (which are affected only by colder temperatures). This could account for the mixed size compositions in the spawning runs since 1991 and also for some of the increase in two-year-olds in recent commercial catches.

Methods

Age-specific catch rates (C_t) are available for purse seines and traps from Nakashima (1995) and Winters (1994). Catch rates of two-year-olds will be compared for two time periods representing the normal (1982-96) and anomalous (1991 onwards).

The relative selection of a particular age group is merely the ratio of occurrence to its population index (in this case $q = C_t/N_t$). Estimates of C_t are available from the aforementioned sources. A population index of two-year-olds can be estimated for each period as follows:

$$N^1_2 = N_3/S_2$$

$$= C_3/PM_3/S_2$$

where N^1_2 = retrospective population index of two-year-olds

N_3 = population index of three-year-olds (i.e. age 3 catch-rate)

PN_3 = maturation rate of three-year-olds (from Shackell et al. 1993)

S_2 = survival rate of two-year-olds (= 0.40 from Shackell et al. 1993 - both sexes combined)

If it can be assumed that the mean maturation rate has remained unchanged across the two time periods and if the selection of three-year-olds has remained unchanged then the relative selection rate of two-year-olds can be estimated for each period as follows (common cohorts):

$$q = C_2/N^1_2$$

For the aerial survey index similar calculations were carried out. In this case the change in q of two-year-olds would be expected since the 1982-90 indices were broken down using the Trinity Bay-Conception Bay commercial age compositions whereas research samples collected in Trinity Bay-Conception Bay throughout the beach-spawning period were used for the 1991-95 aerial indices. These research samples would be expected to include a more representative contribution of two-year-olds than the commercial fishery which traditionally selects for larger females.

Results and Conclusions

The results of the selectivity analyses are provided in Tables 1-3. They show that under the assumptions made two-year-olds were being selected in the 1990's at approximately 2.5 times the level during the 1980's for both purse seine and traps. For the aerial survey the difference in q was somewhat less (q = 1.60).

These results, at least in direction, are consistent with expectations and observations from the commercial fisheries re the increased market tolerance for smaller capelin caused by reduced growth and lack of size structure in the spawning runs.

An approximate downward adjustment of 2.5 is necessary to bring the 1991-93 index of two-year-olds for traps and purse seines in line with the historical selection pattern. For the aerial index a reduction of 1.60 should reduce the two-year-olds in research samples to the commercial equivalent in the 1980s. This adjustment should continue until such a time as market tolerance/size structure return to normal. For the aerial survey index, use of research age composition can continue with periodic reviews until the commercial fisheries return to normal.

For comparison purposes, the multiplicative model has been rerun with the above adjustments. In Figure 1, the adjusted indices are compared with the multiplicative model run with age 3+ only.

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Table 1.   Calculation of change in the trap selection rate of two-year-old capelin during the 1990's.   See text for details and assumptions.

Age	Period	Σ catch rates	% mature	Age 3 index (N_3)	Estimated population index (N^1_2)	Gear selectivity (PR)
2	1982-89	942			64,113	0.0147
3	1983-90	15,592	60.8	25,645		
2	1991-92	1,453			39,795	0.0365
3	1992-93	9,678	60.8	15,918		
			Δ PR	2.48		

Table 2. Calculation of change in the purse seine selection rate of two-year-old capelin during the 1990's. See text for details and assumptions.

Age	Period	Σ catch rates	% mature	Age 3 index (N_3)	Estimated population index (N^1_2)	Gear selectivity (PR)
2	1982-89	145			10,765	0.0135
3	1983-90	2,618	60.8	4,306		
2	1991-92	198			5,633	0.0352
3	1992-93	1,370	60.8	2,253		
				Δ PR 2.60		

Table 3.   Calculation of change in the aerial survey selection rate of two-year-old capelin during the 1990's. See text for details and assumptions.

Age	Period	Σ catch rates	% mature	Age 3 index (N_3)	Estimated population index (N'_2)	Gear selectivity (PR)
2	1982-89	564			19,848	0.0284
3	1983-90	4,827	60.8	7,939		
2	1992-93	757			16,575	0.0457
3	1993-94	4,031	60.8	6,630		
				Δ PR 1.61		
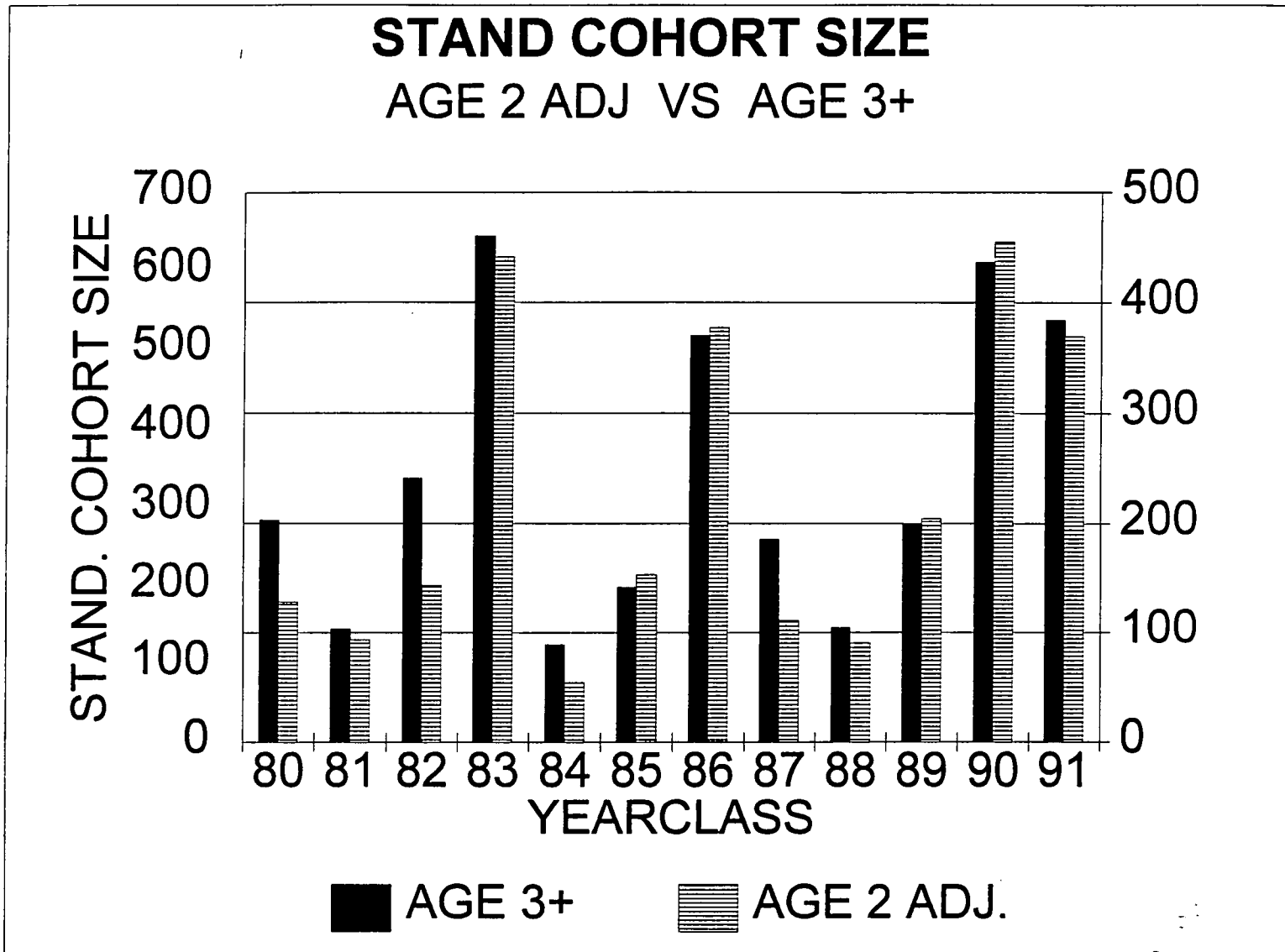
Fig. 1. Comparison of cohort estimates by the multiplicative model using the adjusted age 2 index and using age-groups 3+.

Further Estimates of Survival Schedules of Capelin

by

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Introduction

The 1995 assessment of capelin referenced two sources of age-specific survival schedules used to project stock abundance levels. One source estimated age-specific survival rates from the 2J3K Soviet fall acoustic survey based on the log ratio of geometric mean abundance from age t to age t+1 (sexes and maturities combined). In this analysis no attempt was made to evaluate the validity/integrity of the data source. The second method (reported in Shackell et al. 1994a) utilized a simple statistical technique adapted from Shelton et al. (1993) who applied it to the 3L acoustic survey of Canada. In this approach separate analyses of age-specific survival rates were performed by sex and maturity (i.e. immatures versus matures) after analyzing the underlying data series (i.e. 3L (Can.) acoustic survey) and rationalizing data exclusions (Shackell et al. 1994b). The estimates of survival from the aforementioned sources were different for particular age groups and, for the 3L data series, could be significantly influenced by the exclusion/inclusion of single, influential data points because of the short time series (8 years).

There are other sources from which age specific survival schedules can be derived and these are analyzed below both for comparison with published estimates and to provide (through an expanded data set) improved error structure.

Approach

Abundance-at-age data are available from a variety of sources (see the 1995 assessment document). From these the following selections have been rationalized: (a) the Russian 3L acoustic survey. This time series provides a direct comparison with estimates of immature survival of Shelton et al. (1993) and Shackell et al. (1994a) from the 3L Canadian survey conducted at the same time; (b) the 3 traditional inshore indices (purse seine, trap, and aerial) which form part of the annual assessment and whose components (i.e. all mature fish) are known.

Rejected as unsuitable for survival analyses were the
(a) 2J3KL by-catch series (disjointed, short series, variable
contribution of immatures and matures depending on year);
(b) Russian 2J3K fall acoustic survey (it lacks year-class
coherence with inshore and also 2J3K offshore indices); (c) 2J3K
Canadian acoustic series (biased by distributional changes (see
Winters 1995)); (d) 2J3K Russian CPUE data (these could be included
but no knowledge as to annual composition (matures versus
immatures) or gear selection); (e) 3L spring by-catch (time series
is too short if post 1990 data are rejected using the same
rationale as for 3L acoustics (Shackell et al. 1994b)).

For the 3L acoustic surveys, I have taken the same regression
approach used by Shackell et al. (1994a) viz.:

$$N_{t+1} = N_t S_t \qquad\qquad\qquad (1)$$

In these analyses all sexes as well as immatures and matures
have been combined on the assumption that the time series mean is
perhaps a more robust estimate of the annual mean than the actual
value itself. This reflects the reality of the stock projection
process since, at present, the sex and maturity composition
(immatures and matures) cannot be predicted and therefore the long-
term mean is assumed.

Consistent with Shackell et al. (1994a) only the years 1982-90
have been included in the regression analyses.

For the inshore indices, which exploit only mature fish,
estimates of age-specific maturity rates are required in order to
adjust the mature components to their population equivalents.
These maturation rate data are available from Shackell et al.
(1994a) for 1982-90 and have been combined for both sexes
(weighted). Age-group 2 was excluded from the inshore indices
because they are not fully exploited by the commercial gears and
would therefore underestimate mortality levels. It is assumed that
age 4 and older capelin are 100% mature consistent with Shackell et
al. (1994a). Survival rates of three-year-old capelin were
therefore calculated from the inshore indices as follows:

$$N_{t+1} = N_t/PM \bullet S_t$$

where PM = per mature.

Equation (1) was used for four- and five-year-olds in the
inshore indices.

Results

Age 2 Survival

There are only two sources for estimation of age 2 survival, viz. the 3L acoustics surveys of Canada and Russia. It is assumed that all age 2 capelin are 100% immature (Shackell et al. 1994a) and therefore age 2 survival is an estimate of the survival rates of immature capelin.

The estimates for each time series is shown in Figures 1a and 1b. The Russian estimates is nominally higher than the Canadian estimate (already reported in Shackell et al. 1994a) but the standard errors are sufficiently large (R2 = 0.49 ± 0.13 versus C2 = 0.40 ± 0.06) that the differences are not statistically different. Note that for both surveys (and particularly so for the Russian survey) the relationship between age 2 abundance and age 3 abundance is non-linear. For the Russian data, the 1985 data point (i.e. 1985-86) can justifiably be considered as an underestimate at age 3 because the 1986 survey occurred in June when a greater proportion of the mature capelin would be expected to be inshore and therefore outside the survey area. Nevertheless, its exclusion would not change the non-linear nature of the relationship in Figure 1a.

In order to combined the two data sources into a single plot, it is first necessary to normalize each source to its overall mean; this will remove inter-series differences in population estimation rates. The combined data are shown in Figure 2 (C5 = Canada 1985-86 etc.). The non-linearity of the relationship is quite clear implying that the survival of two-year-olds is density-dependent. Is this the only interpretation? Other possibilities might include (1) non-random mixing of immature and mature fish in the survey area (see Shackell et al. 1994b) resulting in a disproportionate trawl sampling of the slower swimming immatures when yearclasses are large and segregated (note the large differences in the strength of the 1987 yearclass at age 2 between Russia and Canada but their consistency at age 3); (2) large yearclasses of immature capelin have a wider distribution than weak yearclasses; or (3) fortuitously is related to environmental factors (see Shackell et al. 1994b).

It is difficult to test the above alternatives but if age 2 survival is density-dependent then, for the same yearclasses (1980-87), you would expect to see the same non-linear relationship between age 2 and age 3+ abundance indices in the inshore data. In Figure 3 I have plotted the multiplicative cohort model estimates for age 2 (purse seine, traps, and aerial) against the same yearclasses estimated by the multiplicative cohort model at age 3 and older (for the same 3 data sources). There is no apparent non-linearity in the inshore relationship between two-year-olds and

age 3+ as would be expected if 2-year-old mortality was density-dependent.   This provides circumstantial evidence that the assumption of proportional availability of age-groups across years may be violated in the 3L survey area.

If the validity of the relationship in Figure 2d cannot be resolved, the survival rate of two-year-olds can be estimated by fitting a non-linear relationship or using the overall mean.

Age 3 Survival

The two acoustic series are quite consistent in their estimates of age 3 survival (R3 = 0.28 ± 0.08, C3 = 0.31 ± 0.05) (Fig. 4).   Among the inshore indices, only the aerial estimate (Fig. 5a) is consistent with the offshore estimates of age 3 survival (A3 = 0.28 ± 0.09) when the influential 1986 data point is removed; otherwise A3 = 0.39 ± 0.13). Both the trap (Fig. 5b) and purse seine (Fig. 5c) estimates of age 3 survival are much higher than the offshore sources (T3 = 0.50 ± 0.05; AS3 = 0.49 ± 0.06).

For all of the inshore data combined (Fig. 6a), the mean estimate of S3 = 0.46 ± 0.05. There are however several outliers which could be removed (1A and 1P) to provide an adjusted estimate of S3 = 0.41 ± 0.03. However, this estimate is still significantly higher than the combined offshore estimate (Fig. 6b - S3 = 0.30 ± 0.05) for three-year-olds.

For all data sources combined (Fig. 7) the mean estimates of age 3 survival to S3 = 0.38 ± 0.04.   This estimate changes to S3 = 0.35 ± 0.03 when two outlier points (one A and one B) are removed.

The inshore estimates of age 3 survival are significantly higher than similar estimates from the 3L acoustic sources.   An historical estimate by Winters and Campbell (1974) for the Grand Banks (S = 0.48, both sexes combined) is very similar to the current inshore estimates. These higher values may be real or they may be the result of some sampling bias (eg. under selection of three-year-olds etc.) that cannot at present be identified. In the interim, the aggregates estimate has fairly narrow standard errors and amalgamates the best data sets.   As long as the mean age-specific maturity rates continue to be used in projections, there is no advantage (but a requirement for additional assumptions) to do separate projections for immatures and matures. Rather, the mean percent mature should be applied to the age-specific population numbers as a simpler approach to estimating mature biomass.

Age 4 Survival

These data were consistent and only the aggregated scatter plot is represented (Fig. 8). Annual survival of age 4 was estimated to be 0.20 ± 0.02. This was reduced to S = 0.16 ± 0.81 when two outliers were removed (R9 and C7). Winters and Campbell (1974) provide an estimate of 0.16 for Grand Bank capelin during the period 1967-73.

The composite estimate of $S4$ = 0.16 ± 0.1 is probably as good as can be obtained from the existing data sources.

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Winters, G. H. and J. S. Campbell. 1974. Some biological aspects and population parameters of Grand Bank capelin. ICNAF Res. Doc. 74/76.
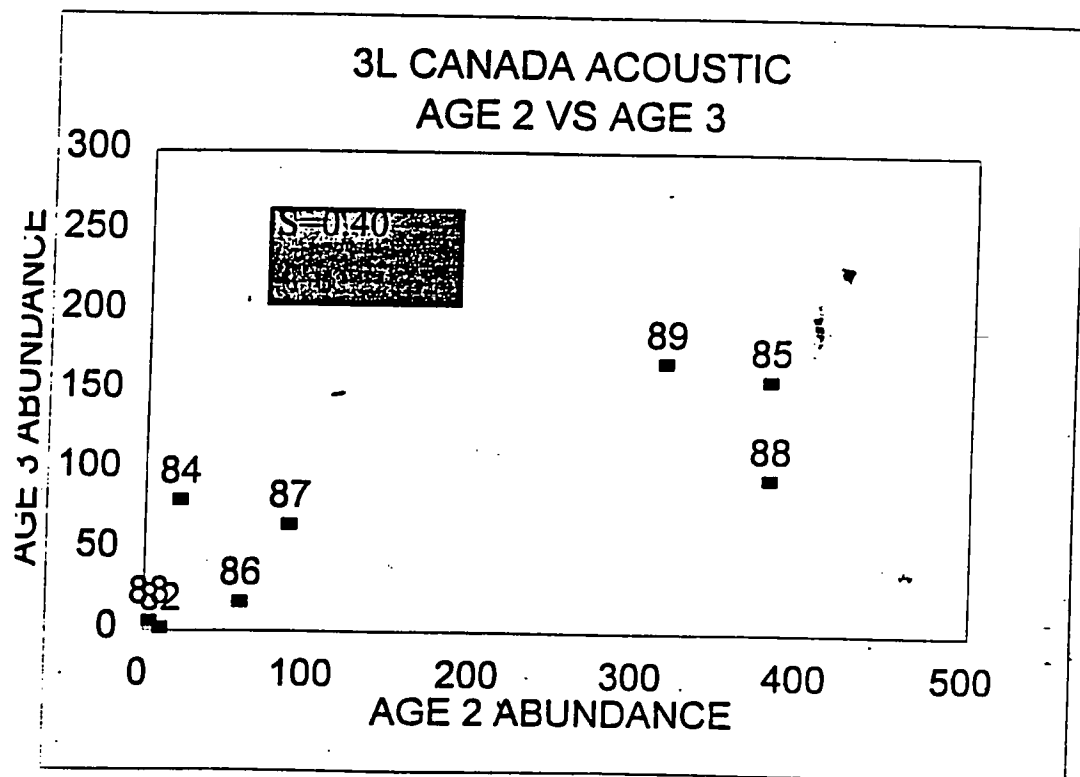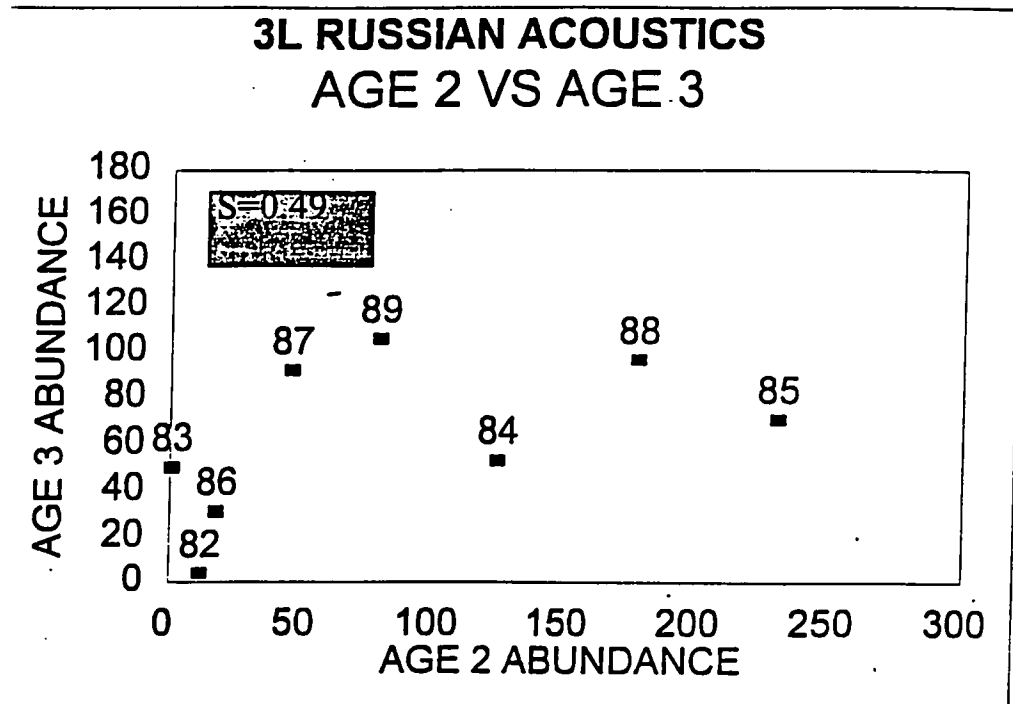
Fig. 1. Relationship between age 2 abundance and age 3 abundance for the Russian (top panel) and Canadian (lower panel) 3L acoustic surveys, 1982-90.
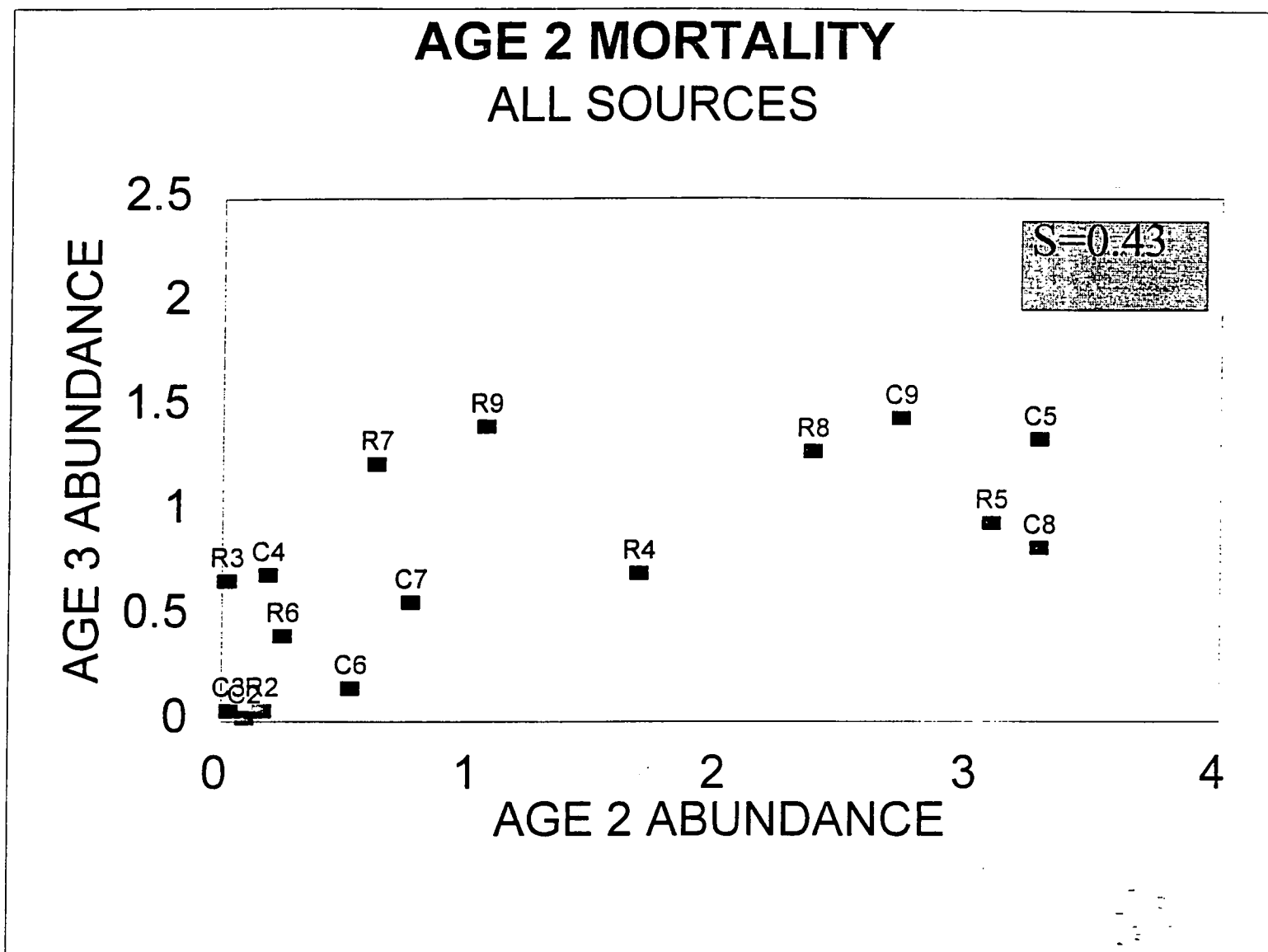
AGE 2 MORTALITY
ALL SOURCES

Fig. 2.   Relationship between age 2 abundance and age 3 abundance
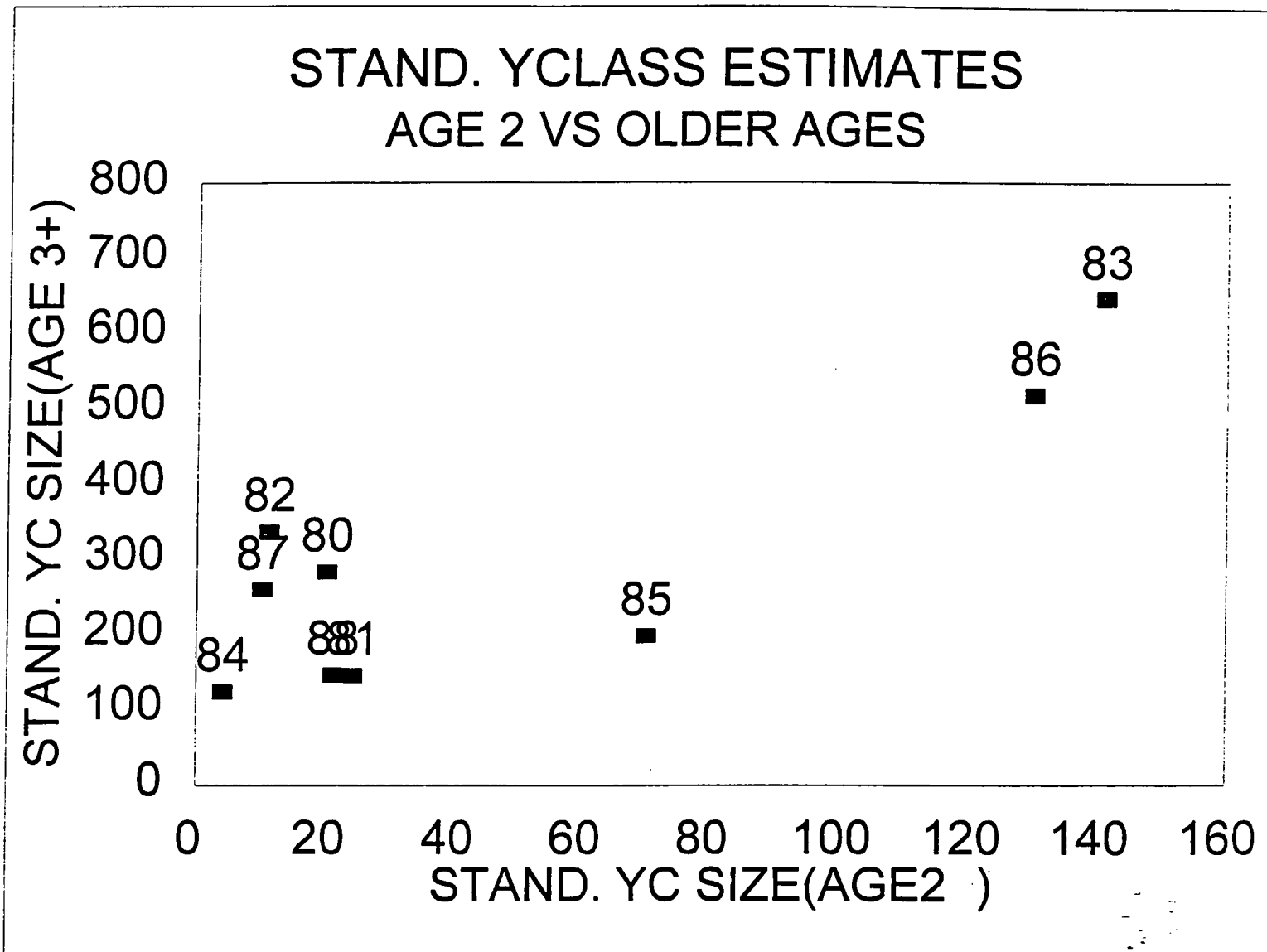for the 3L acoustic surveys of Russia and Canada (R7 = Russia,
1987, etc.).

Fig. 3. Relationship between yearclass size measured at age 2 and
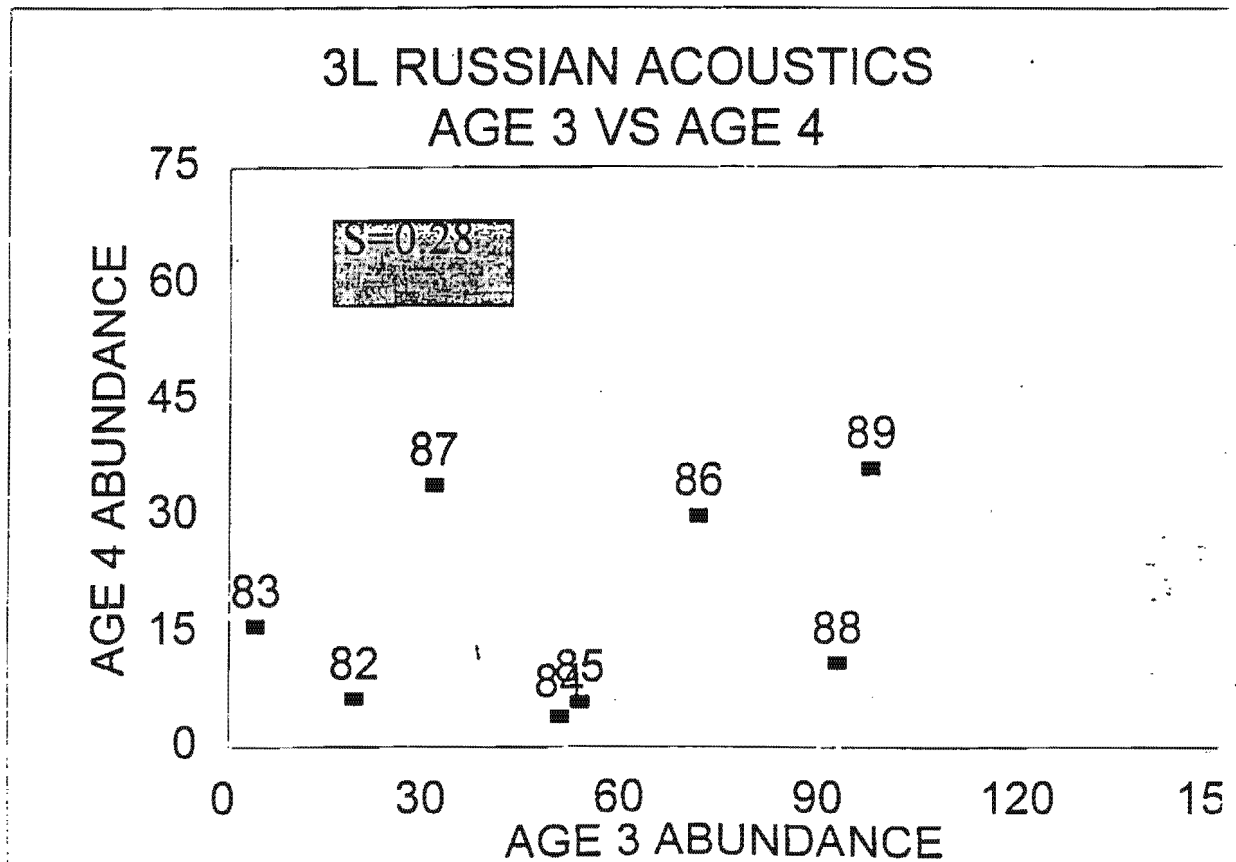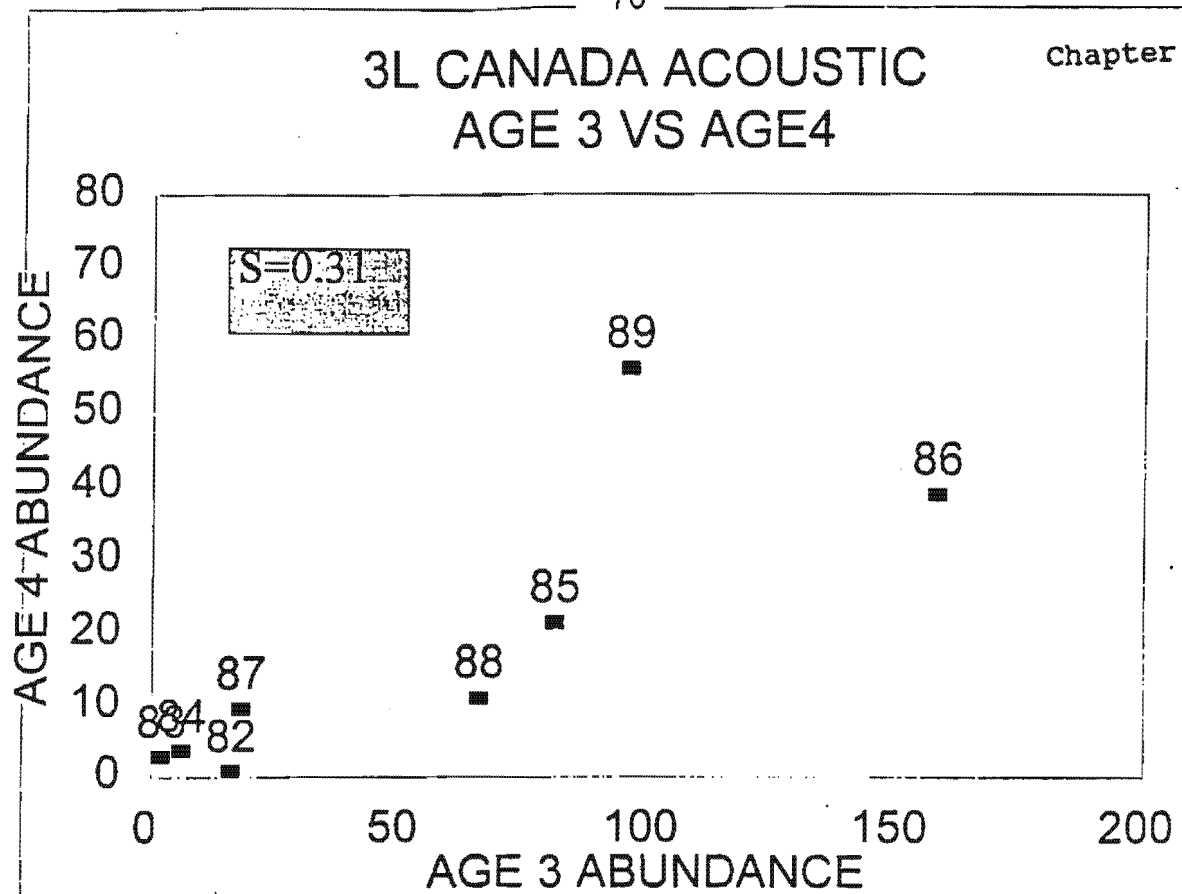the older ages (3-5) for the inshore indices (purse seines, traps,
aerial) combined.

Fig. 4. Relationship between age 3 abundance and age 4 abundance for the Canadian (top panel) and Russian (lower panel) 3L acoustic surveys.
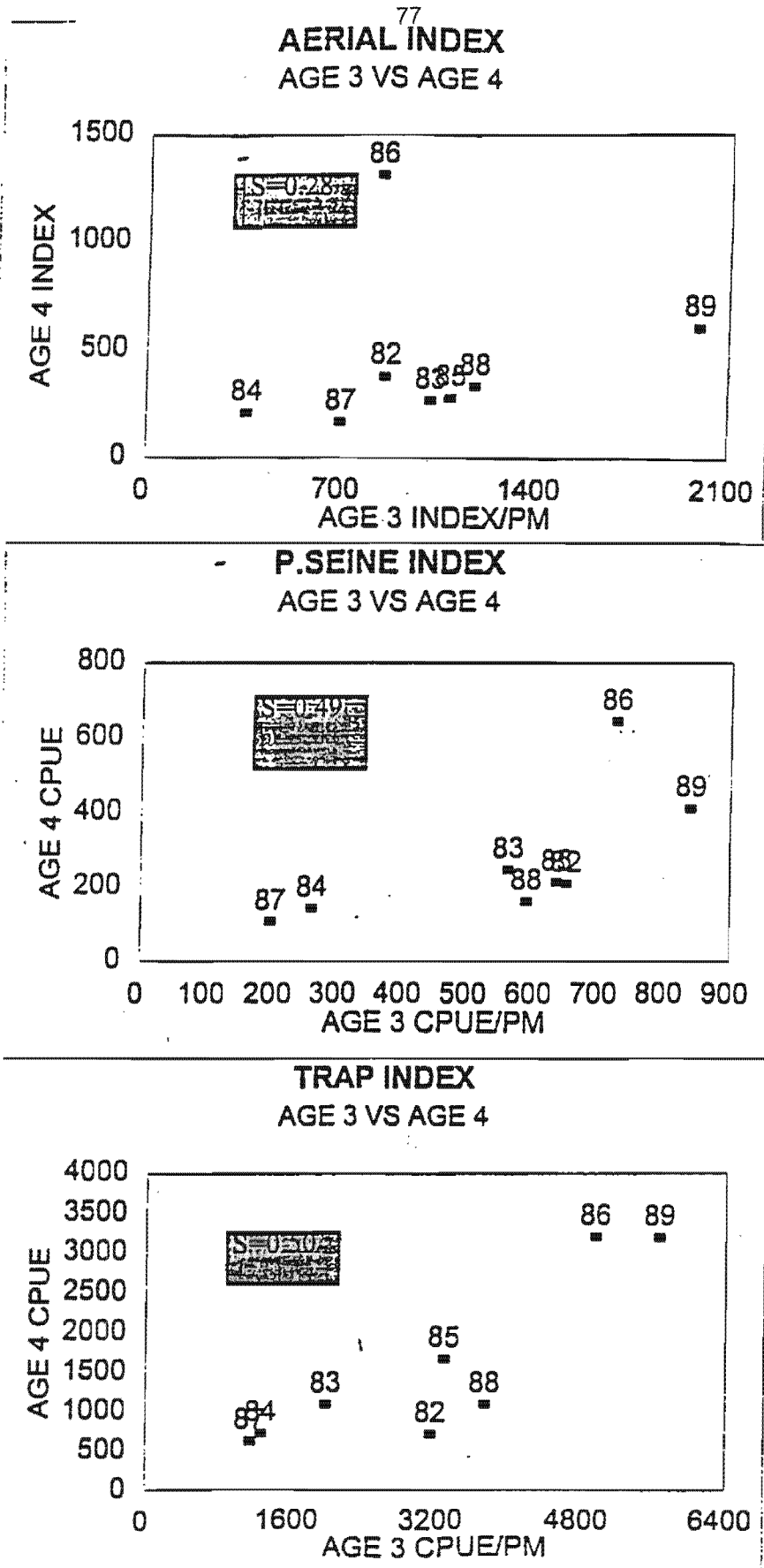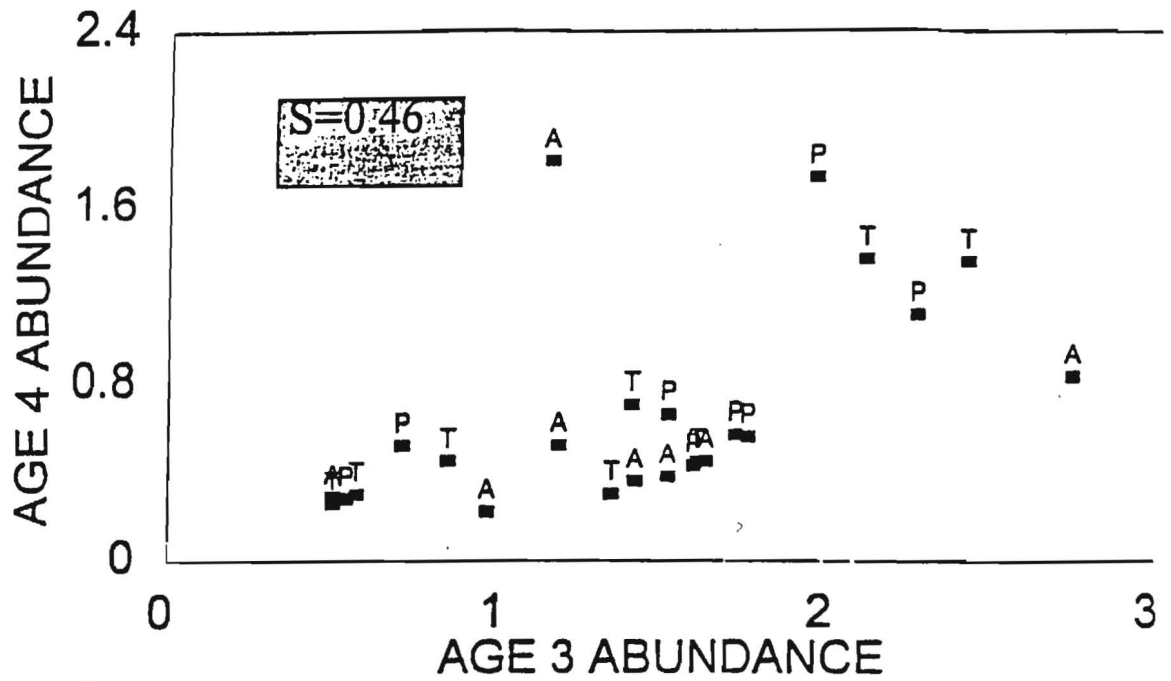
Fig. 5. Relationship between age 3 abundance (adjusted for percent mature) and age 4 abundance for the traditional inshore indices.

AGE 3 MORTALITY
ALL INSHORE SOURCES

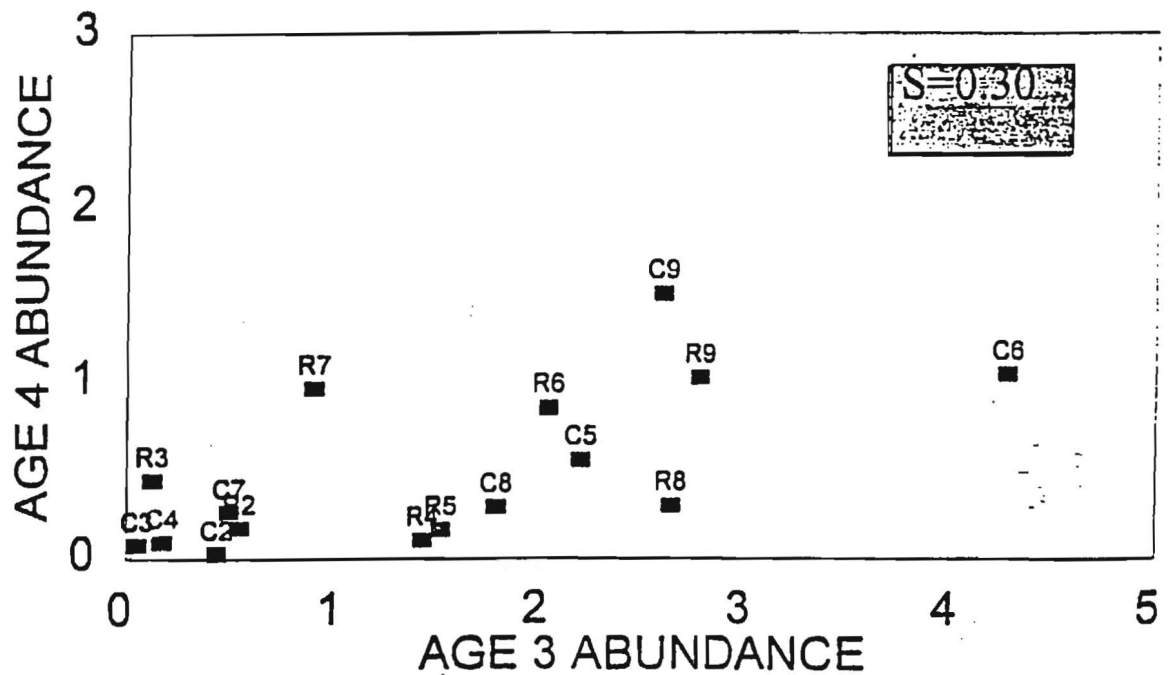# AGE 3 MORTALITY
ALL OFFSHORE SOURCES

Fig. 6. Relationship between age 3 abundance and age 4 abundance for the inshore indices (top panel) and for the offshore indices (lower panel).
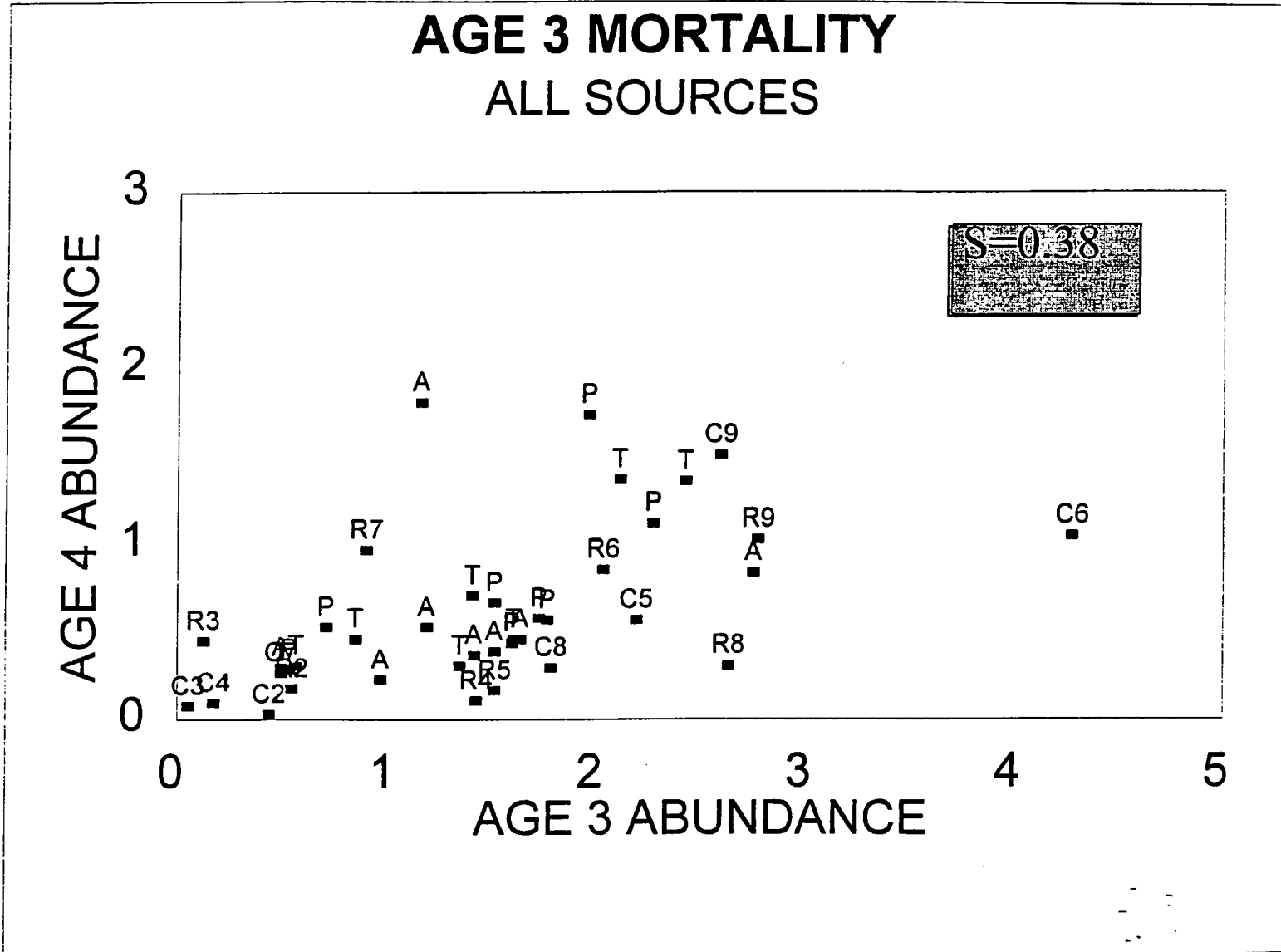
Fig. 7. Relationship between age 3 abundance and age 4 abundance for all data sources.
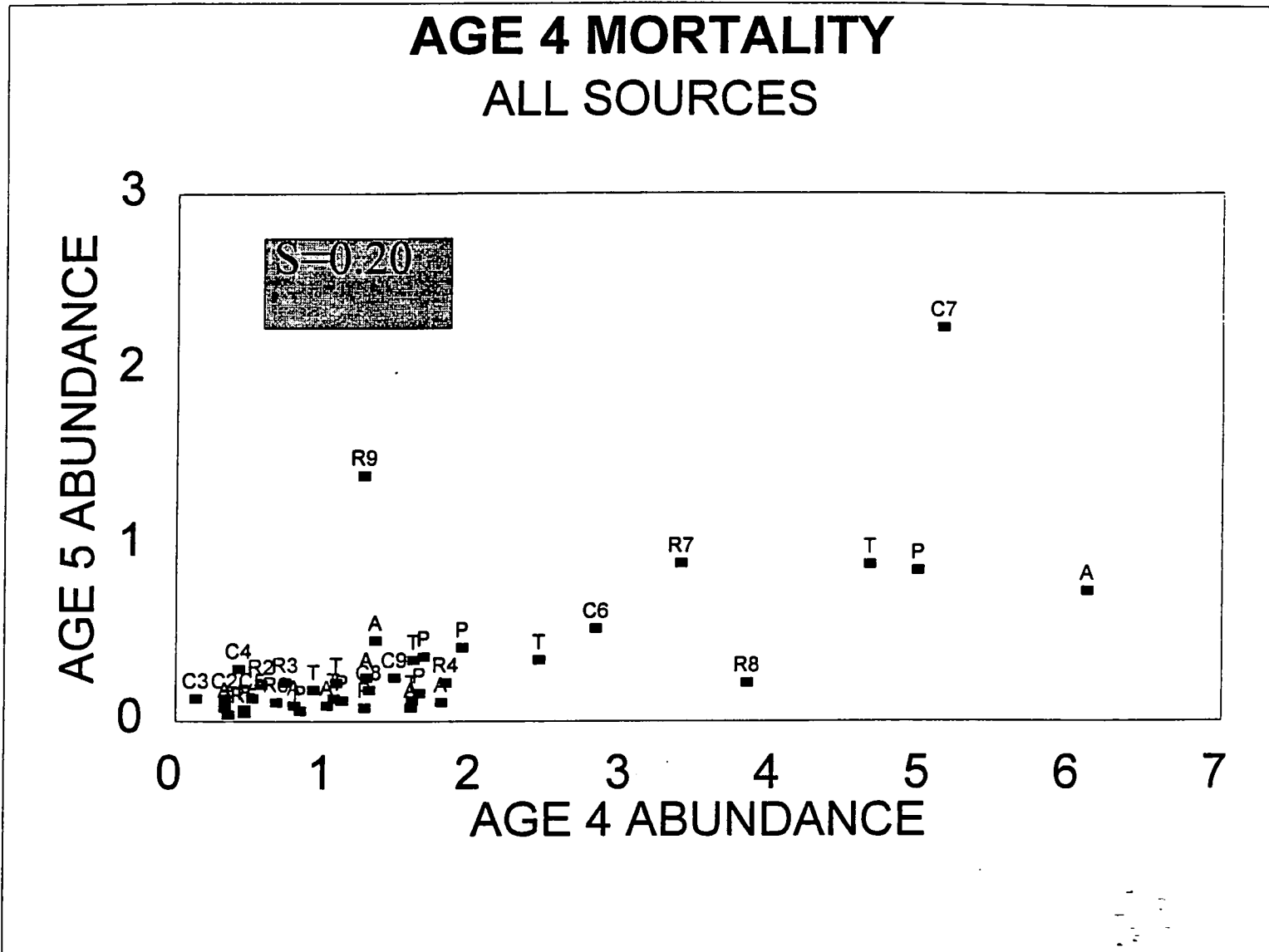
Fig. 8. Relationship between age 4 abundance and age 5 abundance for all data sources (see text for explanation).

Further Considerations of the Age-structured
Multiplicative Abundance Model

by

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Introduction

The multiplicative model provides an objective framework for analytical integration of abundance indices from a wide variety of sources (eg. see Myers et al. 1993, Shepherd and Nicholson 1991, Sinclair and Chouinard 1991). This approach is particularly attractive for efficient extraction of the yearclass effect since multiple estimates from several abundance indices can be integrated across the life-span of the species being evaluated (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). This multiplicative approach was used for the first time in the 1995 assessment of capelin. The approach taken to selecting indices to be included in the model was based on general considerations rather than an objective statistical approach. This resulted in the exclusion of some indices and some more recent indices were not included because of their short time span and/or insufficient analyses were available to justify their inclusion.

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 obvious difficulties in the interpretation of the standardized index. Since divergent indices cannot both be proportional to population abundance, one of them must be rejected as incorrect. Such incompatibility in trends can be examined for through comparisons of statistical coherence in the form of regression plots and consideration of residual patterns. This general approach will be used in the following analyses.

For each survey index, a standardized cohort estimate will be extracted from abundance-at-age data using the multiplicative model formulation below (Winters 1995):

$$\log R_{ti} = \log q_i + \log P_i + \log cohort_{t-1} + \in_{ti}$$

where R_{ti} = number of fish of age i in year t
P_i = relative survival of fish of age = i
q_i = catchability of age = i
$\in_{ti}$ = error term with constant variance

Initially the multiplicative model will be applied to the six indices which formed the basis for the 1995 assessment, viz. purse seines, traps and aerial from inshore and Russian 2J3K acoustic, Russian 2J3K CPUE and 2J3K fall bycatch indices from offshore. Amongst these, the three inshore indices, which have received consistent sampling and which directly measure the regulated biomass (i.e. mature fish) will be evaluated for coherence and then used as a standardized composite for comparison with other indices. Other indices, either rejected in the 1995 assessment or not included for other reasons, will then be tested for statistical coherence with the composite inshore index. Where possible, indices have been updated to include the 1995 estimates.

Results

I   1995 Assessment Indices

(a)   Inshore indices   (trap, purse seine, aerial)

The multiplicative model explained about 85% of the variance for each of these three indices and the main effects (cohort, age-specific survival for each index) were significant in all cases. The standardized estimates of yearclass strength for each index is shown in Figure 1 and the permutative comparisons are shown in Figure 2. For the purse seine-trap comparison (Fig. 2c), the relationship is highly significant ($R^2 = 0.74$, $P < 0.01$) with the 1991 yearclass being a slight outlier for the trap index. The trap index is also significantly correlated with the aerial ($R^2 = 0.72$, $P < 0.01$) index (Fig. 2b); again, the 1991 trap estimate is somewhat anomalous. This cohort estimate, however, is based on only a single measure (age 2 index in the 1993 trap fishery) and has therefore a large standard error. The aerial index is also very consistent with the purse seine index ($R^2 = 0.75$, $P < 0.01$) and in all three comparisons the distribution of individual yearclass estimates shows no evidence of systematic time-dependency in the residual patterns (i.e. interaction effects). That is, these three

indices are measuring integrated yearclass strengths in a consistent and coherent manner and can therefore be combined into a standardized composite (Fig. 1, lower panel) for comparison with other indices.

(b) <u>Offshore indices</u>

These include the Russian 2J3K acoustic time-series, the Russian 2J3K CPUE series, the 2J3K and 3L bycatch (%) of capelin in the fall 2J3KL groundfish survey (see Lilly 1995). In this analysis, the 2J3K and 3L bycatch rates (%) have been combined into a single index to gain advantages in larger age sample sizes and to fill in gaps in the time series (age samples are available from only one of these components in some years). The combined 2J3KL bycatch index retains its time-series relationship with the standardized inshore <u>annual</u> index (Fig. 3).

The multiplicative model estimates of yearclass strength for the 2J3KL bycatch index is significantly correlated with the composite inshore index ($R^2 = 0.35$, $P = 0.04$, Fig. 4). The 1983 yearclass appears to be overestimated in the bycatch index; its removal improves the explained variation to $R^2 = 0.64$ ($P < 0.01$). With the exception of a single yearclass, this index measures yearclass strength variations in a manner that is consistent with the inshore standard.

The relationship between yearclass strengths estimated by the multiplicative model for the 2J3K Russian catch rates and the composite inshore indices is shown in Figure 5. The relationship is not significant when all data points are included ($R^2 = 0.09$) but becomes highly significant ($R^2 = 0.76$, $P < 0.01$) when the 1976 yearclass estimate is removed. This yearclass is estimated to be very poor in the catch rate index. A perusal of the catch-at-age matrix for this index shows that age-composition changed dramatically in 1979 (towards younger ages) when the Canadian Foreign Observer Program assumed responsibility for collecting age-samples from the Russian fleet and recording empirical estimates of catch rates. This change in the nature of the reported data may have influenced the estimate of the 1976 yearclass in the CPUE time series. Nevertheless, with the exception of a single yearclass, this index is also coherent with the inshore standard.

Standardized yearclass strengths estimated from the 2J3K Russian acoustic time series are not significantly correlated with the composite inshore index for the same yearclasses (Fig. 6, $R^2 < 0.01$). There are several anomalous data points (1986, 1989, 1990, 1976) whose exclusion would have to be objectively justified before significant coherence with the inshore standard could be achieved.

The above approach demonstrates that the 2J3KL bycatch series and the Russian CPUE series are, with minor exceptions, coherent in their measures of yearclass size with inshore estimates for the same yearclasses. The Russian acoustic time series, however, show poor coherence with inshore estimates of yearclass strength. Its inclusion could create the potential for a significant underlying interaction term which is sufficient reason to exclude this data set from assessment indices until the entire series is rigorously reviewed for consistency in survey design, area surveyed, and methodological changes. A cursory review would suggest that this time series may have considerable faults.

In Figure 7, the standardized estimates of yearclass strength by the multiplicative model for the composite offshore data (CPUE and bycatch combined) are plotted for comparison with the composite inshore estimates. With the exception of the aforementioned 1976 yearclass, the two time series are quite consistent.

II   Other Offshore Indices

(a)   Acoustics

The relationship between yearclass size in the 3L Canadian acoustic survey and the standardized inshore index is shown in Figure 8a. The relationship is not significant when the entire time series (1982-92) is included ($R^2 = 0.04$). When the 1991-92 data are excluded (based on the analyses of Shackell et al. (1994)) the relationship improves (Fig. 8b) but the explained variation is still relatively low ($R^2 = 0.22$) mainly because of the anomalous 1987 and 1988 yearclasses which are extremely strong in the acoustic time series but only of moderate strength inshore.

Similar plots are shown for the Russian 3L acoustic series in Figures 9a and 9b. The Russian acoustic survey was conducted in the same month as the Canadian 3L acoustic survey (usually May but 1983 and 1986 were in June) and overlapped the Canadian area surveyed. In this case, however, excluding the 1991-93 data (again using the rationale of Shackell et al. 1994) results in the relationship with the inshore index becoming statistically significant ($R^2 = 0.53$, $P = 0.03$).

In Figure 10, standardized estimates of yearclass strength from the Canadian 2J3K fall acoustic survey are compared with the composite inshore estimates. The relationship is not statistically significant ($R^2 = 0.01$). Previous analyses (see Winters 1995) have shown this index to be responding largely to annual shifts in distribution rather than annual changes in capelin abundance.

(b)   3L Spring bycatch

Multiplicative model estimates of yearclass strength from bycatch (in %) of capelin in the spring 3L groundfish survey are compared with the composite inshore indices in Figure 11. The relationship is significant (R^2 = 0.44, P = 0.04) when all data points are included but there is an obvious time-dependence in the residual patterns with the 1989-91 yearclasses being systematically underestimated by the bycatch relative to inshore. This is consistent with the shifts in distribution of capelin in 3L implied from the analyses of Shackell et al. (1994). Excluding the post 1990 data results in the explained variation increasing to R^2 = 0.75.

III   Other Age-structured Indices

(a)   Egg deposition index

Egg deposition levels (stages I-II, integrated for each beach) have been collected since 1990 and are available from Nakashima and Winters (1996). In order to remove the community effect, each beach site has been normalized to its mean thereby allowing relative egg deposition to be averaged for each year for decomposition into age-structured matrices.

The NCSP egg deposition data have been analyzed by the multiplicative cohort model and the standardized estimates of yearclass strength are compared with the composite inshore index in Figure 12. The index is significantly correlated with the composite inshore estimates of yearclass size (R^2 = 0.71, P < 0.01).

IV   Age-by-age Comparisons of Cohort Estimates

The cohort effect has been extracted from the traditional inshore indices (purse seines, traps and aerial) for each age for ages 2-5. The permutative comparisons are shown in Figure 13. There is good correspondence between the age 2 cohort estimates and those for ages 3, 4, and 5. The weaker yearclasses (eg. 1984, 1987, 1988) however, appear to be underestimated as 2-year-olds relative to 3-year-olds. There is also good agreement between age 3 estimates and those from age 4 and age 5. The major exception appears to be the 1989 and 1991 yearclasses which are much stronger at age 3 than as age 2 or age 4.

Cohort estimates at age 4 are coherent with those at age 5 with the exception of the 1989 yearclass which is relatively stronger as 5-year-olds. Overall there is good coherence amongst the specific age groups of the inshore indices as estimators of yearclass size. Annual variability in age-specific survival

maturation rate and survey errors do not appear to be masking, in any systematic way, the ability of the multiplicative model to consistently measure yearclass size.

The foregoing analyses are for illustrative purposes and should be repeated for the final formulation of the multiplicative model.

V   Retrospective Performance of the Multiplicative Cohert Model
      (inshore indices only)

The multiplicative model was used to estimate yearclass size for each year, beginning in 1982. These standardized yearclass estimates were then projected one year ahead in identical fashion as for the 1995 assessment (see Table 2 of Winters 1995). Using year-specific (1982-90, see Shackell et al. 1994) or mean maturity schedules (1991-94) the projected mature abundance estimates were converted to an aggregate mature biomass index (as in the 1995 assessment) for comparison with the observed annual (standardized) index for the traditional inshore indices. Mean weights-at-age used are those for Div. 3L (see Nakashima 1995).

Two survival schedules were used (1) the NAFO schedule (see Carscadden et al. 1985) and (2) those of Shackell et al. (1994). They are as follows:

Age	NAFO	Survival rate (%) (Shackell et al. 1994)
2	74	40
3	45	31
4	20	20
5	n/a	n/a

The projected mature index is compared with the observed annual index in Figure 14 (NAFO) and Figure 15 (Shackell et al. 1994). The different survival schedules do not have a significant impact on the projected index since they are merely rescaling the estimated abundance in a consistent relative manner (the absolute estimates obviously are different). The projected mature indices compare favourably with the observed index except for the early 1990's and particularly 1991. This may be due to the actual survival and/or survival rates being different than those assumed, underestimation of abundance by the inshore index in 1990 (particularly the 1988 yearclass at age 2), or overestimation in 1991, sampling/age reading variability or any combination of the above.   However, a plot of age 2 yearclass abundance versus age 3 abundance (Fig. 16) indicates that the underestimation in the early

1990's is likely due to the general underestimation of yearclass strength as 2-year-olds by the inshore indices (note the large intercept) and particularly so for the 1987 and 1988 yearclasses.

The foregoing analyses are for illustrative purposes and should be repeated for the final formulation of the multiplicative model.

VI   Conclusions and Recommendations

Amongst the abundance indices considered to form the analytical basis for the 1995 assessment of capelin only the Russian 2J3K acoustic survey does not meet the statistical requirements for inclusion in the multiplicative cohort model, i.e. its lack of a cohort-invariant relationship with the other assessment indices points to internal inconsistency in the manner in which it has measured yearclass size. Its exclusion will not affect estimates of yearclasses forming part of the existing stock (1991 yearclass onwards). It is recommended that any further consideration of the Russian 2J3K acoustic survey should be preceded by a rigorous review of its internal consistency as an abundance sampling tool. Regarding the 2J3K Russian CPUE series, it should be noted that this is in fact two series. The earlier data series (1972-78) uses Russian age compositions and the catch rates are reported rather than independently observed. The more recent data (1979-91) uses Canadian age-reading/sampling and was collected by onboard observers from the FCR research program. It is recommended that these data sets be split into two series in any revised configuration of the multiplicative model.

Amongst the other indices, the egg deposition time series now has sufficient data (nine yearclasses) to merit inclusion as an additional (and current) assessment index. This is the only direct measure of current spawning escapement and provides an additional fishery-independent abundance index. The reduction in the number of sampling sites from six to two in 1995 is of concern because of the loss in precision of estimation. The adjustment of this index for annual variations in off-beach spawning is likely to be a minor issue in the longer term.

The multiplicative has been applied to the following indices (discussed above) as a basis for the 1996 assessment of capelin:

1.   aerial survey index 1982-95;
2.   purse seine catch rate index 1981-93;
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 1990-95.

The standardized annual index is shown in Figure 17 and the statistical output is given in Table 1. The standardized cohort estimates are shown in Figure 18 and the statistical output is given in Table 2.

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Table 1.   Statistical output of the multiplicative model used to estimate
standardized annual abundance.   Reference categories were year 1995 and the NCSP
egg deposition survey.

Source	DF	Sum of squares	Mean square	F-value	Pr > F
Model	27	182.75	6.71	56.04	0.0001
Error	66	7.97	0.12		
Corrected total	93	190.72			
		Root MSE	0.35		
		Dep. mean	3.98		
		C.V.	8.73		
		R-square	0.95		

Table 2. Statistical output of the multiplicative model used to estimate
standardized yearclass strengths. Reference categories were yearclass 1993
and age 5 of trap.

Source	DF	Sum of squares	Mean square	F-value	Pr > F
Model	51	896.49	17.58	27.16	0.0001
Error	250	161.81	0.65		
Corrected total	301	1058.30			

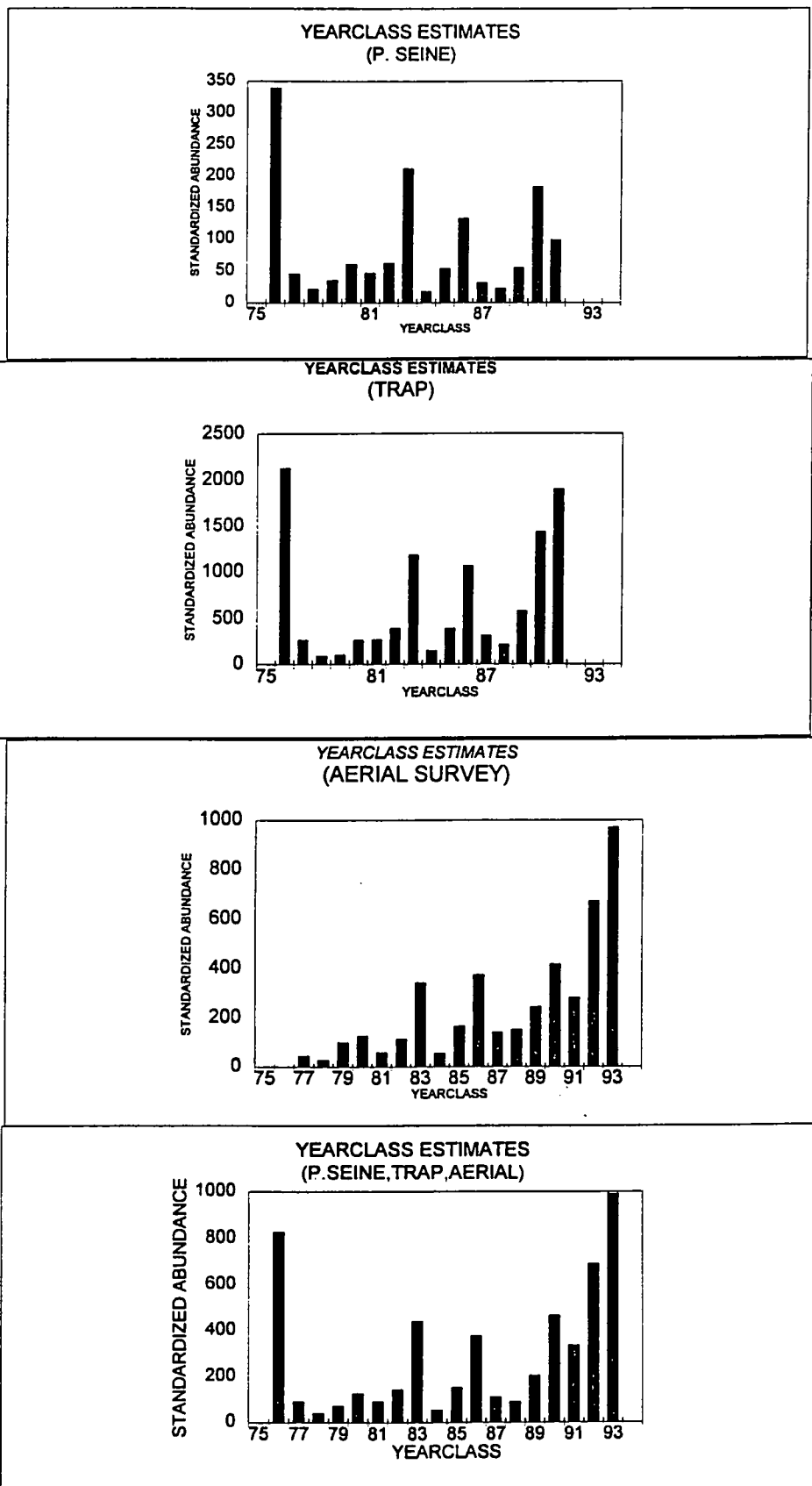|	Root MSE	0.81
	Dep. mean	4.61
	C.V.	17.35
	R-square	0.85

Fig. 1. Multiplicative model estimates of yearclass size from the traditional inshore indices (purse seiners, trap and aerial), including the composite estimates for all indices combined (lower panel).
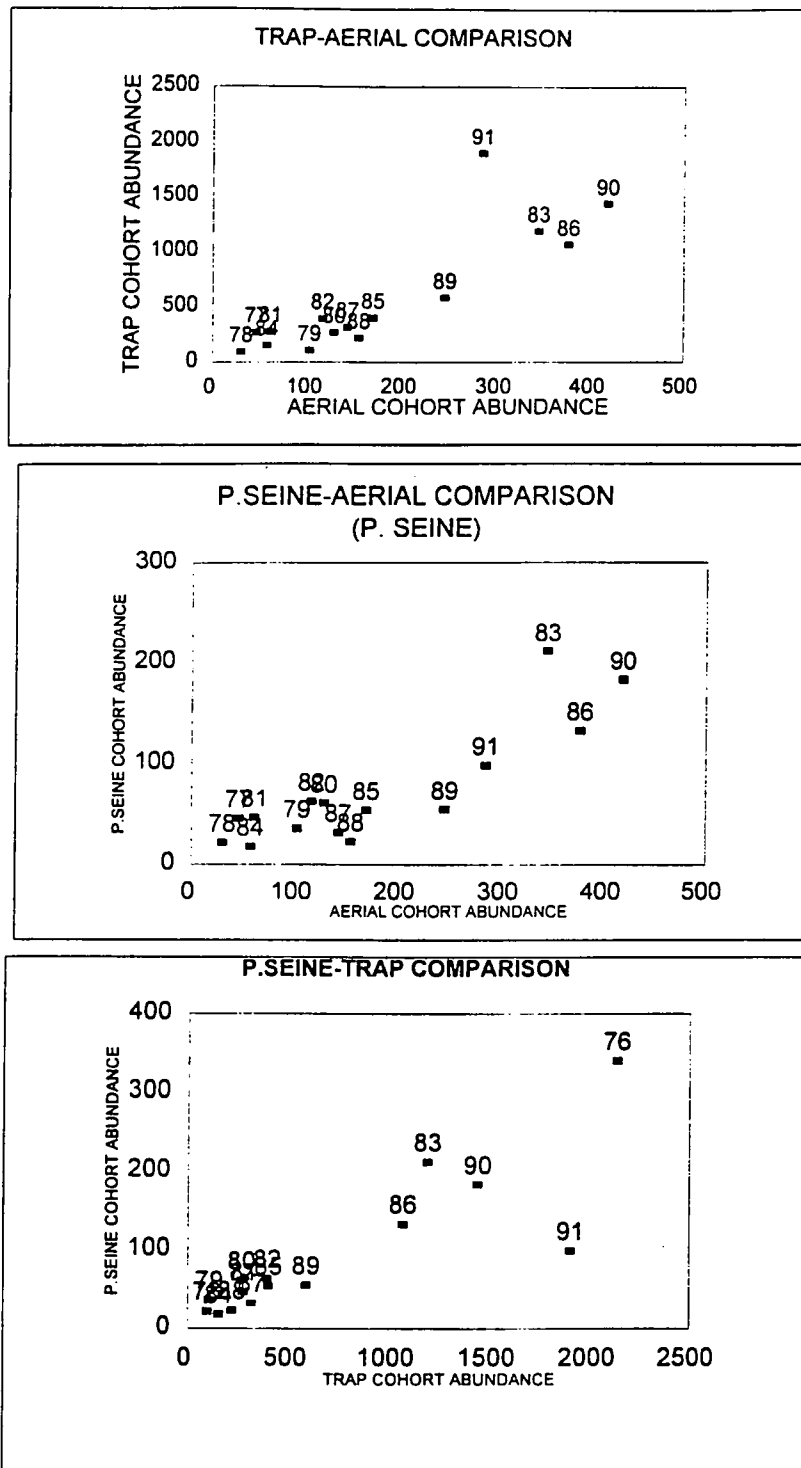
Fig. 2. Permutative comparisons of standardized estimates of yearclass strength for the traditional inshore indices.
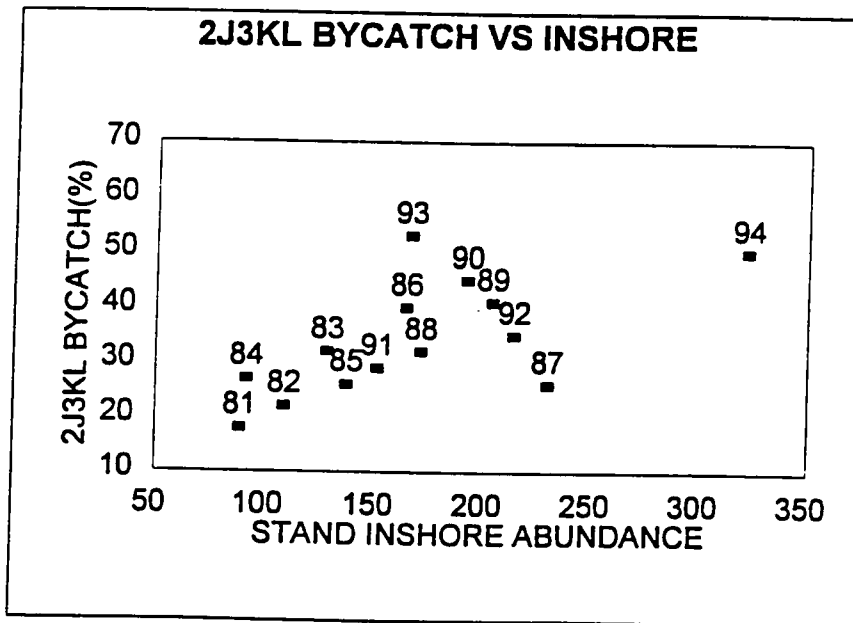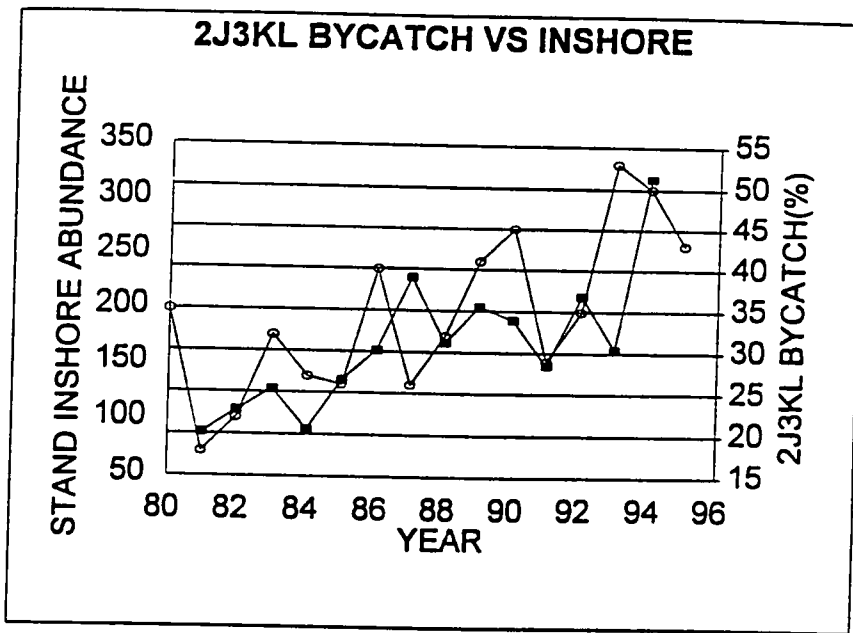
Fig. 3.   Annual bycatch success (%) of capelin in the 2J3KL fall
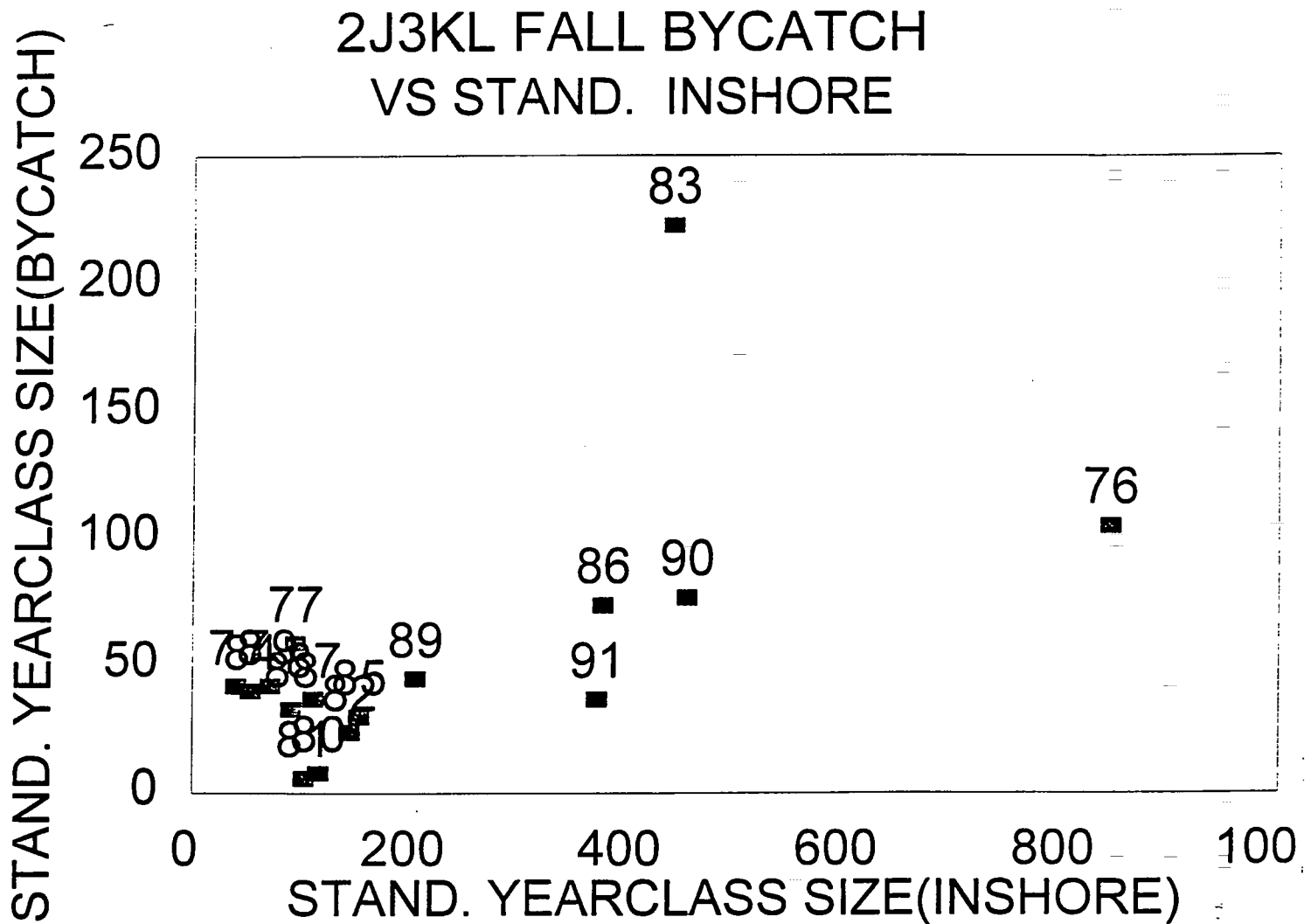groundfish survey in relation to the standardized inshore annual
index.

Fig. 4. Relationship between standardized estimates of yearclass
size in the 2J3KL fall bycatch index and the standardized inshore
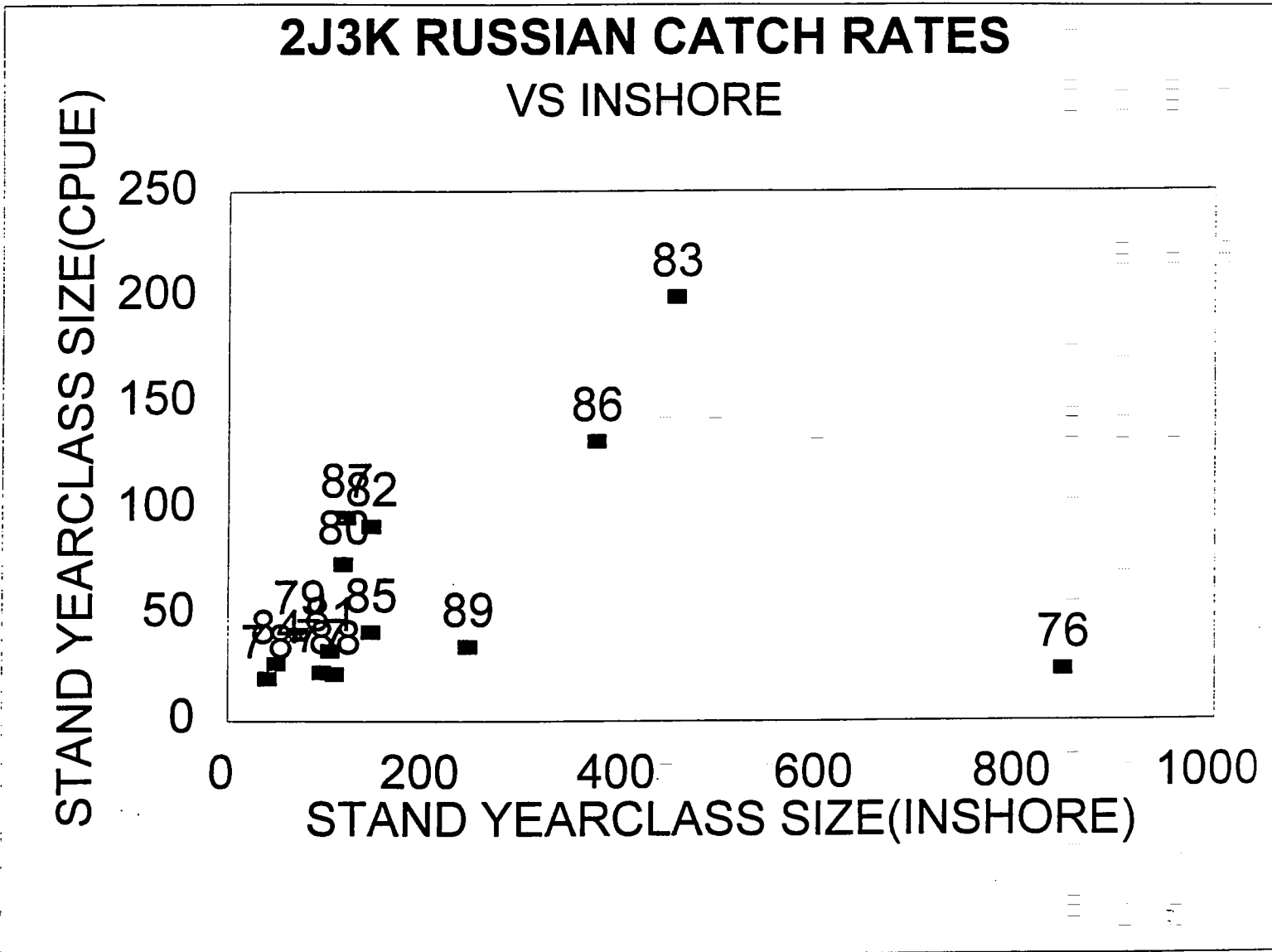estimates of the same yearclasses.

Fig. 5. Relationship between standardized estimates of yearclass size in the 2J3K Russian CPUE index and the standardized inshore estimates of the same yearclasses.

2J3K RUSSIAN ACOUSTICS
VS INSHORE

Fig. 6. Relationship between standardized estimates of yearclass
size in 2J3K Russian acoustics index and the standardized inshore
estimates of the same yearclasses.

Fig. 7. Relationship between standardized estimates of yearclass size in 2J3KL offshore index (Russian CPUE and 2J3KL fall bycatch combined) and the standardized inshore estimates of the same yearclasses.
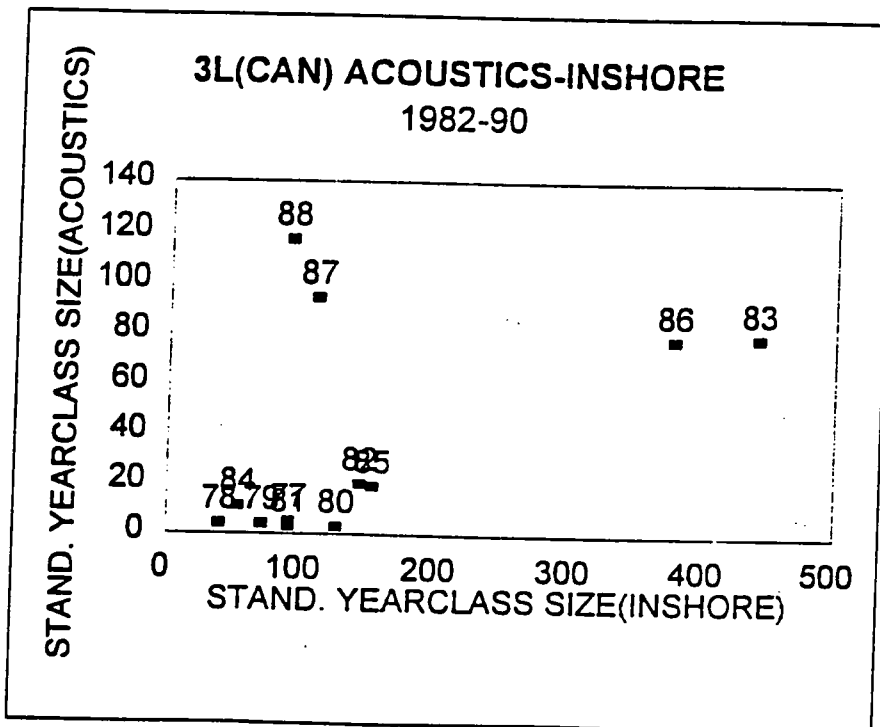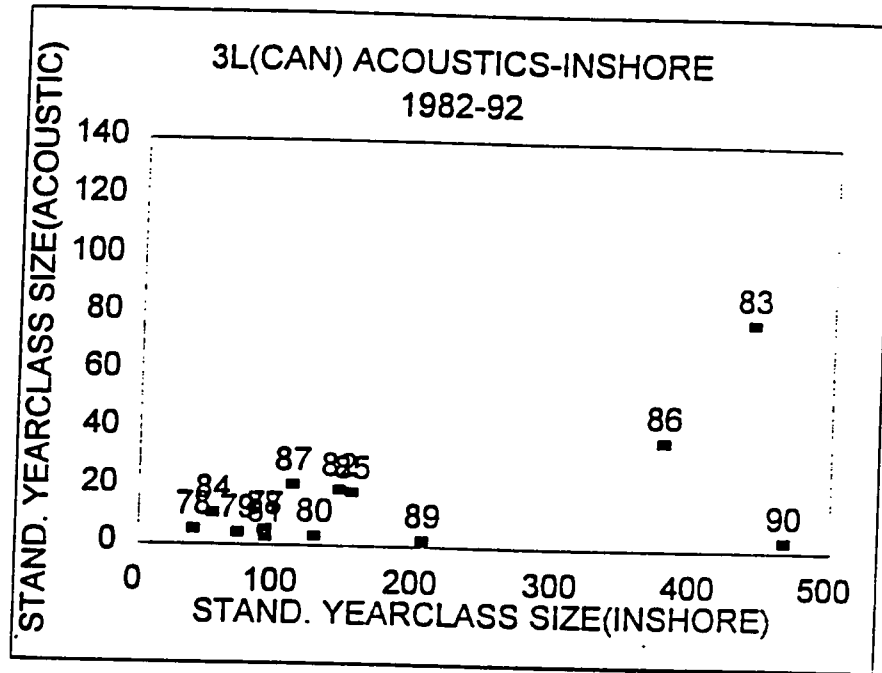
Fig. 8. Relationship between standardized estimates of yearclass size in 3L (Canada) acoustic (1982-92) and the standardized inshore estimates of the same yearclasses.
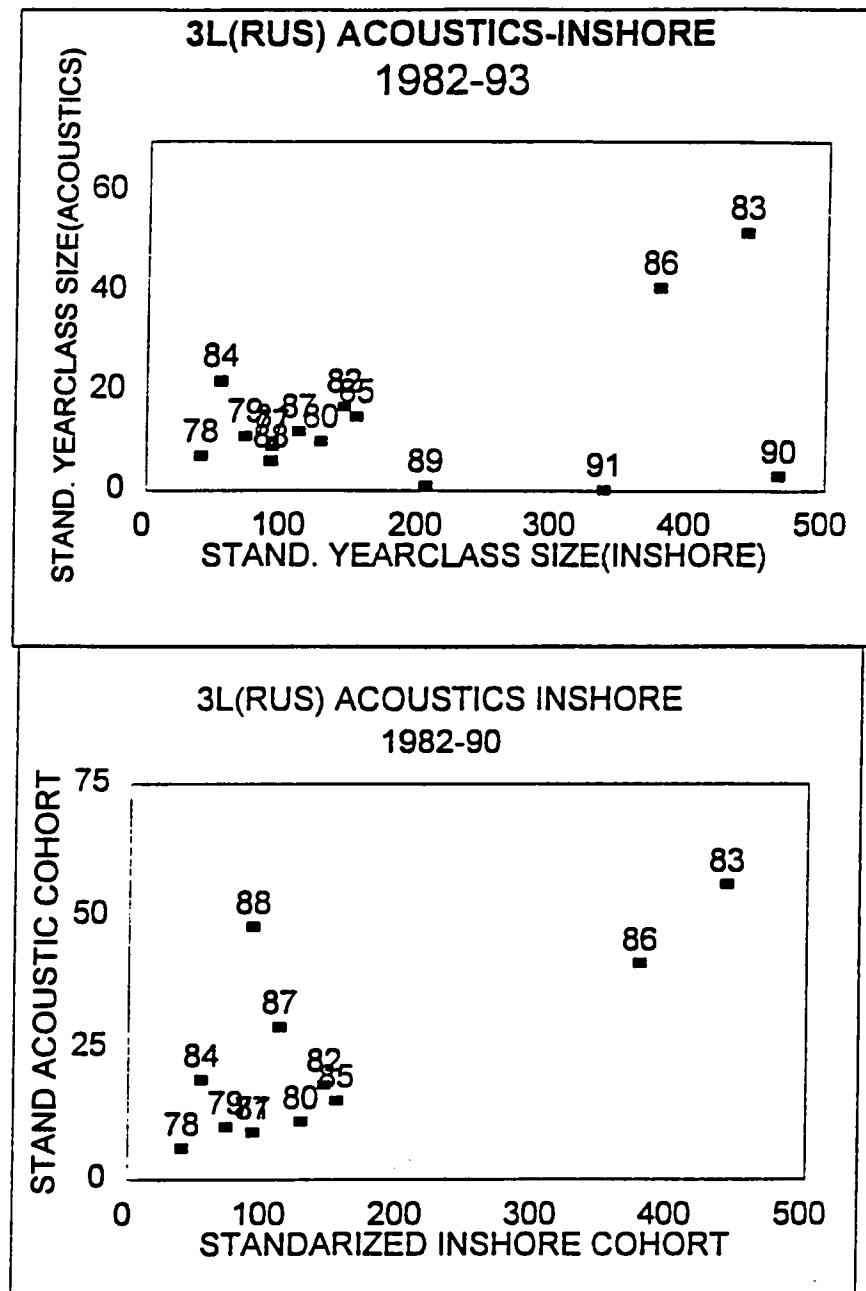
Fig. 9. Relationship between standardized estimates of yearclass size in 3L (Russian) acoustic (1982-92) and the standardized inshore estimates of the same yearclasses.
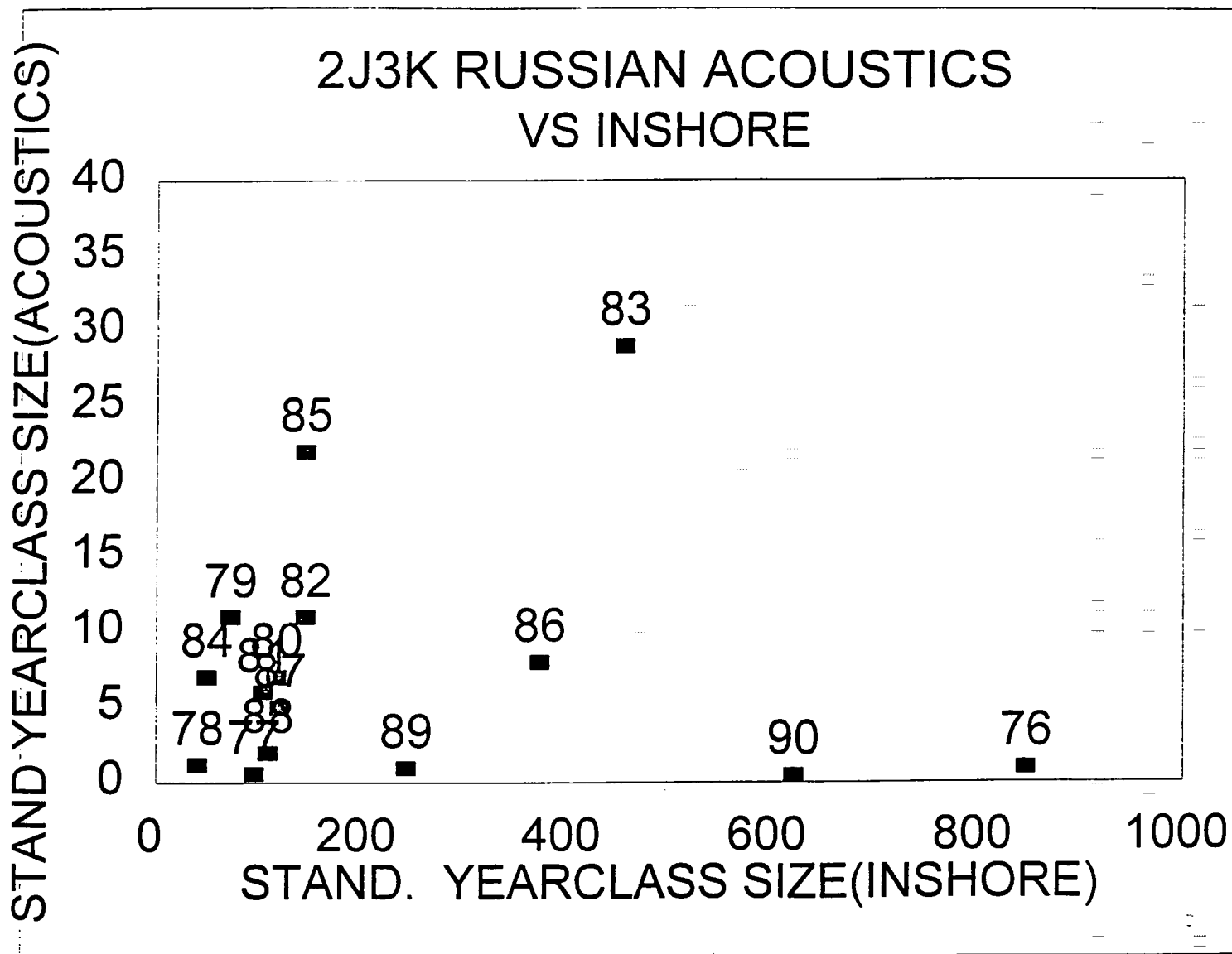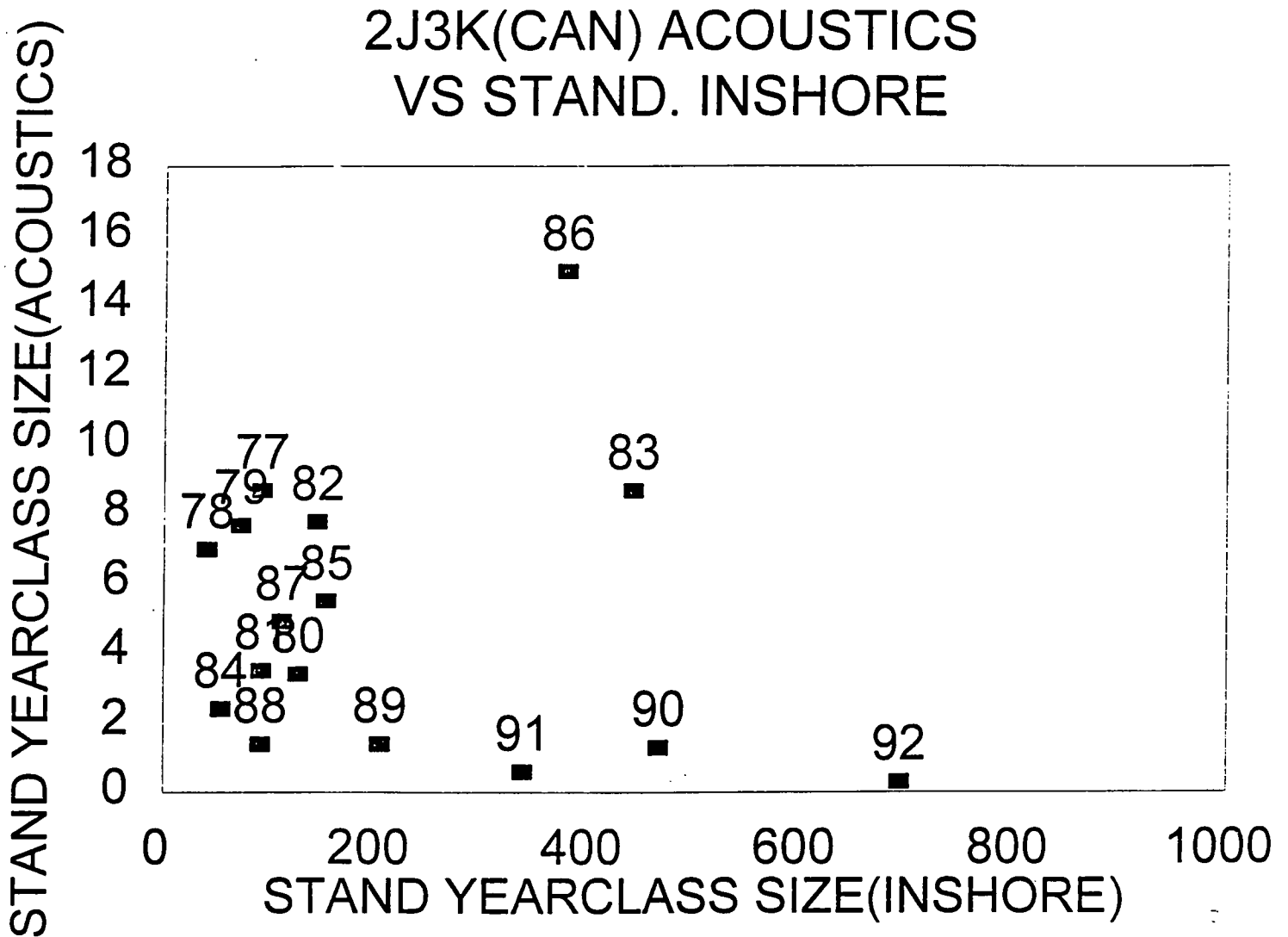
Fig. 10. Relationship between standardized estimates of yearclass
size in the 2J3K (Canada) acoustics and the standardized inshore
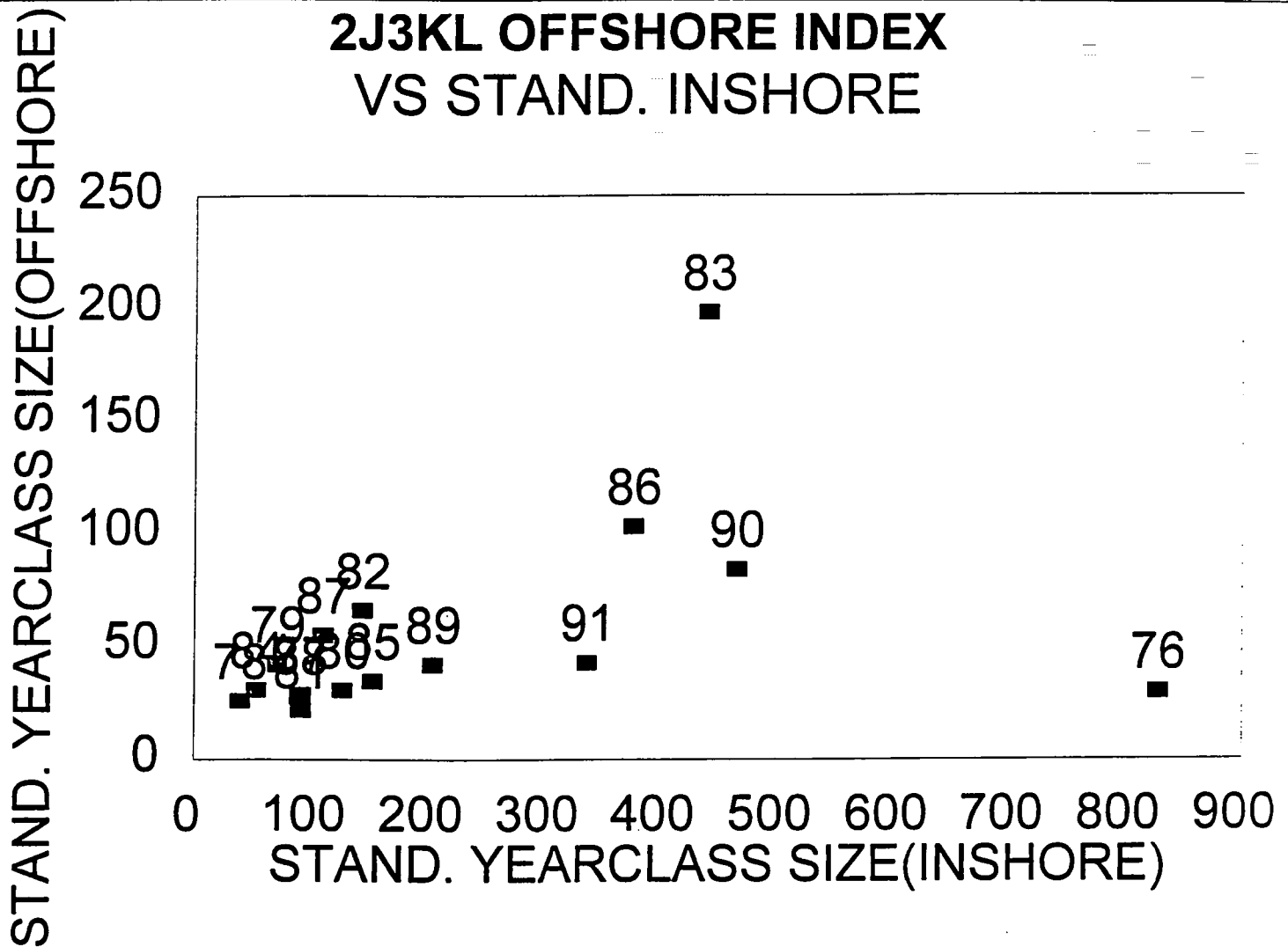estimates of the same yearclasses.
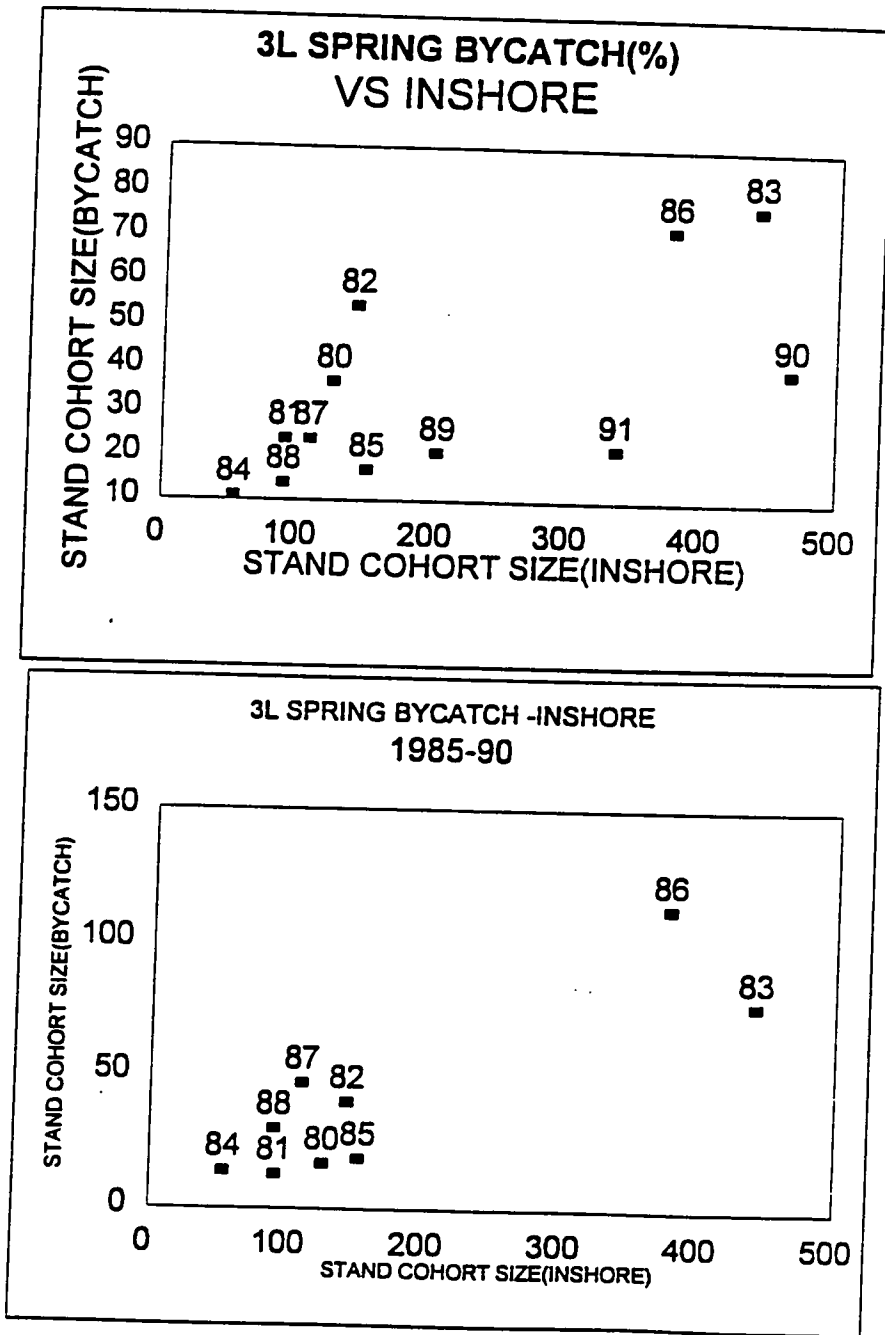
Fig. 11. Relationship between standardized estimates of yearclass size in 3L spring bycatch (%) (1982-92) and the standardized inshore estimates of the same yearclasses.

NCSP EGG DEPOSITION INDEX
VS STAND. INSHORE
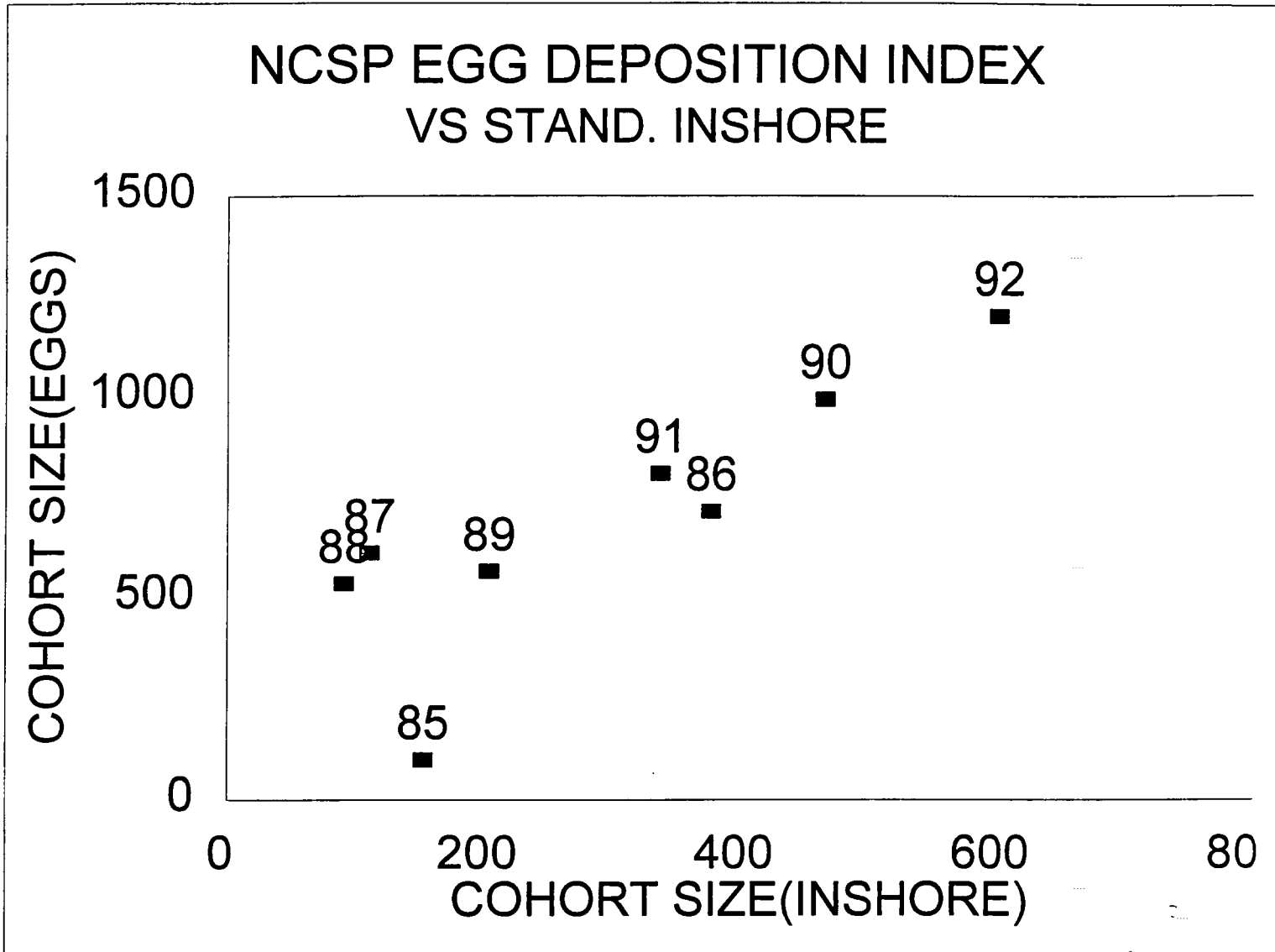
Fig. 12. Relationship between standardized estimates of yearclass size in integrated egg deposition index.
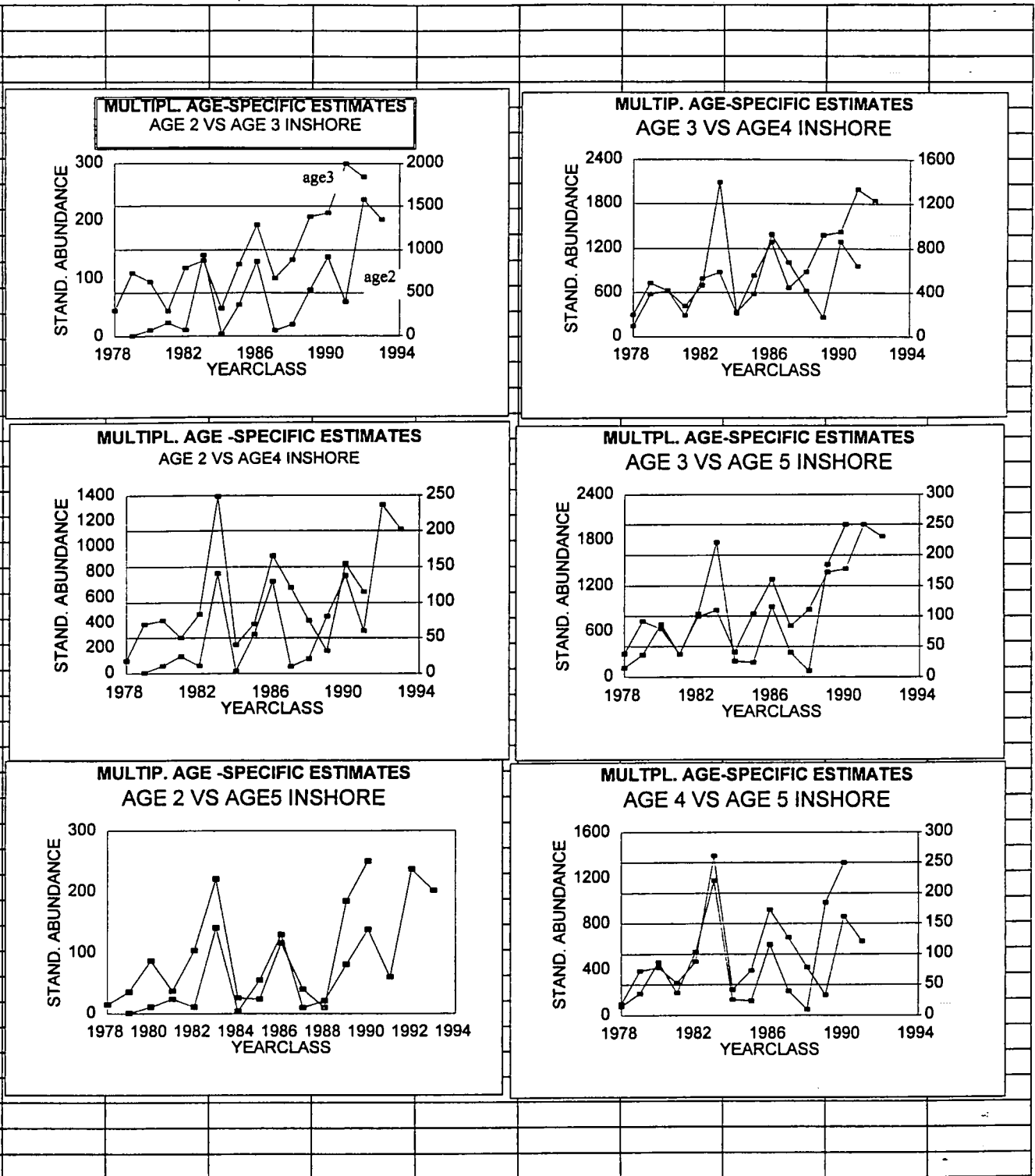
Fig. 13. Comparison of yearclass estimates from the multiplicative model applied to the various age-groups (2-5) of the inshore indices.
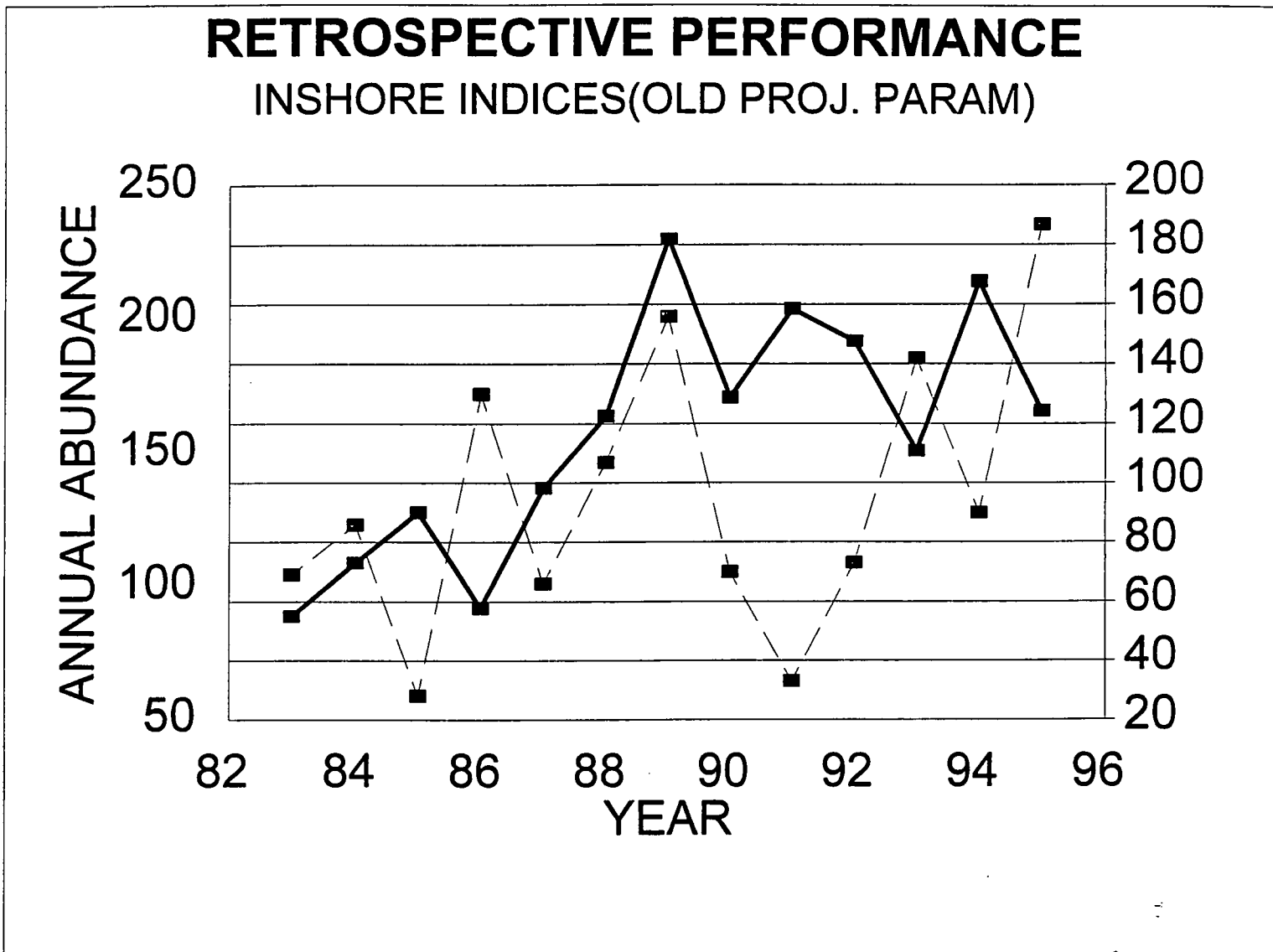
Fig. 14. Retrospective performance of the multiplicative cohort model using the NAFO projection parameters. The solid line represents the observed index.

RETROSPECTIVE PERFORMANCE
INSHORE INDICES(NEW PROJ. PARAM)
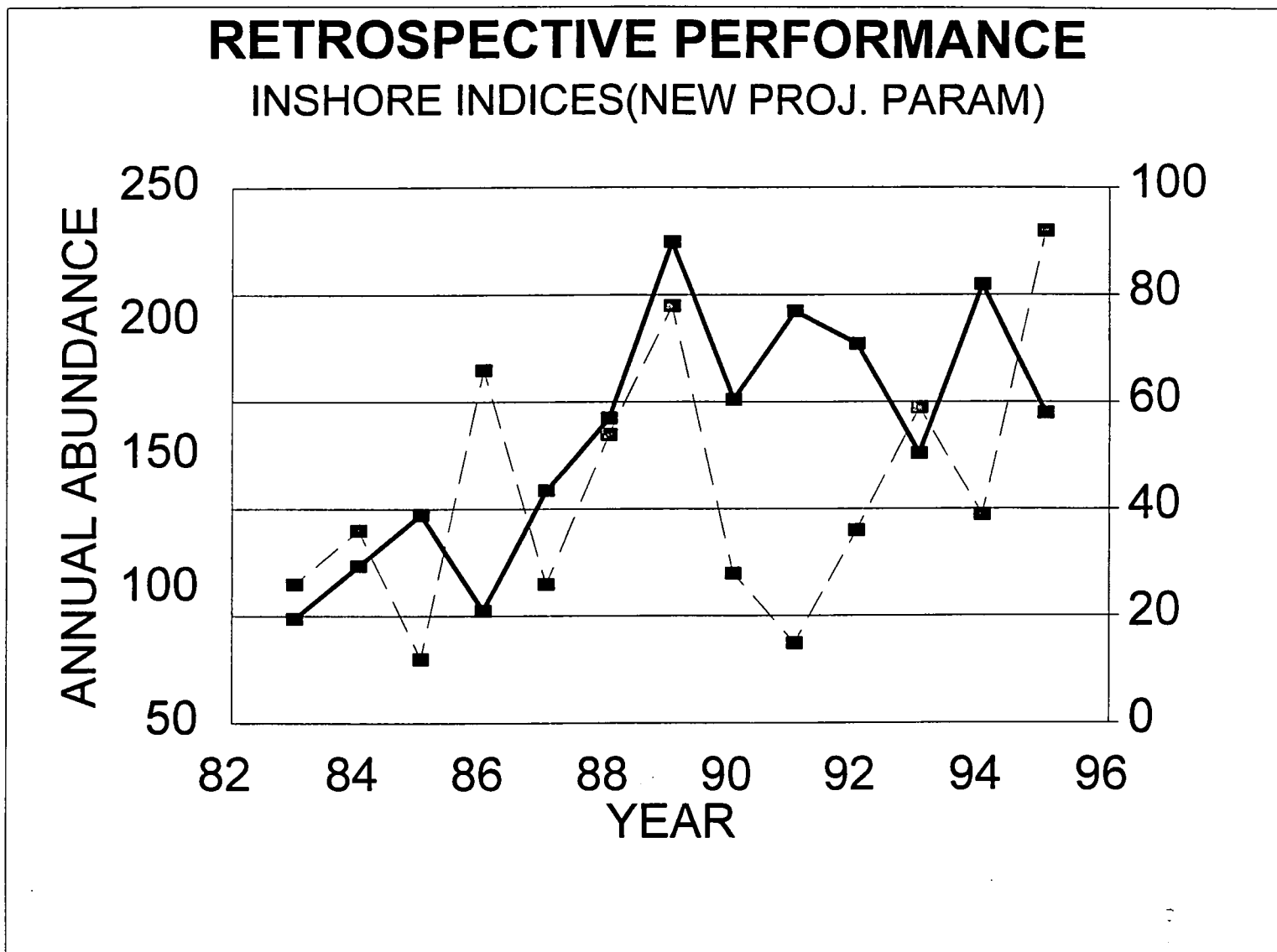
Fig. 15.   Retrospective performance of the multiplicative cohort
model using the projection parameters of Shackell et al. (1994).
The solid line represents the observed index.

MULTIPL. AGE -SPECIFIC ESTIMATES
AGE 2 VS AGE3 INSHORE
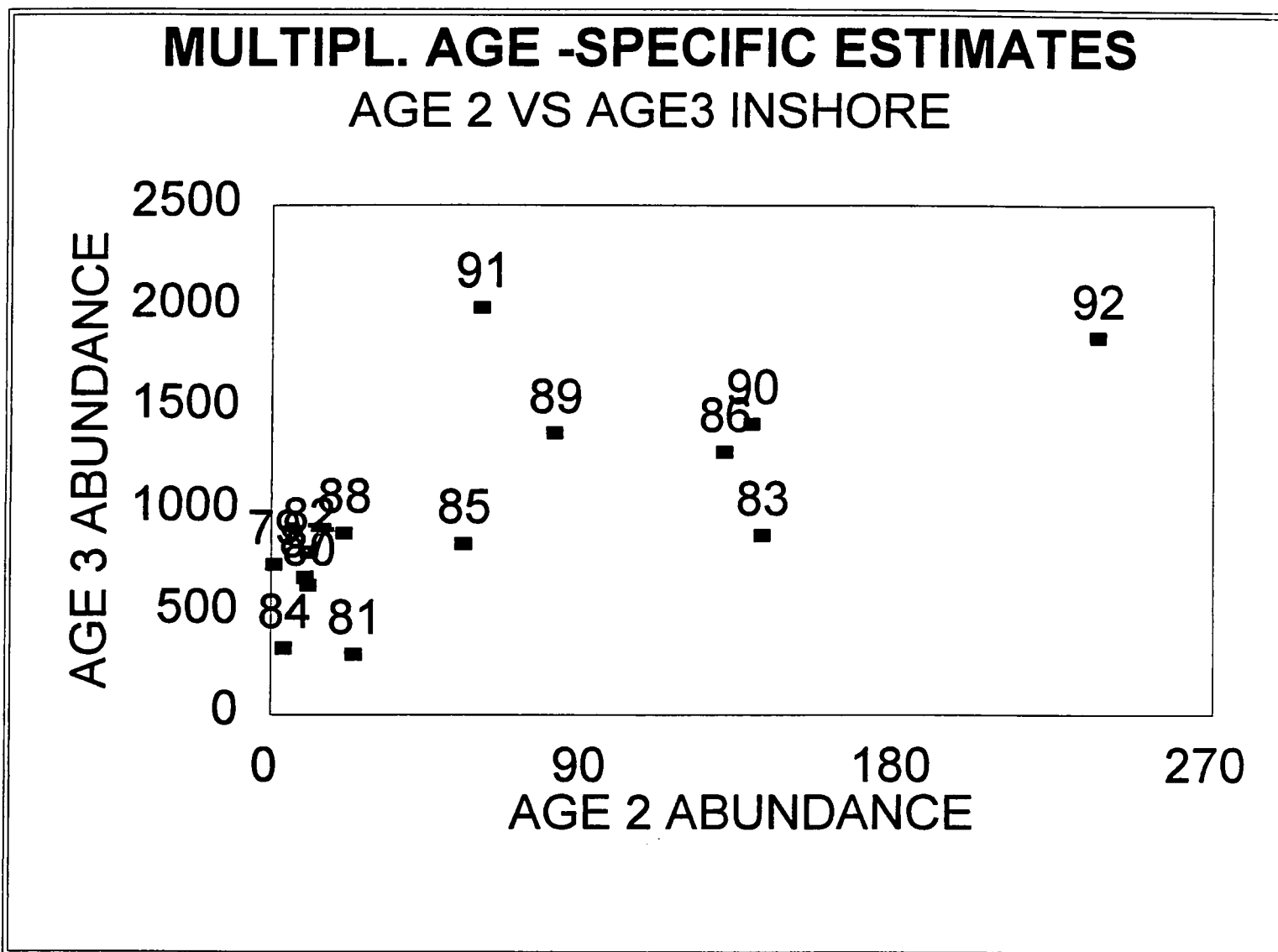
Fig. 16.   Relationship between standardized age 2 abundance and standardized age 3 abundance from the traditional inshore indices (traps, purse seines, aerial).

Standardized Annual Biomass
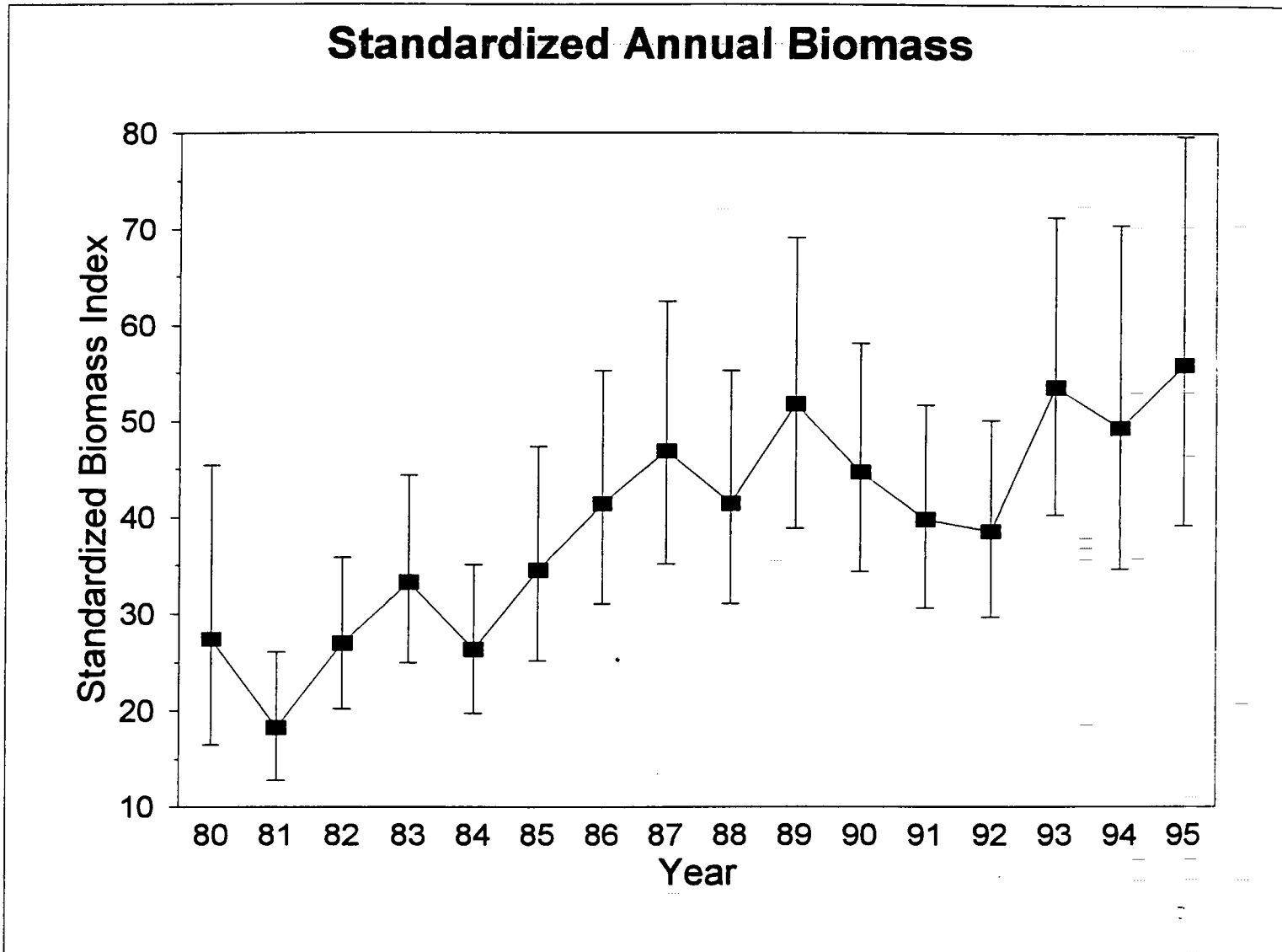
Fig. 17.   Standardized estimates of annual abundance of capelin, including the 95% confidence intervals.
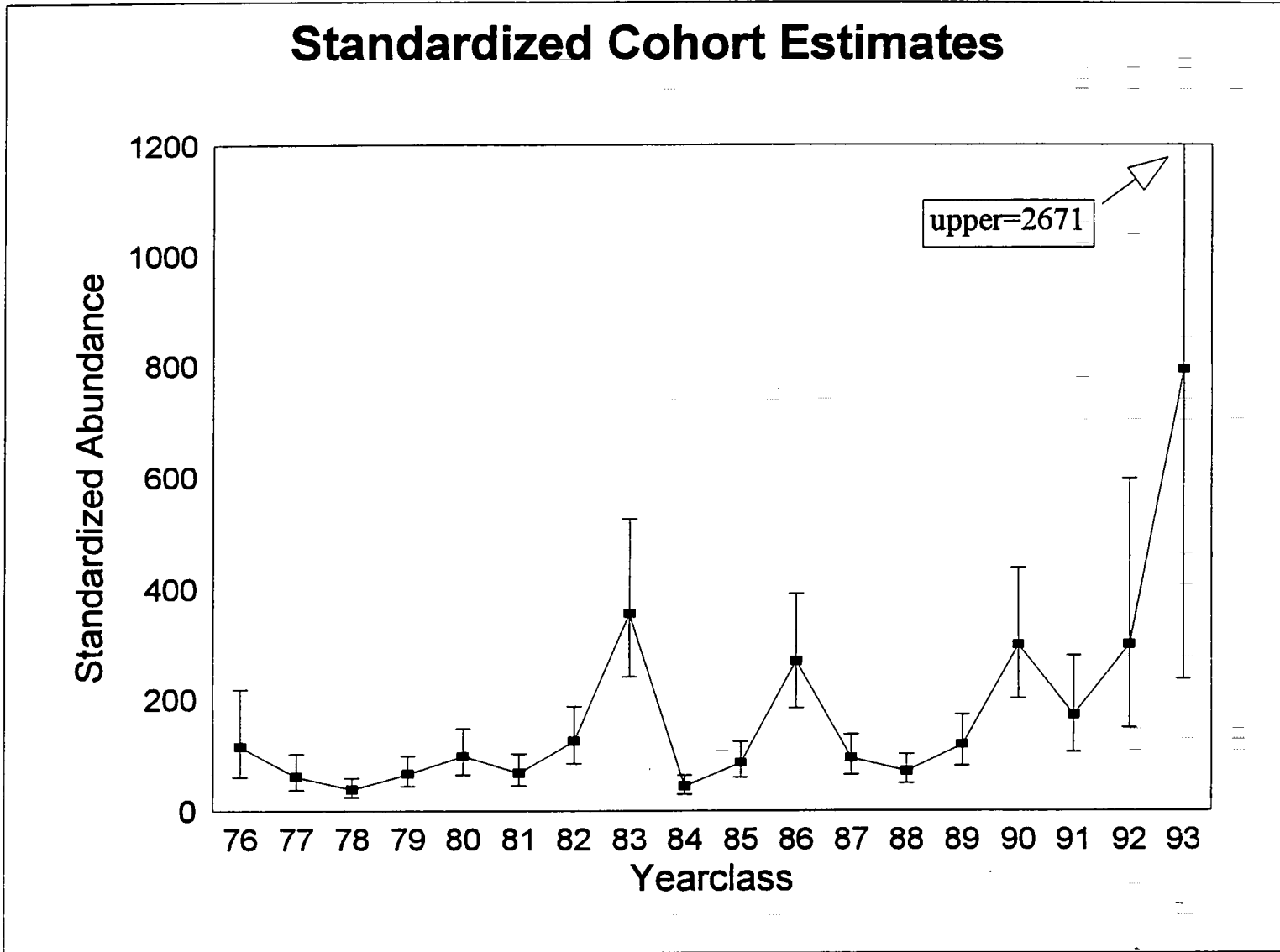
Fig. 18. Standardized estimates of cohort abundance of capelin, including the 95% confidence intervals.

The Case for 0-group Measures of Capelin Recruitment

by

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Introduction

The spawning times (Templeman 1948), hatching period, larval release date and larval survival of east coast capelin have all been linked to oceanographic factors (see Leggett and Frank 1990). Spawning times of capelin are related to the rate of spring warming of water temperatures (Carscadden et al., in press). The incubation period of capelin eggs deposited in beach gravels is largely an integrated function of water and air temperature (Leggett et al. 1984). Further, the release frequency and survival rate of free-swimming larvae is hypothesized to depend on the presence of favourable water masses near shore (Frank and Leggett 1982). This so-called "safe site" hypothesis can be summarized as follows: larvae emergence is triggered by the occurrence of infrequent onshore winds which assist in flushing sediment larvae from the gravel. During the interval between onshore winds larvae accumulate in the gravel where they are subject to time-dependent mortality depletion. Onshore winds are considered to be favourable for larval emergence/survival because they provide a food-rich, predator-deficient environment whereas offshore winds cause upwelling waters characterized by being food-poor and predator-laden and therefore unfavourable for larval survival.

Frank and Leggett (1981, 1982) compared water mass exchange/larval emergence patterns at several sites along eastern Newfoundland (in addition to their main site at Bryant's Cove, Conception Bay) and concluded that these events were largely synchronous. This led them to conclude that yearclass size of capelin was largely determined during larval emergence by broad-scale meteorological weather patterns along eastern Newfoundland. This observation was subsequently (Leggett et al. 1984) used to construct a capelin recruitment model in which the frequency of onshore winds was able to explain about 40% of the variability of capelin abundance at age 2. The model also included water temperature during the larval period; the model however has not been able to consistently predict capelin recruitment. Recent analyses of large-scale oceanographic data has shown that the response of water masses to wind along eastern Newfoundland contains great spatial complexity (Mertz et al. 1994) and that a

single wind index based on frequency (as proposed by Leggett et al. 1984) is unlikely to be suitable for recruitment prediction.

In the past decade or so a considerable body of additional data have been collected on the early life history dynamics of capelin.

Methods

We shall examine the recruitment signal at various stages in the early life history of capelin from sediment larvae (Nakashima and Winters, this meeting; Nakashima and Slaney 1994) to coastal larval abundance and to oceanic larvae (Anderson and Dalley, this meeting). As with other indices, standardized estimates of yearclass size for the traditional inshore indices (purse seines, traps, aerial) will be used to judge coherence of larvae to adult abundance.

Results

A.   Sediment Larvae:

According to Frank and Leggett (1982), newly-hatched larvae accumulate in the beach gravel until they are periodically released by onshore winds; in the event that the time interval between onshore winds is extended (eg. more than 5-7 days) these sediment larvae will perish as yolk sac reserves are depleted.

Implicit in this observation is the assumption that the first signal of yearclass success will be at larval emergence and that sediment larval abundance will be confounded by variable residence time between years.

This assumption can be tested using the extensive data base, accrued since 1990, by the capelin synchronicity project which essentially represents a multi-site extension of the classic work of Frank and Leggett (1981, 1982).

An examination of egg abundance by stage (Fig. 1, top panel) does not show large numbers of sediment larvae (stage LAR) which would be expected to accumulate in the sediment given the duration of this stage (about 6 days). On the other hand, there is an apparent accumulation of eggs at the late-eyed stage (Stage LE) as would be expected from the extended duration of this stage (up to about 7 days). When the abundance of eggs in each egg stage is adjusted for stage duration (based on Fridgeirsson (1976) and rescaled to a 15-day incubation cycle) the fitted mortality curve for the egg stages predicts quite closely the observed numbers of sediment larvae (Fig. 1, bottom panel). This preliminary analysis indicates that sediment larvae are not (as a general rule) accumulating in the beach gravel but rather are emerging into the water column commensurate with the daily hatching rate. Therefore,

the abundance of emergent larvae should be a direct function of the
number of sediment larvae, an observation that is supported by the
comparison of site/year-specific indices for the two larval phases
(Fig. 2). An obvious corollary of this observation is that, for a
given egg production, the abundance of sediment larvae (and
therefore emerging larvae as well) is merely a direct function of
egg mortality. This is also supported by existing data (Fig. 3).
In summary it can be tentatively concluded that the principal
determinant of yearclass success at the beginning of the larval
phase is mortality during the egg stage.

In Figure 4 the composite sediment larval index for the east
coast synchronicity sites (Nakashima and Winters 1996) is shown in
comparison with the standardized inshore (i.e. purse seines, traps,
and aerial) estimates of yearclass size. There is coherence
between the two series for the yearclasses that can be compared
(1990-93).

Sediment larval abundance indices are also available from egg
deposition studies conducted at 15 beaches in Conception Bay during
1987-93 (see Nakashima 1994). Sediment larval abundance data were
collected at each beach along with egg abundance and egg stage
compositions (see Winters and Nakashima, this meeting). The
empirical estimates of sediment larval abundance are shown in
Figure 5 (top panel). These estimates reflect also the relative
stage in the incubation cycle at which sampling occurred (see
Winters and Nakashima, this meeting) for further details) i.e.
sampling earlier in the incubation cycle will produce lower numbers
of sediment larvae than later in the cycle for a given egg
deposition. Nakashima (1994) provides such staging data (Fig. 5,
middle panel) which indicates that certain years (eg. 1988) were
low-biassed because sampling occurred very early in the incubation
cycle (so early, in fact, that none had progressed to the
pre-emergent sediment larval phase in 1988) and certain years were
high-biassed (eg. 1989) because later sampling resulted in more
eggs progressed to hatching. In Figure 5 (lower panel) the
empirical estimates are adjusted for relative stage differences
(simply by dividing by the percent eyed). This is an approximate
adjustment which assumes that the relationship between sediment
larval abundance and percent eyed eggs is linear. This does not
have a great effect on the yearclass rankings other than 1989 (3rd.
to 4th.) and 1992 (4th. to 2nd.). The adjusted estimates are
plotted against the inshore standard in Figure 6. The two series
are coherent in the relative yearclass rankings.

B.   Emergent Larvae:

In Figure 7 the composite larval emergence index for the east
coast synchronicity sites (Nakashima and Winters 1996) is shown in
comparison with the standardized inshore estimates of yearclass
size.   There is coherence between the two series for the 1990-93
yearclasses.

C.   Coastal 0-group:

During the period 1982-86 pelagic ichthyoplankton surveys were
conducted in Trinity Bay during the period mid-July to late August
(two surveys for each year) (Dalley and Anderson, in press).
A substantial component of the ichthyoplankton catches comprised
capelin and the overall mean catch rate for each year is shown in
Figure 8, along with standardized inshore estimates of the same
yearclasses.   There is very good correspondence between the two
time series.

D.   Oceanic 0-group:

Since 1991 synoptic 0-group surveys have been conducted across
the Newfoundland Shelf during the September-October period
(Anderson and Dalley 1995).   These are directed primarily at
groundfish but a major component of the catch are 0-group capelin
larvae.   The surveys in 1991-93 were conducted at approximately the
same time of the year (October) whereas the timing of 1994 and 1995
surveys was 4-6 weeks earlier.   The 1991-93 data are therefore
directly comparable but the 1994 and 1995 data require adjustment
for daily mortality. The table below provides the larval abundance
estimates for each year for a standard area sampled in all years.
The mean day of first larval emergence is the annual mean of site-
specific estimates from the NCSP synchronicity project.

Year	Midpoint of survey (JD)	Mean day of first emergence (JD)	Time since emergence (days)	Larval abundance (nos./m^2)	
1991	289	215	74	3765	
1992	281	209	72	5435	
1993	281	210	71	11273	
1994	239	205	34	7976	(2149)
1995	256	212	44	15011	(5010)

In Figure 9 the 1991-93 data are shown in comparison with the inshore standard. The rankings are consistent with the standardized estimate of the same yearclasses from the inshore adult index.

The 1994 and 1995 indices (as stated previously) require adjustment for daily mortality if they are to be directly comparable to the 1991-93 estimate. Preferably, this should be done using empirical estimates from the survey data themselves; however, it is unlikely that such mortality can be detected given the variability in ichthyoplankton data.

It is possible, however, to estimate daily mortality by indirect means. The ratio of the oceanic 0-group index to the larval emergence index provides a measure of relative survival rates for each year (class). As expected, these survival indices show a negative relationship with the duration of the larval emergence period ($R^2 = 0.83$, P < 0.01) (Fig. 10). The regression parameters of the relationship in Figure 11 provide a simple method of converting the observed 0-group indices in 1994 and 1995 to equivalent estimates for the same mean emergence period (72 days) as for 1991-93. The adjusted estimates (Table above) indicate that the 1994 yearclass is likely below average whereas the 1995 yearclass is of intermediate strength. The implied daily mortality rate is near 4%. It is likely that the 1994 yearclass is underestimated in the above analyses. Larval emergence of beach-spawning capelin was incomplete at the time of the oceanic 0-group survey, based on sediment core and plankton hauls at the various east coast beach-spawning study sites (Nakashima and Winters, this meeting). In addition, the delayed maturation trajectory experienced by mature fish in 1994 (Carscadden et al. 1996) coupled with a very rapid rise in surface water temperatures likely created conditions favourable for increased off-beach spawning. This would have biassed downwards larval emergence estimates from beach spawning and the delayed incubation period of off-beach spawned eggs likely resulted in larval emergence occurring after the 0-group oceanic survey.

E.   Integrated 0-group Index (1987-93):

It is not possible to adjust the individual 0-group indices to a common 0-group standard because of the lack of an overlap between the Trinity Bay index (1982-86) and the more recent indices (1987-95). The indices since 1987, however, do overlap and the multiplicative model has been applied to these indices (described above) to produce a standardized series. This integrated 0-group index is shown in Figure 11 in comparison with the 1996 assessment.

The coherence between the 0-group and adult indices demonstrates that 0-group indices can be used to provide the first measure of incoming recruitment for the commercial fisheries.

General Conclusions

The foregoing analyses confirm the major findings of Frank and Leggett (1982 and other associated publications) viz. (1) that a large component of the variance in yearclass size of capelin is fixed very early in the life cycle. Frank and Leggett concluded that the critical determinant period was during the sediment larval phase whereas recent data indicate a somewhat earlier determination (i.e. egg mortality during incubation); (2) the coherence between localized 0-group indices (eg. the Trinity Bay series and the Conception Bay series) and subsequent adult indices of the same yearclasses (broad scale) indicates that the major factors affecting early survival are coherent across the spawning range along eastern Newfoundland (though not necessarily for each beach). This is consistent with Frank and Leggett's conclusions that large-scale meteorological patterns are generating survival conditions which result in coherent recruitment response.

As a general comment, the continuation of the 0-group indices will provide a unique data set that will enable time series estimates of survival at any later stage in the life cycle of capelin. This is particularly important considering the large changes that occurred in the environment and also the community structure of the Newfoundland Shelf over the past 5-10 years and which includes the demise of key predators (i.e. cod). Given the continuing availability of multiple indices of adolescent and adult abundance, the impact of this decline (and the subsequent rebuilding) will be quantifiable in terms of sequential life-table survival indices.

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Winters, G. H., and B. S. Nakashima. 1996. Application of the multiplicative cohort model to egg deposition data from Conception Bay. pp. 42-49. In: Anon. Capelin in SA2 + Div. 3KL. DFO Atl. Fish. Res. Doc. 96/90.

CAPELIN EGG STAGE ABUNDANCE
1990-94(UNADJUSTED)

EGG ABUNDANCE BY STAGE
ADJUSTED FOR STAGE DURATION

$z=0.25/d$
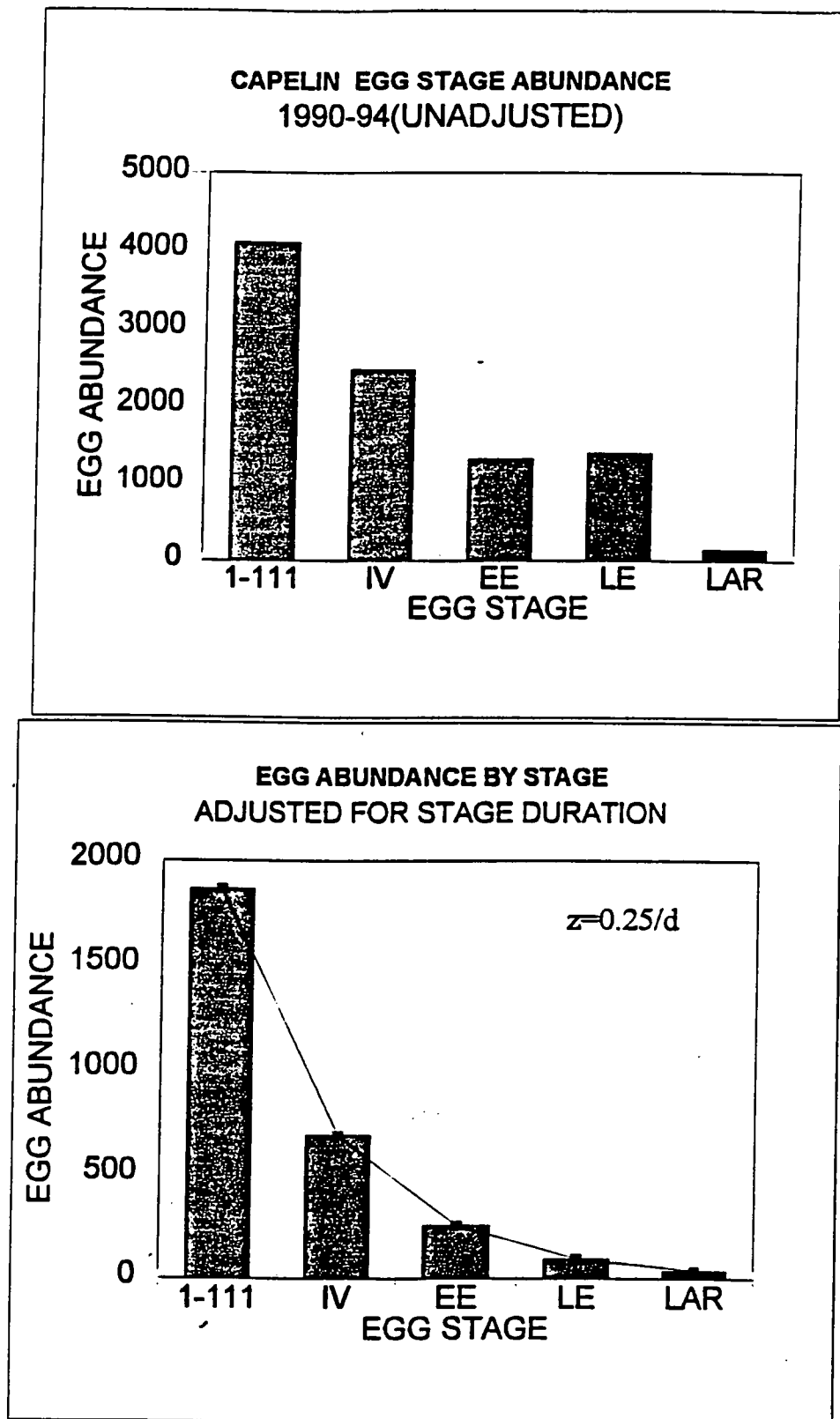
Fig. 1. Mean capelin egg abundance ('000 eggs/core) by stage (top panel) for all beaches sampled along eastern Newfoundland, 1990-94. The bottom panel shows the same data adjusted for stage duration (see text).
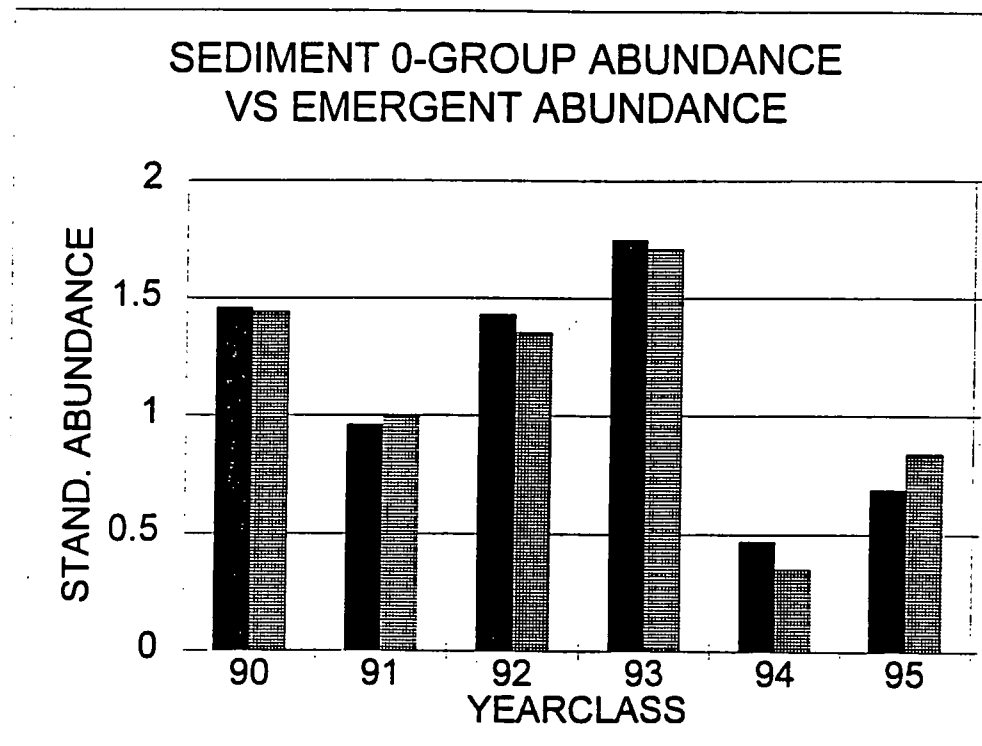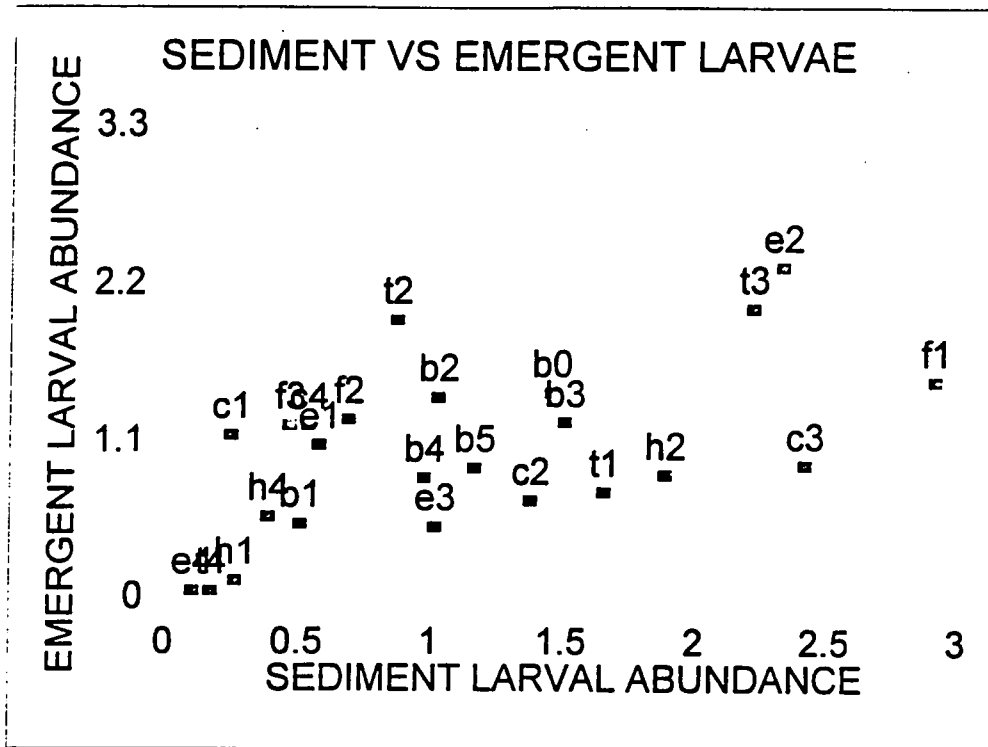
Fig. 2. Relationship between sediment larval abundance and emergent larval abundance for the various spawning beaches (top panel, ep1 = Eastport 1991 etc.; the bottom panel shows the standardized data for each yearclass) (solid bars = emergent larvae).
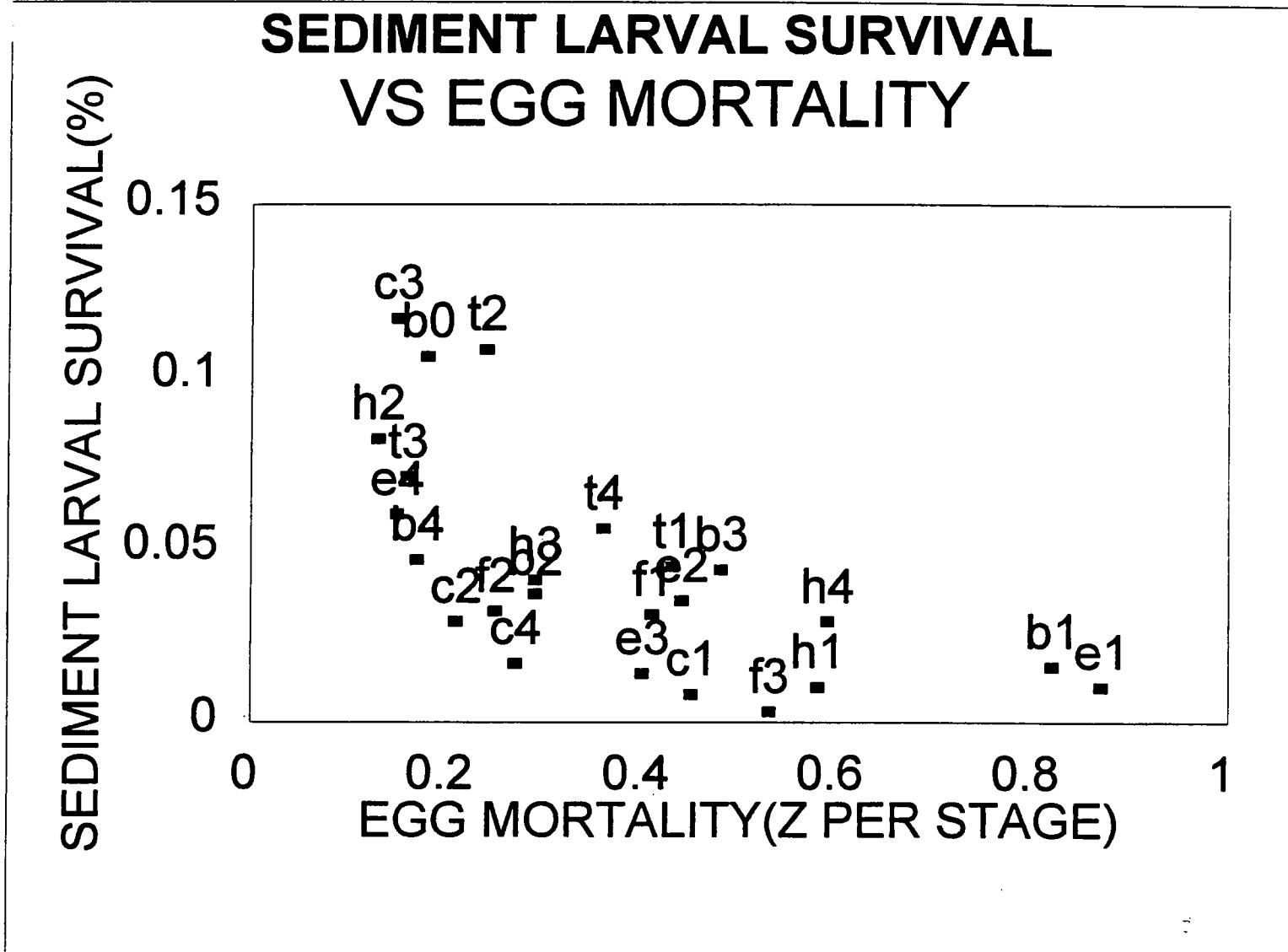
Fig. 3. Relationship between annual (beach-specific) egg mortality and sediment larval survival (no. of sediment larvae per unit egg deposition) for east coast beaches 1990-94 (ep1 = Eastport 1991 etc.).
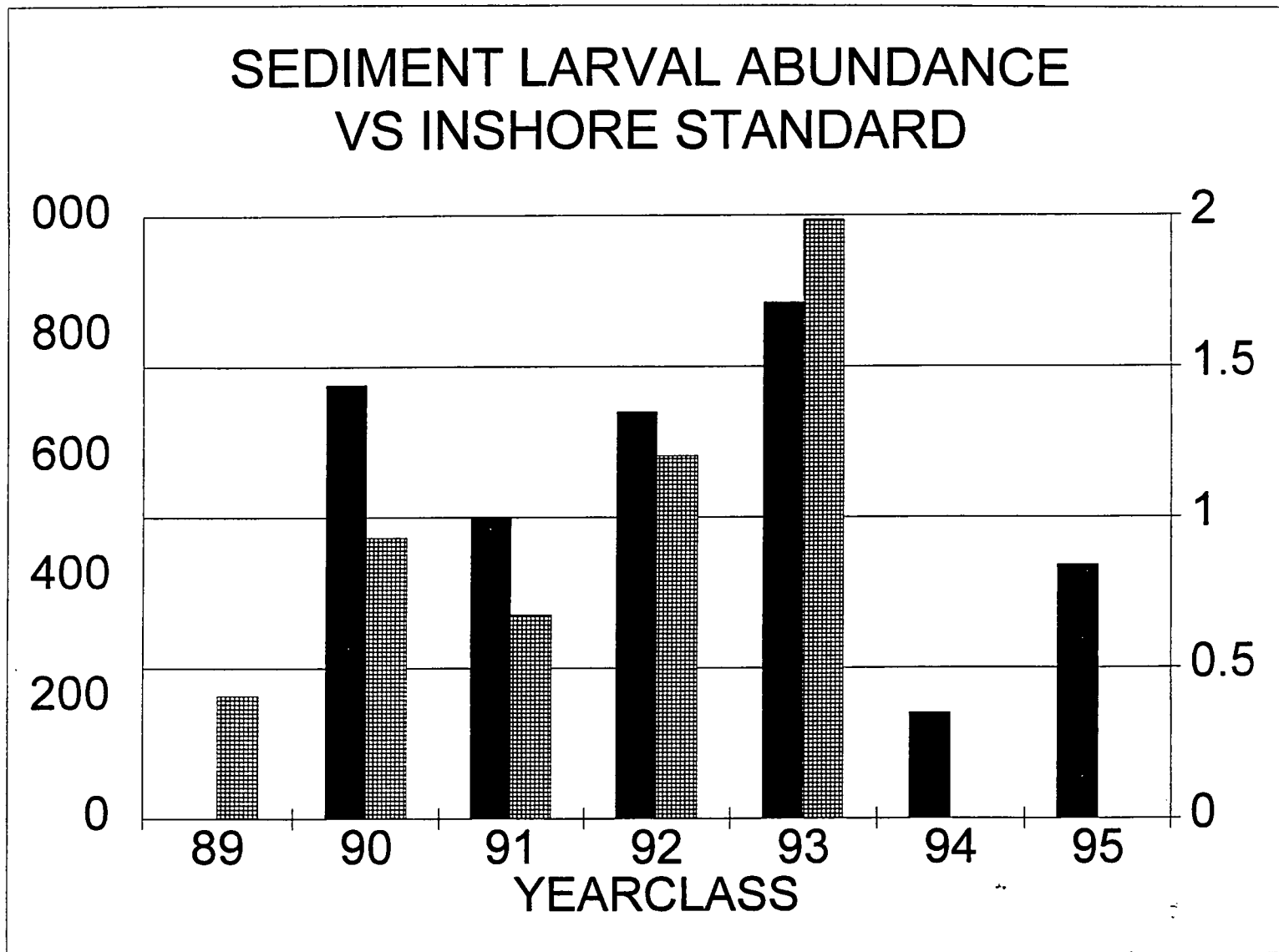
Fig. 4.   Relationship between the composite sediment larval abundance for the east coast spawning beaches and the standardized estimates of yearclass abundance from the inshore indices (solid bars = sediment larvae).

C.BAY SEDIMENT LARVAE
(OBSERVED)

(bar chart: ABUNDANCE(X 10e-8) vs YEAR, 1987–1993)

C.BAY RELATIVE EGG DEVELOPMENTGE
(NAKASHIMA 1994)

(bar chart: PER CENT EYED vs YEAR, 1987–1993)

C.BAY SEDIMENT LARVAE
STAGE ADJUSTED

(bar chart: ABUNDANCE(X10Xe-8) vs YEAR, 1987–1993)
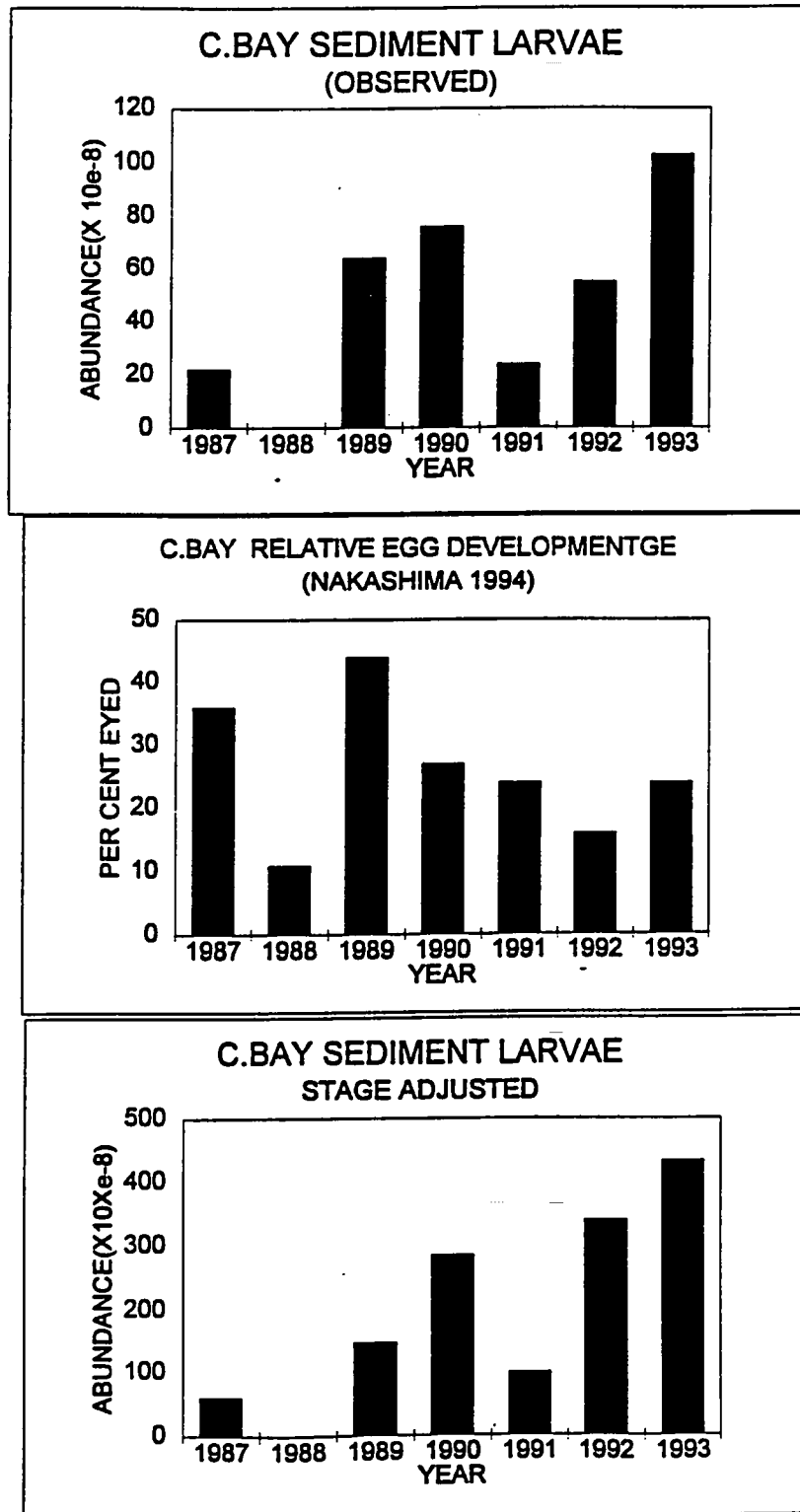
Fig. 5.   Sediment larval abundance indices for the Conception Bay
beach sampling program 1987-93 (see text for details).
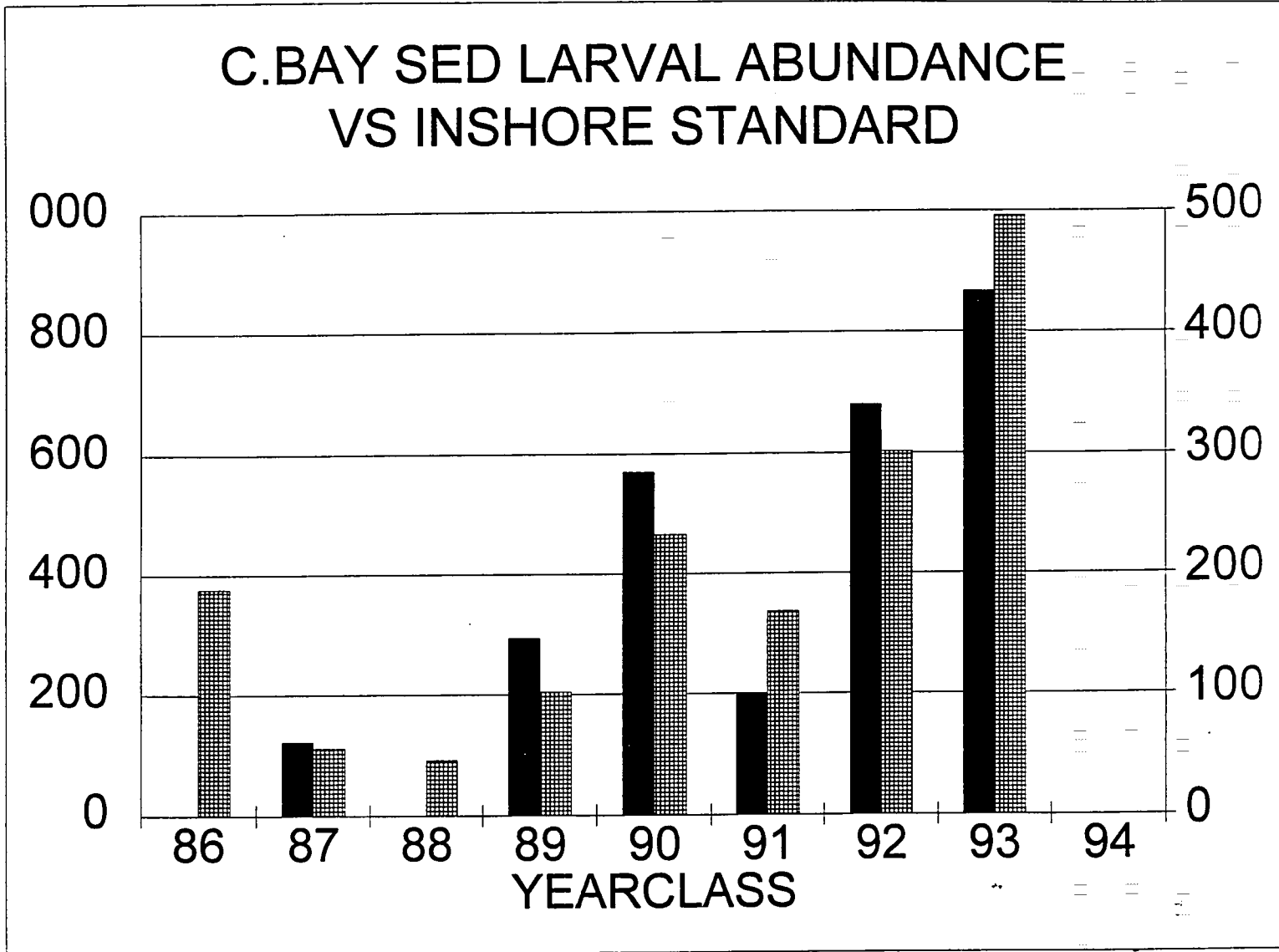
Fig. 6.   Conception Bay sediment larval abundance index versus standardized yearclass estimates for the inshore indices (solid bars = sediment larvae).

LARVAL EMERGENCE ABUNDANCE
VS INSHORE STANDARD
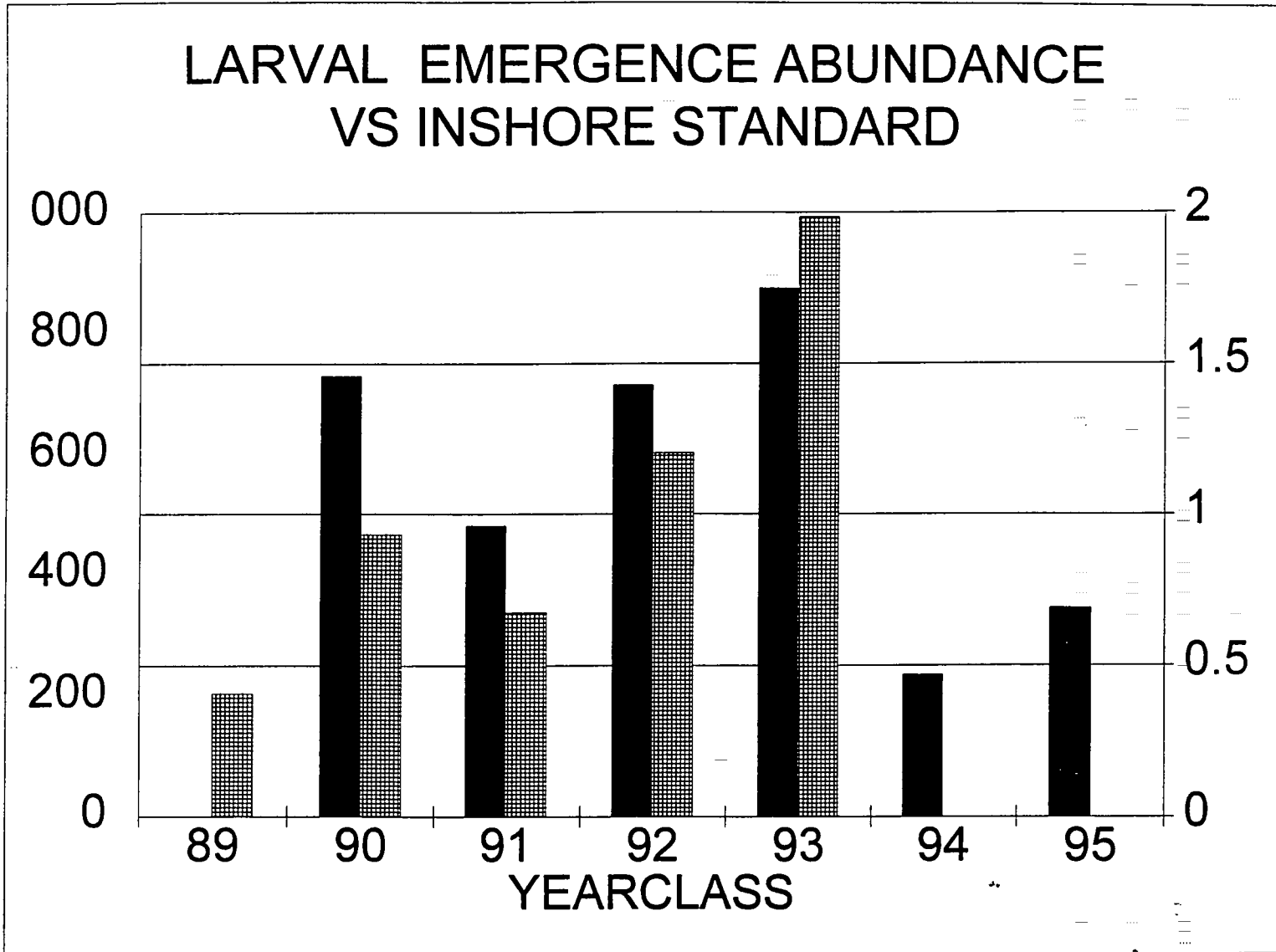
Fig. 7.   Composite larval emergence indices for the east coast
spawning beaches versus the standardized yearclass estimates for
the inshore indices (solid bars = emergent larvae).
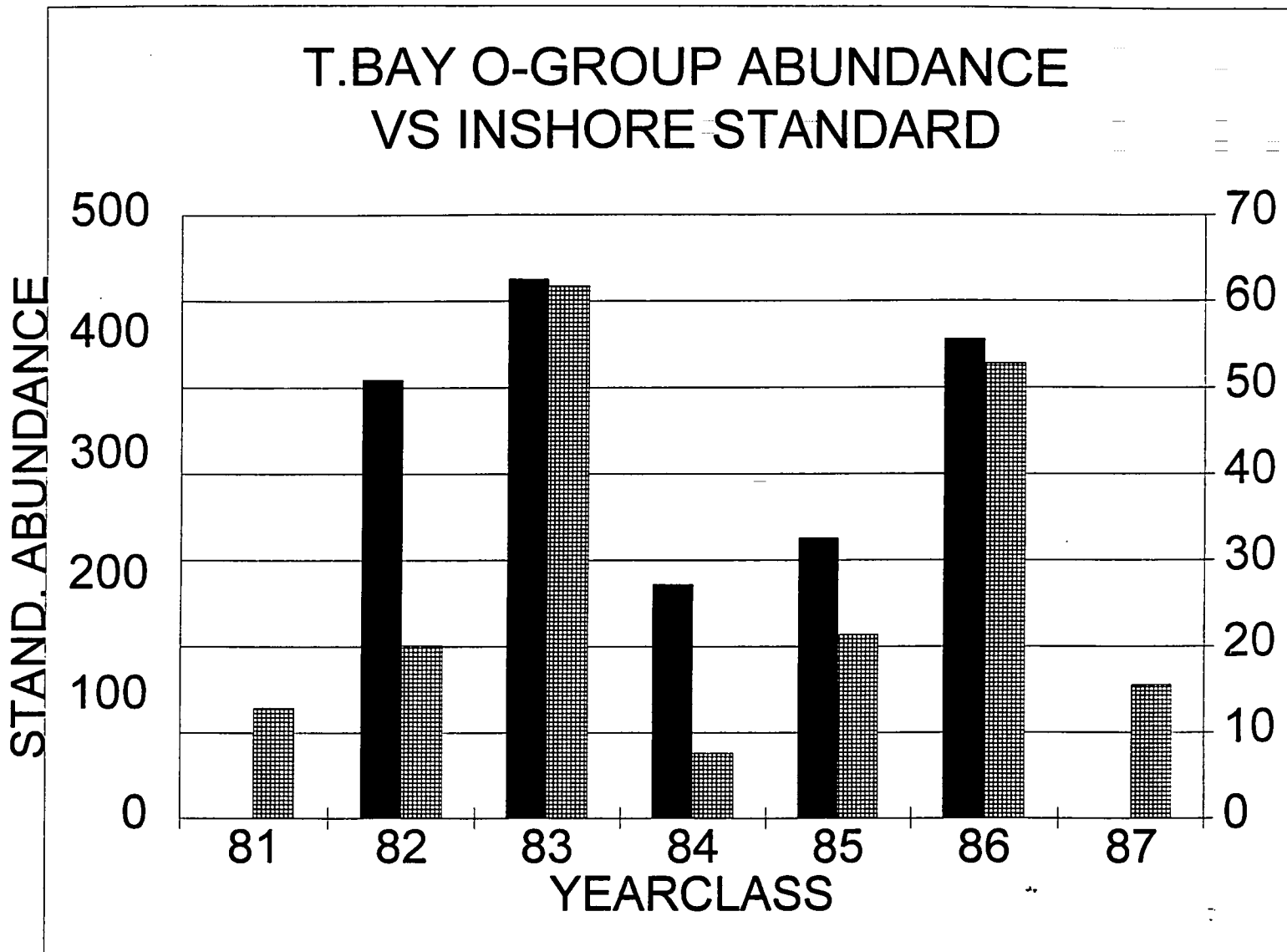
Fig. 8. Trinity Bay 0-group indices of yearclass abundance versus standardized yearclass estimates from the inshore indices (solid bars = Trinity Bay 0-group).

OCEANIC 0-GROUP ABUNDANCE
VS INSHORE STANDARD
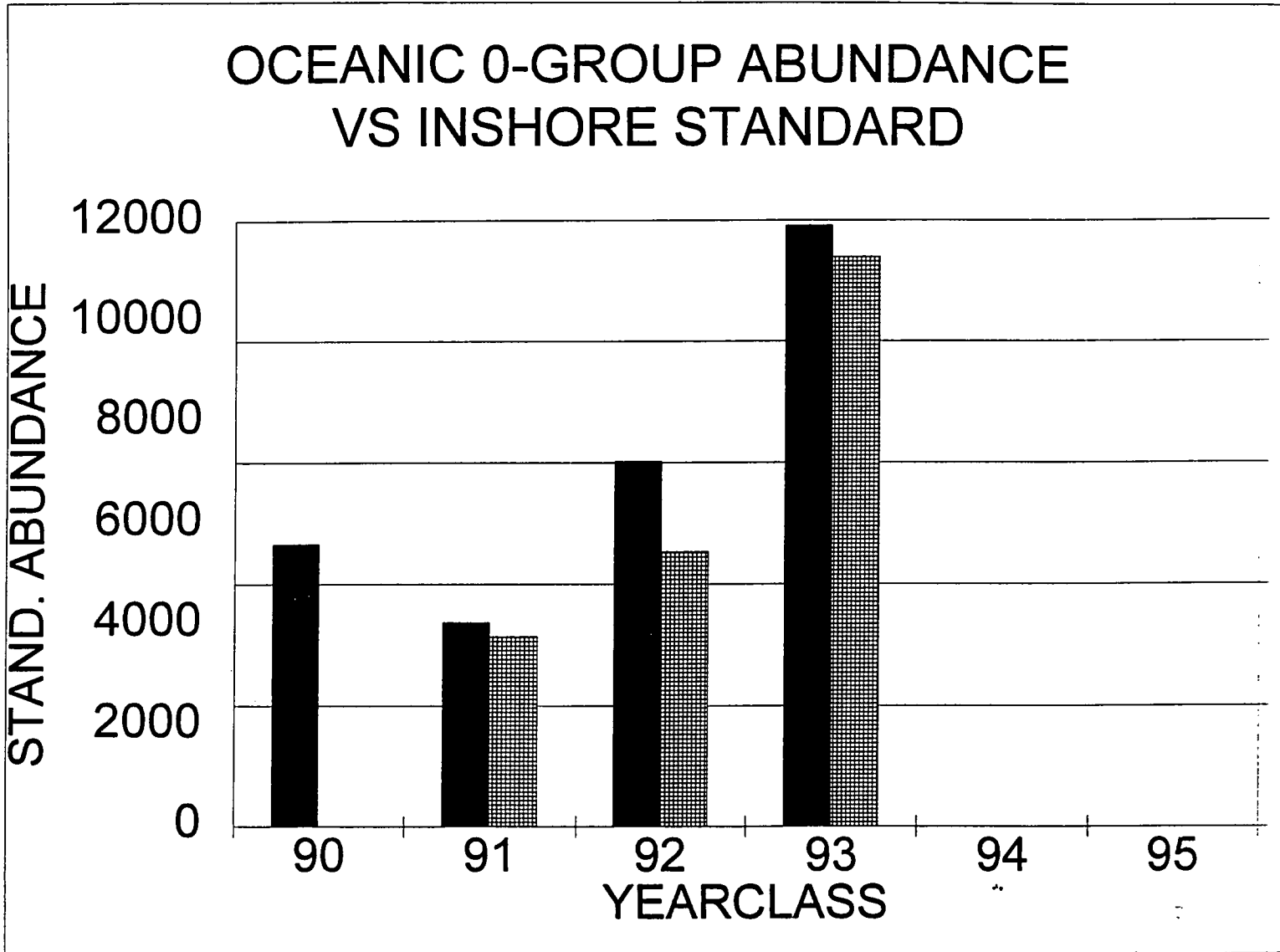
Fig. 9.   Oceanic 0-group larval indices (1991-93 yearclasses)
versus standardized estimates of yearclass size for the inshore
indices (1990-93 yearclasses) (solid bars = inshore indices).
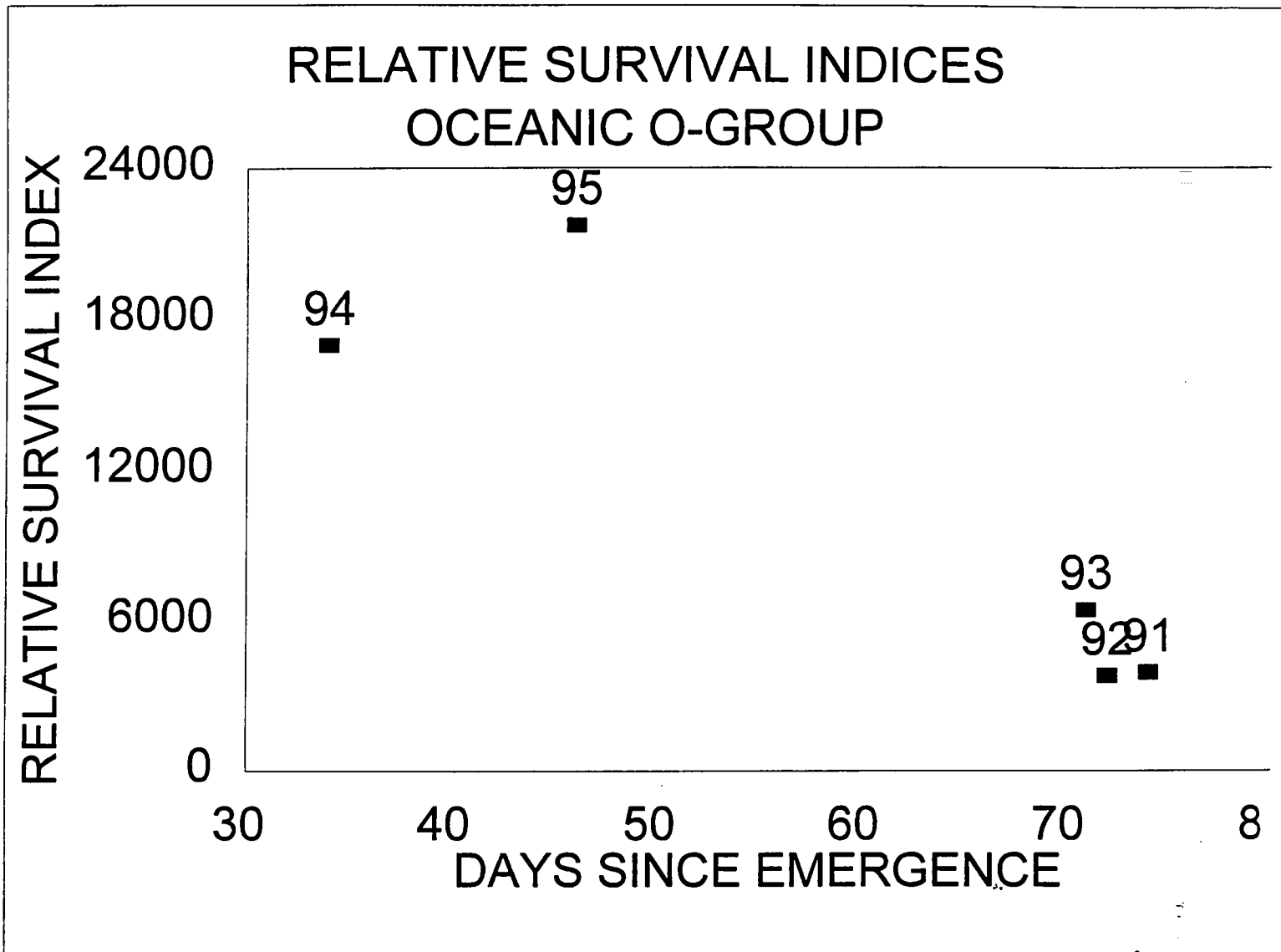
Fig. 10. Relative survival indices of oceanic 0-group capelin in relation to days since mean emergence (see text for details).

STAND.O-GROUP ABUNDANCE
VS 1996 ASSESMENT ESTIMATES
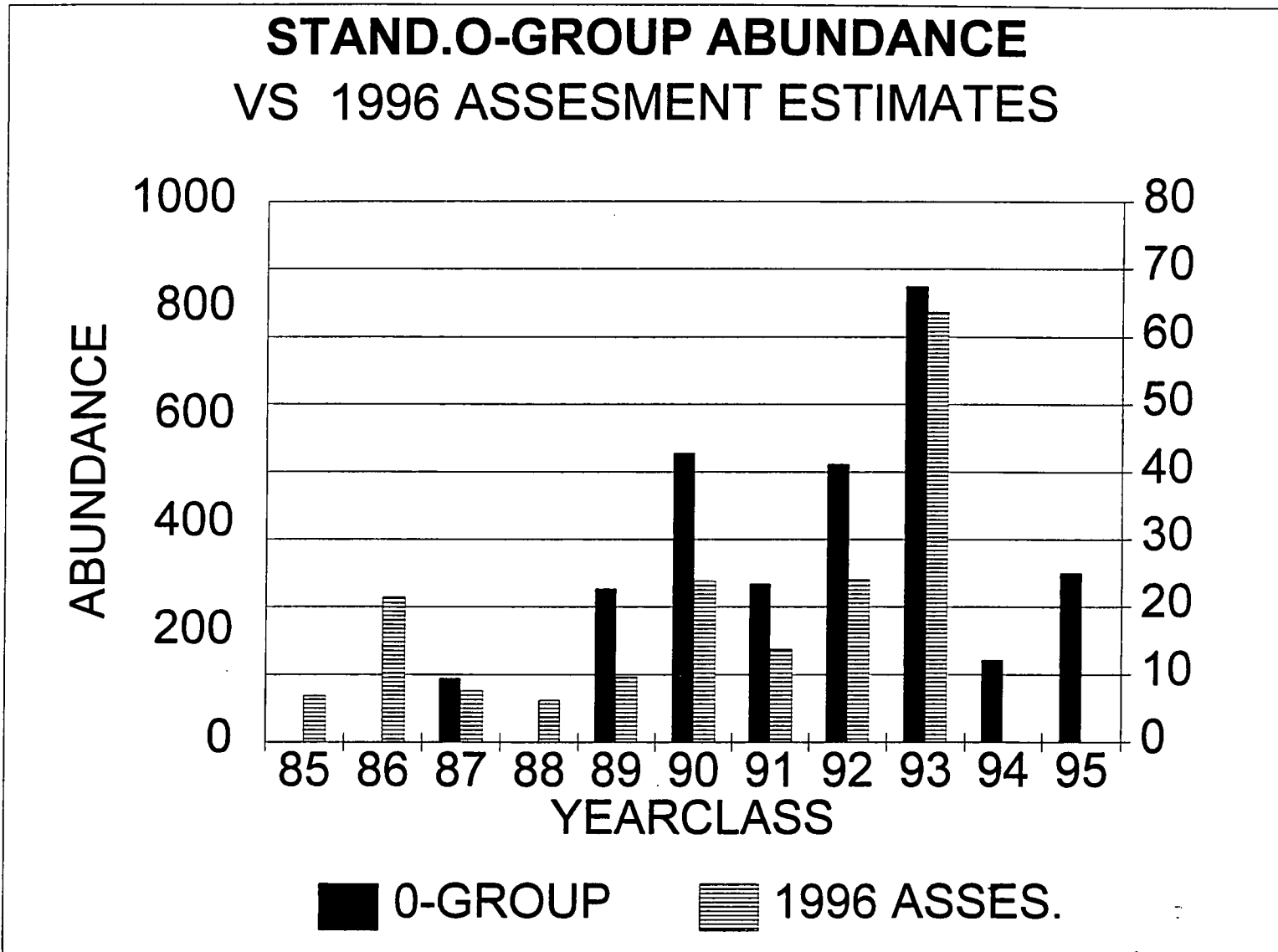
Fig. 11. Standardized estimates of yearclass size for the various 0-group indices versus standardized estimates of the same yearclasses for the inshore indices (solid bars = 0-group).

Multiplicative Estimates of Yearclass Size Using Non-traditional Capelin Abundance Indices

by

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St. John's NF   A1C 5X1

Introduction

The 1995 assessment of capelin reviewed a wide variety of potential abundance indices but the formal assessment included only longer-term traditional indices. In this report a suite of non-traditional indices will be used to provide additional estimates of yearclass strength for those yearclasses produced in the 1982-95 period.

These indices are: (1) NCSP egg deposition survey, 1990-95 (Nakashima and Winters 1996, Ch. 10; (2) Conception Bay egg deposition survey, 1987-93 (Winters and Nakashima 1966, Ch. 3); (3) Conception Bay sediment larval abundance, 1987-93 (Winters et al. 1996, Ch. 8); (4) NCSP emergent larval abundance, 1990-95 (1990-95 (Winters et al. 1996, Ch. 8); (5) NCSP sediment larval abundance, 1990-95 (Winters et al. 1996, Ch. 8); (6) Trinity Bay 0-group survey, 1982-86 (Winters et al. 1996, Ch. 8); and (7) oceanic 0-group survey, 1991-93 (Anderson and Dalley 1996, Ch. 14). (Note that the estimates for the oceanic 0-group survey used in this formulation were derived during the assessment meeting and are not necessarily the same as in Chapter 14.) These 0-group and egg deposition surveys have already been examined for coherence with the inshore standardized series so that crossover effects should not pose a statistical problem for time series integration.

Results and Conclusions

The multiplicative model, incorporating the seven (7) indices referred to above, explained 94% of the variance in yearclass strength and both main effects were significant (Table 1). The time series is shown in Figure 1 in comparison with the updated estimates of the traditional indices included in the 1995 assessment. The two time series show good agreement in yearclass size variations. These non-traditional indices provide an additional 78 estimates of the 1982-95 yearclasses distributed as follows:

Yearclass	82	83	84	85	86	87	88	89	90	91	92	93	94	95
No.		2	3	4	6	7	7	10	8	11	8	5	4	2	2

Yearclass strengths of capelin can now be estimated at nearly all of the sequential stages in their life history, from larval emergence from beach gravel, to their return to the beaches to spawn. These are, however, relative indices. Acoustic surveys are, therefore, important not only as an additional abundance index but also as an absolute scale for calibration of the relative indices.

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Table 1. Statistical output of the multiplicative cohort model used to estimate standardized yearclass strength. Reference categories were the 1995 yearclass and the NCSP larval emergence survey.

Source	DF	Sum of squares	Mean squares	F-value	PR > F
Model	25	535.47	21.42	38.82	0.0001
Error	54	29.79	0.55		
Corrected total	79	565.27			

Root MSE	0.74
Dep. mean	4.38
C.V.	16.95
R. square	0.95

YEARCLASS ESTIMATES
TRADITIONAL VS NON-TRADITIONAL
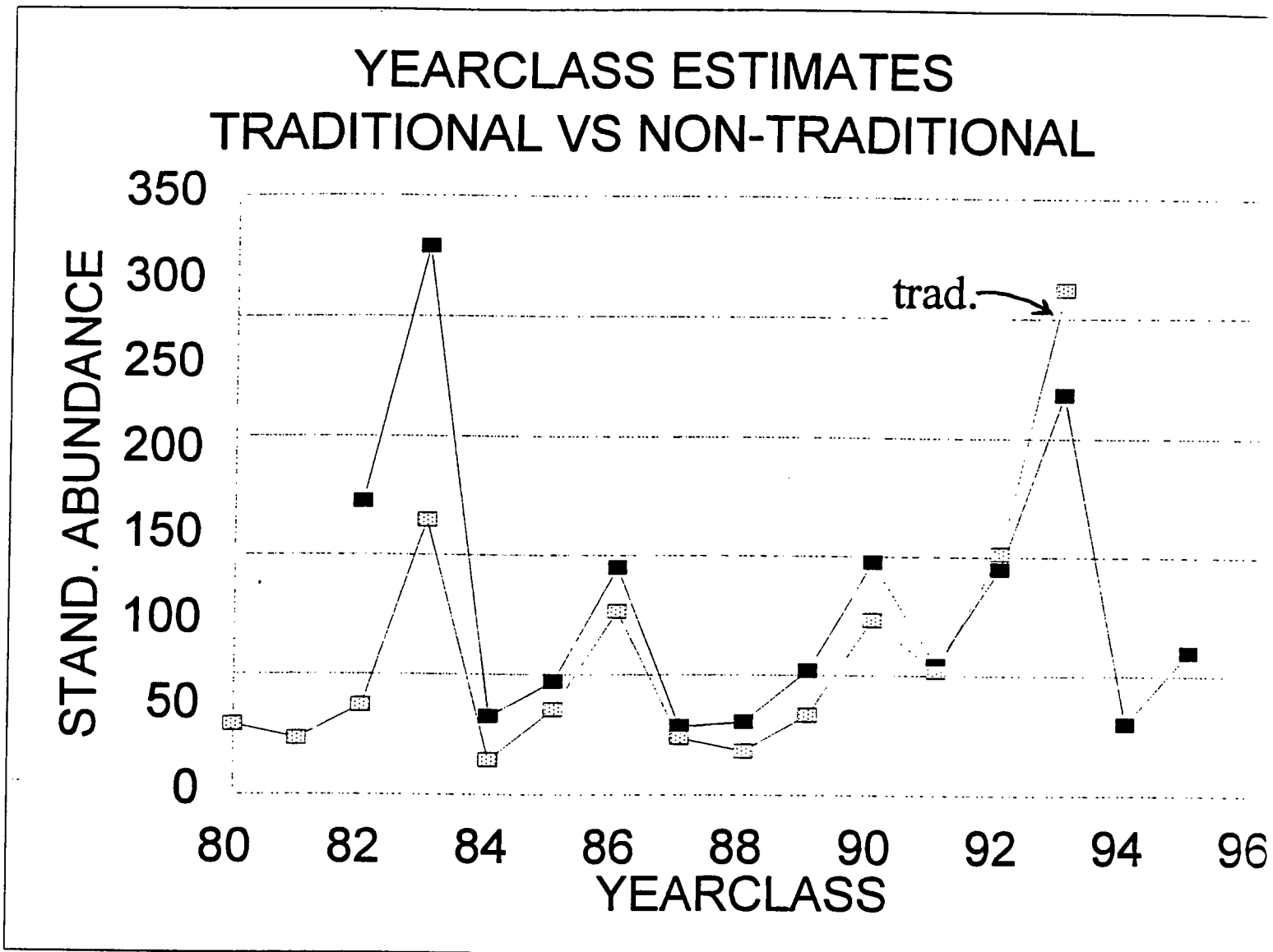
Fig. 1. Comparison of yearclass size estimates from the multiplicative model fitted to non-traditional indices and those included in the 1995 annual assessment of capelin.

Results from Monitoring Capelin Spawning Beaches
on the Northeast Coast of Newfoundland in 1995

by

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Introduction

In 1990 we monitored 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 more beaches in Div. 3KL at Chapels Cove, Eastport, Cape Freels, Twillingate, and Hampden (Fig. 1). In this report we present information on age compositions, fish lengths, spawning times, egg deposition, and larval estimates in 1995 from Chapels Cove and Bellevue Beach located in Div. 3L.

Materials and Methods

Adult Samples

Random samples of 25 males and 25 females were collected at each beach 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 taken place 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 collect 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 μm plankton net was towed 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. Larvae were enumerated from one of the two samples. 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 Density

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 beach was estimated using the trapezoidal integration method.

In 1995 spawning at Chapels Cove had already occurred by the time core sampling began on July 9 (julian day 192). Observations indicated that spawning had started on July 5 (julian day 188). The estimated egg deposition using only stages I-II eggs for Chapels Cove was an underestimate because all eggs collected on julian day 192 were either classified as abnormal, stage III, or Stage IV.

The minimum estimate of egg deposition per core was 14741 (all stage I-II eggs from July 10-August 5) + 27600 (total eggs per core collected on July 9) which equals 42341. This is an underestimate. Spawning occurred several times during the four day period between July 5-9. We assumed July 7 (julian day 190) as the starting date. Estimates of egg mortalities in beach sediments (Winters and Nakashima unpublished data) indicate that eggs over a two day period would have endured a mortality of $e^{-Z} = 0.61$. Backcalculating by dividing egg total on July 9 by e^{-Z} (27600/0.61) gave an estimate of 45226 stages I-II eggs on July 7. To adjust the seasonal egg deposition from trapezoidal integration we solve for (A_{190}) which is the estimated egg deposition between July 7-9:

$$\frac{E_{192}}{A_{192}} = \frac{E_{190}}{A_{190}}$$

where $E_{192} = 14741$ is all stages I-II eggs from July 10-August 5, $E_{190} = 45226$ is the estimated stages I-II eggs on July 7, and $A_{192} = 35700$ is the trapezoidal integration estimate from July 10-August 5. The total egg deposition for Chapels Cove in 1995 is derived by summing the integrated area from July 10 onwards ($A_{192} = 35700$) and the backcalculated area from July 7-9 ($A_{190} = 109500$). The adjusted sum appears in Table 2.

Larval Estimates

In 1993 sampling ended in early September at Bellevue Beach and Twillingate and was intermittent at Hampden before the last cohort had fully emerged (Fig. 2). These data taken at face value would suggest that no emergent larvae were produced from the final spawning run. Consequently earlier summaries underestimated the densities of pre-emergent larvae in beach sediments and emergent larvae (Nakashima and Winters 1995). We assume that survival from stages I-II eggs to emergent larvae is similar for all cohorts produced on a given beach which we can estimate for the main spawning season. The expected density of emergent larvae from the late spawning was then estimated by applying the calculated survival rate to the stages I-II eggs from the late August spawning. Summing the emergent larvae from the main spawning and the expected from the late August spawning gives a total for the season. The ratio of the main spawning to the seasonal total was then used to adjust the estimate from the trapezoidal integration method. The details are shown in Appendix A. The same treatment was employed for pre-emergent larvae and for 'good' condition larvae.

Results and Discussion

Age Composition

Age compositions from samples of spawning fish from 1990 to 1995 indicate that age 3 fish dominated in all years except in 1991 and 1992 when age 4 had the highest proportion (Table 1). Samples collected in 1995 were from two areas only.

Egg Density

Two distinct spawnings occurred on Chapels Cove; one in mid-July (Fig. 3) and one estimated for early July (see earlier). Three spawnings were observed on Bellevue Beach in mid-July, late July, and early August (Fig. 3). Egg density of stages I-II in 1995 on Chapels Cove was the second highest since 1991 and on Bellevue Beach it was the second lowest since 1990 (Table 2). The annual mean of the normalized values suggest that egg deposition in 1995 was higher than in 1994 and similar to 1991 and 1992 (Table 3).

Larval Estimates

Both pre-emergent larvae and emergent larvae were very low at Chapels Cove suggesting low survival during beach residence (Table 2, Fig. 4). Survival at Bellevue Beach was higher (Table 2) with most larvae emerging from beach sediments in August (Fig. 3). The annual mean of the normalized estimates indicate that overall pre-emergent and emergent larval densities in 1995 were higher than in 1994 but low compared to previous years (Table 3).

Spawning Time

The spawning period in 1995 was similar to 1994 for those beaches surveyed (Table 2).

Acknowledgements

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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
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
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
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

Table 2. Annual estimates derived from trapezoidal integration of egg deposition, pre-emerge larvae in beach sediments, and larval emergence, and range of spawning dates for capelin spawning times on beaches in Div. 3KL.

			Site				
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)

Year	Chapel Cove	Bellevue Beach	Eastport	Cape Freels	Twillingate	Hampden	Range
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	–	–	–	–	
$\bar{X}$	102.3	213.3	150.0	131.6	77.7	146.2	

Pre-emergent larvae in beach sediments ('000 larvae/core)

Year	Chapel Cove	Bellevue Beach	Eastport	Cape Freels	Twillingate	Hampden	Range
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	–	–	–	–	
$\bar{X}$	5.0	19.8	6.4	5.1	13.0	14.1	

Emergent larvae ('000 larvae/m^3)

Year	Chapel Cove	Bellevue Beach	Eastport	Cape Freels	Twillingate	Hampden	Range
1990	–	841.5	–	–	–	–	
1991	152.5	290.6	232.2	227.5	122.5	23.2	
1992	40.0	922.3	661.7	176.0	311.2	169.3	
1993	92.4	841.5[c]	118.6	228.5	446.6[c]	855.5[c]	
1994	124.3	527.0	10.9	0	17.8	72.1	
1995	23.0	672.3	–	–	–	–	
$\bar{X}$	86.4	682.5	255.8	158.0	224.5	280.0	

'Good condition' emergent larvae ('000 larvae/m^3)

Year	Chapel Cove	Bellevue Beach	Eastport	Cape Freels	Twillingate	Hampden	Range
1990	–	480.0	–	–	–	–	
1991	116.6	210.8	209.5	168.7	117.7	20.5	
1992	39.2	881.0	546.8	155.6	210.9	165.5	
1993	84.0	823.8[d]	89.1	186.6	437.4[d]	820.8[d]	
1994	118.3	411.7	10.4	0	16.9	71.7	
1995	21.8	599.5	–	–	–	–	
$\bar{X}$	76.0	567.8	214.0	127.7	195.7	269.6	

Spawning dates (Julian Day)

Year	Chapel Cove	Bellevue Beach	Eastport	Cape Freels	Twillingate	Hampden	Range
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

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 532.6, 272.3, and 475.3 respectively
d Adjusted to account for sampling ending before larvae had emerged. Unadjusted were 521.4, 265.1, and 456.0 respectively

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

Year	Chapel Cove (3L)	Bellevue Beach (3L)	Eastport (3L)	Cape Freels (3K)	Twillingate (3K)	Hampden (3K)	Mean
Egg deposition Stages I-II eggs ('000 eggs/core)							
1990	–	0.43	–	–	–	–	0.43
1991	0.59	1.14	1.02	1.12	1.78	0.49	1.02
1992	1.70	1.23	1.66	0.55	0.50	0.42	1.01
1993	0.59	1.59	1.30	2.33	1.71	2.39	1.65
1994	0.71	0.90	0.01	0	0.01	0.70	0.39
1995	1.42	0.72	–	–	–	–	1.07
Pre-emergent larvae in beach sediments ('000 larvae/core)							
1990	–	1.32	–	–	–	–	1.32
1991	0.18	0.45	0.56	2.90	1.35	0.19	0.94
1992	1.36	1.01	2.31	0.67	0.70	1.43	1.24
1993	2.40	0.92	1.00	0.45	1.81	2.09	1.45
1994	0.52	0.88	0.09	0	0.14	0.28	0.32
1995	0.52	1.05	–	–	–	–	0.79
Emergent larvae ('000 larvae/m^3)							
1990	–	1.23	–	–	–	–	1.23
1991	1.77	0.43	0.91	1.44	0.55	0.08	0.86
1992	0.46	1.35	2.59	1.11	1.39	0.60	1.25
1993	1.07	1.23	0.46	1.45	1.99	3.06	1.54
1994	1.44	0.77	0.04	0	0.08	0.26	0.43
1995	0.27	0.99	–	–	–	–	0.63
'Good condition' emergent larvae ('000 larvae/m^3)							
1990	–	0.85	–	–	–	–	0.85
1991	1.53	0.37	0.98	1.32	0.60	0.08	0.81
1992	0.52	1.55	2.55	1.22	1.08	0.61	1.26
1993	1.11	1.45	0.42	1.46	2.24	3.04	1.62
1994	1.56	0.73	0.05	0	0.09	0.27	0.45
1995	0.29	1.06	–	–	–	–	0.68
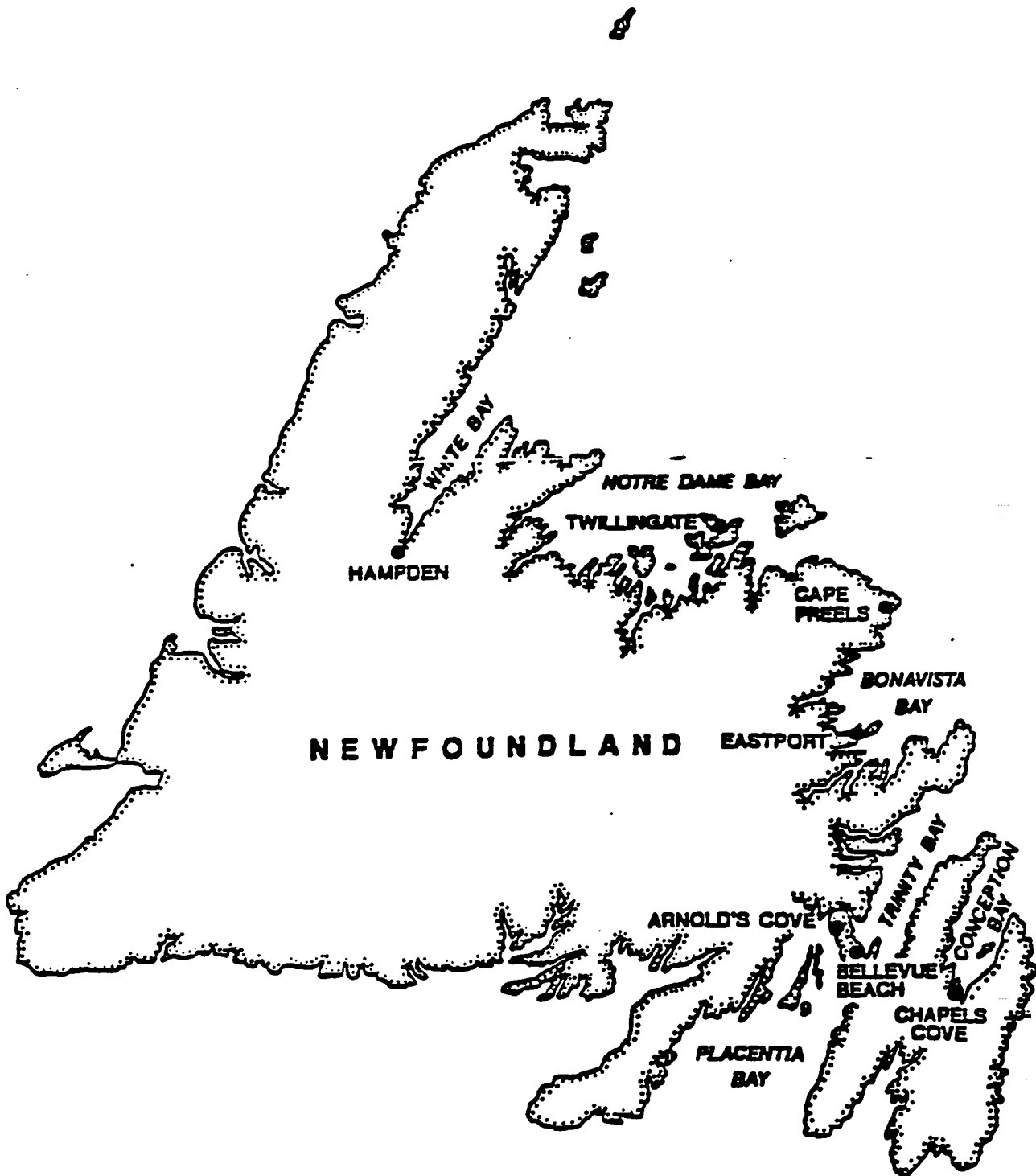
Fig. 1.   Sampling sites.
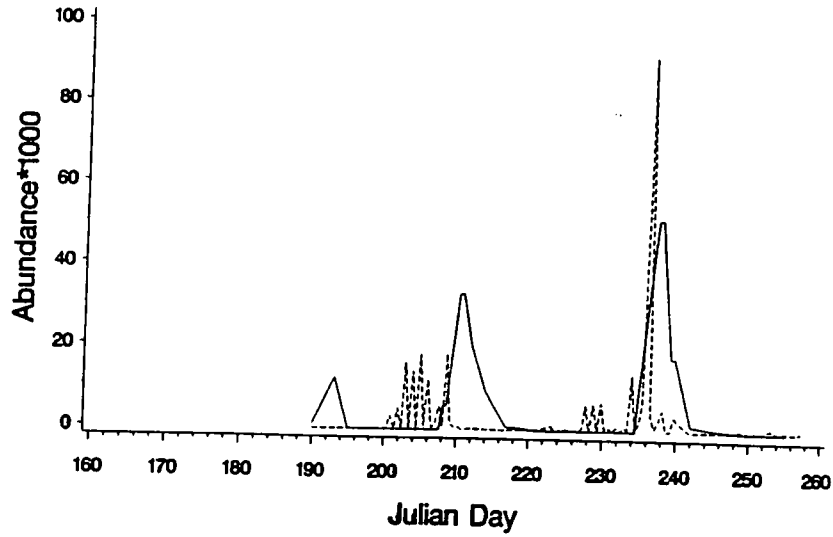
Hampden

YEAR=93

Twillingate

YEAR=93
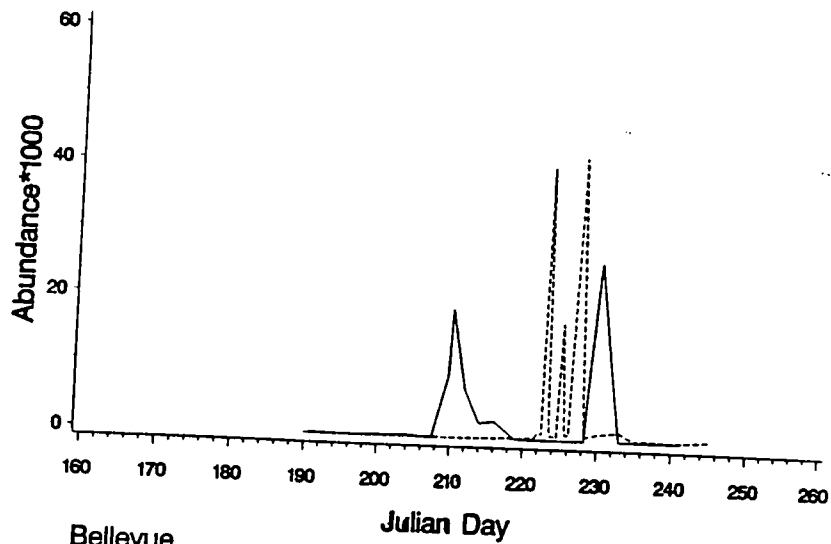
Bellevue

YEAR=93
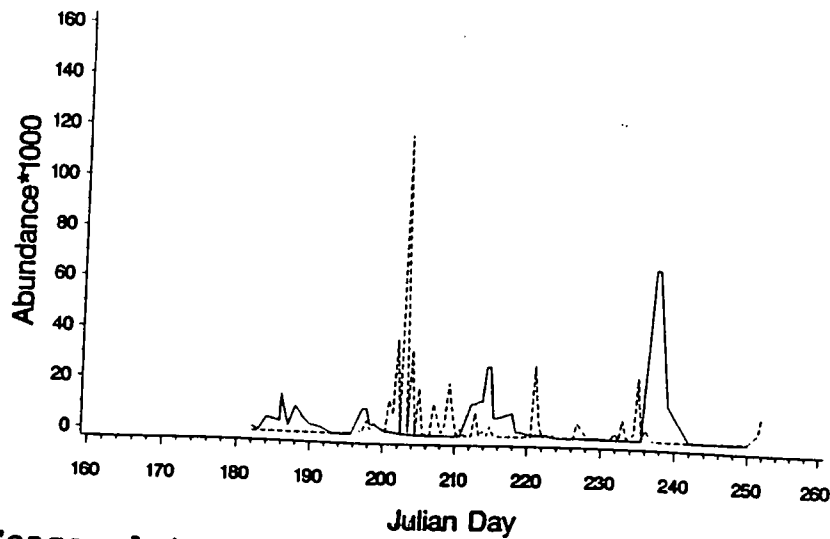
Fig. 2. Seasonal trends in stages I-II eggs/core (—) and emerging larvae/m^3 (---) at Hampden, Twillingate, and Bellevue Beach in 1993.

Chapels Cove   Site: 0   Stage1+2 Eggs

YEAR=95
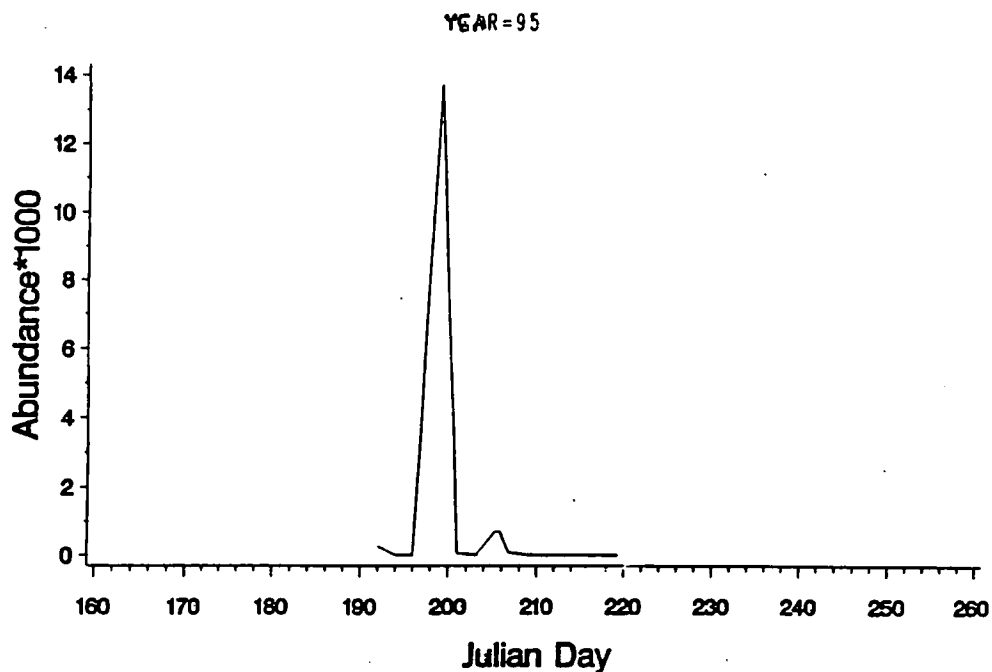
Bellevue   Site: 0   Stage1+2 Eggs

YEAR=95
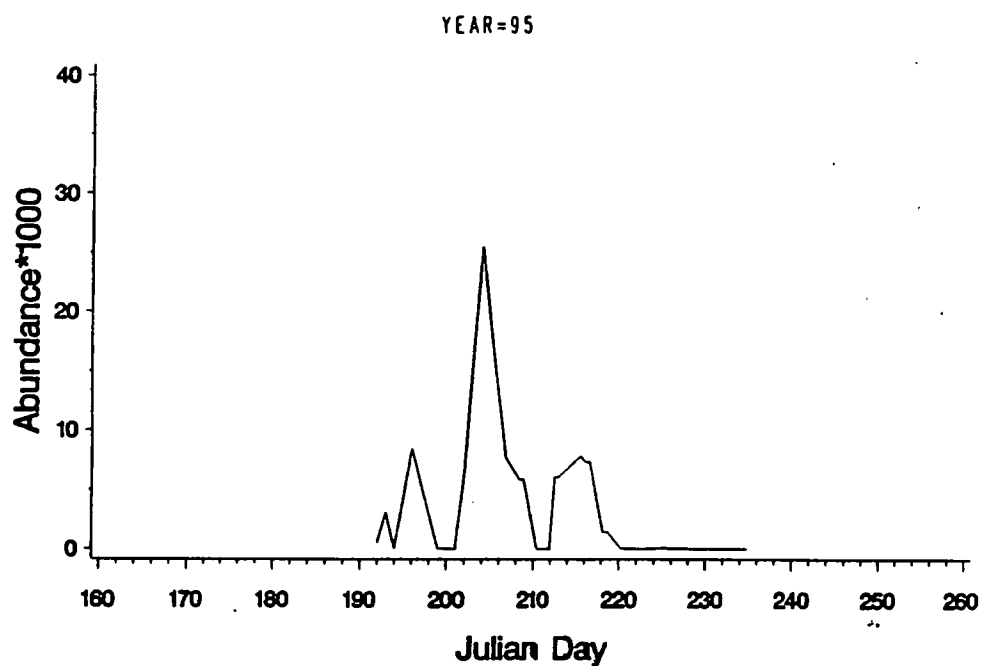
Fig. 3. **Seasonal pattern in egg deposition on Chapels Cove and on Bellevue Beach.**

CHAPEL COVE 95
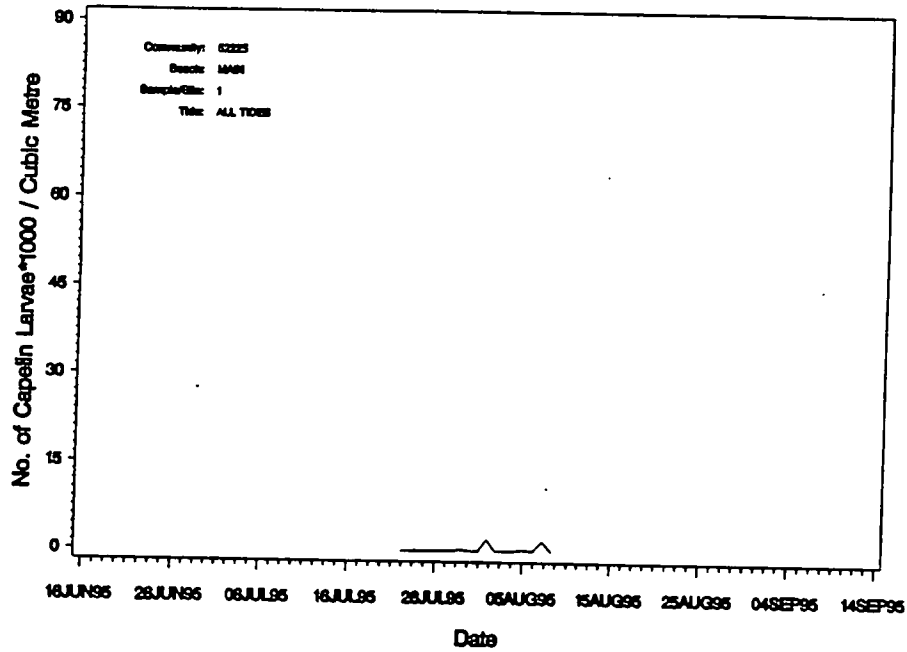
BELLEVUE 95
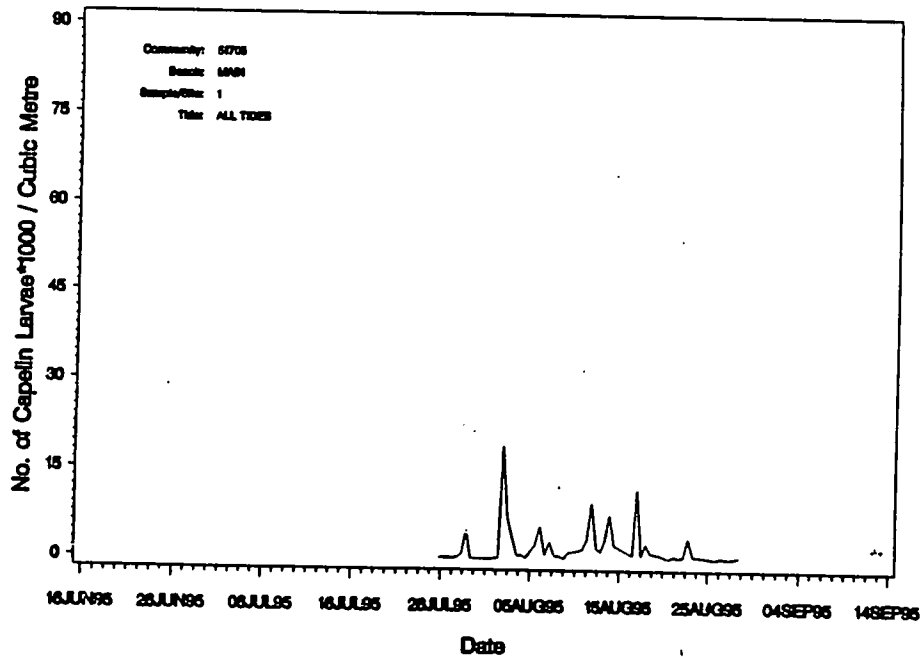
Fig. 4   Seasonal pattern in larval emergence from Chapels Cove and from Bellevue Beach.

APPENDIX A

Adjustment for late spawning in 1993

Site	Main Run				Late Run			
	Eggs	Pre-emergent larvae	Emergent larvae	'Good' condition larvae	Eggs	Pre-emergent larvae	Emergent larvae	'Good' condition larvae
Hampden	90415	8.2	242	233	72240	6.6	195	186
Twillingate	40888	6.6	120	97	26480	4.3	77	63
Bellevue Beach	141561	9.6	283	277	81751	5.5	163	160

Example: For Hampden emergent larvae:

survival for main run = emergent larvae/eggs = 242/90415 = .0027

assuming same ratio for late run, .0027 x 72240 = 195

total emergent larvae = 242 + 195 = 437

ratio of total emergent larvae to main run emergent larvae = 437/242 = 1.80

This ratio is then used to adjust the integrated estimate = 475.3 x 1.80 = 855.5

Bycatch of Capelin in Shrimp Fisheries
in NAFO Div. 2J3K and Div. 3M

by

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Introduction

The shrimp fishery in Hawke Channel + Div. 3K began in 1987 with 1845 tons recorded and expanded such that approximately 11,000 tons were reported for 1994. This fishery has been largely a winter-spring (January-May) fishery (Parsons and Veitch 1995). Canadian vessels have carried fisheries observers since 1987 and capelin bycatch data collected by these observers were examined for this paper.

Capelin were reported as bycatch in the shrimp fishery in Div. 3M in 1993 (Carscadden 1994). In this report I update that information with 1994 data and compare these data from bycatches in Div. 2J3K.

Data Availability

Observers have recorded bycatch information from the shrimp fisheries since 1987. Tow by tow data included date, set location, duration of tow, depth of tow, shrimp and capelin catches. Only data from observed sets were used. For the northern shrimp fishery in this paper I included all catches from Div. 2J (i.e. not just Hawke Channel) and Div. 3K.

Div. 2J3K

Parsons and Veitch (1995) reported that most of the catch and effort occurred in the January-May period, so I grouped annual data for these months.

Details of set locations by year are shown in Figures 1-8. As noted by Parsons and Veitch (1995) there has been a displacement of fishing effort to the east since 1992. In all years, there are many sets with relatively small catches, however, there were several large bycatches as well.

There is little information on overwintering capelin in this area and although the data are limited by the distribution of the shrimp fishing effort, it is clear that capelin were overwintering in the deeper channels.   The mean fishing depth showed little variation between 1988 and 1994 (1987 was somewhat deeper), ranging from 362 to 379 m.   The mean depth of sets with capelin also did not vary greatly, ranging from 363 to 384 m between 1988 and 1994. Between 1988 and 1991 (inclusive) the mean depth of the largest bycatch rates (>100 kg/hr) was shallower than the lower bycatch rates and shallower than the overall mean fishing depths.   However in 1993 and 1994 the largest bycatch rates (>100 kg/hr) were in depths greater than lower bycatch rates and deeper than the mean fishing depths (Table 1).   In all cases, the differences in depth are not great and it is questionable whether the differences are biologically meaningful.

The mean catch rates (kg/hr) rose from a very low value in 1987 to peak in 1989 at about 20 kg/hr and declined steadily to <1 kg/hr in 1994.   The proportion of sets containing capelin also increased between 1987 and 1989 but stayed at a high level (in excess of 70%) until 1991 (inclusive) and declined thereafter (Fig. 9).

If the bycatch in shrimp sets is tracking capelin abundance, then, one would conclude that overwintering capelin in the area have declined substantially since 1989.   However, there are two factors that may be resulting in the pattern observed, independent of capelin abundance.   These are: 1) the general shift in effort to the east since 1992 (Parsons and Veitch 1995); and 2) the introduction of mechanical sorting grates to reduce bycatch.

The impact of sorting grates should not be a problem up to and including 1992.   Even in 1993, few sets were made with the grate, however, by 1994 the grate was heavily used (D. Kulka, pers. comm.).   The impact of the grates on a small fish such as capelin is unknown.   However, Carscadden (1994) reported large, mature capelin caught in the shrimp fishery on Flemish Cap during 1993. This suggests that a range of sizes of capelin are retained using the grate although whether the overall catch rates would be comparable to catch rates without the grates has not been evaluated.   A conservative interpretation of the data would be to accept only data up to and including 1992, although 1993 and 1994 data are included for comparison.

In an attempt to address the impact of the effort moving to the east, I grouped the data geographically into 3 blocks (labelled A, B, and C) as shown in Figure 10 (from Parsons and Veitch 1995). The boundaries were arbitrarily chosen to encompass what visually appeared to be major fishing areas.   Assuming that number of observed sets reflects fishing effort, most of the effort occurred

in Block C (Table 2) although there was substantial effort in the other two blocks as well.

Bycatch rates in Blocks B and C were substantially higher than in Block A (Fig. 11). The catch rates showed similar patterns in the three blocks and similar to the pattern in the entire area (Fig. 9). The proportion of sets with capelin in Block A is lower than the other blocks. The pattern in Blocks A and B is similar to the overall pattern with a decline beginning about 1991. For Block C, the proportion of sets with capelin stayed relatively high until 1992, then dropped abruptly (Fig. 12).

In summary, bycatch rates of capelin declined between 1989 and 1992 as did frequency occurrence, although the latter decline has not been as abrupt. During these years, neither the introduction of the sorting grate nor a shift in fishing effort appears to be a factor. Thus the decline may represent an actual decline in overall abundance or a movement of capelin out of the area during the overwintering period. The decline during this period agrees reasonably well with observations of lack of capelin in these northern areas from the acoustic surveys, bycatch in groundfish surveys and capelin in cod stomachs.

Capelin in Div. 3M

Capelin occurred in 72% of shrimp sets in 1993 but this proportion declined to 55% in 1994. Catch rates also declined from 1.21 kg/hr in 1993 to 0.30 in 1994 (Table 3). Sorting grates were heavily used during the Flemish Cap shrimp fishery (D. Kulka, pers. comm.) so these catch rates probably cannot be related to overall capelin abundance in this area. However, the catch rates are comparable in magnitude to catch rates in the Div. 2J3K area during 1993 and 1994, when presumably similar sorting grates were used.

In both years, the mean fishing depth was generally between 350 and 400 m and capelin tended to be taken, on average, in depths somewhat shallower than the mean fishing depth (Table 3).

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Parsons, D. G., and P. J. Veitch. 1995. Regional, interim review of the status of northern shrimp (Pandalus borealis) resources in areas off Newfoundland and Labrador (Divisions OB to 3K). DFO Atl. Fish. Res. Doc. 95/7, 26 p.

Table 1. Mean dpeths (m) of sets in the shrimp fishery in Div. 2J3K grouped by catch rates, January-May, 1987-94.

Year	No capelin depth (range) (m)	N	0.1-.99 kg/hr depth (range) (m)	N	1-9.99 kg/hr depth (range) (m)	N	10-99.9 kg/hr depth (range) (m)	N	>100 kg/hr depth (range) (m)	N
1987	410 (324-572)	185	394 (358-430)	23						
1988	364 (194-475)	1049	374 (260-439)	262	380 (265-448)	466	366 (265-467)	101	340 (227-418)	15
1989	386 (265-549)	1011	384 (267-487)	753	370 (218-509)	1337	338 (208-500)	583	313 (221-408)	182
1990	390 (240-530)	629	370 (229-511)	565	374 (240-479)	994	363 (266-471)	287	346 (262-420)	66
1991	371 (241-504)	586	368 (260-496)	411	370 (204-498)	689	381 (235-490)	219	356 (289-406)	47
1992	356 (175-571)	964	369 (221-531)	268	366 (210-516)	476	373 (220-500)	163	381 (346-398)	14
1993	363 (187-514)	1774	378 (198-509)	229	382 (205-516)	227	377 (320-494)	42	391 (361-421)	10
1994	379 (187-581)	2576	382 (260-440)	100	392 (353-432)	22				

Year	All sets Depth (m)	N	Sets with capelin Depth (m)	N
1987	408	208	394	23
1988	369	1893	376	844
1989	370	3956	363	2855
1990	375	2541	370	1912
1991	371	1952	371	1366
1992	362	1885	368	921
1993	367	2282	380	508
1994	379	2698	384	122

Table 2.   Number of sets in each block.

Year	Block A	Block B	Block C	Total
1987	144	15		159
1988	166	159	1299	1624
1989	536	229	2750	3515
1990	351	618	1009	1978
1991	423	431	854	1708
1992	186	496	640	1322
1993	13	68	1317	1398
1994	426	6	366	798

Table 3. Details of capelin bycatches in shrimp fishery in Div. 3M, 1993 and 1994.

Year	Month	Total sets	% with capelin	Catch rate (kg/hr)	Mean fishing depth	Mean depth capelin sets
1993	May	183	94.5	1.83	344	344
	June	742	65.3	1.20	387	379
	July	178	77.0	0.70	360	356
	Overall	1103	72.1	1.21	376	367
1994	March	136	33.1	.08	411	360
	April	96	74.0	.43	365	335
	May	368	75.0	.44	327	326
	June	117	3.4	.01	362	313
	Overall	717	55.2	.30	354	331
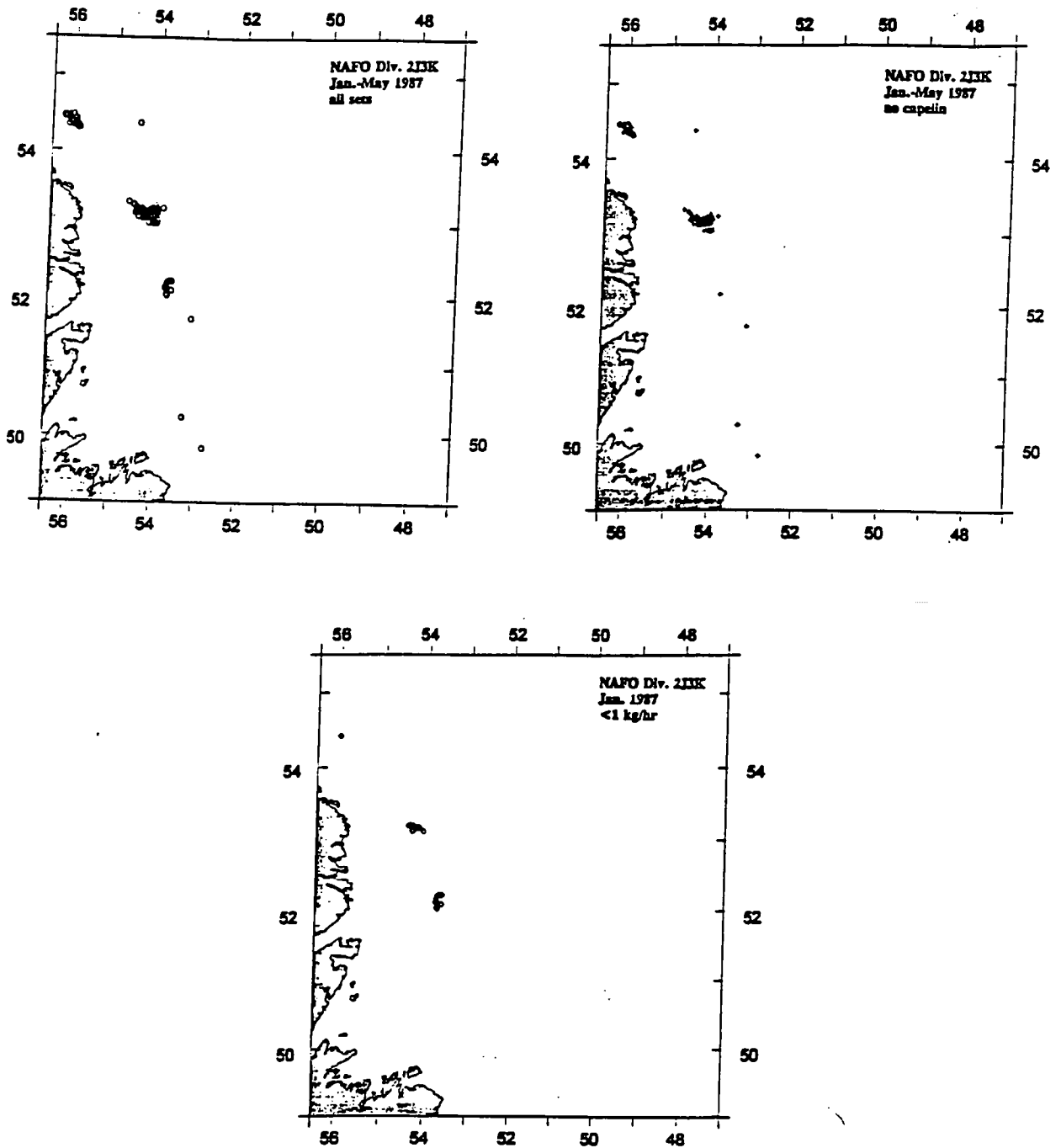
Fig. 1.   Distribution of shrimp sets and shrimp sets with capelin bycatch in Div. 2J3K, January-May, 1987.

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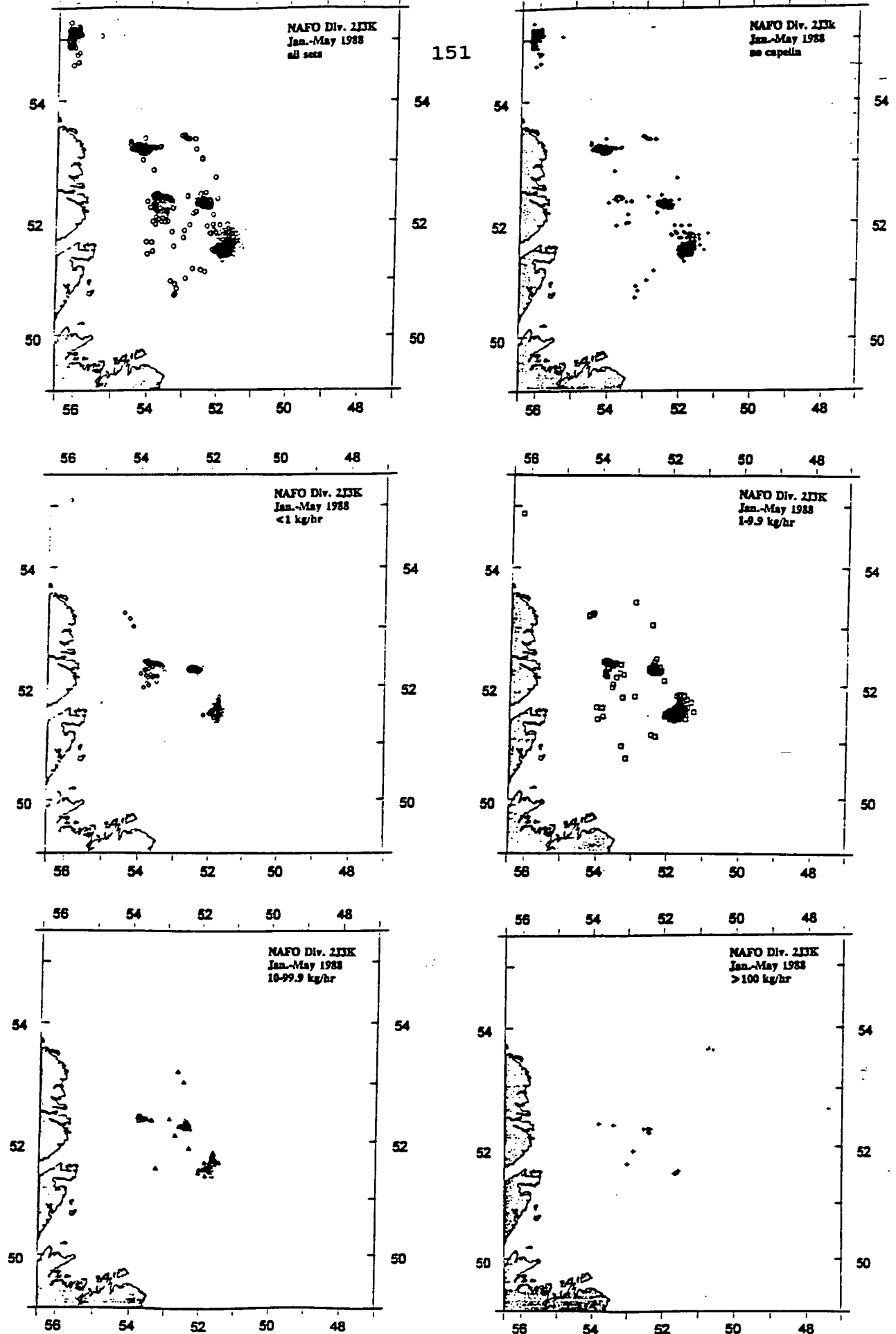
Fig. 2. Distribution of shrimp sets and shrimp sets with capelin bycatch in Div. 2J3K, January-May, 1988.
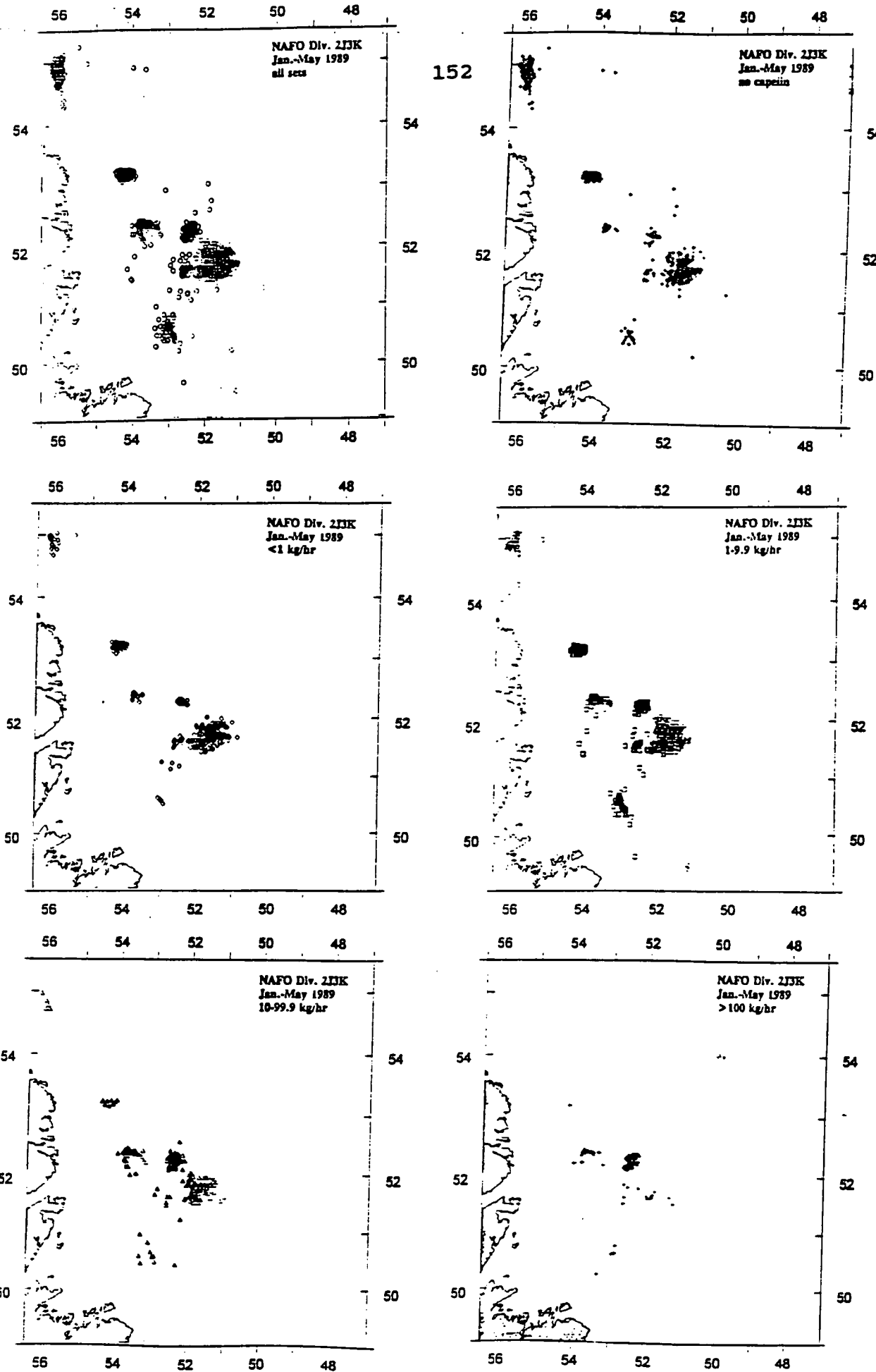
Fig. 3. Distribution of shrimp sets and shrimp sets with capelin bycatch in Div. 2J3K, January-May, 1989.
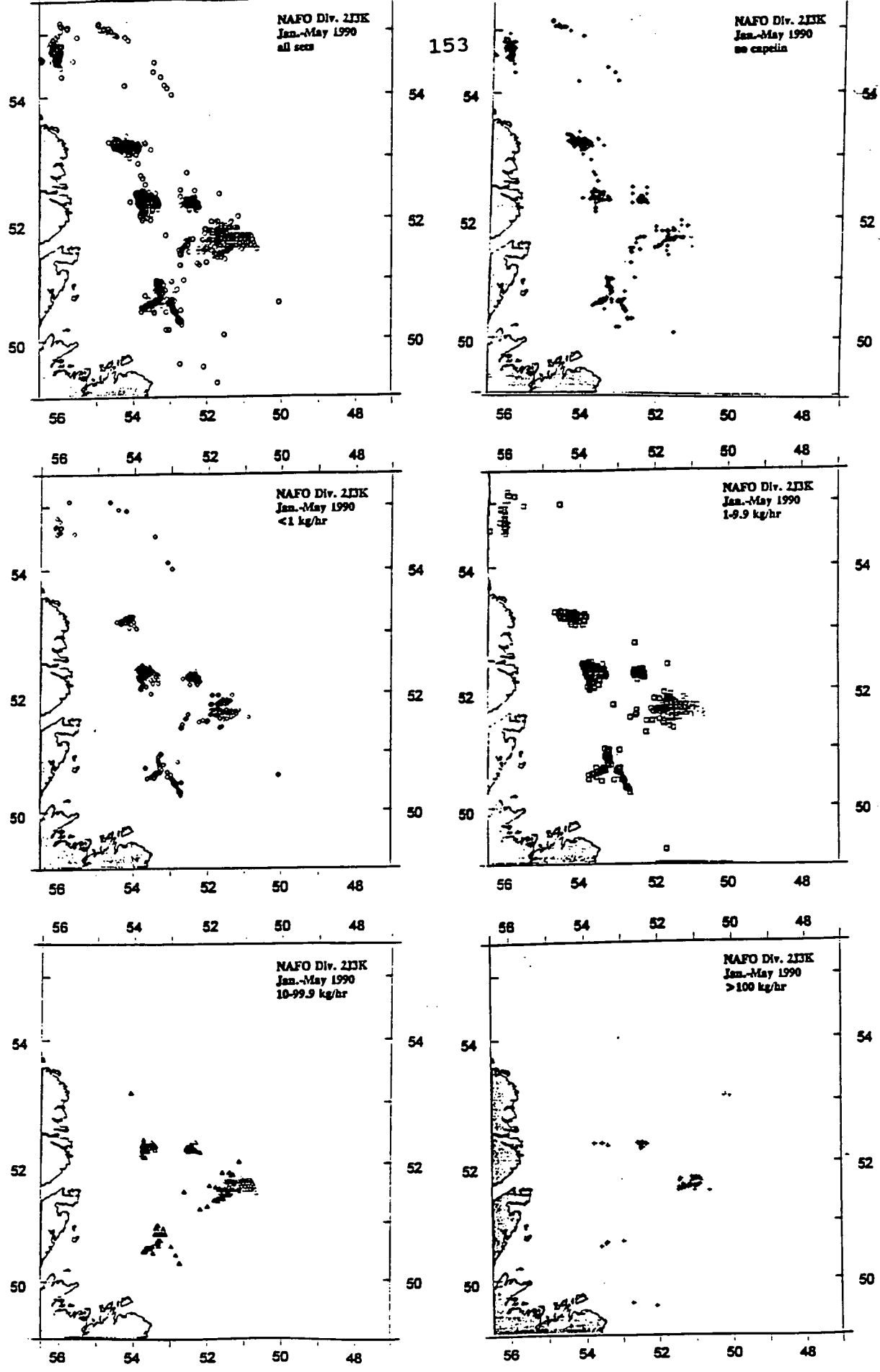
Fig. 4. Distribution of shrimp sets and shrimp sets with capelin bycatch in Div. 2J3K, January-May, 1990.
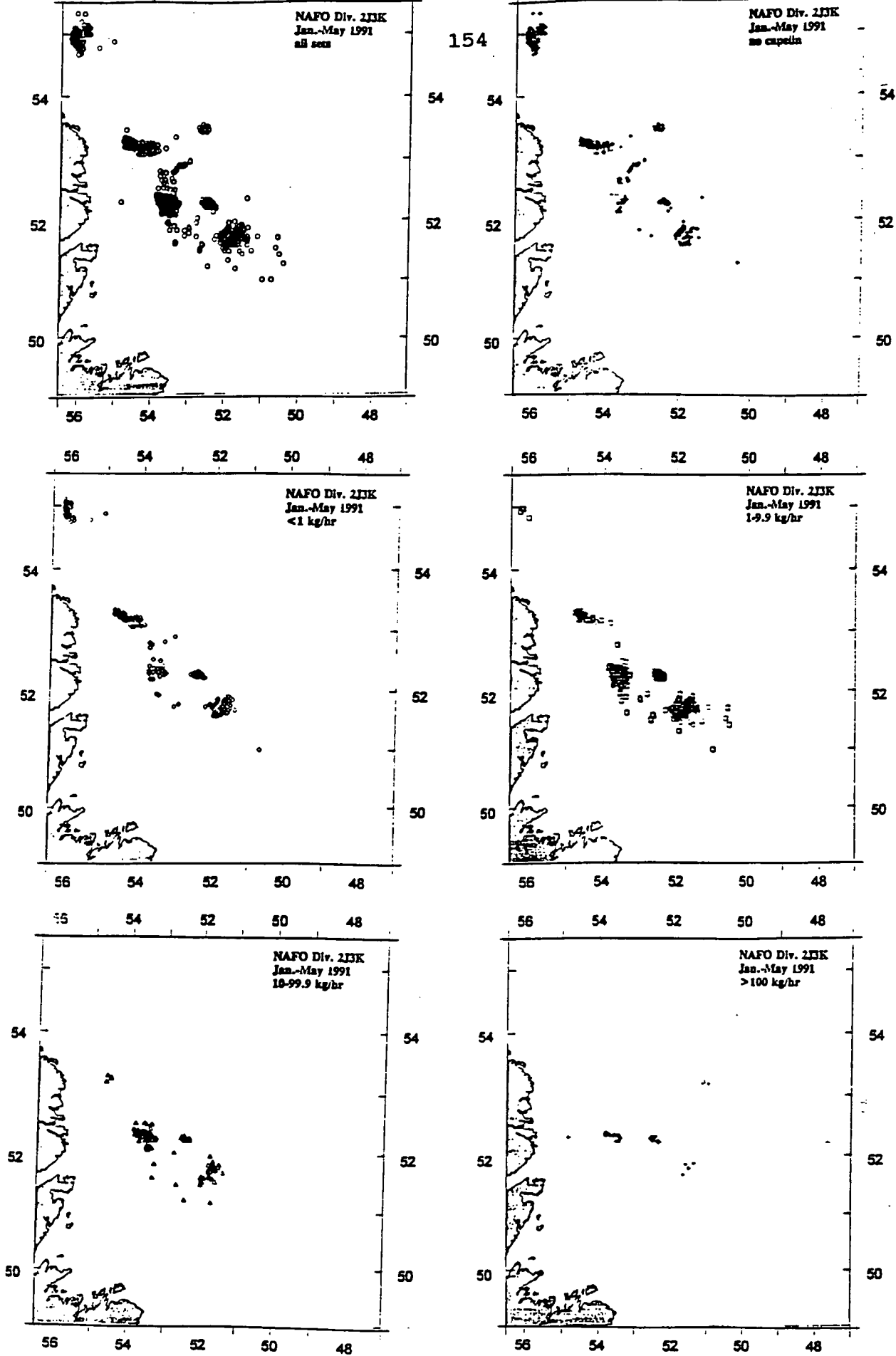
Fig. 5. Distribution of shrimp sets and shrimp sets with capelin bycatch in Div. 2J3K, January-May, 1991.

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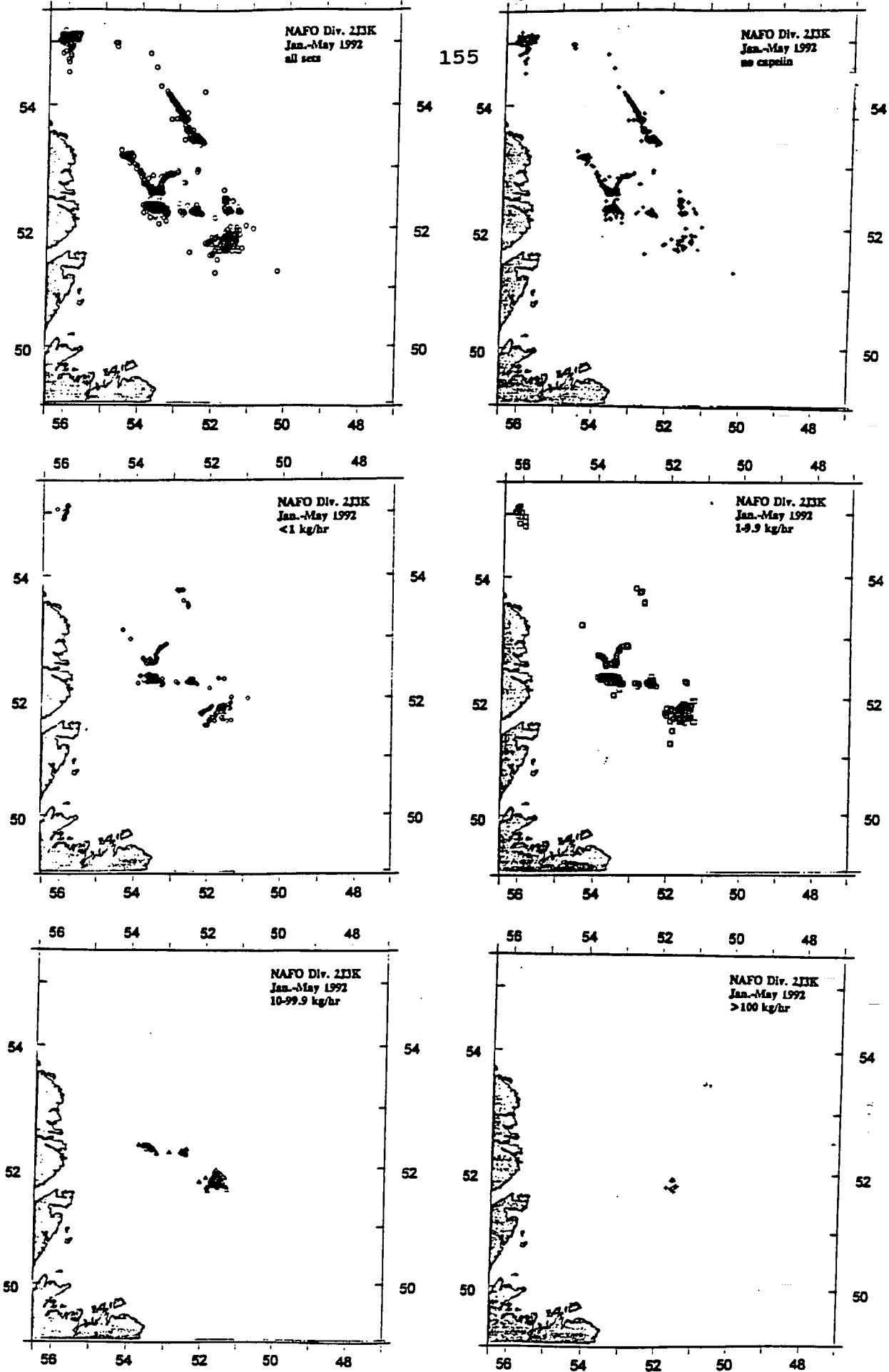
Fig. 6.   Distribution of shrimp sets and shrimp sets with capelin bycatch in Div. 2J3K, January-May, 1992.
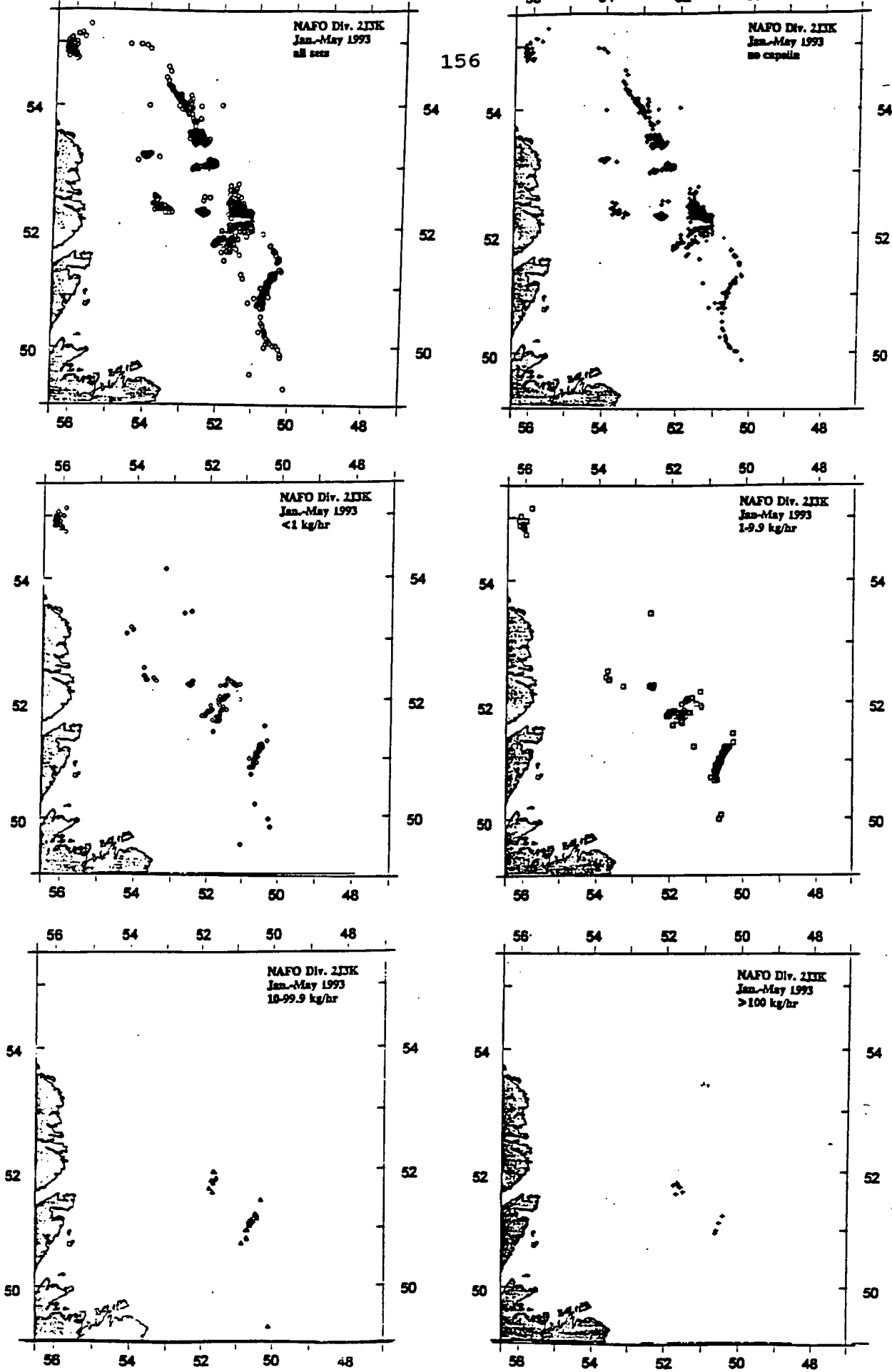
Fig. 7. Distribution of shrimp sets and shrimp sets with capelin bycatch in Div. 2J3K, January-May, 1993.
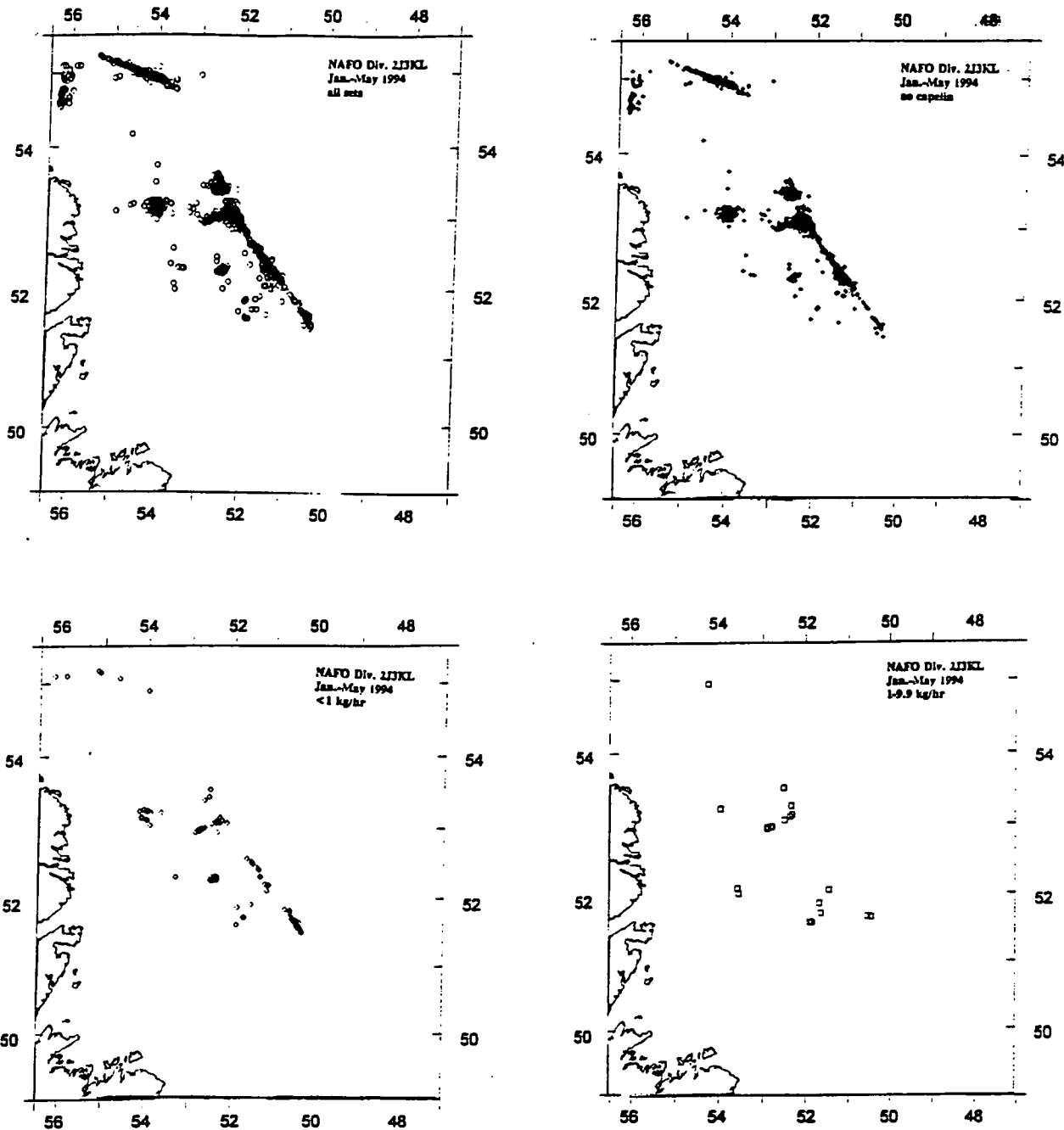
Fig. 8. Distribution of shrimp sets and shrimp sets with capelin bycatch in Div. 2J3K, January-May, 1994.

Capelin in Shrimp Sets
Div 2J 3K Jan-May
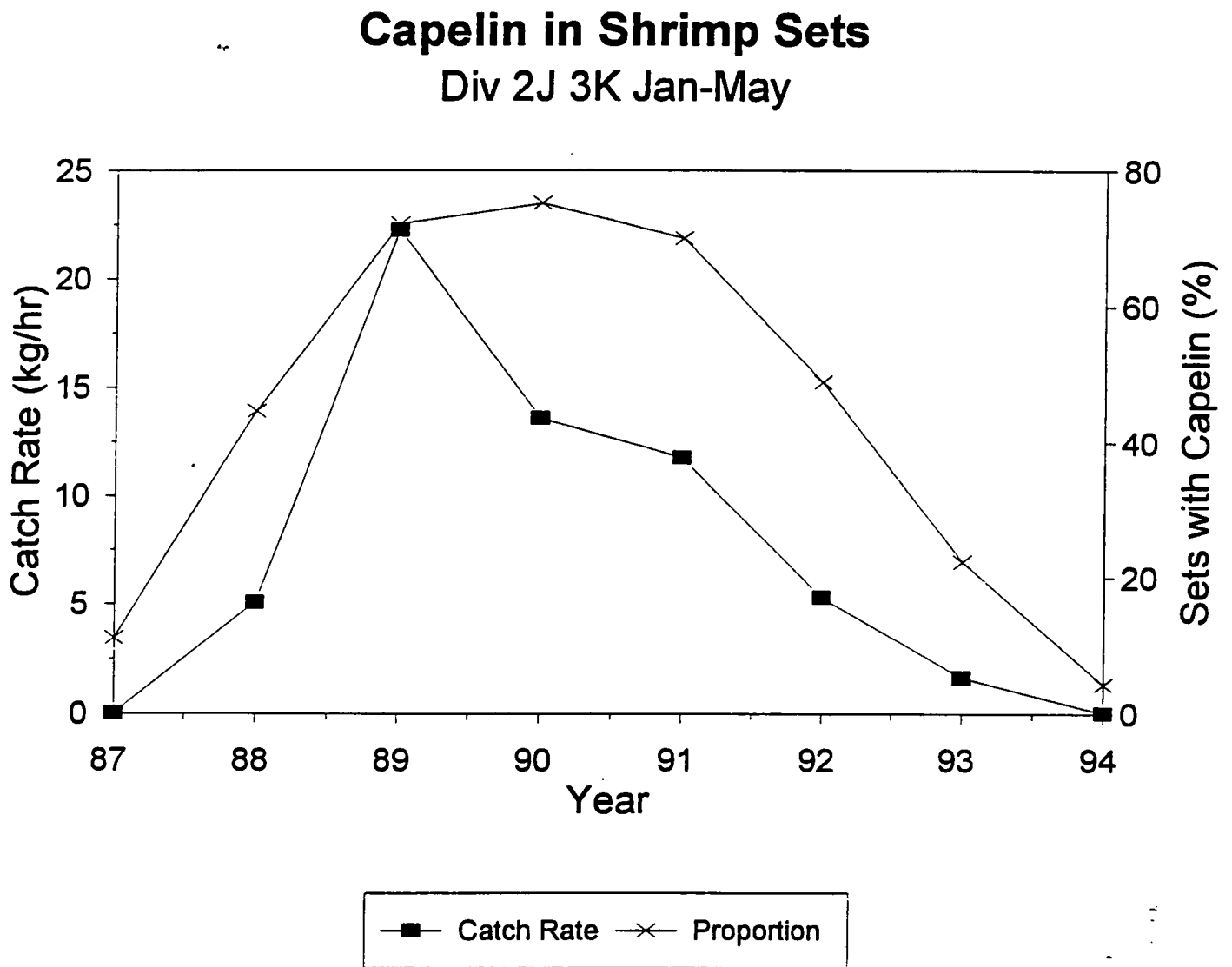
Fig. 9. Catch rates (kg/hr) of capelin and percentage of sets with capelin in shrimp fishery in Div. 2J3K, January-May, 1987-94.
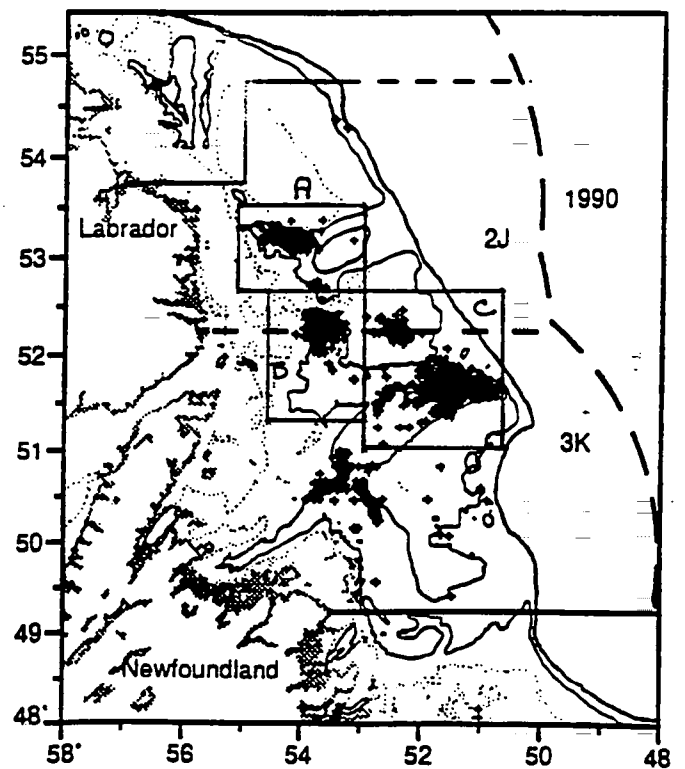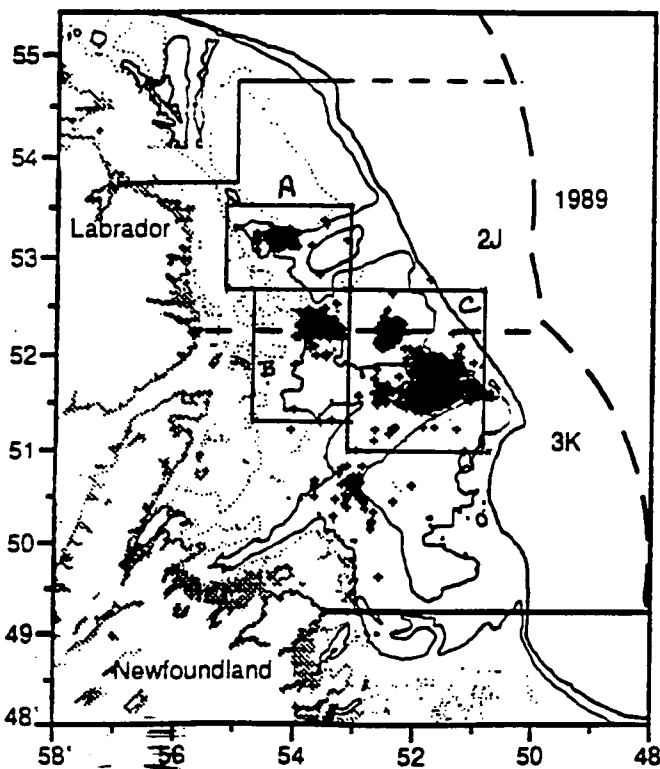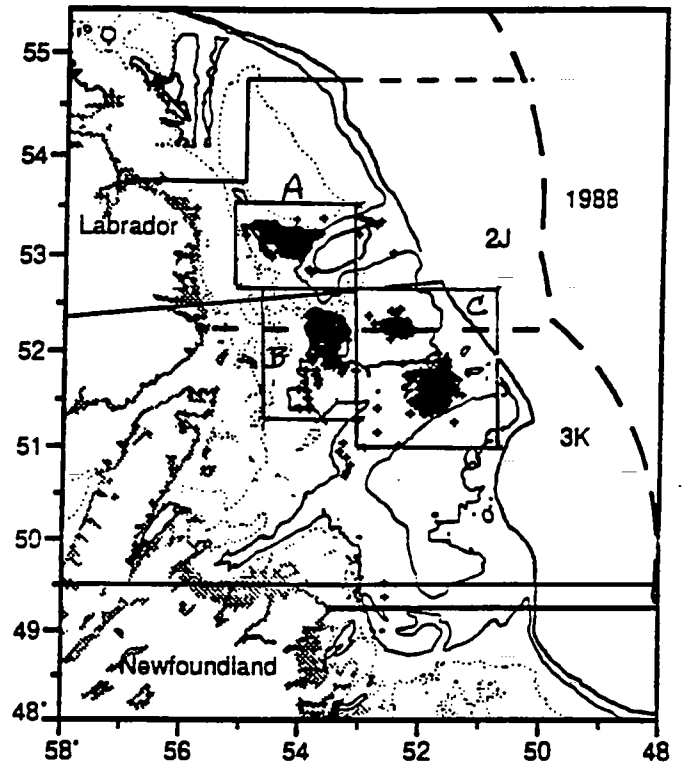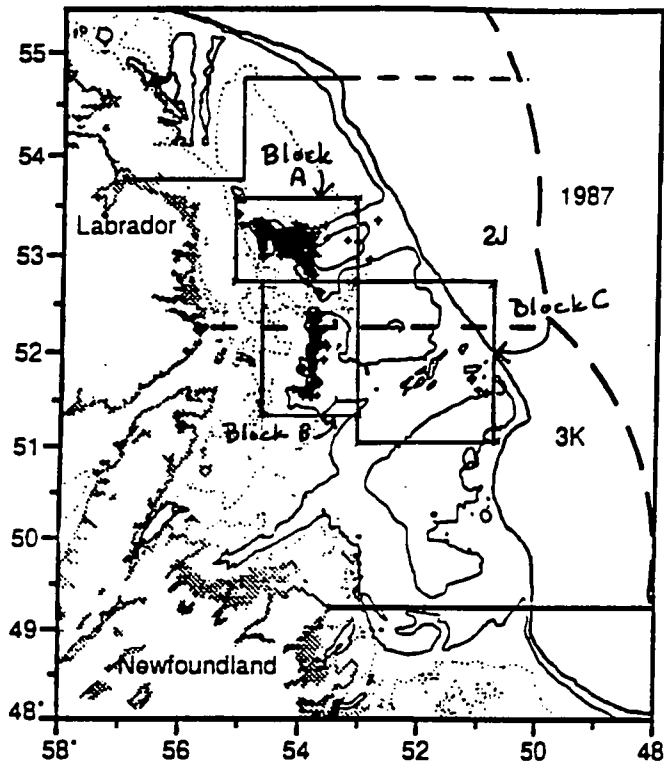
Fig. 10.   Location of shrimp fishery in Hawke Channel and
Div. 3K, 1987-94 (from Parsons and Veitch 1995), showing
Blocks A, B and C used in the present analysis.
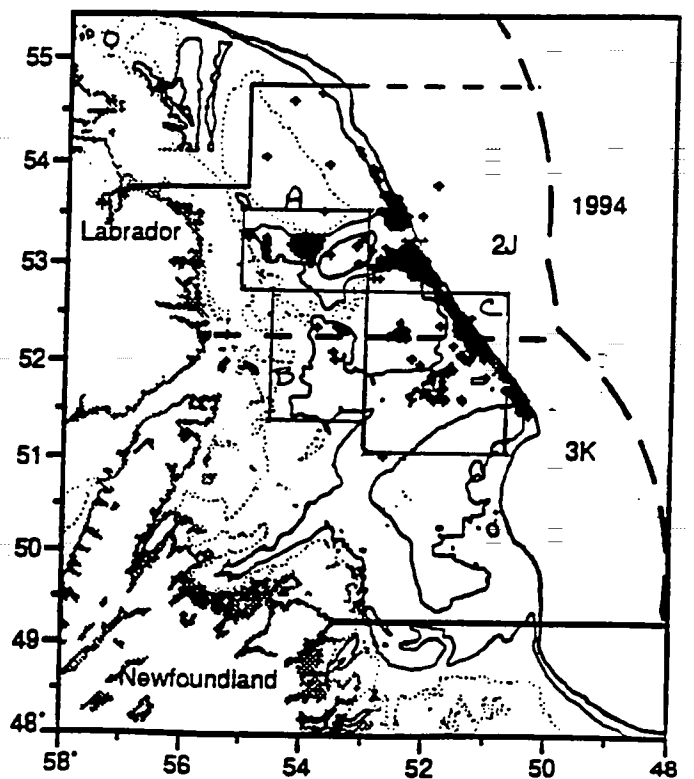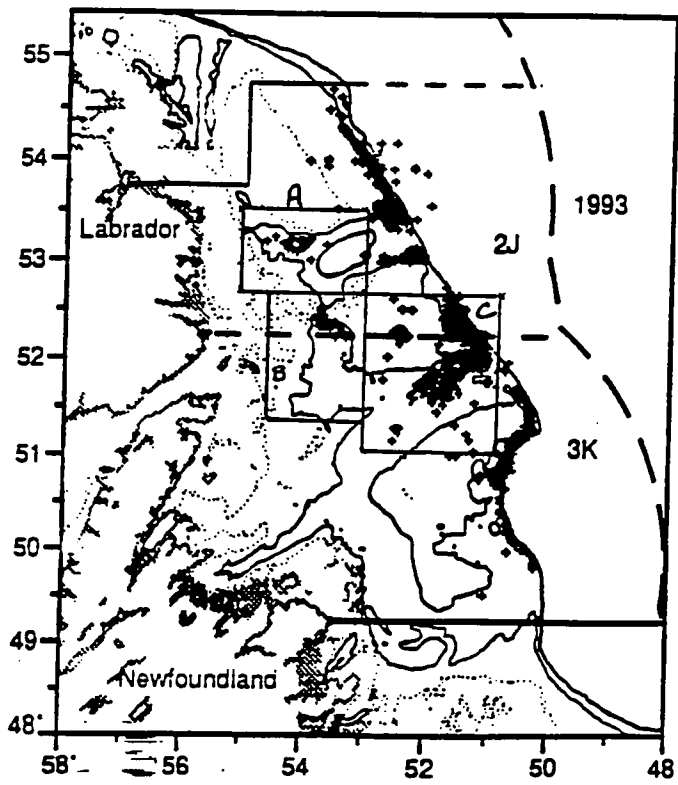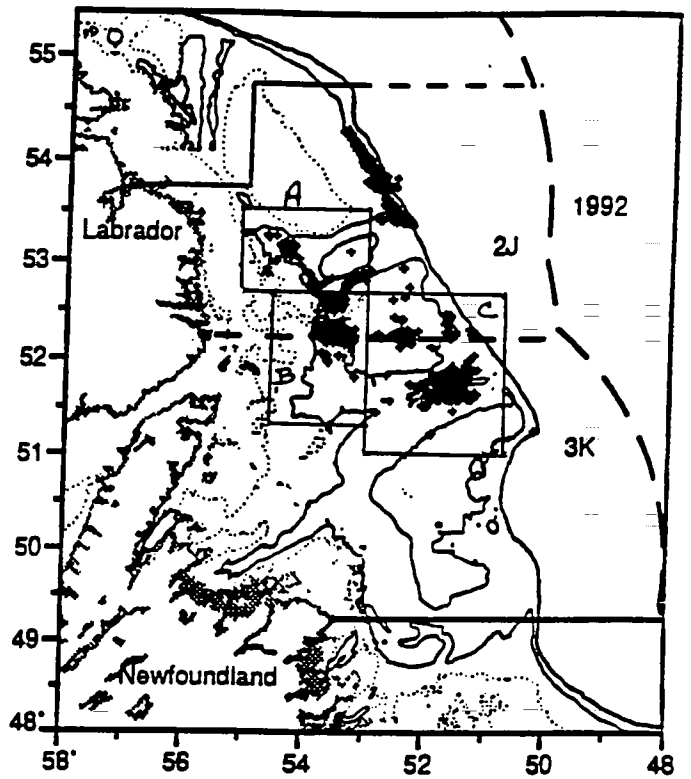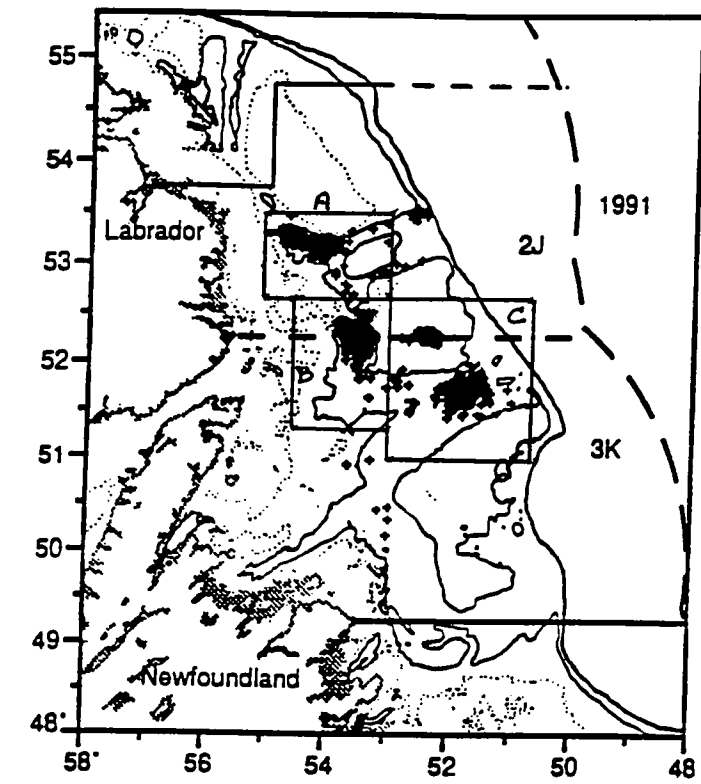
Fig. 10.   Continued ...
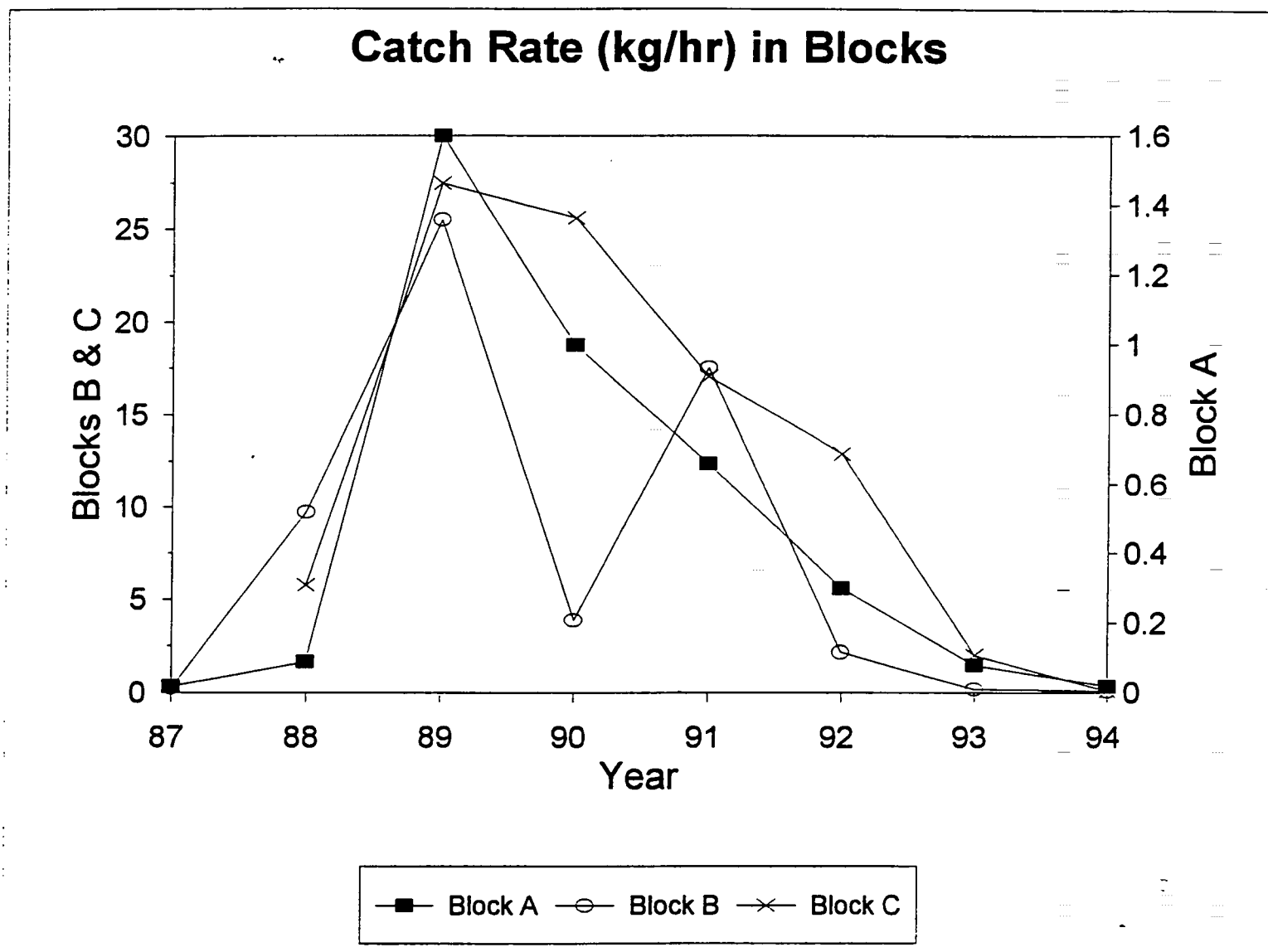
Fig. 11. Catch rates (kg/hr) of capelin in shrimp fishery in Blocks A, B and C illustrated in Figure 10, January-May, 1987-94.

Proportion of Sets with Capelin
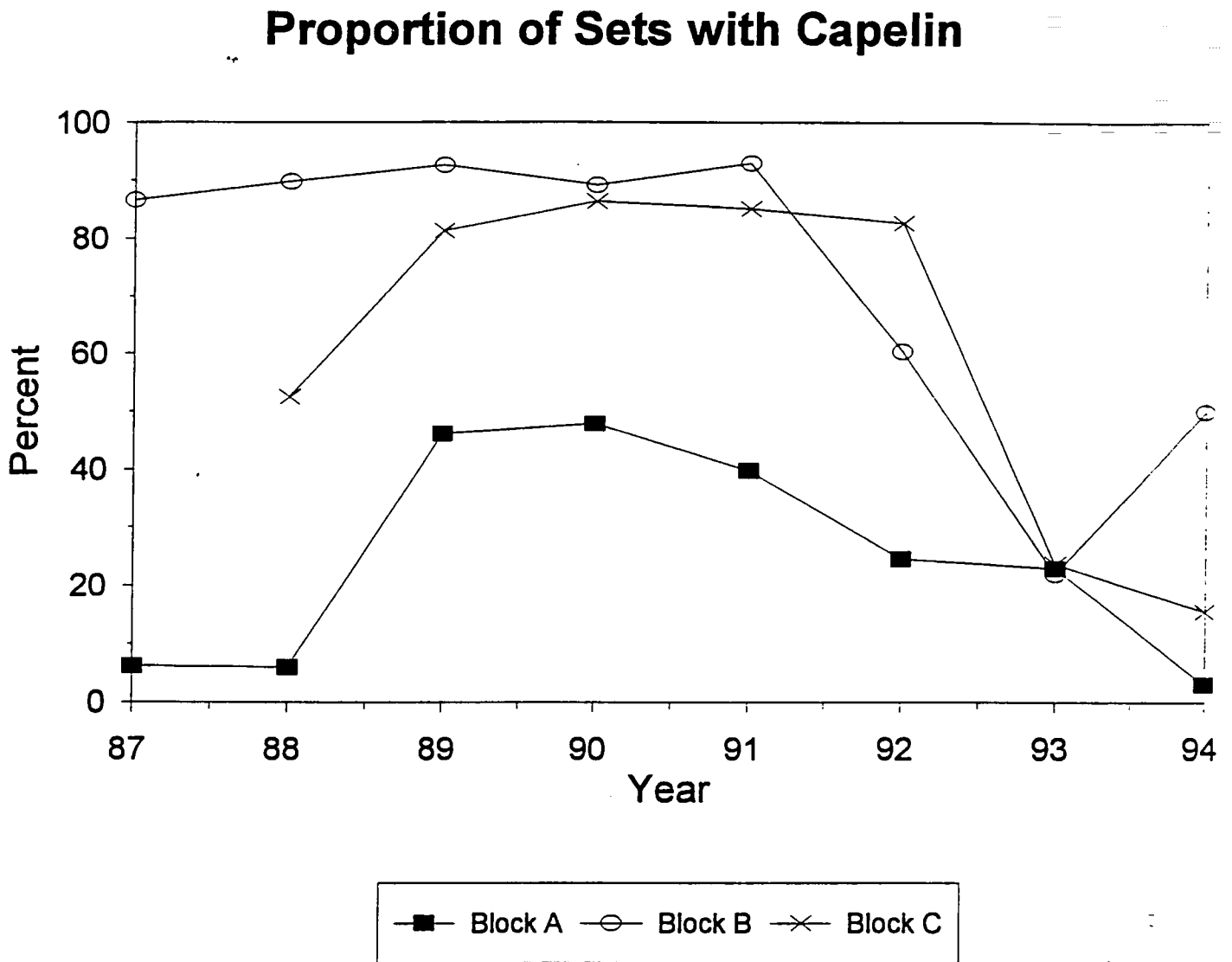
Fig. 12. Percentage of shrimp fishery sets with capelin in
Blocks A, B and C illustrated in Figure 10, January-May, 1987-94.

Results of Breeding Failure of Black-legged Kittiwakes
near Witless Bay, Newfoundland, 1995

by

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Introduction

In recent years Black-legged Kittiwakes (Rissa tridactyla) and other surface feeding seabirds such as Larus gulls (Herring Gull, Larus argentatus, and Great Black-backed Gull, L. marinus) have experienced poor breeding success in many Newfoundland colonies (Neuman 1993, Neuman et al. in prep., Regehr 1994, Regehr et al. in prep., Rodway et al. in prep. a). Failure has been particularly severe in colonies near Witless Bay, se. Newfoundland. Over the same period, pursuit-diving seabirds such as Atlantic Puffins (Fratercula arctica) have bred normally in the same area (Rodway 1994, Rodway et al. in prep. b).

This report documents continued monitoring of the breeding failure of Black-legged Kittiwakes near Witless Bay.

Materials and Methods

Studies were conducted under permit on Great (47°11'N, 52°49'W) and Gull Islands (47°16'N, 52°46'W) within the Witless Bay Seabird Ecological Reserve (Fig. ure 1). Gull Island was visited on 3 July, 7 July, and 9 August. Great Island was visited on 3, 7 and 8 August. On 3 July a study plot containing 73 nest-sites was established within a kittiwake sub-colony on Gull Island (Fig. 2). The position of each nest-site was sketched on a plot map and sites were numbered. On that day and on 7 July, the contents of nests (number of eggs and/or chicks) was determined for as many sites as possible within the plot. The number of adults present at each site also was recorded. The plot was viewed from ca. 20 m away, across an inlet, using binoculars (8x) and a spotting scope (15x). The plot was re-visited on 9 August at which time the contents and the number of adults attending each nest-site was recorded again.

On 3-7 August on Great Island and 9 August on Gull Island areas of kittiwake colony were scanned with a spotting scope (15x) in order to determine the number of older chicks in samples of nests. This is referred to here as the "scan method". Areas scanned on Great Island were a sub-sample of areas scanned by H. Regehr using the same methods in previous years (1992-94; Regehr

1994; Fig. 3). The one area scanned on Gull Island was used as a control plot by J. Neuman in a previous kittiwake study (Neuman 1993; Fig. 2). Dates were chosen so that nests were scanned just before first chicks fledged.

During a scan the spotting scope was aimed at the top of the kittiwake sub-colony and either to the far right or far left of the area to be scanned, such that kittiwake nests filled the scope field. Nests falling within the scope field, and attended by one or more adults were scored as to the number of chicks contained in each (0, 1, 2). Unattended nest-sites were not scored unless one or more chicks were present, in which case the site was included. Nest-sites were scored as "unknown" if the attending adult obscured the contents of the nest. After all nests in a scope field were scored the scope was moved down one scope field and the scan repeated. When the bottom of the sub-colony was reached the scope was moved to the left or right (and up if necessary) such that kittiwake nests again filled the scope field. Scanning ceased when the edge of the kittiwake colony was reached or when the distance to the kittiwake sub-colony reduced the ability of the observer to clearly see nest contents.

Results

1.   Timing of breeding

Timing of breeding of Black-legged Kittiwakes was not studied in detail in 1995 but could be inferred from observations of hatching. During observations on Gull Island in early July, nests contained either eggs, very young chicks or and egg and chick suggesting that early hatching was underway. The incubation period for kittiwakes is 27 days (Lack 1968) thus first eggs were likely laid in early June.

2.   Breeding success derived from "scan method"

Results of the nest scans late in the fledging period are in Appendix 1. Of 2,394 nests checked, 66% contained no chick, 14% contained one chick, and 1% contained 2 chicks. The number of chicks per nest could not be determined in 19% of nests, usually because an adult was sitting in an incubation posture on the nest. It can be safely assumed that these nests did not contain one or more large chicks and if they were in fact empty, the proportion of nests containing no chicks increases to 85%. These figures indicate that kittiwakes on Great and Gull Islands experienced significant breeding failure in 1995.

Figure 4 shows differences in the proportion of nests containing 0, 1, 2, and unknown chicks for each of the sub-colonies scanned on Great and Gull Islands. Breeding failure was consistent across sub-colonies although there was some variation in

productivity. Kittiwakes in sub-colony I on Great Island (Fig. 3) experienced the highest breeding success with about 30% of nests containing one chick. In contrast less than 5% of nests contained a one chick in sub-colonies D on Great Island and the single sub-colony scanned on Gull Island.

Figure 5 compares the breeding failure experienced by Black-legged Kittiwakes on Great and Gull Islands in each year since 1990. The severity of failure has varied between years with an improvement occurring between 1992 and 1994. However, productivity declined again in 1995.

3.   Breeding success at the Gull Island study plot

Of the 73 nest-sites in the study plot on Gull Island (Fig. 2) a minimum of 55% contained eggs and or chicks (active sites) early in the hatching period on 3 July and 5 July. At another 18% of nest-sites an adult was seen in attendance on the nest in an incubating posture. If it is assumed that these birds were incubating eggs or brooding chicks then the proportion of active sites could have been as high as 73%. When the plot was revisited on 9 August, 55% of the nest-sites were attended by one or more adults but not a single nest-site contained one or more chicks-breeding failure was complete in the this plot.

The causes of the total failure are unknown but observations made on 3 July and 5 July show that young chicks were falling from nest sites into the sea below. During a two-hour observation period on 5 July, two small chicks (probably 1-2 days old) were observed to fall from their nest sites into the sea (one chick was from inside the plot and the other was from outside). Within a few minutes both chicks had died likely due to hypothermia.

The reason these chicks fell out of their nests is unknown but observations at nest-site no. 52 on 3 July suggest on an explanation. There, two young chicks were attended by a single parent. Over the course of about an hour, one of the chicks attacked its sibling, vigorously pecking its head and neck. The sibling attempted to evade the attacks by crouching or moving away from the nest-site. At one point the chick moved off the nest and on to the rock in between it and an adjacent nest site (no. 50). The adjacent nest-site had one chick attended by an adult and it appeared on several occasions that the attacked chick was attempting to move into this adjacent nest. While the attacked chick was in between sites out of its nest it seemed to have a precarious foothold on the cliff and easily could have fallen. Observations concluded with the attacked chick back at its home nest-site. On 5 July, both chicks were present at site 52.

Two other observations made at the Gull Island plot over the same period are also noteworthy and may provide other explanations for the severe failure that occurred in this area:

1.   On 3 July an adult was attending a young chick and an egg at site 9. The egg was holed. At 1130 the young chick was observed on several occasions to vigorously peck at the contents of the egg through the hole and consume mucous material from inside the egg. Following this the attending adult pecked at the egg contents through the hole and held on to something in the egg while shaking it. At this point the egg shell broke away revealing a late-stage embryo still being held in the bill of the adult. The adult dropped the embryo onto the nest and the chick immediately attempted to eat the embryo, head-first. The embryo's head appeared too large to be eaten by its sibling and eventually the embryo was left on the nest. At no point was the embryo seen to move so it could not be confirmed whether it was dead or alive when pecked at and subsequently removed from its egg.

2.   On 5 July at nest-site 67 a single adult was in attendance with a young chick and an egg. At 1501 the attending adult was observed eating the liquid contents of its egg. The chick then fed on the egg contents which had spilled out of the egg. When all the egg contents had been consumed or had spilled onto the nest the adult grasped the eggshell in its bill, flew off the nest and out over the sea, and dropped the eggshell into the sea.

4.   Assessing an assumption of the "scan method"

An assumption of the scan method is that attendance at the nest by one or more adults when the survey in done (late fledging period) indicates that the nest previously had been active (i.e., contained one or more eggs or chicks). Adult attendance at nests that were never active would bias estimates of breeding success downwards, whereas, no attendance at nests that were active then failed before the scan would bias estimates upwards.

Of the 19 nest-sites that were not active on 3/5 July, 9 were attended by adults on 9 August and thus included in the scan sample. Of the 40 nests in the study plot that were active on 3/5 July, 18 were unattended by adults on 9 August and therefore were not included in the scan. Thus, the presence of eggs, chicks, or both in the nest in the early hatching period did not appear to affect the chances that the nest-site was subsequently attended by an adult in the late fledging period.

Discussion

Black-legged Kittiwakes at Witless Bay experienced severe breeding failure again in 1995, a pattern which has held since 1990 (Neuman 1993, Regehr 1994). Recent breeding failure seen in Black-legged Kittiwakes nesting in eastern Newfoundland colonies, as well as late breeding and the production of smaller eggs and clutches is thought to result from a combination of reduced food availability and higher predation rates by Larus gulls (Neuman et al. in prep., Regehr et al. in prep.). Larus gulls themselves have likely suffered from reduced food availability as well since their breeding success has also been low in recent years (Rodway et al. in prep. b).

Both kittiwakes and Larus gulls in the Witless Bay area feed their chicks capelin (Mallotus villosus; Maunder and Threlfall 1972, Pierotti and Annet 1987), and they make use of this fish earlier in the breeding season as well. It is becoming clear that significant shifts in distribution, timing, and size at age of capelin have occurred over the past several years in the 2J3KL stock off eastern Newfoundland (Anon. 1995), and it is likely that these changes have reduced the availability of capelin to surface-feeding species such as kittiwakes and Larus gulls. Pursuit-diving seabirds such as the Common Murre (Uria aalge) and Atlantic Puffin (Fratercula arctica), which also feed their chicks capelin (Brown and Nettleship 1982) have bred successfully at Witless Bay in the 1990s suggesting that capelin have been available in sufficient quantities for seabirds that can dive for their food. An added food shortage that Larus gulls have faced has resulted from the closure of most groundfish fisheries in Newfoundland commencing in 1993. Larus gulls make use of fish waste at fish plants and after dumping at sea (Pierotti and Annet 1987), and the fisheries closure has significantly reduced the supply of this food source. Being opportunists, Larus gulls have turned their attentions to kittiwake eggs and chicks as a ready source of food at the colony.

Methods used in 1995 did not allow for a determination of the causes of the breeding failure. However, observations of inter-sibling aggression, and real or attempted egg and embryo consumption by parents and siblings suggests kittiwakes were food stressed in early July. At this time, the first capelin of the year were being brought back to the colony by Atlantic Puffin adults to feed their newly hatched chicks (J. Chardine, pers. obs.) and it seems likely that the same capelin were not available to kittiwakes at that time.

The "scan method" is an efficient means of assessing breeding success in kittiwakes in large samples of nests. A problem with the method is that when the scans are done late in the fledging period, it is difficult to determine if a particular nest was

active earlier in the year and therefore counts as a breeding attempt. In the scan method, the presence of one or more adults in attendance at a nest-site is assumed to indicate that the site was active that year, and thus should be included in the sample. The assumption is based on the observation that after complete breeding failure a kittiwake pair will often attend their nest-site through the breeding season even though they attempt no further breeding. Information presented here suggests that this assumption may not hold, and further that estimates of breeding success derived from the scan method may be biased. At 18 sites, adults were not present during the scan and the sites were empty even though all were active on 3/5 July. The exclusion of these sites that failed to produced any chicks would tend to bias the estimate of breeding success upward. On the other hand, 9 sites were attended during the scan and were included in the sample even though none was active on 3/5 July. The inclusion of these sites would tend to bias the estimate of breeding success downward because some or all of them may never have been active sites. The two biases tend to counteract each other with the net result that estimates of breeding success were biased upwards to a degree. Thus the degree of breeding failure reported here for 1995 is likely conservative and the actual degree of failure may be higher.

This attempt to assess bias associated with the scan method is preliminary because it is based on a single visit to the study plot. Clearly, birds in routine attendance but which happened to be absent at that time of the scan would have been missed. More work needs to be done in a larger sample of plots starting at the beginning of egg laying, before a definitive statement can be made on this aspect of the scan method.

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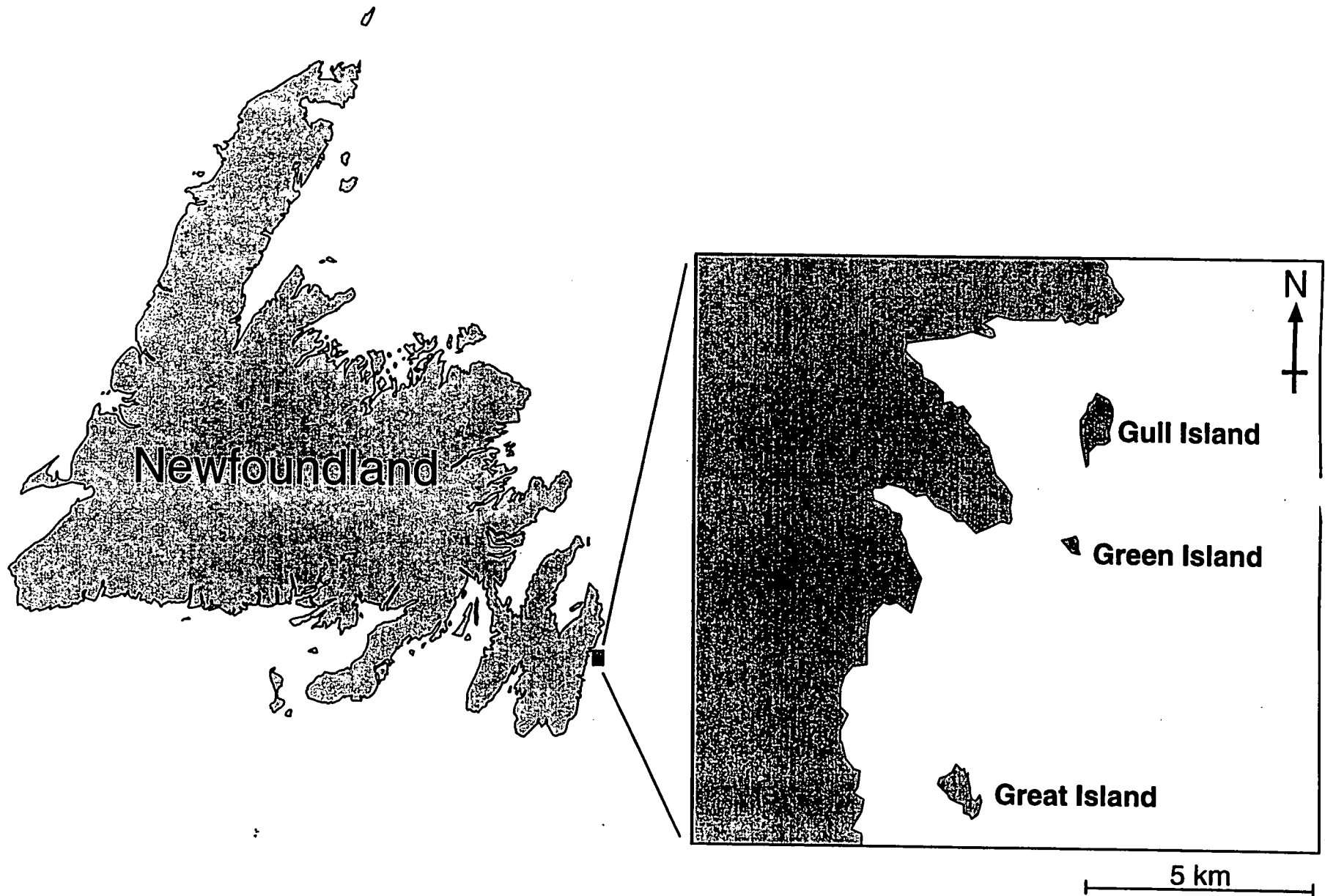
Figure 1. Site map showing location of three main islands within the Witless Bay Seabird Ecological Reserve
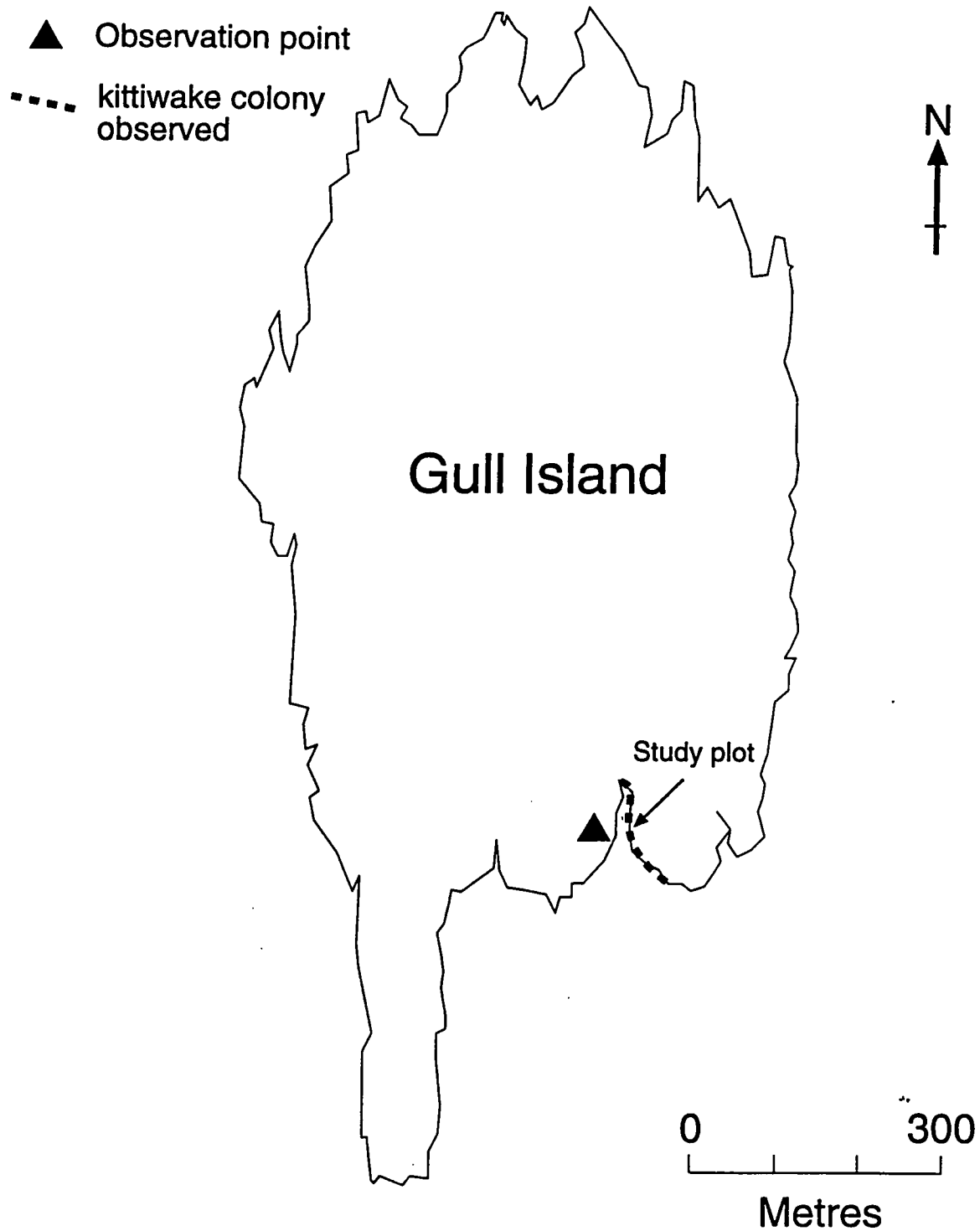
Figure 2. Map of Gull Island showing location of observation point, sub-colony, and study plot of Black-legged Kittiwakes observed using the "scan method"
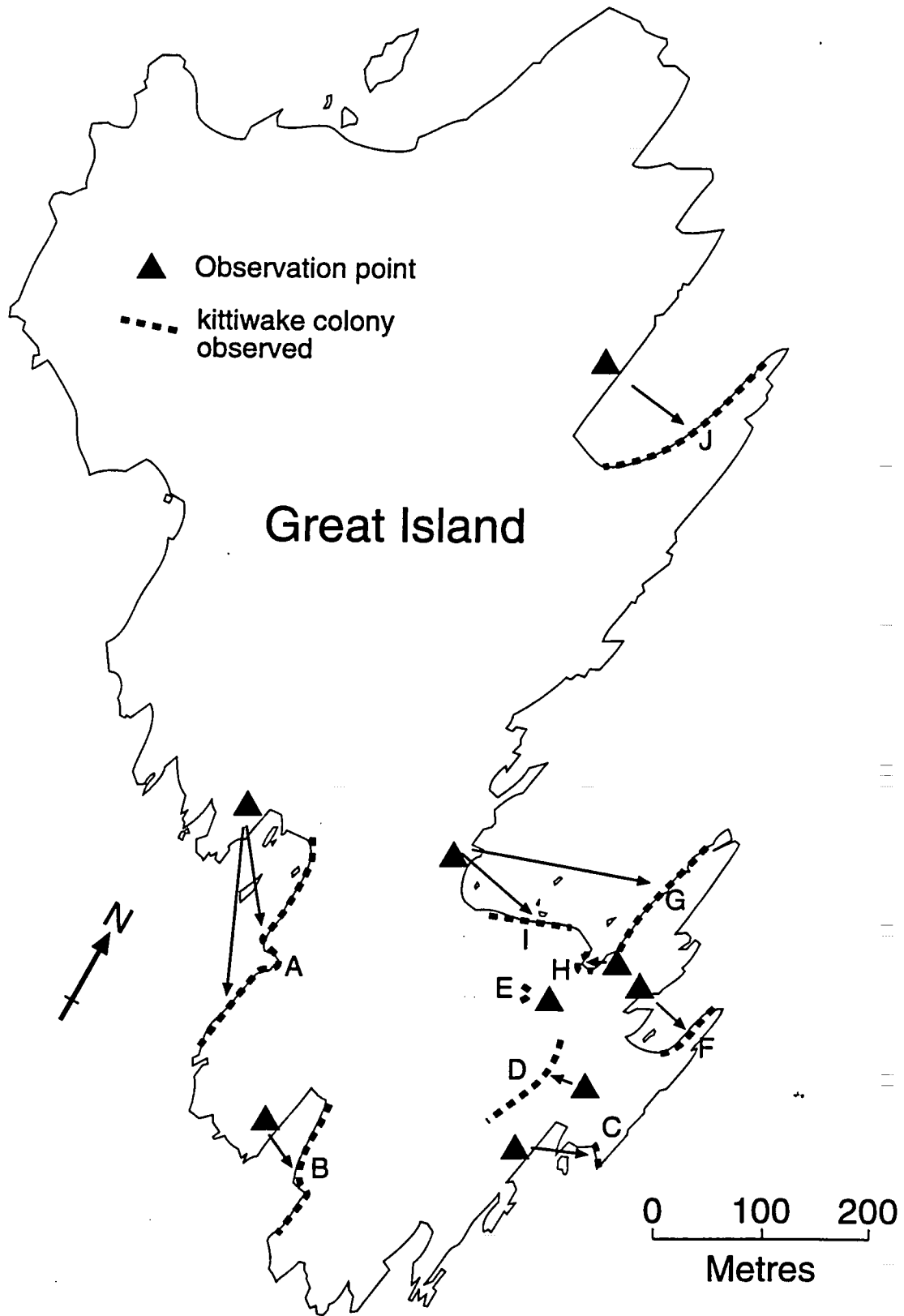
Figure 3. Map of Great Island showing locations of observation points and sub-colonies of Black-legged Kittiwakes observed using the "scan method"
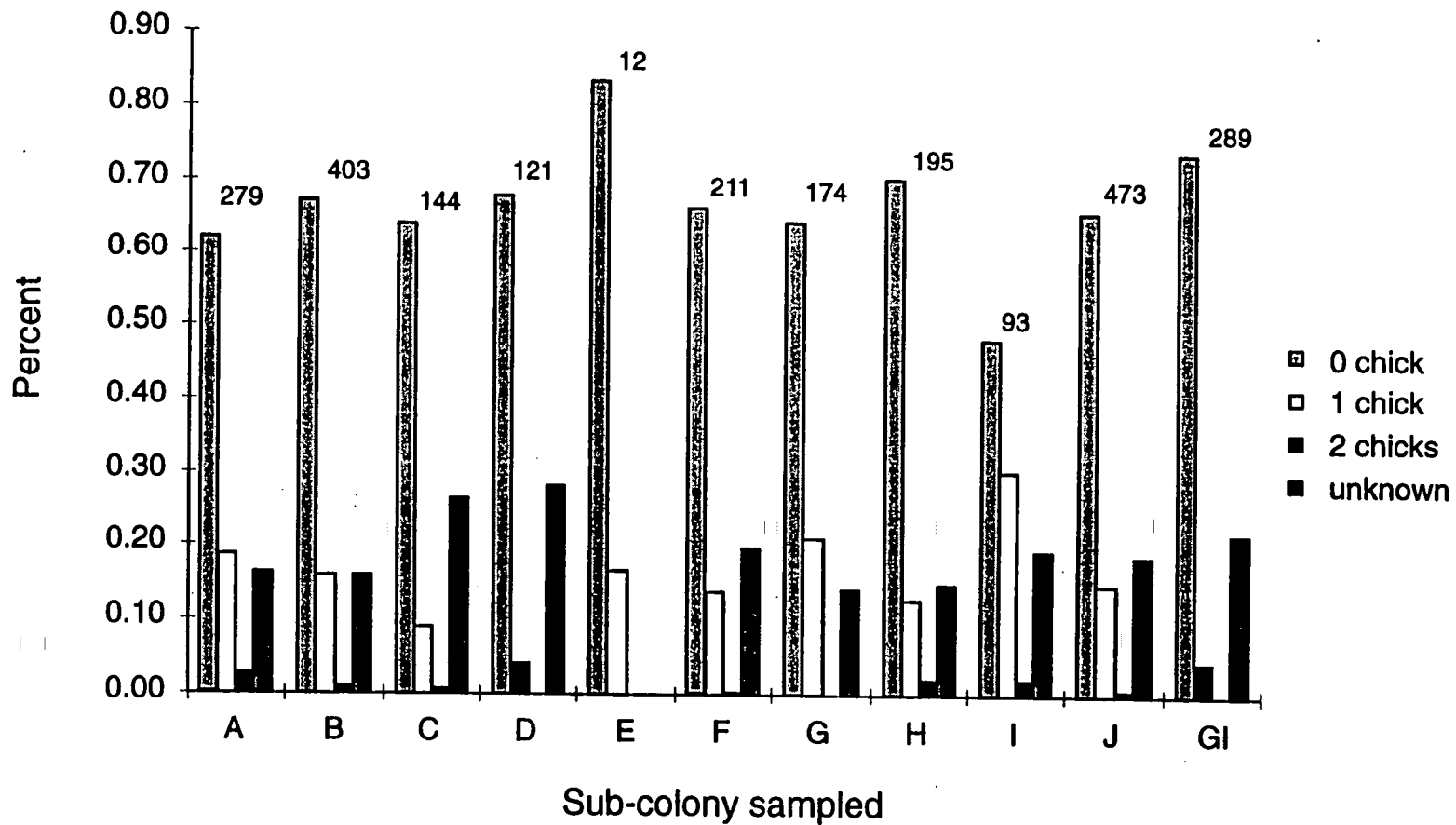
Figure 4. Proportion of nests in each sub-colony containing 0, 1, 2 or unknown numbers of chicks. Sub-colony letters A-J refer to areas on Great Island; sub-colony GI is from Gull Island. Sample sizes for each sub-colony are shown above bars.
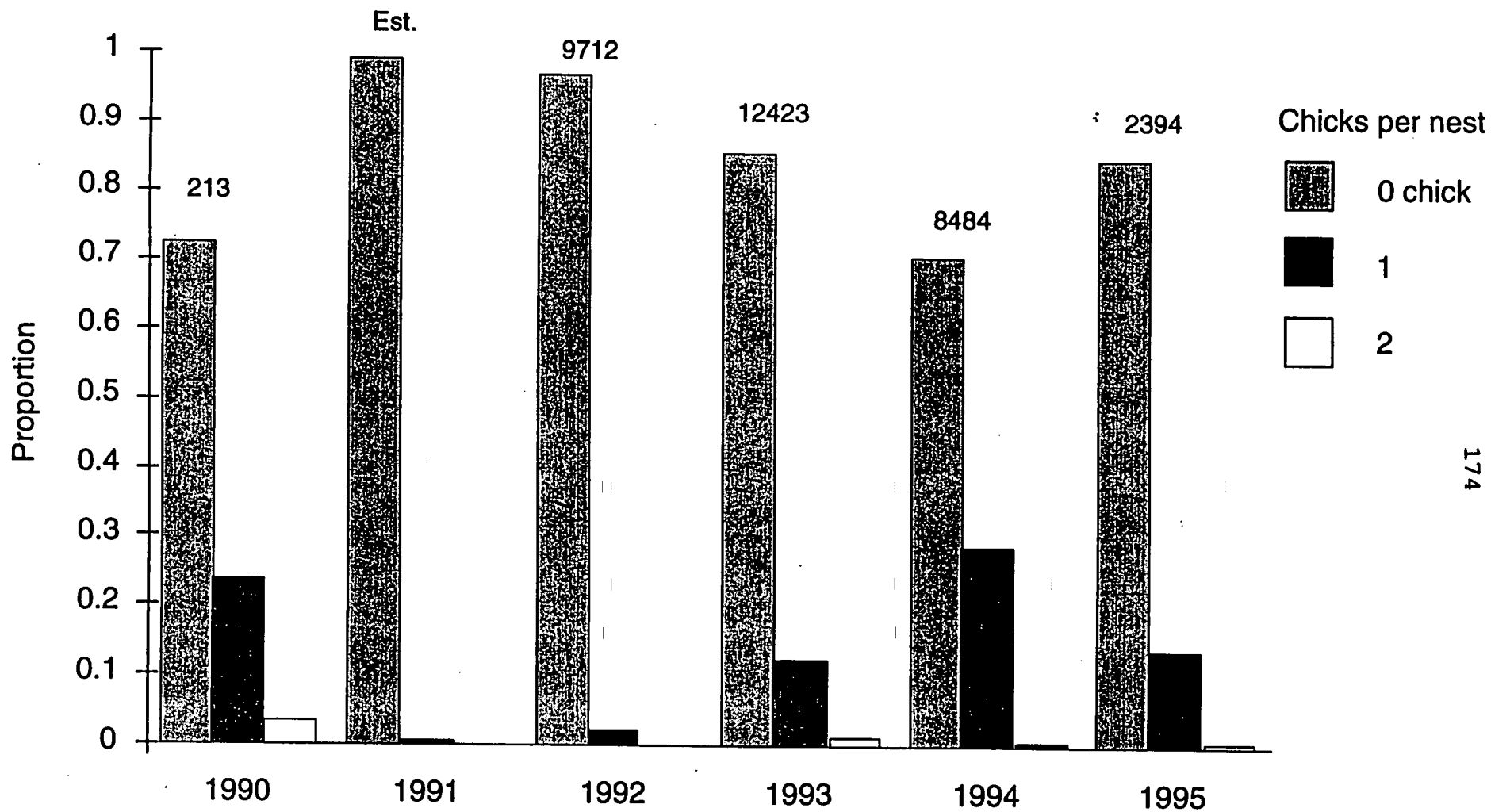
Figure 5. Proportion of nests sampled on Great and Gull Islands that contained 0, 1, or 2 chicks in the late fledging period, 1990-1995. Nests for which the contents was unknown were assumed to contain no chicks. Sample sizes of nests checked are shown.

Appendix 1. Results of surveys of Black-legged Kittiwake nests in sub-colonies on Great and Gull Islands, Witless Bay. Surveys were done in period just before fledging of first chicks: 3-9 August. Sub-colony letter refers to location on Great Island shown in Figure 2.

Number of nest-sites

Chicks per nest

Sub-colony	0	1	2	Unknown	Total
Great Island					
A	173	52	8	46	279
B	270	64	4	65	403
C	92	13	1	38	144
D	82	5	0	34	121
E	10	2	0	0	12
F	139	29	1	42	211
G	112	37	0	25	174
H	137	25	4	29	195
I	45	28	2	18	93
J	311	71	3	88	473
Gull Island	213	13	0	63	289
Total	1584	339	23	448	2394

Observations on the Relationship Between
Acoustic Estimates and Trawl Catches

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Introduction

Historically, incidental catches of capelin in the autumn groundfish trawl survey have occurred in areas where capelin were not detected acoustically in significant numbers. The question has arisen as to whether these incidental catches of capelin represent a significant component of the capelin biomass that is being missed during the acoustic survey. An experiment was conducted in September-October, 1994 to compare estimates by acoustics to trawl catches over the same area to try and determine the relationship between the two techniques. The results of this experiment are presented in this paper.

Methods

A study area was selected between latitude 49^0 and 50^0 30 where capelin were found in abundance during the 1993 and 1994 acoustic surveys. An initial small scale acoustic survey was conducted in this area to locate capelin concentrations and delineate an area where the joint trawling and acoustics experiment would be conducted. Figure 1 show the acoustic transects from the small scale survey. Capelin were detected on the most northerly transects and a series of stations for the trawl/acoustic experiments were selected in this area and to the north as shown by the solid markers in Figure 1.

At each station, two identical short acoustic transects of approximately 9 kilometres were carried out in an east-west direction with the transducer towed shallow (10 metres below the surface) for the first transect and deep (95 metres below surface) for the second transect. After the acoustic measurements were completed, a Campelen bottom trawl set of 15 minutes duration and a IYGPT (International young gadoid pelagic trawl) midwater tow of 30 minutes duration were made over the same ground covered by the east-west acoustic transects. Approximately three hours elapsed between the time of the first acoustic measurements and the last trawl set. The order of trawl sets alternated between stations in order to minimize gear changeover. Measurements of trawl geometry were recorded during each set using a Scanmar system. For catches

containing capelin, a random sample of 200 fish was taken for length, sex, and maturity measurements with a stratified sample for ageing being taken from the length/sex/maturity sample.

At each station, starting and ending positions were recorded for each type of fishing set and a subset of the acoustic data was analysed corresponding to that portion of the acoustic transect that was covered by the fishing set. Capelin backscatter was apportioned based on the ratio of capelin weight to total pelagic catch from the trawl catches. A target strength of -64dB/gram was used to estimate capelin density. Densities were calculated for the first 10 metres above bottom, for 11 to 20 metres above bottom, and for the entire water column (bottom to 5 metres below the transducer. The acoustic density values were applied to the volume sampled by the trawl during each tow (calculated from the Scanmar measurements) to give an acoustic capelin biomass estimate for each of the three acoustic layers to compare to the trawl catches.

Results

Table 1 lists the catches and acoustic estimates in grams for each trawl type. Figures 2 and 3 show scatter plots and the regression lines for IYGPT and Campelen trawl catches versus acoustic estimates. Table 2 gives the parameters of the regressions that were calculated. All regressions were significant at the 1% level.

Figure 4 shows the relationship between shallow and deep acoustic estimates over those portions of the acoustic transects covered by each type of trawl set. Table 3 gives the parameters of the regressions that were calculated.

Discussion

Although the regressions of trawl biomass on acoustic biomass are significant in all cases, the regressions are largely determined by one large value and many near zero values. Examination of the shallow versus deep acoustic regressions show that deep acoustics predict a greater biomass than shallow acoustics (Figure 4). This is particularly evident when examining the acoustic data from Table 1 for the largest catches (sets 35-36 and 53-54). Acoustic data for the smaller catches shows much more variation. The most likely cause of this variation is the fact that the two techniques of acoustic measurement vary both in time and space. In time, the acoustic data may vary up to one hour between measurements being taken. Although the attempt was made to survey exactly the same transect, in reality this is unlikely. If the fish distribution were uniform, this should not cause a problem but capelin are an aggregated species and concentrations do move over time, certainly within the time variation between acoustic

measurements resulting in different concentrations of fish being sampled by the two techniques.

The data from this experiment is limited both in both depth and biomass range and a much larger data set covering a broader range of fish densities and depths is required to better understand the relationship between the two methods of acoustic measurement and trawl catches. Single large estimates separated in time and space that are detected by one technique and not the other do not imply a failure of either technique to detect and measure capelin abundance. To answer the question as to whether incidental catches of capelin in the groundfish trawl survey represent a significant portion of the biomass that is being missed by the acoustic survey, more studies are required.

Table 1. Capelin biomass estimates (grams) for IYGPT and Campelen tows and acoustics.

		Acoustics					
	IYGPT	Shallow	Shallow	Shallow	Deep	Deep	Deep
Set	Catch	Total	0+10	11 to 20	Total	0+10	11 to 20
15	430	6	1	1	43	5	6
19	80	1925	706	4	0	0	0
26	6940	11449	1504	1005	472	194	15
27	4700	6042	2886	640	1180	699	5
30	340	330	0	2	0	0	0
31	60	57	0	0	0	0	0
35	119450	138286	55609	22510	323696	135525	59777
50	20	62	0	0	0	0	0
51	220	235	2	1	11	1	0
54	38550	12531	1024	2453	7534	632	1690
55	220	10915	219	45	14565	407	26
59	240	167	6	4	29	18	0

			Acoustics					
	Campelen		Shallow	Shallow	Shallow	Deep	Deep	Deep
Set	Catch	Total	0+10	11 to 20	Total	0+10	11 to 20	
16	260	0	0	0	1	0	0	
20	2100	155	44	1	0	0	0	
21	3700	327	0	0	15	3	0	
28	4700	203	9	8	454	1	10	
29	1750	32	0	0	0	0	0	
32	530	54	0	0	0	0	0	
33	700	21	0	0	1	0	0	
36	464380	16879	637	2211	343022	94828	36156	
37	490	10	1	0	1	0	0	
40	1090	20	0	0	1	0	0	
41	600	10	2	0	3	0	0	
48	240	7	1	0	0	0	0	
49	6450	210	1	1	2	0	0	
52	1020	4	0	0	2	0	0	
53	167130	10562	587	1301	6785	427	951	
56	9900	1102	43	10	6023	76	5	
57	4000	76	5	0	44	0	0	
60	7550	293	85	3	0	0	0	
61	310	4	0	0	9	3	0	

Table 2. Regression parameters for trawl catches versus acoustics

Independent Variable	Dependant Variable	DF	R^2	F statistic	Significance
IYGPT					
Catch	ShallowTotal	11	0.937	147.7	<.000
Catch	ShallowB-10	11	0.910	100.6	<.000
Catch	Shallow11-20	11	0.956	219.6	<.000
Catch	DeepTotal	11	0.910	101.1	<.000
Catch	DeepB-10	11	0.904	94.6	<.000
Catch	Deep11-20	11	0.918	111.4	<.000
Campelen					
Catch	ShallowTotal	18	0.949	318.6	<.000
Catch	ShallowB-10	18	0.824	79.8	<.000
Catch	Shallow11-20	18	0.961	419.2	<.000
Catch	DeepTotal	18	0.895	145.0	<.000
Catch	DeepB-10	18	0.886	132.1	<.000
Catch	Deep11-20	18	0.899	152.0	<.000

* -not significant at 1%

Table 3. Regression parameters for shallow acoustics versus deep acoustics

Dependant Variable	Independant Variable	DF	R^2	F statistic	Significance
IYGPT					
ShallowTotal	DeepTotal	11	0.990	984.7	<.000
ShallowB-10	DeepB-10	11	0.997	3919.4	<.000
Shallow11-20	Deep11-20	11	0.992	1246.8	<.000
Campelen					
ShallowTotal	DeepTotal	18	0.723	44.3	<.000
ShallowB-10	DeepB-10	18	0.514	17.99	0.001
Shallow11-20	Deep11-20	18	0.754	52.0	<.000
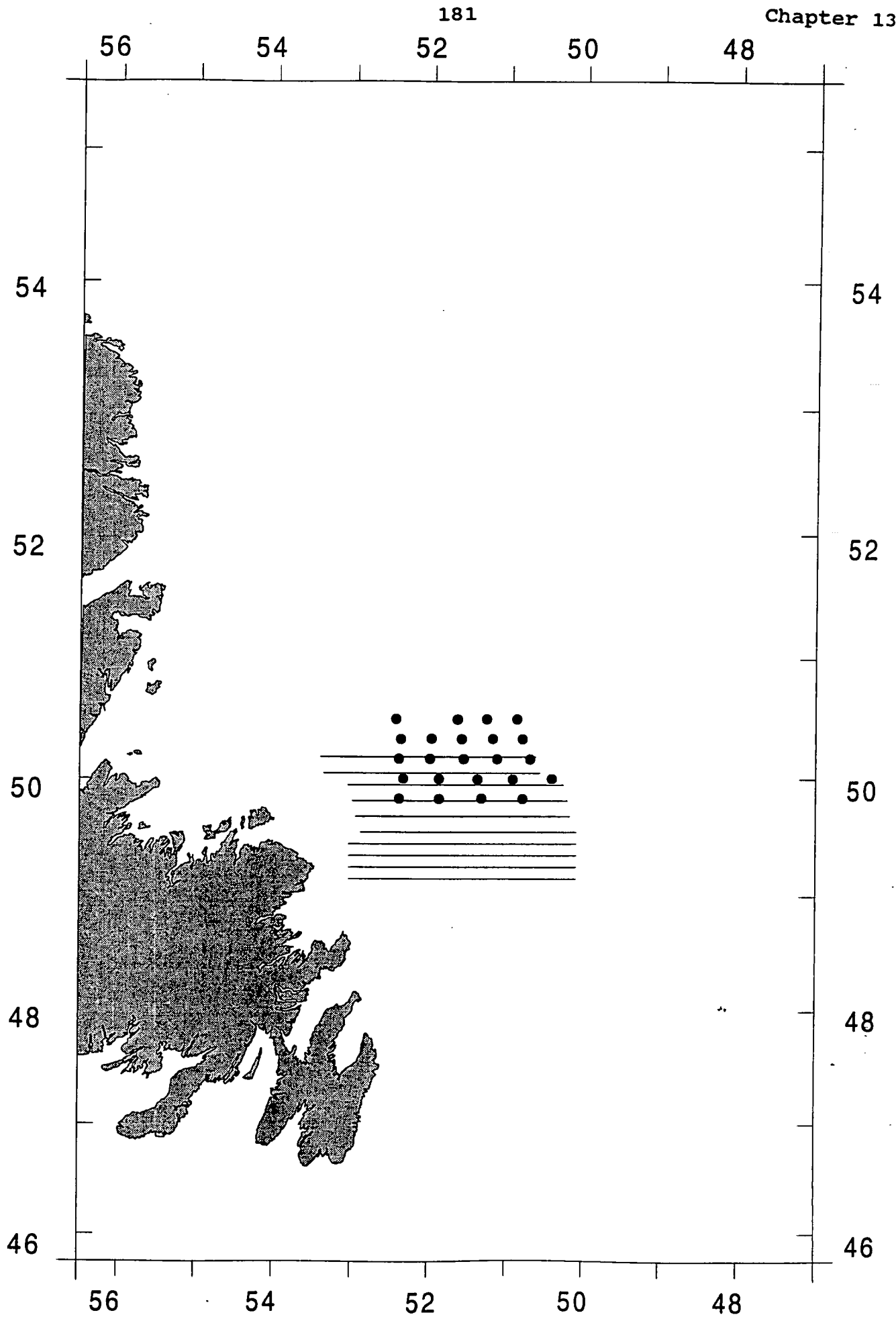
Figure 1.   Exploratory transects and acoustic/fishing stations
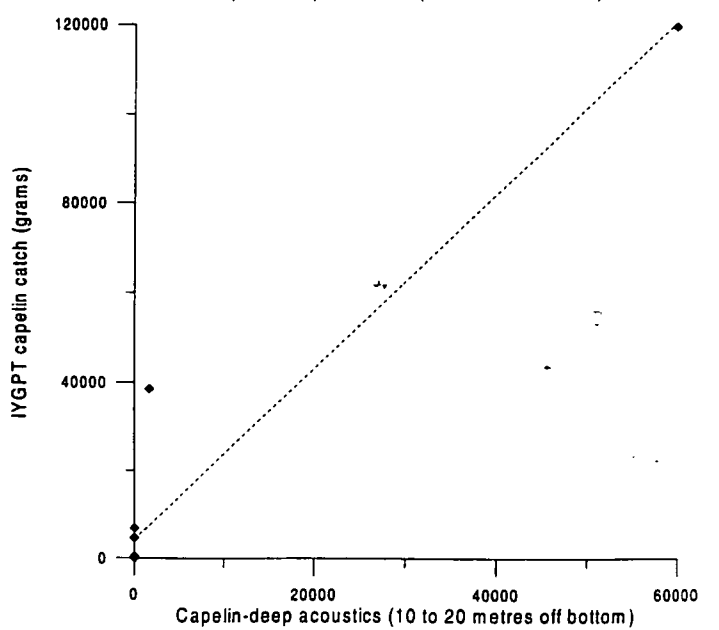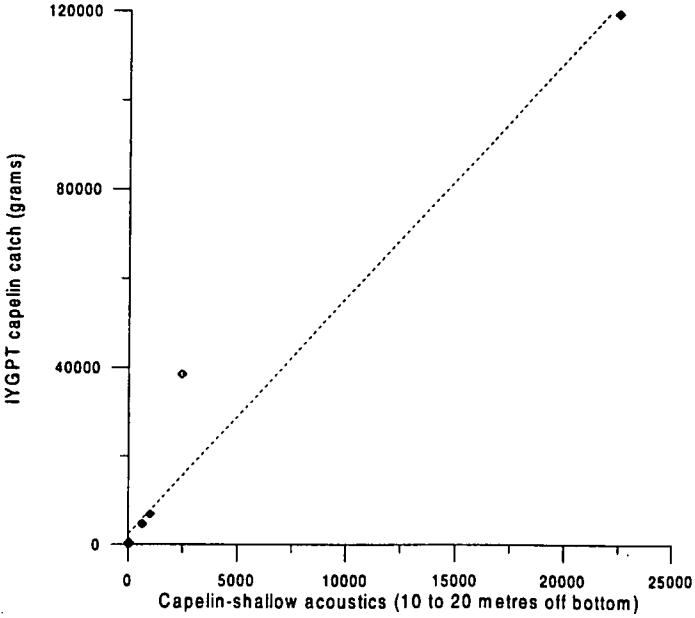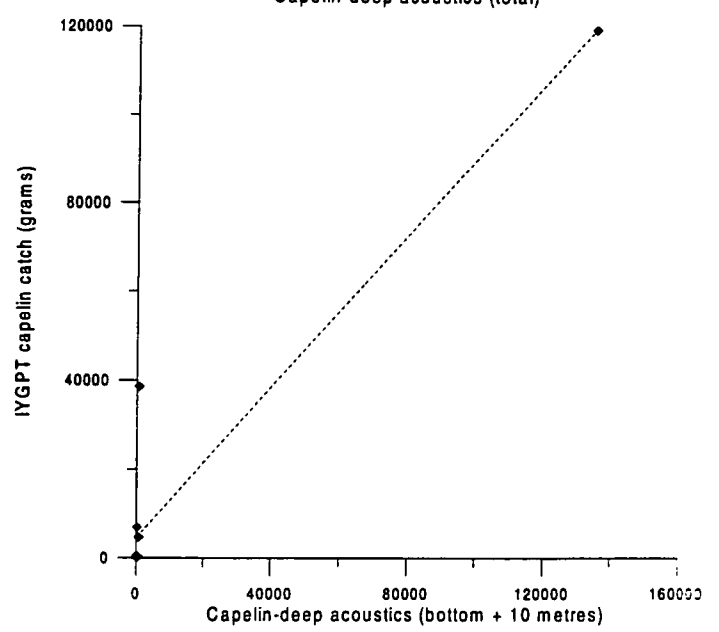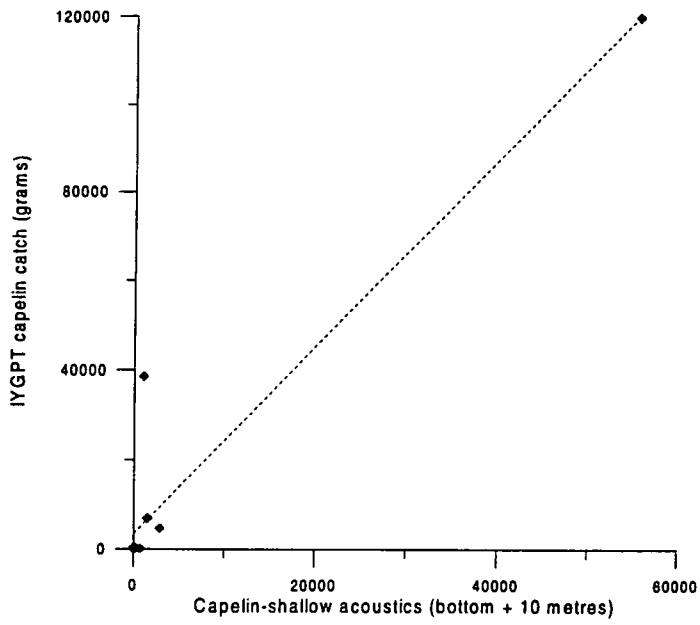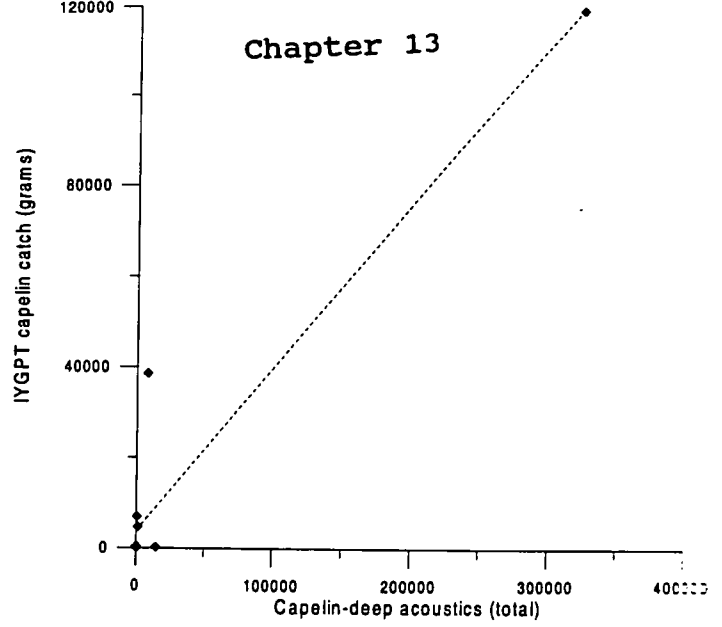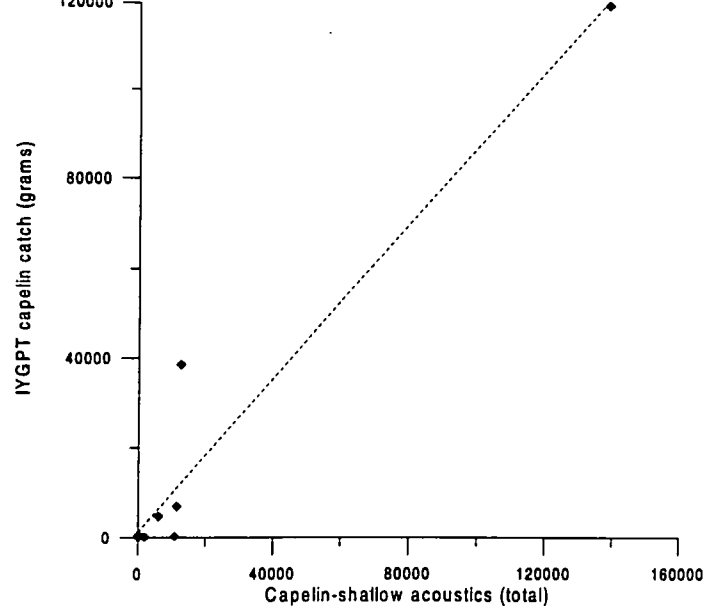
Figure 2. IYGPT trawl catches versus acoustic estimates.
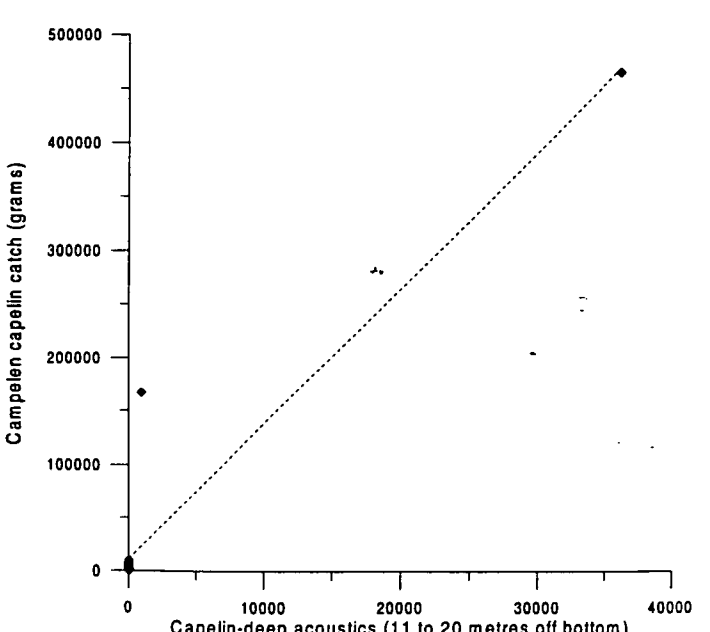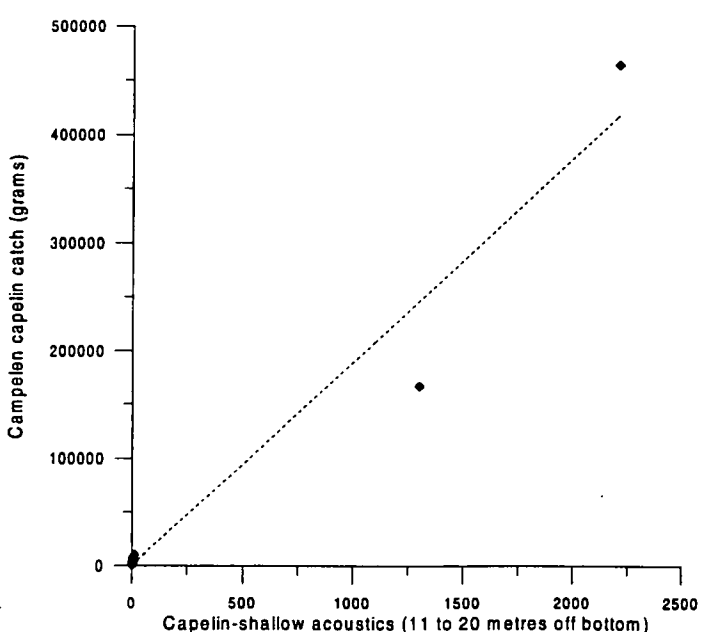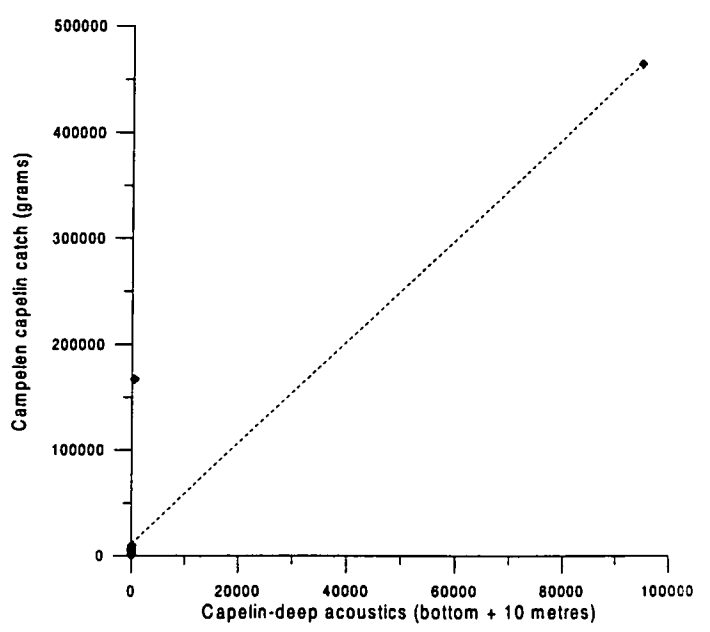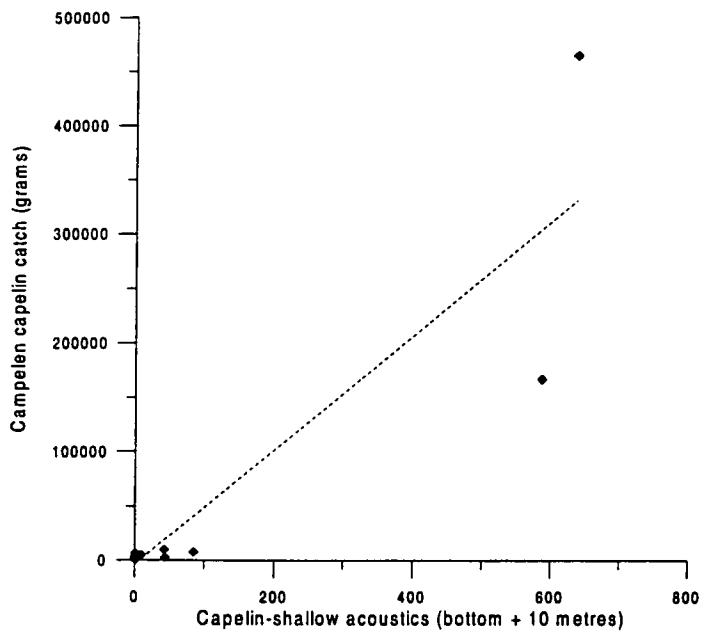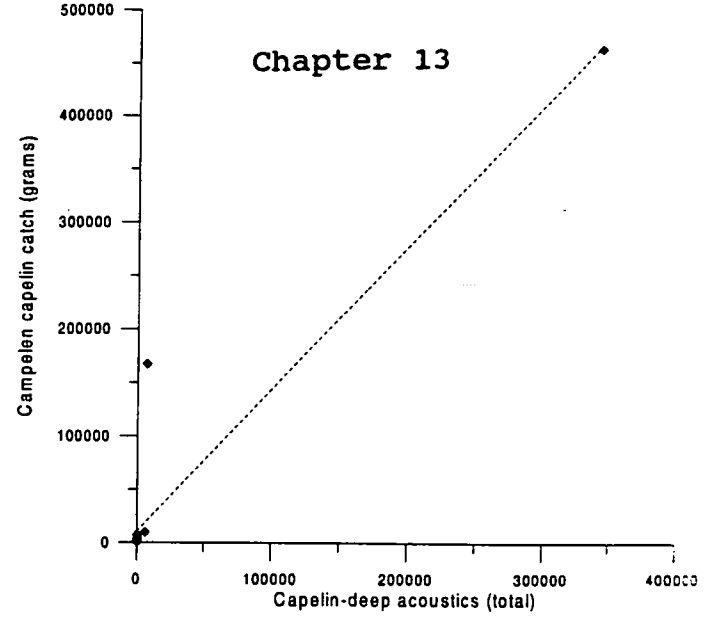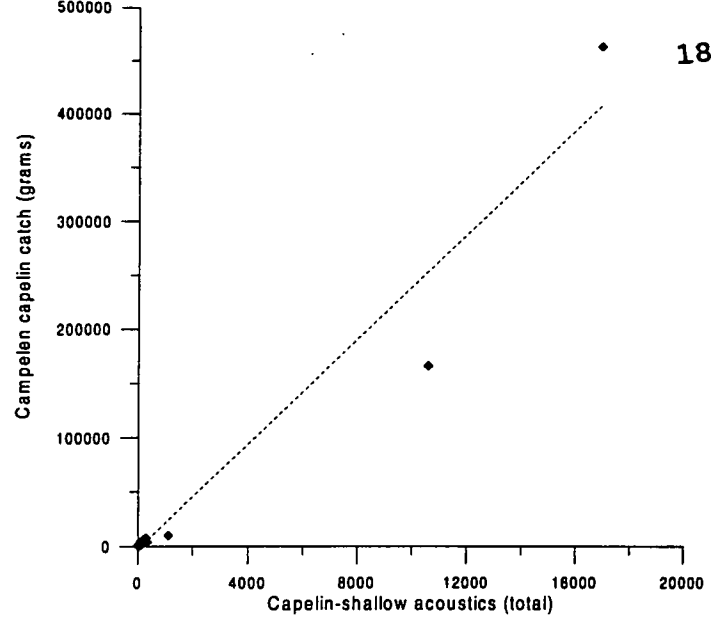
Figure 3. Campelen trawl estimates versus acoustic estimates
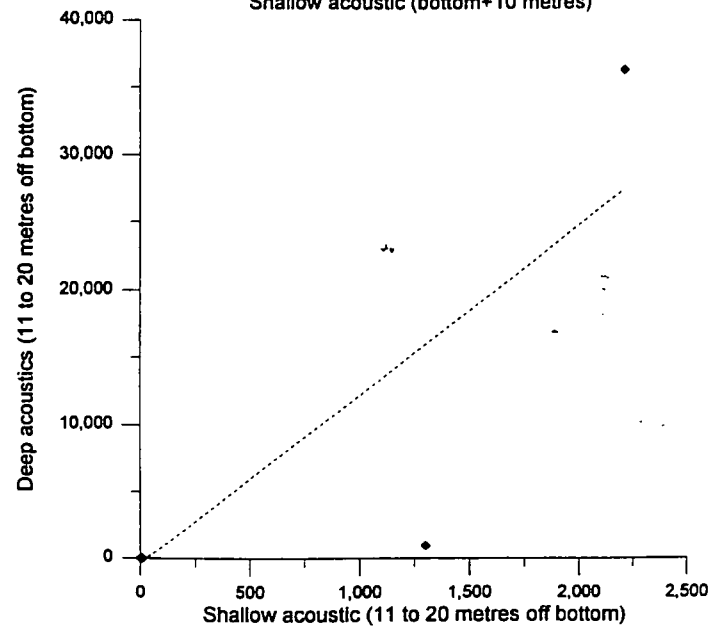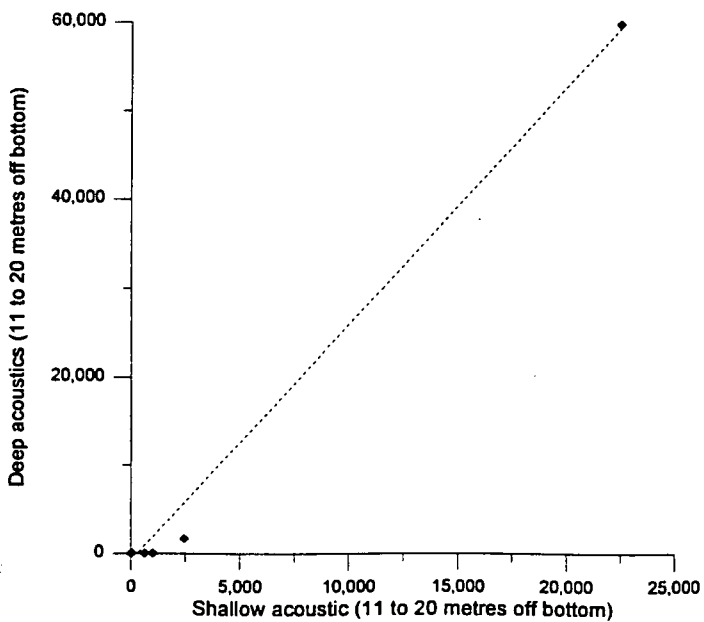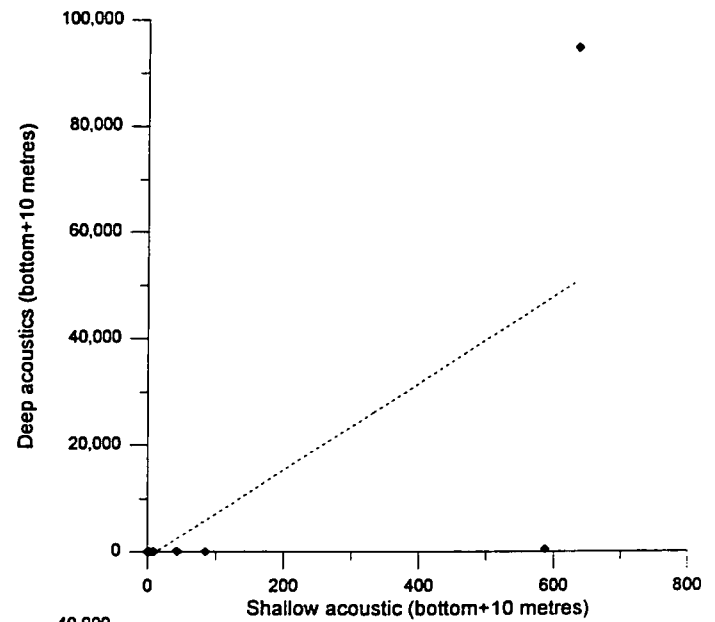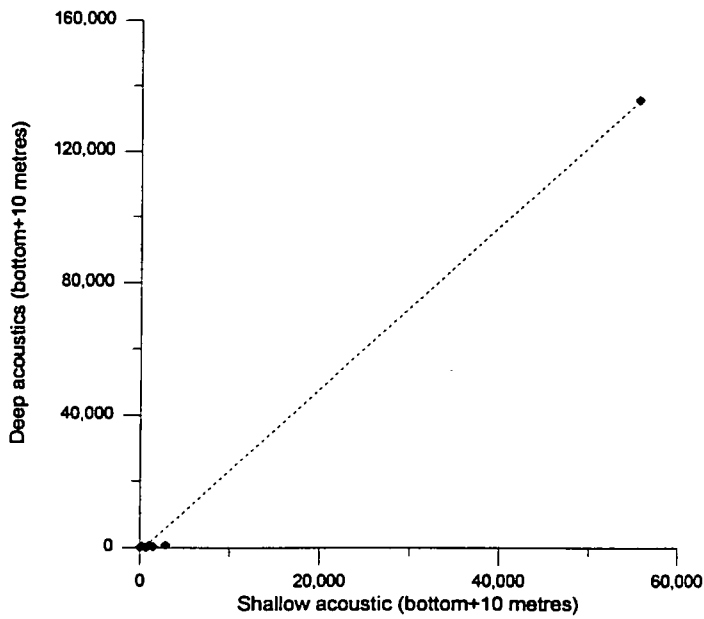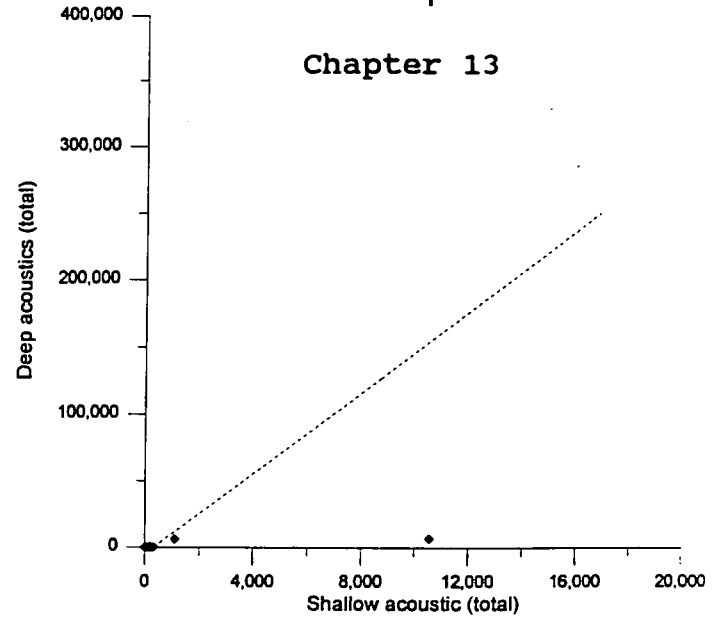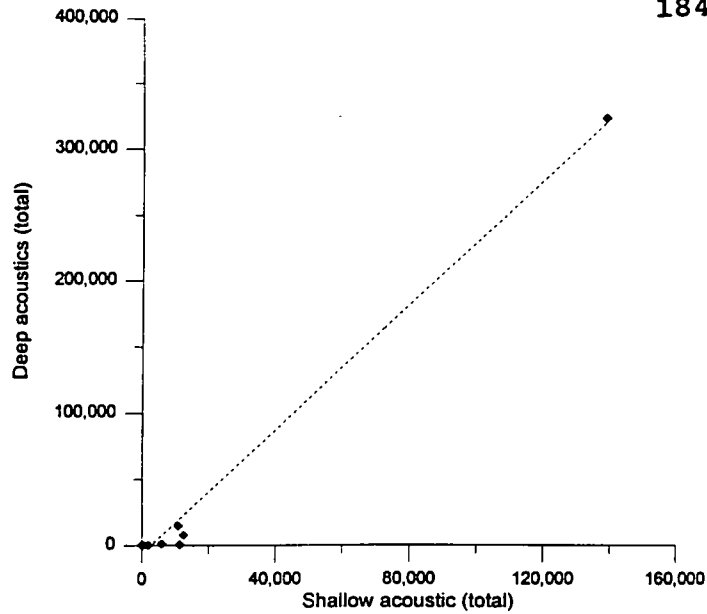
Figure 4. Shallow versus deep acoustic estimates
(for area covered by IYGPT and Campelen sets)

Distributions and Abundances of Pre-Recruit
Capelin (<u>Mallotus villosus</u>) in the
Newfoundland Region (2J3KL), 1994 and 1995

by

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Introduction

A research program to develop a multi-species, 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 Divisions 2J3KLNO, including both inshore and offshore areas (Fig. 1). Large and small gear types are 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 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.

The purpose of this paper is to report on the results of capelin from the 1995 survey, and to compare these results to the 1994 survey. We examine length ranges, geographical distributions and estimates of abundances for three age groups, 0, 1 and 2 years. In addition, we develop a pre-recruit abundance index that incorporates both abundance and distribution.

Materials and Methods

The survey design is based on a random stratified grid, where stations are spaced 54 km apart (Fig. 1). At each station a CTD is profiled 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). The survey was carried out from September 5-22, 1995, which was approximately two weeks later than the 1994 two-ship survey.

An abundance index is developed based on a number of selected areas, following the method of Randa (1982). These Index Areas were chosen to represent different regions for inshore and offshore locations (Fig. 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 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.

Results

Lengths

In 1995, larval capelin (0-group) caught in bongos ranged in length from 4-47 mm. The length frequency distribution was bi-modal, with one mode centered around 7-16 mm and a larger mode centered around 31-40 mm (Fig. 2). This differed from the length distribution sampled in 1994, which only ranged from 4-18 mm and was uni-modal, centered around 7-10 mm (Fig. 2). The bi-modal distribution is not a function of gear selectivity, as the IYGPT trawl catches larval capelin quantitatively from approximately 23-25 mm while the bongos catch capelin up to approximately 20-22 mm (Anderson and Dalley 1995).

Assuming larval capelin growth rates range from 0.25-0.35 mm/d (Anderson and Dalley 1995), then we can approximate the release times of capelin from beach sediments. A range of estimates can be derived, based on combinations of minimum and maximum growth rates and sizes. For example, maximum estimates of age would be derived from a combination of estimating the slowest growth rates for the largest fish. Based on the predominant length modes measured and different growth rates, we estimated probable release dates for capelin in 1994 and 1995 (Table 1).

In 1994, we estimate the maximum range in age of capelin larvae was 6 to 28 days, averaging about two weeks (Table 1). The absence of a strongly right skewed length frequency distribution, where small larvae <5-6 mm dominated, indicates there was no active release of larvae from beaches during our survey. These data indicate that there was one period of release from beach sediments and it occurred relatively late in the season.

In 1995, the maximum range in age of larvae was 9 to 40 days for the smallest length mode and 77 to 144 days for the larger length mode (Table 1). Again, the absence of small larvae (<5 mm) indicates the release period was over by the time of our survey. As in 1994, the smallest size of larvae came from a release period that was relatively late, occurring in early to mid August. The large size mode of larvae came from a release period which appears to have occurred in June. Interestingly, all of the large capelin larvae came from four stations sampled in Notre Dame Bay.

In 1995, one year old capelin (60-120 mm) ranged in length from approximately 70-120 mm (Fig. 2). The dominant length mode ranged from 99-118 mm, while there appeared to be a smaller mode from approximately 77-88 mm (Fig. 2). The dominant size mode in 1994 was approximately 25 mm smaller than in 1995, ranging between 78-95 mm (Fig. 2).

In 1995, two year old capelin (>120 mm) were most abundant in the 128 to 138 mm size range (Fig. 2). In 1994 only a few capelin >120 mm were caught and there was no apparent mode length (Fig. 2).

Ages

Ages of capelin were estimated from a subsample of the IYGPT samples each year. In 1994, 100% of capelin ≤90 mm were age one, while >50% were age two ≥115 mm length, and >50% of the capelin were age three ≤145 mm (Fig. 3). In 1995, 100% of capelin ≤95 mm were age one, while 50% were age two ≤115 mm (Fig. 3). No capelin >140 mm were aged in 1995. These results indicate that the upper size limit for age one capelin is closer to 115 mm, not 120 mm as we had previously assumed from length frequencies.

Distributions

In 1995, larval capelin were distributed throughout the inshore area from southern Labrador to the southern part of the Avalon Peninsula (Fig. 4). Abundance was highest in Trinity and Conception Bays. In all cases, abundances decreased to zero from the inshore areas to the offshore shelves. Abundance also decreased to zero off southern Labrador while no larvae were sampled on the southern Grand Bank. The distribution in 1994 was similar to 1995. The notable differences were highest abundances were observed in Notre Dame Bay in 1994.

In 1995, one year old capelin (the 1994 year-class) were
distributed throughout the inshore areas and over much of the Grand
Bank (Fig. 5).   Highest concentrations were observed on the Grand
Bank, as well as off Cape Freels, north of Bonavista Bay. One year
old capelin were absent from the outer part of the Northeast
Newfoundland Shelf and the most southern part of the Grand Bank.
The distribution of one year old capelin in 1994 (the 1993
yearclass) was very similar to that sampled in 1995 (Fig. 5).

In 1995, two year old capelin (the 1993 year-class) were most
abundant offshore on the Northern Grand Bank (Fig. 6). They were
also present within many of the inshore areas, primarily Bonavista
Bay and off southern Labrador. Very few two year old capelin were
sampled in 1994 (the 1992 yearclass), being confined to one area
off Bonavista Bay and within Notre Dame Bay (Fig. 6).

Abundances

The average unadjusted catch rates of larval (0-group) capelin
caught each year in the bongos increased from 1991 to 1995
(Fig. 7).   However, the major difference in survey times from
1991-93 compared to 1994-95 confounds direct comparison of these
estimates.   The 1994 and 1995 estimates should be adjusted
downwards, relative to 1991-93, as these larvae were younger and
had experienced less mortality. Therefore, we have adjusted the
larval abundance estimates to calendar day 281, the mid-date of the
1992 and 1993 surveys. Mortality rates were assumed to range from
0.03/day to 0.05/day. The adjusted abundance estimates indicate
that the 1993 yearclass was the largest during the period 1991-95,
while the 1994 yearclass was the smallest (Fig. 7). We note that
the 1994 survey was the earliest carried out to date and that we
may have missed larvae due to the late release times in 1994.
Therefore, the 1994 adjusted estimate for capelin larvae may be
biased low.

Catch rates of one year old capelin (1-group) from the IYGPT
indicate that the 1993 yearclass was the most abundant during the
period 1991-94 (Fig. 7). Catch rates of the 1994 yearclass were
higher at age one than either 1992 or 1991 (Fig. 7).

Yearclass abundance estimated by Index Area for 0, 1 and 2
year old capelin can be compared for a number of common areas in
1994 and 1995. Here we estimate age zero abundance from the bongo
data and age one and two capelin from the IYGPT data. These
comparisons are made without adjustment for difference in survey
dates, which was approximately two weeks later in 1995. The 1995
yearclass was higher than the 1994 yearclass in four of six
commonly sampled Index Areas (Table 1). At age one, the 1994
yearclass was higher than the 1993 yearclass in four of the six
areas. At age two, the 1993 yearclass was higher than the 1992
yearclass in five of the six areas.

Discussion

Yearclass Strength

The 1993 yearclass was the most abundant during the period 1991-95, as measured at ages zero (1991-95), one (1991-94), and two (1992-93) years of age. These results indicate that this large year-class was established by the early larval stage when larvae were still dispersing from the inshore to offshore areas. In addition, the high abundance persisted during their first three years of life. This result is consistent with the hypothesis that successful release from beach sediments is a necessary condition for high survival in NW Atlantic capelin (Leggett et al. 1984).

The estimate of yearclass strength for the 1994 yearclass at age 0 was the lowest of the five year time series. In contrast, at one year of age the 1994 yearclass was more abundant than either the 1991 or 1992 yearclasses, although less abundant than the 1993 yearclass. An underestimate of the 1994 yearclass abundance at age 0 would have resulted if we had missed larval capelin released from beaches after the survey was completed, as a result of late spawning in 1994. Therefore, it appears that the 1994 yearclass may rank second to the 1993 yearclass in abundance.

The 1995 yearclass estimate at age zero was higher than the 1994 yearclass but lower than 1993, indicating that it may be a relatively good yearclass. The size range of larvae was much greater than the 1994 yearclass, indicating that length at age one may be larger as well.

One year old capelin were approximately 25 mm larger for the 1994 yearclass than the 1993 yearclass. This difference represents approximately a 30% increase in size for the 1994 yearclass, compared to the 1993 yearclass. While size differences may occur due to differential survival, the relatively high abundance of the 1994 yearclass at one year of age indicates that the observed difference in length resulted from increased growth of the 1994 yearclass.

Yearclass estimates from the Index Areas did not always show differences in yearclass strength that were consistent with the catch rate estimates for age 0 and 1 year old capelin. This may result from the averaging procedure within each area that presently is not weighted by the size of the Index Area. More properly, the Index Areas should be weighted by area, and summed over all areas sampled to produce a more meaningful index of pre-recruit abundance.

In general, capelin larvae were dispersed relatively quickly
from inshore spawning areas to offshore waters, and also they
appeared to be advected to the south onto the northern Grand Bank.
The distributions of larval capelin indicate that spawning occurred
in southern Labrador as well as along the entire northeast coast of
Newfoundland. The decrease in abundance from inshore areas to zero
on the outer Northeast Newfoundland Shelf is consistent with strong
advection from inshore to offshore areas (deYoung et al. 1994).

Both one and two year old pelagic capelin were most abundant
over the northern Grand Bank. One year old capelin were also
observed abundantly throughout the inshore area along the northeast
coast of Newfoundland to southern Labrador as well as south onto
the southern Grand Bank. The continuous distributions of one year
old capelin sampled over these broad geographic areas indicates
that the present survey design adequately samples their geographic
distribution. The similarity between one and two year old capelin
indicates similar spatial requirements for growth and survival.

Acknowledgements

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     fish survey. Coun. Meet. int. Coun. Explor. Sea, 1982
     (G:43): 1-22. Mimeo.

Table 1.   Index of pre-recruit abundance by Index Area
(see Fig. 1) for all available data in 1994 and 1995
for ages zero (0-group), one (1-group) and two (2-group)
years of age.

Area	Sampling Year 1994			Sampling Year 1995		
	0-Group	1-Group	2-Group	0-Group	1-Group	2-Group
Inshore						
CB	4.41	9.85	6.94	6.35	2.78	1.71
TB	3.99	0.84	0	5.16	3.53	1.39
BB				3.51	1.96	1.01
NDB	4.11	2.5	0.76	3.73	2.77	1.11
WB	5.41	2.3	0.4	3.63	1.7	2.12
Offshore						
HB						
ISN				0.37	0.26	1.27
ISS	2.31	0.86	0	3.09	1.09	1.01
BIBI						
BIBO						
FIBI				0.78	0.69	0.71
FIBO	0	0.56	0			
NGB				2.19	2.71	2.2
SGB	0.03	0.4	0.28	0.28	1.11	1.03
NOSE						
TAIL						
SGBO						
WD						
NGBW	3.88	5.26	4.66			
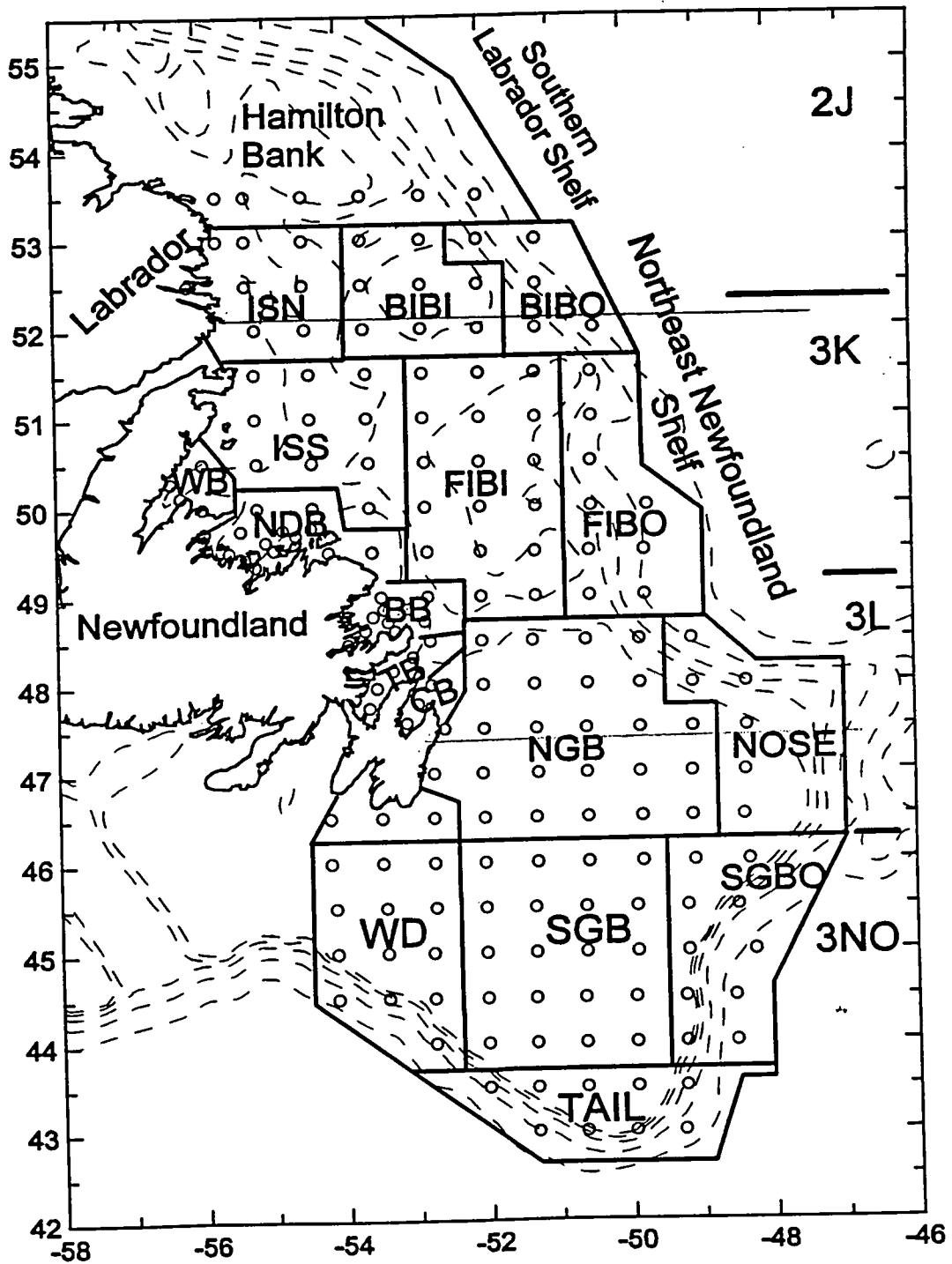
Fig. 1.   Pelagic juvenile fish survey design showing survey stations (open circle) and the Index Areas used in calculation of the pre-recruit abundance index.
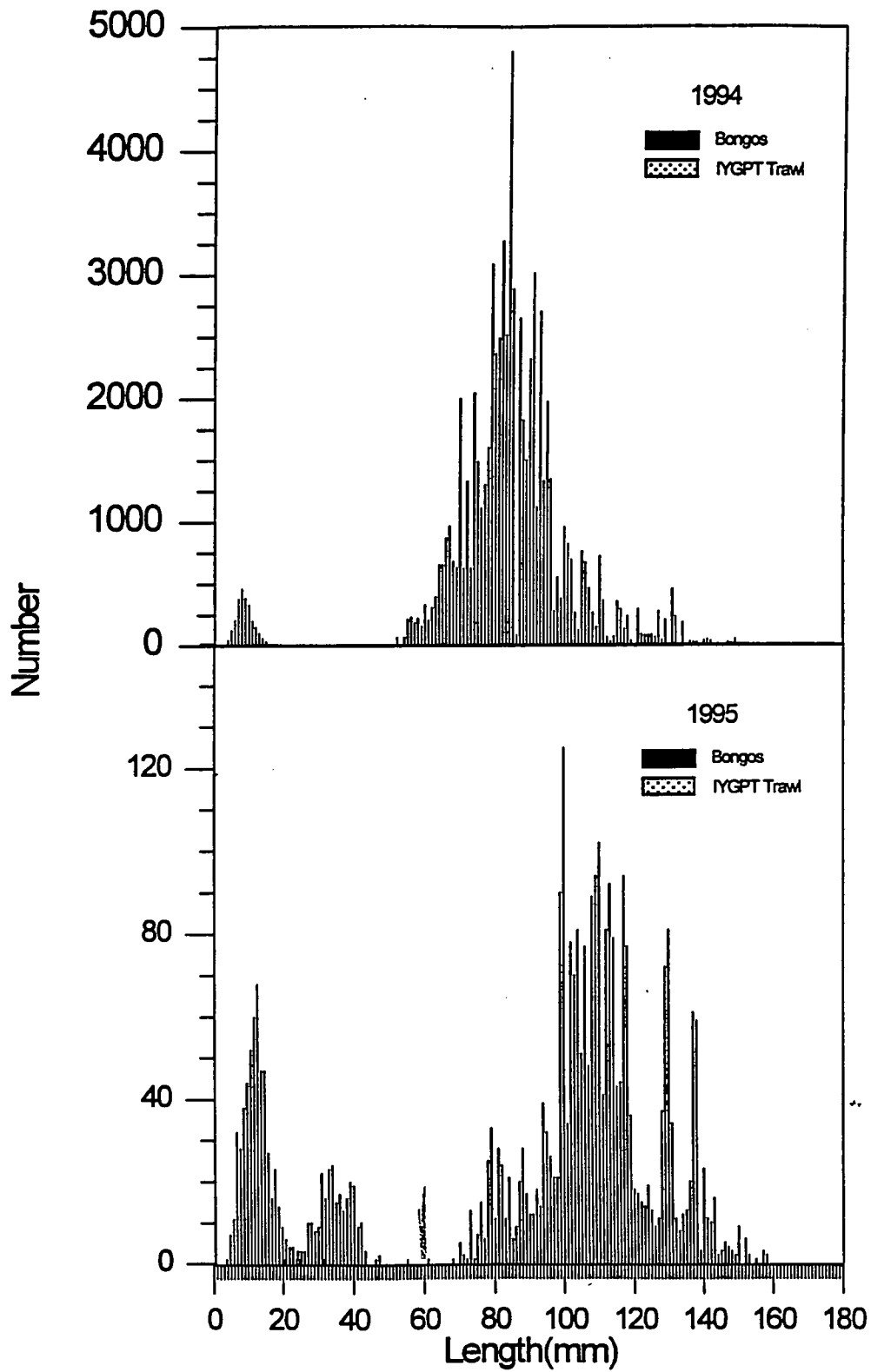
Fig. 2.   Length frequency distributions of capelin caught in 1994
and 1995 by bongo and IYGPT samplers.
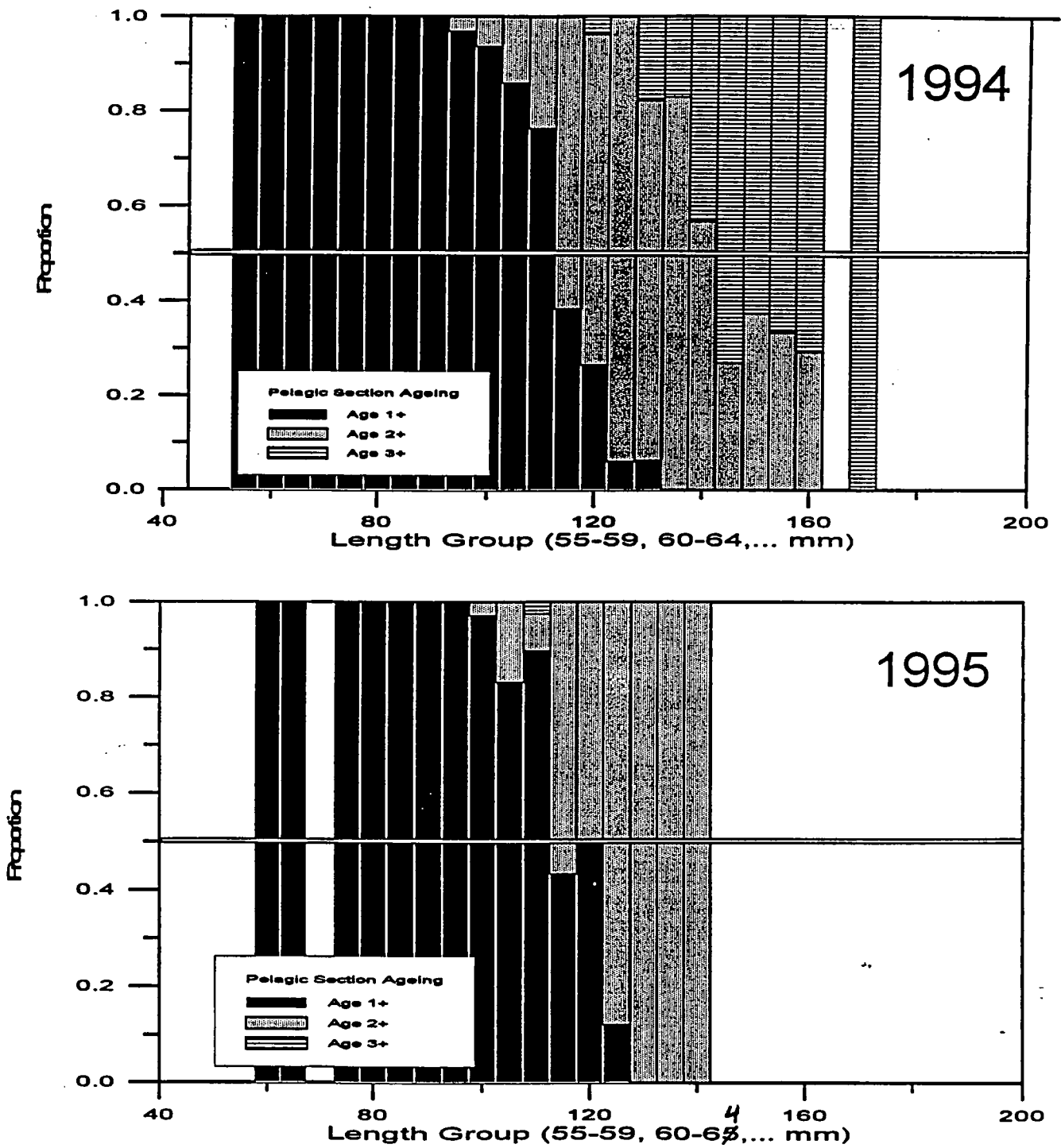
Fig. 3. Proportion of capelin ages for each 5 mm length group based on a subsample of the total catch from the IYGPT. The absence of capelin aged for lengths >140-144 mm resulted from a small subsample aged in 1995.
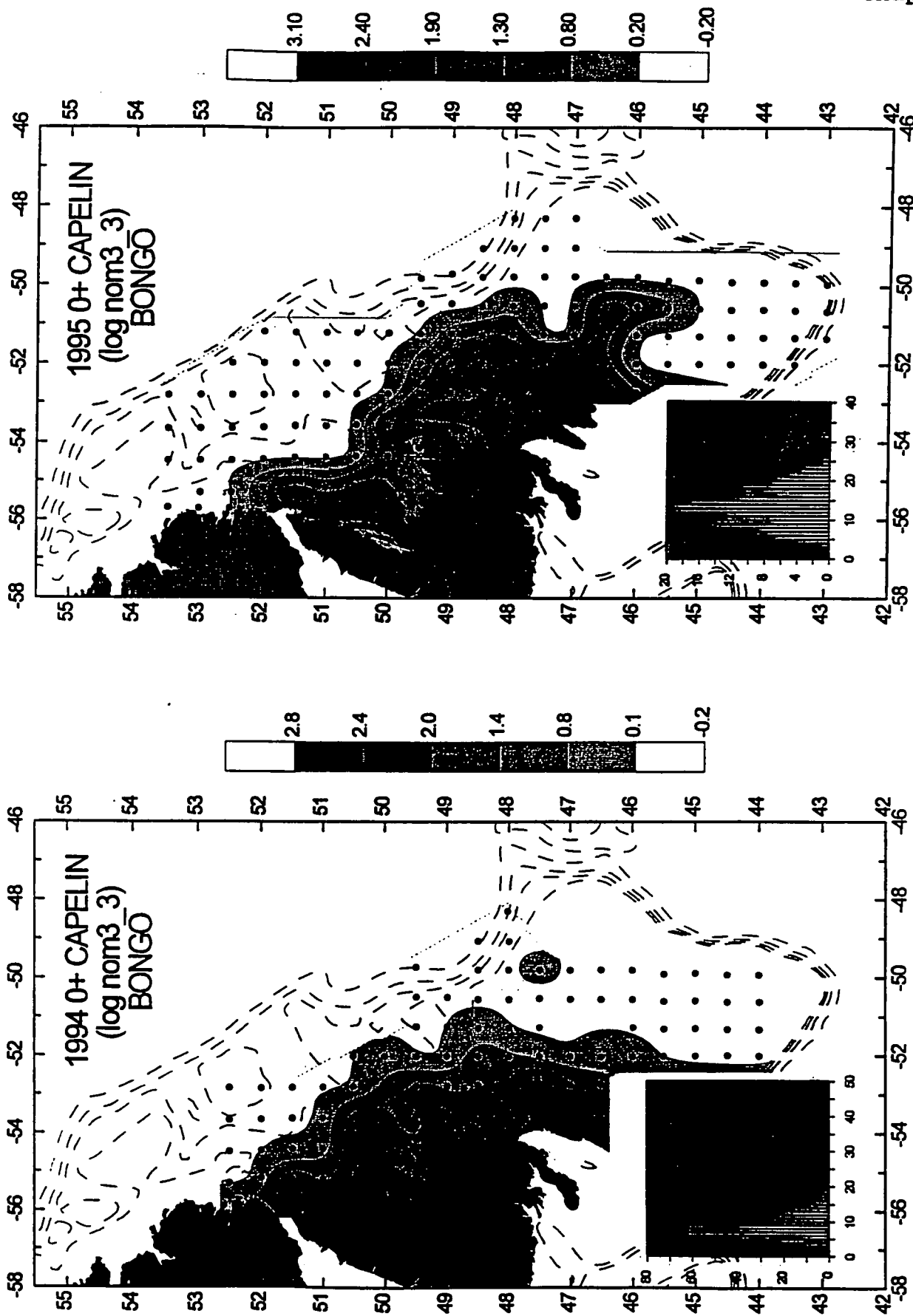
Fig. 4. Distributions of larval capelin sampled in the bongos based on log$_{10}$ transformed abundances (number 10^3 m^{-3}) spatially interpolated by kriging. The length frequency distributions are plotted in the lower left corner of each plot.
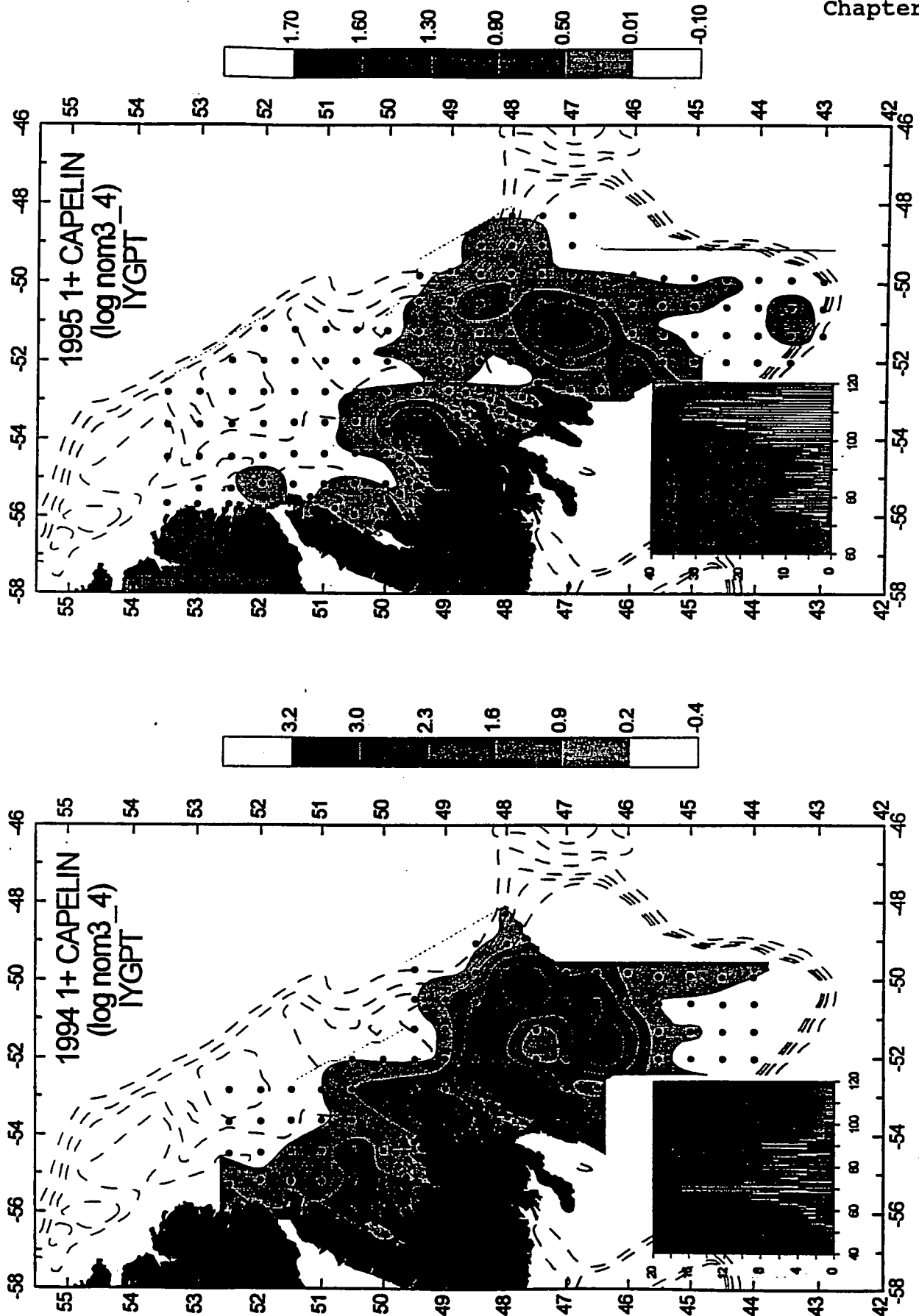
Fig. 5. Distributions of age one capelin sampled in the IYGPT
based on log_{10} transformed abundances (number 10^4 m^{-3}) spatially
interpolated by kriging. The length frequency distributions are
plotted in the lower left corner of each plot.

Fig. 6. Distributions of age two capelin sampled in the IYGPT based on $\log_{10}$ transformed abundances (number 10^4 m^3) spatially interpolated by kriging. The length frequency distributions are plotted in the lower left corner of each plot.
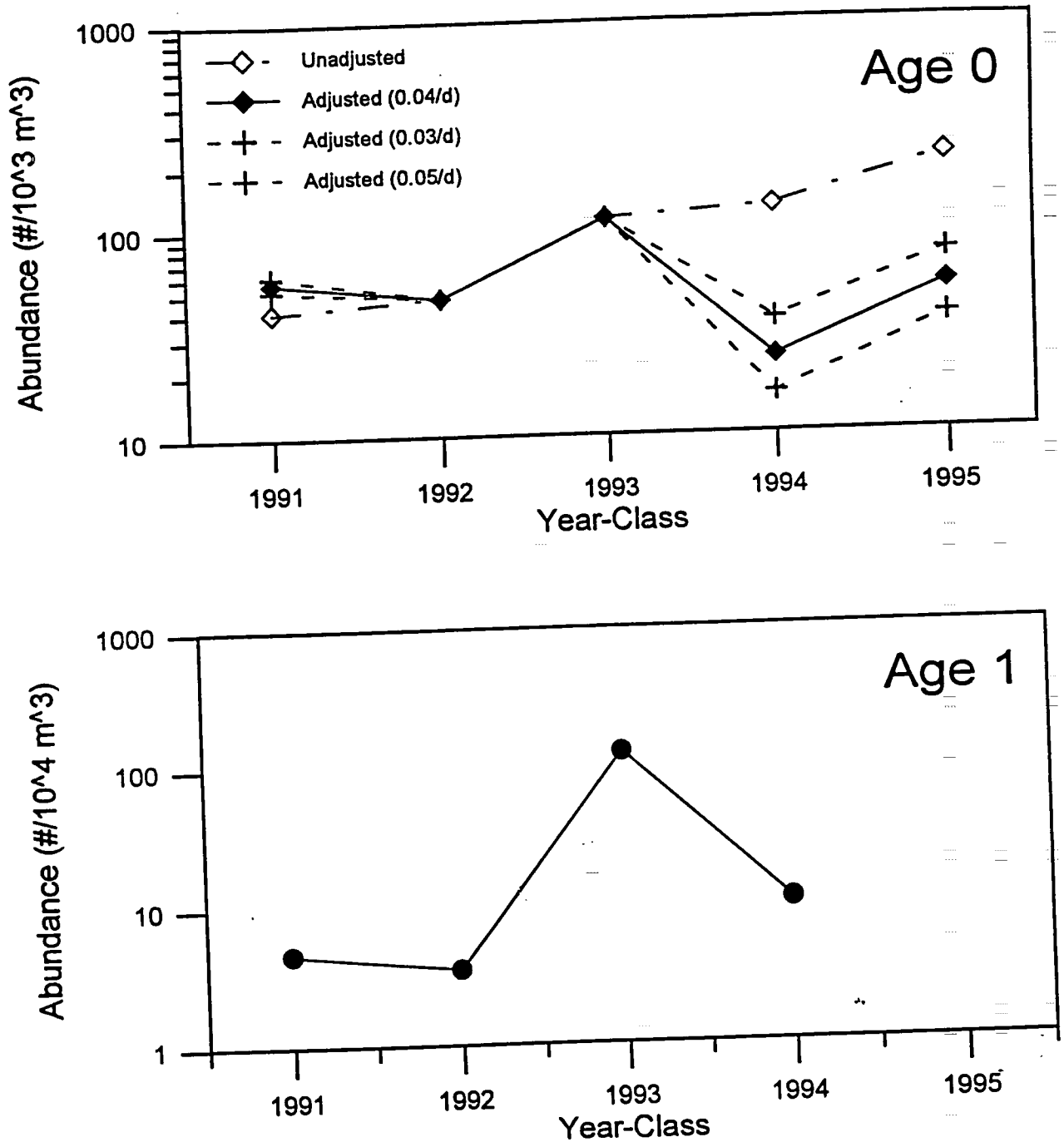
Fig. 7.   Yearclass abundance estimated for age zero and one year old capelin.   For age zero capelin, the unadjusted values represent the mean abundances for each survey without adjusting for the survey dates. The adjusted values represent estimates of abundance made for a common date, calendar day 281, for different assumed mortality rates.

Expected Mean Lengths of Mature Female Capelin During 1996

by

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Introduction

During the last assessment, the relationships between mean lengths of capelin from fall offshore acoustic surveys and inshore the following year were evaluated (Carscadden 1995). This analysis was conducted by sex, by age group and by age groups combined. For most combinations tested, the relationships were significant although generally, the relationships were better for females. Since the sizes of females are of the most interest from an industry perspective, this document updates the earlier information for females.

Data Sources

In the original analysis, data from the 1994 commercial fishery were not used. The data were not considered comparable to previous years because the 1994 fishery was small and restricted to a small geographical area. The 1995 fishery was essentially nonexistent because the fish were too small to meet the management size criteria (less than 50 count/kg) for opening the fishery. As a result, there was no new data to add to the relationships given in Carscadden (1995).

The other major source of data used to derive the relationships was the fall acoustic surveys. However, an acoustic survey was not conducted in 1995 and therefore comparable samples are not available. However, several sources of mean lengths of capelin are available namely: 1) sampling from the special capelin acoustics research conducted in the fall of 1995 (see Miller, this volume); 2) sampling from the Div. 2J3KL fall groundfish survey; and 3) sampling from a special shrimp/cod acoustic survey early in 1996. Different gears were used in the various research activities and the results are presented by gear type.

Results

Original Relationships

The original relationships (Carscadden 1995) for ages 2 (offshore) - 3 (inshore the following year), ages 3-4, ages 4-5, and all ages offshore to ages 2 and older inshore the next year are shown in Figures 1-4. (These correspond to Figures 7-10 inclusive in Carscadden (1995).) Note that the caption for Figure 10 (Carscadden 1995) was in error. (Figure 4 in this paper.) The figure depicts the relationship between all ages in the offshore (including age 1) compared to ages 2 and older in the inshore the following year.

In the original document, females at ages 2, 3 and 4 from the 1994 acoustic survey were small, 137 mm, 158 mm and 164 mm and Carscadden (1995) concluded that if these estimates were representative of the population, growth between November 1994 and the 1995 inshore fishery would have to be above average for these fish to be comparable in size at age to those in the 1990's. Although not included in the 1995 document, the overall mean size of females in the 1994 fall acoustics survey was 133 mm.

Performance of the Model in 1995

Although there was virtually no fishery in 1995, samples of capelin were available from the monitoring program (operated by industry/government to determine the opening of the fishery) and from samples taken during sampling on capelin beaches (see Nakashima and Winters, this volume). The overall mean lengths of females from the two data sources were similar at 142 mm from the monitoring program and 149 mm from the beach sampling. These sizes are consistent with what might have been expected from a prediction using the mean size of 133 mm from the fall 1994 and Figure 4. The mean size in the fall of 1994 was the lowest in the series and therefore outside the bounds of the relationship. However, using this, a mean size of females in 1995 less than 150 mm would have been expected. Estimates from the two sources indicate that this was the case.

Outlook for 1996

The details of the sampling from the fall acoustics research are given in Table 1. Two gear types, IYGPT and Campelen were used and the results are presented for each and combined. It should be noted that the IYGPT trawl was also used in 1994 and therefore these samples are comparable. Sample sizes (N) refer to a sample of 200 fish selected randomly, sampled for length and subsampled for ageing.

The mean sizes of fish from the Campelen are slightly larger than the IYGPT. Females at age 2 from the IYGPT were about the same length (138 mm) as that age group in 1994 (137 mm) and smaller than other years. For age 2 females from the Campelen, mean lengths were larger (144 mm) and about the average length (see Fig. 1). When all samples were combined, the mean length of 141 mm was small.

For age 3 females, the mean lengths were similar (IYGPT = 153 mm and Campelen = 155 mm) and comparable to the smallest in the series (Fig. 2).

For age 4, females from the IYGPT were 159 mm and from Campelen were 163 mm, sizes which are well below the mean sizes observed during the 1980's (Fig. 3).

When all ages were combined (including age 1), the mean lengths of 137 mm (IYGPT), 144 mm (Campelen) and 140 mm (combined) were slightly larger than the 1994 mean length of 133 mm and equal to or smaller than the smallest lengths previously recorded (Fig. 4).

Based on these comparisons, it would appear that fish sizes in 1996 would again be small and growth would have to be well above average to result in mature fish sizes comparable to the 1980's.

Results of sampling from the fall groundfish survey in Div. 2J3KL using the Campelen trawl are given in Table 2. The largest capelin were captured in Div. 3K and the smallest in Div. 3L. Mean sizes in Div. 3K during this survey are slightly larger than mean sizes in Div. 3K from the acoustics research. The groundfish survey is slightly later and the larger sizes may reflect growth between the two surveys. The mean lengths of females in this table should be compared with Figures 1-4 with caution for two reasons. First, the gear types are not comparable (Campelen versus midwater trawl). Second, the timing of the fall data collections are different, with the data from the acoustic surveys (X-axis in Fig. 4) collected prior to the data from the groundfish surveys. The fall is a feeding and growth period for capelin and therefore comparing mean sizes from the groundfish survey to mean sizes on the X-axis in the relationship in Figure 4 is inappropriate. However, the examination of the mean sizes in the table and comparing them to the mean sizes inshore the following year (Y-axis in Fig. 4) indicates that the capelin during the late fall of 1995 had not reached the sizes of capelin seen inshore during the 1980's (eg. greater than 165 mm).

Data were also available from a shrimp/cod acoustic survey in February 1996 (Table 3). The average fish sizes by age (these fish are one year older in 1996) and overall compared to samples from the Campelen trawl in Div. 3K during the fall (Table 2) are comparable. It would appear that there has not been much growth between the fall and February. Furthermore growth would have to be substantial between February and the spawning season (compare to the Y-axis in Fig. 4) for fish to reach the sizes observed during the spawning season in the 1980's.

Summary

Female capelin captured during the 1995 acoustic experiments were small and comparable in size to female capelin captured during 1991-94 inclusive. The female capelin that contributed to the spawning population during 1992-95 were also small and therefore consistent with the overall relationship depicted in Figure 4. Based on these observations, it would appear that mature female capelin in 1996 will again be small.

Samples of female capelin taken in the 1995 fall groundfish survey and in a shrimp/cod acoustic survey in February 1996 indicate some growth had occurred subsequent to the 1995 capelin acoustic research. However, unless growth were substantial during the spring of 1996, mature female capelin in the spawning season of 1996 would be unlikely to achieve the sizes observed during the 1980's.

References

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

Table 1. Details of sampling from October 1995 capelin research on the TELEOST, Div. 3K, females only.

	Age						All ages
	1	2	3	4	5	6	
IYGPT N = 11							
Mean length	129	138	153	159	163		137
% mature	80	94	94	86	100		
% composition	25.2	69.5	4.8	.4	.1		
Campelen N = 14							
Mean length	133	144	155	163	163		144
% mature	93	99	100	100	100		
% composition	15.0	71.2	11.8	1.3	.8		
Gears Combined							
Mean length	131	141	154	165	163		140
% mature	86	97	100	100	100		
% composition	21.3	68.5	8.7	.9	.5		

Table 2. Details of sampling from fall 1995 Div. 2J3KL groundfish survey, Campelen trawl, females only.

	Age						All ages
	1	2	3	4	5	6	
Div. 2J N = 3							
Mean length	131	144	153	161			147
% mature	100	100	100	100			
% composition	1.3	70.6	22.3	5.7			
Div. 3K N = 15							
Mean length	140	149	159	164	183	192	149
% mature	99	100	100	100	100	100	
% composition	11.8	70.5	16.2	1.1	.1	.2	
Div. 3L N = 19							
Mean length	117	131	146	154			126
% mature	50	86	100	100			
% composition	39.5	55.7	4.3	.5			
Div. 2J3K							
Mean length	140	148	157	162	183	172	149
% mature	99	100	100	100	100	100	
% composition	9.7	70.5	17.4	2.1	.1	.2	
Div. 2J3KL							
Mean length	119	137	153	159	103	172	133
% mature	46	91	100	100	100	100	
% composition	30.8	59.8	8.4	.9	0	.1	

Table 3.   Details of sampling from February 1996 shrimp/cod acoustic research,
Div. 3K.   Campelen trawl, female only.   N = 4.

| | Age | | | | | | All ages |
	1	2	3	4	5	6	
Mean length		142	148	157			148
% mature		97.5	100	100			
% composition		25.8	65.8	8.3			
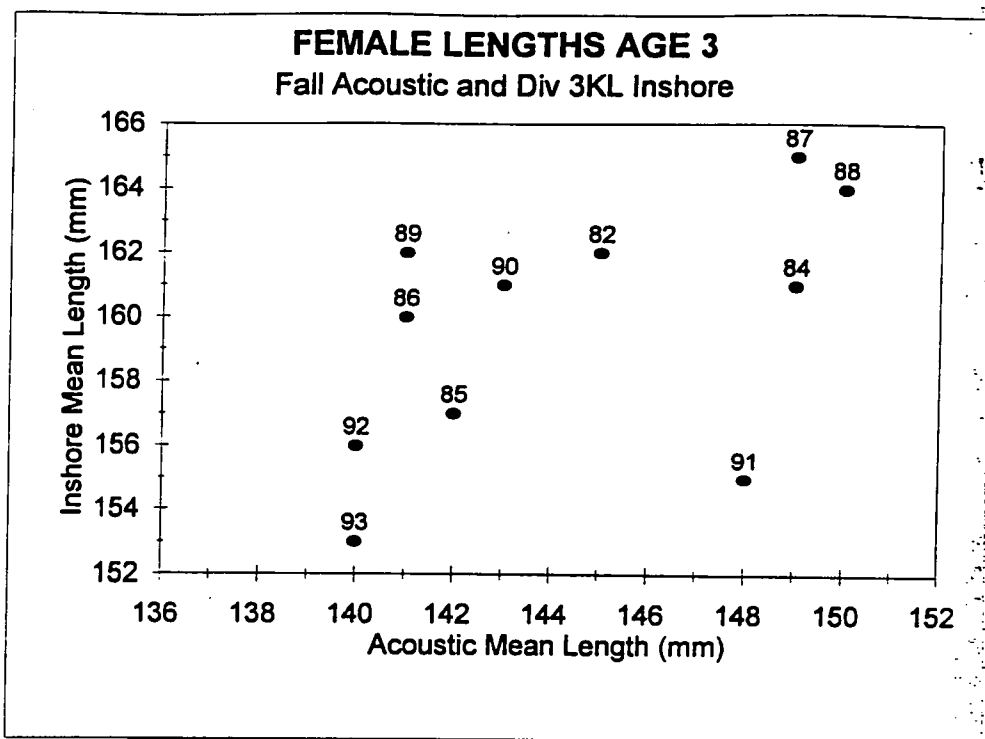
Fig. 1. Relationship between mean lengths of females age 2 in offshore acoustic survey and mean lengths of age 3 females inshore the following year (r = 0.53, p = .10). Years plotted correspond to inshore at age 3.
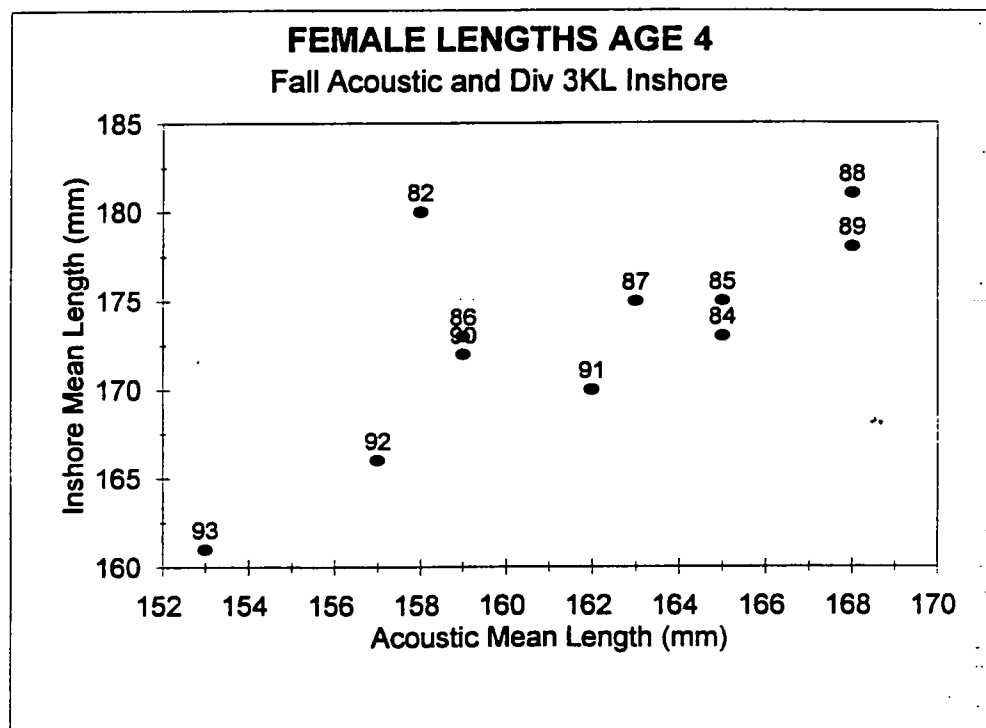
Fig. 2. Relationship between mean lengths of females age 3 in offshore acoustic survey and mean lengths of age 4 females inshore the following year (r = 0.72, p = .01). Years plotted correspond to inshore at age 4.

FEMALE LENGTHS AGE 5
Fall Acoustic and Div 3KL Inshore
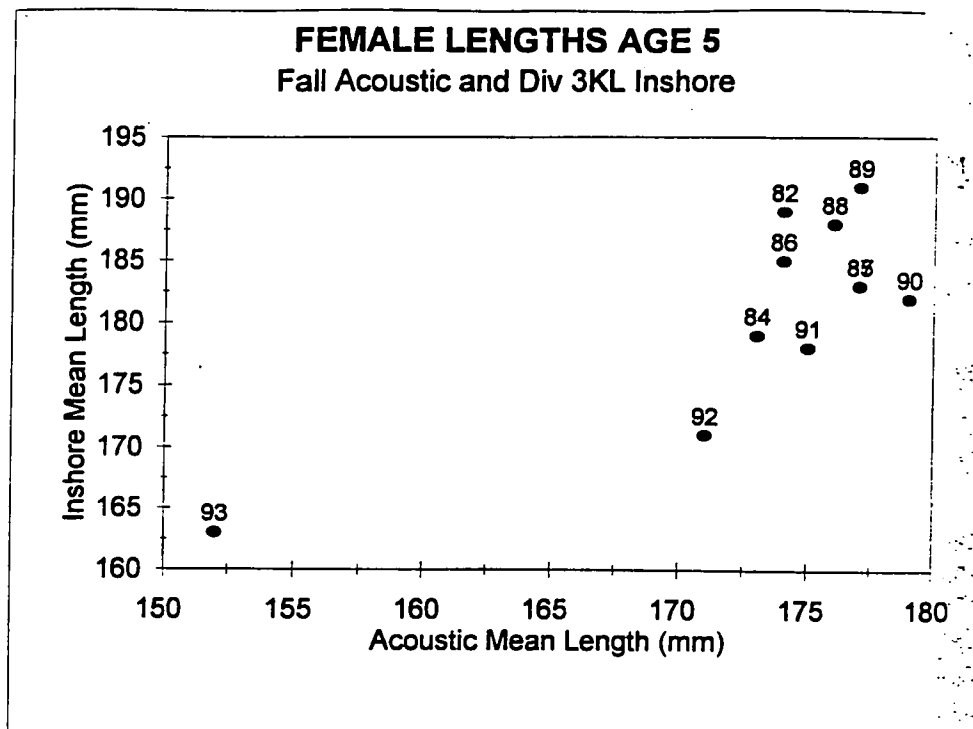
Fig. 3.   Relationship between mean lengths of females age 4 in offshore acoustic surveys and mean lengths of age 5 females inshore the following year (r = .82, p = .002).   Years plotted correspond to inshore at age 5.

FEMALE LENGTHS ALL AGES
Fall Acoustic and Div 3KL Inshore
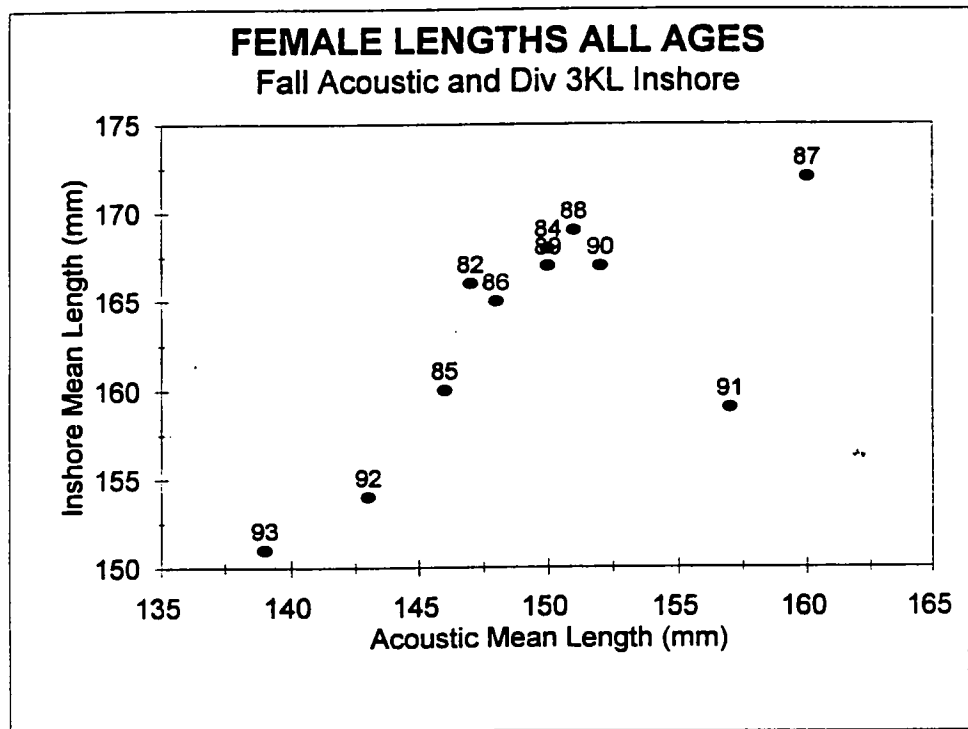
Fig. 4.   Relationship between mean lengths of females all ages in offshore acoustic surveys and mean lengths of females ages 2 and older inshore the following year (r = .70, p = .02).   Years plotted correspond to inshore ages combined.

Capelin Bycatch from Demersal Juvenile Cod Surveys, 1992-95

by

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Introduction

From 1992 to 1994 fixed station demersal trawl surveys were carried out for juvenile cod in inshore and offshore areas of NAFO Div. 3KL. Bycatch of capelin from these surveys was reported (Dalley et al. 1995) at last year's regional annual capelin asessment meeting. In 1995 only the inshore fixed stations of the original design were fished. However, the fixed offshore locations of the old design were approximated using sets from the fall groundfish survey which covered the area more intensively, and at approximately the same time. Catch rates of capelin from the fixed inshore stations and approximations of the old offshore stations are presented here and compared with capelin abundance at the same sites from 1992 to 1994. Catch rates for NAFO Div. 3K and 3L are also presented separately.

Methods

The same fixed stations in the inshore portion of the survey area were fished in 1995 as in 1992-94 (Fig. 1). The fixed stations from the offshore line transects were not fished as in previous years. This was due to the fact that in 1995 the annual Random Stratified Groundfish Survey adopted for the first time the Campelen 1800 survey trawl, the same trawl that was used in the demersal juvenile cod surveys. The Groundfish survey covered the offshore survey much more intensively than the line transects of the juvenile cod survey. To compare capelin bycatch in the offshore in 1995 to that of the past three years each station in the previous design (using line transects) was taken as the center of a 30 x 30 nm. square. The average catch of capelin from tows within each 30 nm. square during the groundfish survey were taken to represent the catch at the fixed station according to the old design. The number of tows used to calculate the mean capelin catch for each square range from 0 (for 2 stations only) up to eight. The mean offshore capelin catch was obtained from an overall mean of the derived catch rates from stations in the old design. In 1995 the indices were calculated from 25 fixed stations

in the inshore and mean catch rates derived for 39 stations in the offshore portion of the survey area. Although the survey protocol called for 15 minute tows in 1995 the catch rate was standardized to 30 minutes to compred with previous surveys. Other sampling protocols are similar to that of Dalley et al. (1995). As was the protocol in the 1992 and 1994 surveys the sampling was carried out in late one year (1995) and January the next (1996).

Results

As in previous surveys (1992-94) capelin were widely distributed throughout the survey area both inshore and offshore. Three null catches were obtained in the inshore and 2 in the offshore for an overall frequency of occurence of 92% for the 1995 survey.

Since the same locations were fished each year the abundance indices from the inshore are directly comparable to those obtained from 1992-94. In the inshore in 1995 both the mean number and weight of fish caught are the highest of the 4 years, increasing each of the last 2 years (Fig. 2, top). The increase since 1994 is more pronounced for mean weight than for mean numbers of fish caught. Overall mean catches in the offshore were slightly higher than in the inshore in 1995. When both inshore and offshore stations are combined as an overall index (Fig. 2, bottom) the same increases noted for the inshore are still evident. The overall mean number of fish caught per 30 minute tow increased from 653 in 1994 to 873 fish in 1995. The mean weight caught nearly doubled from 6,400 to 12,000 gm over the same period.

The relative abundance of fish in 3K compared to 3L varies in the inshore compared to offshore areas (Fig. 3). In the inshore (left panels) mean catch rate in 1995 was much higher in 3K than in 3L. This is consistent with 1994 but the difference between the two divisions is more pronounced than in 1994. For the offshore (right panels) the abundance in 1995 is greater in 3L than in 3K, a switch since 1994. Neither 3K nor 3L has had consistently higher mean catch rates over the past 4 years, in either the inshore or offshore.

The age structure of the capelin caught, from processed samples, is shown in Table 1. Percent at each age from the 1992 to 1994 surveys have been slightly revised and updated since that presented in Dalley et al. (1995). During surveys carried out from 1992-94 the dominant group was age 1, ranging from 47.5 % in 1993 to 55.5% in 1994. In 1995 the age stucture was dominated by age 2's with age 1's constituting only 33.2 % of the population. This percentage at each age is translated into mean catch rate (numbers)

at each age (Table 2). There appears to be a year effect in the catches in 1993, when overall catch rates were relatively low (Fig. 1), since catch rates were relatively low in all 4 of the age groups represented.

Mean catch rate at age has been used as an index of yearclass strength (Fig. 4). Of the 1991 to 1994 yearclasses, the 1993 and the 1994 yearclasses are relatively large, the 1991 ranking relatively close behind and the 1992 is the smallest. At age 2 the 1993 is the largest, with 1992 intermediate, and the 1991 the smallest. Only the 1991 and 1992 yearclasses were estimated at age 3 both being relatively weak, but with the 1992 being ranked slightly higher.

Discussion

Results of the Campelen 1800 trawl surveys carried out 1992 to 1995 indicate that capelin have been widely distributed in both inshore and offshore areas of NAFO Div. 3KL. Overall abundance of capelin was higher in 1995 than any of the previous 3 years. This trend is indicated in both mean numbers and mean weight. The fact that weight has increased more dramatically than numbers indicates that fish in 1995 are generally larger than in 1994. This is substantiated by the fact that the predominant age group has switched from age 1's in 1994 to age 2's in 1995. The relative mean catch rates at age indicate that both the 1993 (estimated as age 1 and age 2) and the 1994 (estimated as age 1's) yearclasses are relatively strong compared to other recent yearclasses.

Reference

Dalley, E.L., J.T. Anderson, and D.S. Miller. 1995. Preliminary catch rates of capelin (_Mallotus villosus_) in inshore and offshore areas of NAFO Div. 3KL during recent demersal juvenile cod surveys. pp. 133-145. In: Anon. Capelin in SA2 + Div. 3KL. DFO Atl. Fish. Res. Doc 95/70.

Table 1. Percent at age (numbers) of capelin from selected
samples in NAFO Div. 3KL Campelen trawl surveys carried out,
1992-95.

Year	Year					
	1	2	3	4	5	6
1992	50.06	47.84	1.93	0.17	-	-
1993	47.50	34.15	16.52	1.83	-	-
1994	53.29	39.93	5.51	1.23	0.05	-
1995	33.18	62.06	4.05	0.61	0.05	0.05

Table 2. Mean catch rate (numbers) at age of capelin Div. 3KL
Campelen trawl surveys carried out, 1992-95.

	Year					
Year	1	2	3	4	5	6
1992	226.3	216.3	8.7	0.8	–	–
1993	40.8	29.4	14.2	1.6	–	–
1994	291.6	218.5	30.1	6.7	0.3	–
1995	283.7	530.7	34.7	5.2	0.4	0.4
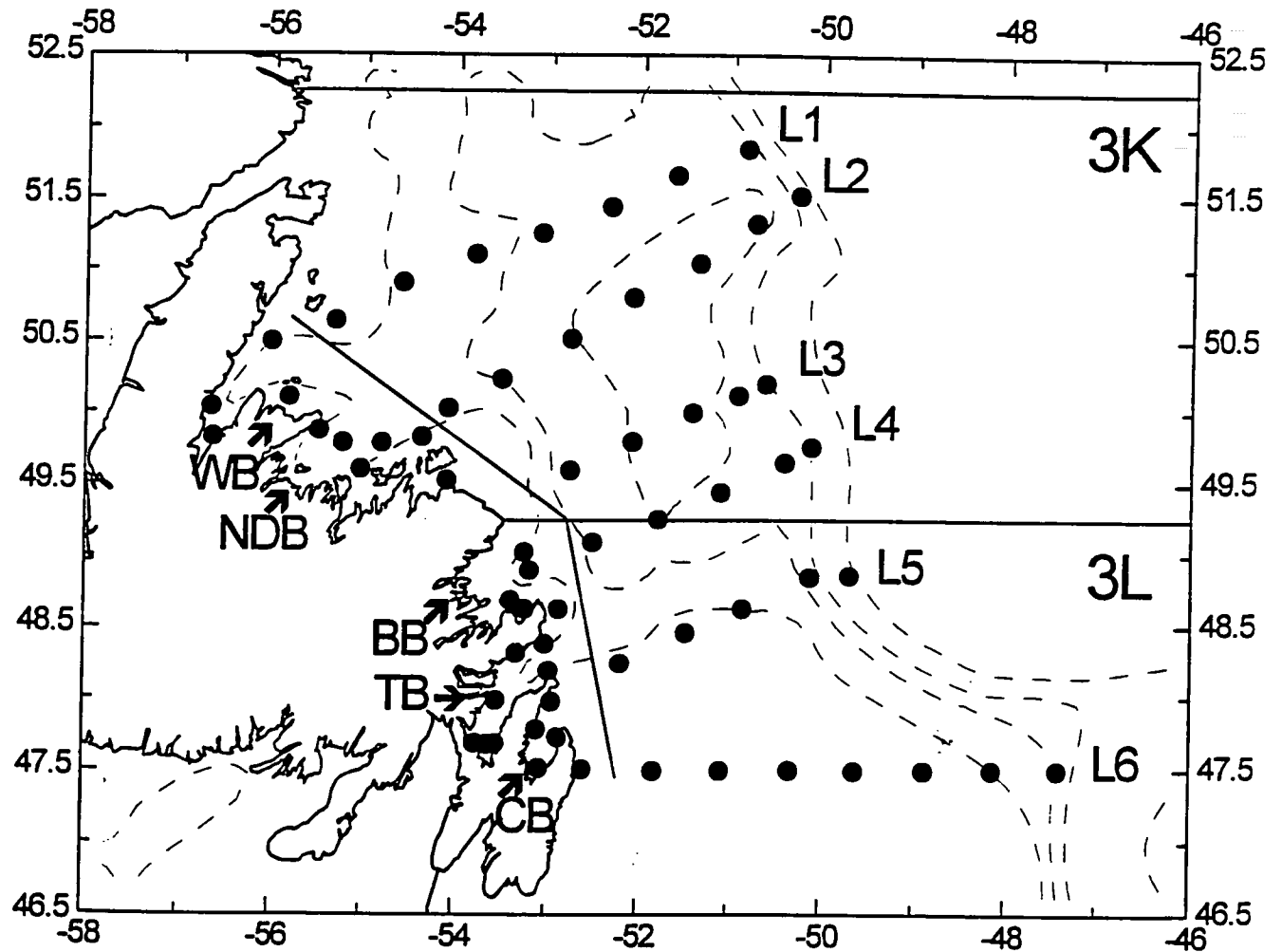
Fig. 1. Map of inshore/offshore Northeast Newfoundland showing the positions of fixed stations sampled during demersal juvenile cod surveys. The black line along the Northeast coast designates inshore from offshore locations. (WB, NDB, BB, TB, CB = White Bay, Notre Dame Bay, Bonavista Bay, Trinity Bay, and Conception Bay, respectively)
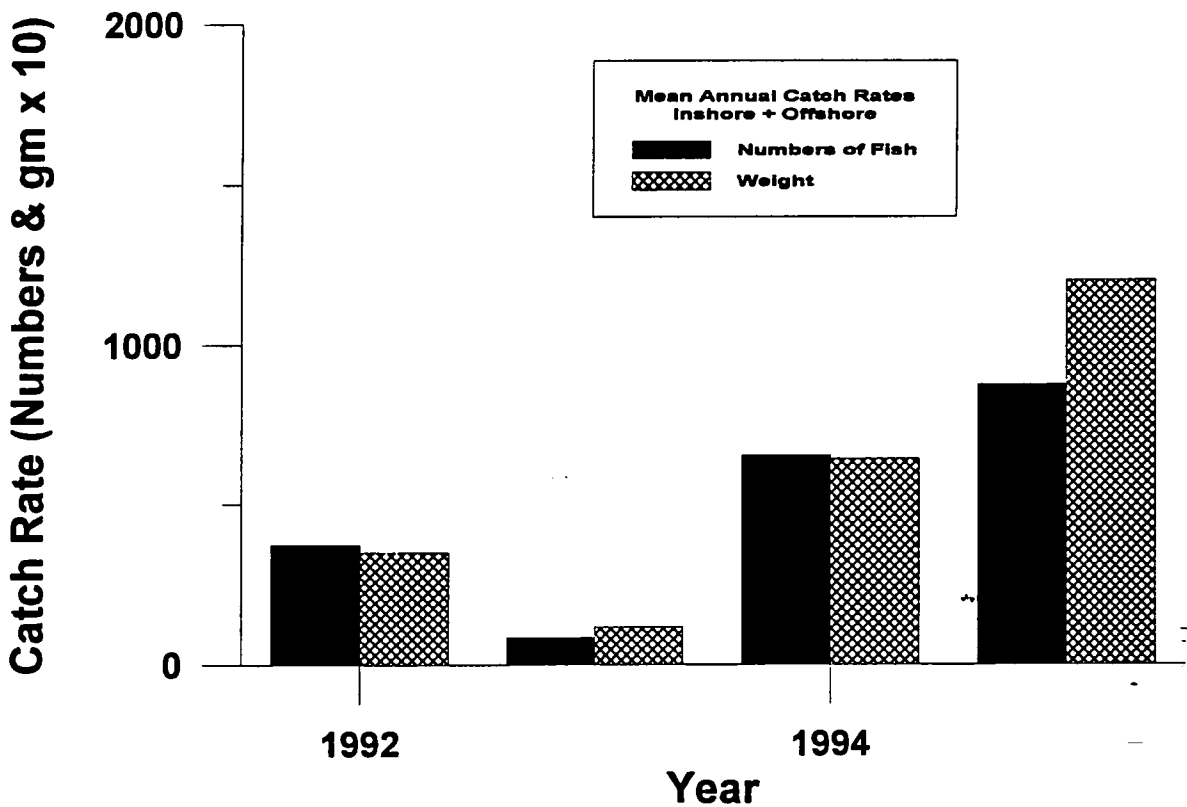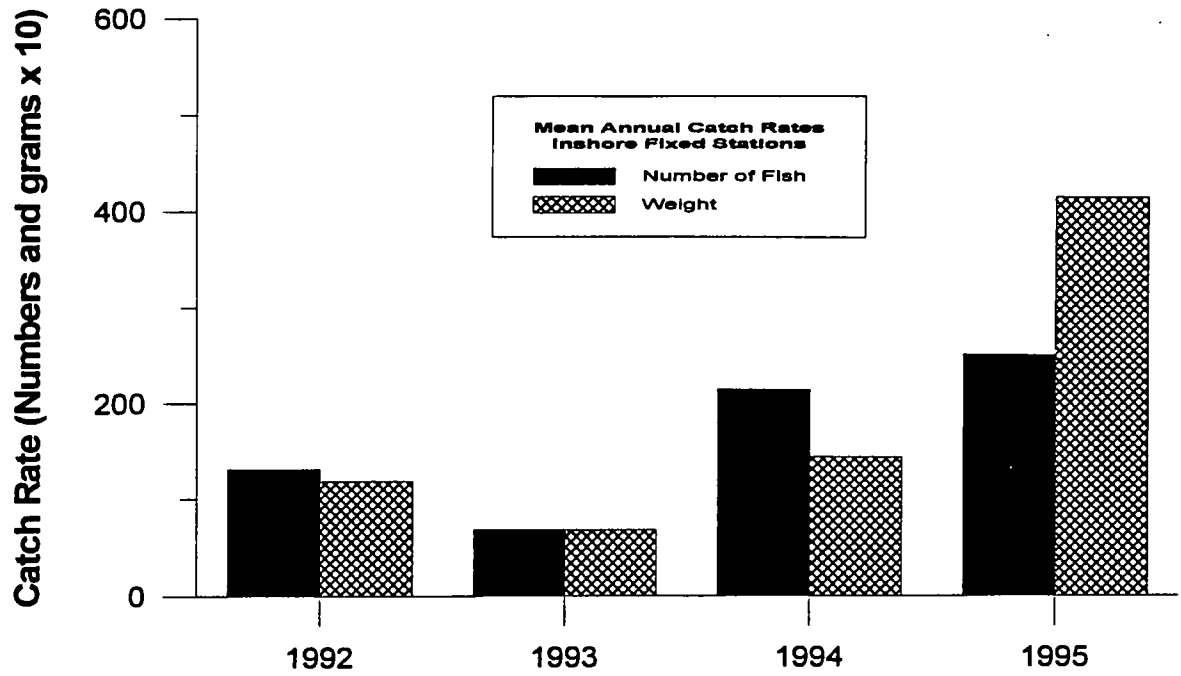
Fig. 2.   Mean annual catch rates of capelin at inshore fixed
stations (top) and inshore and offshore combined as indicated by
Campelen 1800 trawl surveys.
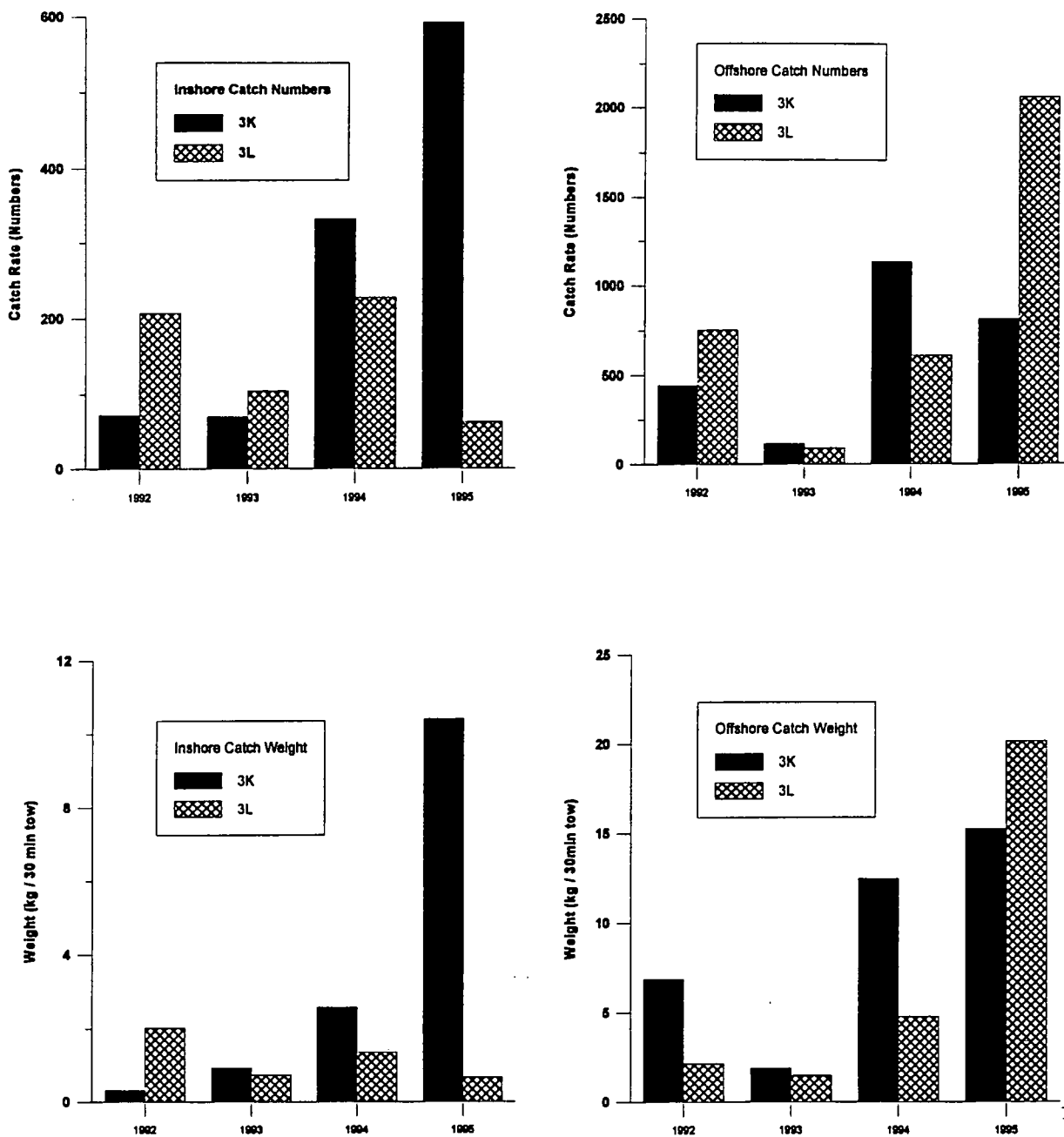
Fig. 3. Comparison of mean catch rates (weight and numbers) of capelin caught in inshore and offshore areas of NAFO Divisions 3K and 3L during Campelen 1800 trawl surveys carried out 1992-95.
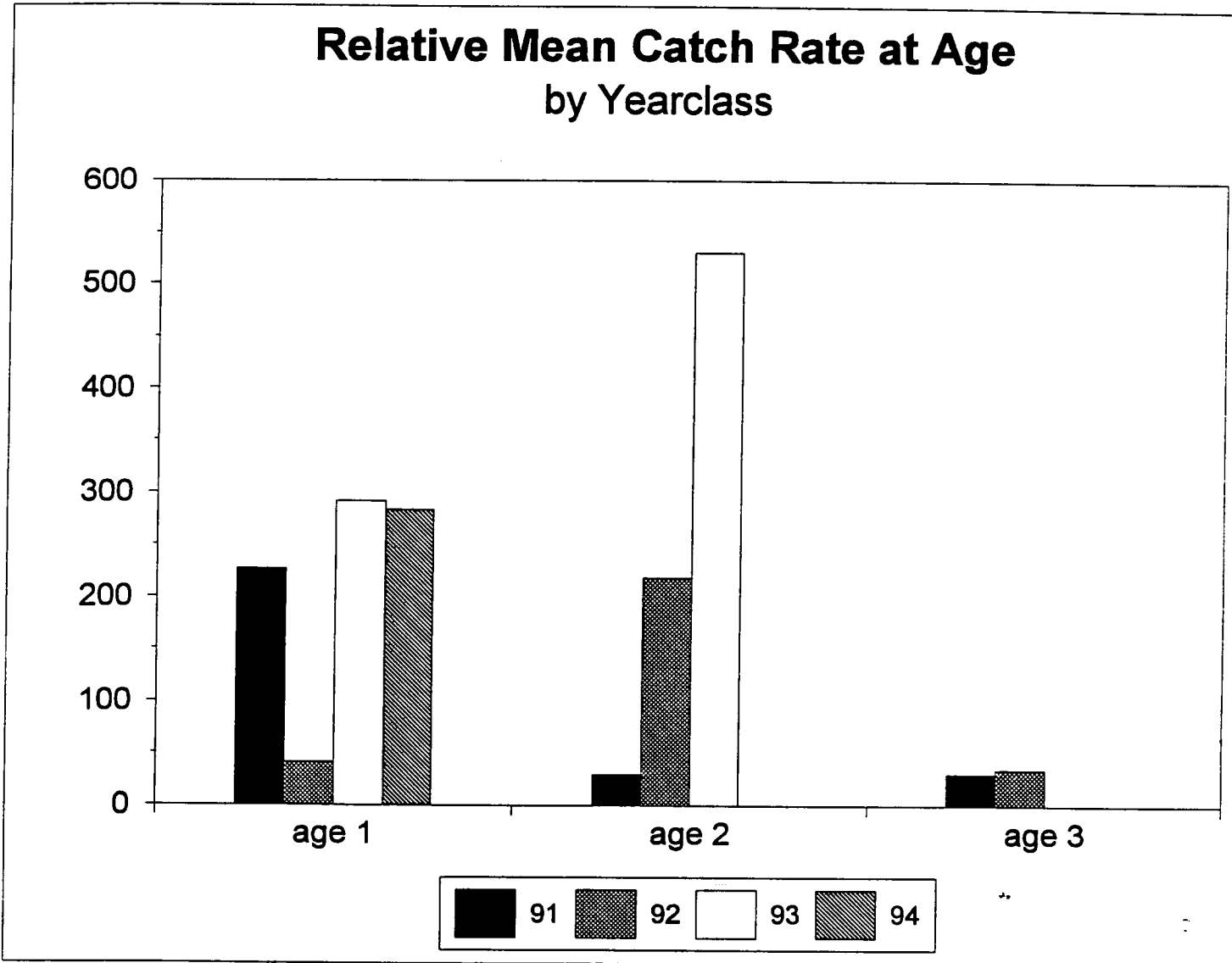
Fig. 4. Relative mean catch rate at age, by yearclass, for capelin sampled during Campelen 1800 trawl surveys, 1992-95.

By-catches of Capelin and Arctic Cod
During Bottom Trawl Surveys in NAFO Divisions 2J3KL

by

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Introduction

Capelin (_Mallotus villosus_) are frequently caught during bottom-trawl surveys directed toward demersal fish off southern Labrador and eastern Newfoundland. The distribution and magnitude of capelin catches from the surveys in Divisions 2J, 3K and 3L during the autumns of 1978-1994 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, 1995a) 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 survey in autumn 1995.

In addition, bottom-trawl surveys on Grand Bank (Divisions 3LNO) in the springs of 1971-1994 were examined by Lilly (1995b) to explore changes in capelin distribution and to provide, for Division 3L only, the frequency of occurrence of capelin and estimates of capelin biomass. This chapter provides an update for 1995.

Finally, the trawl surveys also provide information on the distribution and relative abundance of Arctic cod (_Boreogadus saida_), a small gadoid which is a potential competitor with capelin (Lilly 1980) and a predator on small capelin (unpublished data). This chapter will update the Arctic cod biomass estimates provided by Lilly et al. (1994) and Shelton (1996).

Materials and Methods

Surveys in Div. 2J3KL in autumn

Capelin and Arctic cod were caught during random-stratified bottom-trawl surveys designed to assess the biomass of demersal fish during October-December 1978-1994 (Table 1). All surveys in Divisions 2J and 3K in 1978-1994 were conducted with the 74 m stern trawler R.V. 'Gadus Atlantica'. Surveys in Division 3L in 1981-1983 and 1985-1994 were conducted with the 51 m side trawler R.V. 'A. T. Cameron' (1981-1982) and the sister 50 m stern trawlers R.V. 'Wilfred Templeman' (1983, 1985, 1987-1994) and R.V. '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 Engels 145 high-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. No adjustments were made for possible between-vessel differences in catching efficiency. Additional details regarding areas and locations of strata and changes in survey pattern are provided by Bishop et al. (1994), Lilly and Davis (1993) and Bishop (1994). 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 2) differed from that in previous years in several respects (Brodie 1996). (1) The R.V. 'Gadus Atlantica' was replaced by the R.V. 'Teleost'. (2) The Engels 145 high-lift trawl was replaced with a Campelen 1800 shrimp trawl with rockhopper foot gear. This trawl catches small fish much more efficiently than does the Engels. (3) Tows were made at 3.0 knots for 15 min instead of 3.5 knots for 30 min. (4) In Division 2J3K the survey began late and did not end until January 25, 1996. This was the first time that the survey continued into the new year. In Division 3L, 18 sets were conducted during October 3-5, 143 were conducted during October 30 - November 23, and 5 were conducted in deep water on January 25, 1996. The fishing in early October was more than a month earlier than fishing in Division 3L in 1991-1994. (5) Four strata usually surveyed in Division 2J were not occupied, and intensity of surveying was lower than normal in some other strata. (6) The R.V. 'W. Templeman' fished north of Division 3L for the first time in the time-series.

Surveys in Division 3LNO in spring

Capelin were caught during random-stratified bottom-trawl surveys of Divisions 3LNO during April–June 1971–1995, excluding 1983 (Table 3). Surveys were conducted with the 51 m side trawler R.V. 'A. T. Cameron' (1971–1982) and the sister 50 m stern trawlers R.V. 'Wilfred Templeman' (1985–1995) and R.V. 'Alfred Needler' (1984). The 'A. T. Cameron' deployed a Yankee 41-5 trawl, whereas the 'Wilfred Templeman' and 'Alfred Needler' deployed an Engel-145 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. No adjustments were made for possible between-vessel differences in catching efficiency. Additional details regarding areas and locations of strata are provided by Doubleday (1981) and Bishop (1994). Fishing in all Divisions and years was conducted on a 24-h basis.

Most surveys in Division 3L were conducted in May (see Fig. 1 in Lilly 1995b). 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 and 1995 (June 1, June 2 and June 8 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.

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 proportional to stratum area except in Division 2J3KL during the autumn surveys of 1991–1994, when a relatively higher number of sets was assigned to 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

$$O_{ad} = \frac{\sum_{i=1}^{m} (\frac{nc_h}{N_h} \times 100) A_h}{\sum_{h=1}^{m} A_h}$$

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

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

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, capelin were recorded at 60% of the 194 fishing stations conducted at depths of 750 m or less (Table 4). This is the highest frequency of occurrence in the period 1978-1995. Catches were large compared to most previous years (95th percentile = 56 kg; maximum = 332 kg) (Table 4). 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. 1). Largest catches were concentrated on northern, western and southern Funk Island Bank and near the Div. 3K/3L line. In general, the distribution in 1995 was similar to that observed in 1991-1994 (Lilly 1992, 1994a, 1995a; Lilly and Davis 1993). All of the large catches in Divisions 2J and 3K occurred within the area covered by the acoustic survey in 1994 (Fig. 1).

In Division 3L, capelin were recorded at 72% of the 162 stations (Table 5). This is by far the highest frequency of occurrence in the period 1985-1995. Catches were very large compared to earlier years (95th percentile = 29 kg; maximum = 70 kg) (Table 5). Capelin were caught in northern and northeastern

Division 3L, in the Avalon Channel, and south of the Avalon
Peninsula (Fig. 1). There were only a few small catches on the
plateau of Grand Bank. Many of the moderately large catches in
northeastern Division 3L were near the boundary of the 1994
acoustic survey, and the catches south of the Avalon Peninsula were
outside the acoustic survey area.

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 6, Fig. 2). 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. The value in 1995 (unadjusted, 60%; adjusted, 66%) was the
highest in the time-series. 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 (unadjusted, 72%; adjusted, 76%) was by far the
highest in the time-series.

Estimates of abundance and biomass

        The minimum trawlable abundance and biomass were relatively
high in 1979-1981, due almost entirely to a few very large catches
on the plateau of Hamilton Bank (Carscadden et al. 1989), and
fluctuated without trend from 1981 to 1994 (Fig. 3). The biomass
estimates in 1995 were 2.4, 42.6, and 22.6 thousand tonnes in
Divisions 2J, 3K and 3L, respectively, for a total of 67.6 thousand
tonnes. These estimates, based on catches with the Campelen trawl,
are approximately an order of magnitude greater than estimates in
earlier years.

Capelin in Division 3LNO during spring

Distribution

        In Division 3L, capelin were recorded at 52% of the 151
fishing stations conducted at depths of 750 m or less (Table 7).
This was very similar to levels in 1991-1994. Catches were
relatively small (95th percentile = 6 kg; maximum = 12 kg). A few
moderately large catches were obtained on the northeastern slope of
Grand Bank and on the eastern and southwestern slopes of the bank
in Division 3NO (Fig. 4). The small or nil catches in the Avalon
Channel and on the northwestern edge of Grand Bank continue a
pattern observed in 1991-1994, and contrast markedly with large
catches in these areas in many previous years, including 1986-1990
(Lilly 1995b).

Frequency of occurrence

In Division 3L, the frequency of occurrence (unadjusted, 52%; adjusted 56%) was very similar to levels in 1991-1994 and lower than the levels of 70-80% found in 4 of the 5 years in the period 1986-1990 (Table 8; Fig. 5).

Estimates of biomass

In Division 3L, the biomass estimated from areal expansion of mean catch per tow was low (1100 t) for the fifth consecutive year (Table 8; Fig. 6). During the period 1986-1990 values had varied from 4000 to 34,000 t.

Arctic cod in Division 2J3KL during autumn

The biomass of Arctic cod, estimated by areal expansion of mean catch per tow during the autumn surveys, was relatively low in 1978-1984 but generally higher and more variable in 1985-1994 (Fig. 7). There has been an expansion into northern Division 3L in the 1990s (Lilly et al. 1994). The biomass estimates in 1995 were 28.5, 27.1, and 22.5 thousand tonnes in Divisions 2J, 3K and 3L, respectively, for a total of 78.1 thousand tonnes. These estimates, based on catches with the Campelen trawl, are more than an order of magnitude greater than estimates in earlier years.

Discussion

Capelin distribution, relative abundance and biomass

The bottom-trawl surveys described in this chapter covered the area from southern Labrador to the northern Grand Bank (Division 2J3KL) during the autumn and the whole of Grand Bank (Division 3LNO) during the spring. During the autumn survey, the largest catches of capelin were obtained on northern, western and southern Funk Island Bank, near the 3K/3L boundary, and along the northeastern slope of Grand Bank. A few moderate to large catches were taken on Hamilton Bank, on the coastal shelf off southern Labrador and northeastern Newfoundland, and in the Avalon Channel. Catches were nil or very small near the shelf break in Division 2J3K and on the plateau of Grand Bank. This distribution is similar to that seen in 1991-1994, 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). Capelin distribution seems to be more extensive in 1995 than in 1991-1994. This may be a result of the change in survey gear. The frequency of occurrence of capelin and the estimate of capelin biomass increased in 1995 compared with previous years. This is considered to be a result of the change in survey gear. Data collected in 1995 are not comparable to data collected in 1978-1994.

During the spring survey in Division 3LNO, catches were generally small, but a few moderately large catches were obtained on the northeastern slope of Grand Bank. The lack of large catches in the Avalon Channel and northwestern slope of Grand Bank may be the result of low overall abundance of capelin or a delay in the migration of capelin into the area. The decline in trawlable biomass from a relatively high level in 1990 to a low level in 1991 coincided with the decline observed in the acoustic estimates. The continuing low trawlable biomass from 1992 to 1995 may be a cause for concern.

Interactions with Arctic cod

The trophodynamic role of Arctic cod on the Labrador Shelf and Northeast Newfoundland Shelf is poorly known. Studies throughout its range have shown that Arctic cod is largely planktivorous (Lilly 1980), and may therefore be a competitor of capelin. It also preys on small fish. Limited sampling off northeastern Newfoundland has revealed predation on small capelin (unpubl. data). Because the quantity of Arctic cod off eastern newfoundland has recently increased, especially in northern Division 3L where small capelin are most abundant during the autumn, it is possible that the consumption of capelin by Arctic cod has increased. The feeding of Arctic cod should be more thoroughly investigated, particularly with respect to potential competition with capelin and predation on capelin.

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Table 1. Selected data for bottom-trawl surveys in Divisions 2J3KL in the autumns of 1977-1994. AN = ALFRED NEEDLER, ATC = A. T. CAMERON, GA = GADUS ATLANTICA, WT = WILFRED TEMPLEMAN.

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

Table 1. (Cont'd.)

Year	Div.	Ship/Trip	Sampling dates (d/mo.-d/mo.)	Number of stations occupied		Phase 1 stations with cod		Phase 1 stations with capelin	
				Phase 1	Phase 2	No.	%	No.	%
1991	2J3K	GA 208-210	06/11-17/12	313		229	73	117	37
	3L	WT 114,115	08/11-02/12	219		168	77	45	21
1992	2J3K	GA 224-226	29/10-09/12	319		209	66	153	48
	3L	WT 129,130	05/11-29/11	215		146	68	80	37
1993	2J3K	GA 236-238	30/10-06/12	263		137	52	98	37
	3L	WT 145,146	12/11-04/12	153		94	61	76	50
1994	2J3K	GA 250-252	09/11-19/12	255		81	32	108	42
	3L	WT 161,162	08/11-07/12	200		68	34	83	42

Table 2. By-catches of capelin and other selected data for bottom-trawl surveys in Divisions 2J3KL in autumn 1995 – winter 1996. TEL = Teleost; WT = Wilfred Templeman.

Division	Ship/Trip	Sampling dates (d/mo. – d./mo.)	No. of stations	Stations with capelin No.	%
2J3K	WT 180,181 TEL 20–23	28/11–25/01	215	116	54
3L	WT 176,178,179 TEL 23	03/10–25/01	166	117	71

Table 3. Selected data for bottom-trawl surveys in Divisions 3LNØ in the springs of 1971-1995.

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 %
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 3. (Cont'd)

Year	Div.	Ship/Trip	Sampling Dates (d/mo.-d/mo.)	Number of Stations Occupied	Stations with cod		Stations with capelin	
					No.	%	No.	%
1980	3L	ATC 304, 305	10/05-02/06	115	113	98	20	17
	3NØ	ATC 303, 304	11/04-11/05	140	109	78	4	3
1981	3L	ATC 317, 318	06/04-07/05	81	67	83	28	35
	3NØ	ATC 318, 319	04/05-22/05	77	67	87	10	13
1982	3L	ATC 329	06/05-17/05	103	93	90	44	43
	3NØ	ATC 327, 328	27/03-26/04	138	119	86	20	15
1984	3L	AN 28	17/05-21/05	37	37	100	18	49
	3NØ	AN 27	28/04-08/05	117	86	74	15	13
1985	3L	WT 28-30	17/04-26/05	221	198	90	94	43
	3NØ	WT 29 AN 43	11/04-05/05	178	134	75	33	19
1986	3L	WT 48	07/05-25/05	211	203	96	169	80
	3NØ	WT 47	18/04-04/05	203	160	79	21	10
1987	3L	WT 59, 60	14/05-01/06	181	169	93	53	29
	3NØ	WT 58, 59	23/04-14/05	190	168	88	56	29
1988	3L	WT 70, 71	05/05-24/05	154	142	92	108	70
	3NØ	WT 70	21/04-05/05	161	132	82	28	17

Table 3. (Cont'd)

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

Table 4.   Statistics for by-catches of capelin during bottom-trawl surveys in NAFO Divisions 2J3K during the autumns of 1978 to 1995.

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

[a]   Stations in depths >750 m are not included. Stations in strata 618 and 619 on the coastal shelf off northern Newfoundland are included. These strata were not fished prior to 1984.

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

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

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

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

Table 5. Statistics for by-catches of capelin during bottom-trawl surveys in NAFO Division 3L during the autumns of 1985 to 1995.

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

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

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

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

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

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

Table 6.   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 bottom trawl.   Tows in 1995 were
conducted with a Campelen 1800 shrimp trawl.

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

Table 7.   Statistics for by-catches of capelin during bottom-trawl surveys in NAFO Div. 3L during the springs of 1971 to 1995.

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

[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 8.   The frequency of occurrence and trawlable biomass of capelin in Division 3L in the springs of 1977-1995, as estimated from bottom trawl surveys, and the biomass in 1982-1992, as estimated from acoustic surveys.   The frequency of occurrence of capelin in bottom trawl catches is calculated for the entire survey area and for a reduced area in western Division 3L, corresponding approximately to the area covered by the acoustic surveys prior to 1991.   Both unadjusted and adjusted values are presented.   The method of adjustment is described in the text.   The trawlable biomass of capelin was estimated from the capelin catches during the bottom trawl surveys, and is provided for both the entire survey area and the reduced area.

| | Frequency of occurrence (%) | | | | Biomass ('000 tons) | | |
| | Div. 3L | | Western Div. 3L | | Bottom trawl survey | | |
Year	Unadj.	Adj.	Unadj.	Adj.	Div. 3L	Western Div. 3L	Acoustic survey[a]
1977	35.3	38.2	42.1	44.1	18.246	17.878	
1978	8.4	5.9	11.8	8.6	0.025	0.024	
1979	29.8	31.7	43.2	42.3	15.441	8.372	
1980	17.4	15.6	24.0	23.4	0.492	0.490	
1981	34.6	28.5	44.4	35.8	2.045	1.897	
1982	42.7	47.9	32.8	34.0	6.005	0.843	466
1983							84
1984							353
1985	42.5	41.0	44.7	41.0	1.874	1.286	3426
1986	80.1	79.7	78.8	78.7	33.864	17.571	3697
1987	29.3	32.1	38.7	40.9	12.919	8.223	2576
1988	70.1	69.8	70.5	69.4	4.007	2.351	4551
1989	76.6	78.0	80.0	80.2	6.250	3.819	3829
1990	69.2	71.5	84.3	84.5	15.546	8.624	6958
1991	48.3	52.1	63.8	65.1	1.398	0.603	116
1992	51.7	54.1	56.4	56.8	0.259	0.055	206
1993	51.4	53.1	56.2	57.5	1.436	0.944	
1994	48.7	48.6	54.7	54.7	0.432	0.143	
1995	51.7	55.8	71.2	70.7	1.103	0.305	

[a]   From Miller (1992)
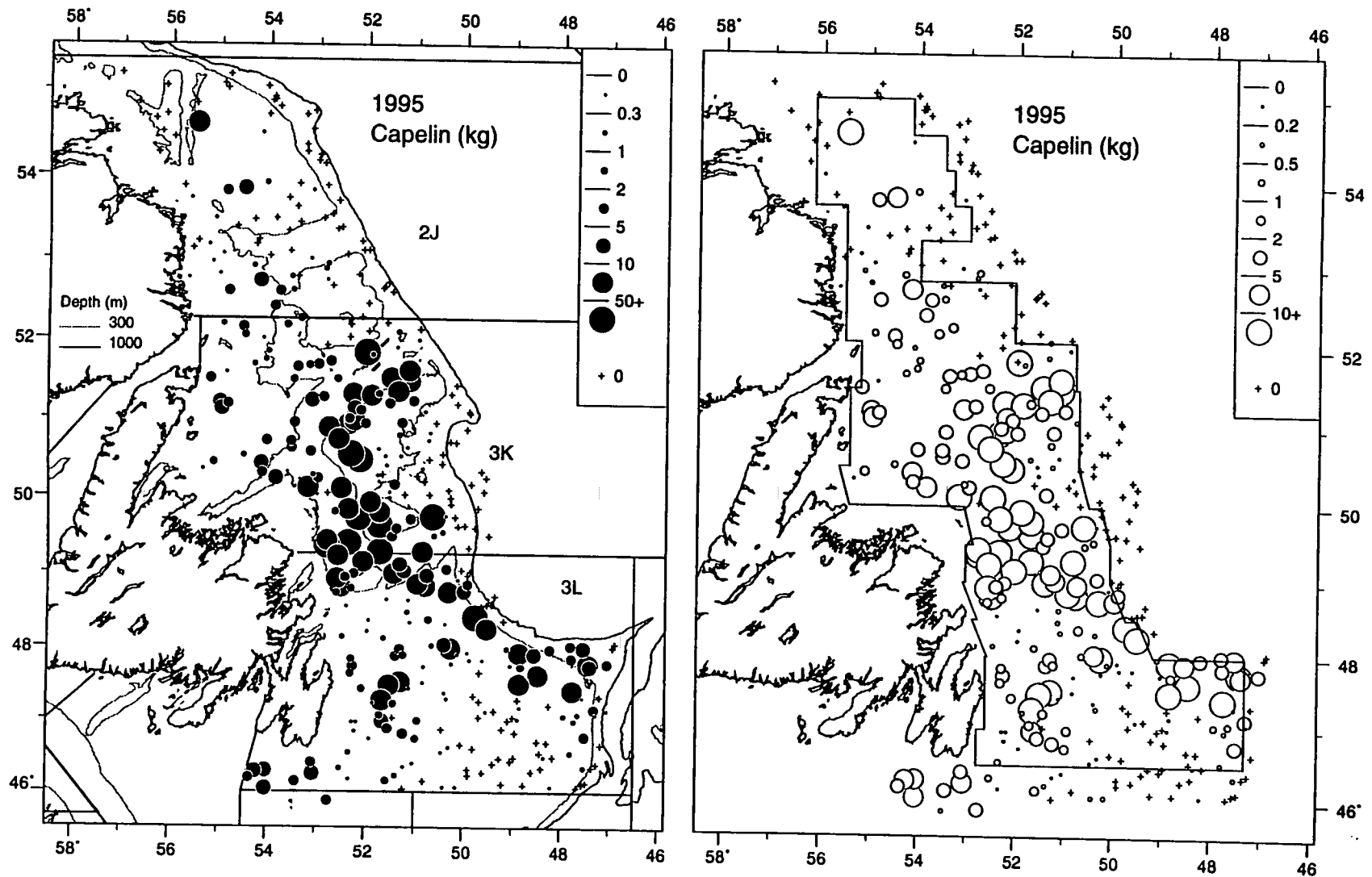
Fig. 1. Capelin catches (kg/15 min tow) during random-stratified bottom-trawl surveys in Divisions 2J3KL during autumn 1995 and early winter 1996. The left panel shows the 300 and 1000m isobaths. The right panel shows the boundary of the acoustic survey in 1994. Symbols in the right panel are scaled as in previous reports (eg. Lilly 1995a).
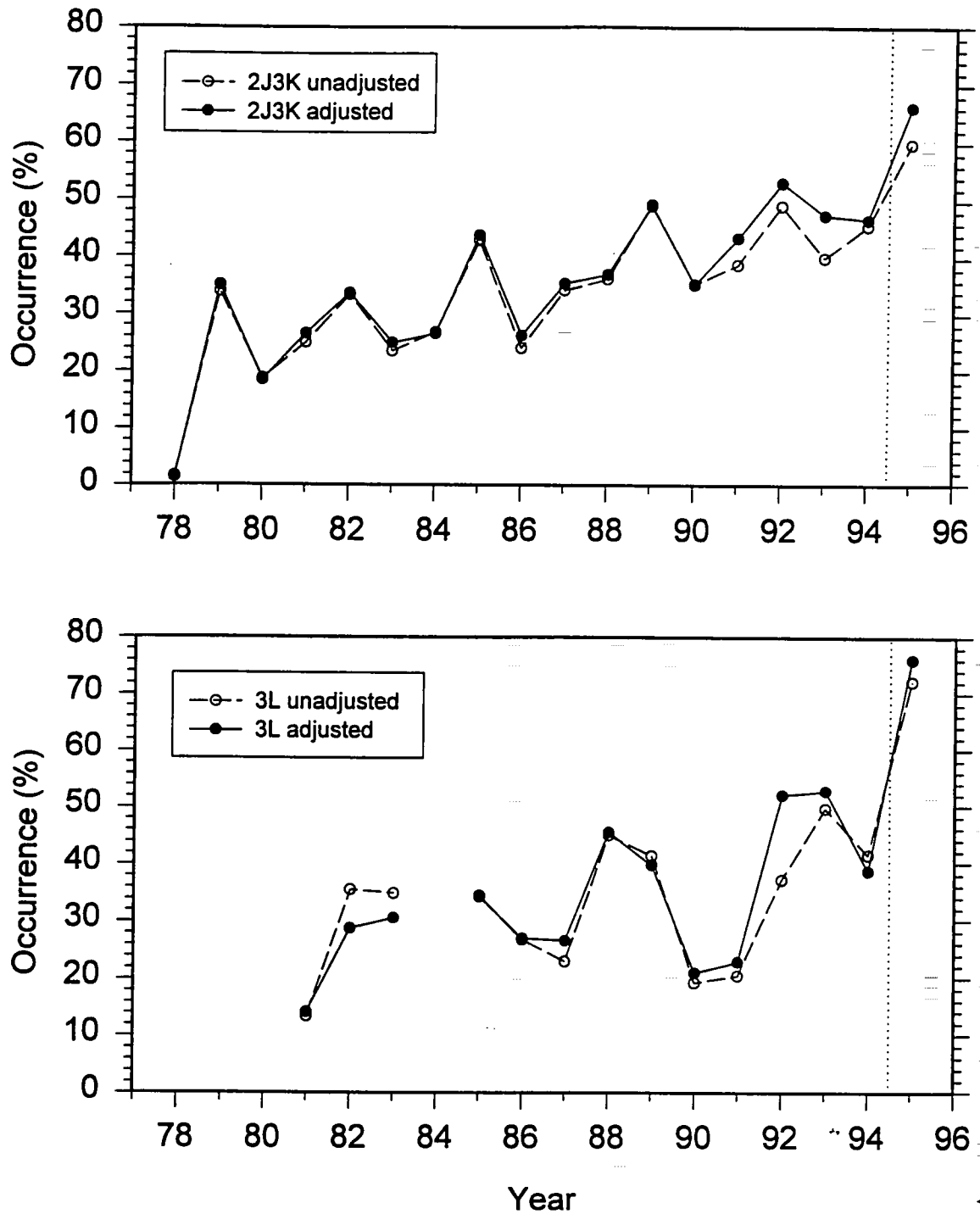
Fig. 2. The frequency of occurrence of capelin in catches during the autumn bottom-trawl surveys in Divisions 2J3K (upper panel) and Division 3L (lower panel) in 1978-1995. Division 3L was not surveyed in 1978-1980 and 1984. In 1995 the survey gear was changed to a Campelen 1800 shrimp trawl from the Engels 145 high-lift trawl used in 2J3K (1978-1994) and 3L (1985-1994). A Yankee 41-5 trawl was used in Division 3L in 1981-1983.
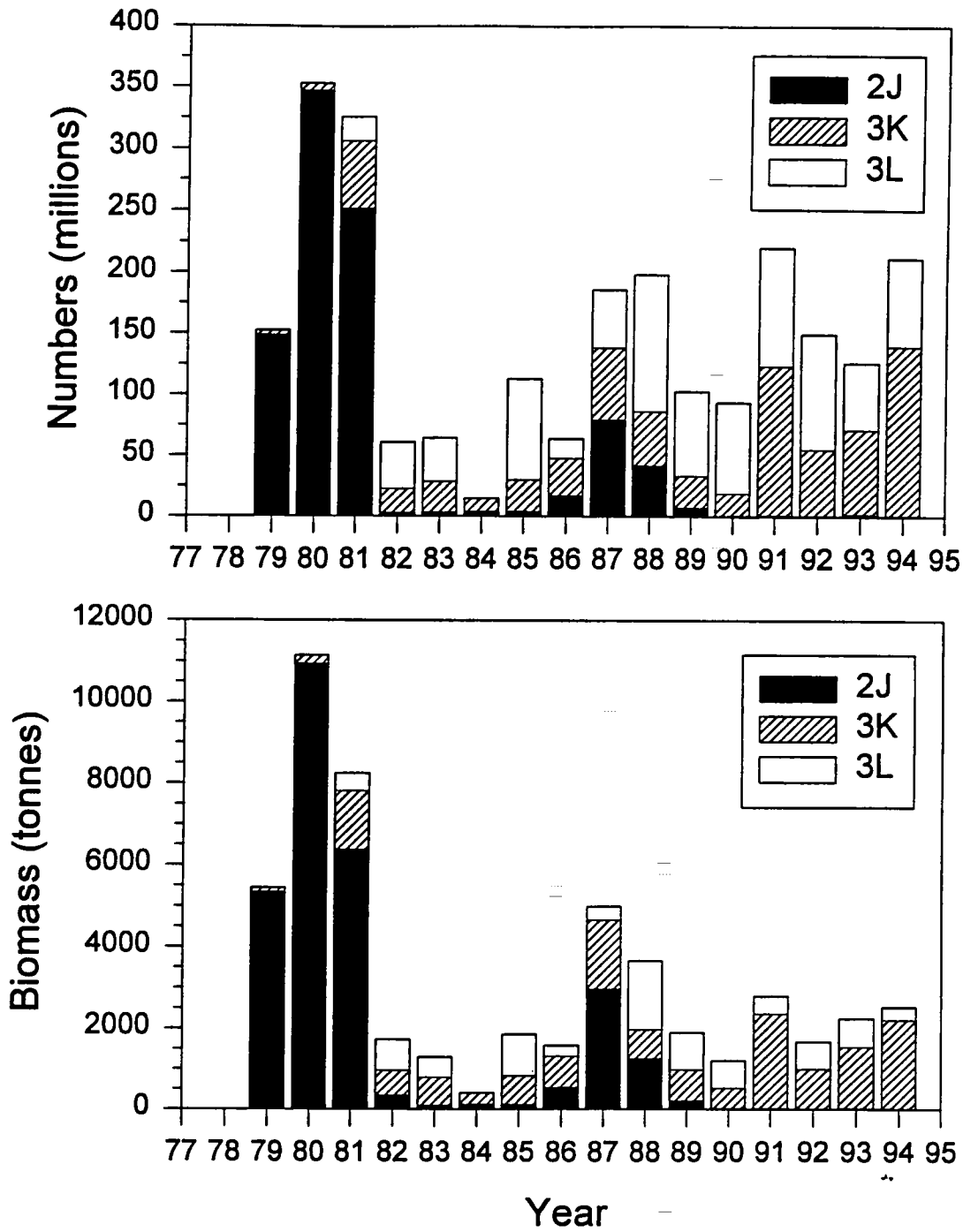
Fig. 3. Abundance and biomass of capelin by year and Division, estimated from areal expansion of stratified mean catch per tow during autumn surveys. Division 3L was not surveyed in 1978-1980 and 1984. (from Lilly 1995a)
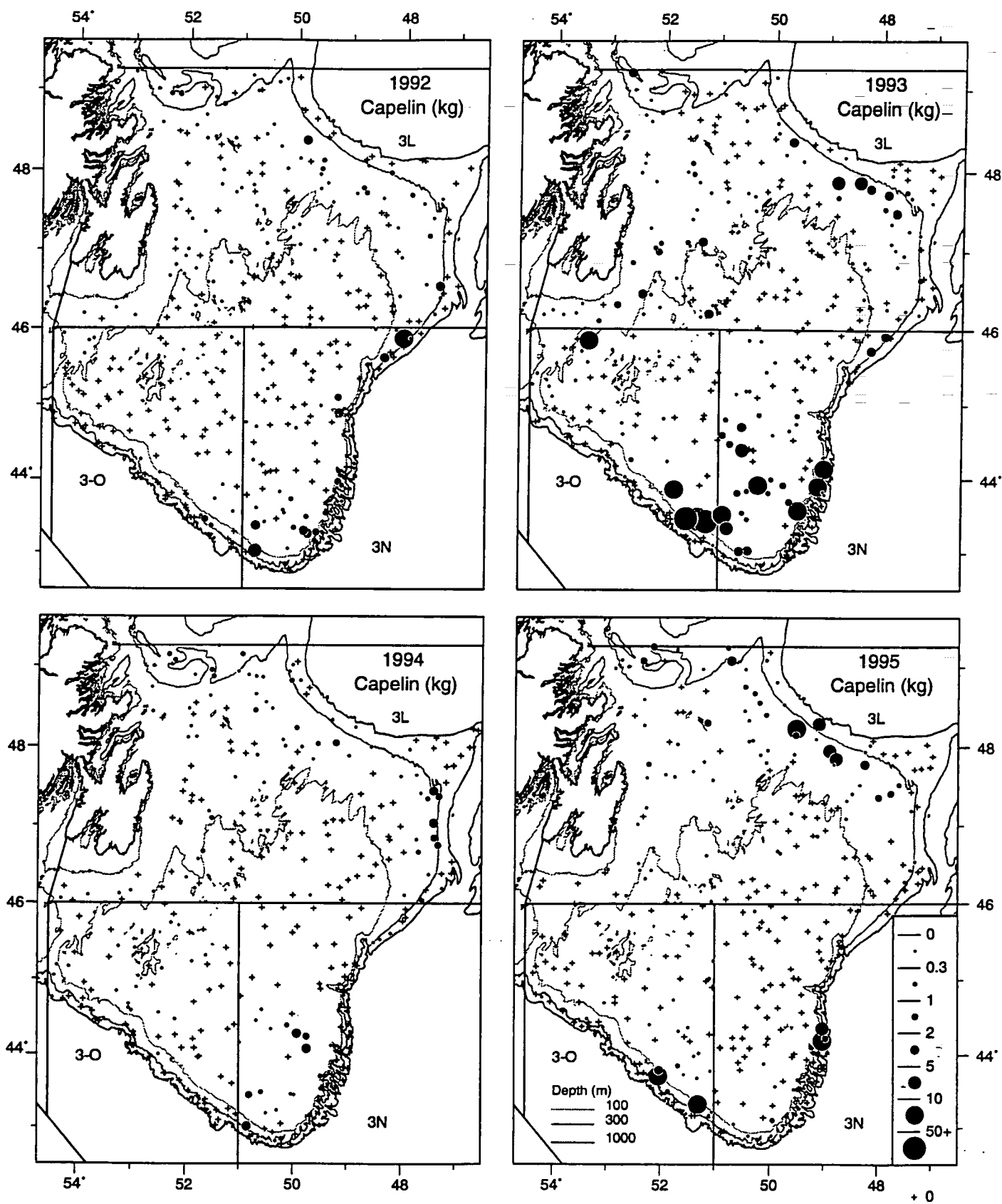
Fig. 4. Capelin catches during stratified-random bottom trawl surveys in Divisions 3LNO in the springs of 1971-1994. There was no survey in 1983.
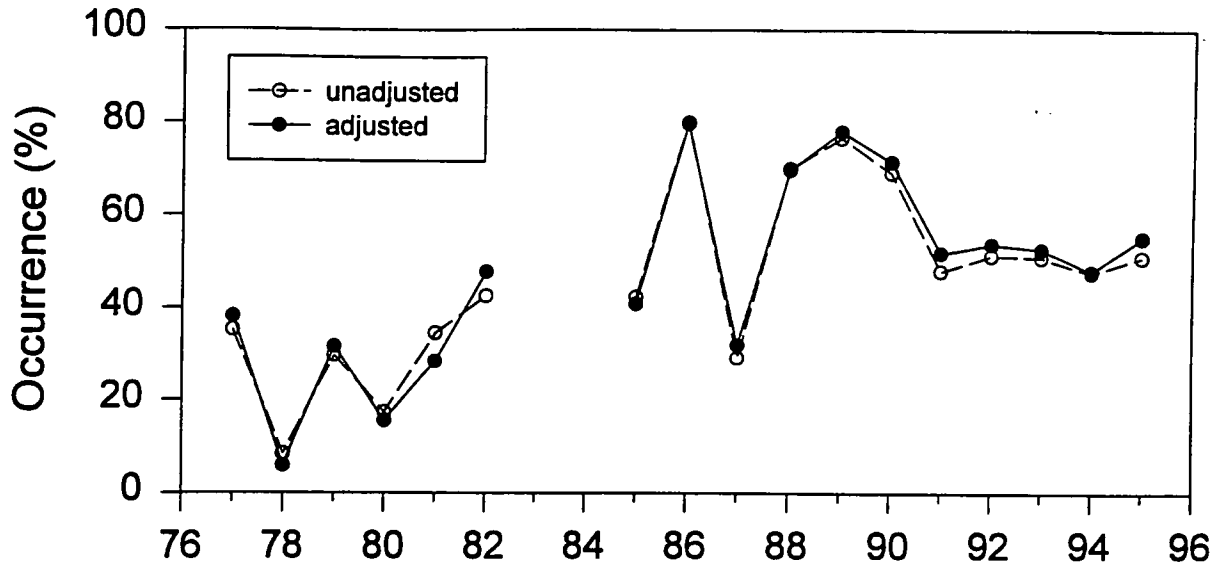
Fig. 5. The frequency of occurrence of capelin in catches during the spring bottom-trawl surveys in Division 3L in 1977-1995. There was no survey in 1983 and coverage was inadequate in 1971-1976 and 1984.
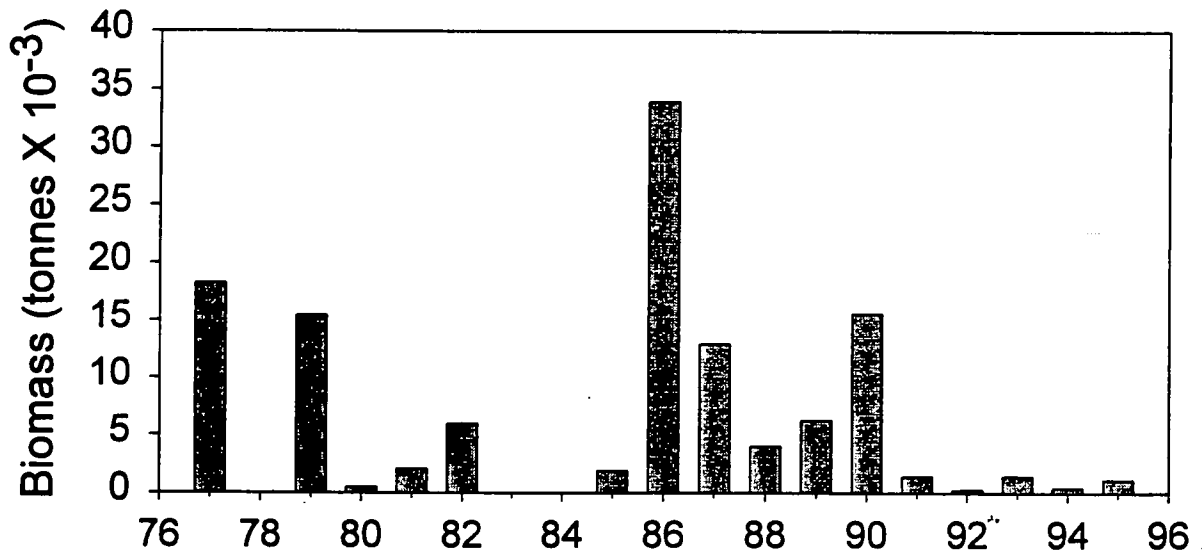
Fig. 6. Biomass of capelin, estimated from areal expansion of stratified mean catch per tow during stratified-random bottom-trawl surveys in Division 3L in 1977-1995. There was no survey in 1983 and coverage was inadequate in 1971-1976 and 1984.
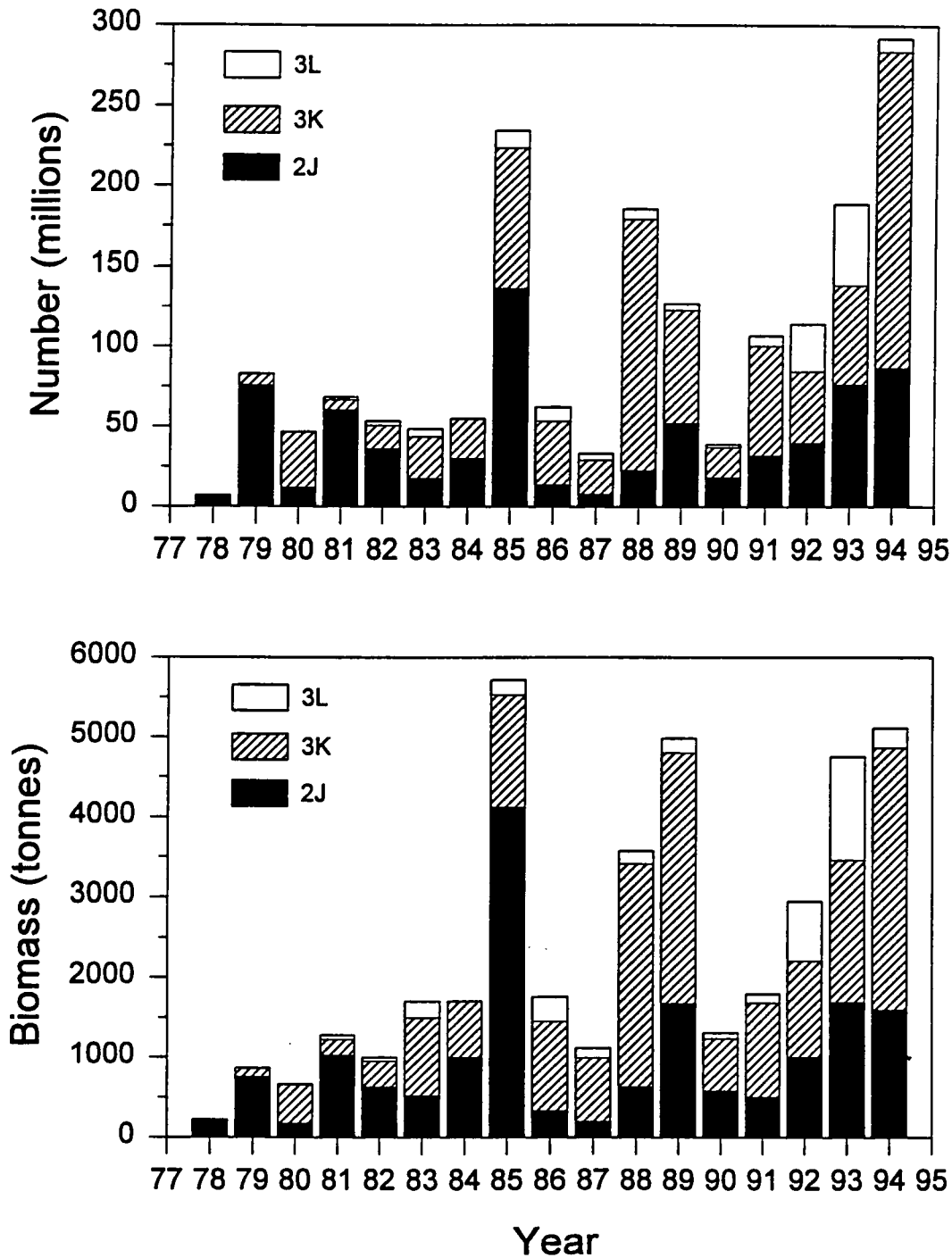
Fig. 7. Abundance and biomass of Arctic cod by year and
Division, estimated from areal expansion of stratified mean catch
per tow during autumn surveys. Division 3L was not surveyed in
1978-1980 and 1984. Updated from Lilly et al. 1994.

Capelin in SA2 + Div. 3KL

1) <u>Introduction</u>

A capelin assessment committee met several times during March 1996 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) <u>Catch Trends</u>

i) <u>SA2 + Div. 3K</u>

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 (Fig. 1).

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 criteria for setting the TAC.

During 1995, monitoring programmes were established in most areas to conduct test fisheries and open the fishery when fish conformed to criteria defined in the Management Plan. The presence of small females in the catch (more than 50 females/kg) was the main reason the fishery did not open in 1995. Low abundance in some areas was also a factor. The landings of 55 t, mostly from the monitoring programme were well below the 11,550 t TAC and comparable to the 67 t reported in 1994.

ii) <u>Div. 3L</u>

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.

In 1995, a monitoring programme similar to SA2 + Div. 3K resulted in no fishery openings. The reported catch of 83 t was from the monitoring. This catch was below the 1994 catch of 893 t and well below the TAC of 21,730 t. Small fish was the main reason for not opening the fishery.

Catches and TACs (tons x 10-3) since 1989 are shown below.

	1989	1990	1991	1992	1993	1994	1995
SA2 + Div. 3K							
Offshore							
Advised TAC	b	107	57	-	-	-	-
TAC	20	71	57	0	0	0	0
Nominal catch	22	57	0.5	0	0	0	0
Inshore							
Advised TAC	b	107	f	d	d	a	-
TAC	24.1	29	29	17	11.4	11.5	11.5
Nominal catch	28	33	20	18	13c	<.1c	<.1c
Div. 3L							
Advised TAC	335	350	e	e	d	a	-
TAC	46	56	56	19.3	21	21	22
Nominal catch	52	48	22	3	23c	1c	1c
SA2 + Div. 3KL							
Total nominal catch	102	138	42.5	21	36	1	1

a data not adequate to advise a TAC
b total inshore and offshore catches could be 200,000-250,000 t without exceeding 10% target exploitation rate
c provisional
d lowest possible level
e STACFIS concluded that a catch of 50,000 t as in recent years would not exceed a 10% exploitation rate
f catch should not exceed that of previous year

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 questionnaire was modified slightly and used to conduct telephone interviews following the 1995 capelin spawning season. Approximately 380 fishers were selected at random from a survey population of 1878 fishers licensed to fish capelin using traps and beach seines in Div. 3Ps, 3L, and 3K in 1995. Between October 10, 1995 and January 4, 1996 330 fishers responded to the survey. No information was collected on fishing effort and fishing practices because the commercial fishery did not open in 1995.

On a scale of one to ten with one being the lowest, the average rating for capelin abundance in 1995 was 3.4. Ninety-four percent indicated abundance was lower than when they started fishing, 5% said it was the same, and 1% felt it was higher.

The number of beaches in their area on which capelin normally spawn was none for 1%, one to five beaches for 47%, six to ten beaches for 30%, and more than ten beaches for 22%. In 1995 25% observed no spawning on beaches in their area, 61% said one to five beaches had spawn, 8% saw capelin spawn on six to ten beaches, 3% indicated eleven or more beaches, and 3% didn't know. On a scale of one to ten with one being the lowest, the average rating for spawning intensity in 1995 was 3.7. Compared to 1994, spawning intensity in 1995 was judged to be lower by 21%, the same by 23%, higher by 28%, and not known by 28%.

Capelin spawned off beaches in deeper water in 1995 according to 37% of fishers, 24% did not see evidence for this, and 39% didn't know. Of those who reported off beach spawning in 1995 47% thought it was due to water temperature, 18% gave miscellaneous reasons, 16% said they always spawned off beaches, and 19% did not know. The prevalence of off beach spawning since starting to fish capelin was every year by 12%, most years by 23%, some years by 33%, rare by 15%, and never by 15%.

When asked specifically about opening the 1996 capelin fishery, 54% were against, 21% were in favour, and 24% were in favour as long as fish were abundant and large enough to sell. Sixty-seven percent of those who were against opening were concerned because capelin were scarce or too small.

The results of the survey have a 5% margin of error nineteen times out of twenty.

4)   Inshore Data

i)   Sampling   (Chapter 2)

Biological samples consisted of monitoring trap samples and cast net samples from a few beaches. The age composition was 44% two-year-olds, 52% three-year-olds, and 4% four-year-olds. Mean-lengths-at-age for age 3 and age 4 fish continue to be lower than in the 1980s. Age 2 fish do not exhibit a similar decline. To make these comparisons we must assume that the samples in 1995 are comparable to what would have been collected had there been a commercial fishery.

ii)   Aerial Survey   (Chapter 4)

Good flying weather allowed frequent coverage of the Trinity Bay and Conception Bay transects in 1995 during July 5-21 and 27-29. The index is the sum of the peak estimate of school area for each bay. The 1995 index was the third highest in the series and 15% lower than the 1994 index. Unlike 1994 school areas and distribution in 1995 were not dissimilar. The Trinity Bay estimate was the third highest in the Trinity Bay series. The Conception Bay value was higher than the 1982-94 geometric mean. The method assumes trends in these two bays are representative of the stock area, school area is related to fish density, and there is a single dominant peak of distribution.

iii)   Egg and Larvae Study   (Chapter 10)

Egg deposition and larval abundance studies were conducted at Chapels Cove, Conception Bay and Bellevue Beach, Trinity Bay which was a reduction from six to two beaches. Seasonal egg deposition, pre-emergent larvae, and emerging larval abundance per beach were estimated by trapezoidal integration. Annual estimates were then normalized to the mean for each beach series. Because sampling occurred at Chapels Cove after capelin had started spawning a backcalculation was performed to

estimate the number of eggs deposited two days prior. Egg deposition in 1995 at Chapels Cove was the second highest in the series and one of the lowest at Bellevue Beach. The combined index in 1995 was similar to 1991 and 1992 and 65% of the highest in 1993.

Pre-emergent and emerging larval abundance were the second lowest in their respective series. Estimates were approximately 54% and 41% respectively of the highest estimate in 1993.

Age composition from spawning fish samples consisted of 14% two-year-olds, 54% three-year-olds, 22% four-year-olds, and 10% five-year-olds. The proportion of two-year-olds was similar to 1994 and more than twice the proportions observed in 1991-93. These samples were collected in two locations throughout the spawning season.

Spawning was delayed in 1995 however the duration of spawning was less than observed in the 1991-94 period.

iv) Conception Bay Beaches Revisited (Chapter 3)

Fifteen beaches in Conception Bay were sampled from 1987-93. Although never used as an index of abundance annual egg deposition at these sites was examined to qualitatively comment on spawner escapement. The level of egg development at the time of sampling suggested that in most years except for 1988 eggs were collected at comparable times relative to peak spawning. A multiplicative approach was used to adjust annual estimates for differences in egg development at sampling. Except for 1988 the relative year effects were the same. The standardized series was then decomposed into numbers at age using age compositions and mean weights of females collected by the commercial fishery in Conception Bay. In comparison to the standardized estimates of yearclasses from inshore indices the trends are similar except the 1982 and 1983 yearclasses appear much stronger in the Conception Bay adjusted egg deposition series.

5) Offshore Data

i) Acoustic Studies (Chapter 13)

The biomass estimates from offshore acoustic surveys have been very low since the 1990 fall survey. In contrast, inshore indices have not declined to the extent that would have been predicted from the acoustic surveys. Furthermore, incidental catches of capelin in the autumn

groundfish trawl survey, conducted after the fall capelin survey, occurred in areas where capelin had not been detected acoustically in significant numbers. The question arose as to whether the capelin acoustic surveys were missing a significant portion of the capelin biomass. Based on recommendations from the 1995 assessment, an experiment was conducted in September-October 1995 to compare estimates by acoustics to trawl catches over the same area to determine the relationship between the two. Catches of capelin in both Campelen and IYGPT trawls were compared to acoustic estimates of capelin in the same depth range and area covered by the trawl sets. Regressions of trawl biomass on acoustic biomass were significant in all cases but the regressions were largely determined by one large value and several very low values. Generally, there was a tendency for trawl catches to produce higher estimates than the acoustic sources. However, the data from the experiment was limited in depth and biomass range and a much larger data set is necessary to better understand the relationships between the two methods of acoustic measurement and trawl catches.

No acoustic surveys to estimate capelin biomass were conducted during 1995.

ii)   <u>Bycatch in Bottom Trawl Surveys in Div. 2J3KL</u> (Chapter 17)

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 1978-1994 have been compared with geographic coverage by 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 1995 differed from surveys in 1978-94 in two major respects. First, the 1995 survey did not finish until January 25, 1996, whereas surveys in earlier years were completed by December 20. Second, the 1995 survey was conducted with a Campelen 1800 shrimp trawl with rockhopper footgear, whereas the earlier surveys were conducted with an Engels 145 High-lift trawl. There has been no direct comparison between the two gears with respect to their abilities to catch capelin. However, experience with the Campelen trawl has revealed that it catches small fish more frequently and in much greater quantities than does the Engels.

The distribution of capelin catches during autumn 1995 was very similar to that observed in 1991-94. Largest catches were concentrated on northern, western and southern Funk Island Bank, near the 3K/3L boundary, and along the northeastern slope of Grand Bank. A few moderate to large catches were taken on Hamilton Bank, on the coastal shelf off southern Labrador and northeastern Newfoundland, and in the Avalon Channel. Catches were nil or very small near the shelf break in Div. 2J3K and on the plateau of Grand Bank. No large catches were taken to the north, east or south of the area which had been covered by the acoustic survey in 1994. However, some moderately large catches were taken south of the Avalon Peninsula.

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. The frequency of occurrence in 1995 was the highest to date in both Div. 2J3K and Div. 3L. However, 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.

Capelin bycatches during the spring Div. 3L bottom trawl surveys were not included in the multiplicative model in 1995. However, they are provided once again 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 had not come into effect at the time of the spring survey, so the 1995 Div. 3L survey is comparable to surveys in 1985-1994. As in 1991-94, catches of capelin were generally small. A few moderately large catches were obtained on the northeastern slope of Grand Bank. The frequency of occurrence was almost unchanged from levels in 1991-94, and the estimate of minimum trawlable biomass was very low for the fifth straight year.

iii) <u>Capelin in Pelagic 0-group Surveys</u> (Chapter 14)

A research program to develop a multi-species, 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 Divisions 2J3KLNO, including both inshore an offshore areas (Fig. 1). 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 were adjusted to account for different survey times in different years.

The 1993 yearclass was the most abundant during the period 1991-95, as measured at ages zero (1991-95), one (1991-94), and two (1992-93) years of age. These results indicate that this large yearclass was established by the early larval stage when larvae were still dispersing from the inshore to offshore areas. In addition, the high abundance persisted during their first three years of life.

The estimate of yearclass strength for the 1994 yearclass at age zero was the lowest of the five year time series. In contrast, at one year of age the 1994 yearclass was more abundant than either the 1991 or 1992 yearclasses, although less abundant than the 1993 yearclass. An underestimate of the 1994 yearclass abundance at age zero would have resulted if larval capelin had been released from beaches after the survey was completed, as a result of late spawning in 1994. Therefore, it appears that the 1994 yearclass may rank second to the 1993 yearclass in abundance.

The 1995 yearclass estimate at age zero was higher than the 1994 yearclass but lower than the 1993, indicating that it may be a relatively good yearclass. The size range of larvae was much greater than the 1994 yearclass, indicating that length at age one may be larger as well.

One year old capelin were approximately 25 mm larger for the 1994 yearclass than the 1993 yearclass. This difference represents approximately a 30% increase in size for the 1994 yearclass, copared to the 1993 yearclass. While size differences may occur due to differential survival, the relatively high abundance of the 1994 yearclass at one year of age indicates that the observed difference in length resulted from increased growth of the 1994 yearclass.

In general, capelin larvae were dispersed relatively quickly from inshore spawning areas to offshore waters, and also they appeared to be advected to the south onto the northern Grand Bank. The distribution of larval capelin indicate that spawning occurred in southern Labrador as well as along the entire northeast coast of Newfoundland. The decrease in abundance from inshore areas to zero on the outer Northeast Newfoundland Shelf is consistent with strong advection from inshore to offshore areas.

Both one and two year old pelagic capelin were most abundant over the northern Grand Bank. One year old capelin were also observed abundantly throughout the inshore area along the northeast coast of Newfoundland to southern Labrador as well as south onto the southern Grand Bank. The similar distribution of one and two year old capelin indicates similar spatial requirements for growth and survival.

iv) Capelin Bycatch from Demersal Juvenile Cod Surveys (Chapter 16

During December 1995 and January 1996 fixed stations fished in the inshore during early winter (1992-94) (Chapter 9, last year's assessment document) were again fished for demersal juvenile cod using the Campelen 1800 shrimp trawl. Those fished from 1992 to 1994 in the offshore portion of Div. 3KL were not fished using the transect lines (fixed station design) used in the previous years. The fixed station design was not utilized in the offshore since the Groundfish random stratified survey, which covers the area more intensively, had adopted for the first time the Campelen trawl used in the juvenile cod surveys. To compare capelin bycatch in the offshore in 1995-96 to that of the past three years, each station fished in the previous design (using the transect lines) was taken to represent catches in a 30 mm x 30 mm square, with the fixed station at the center of the square. Stations fished in each square during the 1995 RS survey were used to obtain a

mean capelin catch for that square to represent the catch of capelin in the fixed station design used in previous years. The number of stations used to calculate the mean capelin catch for each square ranged from 0 (for 2 stations only) up to 8.

Three null catches occurred in the inshore and two in the offshore for an overall frequency of occurrence of 92%. Overall mean catch rate increased from 652 fish per 30 minute tow in 1994 to 873 in 1995. In terms of weight mean catch rate increased from 6.4 kg in 1994 to 12 kg/tow in 1995. Mean numbers and weight in the inshore were 253 fish and 4.2 kg/tow compared to 1270 fish and 17 kg/tow in the offshore both of which were up from 1994. In the inshore larger mean catches (numbers and weight) were taken in Div. 3K than 3L. In the inshore mean catch rates were higher in 3L. The age structure was dominated by age 2's in 1995 (62%) compared with 33% age 1. For the previous years age 1 constituted 47.5 to 53.3% and age 2's 34-48% of the fish in samples from the surveys. Mean catch rate (numbers) at age is used as an index of yearclass strength. Estimated at age 1's the 1993 and 1994 yearlasses are the largest and approximately equal. Estimated at age 2 the 1993 yearclass is over twice as large as the 1992 yearclass which is approximately 7.5 x larger than the 1991 yearclass.

v)   Bycatch in Div. 2J3K and Div. 3M Shrimp Fisheries (Chapter 11

A shrimp fishery in areas of Div. 2J and 3K (shrimp management units = Hawke Channel and Div. 3K) developed beginning in 1987 with catches of 1845 t, rising to 11,000 t in 1994. Most of the fishing effort occurred during January to May. Capelin bycatch during this period rose from 1987 to 1989 and declined steadily until 1994. Bycatch rates expressed as kg/hr and frequency occurrence showed the same trend. The peak rates in 1989 were in the order of 20 kg/hr and 75% frequency occurrence. Catch rates from 1993 and 1994 may be biased down by the extensive use of mechanical sorting devices. Although shrimp fishing effort has moved east in recent years, an examination of catch rates in different areas indicates the decline in capelin bycatch rates cannot be explained by this distributional change in fishing effort.

Capelin were reported as bycatch in shrimp fisheries in Div. 3M during 1993 and 1994 with a decline in 1994. The bycatch rates in Div. 3M were comparable to the catch rates in Div. 2J3K in 1993 and 1994, years in which the sorting grates were used in both areas.

6)   <u>Information on Capelin Predators</u>   (Chapter 12)

Black-legged Kittiwakes at the Witless Bay Seabird Ecological Reserve experienced severe breeding failure again in 1995, a pattern which has held since 1990. Recent breeding failure seen in Black-legged Kittiwakes nesting in eastern Newfoundland colonies, as well as late breeding and the production of smaller eggs and clutches is thought to result from a combination of reduced food availability and higher predation rates by <u>Larus</u> gulls. <u>Larus</u> gulls themselves have likely suffered from reduced food availability as well since their breeding success has also been low in recent years.

Both kittiwakes and <u>Larus</u> gulls in the Witless Bay area feed their chicks capelin and they make use of this fish earlier in the breeding season as well. It is becoming clear that significant shifts in distribution, timing, and size at age of capelin have occurred over the past several years in the 2J3KL stock off eastern Newfoundland, and it is likely that these changes have reduced the availability of capelin to surface-feeding species such as kittiwakes and <u>Larus</u> gulls. Pursuit-diving seabirds such as the Common Murre (<u>Uria aalge</u>) and Atlantic Puffin (<u>Fratercula arctica</u>), which also feed their chicks capelin have bred successfully at Witless Bay in the 1990s suggesting that capelin have been available in sufficient quantities for seabirds that can dive for their food. An added food shortage that <u>Larus</u> gulls have faced has resulted from the closure of most groundfish fisheries in Newfoundland commencing in 1993. <u>Larus</u> gulls make use of fish waste at fish plants and after dumping at sea, and the fisheries closure has significantly reduced the supply of this food source. Being opportunists, <u>Larus</u> gulls have turned their attentions to kittiwake eggs and chicks as a ready source of food at the colony.

Methods used in 1995 did not allow for a determination of the causes of the breeding failure. However, observations of inter-sibling aggression, and real or attempted egg and embryo consumption by parents and siblings suggests kittiwakes were food stressed in early July. At this time, the first capelin of the year were being brought back to the colony by Atlantic Puffin adults to feed their newly hatched chicks and it seems likely that the same capelin were not available to kittiwakes at that time.

7)   Other Studies

   i)   Estimates of Capelin Survival   (Chapter 6)

        In the 1995 assessment, two sources of age-specific
   survival estimates were used to project stock abundance.
   In the current analysis, all possible sources of data
   were examined and two sources were determined to have an
   adequate series of estimates of abundance from which
   survival could reasonably be calculated.   These series
   were a) the Russian 3L acoustic survey, from which
   estimates of immature survival could be compared to
   published estimates from the Canadian acoustic estimates
   in Div. 3L and b) the three inshore indices (purse seine,
   trap and aerial).

        In the first comparison, survival estimates of age 2
   to 3 from the Russian survey were somewhat higher than
   Canadian estimates but not statistically different. For
   both surveys (but particularly the Russian survey) the
   relationship between age 2 and age 3 abundance is
   non-linear.   This characteristic may be a result of
   density-dependence but an examination of cohort estimates
   ages 2 and 3 from the inshore data sources does not show
   non-linearity. This suggests that age 2 survival is not
   density dependent. It may be that proportional sampling
   age-groups across years was not occurring in the Div. 3L
   acoustic surveys.

        For age 3 survival, estimates from both acoustic
   surveys and from the inshore aerial series were similar.
   Estimates from trap and purse seine were higher than the
   aerial and offshore sources. However, when all sources
   are aggregated, standard errors were fairly narrow.

        For age 4 survival, the estimates were consistent
   and the aggregated data were considered to provide
   reasonable estimates of survival.

 ii)   Selection Rate of Two-Year-Olds   (Chapter 5)

        Two-year-old capelin have been appearing in higher
   proportions in inshore commercial catches in the 1990's
   relative to their historical contribution to these fisheries
   in the 1980's. Research age compositions from beach-spawning
   studies, 0-group studies and bycatch compositions indicate
   that increased recruitment could account for some, but
   probably not all of the increased contribution of two-year-
   olds to commercial catches.

An examination of changes in the mean size of mature capelin during beach spawning demonstrates that the size structure typically present has virtually disappeared during the 1990's, i.e. instead of the expected inverse relationship between size and spawning time, compositions since 1991 have been mixed throughout the spawning season. At the same time, older capelin have dramatically declined in size while the mean lengths of two-year-old capelin have not declined.

A recent study by Carscadden et al. (1996) combined with the observed differential growth patterns permit the formulation of a hypothesis to account for mixed size compositions in the spawning runs since 1991. Carscadden et al. (1996) showed that annual variations in spawning times of inshore capelin were inversely related to water temperatures during maturation and mean fish size. Thus, it can be hypothesized that recent shifts in the spawning times of older capelin have been more dramatic (because they are affected by both colder temperatures and reduced sizes) than for two-year-olds (which are affected only by colder temperatures). This could account for the mixed size compositions in the spawning runs since 1991 and could account for some of the increase in two-year-olds in recent commercial catches.

This change in availability by age is important since the multiplicative model used to standardize abundance indices assumes that selection-at-age (= q) remains constant for each index. Systematic changes in q will therefore appear as abundance changes unless corrections to q are made.

Selection rates of two-year-olds were estimated using the ratio of catch rates to its population index. Catch rate indices at age 2 were available from traps and purse seines and population indices were calculated from catch rates at age 3, maturation rates at age 3 and survival estimates, both from published accounts. Similar estimates were made using the aerial survey index.

Using these assumptions and calculations, two-year-olds at age 2 were being selected during the 1990's at approximately 2.5 times the level during the 1980's for both purse seines and traps. For the aerial survey the difference in selection was somewhat less at q = 1.60.

iii) Comparisons of 0-group Measures of Capelin Recruitment

Comparisons of larval abundance in beach sediments from the Conception Bay beach study (1987-93) were compared to indices of yearclass strength from 0-group surveys in Trinity Bay, from oceanic 0-group surveys and from output from the multispecies model using inshore abundance indices

(Chapter 8). In all cases, coherence was evident. These analyses confirmed the major findings of Frank and Leggett viz. (1) that a large component of the variance in yearclass size of capelin is fixed very early in the life cycle. Frank and Leggett concluded that the critical determinant period was during the sediment larval phase whereas recent data indicate a somewhat earlier determination (i.e. egg mortality during incubation); (2) the coherence between localized 0-group indices (eg. the Trinity Bay series and the Conception Bay series) and subsequent adult indices of the same yearclasses (broad scale) indicates that the major factors affecting early survival are coherent across the spawning range along eastern Newfoundland (though not necessarily for each beach) (although not necessarily timing coherence). This is consistent with Frank and Leggett's conclusions that large-scale meteorological patterns are generating survival conditions which result in coherent recruitment response.

The coherent patterns in early life history indices offer promise in providing early estimates of yearclass strength which would be useful for assessment purposes. The research on several early life history stages should also be continued to provide greater insights into factors affecting population dynamics at these stages. These estimates would be particularly relevant in light of the anticipated recovery of key predator stocks.

iv) Mean Lengths of Capelin Expected in 1996 (Chapter 15)

During the last assessment, positive relationships were reported bettween mean lengths of capelin from fall offshore acoustic surveys and inshore the following year. Based on these relationships, it appeared that capelin inshore in 1995 would be small. There was virtually no fishery in 1995, mainly due to fish too small to meet the management criteria. Samples available from the monitoring programme indicated that fish were small, consistent with the prediction in last year's assessment.

For the present comparisons, the same relationships as last year were used. There was no fall acoustic survey in 1995 and therefore, samples consistent with the previous years were not available. However, mean lengths of capelin from the special acoustic study (see elsewhere in this report). , from Div. 2J3KL fall 1995 groundfish survey and from a special shrimp/cod acoustic survey early in 1996 were small. Based on these comparisons, it appeared that mature female capelin in the spawning season of 1996 would likely be small. Unless growth were substantial during the spring of 1996, mature females would be unlikely to achieve the sizes observed during the 1980's.

8) <u>Multiplicative Model</u>

In the 1995 assessment, a multiplicative model was used to provide standardized estimates of abundance for each cohort. This approach was again used but before final selection of the indices for inclusion of the model was made, an analysis of interaction effects was considered (Chapter 7). The multiplicative model assumes that the various indices to be integrated show the same trends throughout the time-series. The interaction effects were tested by comparing statistical coherence in the form of regression plots and consideration of residual patterns.

The results of this analysis indicated that among the abundance indices considered to form the analytical basis for the 1995 assessment, only the Russian 2J3K acoustic survey does not meet the statistical requirements for inclusion in the multiplicative cohort model. In the 1995 assessment, this index was included only in the final run of the model as a means of calibration. Because it was only one of seven unweighted indices and there were no recent surveys, its inclusion had no effect on estimates of yearclass abundance. However, given the present analysis, the Russian 2J3K acoustic series was not included as a means of calibrating the multiplicative model in the current assessment.

Standardized estimates of annual and cohort abundance were derived from the multiplicative model applied to the following indices:

1) aerial survey index 1982-95
2) purse seine catch rate index 1981-93
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) NCSP egg deposition series 1990-95

The first six series also were used in the 1995 assessment while the egg deposition series is an addition in the current run of the multiplicative model.

A selection factor of 2.5 was applied to age 2 for purse seines and traps from 1991 to the present and 1.6 for age 2 in the aerial index from 1992 to the present. The results of the multiplicative cohort model are shown in Figure 1. Historically the 1983 and 1986 yearclasses were abundant. More recently, the 1990 and 1992 yearclasses were also abundant. Based on this analysis the 1993 yearclass is the strongest in the entire series, however, the 95% confidence intervals are very wide.

The results from the multiplicative model (Fig. 1) indicate that yearclasses in the 1990's have been above average or abundant and this implies that biomass should be increasing. However, the decline in individual mean size during the same time period tends to counterbalance the increase in numbers. This is illustrated in Figure 2 where an annual biomass index has been constructed using the multiplicative model. The biomass index has been at a historical high during the 1993-95 period but not dramatically higher than the 1987-89 period when the strong 1983 and 1986 yearclasses contributed to the population.

A listing of all available data of potential use in the multiplicative model is given in Appendix II.

Besides the "traditional" indices used in the multiplicative mode, a suite of non-traditional indices were available, derived from early life history studies (Chapter 9). These seven indices were the NCSP egg deposition survey (1990-95), Conception Bay egg deposition survey (1987-93), Conception Bay sediment larval abundance (1987-93), NCSP emergent larval abundance (1990-95), NCSP sediment larval abundance 1990-95, Trinity Bay 0-group survey (1982-86), and oceanic 0-group survey (1991-93). It is important to note that the indices of abundance for the oceanic 0-group survey used in this formulation of the multiplicative model were those presented during the assessment and not necessarily the same as the revised estimates in Chapter 14. The multiplicative model using these seven indices explained 94% of the variance in yearclass strength. The estimates of yearclass strength from this formulation of the model are in good agreement with estimates from the model using the same indices as in the 1995 assessment. These non-traditional idnices offer an opportunity in future assessments to be incorporated into the final version of the multiplicative model. Like other indices derived from the multiplicative model, the estimates of yearclass strength are relative and need to be calibrated with absolute estimates from, for example, acoustic surveys.

Stock Status in 1995

The results of the multiplicative model indicate that the 1995 capelin stock biomass was the highest since 1980. This occurred because all yearclasses since 1990, as estimated from the multiplicative model, have been above average. The number of indices used to evaluate stock status in 1995 were reduced to two, the aerial survey and egg deposition indices. The 1995 aerial survey index was the third highest in the series (1982-95) while the egg deposition index was the second highest (1990-95). The aerial survey has maintained the same geographical coverage since

its inception while the egg deposition survey was reduced to two beaches in 1995 compared to 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. No large-scale acoustic surveys aimed at estimating biomass were conducted in 1995 and the divergence noted during earlier years has not been explained. Research attention has focused on the offshore acoustic surveys and the dramatically low biomass estimates. While the reasons for these low estimates are not understood, there is evidence to suggest that poor acoustic detectability when capelin are dispersed and unusual geographical distributions over a large scale may be contributing to estimates that are lower than the true population size and not comparable to estimates from the 1980's.

The results of the second year of an opinion survey of trap net fishermen are somewhat different from the results of the multiplicative model. Trap fishermen were of the opinion that capelin abundance was below average in 1995 but higher than 1994. Fishermen thought capelin abundance in both years was lower than when they had first started to fish capelin.

Prognosis for 1996

The 1992 and 1993 yearclasses are expected to make strong contributions to the spawning stock in 1996. The results from the multiplicative model indicate these yearclasses are strong and therefore spawning capelin would be abundant in 1996. It should be noted, however, that the estimate of the 1993 yearclass has large confidence intervals and is derived from only two indices in 1995. Although the dataseries are relatively short, 0-group indices have shown coherence with yearclass strengths as adults. Both the 1992 and 1993 yearclasses were abundant at the 0-group stage.

During the 1995 assessment, historical trends in individual fish size in the fall acoustic surveys and size inshore the following year were compared and as a result, it was predicted that capelin would likely be small in 1995. As noted, the fishery did not open in 1995, largely due to the small size of capelin. Mean lengths of capelin in samples from the monitoring programme and on the spawning beaches were small. Capelin taken during fall surveys in 1995 were also small indicating that capelin in the 1996 spawning stock will likely be small. Even if spring water temperatures were average or above normal, growth would have to be exceptional for capelin to reach sizes attained in the late 1980's. The overall average size in the spawning stock will be dependent on the relative proportions of the yearclasses present. The strong 1993 yearclass would be expected to dominate and will likely contribute to an overall small mean size. The abundance of the 1994 yearclass could not be quantified but if it is strong, it too

could appear in the 1996 spawning population and contribute to a small overall mean size.

Research Recommendations:

1. Investigate the possible linkage between changes in size-at-age and environmental factors.

2. During 1995, the six beaches that had been monitored in detail during NCSP were reduced to two sampling sites because of budget constraints. This reduction represents a significant loss of both ecological and stock assessment information. If possible, the monitoring program should be re-instated on the original six beaches.

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

4. Mean lengths in the fall acoustic survey have proven valuable in providing insight into the size of fish during the next spawning season. This information has been useful for the industry. Since the fall acoustic survey has been terminated, the Committee recommends that other data sources be examined to determine whether size of fish during the spawning season can be predicted.

5. 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.

6. Refer the multiplicative model to the CODE for advice on its appropriateness for combining diverse indices and weighting methods.

7. Alternate methods for calibration and projecting biomass using the multiplicative model should be investigated.

8. The aerial survey index using school areas assumes all capelin schools encountered are of uniform and similar density. The Committee recommends an inshore acoustic program be developed in coordination with the aerial survey to investigate the relationship between school area, colour as viewed by the imaging school area, colour as viewed by the imaging spectrophotometer and acoustic density for prespawning schools.

9.   Greenland halibut are known to be important predators of capelin. There is an extensive database on Greenland halibut food and feeding and the Committee recommends that this database be analyzed to augment our knowledge of predator-prey relationships and distribution patterns of capelin from predator stomachs.

10. The degree of off-beach spawning should be investigated.
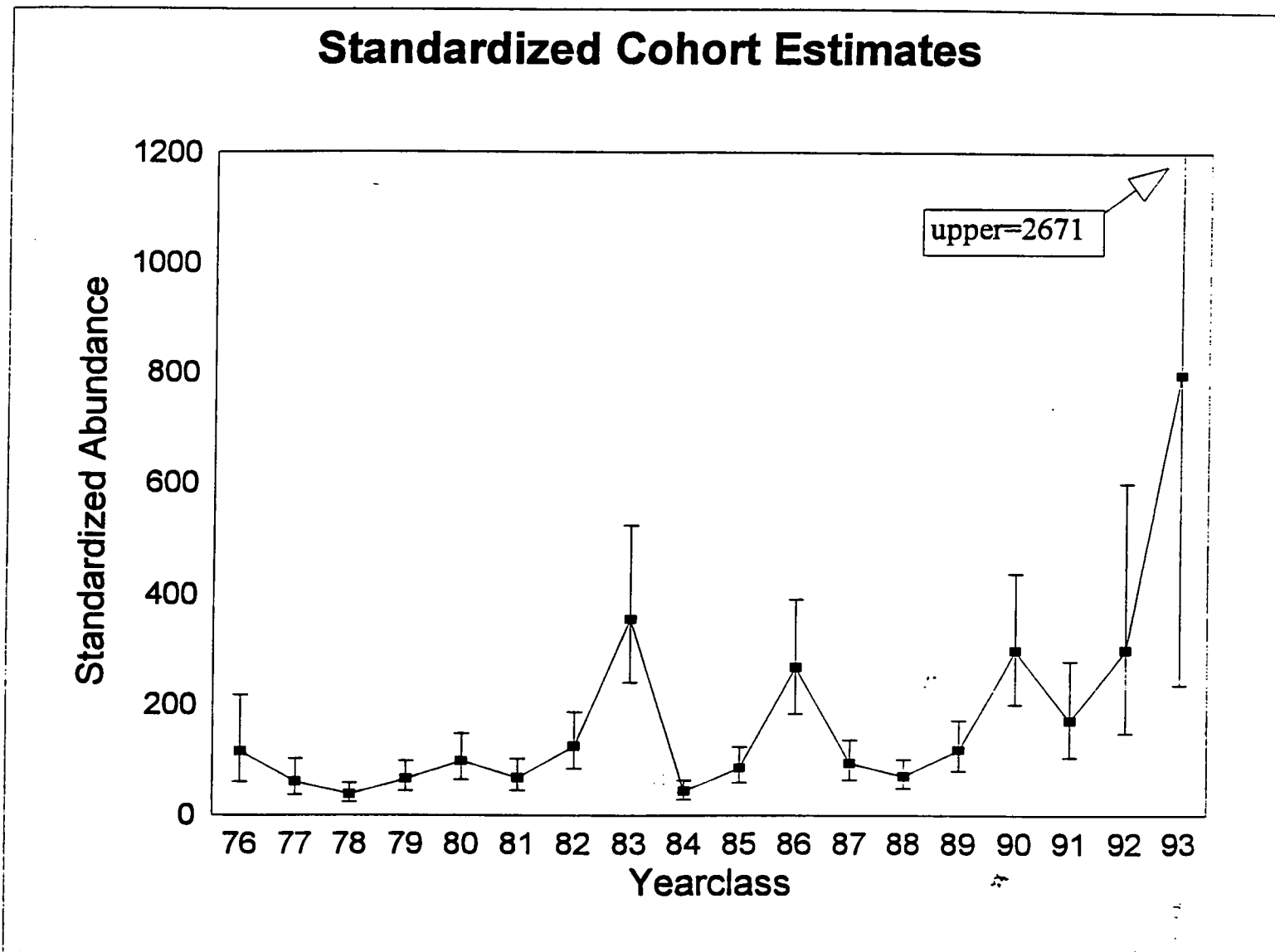
Fig. 1.   Standardized abundance and 95% confidence intervals of
capelin yearclass from the multiplicative model.
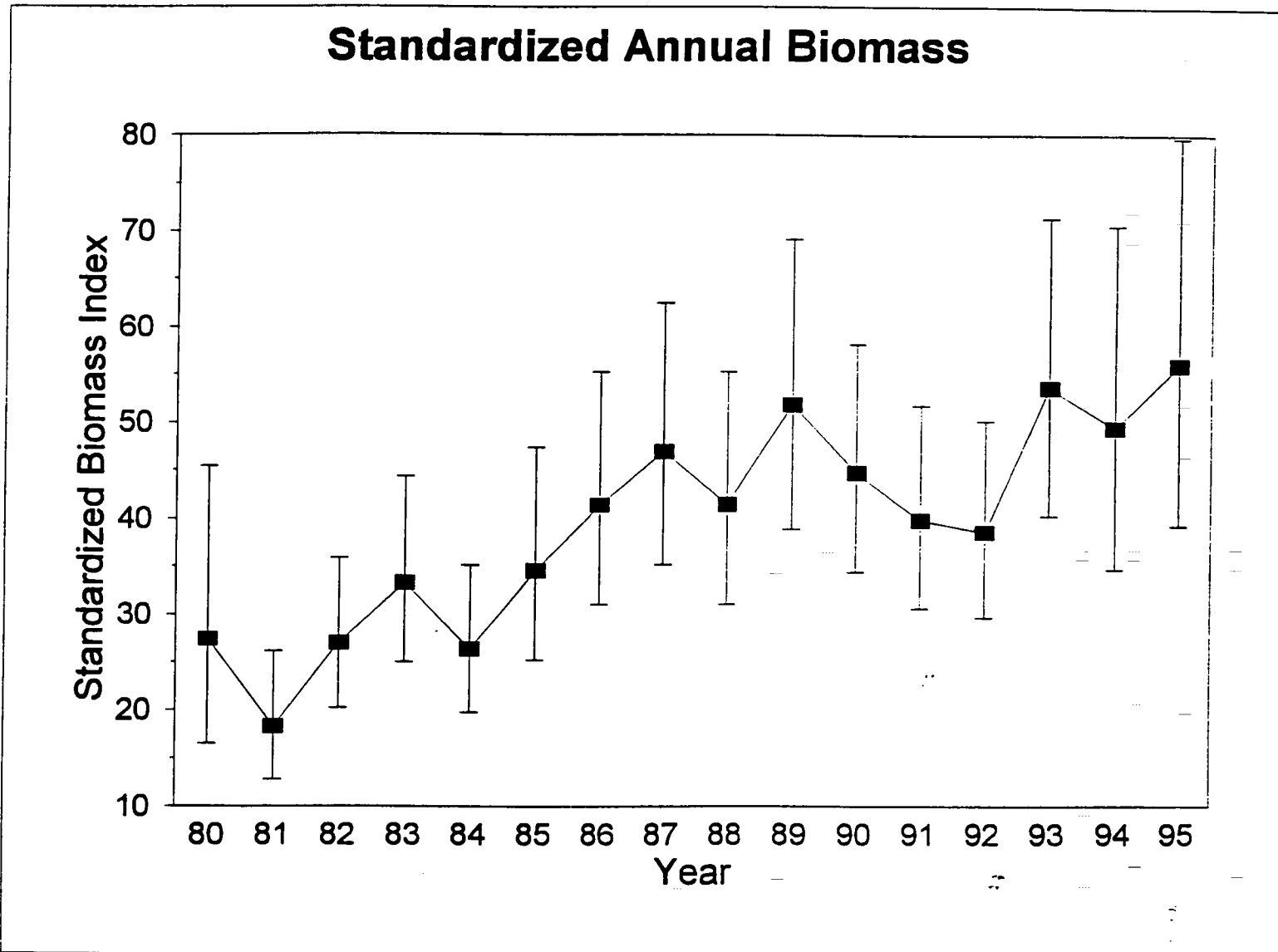
Fig. 2. Standardized annual biomass indices and 95% confidence
intervals from the multiplicative model.

Appendix I

Name	Affiliation
Anderson, J.	Ocean Ecology, Science Branch, DFO
Carscadden, J.	PFSS, Science Branch, DFO
Cardine, J.	Canadian Wildlife Service
Coombs, R.	Provincial Fisheries
Dalley, E.	Ocean Ecology, Science Branch, DFO
Helbig, J.	Ocean Ecology, Science Branch, DFO
Lilly, G.	Groundfish, Science Branch, DFO
Miller, D.	PFSS, Science Branch, DFO
Montevecchi, W.	Memorial University of Newfoundland
Nakashima, B.	PFSS, Science Branch, DFO
Parsons, D.	PFSS, Science Branch, DFO
Sjare, B.	Ocean Ecology, Science Branch, DFO
Stenson, G.	Ocean Ecology, Science Branch, DFO
Wheeler, J.	PFSS, Science Branch, DFO
Winters, G.	PFSS, Science Branch, DFO

Appendix II. Indices available for use in the multiplicative model.

		Age					
	Year	0	1	2	3	4	5

Aerial survey index

	Year	0	1	2	3	4	5
	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	-	-	365	1472	604	256

Conception Bay eggs index

	Year	0	1	2	3	4	5
	1987	-	-	39	61	130	17
	1988	-	-	77	225	53	90
	1989	-	-	2	120	37	3
	1990	-	-	9	191	196	9
	1991	-	-	35	189	68	16
	1992	-	-	96	377	24	1
	1993	-	-	14	298	31	1

Egg deposition index (normalized)

	Year	0	1	2	3	4	5
	1990	-	-	83	856	725	55
	1991	-	-	215	1664	1818	705
	1992	-	-	543	1968	2363	417
	1993	-	-	894	6729	1745	294
	1994	-	-	347	1019	519	162
	1995	-	-	1611	3963	1048	511

Trinity Bay 0-group (July-August mean no./tow)

	Year	0	1	2	3	4	5
	1982	50.9	-	-	-	-	-
	1983	62.5	-	-	-	-	-
	1984	27.2	-	-	-	-	-
	1985	32.6	-	-	-	-	-
	1986	55.6	-	-	-	-	-

Appendix II. Continued ...

	Year	Age					
		0	1	2	3	4	5

Purse seine catch rate index

	Year	0	1	2	3	4	5
	1981	-	-	1	123	123	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	414	10
	1991	-	-	50	315	219	36
	1992	-	-	148	705	89	5
	1993	-	-	51	665	45	3

Trap catch rate index

	Year	0	1	2	3	4	5
	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	-	-	675	5622	432	20

Russian 3L spring acoustic index

	Year	0	1	2	3	4	5
	1982	-	-	12	19	5	1
	1983	-	-	.7	4.3	6.4	1.9
	1984	-	-	124	50	16	2
	1985	-	-	231	53	4	0.9
	1986	-	-	18.4	70.9	5.9	
	1987	-	-	46	31	30	1
	1988	-	-	178	92	34	8
	1989	-	-	79	97	11	2
	1990	-	-	156	106	36	2.5
	1991	-	-	4	3	2	.1
	1992	-	-	-	-	-	-
	1993	-	-	1	9	1	-

Appendix II. Continued ...

		Age				
Year	0	1	2	3	4	5

Canadian 3L spring acoustic index

Year	0	1	2	3	4	5
1982	–	<.1	9.7	16.2	2.4	1.0
1983	–	<.1	3.4	1.9	1.0	1.0
1984	–	.1	21.0	6.2	3.1	1.0
1985	–	.2	379.0	81.0	3.8	2.3
1986	–	0	59.4	158.0	21.3	1.0
1987	–	.3	88.0	18.0	38.9	4.0
1988	–	13.6	380.0	66.0	9.7	17.0
1989	–	3.4	315.0	96.0	11.0	1.4
1990	–	18.9	353.0	169.0	56.0	1.9
1991	–	18.7	8.0	3.0	1.0	<0.1
1992	–	5.7	19.0	6.5	0.7	

Groundfish 3L spring bycatch index

Year	0	1	2	3	4	5
1985	–	–	63.0	149.0	14.0	6.0
1986	–	–	14.0	243.0	80.0	6.0
1987	–	–	7.0	14.0	65.0	7.0
1988	–	–	141.0	96.0	43.0	36.0
1989						
1990	–	–	23.0	128.0	94.0	8.0
1991	–	–	58.0	146.0	55.0	8.0
1992	–	–	421.0	70.0	13.0	1.0
1993	–	–	81.0	193.0	11.0	1.0
1994	–	–	474.0	41.0	5.0	4.0

Russian 2J3K fall acoustic index

Year	0	1	2	3	4	5
1974	–	–	6.0	27.0	10.0	4.4
1975	–	–	27.0	13.0	3.0	1.5
1976	–	0.5	7.0	36.0	2.0	.4
1977	–	–	–	–	–	–
1978	–	0.1	1.0	.8	.4	.1
1979	–	0	.03	.2	.3	.1
1980	–	–	.1	.4	.2	.04
1981	–	–	–	–	–	–
1982	–	.2	18.0	18.0	1.0	–
1983	–	2.5	20.0	16.0	3.0	–
1984	–	41.5	20.0	4.0	1.0	–
1985	–	0.8	81.0	18.0	3.0	.2
1986	–	0.5	19.0	45.0	4.0	.1
1987	–	6.0	45.0	7.0	7.0	.2
1988	–	–	–	–	–	–
1989	–	–	–	–	–	–
1990	–	0	15.0	13.0	3.0	.1
1991	–	0	4.0	1.0	1.0	0
1992	–	0	0.5	.1	–	–

Appendix II. Continued ...

	Year				Age		
		0	1	2	3	4	5

Groundfish 3L fall bycatch index

	Year	0	1	2	3	4	5
	1985	-	44	220.0	28.0	.4	0
	1986	-	-	-	-	-	-
	1987	-	-	-	-	-	-
	1988	-	45	261.0	5.0	.5	1.0
	1989	-	57	140.0	71.0	1.7	0
	1990	-	-	-	-	-	-
	1991	-	352	56.0	12.0	-	-
	1992	-	99	466.0	2.0	-	-
	1993	-	154	125.0	66.0	5.1	0
	1994	-	1586	8.0	0	0	0

Groundfish 2J3K fall bycatch index

	Year	0	1	2	3	4	5
	1980	-	4	34.0	31.0	7.0	0.7
	1981	-	1	77.0	26.0	5.0	1.3
	1982	-	0	31.0	97.0	6.0	0
	1983	-	-	-	-	-	-
	1984	-	-	-	-	-	-
	1985	-	-	-	-	-	-
	1986	-	-	-	-	-	-
	1987	-	0	39.0	23.0	41.0	11.9
	1988	-	15	131.0	37.0	2.0	2.5
	1989	-	-	-	-	-	-
	1990	-	-	-	-	-	-
	1991	-	5	166.0	49.0	2.0	0.2
	1992	-	1	248.0	29.0	1.0	0
	1993	-	7	128.0	87.0	9.0	0
	1994	-	40	173.0	20.0	3.0	1.1

Canadian 3L fall acoustic index

	Year	0	1	2	3	4	5
	1993	-	107	4.0	.1	0	0
	1994	-	332	11.0	.1	.1	0

Russian 2J3K fall commercial catch rate index

	Year	0	1	2	3	4	5
	1972	-	0	33.0	180.0	59.0	8.0
	1973	-	0	83.0	99.0	132.0	16.0
	1974	-	0	92.0	223.0	80.0	56.0
	1975	-	0	400.0	179.0	53.0	12.0
	1976	-	3	46.0	437.0	36.0	5.0
	1977	-	0	12.0	124.0	248.0	26.0
	1978	-	9	38.0	71.0	97.0	14.0
	1979	-	3	105	14	3	4
	1980	-	5	206	185	49	7
	1981	-	32	248	59	15	13
	1982	-	6	247	61	5	1
	1983	-	19	215	256	39	3
	1984	-	41	262	77	39	5
	1985	-	1	464	200	19	10
	1986	-	2	128	419	50	4
	1987	-	5	340	150	248	27
	1988	-	5	430	112	14	33
	1989	-	2	248	332	26	2
	1990	-	0	208	281	95	3
	1991	-	5	104	18	0	0

Appendix II. Continued ...

		Age					
	Year	0	1	2	3	4	5

Canadian 2J3K fall acoustic index

	Year	0	1	2	3	4	5
	1981	–	68	59	7	3	1
	1982	–	–	–	–	–	–
	1983	–	0	3	1	1	0
	1984	–	0	35	7	4	.4
	1985	–	0	54	14	2	.6
	1986	–	0	7	12	1	.2
	1987	–	.7	4	1	1	.1
	1988	–	15.8	96	14	2	3.9
	1989	–	1.9	59	35	3	.5
	1990	–	1.4	3	2	1	<.1
	1991	–	4.7	3	1	1	<.1
	1992	–	0.1	2	.2	<.1	0
	1993	–	0.2	1	.3	<.1	<.1
	1994	–	0.3	.5	.1	<.1	0

Oceanic 0-group (provisional)

	Year	0	1	2	3	4	5
	1991	3765	–	–	–	–	–
	1992	5436	–	–	–	–	–
	1993	11273	–	–	–	–	–
	1994	2067	–	–	–	–	–
	1995	4828	–	–	–	–	–

Conception Bay sediment 0-group

	Year	0	1	2	3	4	5
	1987	61	–	–	–	–	–
	1988	–	–	–	–	–	–
	1989	147	–	–	–	–	–
	1990	285	–	–	–	–	–
	1991	99	–	–	–	–	–
	1992	340	–	–	–	–	–
	1993	432	–	–	–	–	–

NCSP sediment larval index (normalized)

	Year	0	1	2	3	4	5
	1990	132	–	–	–	–	–
	1991	94	–	–	–	–	–
	1992	124	–	–	–	–	–
	1993	145	–	–	–	–	–
	1994	32	–	–	–	–	–
	1995	79	–	–	–	–	–

NCSP emergent larval index (normalized)

	Year	0	1	2	3	4	5
	1990	123	–	–	–	–	–
	1991	86	–	–	–	–	–
	1992	125	–	–	–	–	–
	1993	154	–	–	–	–	–
	1994	43	–	–	–	–	–
	1995	63	–	–	–	–	–