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Capelin in SA2 + Dlv. 3KL

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Abstract

This document contains a number of discrete research results which were considered during the February 1994 assessment of capelin in SA2 + Div. 3KL. Capelin in these NAFO Divisions have in the past been assessed as two separate stocks (SA2 + Div. 3K and Div. 3L) but based on recommendations during 1993, they are now combined into one stock. The research results are arranged in chapters and contain relevant data on the inshore fishery, analyses relevant to the inshore fishery, biological data collected during the spawning season, capelin bycatch in the groundfish survey, diel migrations of capelin and unusual occurrences of capelin on Flemish Cap and Scotian Shelf.

Résumé

Le présent document contient des résultats de recherche discrets qui ont été pris en considération durant l'évaluation du capelan dans SA2 + div. 3KL réalisée en février 1994. Auparavant, le capelan de ces divisions de l'OPANO était traité aux fins d'évaluation comme s'il appartenait à deux stocks distincts (celui de SA2 + div. 3K et celui de la div. 3L), mais suite aux recommandations formulées en 1993, on considère désormais qu'il fait partie d'un seul et même stock. Les résultats de recherche sont présentés par chapitres et contiennent des données pertinentes sur la pêche côtière, des analyses connexes, ainsi que des données biologiques recueillies durant la saison de frai; ils font également état des prises accidentelles de capelan dans les relevés de recherche sur le poisson de fond, des migrations nycthémérales du capelan et de ses apparitions inusitées sur le Bonnet Flamand et sur le plateau néo-écossais.

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Capelin in SA2 + Div. 3KL

Compiled by J. E. Carscadden

INTRODUCTION

This document contains a number of discrete research results arranged in chapters which were considered during the February 1994 assessment of capelin in SA2 + Div. 3KL. Capelin in these NAFO Divisions have in the past been assessed as two separate stocks (SA2 + Div. 3K and Div. 3L) but based on recommendations during 1993, they are now combined into one stock. Thus in most of the following chapters data are combined and presented for the SA2 + Div. 3KL stock. The first chapter summarizes information relevant to the inshore fishery in 1993 along with relevant historical data. Chapters 2-5 contain data collected during the spawning season/inshore fishery and analyses relevant to this fishery. Chapter 7 contains data on capelin bycatch in the groundfish survey conducted immediately after the acoustics survey and Chapter 8 provides data on diel migration of capelin based on an analyses of the historical database. Chapters 9 and 10 provide data on unusual occurrences of capelin on Flemish Cap and Scotian Shelf.

Two other papers which have been published elsewhere but were relevant to the assessment were Lilly and Davis (1993) and Shackell et al. (1993).

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Shackell, N. L., P. A. Shelton, J. M. Hoenig, and J. Carscadden. 1993. Age and sex-specific survival of northern Grand Bank capelin (Mallotus villosus). ICES CM/H:41. 18 p.

Chapter 1

The Inshore Capelin Fishery in NAFO Div. 3KL in 1993

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INTRODUCTION

Landings based on quota reports in 1993 were 34,970 t in Div. 2J3KL compared to a market-based quota allocation of 32,400 t. Landings in Div. 3K were lower than in 1992 and increased substantially in Div. 3L from 1992 landings (Table 1). A summary of the 1993 commercial capelin roe fishery, the age composition of the catch, trends in mean lengths and weights, and the information compiled in research logbooks given to commercial fishers is presented.

MATERIALS AND METHODS

Commercial samples were collected by fishers and at fish plants by reliable collectors at the rate of two samples per gear type per week per statistical section (Fig. 1). 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 43 purse seine and 145 fixed gear licensed fishers residing in Div. 3KL. Of these 23 purse seine and 71 fixed gear logbooks have been returned to us to date. Eleven purse seiners and 38 fixed gear fishers did not fish in 1993. Only the records of 59 fishers who fished traps and filed complete information were used in this analysis. Records from beach seines were not presented in this report.

Fishing effort was estimated from research logbook records for both purse seines and capelin traps. Fishing days for purse seines are defined as those days when the vessel was out searching for capelin schools. Similarly fishing days for traps were defined as those days when the trap was fishing. In 1993, 40 trap fishers fished one trap each and 19 fishers fished two traps per trap crew. Unlike 1992 (Nakashima 1993) trap logbook records were available from all areas on the northeast coast.

Mean lengths and weights for Div. 3K and 3L were estimated from commercial samples for each gear type and combined weighted by landings.

RESULTS AND DISCUSSION

The Inshore Fishery

The inshore fishery in Div. 3KL was prosecuted by purse seines, capelin traps, and beach seines and has been regulated by quota management since 1982. Quotas by area and gear type are presented in Appendix A. Opening and closing dates varied considerably in 1993 (Appendix B). Monitoring programs in most areas were set up to close and reopen areas in response to market demands. Small fish was the main reason areas were temporarily closed except in parts of Notre Dame Bay where bycatches of herring were observed. Unlike 1992 all areas and gear sectors except for fixed gear in Bonavista Bay reached or slightly exceeded their allocations.

Age Composition of the Commercial Catch

In 1993 81 biological samples were processed from commercial catches throughout Div. 3KL (Table 2). The mean number of otolith pairs per sample was less in Div. 3K than in Div. 3L (Table 2).

The 1993 catch in numbers was dominated by the 1990 year-class as three-year-olds (83.3%) followed by the 1991 year-class as two-year-olds (13.3%) and the 1989 year-class as four-year-olds (6.4%) (Table 3). The latter is surprising because the 1989 year-class was apparently strong in 1992 and was expected to be relatively more abundant in 1993 yet the proportion of four-year-olds in the catch was the lowest in the series since 1979.

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

In Div. 3K (Fig. 2) there is no apparent trend in mean length at age 2. For ages 3 and 4 and all ages combined, there has been a general decline in the mean length with 1991-93 mean lengths being the smallest in the series.

The mean lengths-at-age in Div. 3L during 1981 were small (Fig. 3). For age 2, the 1982-90 mean lengths did not vary much or exhibit any trends but declined during 1991-93. 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 seems more severe during 1991 and 1992 with an apparent increase in 1993.

For males, age 2 fish usually comprise only a small proportion of the mature stock, so sample sizes are small. However, for age 3 males, differences between Div. 3L and 3K were small except in 1992 when Div. 3L males at age were much smaller. At age 4, Div. 3L and 3K males were approximately the same length.

Age 2 females contribute more to the spawning stock than age 2 males (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 therefore contributed to the decline in overall mean size (all ages combined) of females in the population. Females in Div. 3L at age 3 were only slightly smaller than females at the same age in Div. 3K except in 1992 when the difference was larger. At age 4, females in Div. 3L and 3K were approximately the same length until 1993 when Div. 3L females were smaller than in Div. 3K.

The sample mean weights from the inshore fishery are given in Table 4. For Div. 3K the sample mean weights-at-age are given only for 1984-92. In some years prior to 1984, sample sizes were small.

Research Logbook Survey

The predominant reasons reported by fishers for discarding capelin in 1993 were variable with low percentage of females, quota limits due to area closures or trip limits, and small females as the reasons often given (Table 5). For traps in White Bay, Bonavista Bay, and Conception Bay small females (61-74%) and area closures (24-34%) were the main reasons fish were discarded. In Notre Dame Bay area closures (64%) and discarding males (35%) to improve the female percentage of the catch were reasons to discard capelin. In Trinity Bay capelin mixed with herring or cod (89%) were discarded. For purse seiners in White Bay and on the Southern Shore discarding occurred because small females were in the catch (98-100%). In Bonavista Bay and St. Mary's Bay all the reported discarding was due to the 50,000 lb trip limit on purse seine vessels (100%). Small females (76%) made up most of the discards in Conception Bay while redfeed (62%) and sets with herring (30%) constituted the discards in Trinity Bay. Similar to 1992 (Nakashima 1993, Nakashima and Carscadden 1993) redfeed problems were virtually absent in the research logbook reports.

Discarding as a percentage of landings in 1993 in Div. 3L varied among areas for traps (Table 6: 0-38%) and for purse seines (Table 7: 3-24%) but were generally low. Discarding rate was the lowest since 1981 when estimates were available for traps (Table 8) and for purse seines (Table 9). Discarding from capelin traps continued to decline from 82% of landings in 1991 and 46% in 1992 to 13% in 1993 (Table 8). Purse seine discards were 12% of landings in 1993 and slightly lower than the 15% estimated in 1992 (Table 9). The reported discards for purse seines include 3.6 t of capelin given away to another seiner. According to information provided in the research logbooks 90% of trap and 93% of purse seine discards were released alive at sea. In the analyses presented in Tables 6-9 discards are defined as all capelin caught but not landed by the fishers who caught them and includes both live and dead fish. The overall level of reported discarding in 1993 was low.

The average fishing effort in 1993 decreased for traps and increased for purse seiners in 1993. Traps averaged 5.1 fishing days and were hauled 11.1 times in 1993 compared to 8.7 days and 19.6 hauls per trap in 1992 (Table 8). Purse seiners had 8.0 searching days and made 13.9 sets per vessel in 1993 compared to 5.6 searching days and 8.6 sets in 1992 (Table 9). The lowest effort in 1993 occurred in St. Mary's Bay and in Notre Dame Bay (Table 6). The fixed gear fishery in St. Mary's Bay is usually brief due to the smaller allocations compared to other areas. The fishery in Notre Dame Bay was best in the western part of the area which was similar to 1991 and 1992. The last area to reach its quota and close was the eastern section of Notre Dame Bay. Most purse seiners fished in two or more areas with most effort occurring in Conception Bay and St. Mary's Bay and the least effort in Trinity Bay and Bonavista Bay (Table 7). This was the first year that purse seine fishing effort on the Southern Shore was reported in research logbook records.

Catch/effort (CPUE) estimates were available since 1981 for capelin traps and for purse seines (Tables 8 and 9). The 1993 capelin trap CPUE of 6.4 t/day was higher than the average CPUE from 1981 to 1992 of 5.4 t/day and the CPUE of 3.0 t/haul was slightly lower than the mean of 3.4 t/haul (Table 8). The purse seine CPUE of 16.2 t/day in 1993 was lower than the average from 1981 to 1992 of 17.5 t/day (Table 9).

If we accept trap CPUE's as an index of inshore abundance of mature capelin and assume that total catch (i.e. landings + discards) as reported in these research logbooks is more realistic than landings alone, then trap CPUE's indicate that inshore abundance was higher in 1993 than in 1992 (Fig. 4). Purse seine CPUE's are not considered a relative indicator of abundance of pelagic fishes due to the fishing behaviour generally associated with purse seiners (Powles 1981).

Comments written in research logbooks and from telephone conversations and direct contact with some fishers supported many of the observations and results of information collected in logbooks during 1993. In many areas fishers reported small fish at the beginning of the season and larger fish later. Several comments were made that higher concentrations and better quality capelin were arriving in their areas just as or after the quotas were reached. In many areas especially north of Conception Bay fishers indicated that spawning beaches had more eggs than observed in recent years. Also some fishers noted that spawn was deposited just off some beaches in deeper water. These comments were unsolicited and represent the remarks of only some of the fishers who actively participated in the research logbook programme in 1993.

Relative Year-class Strength

Relative year-class strength was estimated for catches by purse seines and traps by estimating total effort (days fished) from landings (Table 1) and catch rates (Tables 8, 9). The total effort (Table 10) and catch-at-age numbers (Table 11) were used to derive catch rates-at-age given in Table 12. To visualize trends in year-class strengths in the 1980's the catch rates-at-age were summed for ages 3 and 4 for year-classes 1979 to 1989 (Table 13) and for ages 2, 3, and 4 for year-classes 1980 to 1989 (Table 14). The normalized values in Figure 5 suggest that the same strong (eg. 1983, 1986, 1989) and weak (eg. 1981, 1984) year-classes were prosecuted by both inshore gears. Interestingly enough the 1988 year-class appears weak in the purse seine series and average in the trap series despite its strong appearance as two-year-olds in acoustic surveys in 1990 (Anon. 1991). Evidence from catch rates-at-age in Table 12 for age 3 suggest that the 1990 year-class may be one of the largest observed since the late 1970's.

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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 = SMS) in Div. 2J3KL.

Year	Area	Purse seine	Beach seine	Capelin trap	Total
1984	2J	0	1	0	1
	WB	1034	451	957	2442
	NDB	2627	1887	162	4676
	3K	3661	2338	1119	7118
	BB	3805	49	2037	5891
	TB	4928	799	5531	11258
	CB	6628	89	6806	13523
	SS	0	17	672	689
	SMB	1714	28	159	1901
	3L	17075	982	15205	33262
1985	2J	0	1	0	1
	WB	1114	16	1541	2671
	NDB	2834	819	1044	4697
	3K	3948	835	2585	7368
	BB	2286	115	1593	3994
	TB	1624	545	6816	8985
	CB	3649	211	6804	10664
	SS	33	9	348	390
	SMB	1284	12	121	1417
	3L	8876	892	15682	25450
1986	2J	0	3	0	3
	WB	1675	465	3684	5824
	NDB	2547	2069	1459	6075
	BB	3323	199	3197	6719
	TB	4005	648	12142	16795
	CB	7454	133	9589	17176
	SS	37	52	1362	1451
	SMB	5685	34	337	6056
	3L	20504	1066	26627	48197
1987	2J	0	4	0	4
	WB				
	NDB				
	3K	3038	2145	5625	10808
	BB	2140	76	2139	4355
	TB	1644	193	6780	8617
	CB	1317	120	3084	4521
	SS	106	32	633	771
	SMB	712	0	0	712
	3L	5919	421	12536	18976
1988	2J	0	2	0	2
	WB	3309	517	6751	10577
	NDB	6414	3213	6636	16263
	3K	9723	3730	13387	26840
	BB	3664	157	3960	7781
	TB	4275	164	15417	19856
	CB	7064	210	10586	17860
	SS	220	33	3194	3447
	SMB	3636	228	605	4469
	3L	18859	792	33762	53413

Table 1. Continued ...

Year	Area	Purse seine	Beach seine	Capelin trap	Total	
1989	2J	0	3	304	307	
	WB	3276	643	9513	13432	
	NDB	3235	2793	7938	13966	
	3K	6511	3436	17451	27398	
	BB	2704	111	4426	7241	
	TB	4822	172	14845	19839	
	CB	8662	75	8579	17316	
	SS	207	11	3048	3266	
	SMB	3327	1	643	3971	
	3L	19722	370	31541	51633	
1990	2J	0	1	0	1	
	WB	4462	318	11820	16600	
	NDB	5842	3403	9294	18539	
	3K	10304	3721	21114	35139	
	BB	3171	90	5619	8880	
	CB	6852	41	11373	18266	
	SS	31	45	2897	2973	
	SMB	610	0	1016	1626	
	3L	15072	284	32636	47992	
1991*	2J	0	1	0	1	
	WB	239	227	12045	12511	
	NDB	426	2709	4291	7426	
	3K	665	2937	16336	19937	
	BB	33066	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	3390	124	8242	11756	
	NDB	3014	1290	2293	6597	
	3K	6404	1414	10535	18353	
	BB	1073	29	63	1165	
	TB	95	173	70	338	
	CB	899	57	240	1196	
	SS	0	5	21	26	
	SMB	223	3	42	268	
	3L	2290	267	436	2993	
1993*	2J	0	1	0	1	(1)**
	WB	750	18	1489	2257	
	NDB	1176	722	263	2161	
	3K	1926	740	1752	4418	(12230)**
	BB	930	67	73	1070	(3442)**
	TB	651	74	20	745	(6812)**
	CB	1135	47	168	1350	(8299)**
	SS	0	14	4	18	(1857)**
	SMB	345	4	0	349	(2329)**
	3L	3061	206	265	3532	(22739)**

* provisional
** DFO capelin quota report for 1993

Table 2. Summary of the commercial samples processed and aged from the 1993 inshore capelin fishery 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	8	239	29.9 ± 3.2
Beach seine	2	55	27.5 ± 0.7
Capelin trap	12	350	29.2 ± 2.0
TOTAL	22	644	
Div. 3L			
Purse seine	19	660	34.7 ± 4.3
Beach seine	3	83	27.7 ± 3.2
Capelin trap	37	1319	35.7 ± 3.1
TOTAL	59	2062	

Table 3. Age compositions (%) of capelin from the inshore commercial capelin fishery, Div. 3KL, 1979-93. 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	8.9	85.5	5.6	+	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	13.0	79.4	7.2	0.4	+
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	10.0	83.3	6.4	0.2	+

Table 4. Mean weights (gm) for commercial samples in Div. 3K and Div. 3L, sexes combined.

Year	Age 2	3	4	5	6	All
Div. 3K						
1984	14.7	30.5	37	34.5	32.3	35
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	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	18.3	22.5	28.0	28.6		22.1
Div. 3L						
1981	7.8	22.3	29.8	32.3	36.4	28.1
1982	12.6	32.5	37	37.2	39.9	33
1983	13.9	27.7	33.8	34	27.6	29.1
1984	13.9	27.6	34.7	30.5	33.6	31.3
1985	12	25.4	35.9	32.6	33.1	26.7
1986	18	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	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	13.4	21.8	23.2	22.4	26.3	21.1

Table 5. Percent contribution by weight of reasons for discarding capelin in 1993. This analysis excludes capelin given to other fishermen.

Area	Redfeed	Low % females	Small females	Males picked out	Females spawned out	No market/ quota filled	Misc.	Not given
<u>Traps</u>								
White Bay	0	61	0	1	0	34	4	0
Notre Dame Bay	0	0	+	35	0	64	1	0
Bonavista Bay	0	74	0	0	0	24	2	0
Trinity Bay	0	11	0	0	0	0	89	0
Conception Bay	0	61	2	2	0	26	8	1
<u>Purse seine</u>								
White Bay	0	0	98	0	0	0	2	0
Notre Dame Bay	0	100	0	0	0	0	0	0
Bonavista Bay	0	0	0	0	0	100	0	0
Trinity Bay	62	0	0	0	0	0	38	0
Southern Shore	0	0	100	0	0	0	0	0
Conception Bay	0	22	76	0	0	0	2	0
St. Mary's Bay	0	0	0	0	0	100	0	0

Table 6. Capelin landings (t), discards (t), and catch/effort from research logbook records for capelin traps in Div. 3KL in 1993.

Area	No. fishermen	No. traps	Landings	Discard logbook	Bycatch		No. days fished (D)	No. times hauled (H)	L = Landings		C = Landings + discards	
					Cod	Herring			L/D	L/H	C/D	C/H
White Bay	11	14	621.2	40.4	+	1.4	83.0	144	7.5	4.3	8.0	4.6
Notre Dame Bay	8	8	86.4	32.5	0.4	0.4	19.1	47	4.5	1.8	6.2	2.5
Bonavista Bay	10	14	250.7	38.3	5.0	27.5	91.4	210	2.7	1.2	3.2	1.4
Trinity Bay	13	18	598.3	44.3	9.5	3.9	83.2	191	7.2	3.1	7.7	3.4
Conception Bay	12	18	553.8	141.5	4.1	0	96.2	200	5.8	2.8	7.2	3.5
Southern Shore	2	3	18.7	0	+	+	20.4	54	0.9	0.3	0.9	0.3
St. Mary's Bay	3	3	132.0	0	0	0	7.1	17	18.6	7.8	18.6	7.8

Table 7. Capelin landings (t), discards (t), bycatch (t), and catch/effort compiled from research logbooks for Div. 3KL in 1993.

						L = Landings		C = Landings + discards	
Area	No. of fishermen	Landings by logbook	Discards by logbook*	No. days fished	No. sets made	L/D	L/S	C/D	C/S
White Bay	6	116.9	6.0	12	20	9.7	5.8	10.2	6.1
Notre Dame Bay	9	151.0	4.5	32	42	4.7	3.6	4.9	3.7
Bonavista Bay	6	298.6	22.7	13	25	23.0	11.9	24.7	12.9
Trinity Bay	12	272.4	65.8	17	46	16.0	5.9	19.9	7.4
Conception Bay	13	692.0	108.6	69	101	10.0	6.9	11.6	7.9
Southern Shore	2	59.0	13.6	4	6	14.8	9.8	18.2	12.1
St. Mary's Bay	5	858.8	70.3	22	52	39.0	16.5	42.2	17.9

* includes capelin given to other fishermen

Table 8. Capelin landings (t), discards (t), bycatch (t), and catch/effort from research logbook records for capelin traps in Div. 3KL, 1981-93. Data available from Div. 3L only for 1981 and 1982.

Year	No. fishermen	No. traps	Landings	Discard logbook	Bycatch		No. days fished (D)	No. times hauled (H)	L = Landings		C = Landings + discards	
					Cod	Herring			L/D	L/H	C/D	C/H
1981	35	41	1281.0	417.7	5.8	0	577	680	2.2	1.9	2.9	2.5
1982	60	81	4366.5	605.2	60.4	0	1630	1996	2.7	2.2	3.1	2.5
1983	50	71	3051.2	1338.0	23.6	32.8	1277	1460	2.4	2.1	3.4	3.0
1984	67	89	4172.5	634.1	48.3	1.8	1615	2442	2.6	1.7	3.0	2.0
1985	60	80	3011.3	1850.1	31.0	0.1	1108	1508	2.7	2.0	4.4	3.2
1986	64	91	5056.4	2436.4	17.8	0.4	1567	2095	3.2	2.4	4.8	3.6
1987	68	93	3150.6	2437.5	11.8	0	622	1104	5.1	2.9	9.0	5.1
1988	86	125	6792.6	1500.4	28.0	0.2	1353	2415	5.0	2.8	6.1	3.4
1989	102	154	6275.8	2188.1	53.0	+	1314	2431	4.8	2.6	6.4	3.5
1990	106	167	6638.1	2986.6	100.4	0.7	1041	1825	6.4	3.6	9.2	5.3
1991	59	76	2793.0	2287.5	23.7	1.4	860	1325	3.2	2.1	5.9	3.8
1992	28	34	1225.8	567.1	1.5	5.7	297	666	4.1	1.8	6.0	2.7
1993	59	78	2261.1	297.0	52.3	10.7	400	863	5.6	2.6	6.4	3.0

Table 9. Capelin landings (t), discards (t), and catch/effort from research logbook records for purse seines in Div. 3KL, 1981-93.

Year	No. fishermen	Landings	Discards logbook	No. days fished (D)	No. sets made (S)	L = Landings		C = Landings + discards	
						L/D	L/S	C/D	C/S
1981	23	2705.3	810.4	376	707	7.2	3.8	9.4	5.0
1982	61	11541.9	2484.8	859	1670	13.4	6.9	16.3	8.4
1983	48	6439.0	4551.3	626	1155	10.3	5.6	17.6	9.5
1984	46	8185.5	1517.2	679	1305	12.1	6.3	14.3	7.4
1985	35	4191.0	2314.3	396	696	10.6	6.0	16.4	9.3
1986	36	8654.5	2745.2	605	991	14.3	8.7	18.8	11.5
1987	29	2100.5	869.1	169	267	12.4	7.9	17.6	11.1
1988	41	8282.7	1247.1	476	927	17.4	8.9	20.0	10.3
1989	46	7463.5	1687.1	421	863	17.7	8.6	21.7	10.6
1990	32	5081.4	2327.4	344	630	14.8	8.1	21.5	11.8
1991	9	699.0	413.7	74	95	9.4	7.4	15.0	11.7
1992	17	1719.8	254.0	95	146	18.1	11.8	20.8	13.5
1993	21	2448.7	291.5	169	292	14.5	8.4	16.2	9.4

Table 10. Capelin landings (t), catch rates (t/day), and effort (days fished) for purse seines (PS) and capelin traps (T) in NAFO Div. 3KL, 1982-93.

Year	Gear	Landings	Catch rate	Effort
1981	PS	15210	9.4	1618
	T	7917	2.9	2730
1982	PS	19631	16.3	1204
	T	8845	3.1	2853
1983	PS	16072	17.6	913
	T	10831	3.4	3186
1984	PS	20736	14.3	1450
	T	16324	3.0	5441
1985	PS	12824	16.4	782
	T	18266	4.4	4151
1986	PS	24726	18.8	1315
	T	31770	4.8	6619
1987	PS	8957	17.6	509
	T	18161	9.0	2018
1988	PS	28626	20.0	1431
	T	47115	6.1	7724
1989	PS	26330	21.7	1213
	T	49296	6.4	7703
1990	PS	25376	21.5	1180
	T	53730	9.2	5842
1991	PS	10139	15.0	676
	T	28918	5.9	4901
1992	PS	8694	20.8	418
	T	10971	6.0	1829
1993	PS	13340	16.2	823
	T	21629	6.4	3380

Table 11. Catch-at-age (numbers x 10^{-3}) for mature capelin by purse seines and traps in NAFO Div. 3KL since 1981.

Gear	Year	Age 2	3	4	5	6
Purse seine	1981	721	198444	198587	180638	7945
	1982	3995	475295	70373	22010	6136
	1983	13174	31192	191400	7729	286
	1984	5721	229158	360170	29505	806
	1985	50257	301578	111460	42481	2096
	1986	1172	580679	282768	21254	5667
	1987	6882	61246	327136	23813	903
	1988	59543	511866	153467	158773	9273
	1989	3999	618490	197740	9538	9998
	1990	11700	359250	487985	11863	440
	1991	33859	212933	148074	24156	174
	1992	61671	294536	37137	1870	109
	1993	42336	547577	36679	2143	0
Trap	1981	0	106596	100848	74584	4178
	1982	2154	252868	21565	7321	1493
	1983	15952	204722	116720	3430	89
	1984	12202	224423	273686	23330	8911
	1985	73260	414647	146383	39388	2219
	1986	3081	619045	379517	26650	7707
	1987	16293	80423	370689	28980	1632
	1988	147698	891598	24116	204508	11311
	1989	16840	114372	355229	17827	23374
	1990	16009	692405	1051466	29035	137
	1991	157584	596754	407968	66436	937
	1992	52152	337132	61064	7683	0
	1993	140640	787881	69161	1768	52

Table 12. Catch rates-at-age and total catch rate (numbers x 10^{-3}/day) for mature capelin from purse seines and traps in NAFO Div. 3KL since 1981.

Gear	Year	Age 2	3	4	5	6	Total
Purse seine	1981	0.4	122.6	122.7	111.6	4.9	362.2
	1982	3.3	394.8	58.4	18.3	5.1	479.9
	1983	14.4	340.8	209.6	8.5	0.3	573.6
	1984	3.9	158.0	248.4	20.3	0.6	431.2
	1985	64.3	385.6	142.5	54.3	2.7	649.4
	1986	0.9	441.6	215.0	16.2	4.3	678.0
	1987	13.5	120.3	642.7	46.8	1.8	825.1
	1988	41.6	357.7	107.2	111.0	6.5	624.0
	1989	3.3	509.9	163.0	7.9	8.2	692.3
	1990	9.9	304.4	413.5	10.1	0.4	738.3
	1991	50.1	315.0	219.0	35.7	0.3	620.1
	1992	147.5	704.6	88.8	4.5	0.3	945.7
	1993	51.4	665.3	44.6	2.6	0	763.9
Trap	1981	0	39.0	36.9	27.3	1.5	104.7
	1982	0.8	88.6	7.6	2.6	0.5	100.1
	1983	5.0	64.3	36.6	1.1	0	107.0
	1984	2.2	41.2	50.3	4.3	1.6	99.6
	1985	17.6	99.9	35.3	9.5	0.5	162.8
	1986	0.5	93.5	57.3	4.0	1.2	156.5
	1987	8.1	39.9	183.7	14.4	0.8	246.9
	1988	19.1	115.4	31.2	26.5	1.5	193.7
	1989	2.2	148.4	46.1	2.3	3.0	202.0
	1990	2.7	118.5	180.0	5.0	0	306.2
	1991	32.2	121.8	83.2	13.6	0.2	251.0
	1992	28.5	184.3	33.4	4.2	0	250.4
	1993	41.6	233.1	20.5	0.5	0	295.7

Table 13. Catch rate-at-age (numbers x 10^{-3}) for ages 3 and 4 mature capelin combined for NAFO Div. 3KL, 1978-89. Normalized estimates in parentheses.

Year-class	Purse seine		Trap	
1978	181.0	(.17)	46.6	(.14)
1979	604.4	(.56)	125.2	(.38)
1980	589.2	(.54)	114.6	(.35)
1981	300.5	(.28)	76.5	(.23)
1982	600.6	(.55)	157.2	(.48)
1983	1084.3	(1.00)	277.2	(.84)
1984	227.5	(.21)	71.1	(.22)
1985	520.7	(.48)	161.5	(.49)
1986	923.4	(.85)	328.4	(1.00)
1987	523.4	(.48)	201.7	(.61)
1988	403.8	(.37)	155.2	(.47)
1989	749.2	(.69)	204.8	(.62)

Table 14. Catch rate-at-age (numbers x 10^{-3}/day) for ages 2, 3, and 4 mature capelin combined for NAFO Div. 3KL year-classes, 1979-89. Normalized estimates in parentheses.

Year-class	Purse seine		Trap	
1979	604.8	(.53)	125.2	(.36)
1980	592.5	(.52)	115.4	(.33)
1981	314.9	(.27)	81.5	(.23)
1982	604.5	(.53)	159.4	(.46)
1983	1148.6	(1.00)	294.8	(.85)
1984	228.4	(.20)	71.6	(.21)
1985	534.2	(.47)	169.6	(.49)
1986	965.0	(.84)	347.5	(1.00)
1987	526.7	(.46)	203.9	(.59)
1988	413.7	(.36)	157.9	(.45)
1989	799.3	(.70)	237.0	(.68)

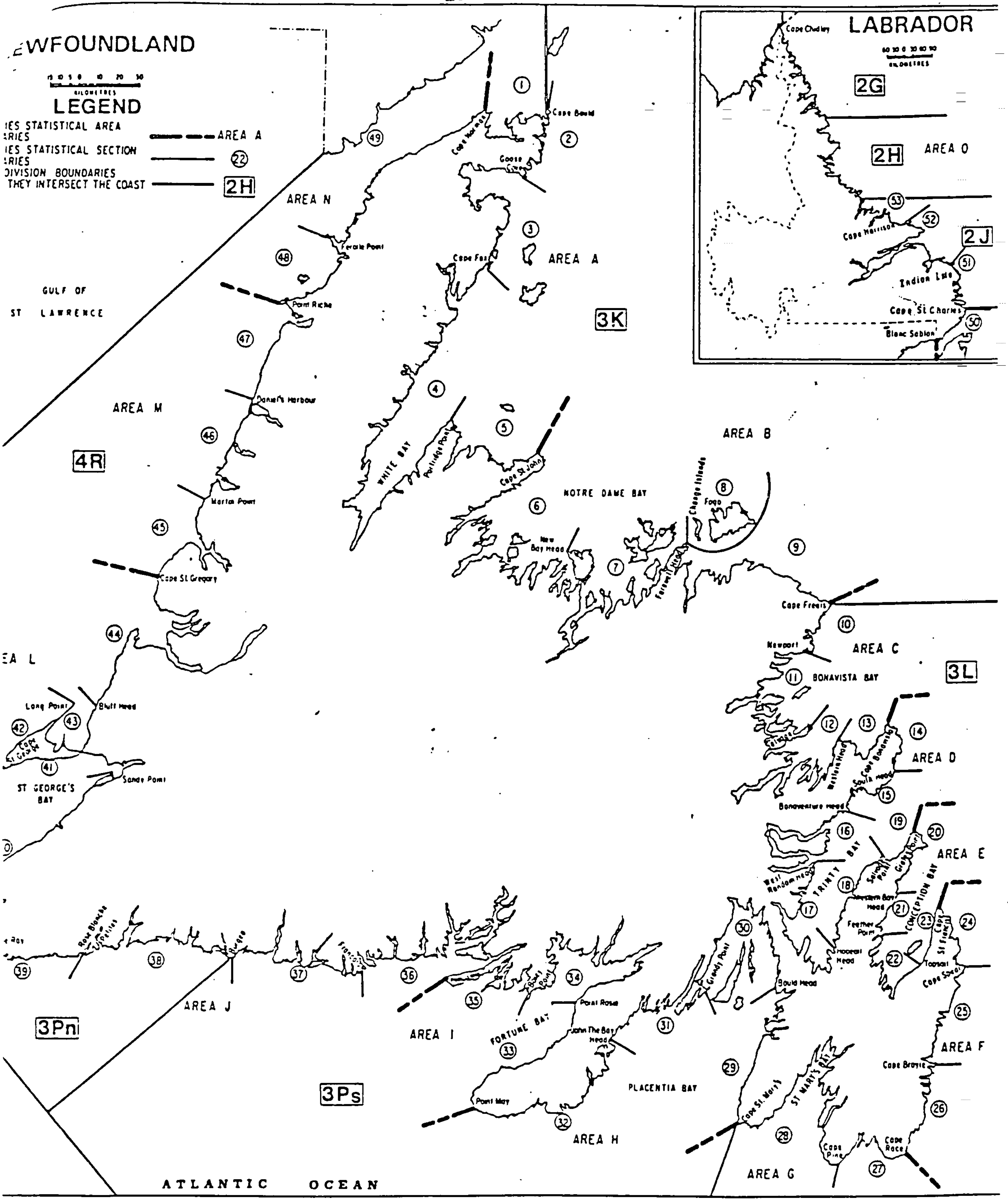

Fig. 1. Statistical areas in Div. 3L and Div. 3K.

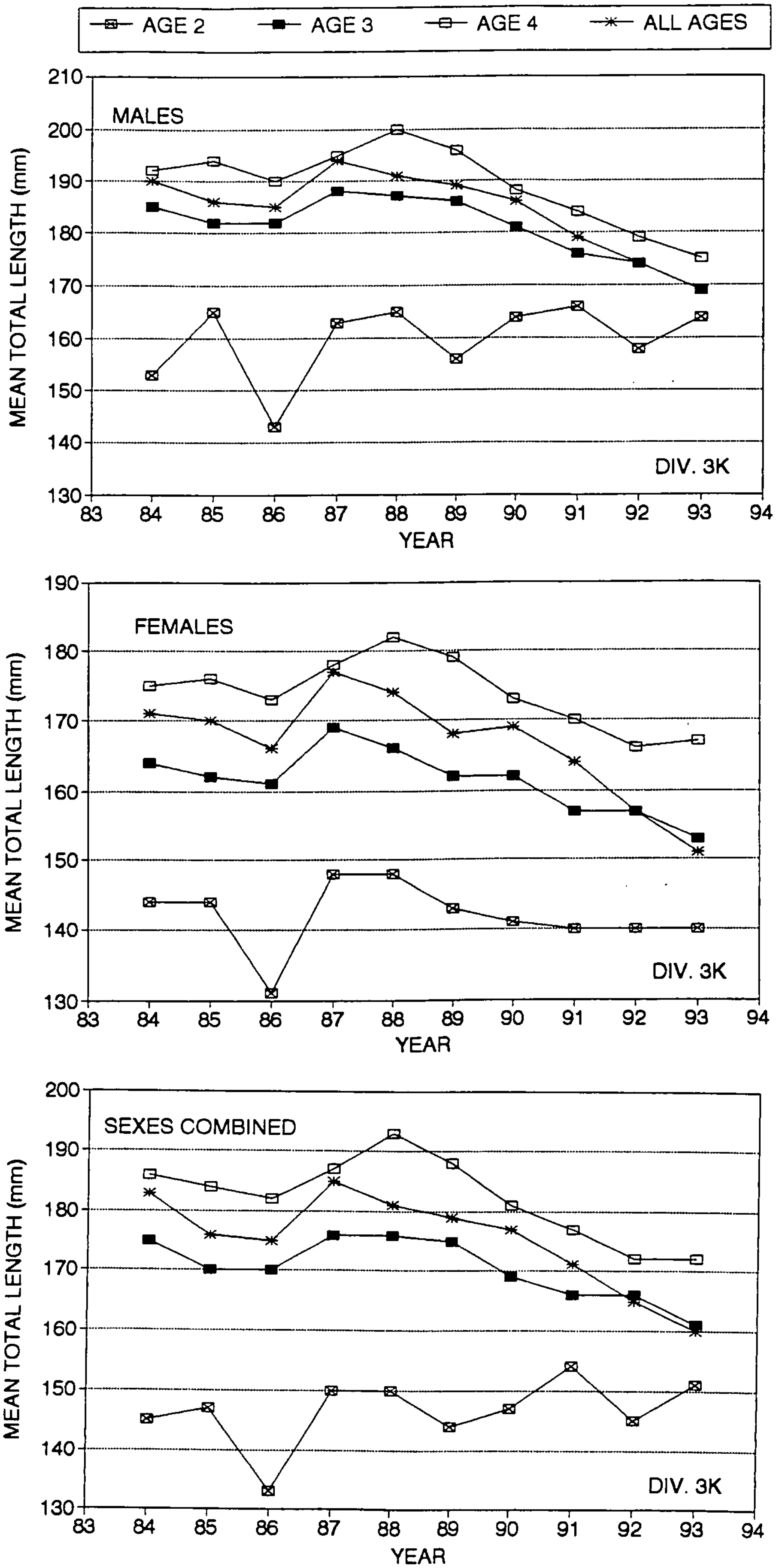

Fig. 2. Mean total length-at-age for males, females, and sexes combined for Div. 3K.

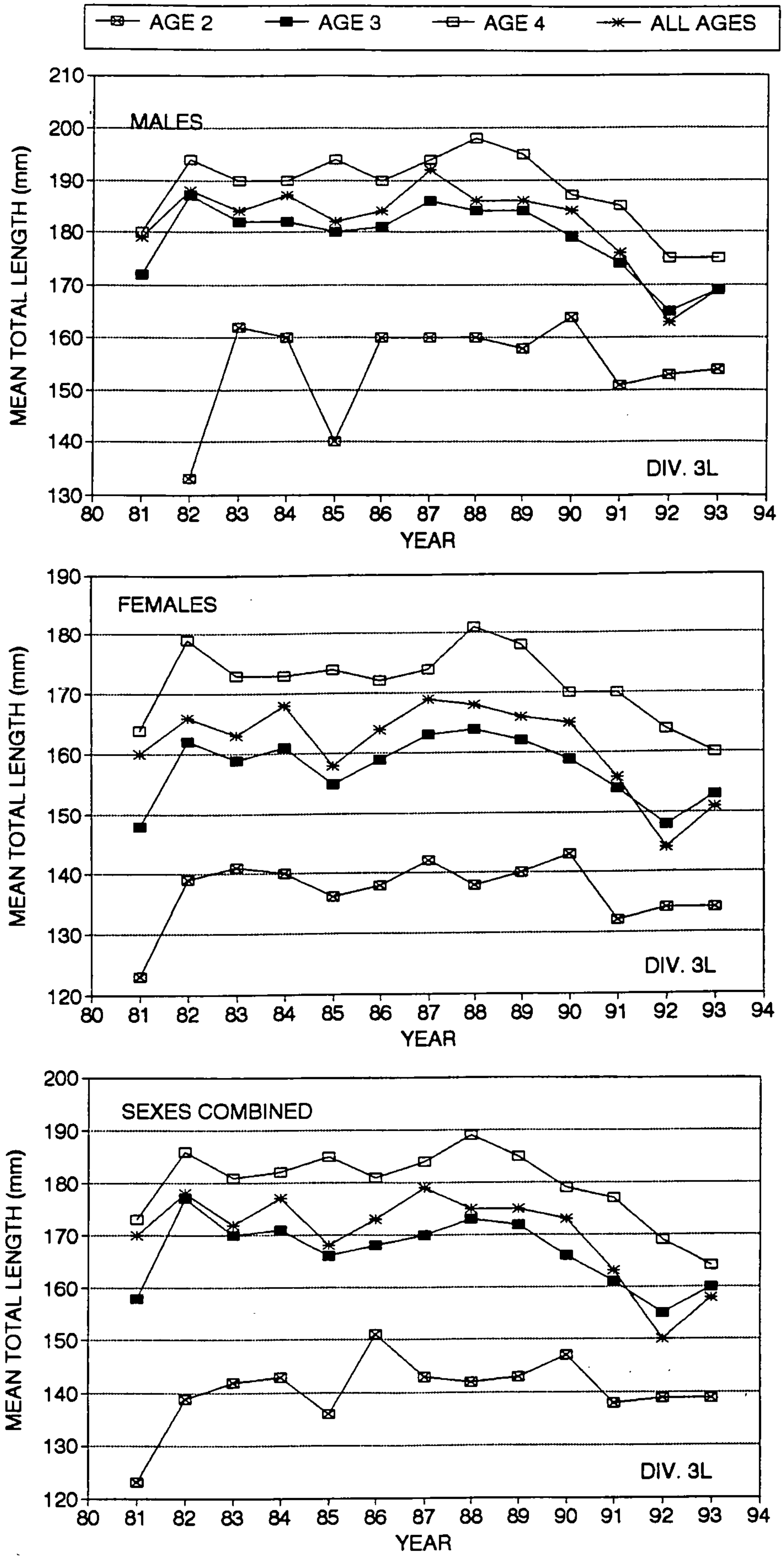

Fig. 3. Mean total length-at-age for males, females, and sexes combined for Div. 3L.

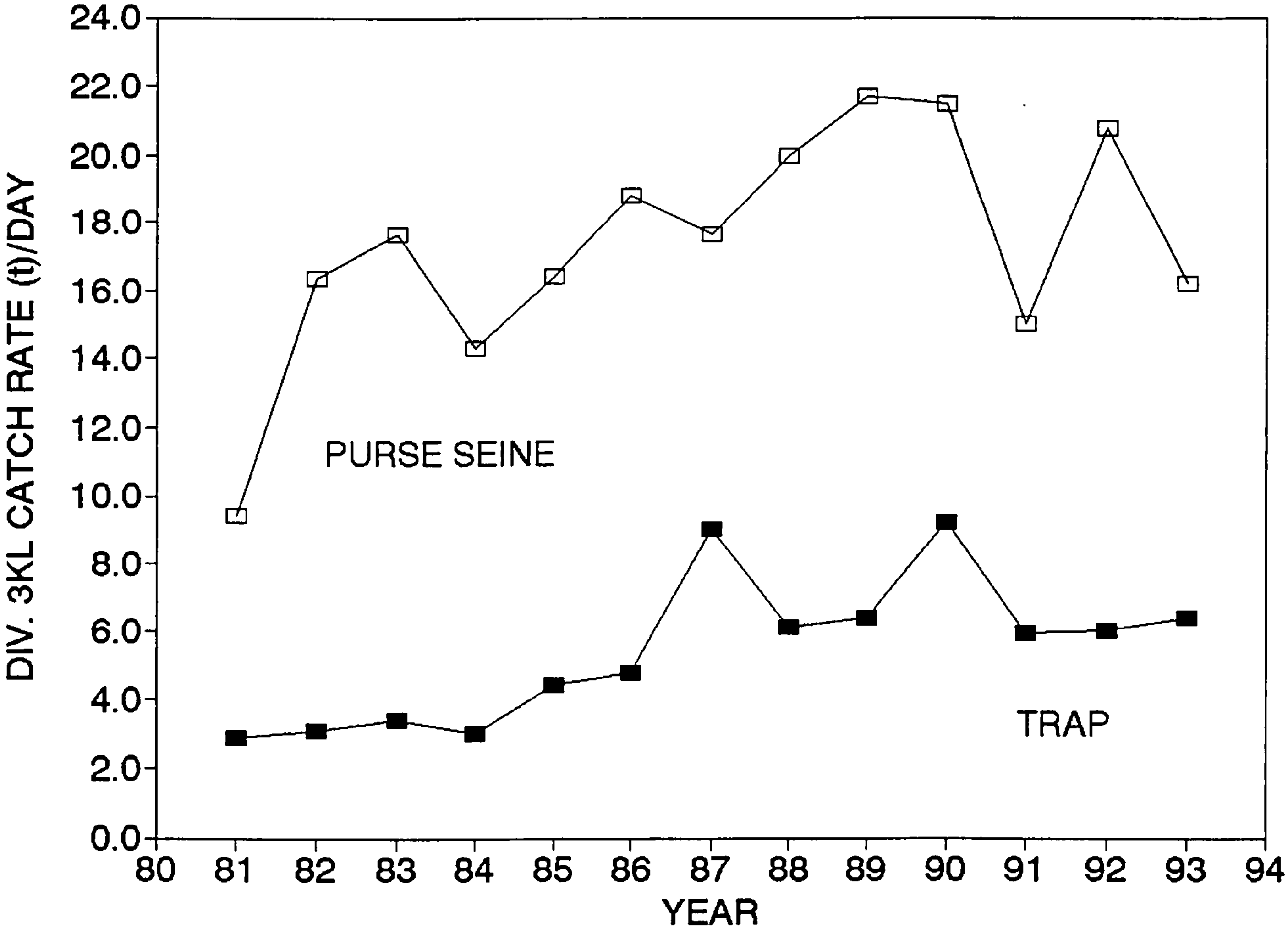

Fig. 4. Div. 3KL catch rate (t)/day trends for traps and purse seines.

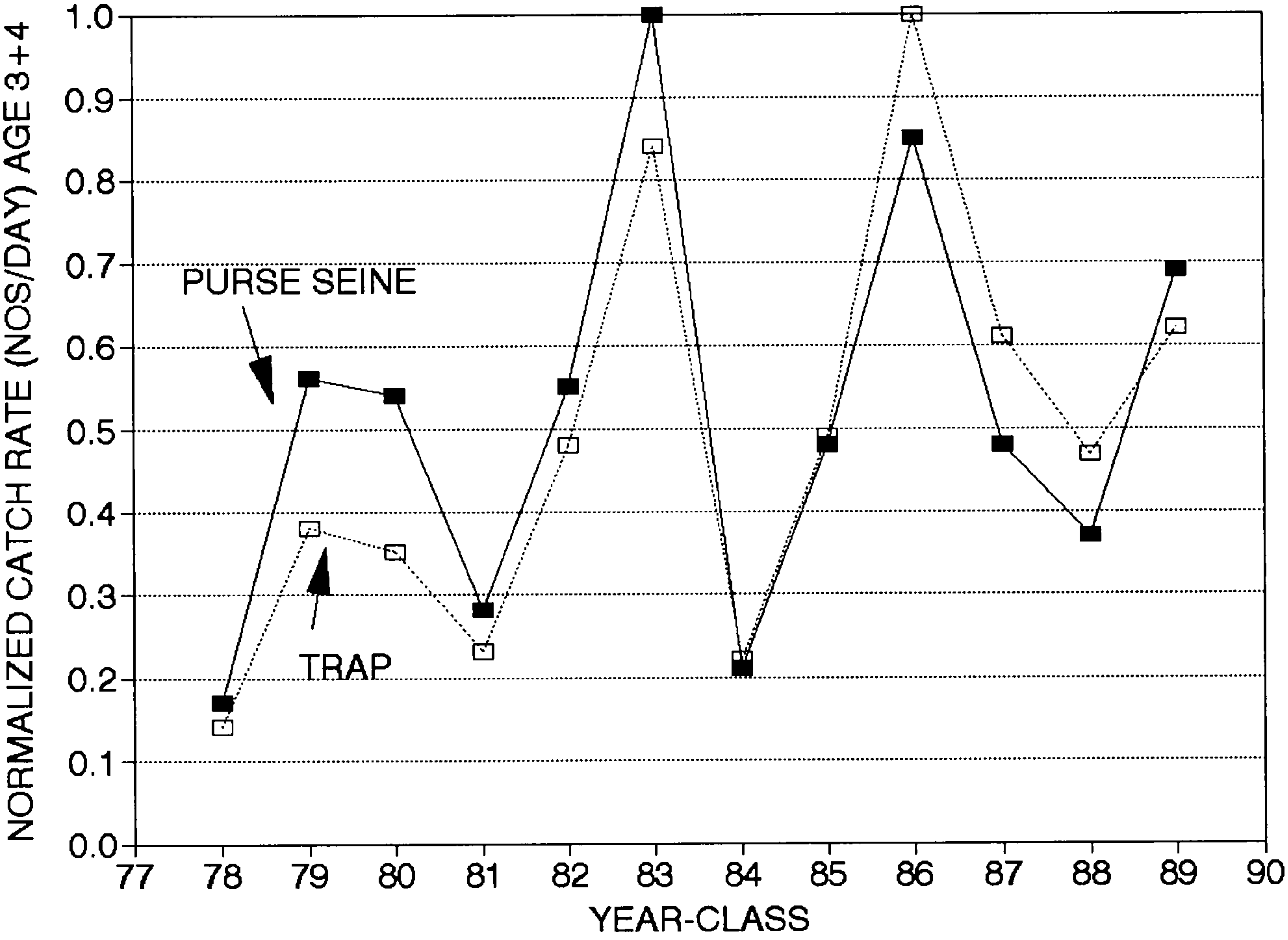

Fig. 5. Normalized catch rates for ages 3 and 4 combined for Div. 3KL.

1993 CAPELIN ALLOCATIONS

NAFO AREA	AREA	FIXED GEAR	PURSE SEINE	TOTAL
2J	LABRADOR	150		150
3K	W.B.N.-NORTH OF FISCHOTT ISLD	965		965
	W.B.N.-SOUTH OF FISCHOTT ISLD	325		325
	WHITE BAY	3185	1500	4685
	N.D.B. - WEST[1]	1105		1105
	N.D.B. - CENTRAL[1]	2300		2300
	N.D.B. - EAST[1]	520		520
	NOTRE DAME BAY		1500	1500
	TOTAL	8400	3000	11400
3L	BONAVISTA BAY	2245	1425	3670
	TRINITY BAY	4490	1870	6360
	CONCEPTION BAY	3710	3370	7080
	SOUTHERN SHORE[2]	1650	190	1840
	ST.MARY'S BAY	370	1680	2050
	TOTAL	12465	8535	21000
3Ps	PLACENTIA BAY	1740	260	2000
	FORTUNE BAY	60	30	90
	TOTAL	1800	290	2090
4R	WEST COAST	2255	6770	9025
NFLD PROVINCE TOTAL		25070	18595	43665
4ST				1725
ATLANTIC COAST TOTAL				45390

1. Notre Dame Bay West - Cape John to North Head
Notre Dame Bay Central - North Head to Dog Bay Point (including Fogo and Change Islands)
Notre Dame Bay East - Dog Bay Point to Cape Freels

2. Includes Trepassey Bay.

Appendix B

1993 Opening and Closing Dates

White Bay

- open June 25 all areas and gears
- closed fixed gear July 9 areas north and south of Fischott Is. due to small fish
- closed purse seine July 9 because quota was reached
- closed fixed gear July 11 1200 in White Bay because quota was reached
- reopened and closed fixed gear July 14 (0600-1200) south of Fischott Is. because quota was reached
- reopened fixed gear July 21 0600 north of Fischott Is.
- closed fixed gear July 24 2100 north of Fischott Is. because quota was reached

Notre Dame Bay: West (Cape John-North Hd.), Central (North Hd.-Dog Bay Pt.), East (Dog Bay Pt.-Cape Freels)

- open June 20 all areas and gears
- closed purse seine July 8 because quota was reached
- closed fixed gear July 7 in Central and East due to high bycatch
- closed fixed gear July 9 in West due to small fish
- reopened fixed gear July 15 0600 in West
- closed fixed gear July 17 1500 in West because quota was reached
- reopened fixed gear July 23 0600 in Central
- closed fixed gear July 24 2000 in Central because quota was reached
- reopened and closed fixed gear August 13 (0600-2100) in East because quota was reached

Bonavista Bay:

- open June 20 all gears
- closed July 15 2000 all gears due to small fish
- reopened August 7 0600 all gears
- closed purse seine August 7 1600 because quota was reached
- closed fixed gear August 13 1800 because quota was reached

Trinity Bay:

- open June 15 all gears
- closed July 2 all gears due to small fish
- reopened July 30 0600 all gears
- closed purse seine July 30 1900 because quota was reached
- closed fixed gear August 2 1600 because quota was reached

Conception Bay:

- open June 15 all gears
- closed July 6 2100 all gears due to small fish
- reopened July 15 0600 all gears
- closed July 16 2100 all gears due to small fish
- reopened July 20 0600 all gears
- closed purse seine July 20 2100 because quota was reached
- closed fixed gear July 21 2100 because quota was reached

Southern Shore:

- open June 5 all gears
- closed purse seine July 3 because quota was reached
- closed fixed gear July 7 due to small fish
- reopened fixed gear north of Cape Broyle on July 8
- reopened fixed gear south of Cape Broyle on July 10
- closed fixed gear July 12 1600 because quota was reached

St. Mary's:

- open June 5 all gears
- closed purse seine June 29 because quota was reached
- closed fixed gear June 30 because quota was reached

Placentia Bay:

- open June 5 all gears
- closed to fixed gear July 3 0000 because quota was reached
- closed purse seine July 30

Chapter 2

Reanalysis of Inshore Abundance Indices

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Annual variations in the abundance of mature capelin during their inshore spawning run are monitored through a voluntary logbook program covering both the purse seine and trap fisheries. In addition, aerial estimates of spawning schools have been conducted since 1982 in Trinity and Conception Bays. We shall deal with the commercial indices first.

Purse seine catch rates are well known for their potential intrinsic biases, particularly under conditions of widely varying population change (see Winters and Wheeler 1985 and references therein). That is not to say that the capelin purse seine catch rate series in NAFO Div. 3KL is biased; rather the potential for systematic catchability change is so great that we will exclude this time series from further analyses and deal exclusively with the trap catch rate series.

Capelin traps are passive gears which intercept capelin schools during their spawning runs to the coastal beaches. Trap catch-rates have been expressed as both catch-per-day and catch-per-haul, although catch-per-day has historically been used as the main abundance index. Statistically, catch-per-haul is a more attractive index since it utilizes more information (sample sizes are approximately twice as large) and therefore will have reduced variances. In addition, catch-per-day could be biased, if the number of trap hauls per day exhibited a temporal trend. Using the comparable catch rate statistics (see Table 8, Chapter 1), we see that this is indeed the case (Fig. 1). From these perspectives, we consider trap catch-per-haul a more appropriate index of inshore capelin abundance and will restrict our subsequent analyses to this statistic.

Initially, multiplicative analyses were carried out to examine the sources of variability in catch-per-haul. Since the catch rates were not normally distributed it was necessary to linearize by taking logarithms of the data. This required a consideration of how to treat zero catches. General guidelines are available from a variety of statistical sources but there is no set rule. We chose to add 0.01 to all zero catches. All analyses were conducted using the General Linear Model Procedure

(GLM) of SAS Institute Inc., North Carolina). Initial analyses used year (YRFish) and Bay (BAYFish) as main effects (Table 1). These class variables were statistically significant but explained only 4% of the variation in catch-per-haul. Further trials indicated that the highest R^2 value was achieved only when the individual fisherperson (FIN) was included as a main effect (Table 1). As this still explained only 16% of the overall variation in catch rates and in view of the statistical problems inherent in the treatment of zero catches we did not purse the multiplicative approach any further.

Trap catch rates and their standard deviations were compared for NAFO 3K and 3L for the period 1983-93. The statistical relationship was highly significant ($p < 0.01$) in both cases (Fig. 2) indicating that the year effects were being consistently measured in NAFO 3K and 3L. We therefore combined the Div. 3K and Div. 3L into a single catch rate series (Table 2).

It is important to note that trap catch rates can be considered a measure of local density of capelin spawning runs as they are being intercepted enroute to beach spawning. The only comparable index for comparison purposes is the aerial survey results. In theory, two comparisons are possible, viz. (a) the encounter rate of the trap (% of trap hauls with positive catches) versus the aerial encounter rate (no. of schools detected per unit survey time) and (b) trap catch rates (kg/haul) (encounter rate times mean catch/positive haul) versus school abundance (m^2/hr) (aerial encounter rate times mean school size).

There is a statistically significant ($r = 0.67$, $p = 0.03$) relationship between trap encounter rates and aerial encounter rates for the period 1982-93 (Fig. 3), although the relationship depends heavily on the leverage of one data point (1987). Trap catch (kg/haul) rates are not statistically correlated with aerial density estimates (m^2/hr) when all data points are included ($r = 0.54$, $p = 0.06$) (Fig. 4). The 1983 aerial survey estimate is an outlier. In that year, the aerial survey was conducted in two periods of consecutive-day surveys (June 23-25, June 29-July 1). Aerial surveys conducted on consecutive days likely result in double counting since capelin schools would not have had time to move onto the spawning beaches. Exclusion of the 1983 data points results in a statistically significant relationship ($r = 0.77$, $p = 0.01$) between trap catch rates (kg/haul) and aerial density estimates of capelin schools. From these analyses we conclude that trap catch rates, expressed as catch-per-haul, are measuring spawning runs of capelin in similar fashion as the aerial survey results.

Trap catch-rates provide only an index of mean abundance of capelin during their spawning runs towards the coastal spawning beaches. Extrapolation of this index to measures of annual spawning biomass requires additional information, i.e. annual spawning runs of equivalent biomass will have different mean catch rates if the duration of the spawning season is different in the years of comparison. Therefore, estimates of the duration of the spawning season are needed in order to integrate the seasonal index of mean density into an annual index of spawning biomass. The aerial survey estimates of mean abundance (m^2/hr) require a similar adjustment. We used the duration of the trap fishing season in NAFO Div. 3KL as a proxy for the duration of the capelin spawning season. We tested whether or not the expansion of the 3K fishery since 1983 may have introduced a temporal bias in the duration of the fishing season. Other than 1985, the 3K capelin trap season is synchronous with that in 3L (Fig. 5). There have been significant interannual variations in the duration of the fishing season since 1981 (Table 3, Fig. 6), which, at least for 1990-93, are consistent with the duration of the beach spawning season as measured by egg deposition studies at six sites in Div. 3KL (see Table 2, Chapter 3). Mean catch rates (mean kg/haul by day of the year) were therefore integrated over the fishing season in Div. 3KL as an index of annual spawning biomass for the period 1981-93 (Table 3). It is evident from Table 3 that such an adjustment changes the stock trajectory perspective during 1981-93 in comparison with that shown by the mean seasonal index (kg/haul). A similar change in stock perspective occurs when the aerial survey index is also adjusted for the duration of the spawning season.

We evaluated the relative performance of the integrated index to the mean trap index through comparisons with other available indices, viz. aerial survey index and the egg deposition index from the inshore spawning season, the groundfish bycatch rate, the mean partial fullness index of capelin in cod stomachs and acoustic biomass estimates from offshore surveys. All of these can be considered to be potential indices of capelin abundance but none have been rigorously tested for the consistency of their performance. We will consider the inshore indices first.

The integrated trap index of capelin spawning biomass has a stronger statistical relationship with the adjusted aerial survey index than mean trap catch rate (Fig. 7). The relationships are statistically significant in all cases. The only other index available from the inshore area is the egg deposition index from six beach-spawning sites sampled since 1991 (see Table 2, Chapter 3). This is the only direct empirical measure of spawning biomass available for comparison purposes. Although the time series is short (1991-93), the ranking (1, 2, 2) is identical to that of the integrated trap index but differs from that of the mean trap catch rate index (2, 1, 3).

For the offshore area bycatches of capelin from fall bottom-trawl surveys in 2J3KL are provided by Lilly and Davis (1993). These are expressed as percentages of trawl sets in which capelin are caught (i.e. probability of capture). It is generally accepted that the habitat (range) occupied by pelagic species is a direct function of stock biomass levels (Winters and Wheeler 1985 and references therein). This trait also appears to prevail for groundfish species as well (Rose and Leggett 1991 and references therein). It is not unreasonable therefore that bottom trawl surveys could provide useful relative indices of distribution and abundance of capelin as has been suggested by Carscadden et al. (1989). We have combined the data on capelin bycatch rates (% of sets containing capelin) given in Lilly and Davis (1993) by weighting the divisional estimates (2J3K, 3L) by the number of sets. These bycatch success rates (in year t) are compared with trap catch rates and integrated trap index (year t+1) in Figure 8. The statistical comparison shows that the groundfish bycatch rates of capelin are significantly correlated ($p = 0.62$, $p = 0.02$) with the integrated trap index but the relationship is not significant for the trap catch rate comparison ($r = 0.24$, $p = 0.43$).

Lilly (1991) compared the partial fullness index (PFI) of capelin in cod stomachs with acoustic estimates of capelin biomass and concluded that the PFI index was capable of measuring broad changes in capelin abundance. The time series of PFI data is given in Lilly and Davis (1993) for 2J3K and 3L separately. We have combined these into a single 2J3KL PFI data set (weighted by number of sets). In Figure 9 we show plots of time series trends of PFI in relation to the trap catch rate series and the integrated trap index. The relationship is not statistically significant ($r = 0.37$, $p = 0.21$) in the former case but is highly significant ($r = 0.80$, $p = 0.01$) when compared against the integrated index.

The offshore acoustic surveys (2J3K in the fall and 3L in the spring) provide another template against which the performance of the two trap rate indices can be compared. The fall acoustic survey in 2J3K is not statistically related to any of the above indices and will not be discussed further here. The spring acoustic survey in 3L has been used by NAFO (Anon. 1992) to provide projections of mature biomass in the following year. Up to 1991 these projections were statistically correlated with the two traditional inshore indices (trap catch/day and peak aerial estimates) but the relationships fell apart when the 1992 and 1993 projections are included. It is likely (as NAFO concluded) that the 1991 and 1992 3L acoustic surveys were aliassed by severe environmental conditions affecting the distribution of capelin (see the section of this report on capelin distributions). For the time series up to 1991 the integrated trap index is statistically correlated with the 3L projections of mature capelin biomass ($r = 0.80$, $p = <0.01$) whereas the mean seasonal catch rate is not ($r = 0.39$, $p = 0.30$) (Fig. 10).

In summary, based on statistical comparisons with other potential indices of capelin abundance, the integrated trap catch rate index outperforms the seasonal index in all cases. This provides good evidence that the integrated index has improved our perception of trends in capelin biomass. However, as with all indices, vigilance must be maintained to ensure that potential biases are detected and accounted for. In Table 4 and 5 we provide the two catch rate indices decomposed into their age-specific components.

The integrated catch-rate index in Table 3 has potential for predicting abundance of the spawning stock in the following year. Simply put, the spawning runs of capelin are dominated by 3- and 4-year-olds which normally comprise in excess of 80% of the mature stock. In Figure 11 we show the statistical relationship between catch rates of each year-class at ages 2 versus age 3 and ages 3 versus age 4. The relationship is highly significant for ages 2 and 3 ($r = 0.86$, $p = 0.01$) but is not statistically significant for ages 3 to 4 ($r = 0.40$, $p = 0.28$). In the latter comparison, the 1992 and 1993 data points are outliers. This could be the result of aging inconsistencies or other factors such as change in age-specific maturation rates. When ages 2+3 are combined and compared with the same year-classes at ages 3+4 the relationship is highly significant ($r = 0.81$, $p = 0.01$). For comparison purposes, we also show the same age-structured relationships for the seasonal catch rate index (catch/haul) (Fig. 12). The relationship is significant only for the age 2 to age 3 comparisons ($r = 0.72$, $p = 0.01$). From Table 4, the age 2+3 integrated index in 1993 suggests that abundance of these two year-classes (1990, 1991) will be extremely good in the 1994 spawning runs. The only other source for which data are available (for 1993) is the 1993 bycatch rate of capelin in the 2J3KL groundfish survey (G. R. Lilly, pers. comm.). From the relationship in Figure 8 (lower right panel) the 1993 bycatch rate (44%) also suggests that abundance will be good in 1994.

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Table 1. Results of multiplicative analyses of capelin trap rate data (kg/haul) for the period 1981-93.

General Linear Models Procedure

Dependent Variable: CUE_01

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	18	20245.11477358	1124.72859853	35.97	0.0001
Error	14591	456273.27197195	31.27087053		
Corrected Total	14609	476518.38674553			

	R-Square	C.V.	Root MSE	CUE_01 Mean
	0.042485	124.7827	5.59203635	4.48141857

Source	DF	Type I SS	Mean Square	F Value	Pr > F
YRFISH	12	12331.94650013	1027.66220834	32.86	0.0001
BAYFISH	6	7913.16827345	1318.86137891	42.18	0.0001

Source	DF	Type III SS	Mean Square	F Value	Pr > F
YRFISH	12	13345.19869816	1112.09989151	35.56	0.0001
BAYFISH	6	7913.16827345	1318.86137891	42.18	0.0001

General Linear Models Procedure

Dependent Variable: CUE_01

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	206	78170.27959362	379.46737667	13.72	0.0001
Error	14403	398348.10715191	27.65730106		
Corrected Total	14609	476518.38674553			

	R-Square	C.V.	Root MSE	CUE_01 Mean
	0.164045	117.3517	5.25902092	4.48141857

Source	DF	Type I SS	Mean Square	F Value	Pr > F
YRFISH	12	12331.94650013	1027.66220834	37.16	0.0001
FIN	194	65838.33309349	339.37285100	12.27	0.0001

Source	DF	Type III SS	Mean Square	F Value	Pr > F
YRFISH	12	12570.07602335	1047.50633528	37.87	0.0001
FIN	194	65838.33309349	339.37285100	12.27	0.0001

Table 2. Catch-rate statistics of capelin traps, expressed as catch per haul, for Div. 3KL, 1981-93.

Year	No. trap hauls	Catch/haul (kg)	St. error (kg)
1981	624	2722	145
1982	1281	2610	88
1983	658	3008	166
1984	1597	2103	69
1985	829	3890	161
1986	1404	4067	122
1987	757	6097	247
1988	1807	3139	116
1989	2041	3279	102
1990	1427	5116	151
1991	1129	3247	134
1992	355	3699	256
1993	701	2937	163

Table 3. Calculation of revised trap and aerial survey abundance indices of Div. 3KL capelin, based on adjusting for the duration of the spawning season as measured by the fishing season.

	Fishery data			Aerial survey data				
Year	Mean seasonal CPUE (kg/haul)	Duration of season (days)	Integrated trap index	School total area ('000 m^2)	Survey time hrs)	School area/hr (m^2/hr)	Duration of season (days)	Adj. survey index
1981	2722	32	75,219	-	-	-	-	-
1982	2610	31	69,895	407.5	(25.8)	15.8	31	490
1983	3008	30	64,047	1141.3	25.8	44.2	30	1326
1984	2103	36	59,748	460.6	38.5	12.0	36	432
1985	3889	30	89,321	596.6	27.1	22.0	30	660
1986	4067	40	148,965	299.6	13.4	22.4	40	896
1987	6097	(41.5)[a]	155,474	1546.3	37.0	41.8	(41.5)	1735
1988	3139	43	121,063	806.9	33.0	24.5	43	1054
1989	3279	32	148,680	854.9	26.0	32.9	32	1053
1990	5116	42	166,636	788.7	27.0	29.2	42	1226
1991	3247	56	153,159	477.3	19.9	27.4	56	1343
1992	3699	42	131,724	1240.0	34.6	35.8	42	1504
1993	2937	49	145,770	863.5	35.9	24.1	49	1181

[a] strike-shortened season; mean of 1986 and 1988

Table 4. Catch rates-at-age and total catch rate (integrated numbers x 10^{-3}/haul) for mature capelin from traps in Div. 3KL since 1981.

Year	Age 2	Age 3	Age 4	Age 5+	Total
1981	0.0	941	943	831	2715
1982	16	1908	237	95	2256
1983	67	1202	719	26	2014
1984	30	766	1095	93	1984
1985	334	1998	731	245	3308
1986	10	3014	1674	155	4853
1987	124	697	3216	243	4260
1988	323	2271	634	615	3843
1989	38	3447	1083	122	4690
1990	55	2198	3200	83	5536
1991	723	3180	2248	365	6516
1992	730	4056	648	55	5489
1993	675	5622	432	19	6749

Table 5. Catch rates-at-age and total catch rate (numbers x 10^{-3}/haul) for mature capelin from traps in Div. 3KL since 1981.

Year	Age 2	Age 3	Age 4	Age 5+	Total
1981	0.0	34.0	34.2	30.1	98.3
1982	0.6	71.2	11.7	3.5	84.4
1983	3.1	56.5	33.8	1.2	94.6
1984	1.0	27.0	38.6	3.3	69.9
1985	14.5	87.0	31.8	10.7	144.0
1986	0.3	82.2	45.7	4.3	132.5
1987	4.8	26.6	126.1	9.5	167.0
1988	8.4	58.9	16.5	15.9	99.7
1989	0.8	76.0	23.9	2.7	103.4
1990	1.7	67.5	98.3	2.5	170.0
1991	15.3	67.4	47.7	7.8	138.2
1992	20.5	113.9	18.3	1.5	154.2
1993	13.6	113.3	8.7	0.6	136.0

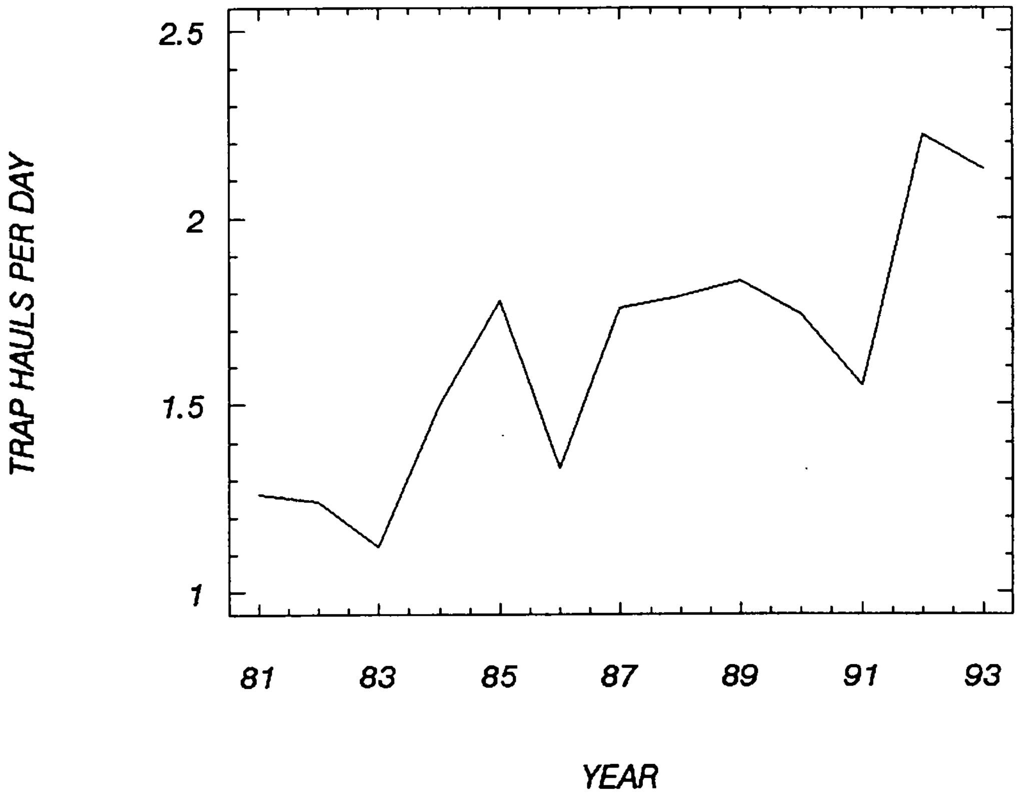

Fig. 1. Mean number of trap hauls per day fished for capelin traps in NAFO Div. 3KL, 1981-93.

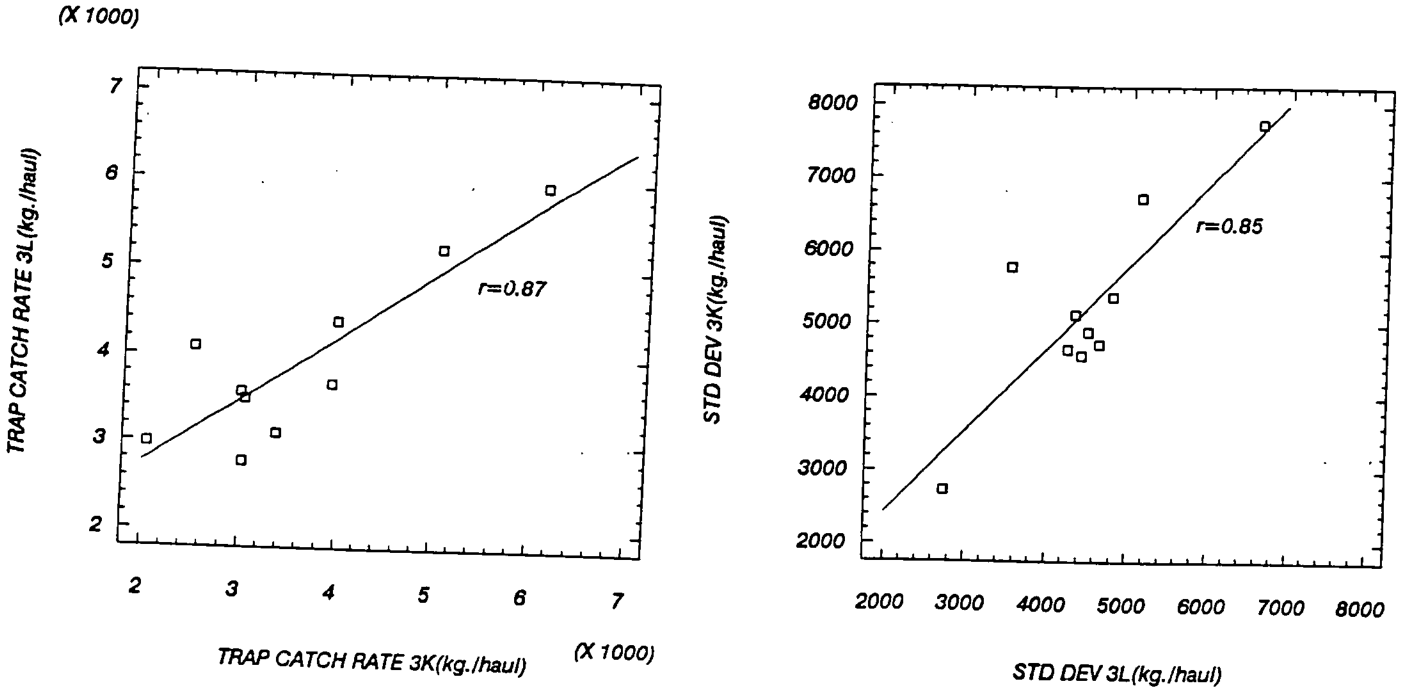

Fig. 2. Comparison of trap catch rates (kg/haul) in NAFO Div. 3K and 3L (left panel) and similar comparison of their standard deviations (right panel).

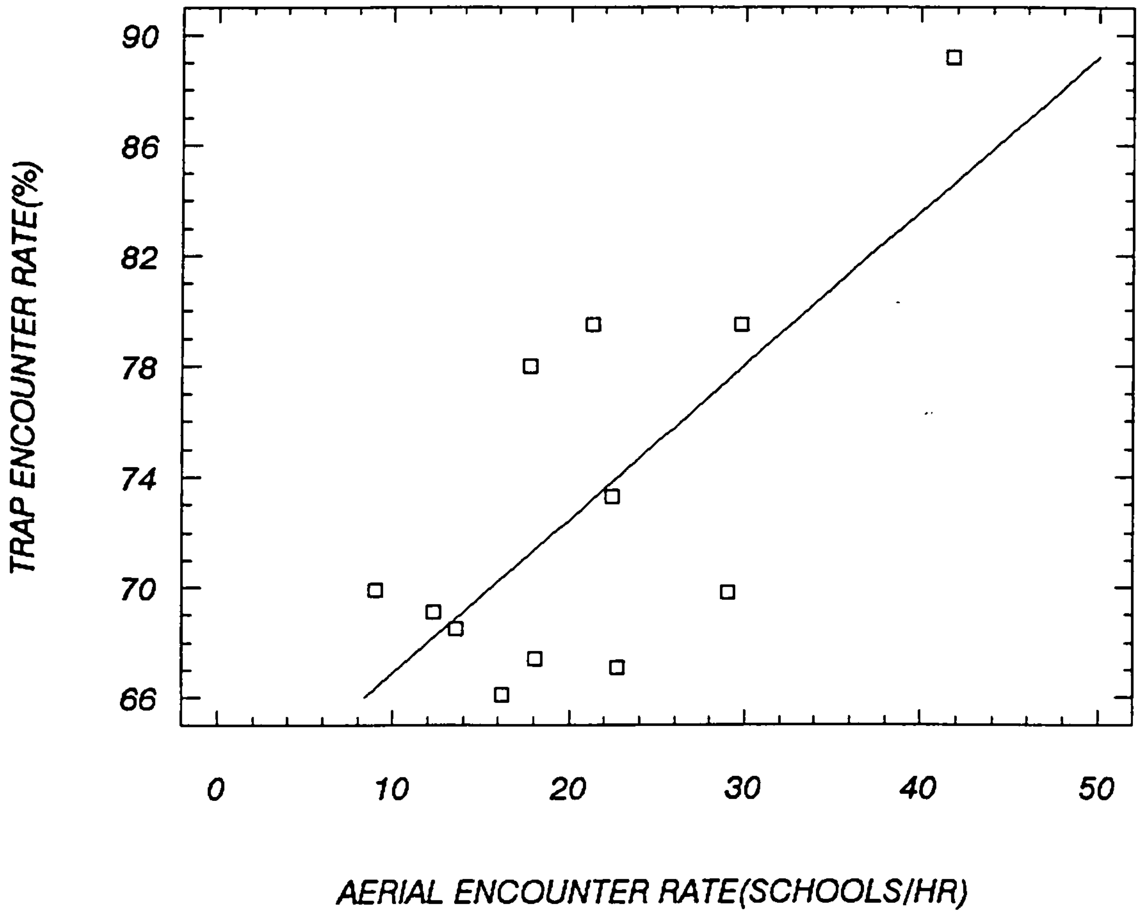

Fig. 3. Relationship between trap encounter rates (% of trap hauls containing capelin) and the aerial survey encounter rates (number of schools detected per unit survey time).

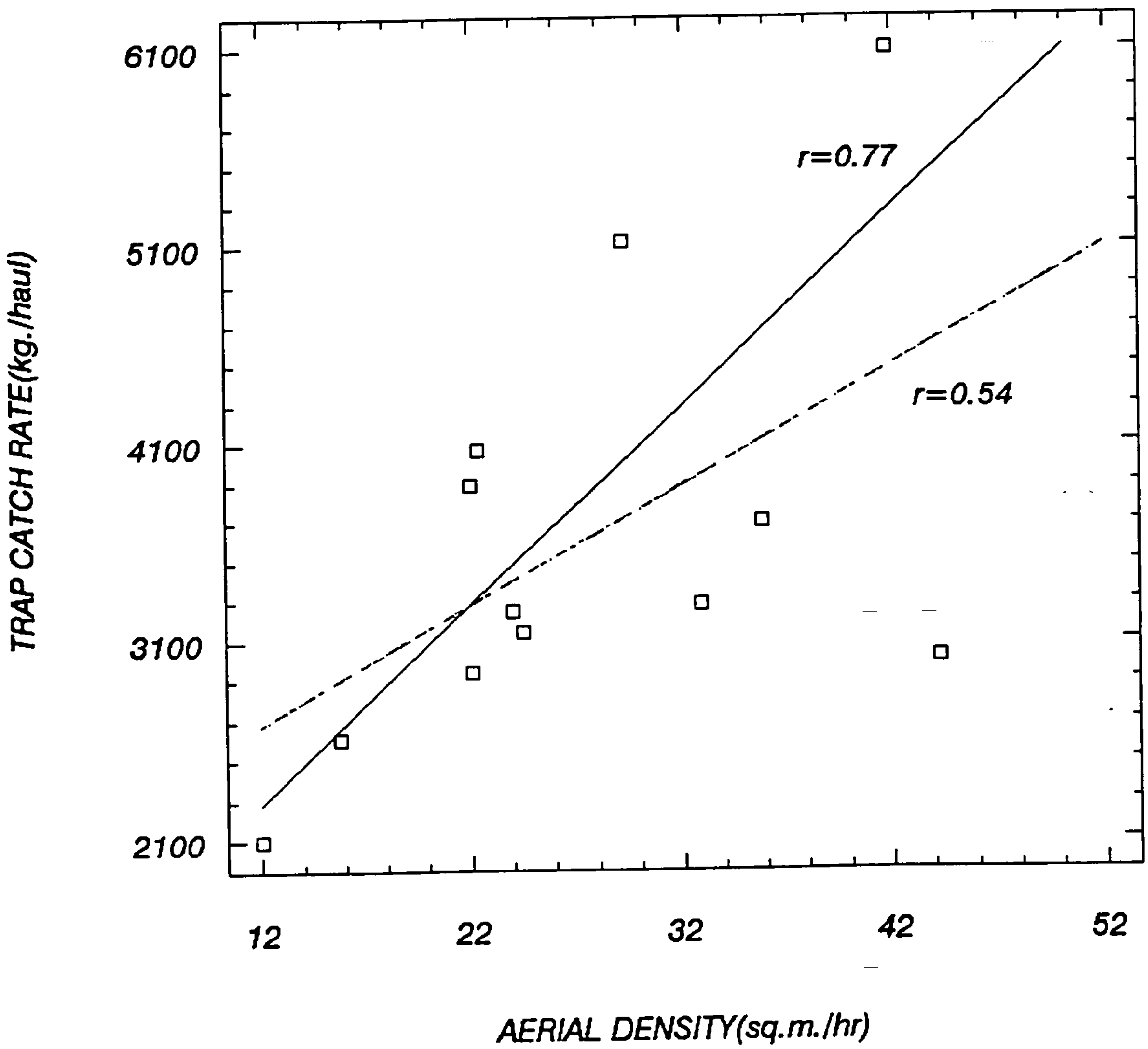

Fig. 4. Relationship between the mean catch rate (kg/haul) of capelin traps in NAFO Div. 3KL and capelin abundance (m^2 of capelin detected per unit survey time) as measured by the aerial survey.

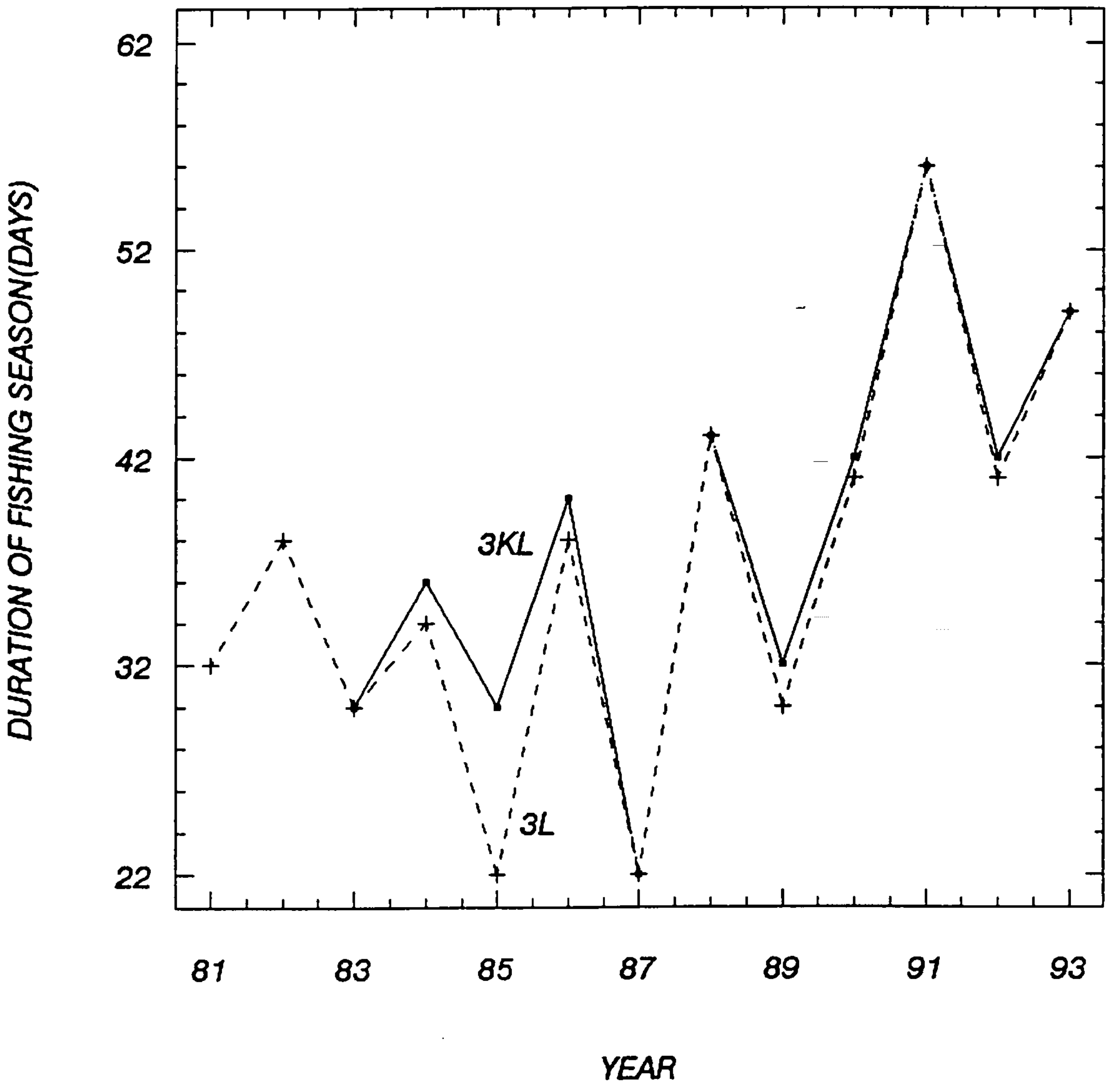

Fig. 5. Duration of the capelin fishing seasons in NAFO Div. 3K compared with NAFO Div. 3KL for the period 1981-83.

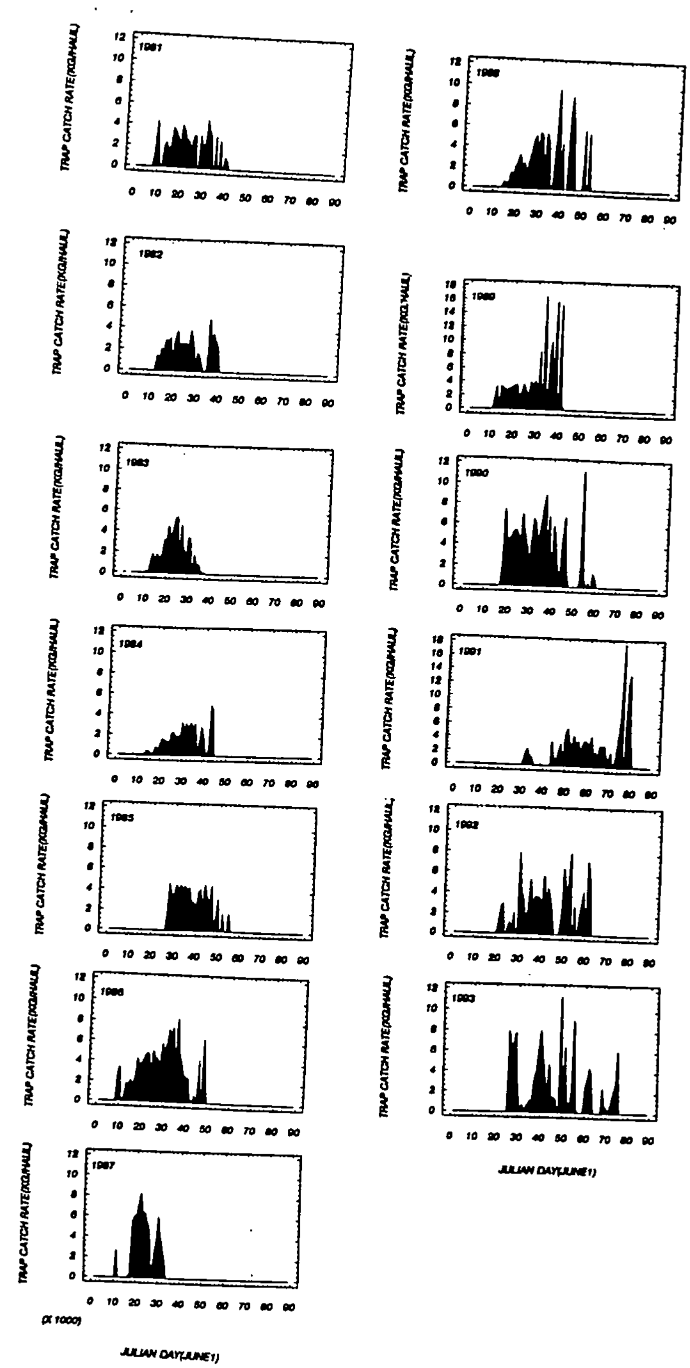

Fig. 6. Daily trap catch-rates (kg/haul) of capelin traps in NAFO Div. 3KL for the period 1981-93.

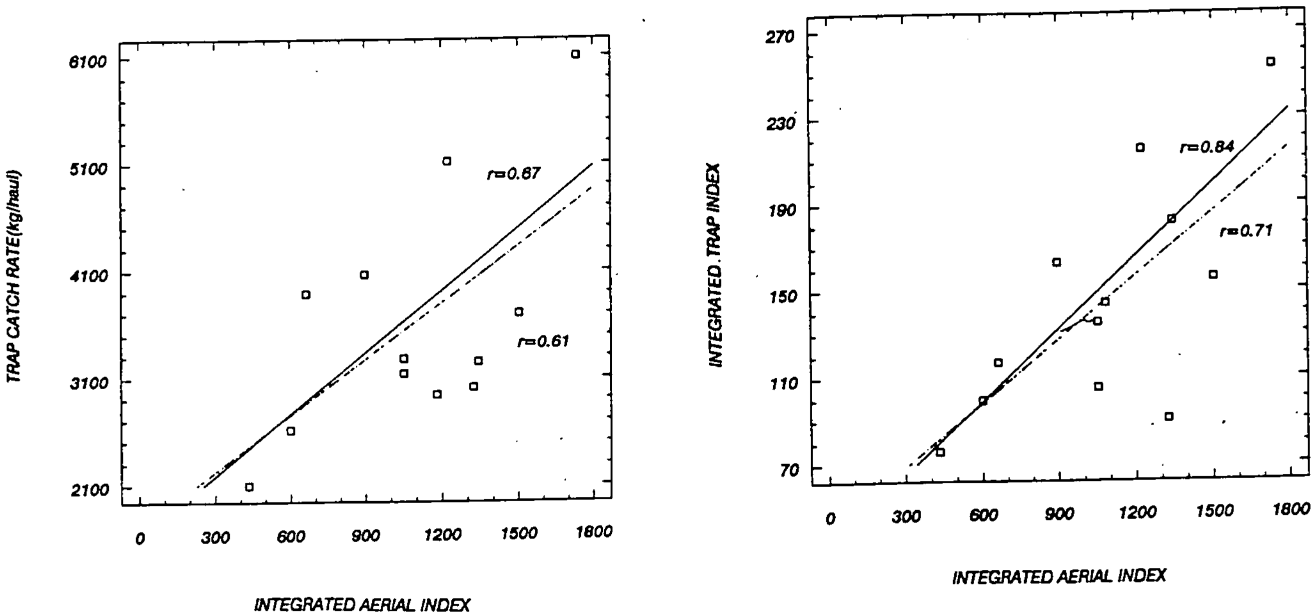

Fig. 7. Relationship between the integrated aerial index of annual capelin abundance and the mean trap catch rate (left panel) for the years 1982-93; the right panel provides a similar comparison for the integrated trap index. The solid line represents the relationships with the 1983 data point omitted.

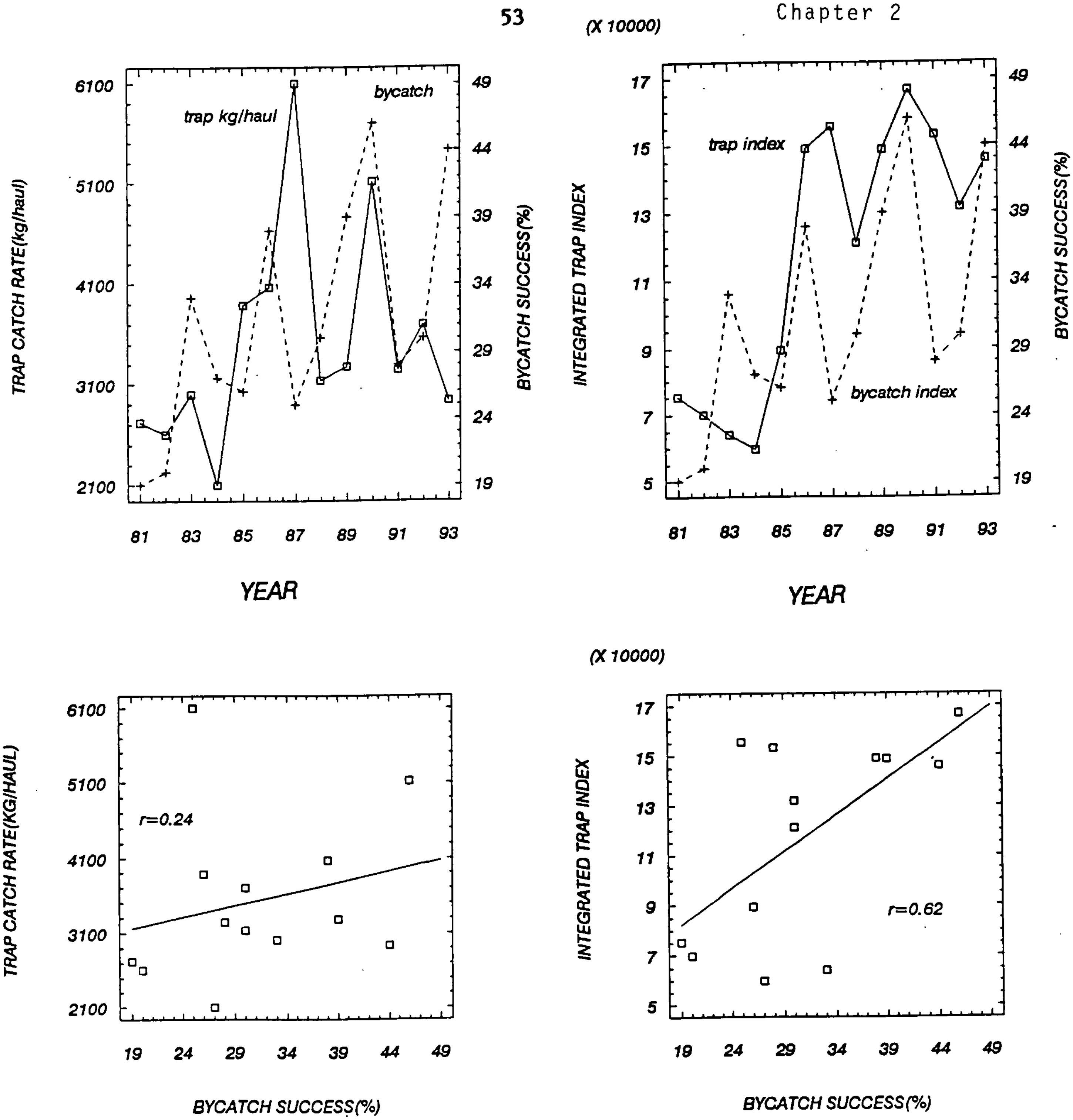

Fig. 8. By-catch rates of capelin (% of sets containing capelin) in the Div. 2J3KL groundfish survey in relation to the mean trap catch rate index (left panels) and the integrated trap index (right panel) for the years 1981-93.

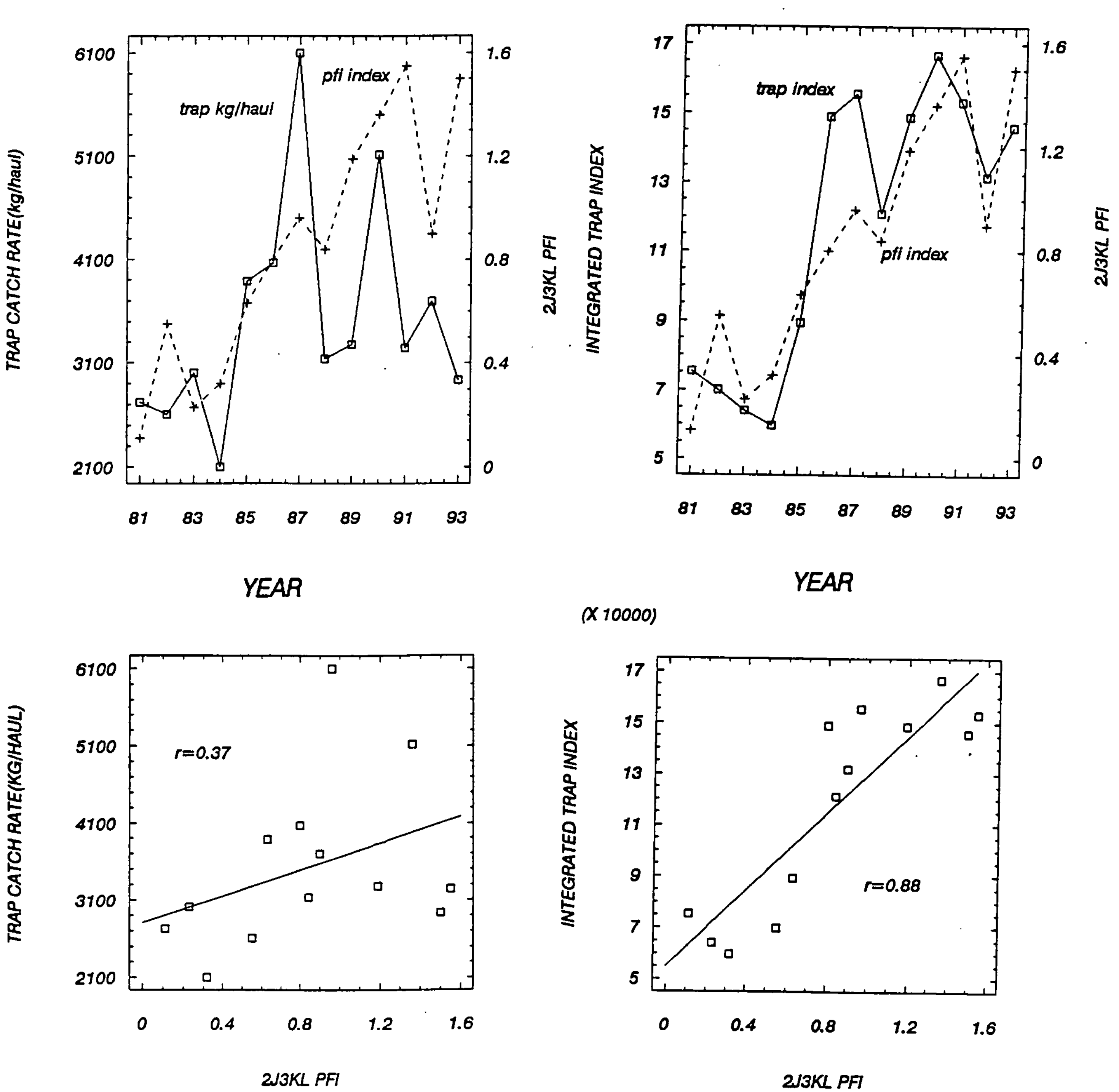

Fig. 9. Occurrence rates of capelin in cod stomachs (PFI) in the Div. 2J3KL groundfish survey in relation to the mean trap catch rate (left panel) and the integrated trap index (right panel) for the years 1981-93.

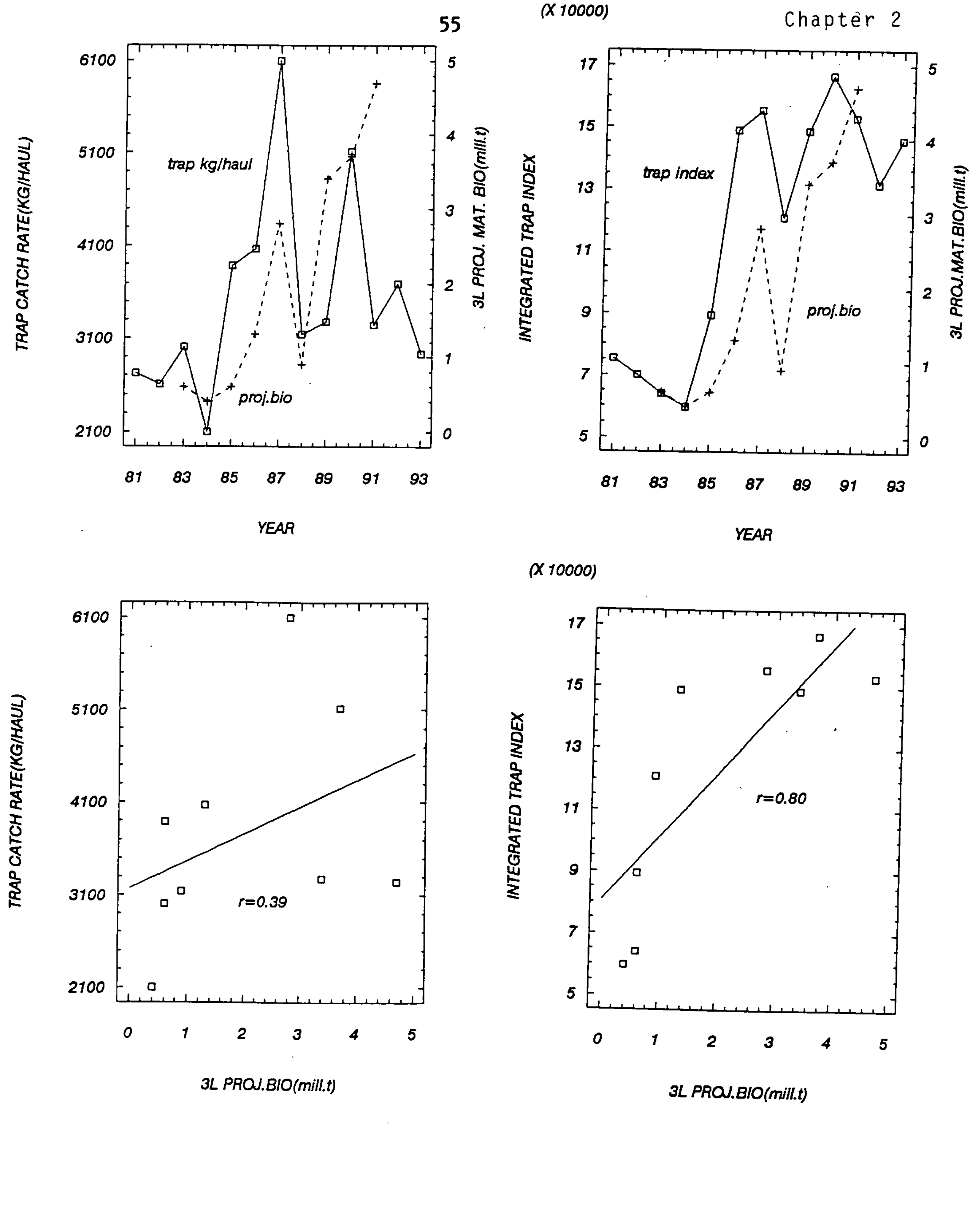

Fig. 10. Projections of mature capelin biomass from the Div. 3L acoustic survey in relation to the mean trap catch-rate index (left panels) and the integrated index (right panels) for the years 1981-93.

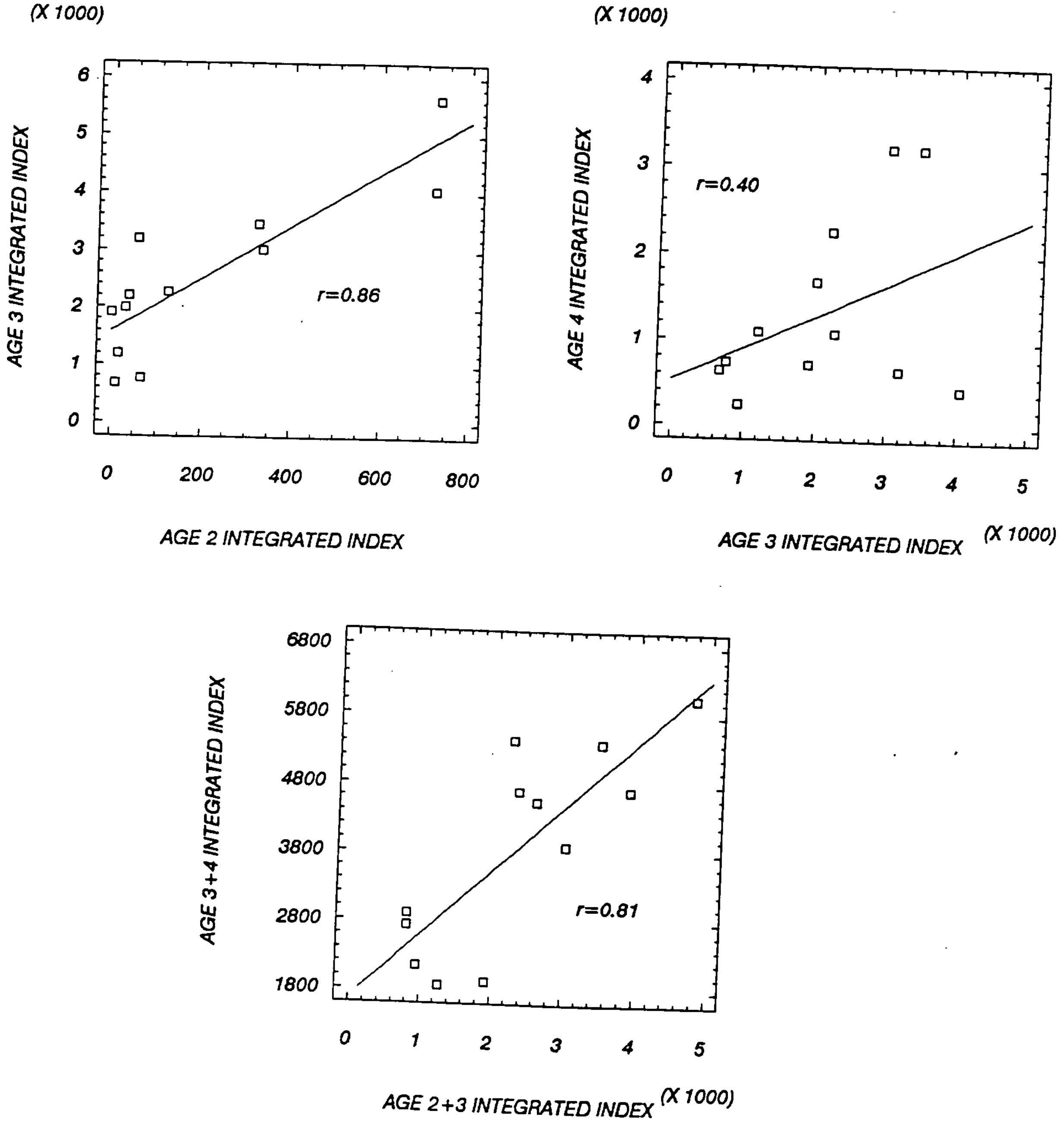

Fig. 11. Relationship between the catch rates at age in year t and catch rates at age in year t+1 for ages 2, 3, and 2+3 using the integrated trap catch rate index.

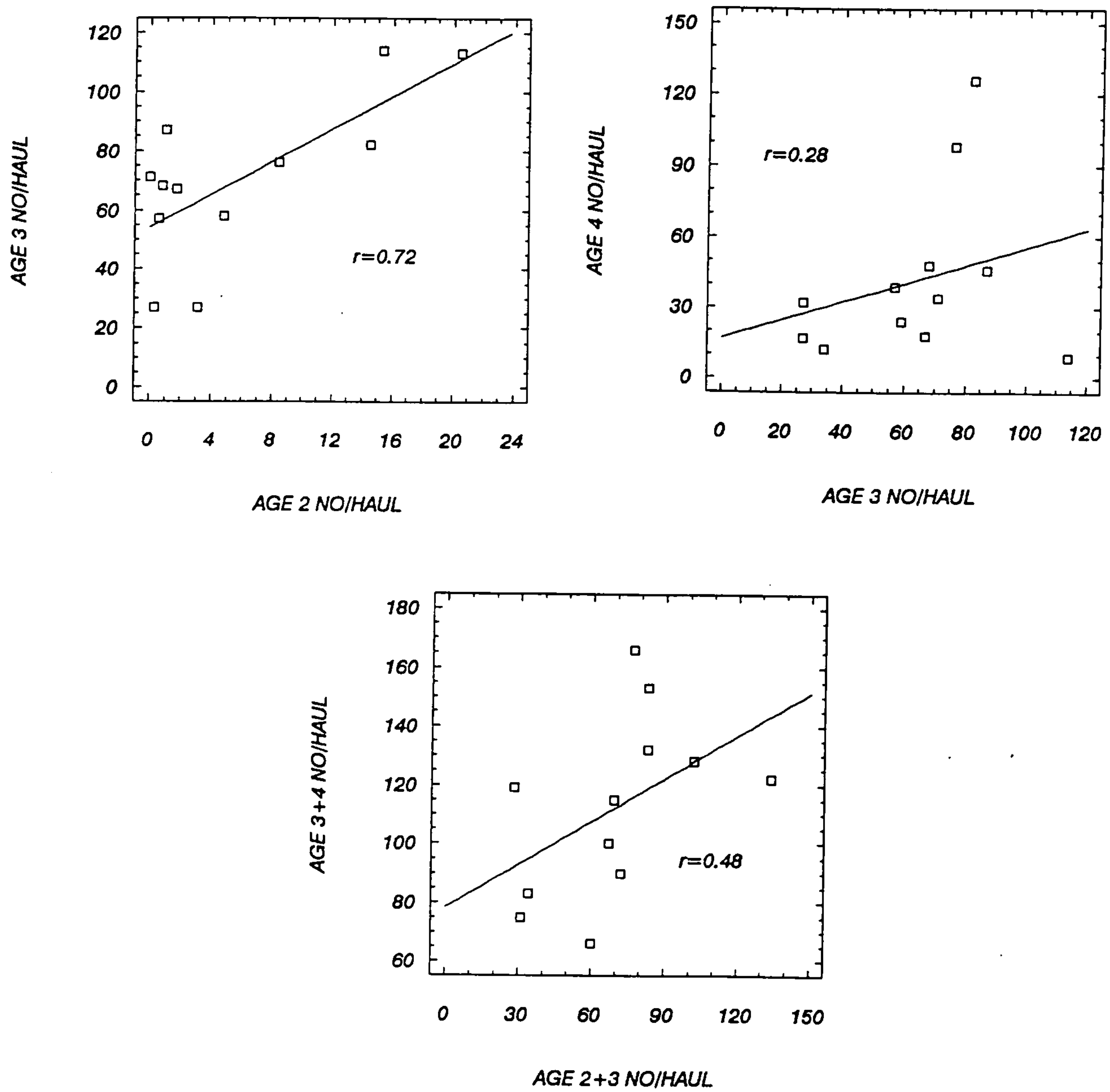

Fig. 12. Relationship between the catch rates at age in year t and catch rates at age in year t+1 for ages 2, 3, and 2+3 using the mean trap catch rate index.

Chapter 3

Some Results from the NCSP Project on Synchronous Events and Recruitment in Capelin

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, and egg deposition estimates from six beaches located in Div. 3KL.

MATERIALS AND METHODS

Adult Samples

Random samples of 25 males and 25 females were collected at each beach every time significant spawning had taken place. Fish were measured for length and weight and otoliths removed for age determination. In 1990 only females were collected from Bellevue Beach.

Egg Samples

During low tide conditions egg samples in beach sediments were collected every time substantial spawning had taken place and once every 48 hours 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 (1992). 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 hr. To estimate egg abundance, egg counts by subsampling (Pitt 1965) or by volume displacement techniques were used.

At each sampling at least 50 eggs were placed in Stockard's solution (Bonnet 1939) to fix and clear the eggs. Stages I-III which include eggs from fertilization to the end of gastrulation accounts for early egg development up to the first 3.5 days according to Fridgeirsson (1976).

Egg Deposition Index

The ratio of Stage I-III eggs to all eggs in the Stockard's sample was used to estimate the number of Stage I-III eggs occurring in each beach core sample assuming that these eggs had been deposited recently on the beach. The average density of Stage I-III stage eggs in all cores on a given beach was multiplied by the number of days coring took place to determine an index of total egg deposition. Each of the single beach estimates were averaged by year to provide an annual mean egg deposition index for Div. 3KL.

RESULTS AND DISCUSSION

Age Composition and Lengths

Age compositions from samples of spawning fish from 1990 to 1993 indicate that age 3 fish dominated in 1990 and 1992 and age 4 in 1991 and 1992 (Table 1). Differences in age composition between these samples and the commercial samples in 1993 may be due to the commercial fishery ending in mid July to early August in most areas before the spawning run of larger fish had arrived inshore. Capelin at Bellevue Beach, Eastport, and Hampden declined in mean length during the spawning season but at Eastport a late spawning run in early August and at Bellevue runs in early and late August were made up of larger mature fish (Fig. 2). At Hampden a decline was observed in mean length and the run in late August did not show as great an increase as observed at Bellevue Beach. Samples collected over the entire spawning season may be more representative of the spawning population than the commercial samples which covered only the period of the fishery in 1993.

Egg Deposition Index

The egg deposition index based on three complete (1991-93) and one incomplete (1990) survey indicated that egg deposition was much higher than in 1992 but not as high as 1991 (Table 2). However, there are no estimates from the 1980's when spawning times were earlier and insufficient years to assess trends in the estimates. The short series suggests that egg deposition and hence spawner abundance was higher at five of six beaches in 1993 compared to 1992.

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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
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
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

Table 2. Mean egg densities ('000 eggs/core), number of core sampling days and the total egg deposition index ('000 eggs per standard core times number of core days) for each of the 6 beach-spawning sites in NAFO Div. 3KL. Estimates refer to egg stages I-III only; sampling area is constant for each year.

	Site						Mean		
Year	Chapel Cove (3L)	Bellevue Beach (3L)	Eastport (3L)	Cape Freels (3K)	Twillingate (3K)	Hampden (3K)	(3L)	(3K)	(3KL)
Mean core density ('000 eggs/core)									
1993	3.3	9.7	17.0	34.4	9.9	6.8	10.0	17.0	13.5
1992	7.0	12.9	16.1	7.9	3.3	5.0	12.0	5.4	8.7
1991	4.1	14.4	9.4	31.7	14.6	10.4	9.3	18.9	13.6
1990	-	8.8	-	-	-	-	8.8	-	8.8
Number of core days									
1993	15	32	18	11	14	31	21.7	18.7	20.2
1992	15	20	15	10	12	19	16.7	13.7	15.2
1991	18	34	29	15	13	15	27.0	14.3	20.7
1990	-	25	-	-	-	-	25.0	-	25.0
Egg deposition index									
1993	48.8	310.5	305.2	377.9	139.1	211.6	221.5	242.9	232.2
1992	104.8	257.6	242.1	79.4	39.3	95.1	201.5	71.3	136.4
1991	74.1	489.1	271.7	476.2	189.6	156.1	278.3	273.9	276.1
1990	-	220.9	-	-	-	-	220.3	-	220.1
Spawning dates (Julian Day)									
1993	190-218	182-242	197-220	198-229	190-233	188-249	182-242	188-249	182-249
1992	205-230	185-232	187-204	205-230	190-210	192-224	185-232	185-230	185-232
1991	192-219	185-234	178-214	209-230	210-226	188-232	178-234	188-232	178-234
1990	-	175-207	-	-	-	-	175-207	-	175-207

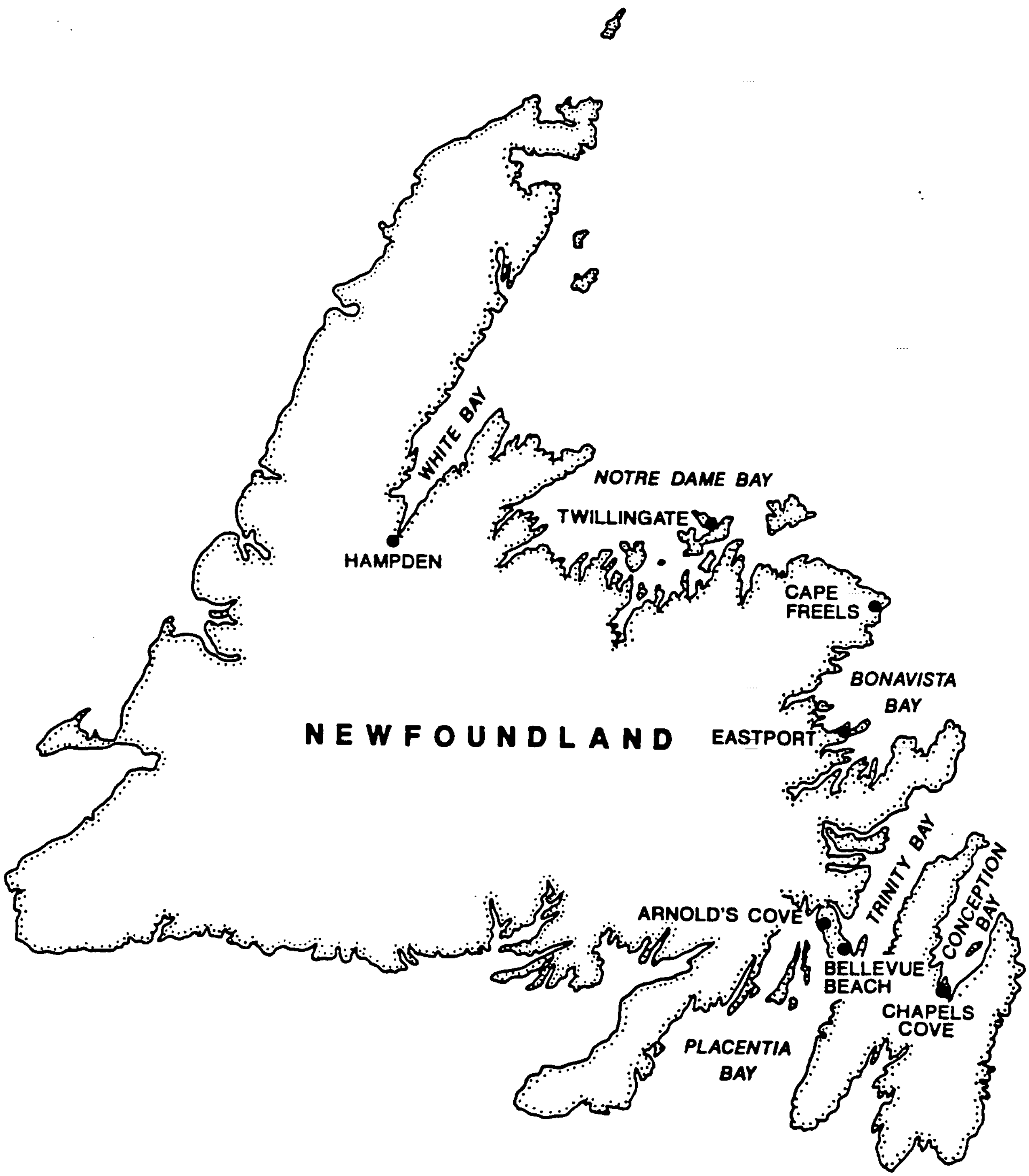

Fig. 1. Sampling sites.

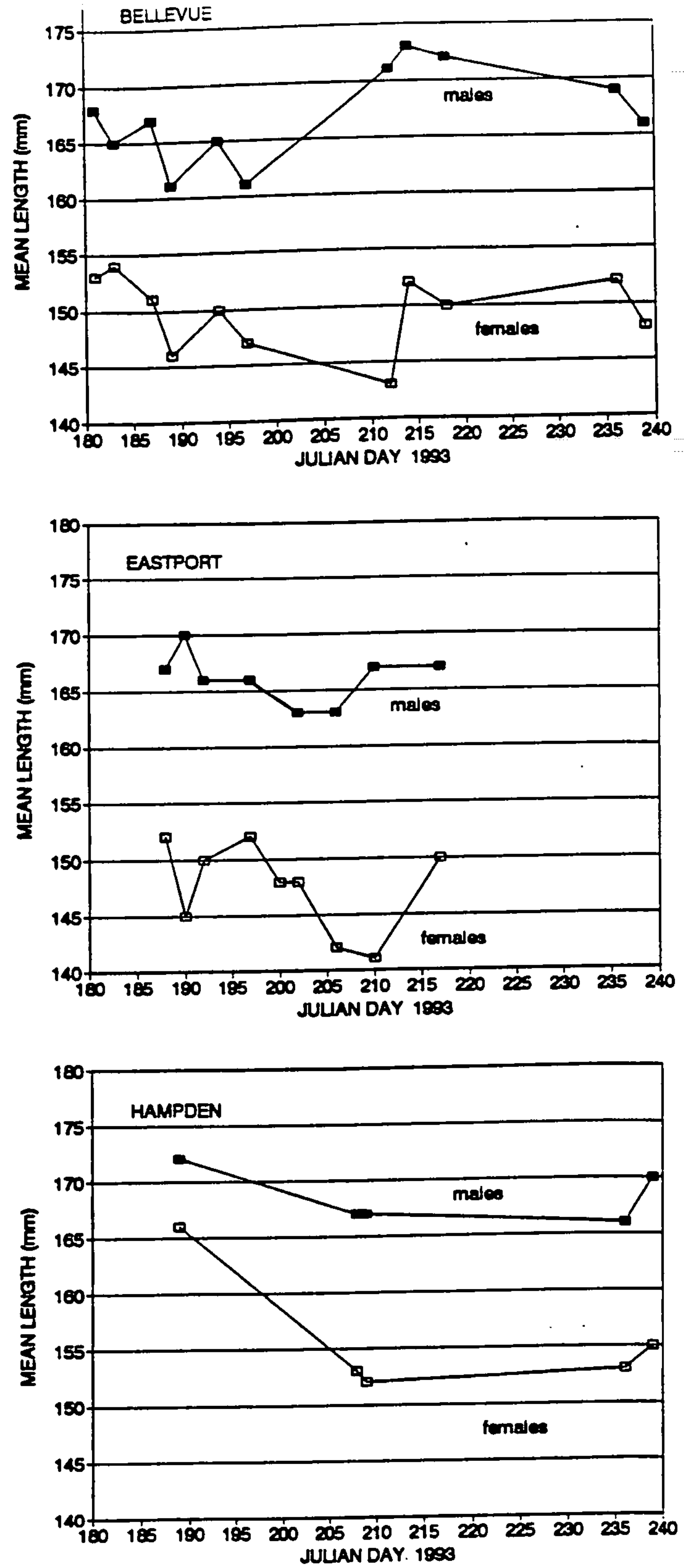

Fig. 2. Sample mean lengths during 1993 at Bellevue Beach, Trinity Bay; Eastport, Bonavista Bay; and Hampden, White Bay.

Chapter 4

Capelin (*Mallotus villosus*) Egg Deposition on Fifteen Spawning Beaches in Conception Bay, Newfoundland in 1993

by

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INTRODUCTION

Capelin (*Mallotus villosus*) spawn intertidally on gravel beaches during June and July in coastal areas of the northwest Atlantic Ocean. Eggs remain adhesive for as long as 2 hours after exposure to water (Fridgeirsson 1976), and attach to the surrounding beach substrates. The fertilized eggs incubate and develop in the beach sediments at depths of up to 20 cm (Taggart and Leggett 1987).

Capelin beaches are known to exhibit annual differences in the abundance of spawn. Fishermen have often reported that the abundance of capelin eggs observed along spawning beaches in Newfoundland is highly variable. Egg abundances estimated for the mid-tide area of 15 beaches in Conception Bay from 1987 to 1992 exhibited three orders of magnitude difference (Nakashima and Slaney 1993).

We report on the results of sampling 15 spawning beaches along the perimeter of Conception Bay, Newfoundland in 1993 and compare the results to findings from previous years.

MATERIALS AND METHODS

Sampling Sites

We selected 15 known capelin spawning beaches around Conception Bay (Fig. 1). Fourteen beaches were accessible by land and one (Caplin Cove) by sea. Beach sampling commenced immediately following the occurrence of significant numbers of spawning capelin schools along the coastline of Conception Bay. Peak spawning in Conception Bay was determined from aerial surveys of spawning schools and from periodic checks of several beaches for evidence of egg deposition. There appeared to be at least two major spawnings in 1993, one in mid-July and the second 7-10 days later.

Samples were collected in the mid-tide (MT) zone during low tide conditions to maximize the sampling of several beaches in a short period of time. The MT zone is defined as the area of the intertidal zone which lies between the low and high tide water marks. The low-tide zone is covered by seawater except at low tide conditions which would restrict sampling to one daylight period of less than two hours. The high-tide zone is exposed during most of the tidal cycle and eggs are subjected to faster development and higher mortality than the low- and mid-tide zones (Frank and Leggett 1981). Capelin tend to spawn more on the falling tide than the rising tide and mass spawning usually occurs at intermediate tidal levels (Templeman 1948). Consequently eggs are more likely to be deposited in the mid-tide areas. Given the number of personnel and location of sites it was not feasible to sample all three tidal zones of each beach within the short time following peak spawning and hatching of eggs. Consequently we chose to sample only the MT zone assuming that the results would represent a minimum estimate of the number of eggs deposited there after peak spawning.

The area of the MT zone on each beach was calculated using length and width measurements estimated when samples were collected. The number of samples collected at each beach depended on a qualitative inspection of the egg distribution in the MT zone that consisted of visually examining the concentration of eggs along the entire length of the MT zone. Two qualitative and relative indices were employed: HC (high concentration) and LC (low concentration). When egg distribution was judged to be relatively heterogeneous the MT zone was stratified into HC and LC areas (each measured) and up to two sediment core samples were collected within each stratum. Beaches judged to have a relatively uniform egg distribution were sampled at two different locations randomly chosen in the MT zone.

A steel sediment corer (6.5 cm internal diameter) was used to collect each sediment core sample. At each sampling location the corer was manually "drilled" into the beach sediments to the greatest depth possible (limited by the strength of the operator or subsurface grains larger than 6.5 cm) and the depth was measured with a calibrated plunger inside the corer. Each core sample was fixed with a 4% formalin and seawater solution buffered with sodium borate to protect the eggs from deterioration. Egg concentration and development rate were assumed to be vertically homogeneous within the beach sediments (Frank and Leggett 1981).

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Eggs and Pre-emergent Larvae

Adhesive capelin eggs were separated from beach sediments by rinsing each sample with fresh water over a 250 μm-mesh screen followed by submersion in a 2% (by weight) KOH solution for a period of 24 to 36 hr. Separated eggs were subsequently washed from the sediments, decanted, and collected on a 250 μm-mesh screen.

Egg abundance was estimated by subsampling the separated eggs with a ten-chamber whirling vessel (Pitt 1965). The entire sample was sequentially fractioned until the number of eggs per chamber was reduced to ~2500. Eggs from two randomly selected chambers were counted and averaged (Nakashima 1987). Egg abundance for each beach was estimated using the sediment-core egg concentration weighted by beach stratum area.

We examined variation in developmental stage among samples to ensure that our concentration estimates were not unduly biased by variations in egg development among beaches that might lead to a significant 'loss' of eggs through differential hatching. A minimum of 50 eggs from each core sample were placed in Stockard's solution (Bonnet 1939) and the eggs were classified as dead (opaque or showing arrested development), in early development (stages I-IV) as described by Fridgeirsson (1976) and generally associated with the first 6 days of development, or in the eyed (eyed embryo) stage.

Pre-emergent (hatched and residing in the beach sediments) larvae were enumerated from each core sample collected. For large numbers of larvae (>500) the sample was subdivided and estimates were made using the Huntsman Marine Laboratory beaker technique (Van Guelpen et al. 1982). When numbers of larvae were low, all larvae were counted. The average larval concentration per beach was estimated using the sediment-core larval concentration weighted by stratum area.

To compare the egg and larval concentrations between years the estimates were standardized to a MT area common for each beach. Prior to 1991 the MT area where eggs were observed was equal to or less than the standard area. In 1991-93 the MT area was larger for most beaches compared to previous years because the width of the mid-tide zone was wider. This may have been due to the differences in tidal conditions occurring in late June-early July compared to the late July-early August period and to differences in the slope of the beach between years. Field observations indicated that the slope or steepness of the beaches were more gradual in 1991-93 than in the 1987 to 1990 period.

Chapter 4

RESULTS

Sampling Time

Sampling times were variable between 1987 and 1993 (Table 2). The earliest sampling period occurred in 1987. In 1988 the beaches were surveyed about five days later than in 1987. Collections in 1989 were two days later and 1990 was seven days later than in 1987. From 1987 to 1990 timing of the survey varied within seven days, however, the 1991 survey was 30 days later than in 1987. The 1992-93 sampling period was 22 days later than in 1987 but eight days earlier than in 1991. However, samples collected in 1993 were taken over a longer time period (Table 1) due to the protracted spawning season.

Sampling times assume that all beaches are sampled after peak spawning and before significant hatching and larval release have occurred. Examination of the 1993 egg development stages showed that the proportion of dead eggs (at the time of sampling) varied among beaches (Table 1: 3-28%) but the annual mean of 19.0% was slightly lower than averages estimated in previous years (Table 2). Unlike previous years where the proportion of early stage eggs declined with time, the proportion of eggs in the early and eyed developmental stages between July 14-25, 1993 tend to show a decline followed by an increase in the proportion of early stage eggs (Table 1).

If the proportion of eggs in early development is indicative of eggs recently fertilized then the 1993 survey was sampled closest to peak spawning for most beaches except Spout Cove, Bristols Hope, and Burkes Cove (Table 2). Estimates of concentrations of pre-emergent larval capelin indicated that some beaches such as Holyrood, Western Bay, Spout Cove, and Kingston experienced substantial hatching and possible release of larvae, whereas other beaches had no or low numbers of pre-emergent larvae comparable to previous years (Table 3). The presence of pre-emergent larvae in the core samples may indicate that spawning of small numbers of fish occurred prior to peak spawning or more than one major spawning had taken place. Daily observations at six beaches along the northeast coast favoured the latter interpretation (unpublished data, Winters and Nakashima). The mean concentration of pre-emergent larvae of the fifteen beaches in 1993 was higher than annual means estimated in 1987-92.

Chapter 4

Egg Deposition and Beach Observations

There was a high degree of variation in egg deposition among the 15 beaches we sampled (Table 3). The total egg abundance in the MT zone varied from low spawning of 0.01 x 10^{10} eggs on Burkes Cove to 23.32 x 10^{10} eggs on Kingston. The pattern of annual mean egg concentrations mirrors the total egg abundance series, however, the geometric mean egg concentration suggests a different pattern with the 1993 estimate as the lowest in the series (Table 3).

Field teams in 1993 noted that capelin spawning was rarely observed near the sampling sites. Similarly, at seven beach sites monitored daily around Newfoundland, spawning occurred only at night (unpublished data Winters and Nakashima).

DISCUSSION

Total abundance of eggs, the mean concentration of eggs, and the geometric mean concentration of eggs varied between 1987 and 1993. The total abundance and mean concentration were highest in 1988 followed by 1990, 1992, 1991, 1987, 1993, and 1989. The geometric mean egg concentration was also highest in 1988 and was twice the estimates for 1987, 1991, and 1990; three times the 1989 and 1992 estimate; and four times the 1993 estimate.. Annual egg deposition appeared to be unrelated to spawning biomass levels. For example 1988 had the highest concentration of eggs in the MT zone when the projected spawning biomass was lower than any other year from 1987 to 1991 (Nakashima 1993). If egg deposition in MT zones of beaches can be considered an index of spawning biomass then in Conception Bay in 1993, egg deposition was similar to 1987 and 1991 levels. Total egg abundance of 71.1 x 10^{10} in 1993 was lower than the average abundance of 92.20 x 10^{10} for the period 1987-92.

This analysis assumes that eggs retained 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. Spawning may occur several times and over several days on a beach (unpublished data, Winters and Nakashima), consequently our estimates do not represent the total egg deposition of any year's spawning biomass. Also we do not take into account eggs in the high-tide or low-tide areas due to the logistics of sampling. Finally spawning can occur subtidally as observed in 1991-93.

ACKNOWLEDGMENTS

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Table 1. Collection dates, number of samples, and developmental stages of capelin eggs for 15 beaches in Conception Bay, Newfoundland in 1993.

Beach	Collection date	No. of samples	Developmental stages (%)		
			Early	Eyed	Dead
Bryants Cove	Jul 14	4	78.3	11.1	10.7
St. Phillips	Jul 15	3	86.7	0.6	12.7
Topsail	Jul 17	7	83.9	0	16.1
Chapel Cove	Jul 20	3	60.9	7.7	31.4
Kingston	Jul 21	7	43.3	29.0	27.7
Western Bay	Jul 22	5	50.9	22.2	26.9
Spout Cove	Jul 22	5	30.8	44.0	25.2
Burkes Cove	Jul 23	2	0	94.7	5.3
Bears Cove	Jul 23	3	84.5	0	15.5
Bristols Hope	Jul 23	3	1.9	81.3	16.8
Ochre Pit Cove	Jul 24	3	62.4	22.5	15.1
Jobs Cove	Jul 24	3	58.2	13.8	28.0
Caplin Cove	Jul 24	4	52.5	19.4	28.2
Holyrood	Jul 25	3	76.8	0.7	22.5
Coleys Point Cove	Jul 25	5	87.0	9.8	3.2
Grand Mean		3	57.2	23.8	19.0

Table 2. Summary of collection dates and grand mean of developmental stages of capelin eggs for capelin beaches in Conception Bay, Newfoundland, 1987-93. In 1992, Burkes Cove was not included because spawning had not taken place.

Year	Collection date	Developmental stages (%)		
		Early	Eyed	Dead
1987	Jun 23-30	39.3	36.0	24.7
1988	Jun 28-Jul 4	66.7	11.2	22.1
1989	Jun 26-Jul 2	32.6	43.5	24.3
1990	Jul 1-8	49.9	26.7	23.5
1991	Jul 23-Aug 2	49.5	24.3	26.0
1992	Jul 15-21	64.5	16.2	19.9
1993	Jul 14-25	57.2	23.8	19.0

Table 3. Total abundance of capelin eggs (no. eggs x 10^{10}), egg concentration (no. eggs/cm^2), pre-emergent larval concentration (no. larvae/cm^2), and mid-tide area (m^2) for 15 beaches in Conception Bay, 1987-93.

Year	Caplin Cove	Jobs Cove	Ochre Pit Cove	Western Bay	Kingston	Spout Cove	Bristols Hope	Bears Cove	Bryants Cove	Coleys Point	Burkes Cove	Chapel Cove	Holyrood	Topsail	St. Phillips		
Egg Abundance																Total	
1987	8.50	3.02	2.49	8.57	22.10	4.29	2.52	3.28	6.40	3.18	0.30	2.07	0.52	0.91	0.26	68.41	
1988	6.73	3.16	5.33	13.45	6.73	9.47	5.11	16.73	5.06	12.90	7.23	5.39	0.45	27.90	1.03	126.67	
1989	4.18	2.81	0.91	6.99	13.44	6.55	1.90	0.27	1.40	1.53	0.55	1.10	0.35	3.08	1.11	46.17	
1990	7.45	2.58	5.27	26.94	21.19	11.83	4.63	4.29	5.77	14.96	0.07	1.02	0.04	2.06	0.17	108.27	
1991	1.25	4.56	1.49	18.45	20.88	5.46	3.65	4.04	5.57	0.74	3.29	1.75	1.17	0.70	0.44	73.44	
1992	10.76	3.34	0.79	8.19	34.41	14.08	4.87	3.99	1.28	15.51	0	1.26	0.55	3.34	0.90	103.27	
1993	4.14	0.68	1.64	5.73	23.32	2.67	0.14	0.39	5.68	4.49	0.01	0.80	0.82	18.69	1.90	71.10	
Egg Concentration																Mean	G Mean
1987	4254	2898	1684	2640	2947	1661	1563	946	3708	635	168	1762	2251	68	385	1838	1204
1988	3368	3033	3604	4144	898	3666	3170	4824	2932	2577	4050	4587	1948	2088	1481	3092	2846
1989	2092	2697	615	2153	1792	2536	1179	79	811	306	308	936	1515	230	1644	1260	873
1990	3729	2476	3563	8299	2826	4580	2872	1237	3343	2989	39	868	173	154	252	2493	1250
1991	626	4376	1007	5684	2785	2114	2264	1165	3227	148	1843	1489	5065	52	652	2166	1306
1992	5384	3202	532	2523	4589	5451	3020	1151	742	3098	0	1070	2390	250	1333	2316	1096
1993	2073	655	1109	1766	3110	1032	84	111	3290	898	4	445	3545	1398	2821	1489	710
Pre-emergent Larval Concentration																Mean	
1987	0	0	0	0	0	38	0	0	0	0	0	0	0	97	8	10	
1988	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
1989	6	1	16	30	9	11	6	14	5	8	4	30	24	23	27	14	
1990	21	34	0	23	10	86	0	0	3	11	38	7	3	1	0	16	
1991	1	88	0	6	19	39	0	0	0	0	6	3	0	0	0	11	
1992	1	9	1	7	86	50	2	6	7	1	0	1	3	1	20	13	
1993	2	0	0	95	27	27	20	0	5	11	7	3	295	0	0	33	
MT	1998	1042	1479	3246	7498	2583	1612	3468	1726	5005	1785	1175	231	13363	675		

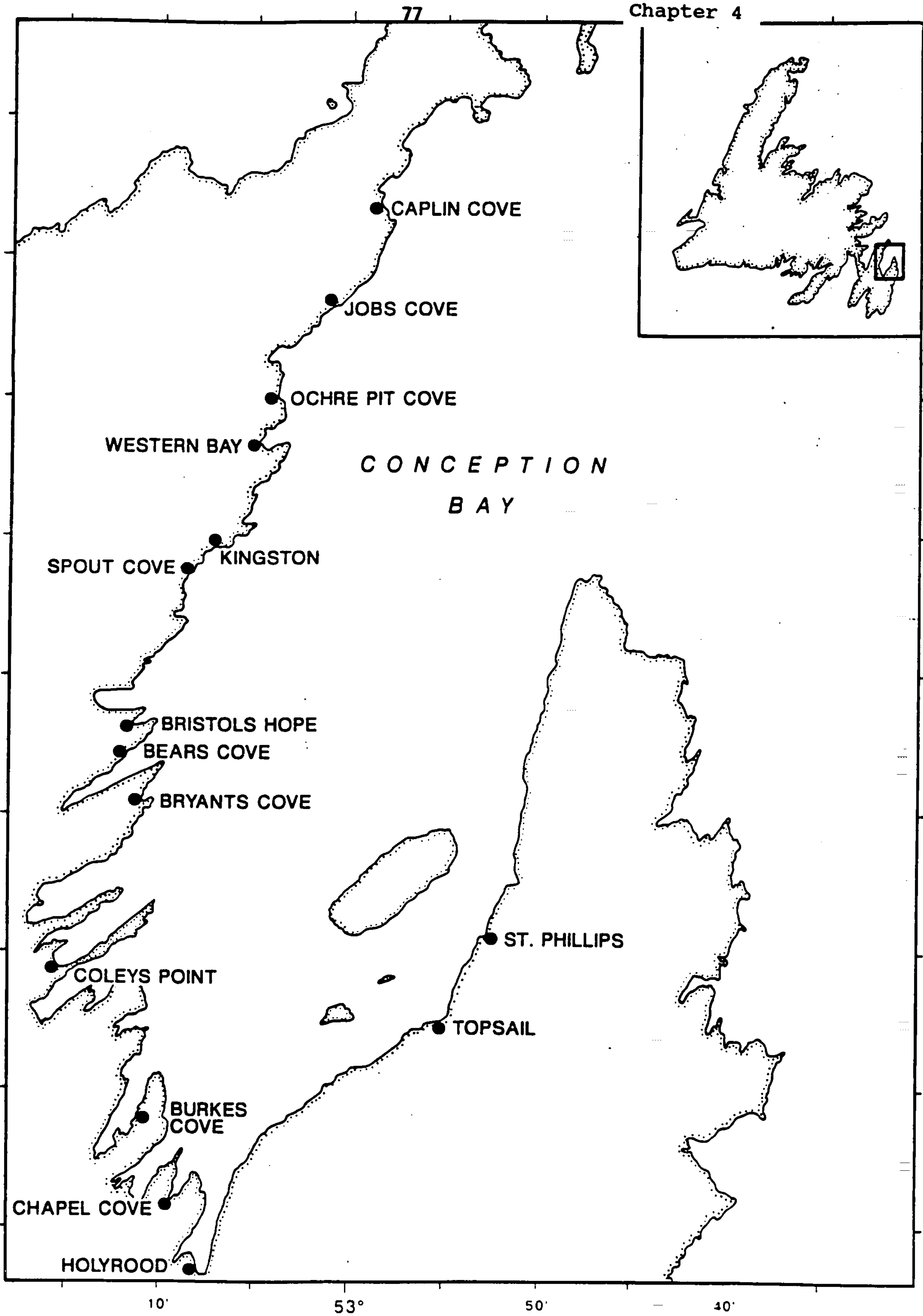

Fig. 1. Sampling sites in Conception Bay.

Chapter 5

Results of the 1993 CASI Aerial Survey of Capelin (*Mallotus villosus*) Schools

by

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INTRODUCTION

Areal estimates of capelin (Mallotus villosus) schools conducted since 1982 have been used as an index of inshore abundance of mature capelin in NAFO Div. 3L (eg. Nakashima 1993). From 1982 to 1989 school areas were measured from aerial photographs (eg. Nakashima 1990). Since 1990 school areas have been estimated from digital data collected by the Compact Airborne Spectrographic Imager (CASI) (Nakashima 1992). The digital images collected using the CASI and processed by image classification techniques were superior to aerial photographs (Nakashima et al. 1989, Borstad et al. 1990, Borstad et al. 1992).

This report presents the results of the 1993 CASI aerial survey and compares the school surface area index to other indices of relative abundance of mature capelin.

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. Spectral data are collected across 288 elements in the along track dimension of the array. 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, 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

Survey Method

Particulars of previous aerial surveys including aircraft type, camera and film used, survey time, and altitudes flown are listed in Table 1. When weather conditions were favourable CASI surveys in 1993 were flown at 1212 m to obtain a swath width comparable to aerial photographs taken at 457 m. Most of the images were obtained at altitudes close to 1212 m, however some flights occurred at lesser altitudes due to low ceilings (Table 1). The 1993 survey covered three transects as often as possible; the inside of Trinity Bay from Gooseberry Cove 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. Flight tapes and survey records were examined following each flight or shortly thereafter to assess the quality of the imagery.

Analytical Methods

CASI image 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, tested in 1989 to estimate school areas from the digital survey data (Borstad et al. 1990), was used to analyze the 1993 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).

RESULTS AND DISCUSSION

In 1993, the aerial survey provided frequent coverage of the two Conception Bay transects and less coverage of Trinity Bay. Useful data were collected in Trinity Bay three times (Table 2a), along the outside transect of Conception Bay four times (Table 2b), and the inside of Conception Bay seven times (Table 2c). CASI data collected on July 2-4 were not analyzed because the data were blurry due to a loose lens on the CASI, however, few capelin had entered the survey area at that time. Eleven days (June 30-July 1, and July 5-10, 16, 22, and 26) were lost because of poor weather conditions. In Trinity Bay the highest school area estimate was on July 14 (Table 2a). In Conception Bay the highest amounts occurred on the outside of Conception Bay on July 13 (Table 2b) and on the inside of Conception Bay on July 27 (Table 2c). The total school surface area taken from the highest estimates in Conception and Trinity Bays was 334,956 m^2.

The 1993 aerial survey covered the two spawning periods in July in Conception Bay but failed to overlap the main spawning runs in August in Trinity Bay. The two spawning runs observed in the Conception Bay spawning beaches survey (this report) coincided with peak school abundance observed on July 13 and July 27 during the CASI flights of Conception Bay. Evidence from an egg deposition monitoring programme of Bellevue Beach, Trinity Bay (Fig. 1) indicated that the two highest depositions of newly spawned eggs in 1993 occurred on August 5 (3836 eggs/cm^2) and on August 25 (5938/cm^2). Both spawnings were after July 28, the last day of the aerial survey.

The 1993 school surface area index suggests that mature biomass was lower than observed in 1992 (Table 3). However, the 1993 school surface area index did not measure peak capelin abundance in Trinity Bay resulting in an overall lower estimate. The 1992 school surface area index reported in Nakashima (1993) has been re-evaluated and lowered from 750,045 to 547,686 m^2 (Table 3).

ACKNOWLEDGMENTS

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Table 1. Summary of aerial surveys conducted from 1982 to 1993.

Year	Aircraft	Camera	Lens (mm)	Film	Radar altimeter	Survey period	Altitude (m)	Survey flight time (hrs)
1982	Piper Aztec	RC 10	152	Aerocolour Neg. 2445	No	Jun 18- Jul 5	152-160	
1983	Aero-Commander	Wild RC 10	152	Aerocolour Neg. 2445	Yes	Jun 19- Jul 9	457	25.9
1984	Cessna 310	Wild RC 10	152	Aerocolour Neg. 2445	Yes	Jun 17- Jul 7	457	38.5
1985	Aero-Commander 500 B	Wild RC 10	152	Aerocolour Neg. 2445	Yes	Jun 18- Jul 3	290-610	28.6
1986	Aero-Commander 500 B	Wild RC 10	152	Aerocolour Neg. 2445	Yes	Jun 19- Jul 5	381-579	13.4
1987	Piper Aztec	Zeiss RMK	153	Aerocolour Neg. 2445	Yes	Jun 16- Jul 3	457	37.0
1988	Piper Navajo Piper Aztec	Zeiss RMK	153	Aerocolour Neg. 2445	Yes	Jun 15- Jul 5	305-488	33.0
1989	Piper Navajo	Zeiss RMK	153	Aerocolour Neg. 2445	Yes	Jun 16-27 Jun 30-Jul 4	434-732	26.0
1990	Piper Aztec	Zeiss RMK CASI	153	Aerocolour Neg. 2445	Yes	Jun 17- Jul 6	570-1260	27.0
1991	Piper Navajo	CASI		-	Yes	Jun 21-25 Jul 3-17	1212	27.3
1992	Cessna 185	CASI		-	No	Jun 21- Jul 14	275-1280	34.6
1993	De Havilland Beaver	CASI		-	No	Jun 30-Jul 16 Jul 19-22 Jul 26-28	364-1212	46.2

Table 2a. Schooling data for the inside part of Trinity Bay from Gooseberry Cove to Hopeall, 1982-93.

Date	No. of schools	Total surface area (m²)	School size (m²) Mean	SD	Median
June 19, 1982	31	12724	411	712	149
June 26, 1982	29	35607	1228	2755	299
June 29, 1982	11	62397	5672	8378	592
July 2, 1982	8	31365	3921	9281	705
July 3, 1982	2	1920	960	17	960
June 23, 1983	11	69583	6326	6299	4241
June 24, 1983	26	39004	1500	1880	753
June 25, 1983	30	174487	5816	12759	781
June 29, 1983	35	152557	4359	11139	781
June 30, 1983	46	199373	4334	6927	558
July 1, 1983	25	189497	7580	19791	2288
June 19, 1984	13	15624	1202	1770	335
June 23, 1984	9	8314	924	888	502
June 25, 1984	96	31526	328	505	117
June 26, 1984	96	40510	422	679	223
June 29, 1984	47	12053	256	314	167
July 3, 1984	57	23827	418	814	167
July 7, 1984	77	43245	562	1124	223
June 21, 1985	13	7041	542	706	270
June 25, 1985	35	22459	642	1144	211
June 26, 1985	30	16540	551	721	214
July 1, 1985	125	60245	482	963	181
July 2, 1985	130	195659	1503	6046[a]	179
June 28, 1986	59	95898	1625	4502	340
June 17, 1987	45	167567	3724	17727	223
June 19, 1987	91	399026	4385	31197	167
June 27-28, 1987	37	59315	1603	5612	446
July 3, 1987	5	1786	357	322	279
June 16, 1988	27	18749	694	902	391
June 19, 1988	50	104179	2084	4546	502
June 22, 1988	67	112863	1685	5749	391
June 25, 1988	20	87103	4338	15287[a]	474
July 5, 1988	23	32252	1402	3199	223
June 17, 1989	60	84349	1389	5040[a]	191
July 3, 1989	0				
June 24, 1990	4	69498	17375	11184	21483
June 27, 1990	30	58174	1831	3717	701
June 29, 1990	38	141122	3714	5486	1503
June 23, 1991	0				
June 24, 1991	0				
July 5, 1991	139	170681	1228	1827	535
July 14, 1991	54	64598	1196	1894	567
July 16, 1991	33	93680	2839	5562	800
June 25, 1992	29	40836	1408	1591	1078
June 29, 1992	71	97424	1372	1510	679
July 6, 1992	70	97565	1394	4273	267
July 8, 1992	124	173219	1397	3862	370
July 13, 1992	50	67889	1358	4008	263
July 3, 1993	27	CASI data unavailable			
July 12, 1993	31	30502	1006	1747[a]	515
July 14, 1993	14	58786	4199	2847	3976
July 21, 1993	22	9760	451	611[a]	260

a calculation excludes capelin in traps

Table 2b. Schooling data for the outside of Conception Bay from Bay de Verde to Harbour Grace Islands, 1982-93.

Date	No. of schools	Total surface area (m²)	School size (m²)		
			Mean	SD	Median
June 29, 1982	10	6577	658	366	642
July 2, 1982	2	1357	679	554	679
June 23, 1983	34	51838	1374	2266[a]	530
June 24, 1983	16	10658	666	823	447
June 25, 1983	4	4408	349	184	279
July 1, 1983	5	5413	1083	1884	112
June 18, 1984	1	391	391		
June 19, 1984	0	0			
June 25, 1984	49	63779	1294	2874	391
June 26, 1984	67	65956	697	1091[a]	279
June 30, 1984	21	22320	818	1509[a]	223
July 3, 1984	4	1786	446	599	195
June 20, 1985	0	0			
June 24, 1985	0	0			
June 27, 1985	30	8840	268	378[a]	120
June 28, 1985	125	50837	368	800[a]	132
June 29, 1985	22	19253	875	1169	291
July 1, 1985	28	28036	991	1616[a]	264
July 2, 1985	66	69166	914	2064[a]	223
June 19, 1986	88	132455	1462	2853[a]	279
June 16, 1987	139	184307	1322	2924[a]	391
June 19, 1987	143	112660	766	1516[a]	279
June 27, 1987	21	12164	539	559[a]	391
June 30, 1987	37	29462	790	1481[a]	279
June 20, 1988	54	36993	679	1099[a]	223
June 22, 1988	64	18916	230	324[a]	112
June 25, 1988	116	87534	676	1331[a]	279
July 4, 1988	51	39785	578	805[a]	279
June 16, 1989	180	266878	1483	5512	335
June 18, 1989	162	197372	1132	3607[a]	335
July 1, 1989	8	6140	730	1359[a]	198
June 24, 1990	89	85437	863	1483[a]	396
June 26-27, 1990	42	88759	1937	3671[a]	670
June 30, 1990	38	26013	686	771[a]	368
June 23, 1991	0				
June 24, 1991	0				
July 14, 1991	11	6374	579	2789	520
June 30, 1992	5	27150	5430	4668	2629
July 5, 1992	32	49308	1541	3383	558
July 9, 1992	45	135723	3016	6069	883
July 13, 1992	72	225838	3137	5026	1101
July 2, 1993	6	CASI data unavailable			
July 4, 1993	13	CASI data unavailable			
July 11, 1993	30	30130	1560	4118[a]	239
July 13, 1993	61	77202	1746	6014[a]	299
July 15, 1993	54	32321	621	803[a]	239
July 21, 1993	26	23598	908	1536[a]	1041
July 27, 1993	20	8095	405	271	276
July 28, 1993	21	27540	1311	1225	783

a calculation excludes capelin in traps

Table 2c. Schooling data for the inside of Conception Bay from Harbour Grace Islands to Portugal Cove, 1982-93.

Date	No. of schools	Total surface area (m^2)	School size (m^2)		
			Mean	SD	Median
June 26, 1982 AM	33	19408	571	907[a]	135
June 26, 1982 PM	20	36513	1826	1914	2089
June 27, 1982	48	151214	3134	6015[a]	527
June 29, 1982	27	30275	1121	1707	418
July 4, 1982	3	13042	4347	4951	1409
July 5, 1982	7	5127	732	582	592
June 23, 1983	53	97595	1787	2754[a]	558
June 24, 1983	30	56860	1819	2965[a]	558
June 25, 1983	29	79961	2677	3725[a]	781
June 30, 1983	7	8091	1156	1181	558
July 1, 1983	1	2009	2009		
June 18, 1984	0	0			
June 23, 1984	8	17689	2085	2556[a]	949
June 25, 1984	70	63891	879	1789[a]	223
June 26, 1984	33	23603	703	1708[a]	223
June 30, 1984	29	16852	508	467[a]	335
July 3, 1984	18	9040	329	254[a]	223
July 5, 1984	0	0			
June 20, 1985	0	0			
June 24, 1985	2	1600	800	834	800
June 26, 1985	17	10124	596	1145	314
June 27, 1985	76	16552	214	426[a]	78
June 28, 1985	120	33858	274	938[a]	67
July 1, 1985	16	43228	2702	5140	308
July 2, 1985	17	13436	676	1872[a]	191
June 19, 1986	39	31574	786	1105[a]	357
June 20, 1986	4	3515	698	769[a]	363
June 22, 1986	86	30930	343	616[a]	131
July 2, 1986	10	5019	502	600	358
June 17, 1987	196	53066	263	350[a]	167
June 19, 1987	365	205846	556	1482[a]	167
June 21, 1987	179	74128	393	699[a]	167
June 27, 1987	138	94747	681	2389[a]	167
June 28, 1987	63	68969	1036	2402[a]	167
June 30, 1987	41	51336	1226	2892[a]	391
July 3, 1987	47	34863	742	1400	279
June 19, 1988	77	25780	335	599	223
June 20, 1988	31	7742	240	256[a]	167
June 24-25, 1988	289	201642	682	1091[a]	391
July 4, 1988	24	32141	1295	4242a	251
June 16, 1989	186	187311	991	2032[a]	319
June 18, 1989	113	88283	686	1422[a]	279
June 30, 1989	0				
July 1, 1989	22	13905	587	512[a]	396
July 4, 1989	24	10707	446	651	279

Table 2c. Continued ...

Date	No. of schools	Total surface area (m^2)	School size (m^2) Mean	SD	Median
June 26, 1990	112	128743	1092	2960[a]	360
June 29, 1990	32	88310	2591	4544[a]	742
June 30, 1990	96	102615	1069	1993[a]	489
July 3, 1990					
June 25, 1991	0				
July 8, 1991	Few schools observed - no CASI data				
July 11, 1991	56	15577	278	359	124
July 17, 1991	8	8453	1057	531	875
June 24, 1992	8	4772	597	328	468
June 27, 1992	7	11726	1675	3478	133
July 5, 1992	12	24263	2708	2880	2143
July 6, 1992	23	10775	468	620	272
July 9, 1992	30	45748	1525	1865	792
July 13, 1992	63	148629	2359	3294	981
July 14, 1992	143	350988	2454	6098	751
July 2, 1993	16	CASI data unavailable			
July 4, 1993	45	CASI data unavailable			
July 11, 1993	60	102645	1867	4904[a]	440
July 13, 1993	53	44184	910	1247[a]	455
July 15, 1993	18	9670	551	681[a]	323
July 20, 1993	73	69246	984	1357[a]	385
July 21, 1993	72	98938	1390	3678	309
July 27, 1993	69	198968	2884	5960	587
July 28, 1993	35	41844	1196	1521	546

a calculation excludes capelin in traps

Table 3. Total school surface area (m^2) index, 1982-93. The survey in 1991 was completed before inshore spawning had begun.

Year	School surface area (m^2)
1982	220,188
1983	348,806
1984	173,092
1985	308,053
1986	259,927
1987	717,532
1988	402,039
1989	538,538
1990	358,624
1991	192,632
1992	547,686
1993	334,956

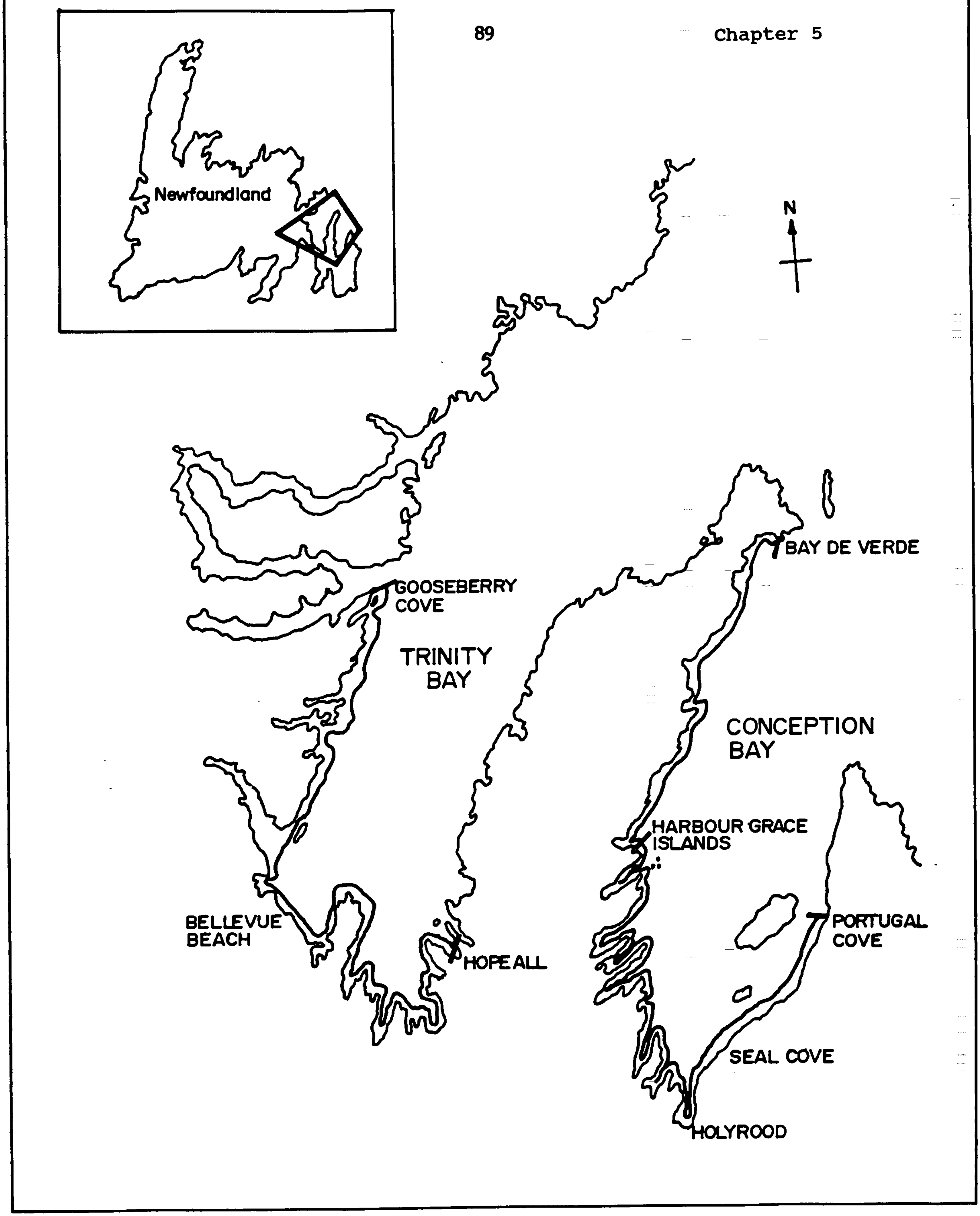

Fig. 1. Aerial survey transects in Conception Bay and Trinity Bay.

Chapter 6

Results from an acoustic survey for capelin (*Mallotus villosus*) in NAFO Divisions 2J3KL in the autumn of 1993

by

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INTRODUCTION

The NAFO Subarea 2 and Division 3K capelin stock has been surveyed acoustically in the autumn since 1981. Results of these surveys have provided the basis for setting a TAC for the capelin fishery on this stock. The offshore abundance of the stock declined dramatically from 1989 to 1990 and has continued. Over the same time period, indices of inshore abundance have not reflected the same decline (Nakashima and Carscadden, 1993). The survey area was expanded in 1993 to include southern Division 3K and Division 3L.

METHODOLOGY

The survey was conducted from the research vessel *Gadus Atlantica* during the period August 29 to October 19, 1993. The configuration of the acoustic data acquisition system was the same as that used in recent surveys of this stock. The acoustic system was calibrated at the beginning, during, and at the end of the survey. The geometric mean of the combined source level /receive sensitivity measurements from each calibration was used to integrate the data. Calibration parameters used were as follows:

Calibration date:	August 27	September 15	October 21
Combined source level/ receive sensitivity:	56.23dB	55.45dB	55.92dB
	Geometric mean=55.88dB		

Fixed receiver gain:	10.84 dB
TVG gain:	20 log R
Attenuation coefficient:	.012 dB/m
Pulse length:	600 μsecs
Bandwidth:	3.3 kHz
Average beam pattern:	-28.79 dB
Target strength:	-34 dB/kg

In recent years, it has been hypothesized that the decline in the acoustic estimates of offshore abundance of the Division 2J3K capelin stock may have been caused by a movement of capelin into southern Division 3K and Division 3L in the autumn where they were excluded from the area traditionally covered by the survey. By-catch of capelin in the autumn groundfish trawl surveys and occurence of capelin in the stomachs of cod captured during these surveys supports this hypothesis (Lilly and Davis, 1993). Consequently, the survey was expanded in 1993 to include these areas and test the hypothesis of stock distribution (Figure 1). Survey strata extend to the 500 meter depth contour to the east which is a depth limitation of the acoustic data acquisition system.

Because of expected low stock abundance and a desire to space out the sampling effort to have the greatest probability of covering any capelin concentrations, a uniform parallel transect survey design was used. This design precludes obtaining an estimate of survey sampling variance but still provides an unbiased estimate of the mean.

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

RESULTS AND CONCLUSIONS

Figure 1 shows strata outlines and transect locations and fishing set locations. Figure 2 shows contoured capelin density from estimates of acoustic density that were calculated for each 3.1 kilometre segment of survey track. The distribution of capelin can be compared to similar plots from previous years (Miller 1993, Miller and Lilly 1991). Estimates of transect mean biomass and backscatter were calculated using the same algorithm for surveys since 1989.

Table 1 provides the biomass estimate and acoustic estimation parameters for each stratum from the survey. Stratum K is equally divided by the boundary line between NAFO Divisions 3K and 3L so the biomass estimate for this stratum was split 50/50 between 3K and 3L.

Table 2 provides the acoustic parameters and the biological sampling of capelin for each transect in the survey. Catches from midwater trawl sets in strata A-E indicated that capelin were not present in this area. No acoustic data was collected for transects G1 and G2 because of a problem with the acoustic data acquisition system.

Tables 3 and 4 provide the acoustic estimate broken down by age groups into numbers and biomass respectively. For purposes of comparison with the historical series, the 1993 estimate is shown for Division 2J-3K, Division 3L and Divisions 2J-3K-3L in total.

Table 5 provides age composition and mean length at age by survey stratum. Larger (3+) capelin occurred almost exclusively in Divisions 2J-3K while one year old 1992 yearclass capelin were predominant in Division 3L.

The decline of the 2J-3K stock which began in 1990 has continued and has reached the lowest level (17,882 tons) observed for this stock since acoustic surveys were started in 1981. The expansion of the survey area in 1993 clearly shows that capelin do occur to the south and east of the traditional survey area. However, the age and length compositions of capelin from the Division 3L portion of the expanded survey area are signifigantly different from those observed in Divisions 2J-3K.

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Table 1. Statistics for each stratum and total survey

Strata	Transects sampled	Number of possible transects	Transect area (km²)	Transect area scattering coefficient (sr⁻¹)	Strata total backscatter (m²/sr)	Biomass per transect (tons)	Total biomass (tons)
F	5.	45.	432.5	14.	651.	36.3	1635.
G	4.	35.	555.6	38.	1335.	95.8	3354.
H	6.	60.	604.3	4.	217.	9.1	544.
I	4.	30.	642.4	49.	1477.	123.7	3710.
J	4.	30.	372.1	90.	2700.	226.1	6782.
K	4.	30.	396.2	49.	1479.	123.8	3714.
L	4.	30.	409.2	59.	1772.	148.3	4450.
M	4.	30.	463.7	61.	1828.	153.0	4591.
N	5.	60.	359.8	30.	1788.	74.8	4490.
O	5.	60.	370.1	57.	3395.	142.1	8527.
P	4.	30.	765.9	43.	1281.	107.2	3217.
Q	3.	30.	433.9	5.	138.	11.6	347.
R	3.	30.	261.0	2.	62.	5.2	157.
Total	71.	630.		29.	18121.	72.3	45518.

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

Strata	Transect Number	Transect length (km)	Transect area (km²)	Area scattering (sr⁻¹)	Total backscattering (m²/sr)	Density (g/m²)	Transect biomass (tons)	# of sets	Lsms	Ages
F	1	233.5	432.5	.00	0.	.00	0.	1	0	0
	2	233.5	432.5	.00	0.	.00	0.	1	0	0
	3	233.5	432.5	.00	0.	.00	0.	1	0	0
	4	233.5	432.5	.01	3.	.02	9.	1	143	27
	5	233.5	432.5	.16	69.	.40	173.	1	200	57
G	1*	-	-	-	-	-	-	1	200	41
	2*	-	-	-	-	-	-	1	88	37
	3	300.0	555.6	.07	38.	.17	94.	1	0	0
	4	300.0	555.6	.21	115.	.52	289.	0	0	0
H	1	326.3	604.3	.01	5.	.02	12.	1	0	0
	2	326.3	604.3	.01	5.	.02	12.	1	0	0
	3	326.3	604.3	.00	2.	.01	6.	1	0	0
	4	326.3	604.3	.00	2.	.01	6.	0	0	0
	5	326.3	604.3	.01	5.	.02	12.	1	0	0
	6	326.3	604.3	.00	2.	.01	6.	1	0	0
I	1	346.9	642.4	.00	0.	.00	0.	2	0	0
	2	346.9	642.4	.00	0.	.00	0.	1	0	0
	3	346.9	642.4	.15	95.	.37	238.	2	400	82
	4	346.9	642.4	.16	102.	.40	257.	1	200	47
J	1	200.9	372.1	.46	172.	1.16	432.	2	400	84
	2	200.9	372.1	.22	81.	.55	205.	2	400	87
	3	200.9	372.1	.14	52.	.35	130.	1	200	43
	4	200.9	372.1	.15	55.	.37	138.	2	379	83
K	1	213.9	396.2	.10	41.	.26	103.	1	200	47
	2	213.9	396.2	.15	58.	.37	147.	0	0	0
	3	213.9	396.2	.08	33.	.21	83.	1	200	46
	4	213.9	396.2	.16	65.	.41	162.	2	400	93
L	1	221.0	409.2	.18	73.	.45	184.	0	0	0
	2	221.0	409.2	.18	75.	.46	188.	0	0	0
	3	221.0	409.2	.11	46.	.28	115.	1	200	45
	4	221.0	409.2	.10	42.	.26	106.	0	0	0
M	1	250.4	463.7	.16	72.	.39	181.	0	0	0
	2	250.4	463.7	.18	83.	.45	209.	1	200	32
	3	250.4	463.7	.12	55.	.30	139.	1	200	44
	4	250.4	463.7	.07	33.	.18	83.	1	0	0
N	1	194.3	359.8	.14	49.	.34	122.	0	0	0
	2	194.3	359.8	.15	54.	.38	137.	1	200	39
	3	194.3	359.8	.00	0.	.00	0.	1	0	0
	4	194.3	359.8	.04	16.	.11	40.	1	200	40
	5	194.3	359.8	.08	30.	.21	76.	1	200	37
O	1	199.8	370.1	.33	122.	.83	307.	1	200	39
	2	199.8	370.1	.31	116.	.79	292.	1	200	20
	3	199.8	370.1	.04	15.	.10	37.	0	0	0
	4	199.8	370.1	.00	0.	.00	0.	1	0	0
	5	199.8	370.1	.08	29.	.20	74.	0	0	0
P	1	413.6	765.9	.05	40.	.13	100.	3	200	34
	2	413.6	765.9	.06	46.	.15	115.	5	600	108
	3	413.6	765.9	.06	49.	.16	123.	3	354	91
	4	413.6	765.9	.05	37.	.12	92.	3	311	76
Q	1	234.3	433.9	.00	2.	.01	4.	1	0	0
	2	234.3	433.9	.00	2.	.01	4.	1	200	26
	3	234.3	433.9	.02	10.	.06	26.	1	0	0
R	1	140.9	261.0	.01	2.	.02	5.	2	0	0
	2	140.9	261.0	.01	2.	.02	5.	0	0	0
	3	140.9	261.0	.01	2.	.02	5.	0	0	0

* problem with acoustic data acquisition system on these transects prevented data collection

Table 3. Numbers (billions) at age of capelin from NAFO Division 2J3K hydroacoustic surveys.

Year	Cruise	Date/Age	1	2	3	4	5+	Total
1993	234	Aug 29-Oct 19						
		2J3KL combined	10.9	1.1	0.3	<0.1	<0.1	12.4
		2J3K only	0.2	0.7	0.3	<0.1	<0.1	1.3
		3L only	10.7	0.4	<0.1	0.0	0.0	11.1
1992	223	Oct 2-25	0.1	1.9	0.2	<0.1	0.0	2.3
1991	207	Oct 4-28	4.7	2.5	0.4	0.1	<0.1	7.7
1990	189	Oct 6-28	1.4	2.6	1.6	0.6	<0.1	6.2
1989	173	Oct 13-29	1.9	59.0	35.3	2.5	0.5	99.2
1988	158	Oct 7-24	15.8	96.0	13.6	2.0	3.9	131.3
1987	144	Oct 10-25	0.7	4.4	0.5	0.6	0.1	6.3
1986	130	Oct 18-29	0.1	6.6	12.1	1.1	0.2	20.1
1985	115	Sept 26-Oct 19	1.5	54.0	13.5	1.5	0.6	71.1
1984	100	Sept 29-Oct 22	6.2	34.7	7.1	4.1	0.4	52.5
1983	85	Oct 2-24	2.6	2.5	1.3	0.2	0.0	6.6
1981	56	Oct 1-19	67.8	59.3	7.4	2.8	0.7	138.0

Table 4. Biomass (thousands of tons) at age of capelin from NAFO Division 2J3K hydroacoustic surveys.

Year	Cruise	Date/Age	1	2	3	4	5+	Total
1993	234	Aug 29-Oct 19						
		2J3KL combined	25.8	12.4	6.6	0.7	<0.1	45.5
		2J3K only	1.6	9.5	6.1	0.7	<0.1	17.9
		3L only	24.2	2.9	0.5	0.0	0.0	27.6
1992	223	Oct 2-25	0.5	28.6	4.3	0.6	0.0	34.0
1991	207	Oct-4-28	10.7	32.6	8.8	2.1	0.4	54.6
1990	189	Oct 6-28	1.8	43.8	36.2	14.1	0.5	96.4
1989	173	Oct 13-29	15.4	850.1	791.2	68.9	18.5	1744.1
1988	158	Oct 7-24	76.2	1208.7	336.9	55.1	127.0	1803.9
1987	144	Oct 10-25	3.9	77.8	12.0	15.1	3.0	111.8
1986	130	Oct 18-29	0.7	109.9	284.1	30.2	6.0	430.9
1985	115	Sept 26-Oct19	8.4	686.6	286.3	36.7	17.8	1035.4
1984	100	Sep 29-Oct 22	25.5	497.9	181.9	109.8	11.3	826.4
1983	85	Oct 2-24	17.6	41.1	31.2	4.3	0.0	94.2
1981	56	Oct 1-19	337.8	891.2	172.4	71.9	20.8	1494.1

Table 5. Age composition and mean length at age ,total number in billions, total mean length, and number of samples by survey stratum.

Stratum	Age	1	2	3	4	5+	Total N/L	Number of samples
F	%	29.2	56.7	13.7	0.3	0.0	0.1	2
	L	103	142	153	168	-	132	
G	%	13.4	71.2	14.7	0.6	0.0	0.3	2
	L	116	136	146	163	-	135	
H	%	13.8	51.9	30.3	4.0	0.0	<0.1	5
		124	142	162	165	-	146	
I	%	11.8	40.0	42.5	5.7	0.0	0.2	3
	L	130	147	165	166	-	154	
J	%	13.6	50.4	32.2	3.7	0.1	0.4	7
	L	134	146	159	161	188	149	
K	%	21.8	64.1	12.9	1.1	0.0	0.3	4
	L	125	143	160	168	-	142	
L	%	95.8	4.3	0.0	0.0	0.0	1.3	1
	L	97	127	-	-	-	98	
M	%	96.8	3.3	0.0	0.0	0.0	1.7	2
	L	97	122	-	-	-	98	
N	%	99.1	0.9	0.0	0.0	0.0	1.9	3
	L	97	128	-	-	-	97	
O	%	97.2	2.8	0.0	0.0	0.0	4.5	2
	L	93	108	-	-	-	94	
P	%	95.6	4.2	0.3	0.0	0.0	1.2	8
	L	99	120	144	-	-	100	
Q	%	99.5	0.5	0.0	0.0	0.0	0.3	1
	L	95	123	-	-	-	95	

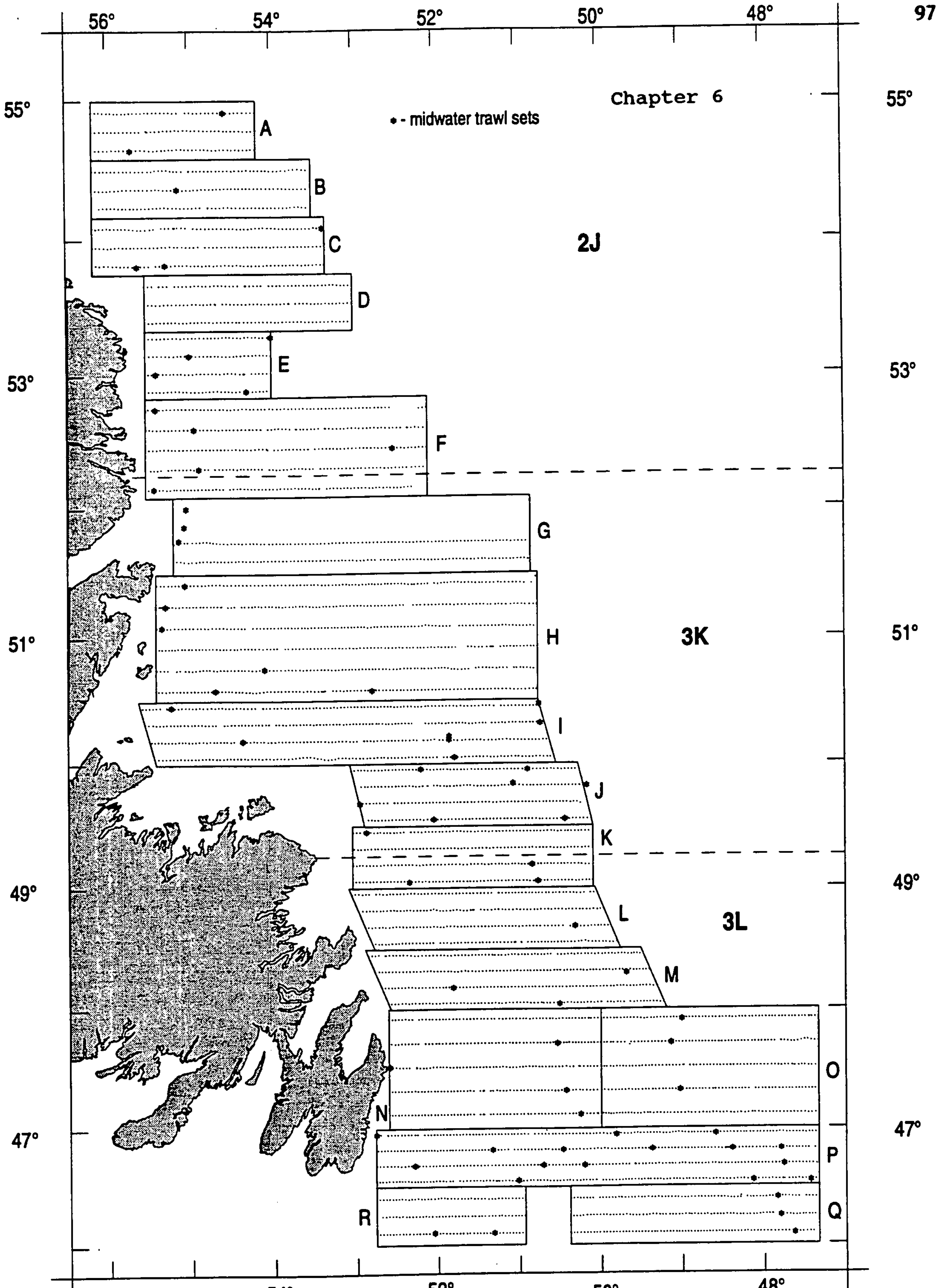

Figure 1. Cruise track, survey area, and fishing sets for the 1993 autumn capelin survey.

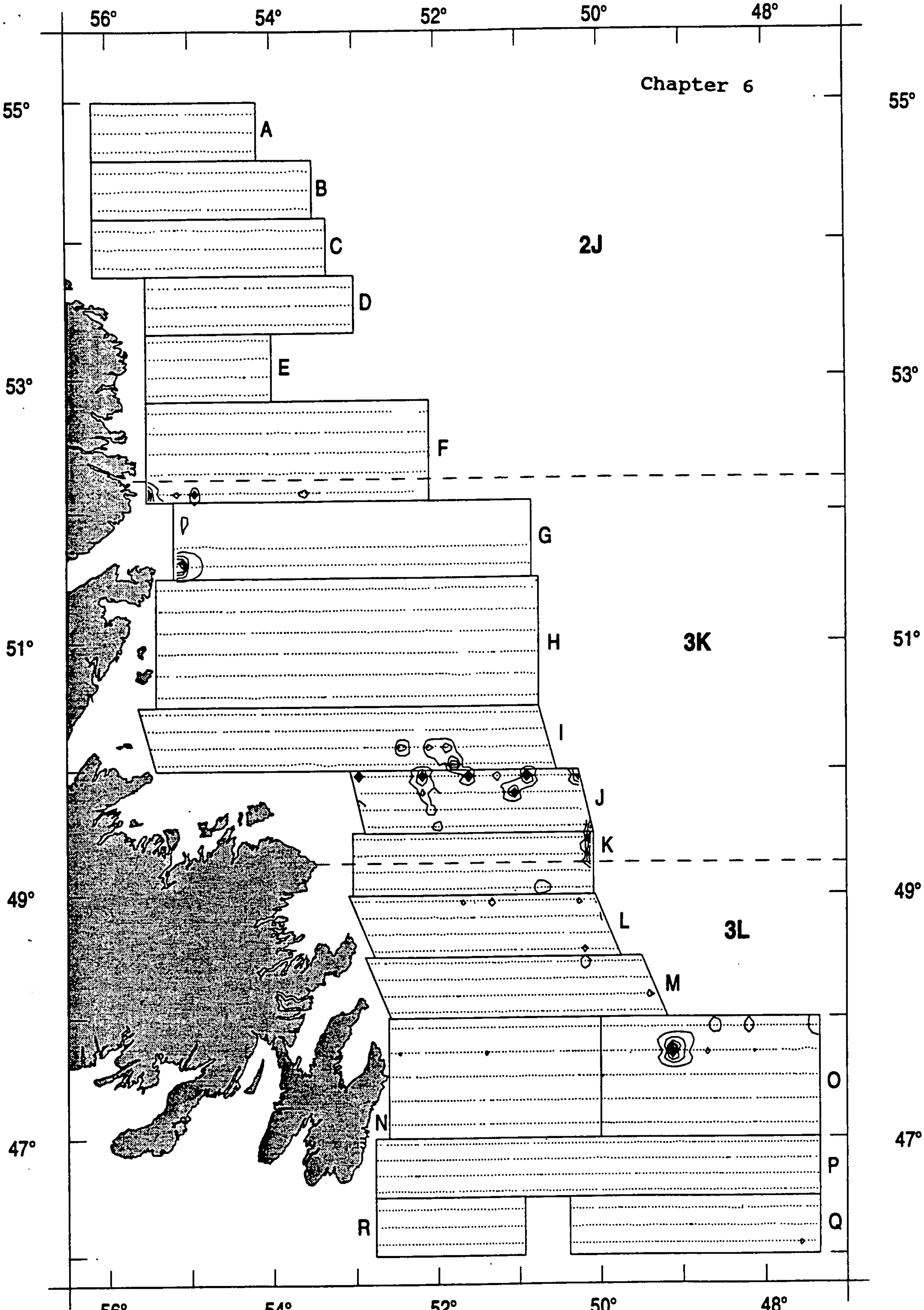

Figure 2. Contoured capelin distribution from the autumn 1993 capelin survey

Chapter 7

By-catches of capelin in bottom-trawl surveys

by

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INTRODUCTION

Capelin 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 and 3K during the autumns of 1978-91 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), and to provide supporting data on changes in capelin distribution (Lilly and Davis 1993). This paper continues this series of comparisons with data from the bottom-trawl survey in autumn 1993. In addition, the broader-scale distribution of capelin in autumn 1993 is examined with catch data from bottom-trawl surveys on Grand Bank (Div. 3LNO). These surveys provide information on capelin distribution south of the area covered by the acoustic survey, which was restricted to Divisions 2J and 3K in 1981-1992 and extended to Division 3L in 1993.

MATERIALS AND METHODS

Capelin were caught during random depth-stratified bottom-trawl surveys conducted from southern Labrador to the southern Grand Bank during a 2-month period in October-December 1993 (Table 1). Both the GADUS ATLANTICA and the WILFRED TEMPLEMAN towed an Engel-145 trawl, with 29 mm mesh liner in the codend, at 3.5 knots for 30 min at each fishing station. Catches from the few stations of duration other than 30 min were appropriately adjusted.

The survey design was again modified from earlier years. In Division 2J, the number of fishing stations assigned to each stratum was roughly proportional to the size of the stratum, as had been the case for the entire survey prior to 1989 and phase 1 of the surveys in 1989 and 1990. In Divisions 3K and 3L, the number of stations assigned to each stratum was selected so as to minimize variance as observed during earlier years. This practice, which was employed for the entire Division 2J3KL survey in 1991 and 1992 (Lilly and Davis 1993), resulted in fishing intensity being much greater in some strata than in others.

Chapter 7

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, the relationship between capelin catches and bathymetry, and the variability among stations.

RESULTS

Divisions 2J3K

The bottom-trawl survey in Divisions 2J3K was conducted from October 30 to December 6 (Table 1), with a median date of fishing of November 15. This was similar to other recent years (Carscadden et al. 1989; Carscadden et al. 1990; Miller and Lilly 1991; Lilly 1992).

Capelin were recorded at 40% of the 245 fishing stations conducted at depths less than 750 m (Table 2). This is the fourth highest frequency of occurrence in the period 1978-1993, but as noted above, the 1993 survey is not directly comparable to surveys prior to 1991. Many catches of capelin occurred in those Division 3K strata which received higher intensity of fishing. Catches were moderate compared to previous years (95th percentile = 6 kg; maximum = 9 kg) (Table 2).

Very few capelin were caught on Hamilton and Belle Isle Banks and near the coast off southern Labrador and northeast Newfoundland (Division 2J and western Division 3K) (Fig. 1). Largest catches were on the western flank of Funk Island Deep and western Funk Island Bank. In general, the distribution in 1993 was similar to that observed in 1987, 1990, 1991, and 1992 (Carscadden et al. 1989; Miller and Lilly 1991; Lilly 1992; Lilly and Davis 1993), but with a lesser tendency toward the southeast than in 1991 and 1992.

All of the large catches in Divisions 2J and 3K occurred within the area covered by the acoustic survey, although several near the Fogo Shelf (south-central Division 3K) were very close to the boundary of the survey (Fig. 1).

Division 3L

The bottom-trawl survey of Division 3L was conducted from November 12 to December 4 (Table 1), with a median date of fishing of November 27. This is approximately 1 week later than in 1992. Capelin were recorded at 50% of the 153 stations (Table 1). This is the highest frequency of occurrence in the period 1985-1993 (Table 3), but it must be noted that a high proportion of the fishing stations were located in the northern and northeastern regions of Division 3L, which is where most capelin have been found in the past at this time of year (Lilly and Davis 1993). Catches were moderate compared to earlier years (95th percentile = 3 kg; maximum = 16 kg) (Table 3).

Capelin were caught in northern and northeastern Division 3L and in the Avalon Channel in western Division 3L (Fig. 1,2). There were very few catches on the plateau of Grand Bank. The occurrence of catches at the extreme northeast of Division 3L, near the boundary of the acoustic survey, is similar to the situation in 1992, but the 1993 catches were larger. Such an extreme northeasterly distribution was not seen in 1985-1991.

Division 3NO

The bottom-trawl survey of Division 3NO was conducted from October 24 to November 12 (Table 1), with a median date of fishing of November 1. Capelin were recorded in just 8% of the 145 stations (Table 1). Small catches occurred primarily on western Whale Bank and in north-central Division 3O (Fig. 2).

DISCUSSION

Most of the capelin caught during the bottom-trawl surveys in autumn 1993 were taken in the area from just south of Belle Isle Bank (approximately 52^0 N) in Division 3K to the northeastern slope of Grand Bank in Division 3L. The greatest concentration of large catches was on the slopes of Funk Island Deep in south-central Division 3K. The distribution in Division 3K was not as easterly as in 1991 and 1992.

There is no evidence from these surveys that large quantities of capelin occurred outside the boundary of the acoustic survey in Divisions 2J, 3K and 3L, but several large catches were very close to the boundary in south-central Division 3K and northeastern Division 3L. As in 1991 and 1992, there is no clear distinction between capelin catches in southeastern Division 3K and northern Division 3L.

Comparisons between capelin distribution as observed during the acoustic survey and capelin distribution as inferred from the bottom-trawl survey must be treated with caution because the bottom-trawl survey required about 6 weeks to complete and did not start until the acoustic survey had been completed. Thus, for any point in space, the duration between coverage by the two surveys could be as great as two months.

Additional information on the distribution of capelin in autumn 1993 will become available from the examination of stomach contents of predators caught during the bottom-trawl surveys reported in this paper. Broad-scale patterns of capelin distribution are apparent from analysis of stomach contents of both cod (Lilly 1991; Lilly and Davis 1993) and Greenland halibut (Bowering and Lilly 1991).

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Table 1. By-catches of capelin and other selected data for bottom-trawl surveys in Divisions 2J3KLNO in autumn 1993.

Division	Ship/Trip[a]	Sampling dates (d/mo. - d./mo.)	No. of stations	Stations with capelin No.	Stations with capelin %
2J3K	GA 236-238	30/10 - 06/12	263	98	37
3L	WT 145-146	12/11 - 04/12	153	76	50
3NO	WT 144-145	24/10 - 12/11	145	12	8
TOTAL		24/10 - 06/12	561	186	33

[a] The GADUS ATLANTICA (GA) is a 74 m stern trawler and the WILFRED TEMPLEMAN (WT) is a 50 m stern trawler.

Table 2. Statistics for by-catches of capelin during bottom-trawl surveys in NAFO Div. 2J3K during the autumns of 1978 to 1993.

Year	GADUS ATLANTICA trip number	Number[a] of stations	Stations with capelin No.	Stations with capelin %	Percentiles of capelin catches (kg)[b] 50	75	95	Max.
1978	15	125	2	2	0.03			<<1
1979	29	124	42	34	0.09	0.3	9	185
1980	44	134	25	19	0.50	1.8	149	172
1981	58,59	214	53	25	0.30	1.0	234	345
1982	71,72	291	97	33	0.20	0.5	3	18
1983	86-88	248	58	23	0.10	0.3	2	24
1984	101-103	251	67	27	0.15	0.4	2	3
1985	116-118	297	127	43	0.12	0.4	3	10
1986	131-133	210	50	24	0.18	0.8	12	24
1987	145-147	276	94	34	0.20	1.0	18	117
1988	159-161	233	84	36	0.15	0.8	3	39
1989	174-176	273[c]	134	49	0.12	0.3	2	32
1990	190-192	232[c]	82	35	0.09	0.3	1	11
1991[d]	208-210	302	117	39	0.14	0.5	4	68
1992[d]	224-226	308	151	49	0.10	0.3	3	15
1993[d]	236-238	245	98	40	0.14	0.5	6	9

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 these stations in which capelin were recorded in the catch.

c Only stations from first-stage sampling are included.

d Not directly comparable to 1978-90, because the number of fishing stations assigned to each stratum was not roughly proportional to stratum area, as was the case in the earlier years.

Table 3. Statistics for by-catches of capelin during bottom-trawl surveys in NAFO Div. 3L during the autumns of 1985 to 1993.

Year	Ship[a] and trip number	Number of stations	Stations with capelin		Percentiles of capelin[b] catches (kg)			
			No.	%	50	75	95	Max.
1985	WT 37-39	232	80	35	0.33	0.8	6	16
1986	AN 72	142	38	27	0.11	0.4	2	6
1987	WT 65	165	38	23	0.10	0.5	2	4
1988	WT 78	189	85	48	0.20	0.8	7	21
1989	WT 87	174[c]	72	41	0.20	0.4	7	30
1990	WT 101	161[c]	31	19	0.10	0.5	11	17
1991[d]	WT 114,115	219	45	21	0.11	0.5	7	10
1992[d]	WT 129,130	215	80	37	0.12	0.4	2	6
1993[d]	WT 145,146	153	76	50	0.13	0.4	3	16

a WT = WILFRED TEMPLEMAN, AN = ALFRED NEEDLER

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 Not directly comparable to 1985-90, because the number of fishing stations assigned to each stratum was not roughly proportional to stratum area, as was the case in the earlier years.

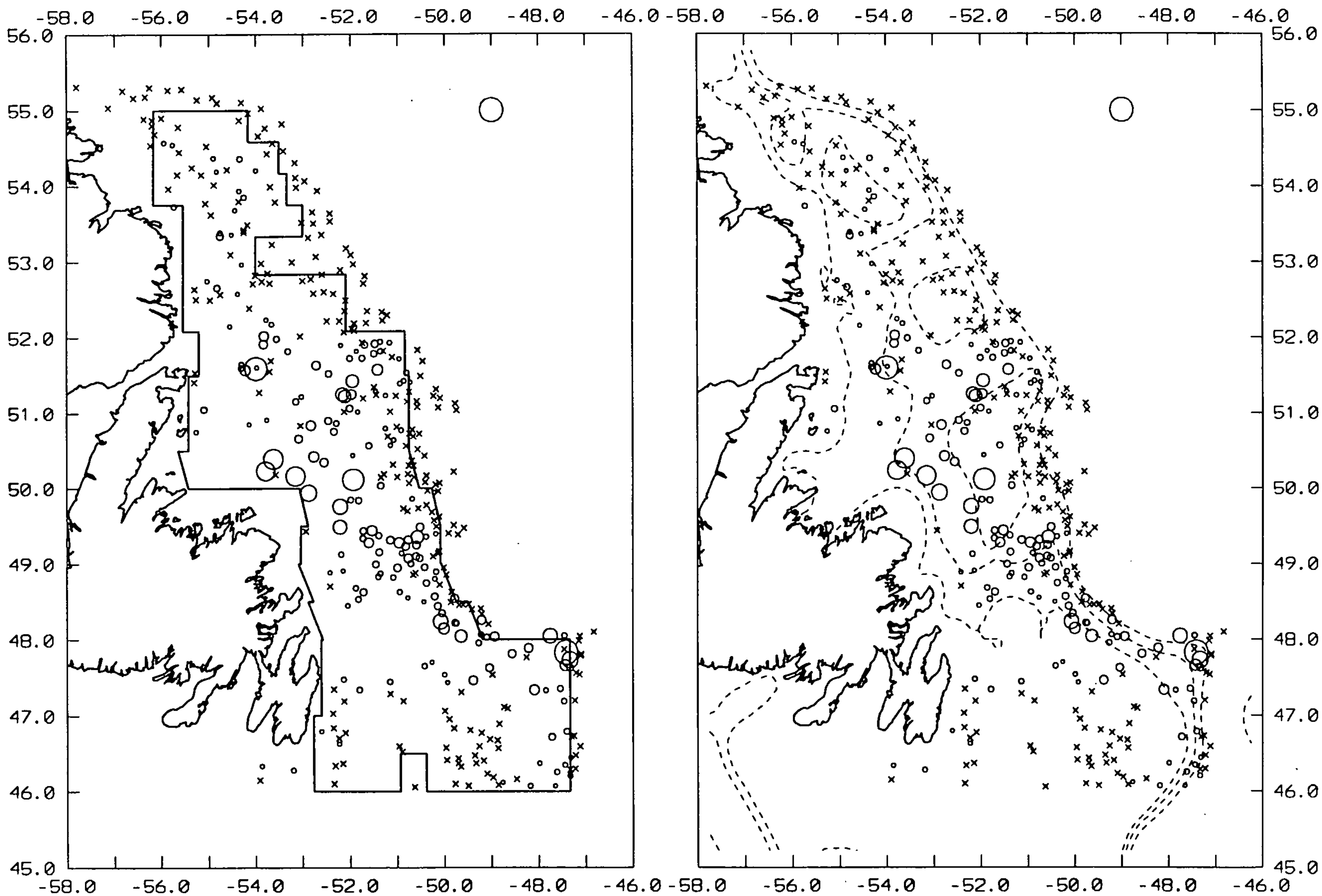

Fig. 1. Capelin catches (kg/30 min tow) during random depth-stratified bottom-trawl surveys in Div. 2J3KL in autumn 1993. Catches were set to a maximum of 10 kg before plotting. A symbol for 10 kg is shown in the upper right. Symbol area is proportional to catch. x = nil. Also shown is the boundary of the acoustic survey (left panel) and the 200, 300 and 500 m isobaths (right panel).

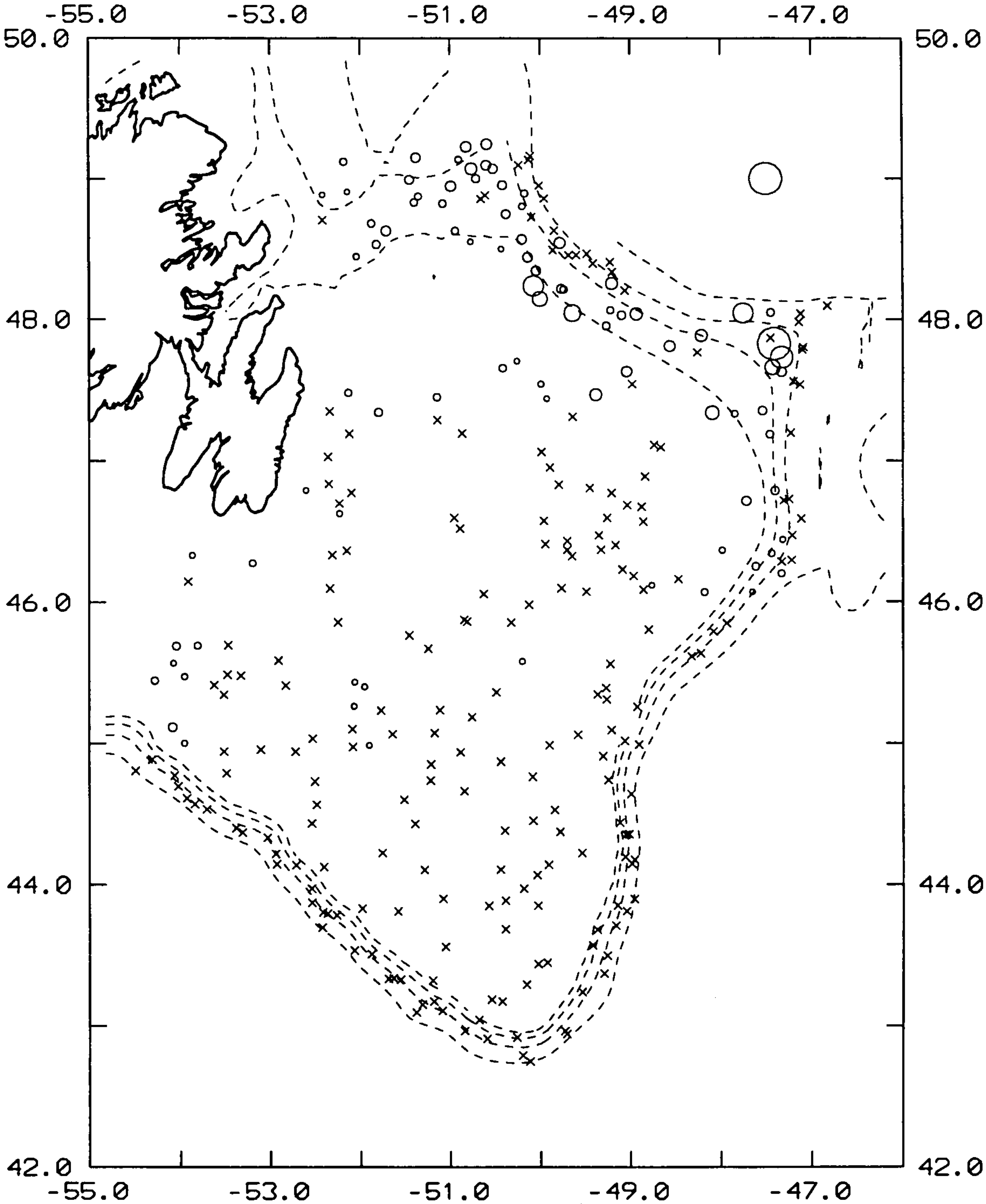

Fig. 2. Capelin catches (kg/30 min tow) during random depth-stratified bottom-trawl surveys in Div. 3LNO in autumn 1993. Catches were set to a maximum of 10 kg before plotting. A symbol for 10 kg is shown in the upper right. Symbol area is proportional to catch. x = nil.

Chapter 8

Diel vertical migration of capelin (*Mallotus villosus*) and its effect on acoustic estimates of density

by

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INTRODUCTION

Capelin (*Mallotus villosus*) is both a commercial and a key forage species in the Northwest Atlantic. Because it has a short life-span and high natural mortality, it is difficult to estimate its abundance using traditional population assessment techniques such as Virtual Population Analysis. Abundance can be assessed more directly using hydroacoustic techniques, such as echo integration, because capelin occur in open water in largely single-species schools. Hydroacoustic surveys on the northern Grand Bank from 46°N-49°N (Fig. 1) were used to derive an abundance index of capelin off the Avalon peninsula of Newfoundland from 1982 to 1992.

The use of acoustics and integration of the acoustic signal to estimate biomass requires estimates of various parameters (e.g. speed of sound in seawater, beam angle and receiving sensitivity of the transducer) most of which can be relatively easily measured. One of those parameters, target strength (TS) represents the amount of incident energy reflected by the fish which in turn is directly dependent on fish behaviour. The major determinants of a change in TS are a change in swimbladder volume (Ona, 1990) and/or a change in individual orientation (Foote, 1987).

The extent to which fish behaviour affects TS varies (reviewed in Olsen, 1990; MacLennan and Simmonds 1992) and is recognized as problematic in fisheries acoustics (e.g. Ona, 1990). TS changes can be unpredictable and inconsistent. For example, Edwards and Armstrong (1984) showed how the TS of herring (*Clupea harengus*) decreased with depth during the day while Buerkle (1983) measured an increased TS during the day due to a change in individual orientation. TS is a dynamic parameter even within one species between regions (cf. Ona, 1990; Rose, 1992).

A common pattern in species that vertically migrate on a diel basis is that TS is different at night when fish rise in the water column than during the day when fish migrate to deeper depths. Changes in TS can be attributed to a change in swimbladder volume in some species (Olsen, 1990; MacLennan and Simmonds, 1992) or a change in orientation between day and night (e.g. Traynor and Williamson, 1983) as when animals are feeding, fleeing, or dispersing (MacLennan and Simmonds, 1992). Indeed, it has been shown that TS changed as capelin changed orientation to swim downward (Olsen and Angell, 1983; Olsen *et al.*, 1983; Halldorsson and Reynisson, 1983).

There are causes other than TS which may bias acoustic estimation of biomass. The extent of aggregation can bias estimates because attenuation (loss of acoustic energy) can occur in the upper layers of dense schools (e.g. Lytle and Maxwell, 1983; Foote, 1990; Appenzeller and Leggett, 1992). There is no *a priori* reason to expect attenuation in capelin schools as they do not school at high densities relative to other species. There is no documented evidence of acoustic attenuation in capelin and several years of observations on our acoustic surveys suggest that attenuation is not a problem. For example, faded bottom echoes, which are evidence of acoustic attenuation, were not observed at the highest densities we observed in a shoal-spawning stock during spawning (C. Lang, pers. comm., DFO, P.O. Box 5667, St. John's NF A1C 5X1). Although, acoustic attenuation cannot be completely discounted as a factor biasing density estimates, our observations suggest that acoustic attenuation is less likely to affect density estimates than are depth-related variations in TS.

In our capelin acoustic surveys on the Northern Grand Bank, we used a single-beam acoustic transducer, thus *in situ* TS could not be measured. For biomass calculations, we used an average TS assuming that TS induced errors would average out given the range of behaviour expected over large temporal/spatial scales. Based on one year of data, Miller (1985) showed that capelin underwent diel migration. Capelin occurred in discrete schools at greater depths during the day and dispersed to shallower depths at night (Fig. 2). Since we have no estimates of the dynamic nature of TS during the surveys, nor of acoustic attenuation, we cannot directly quantify any bias in density estimates caused by diel behaviour, but we can test whether a bias exists. Depth-related biases in acoustic estimation are reported in the literature (reviewed in MacLennan and Simmonds, 1992). Since capelin migrate vertically and alter the extent of their aggregations, there exists the potential for a depth-related bias in acoustic biomass estimates.

In this paper, we examine whether diel vertical migration was a consistent phenomenon from 1982 to 1992 and test whether density estimates were related to depth in each year. We briefly address the probable reason for depth-related differences and its effects on the acoustic survey series.

MATERIAL AND METHODS

From 1982 to 1992, annual acoustic surveys of capelin (predominantly ages two and older) were conducted in Northwest Atlantic Fisheries Organization (NAFO) Division 3L (Fig. 1) during the months of April/May. Acoustic data were collected using a Simrad EK400 echo sounder operating at 49kHz with a pulse length of 0.4 ms in 1982, 0.3 ms in 1983 and 0.6 ms from 1984 to 1992. Band width was 3.3 kHz while the time-varied-gain used was 20LogR + 2α R (α = 0.012 dB/m). The echo sounding equipment was calibrated at the beginning and/or the end of each survey using a calibrated hydrophone (details in Carscadden *et al.*, in press). The echo signals were digitized at 15 kHz (equivalent to a sample for every 5 cm in the water column) and stored on tape for later analysis (Stevens, 1986). Echo integration, using standard acoustic techniques and assuming a constant average TS, produced volumetric density (g/m^3) estimates (see Miller, 1985). TS was empirically estimated from measurements on caged capelin (cf. Miller 1985) and calculated as -34 dB/kg (± 0.5 dB) based on capelin in the expected size range. The sum of the volumetric densities at each depth gave an estimate of areal density (g/m^2).

Analysis of Vertical Distribution

For this study, density (g/m^3) was summarized into depth intervals (5m-20m, 21m-40m, 41m-60m....) for every 1 hour of data collection at constant ship speed (1 hour of ship travel is equal to approximately 18.5 kms). The first 5 m's were excluded because that is the near field of the transducer. The weighted mean depth (Z) and standard deviation (SD) were calculated as

$$Z = \frac{\Sigma(\rho_i X_i)}{\Sigma\rho_i} \qquad (1)$$

$$SD = \sqrt{\frac{\Sigma\ \rho_i\, X_i^2\ -\ (\Sigma\ \rho_i\ )\, Z^2}{(\Sigma\ \rho_i\ )\ -\ 1}} \qquad (2)$$

where Z is mean depth weighted by volumetric density, ρ is density at interval i, X is mean depth of interval i, and SD is the standard deviation of Z.

Both the mean (Z) and the coefficient of variation (SD/Z) were examined for association with other sampling variables (water depth, date, latitude and longitude). Z was positively correlated with bottom depth so we corrected Z by dividing by bottom depth, and then multiplied by the average bottom depth from 1982 to 1992 (157m) to re-express depth in m's. The transducer level varied between about 10-25m among years but was not consistently recorded. We referred to the level of the transducer as zero in all years as (1) the statistical tests are intra-annual and (2) the extent of diel patterns were not obscured by transducer depth.

The data were further adjusted to examine diurnal trends on an annual scale by grouping the data by hour within a year and each hourly sample within a year was weighted by areal density.

$$MVD = \frac{\Sigma\ (P_i\ C\, Z_i)}{P-1} \qquad (3)$$

where MVD is annual mean vertical depth, P is areal density (g/m^2) and CZ is corrected depth as above. Standard deviations were calculated as above.

Analysis

Densities were not normally distributed and could not be rendered so by transformation. For each year (n=11), we used non-parametric rank correlation analysis to explore relationships between density estimates and depth. We also wished to test whether there were differences in density estimates at various positions in the water column, which depended on time of day (Fig. 3). We defined density estimates as shallow (0-80m) and deep (81m-172m) based on diel migration patterns in Fig. 3. We used the Kruskal-Wallis non-parametric analysis to test for depth-related densities, and to test whether significant differences in densities occurred between deep and shallow categories. Since the probability of rejecting a null hypothesis increases with the number of tests (Type I error), we used the sequential Bonferroni test for simultaneous inference to regulate the probability of incorrectly rejecting a null hypothesis on a table-wide basis (see Rice, 1989). Probability levels of simultaneous tests were evaluated sequentially, starting with the smallest to the largest. The smallest probability was declared significant if it was less than a level of significance (α) divided by k, where k is the number of tests (α/k). If significant, the second smallest probability was evaluated at significance level $\alpha/k-1$, the third probability, $\alpha/k-2$, and so on until the probability was not significant, at which stage all remaining, larger probabilities were deemed not significant.

RESULTS

Capelin underwent a diel vertical migration in all years although the extent of vertical migration varied. Capelin were observed at shallower depths at night and at deeper depths during the day (Fig. 3) . The annual average vertical depth, weighted by areal density, was deepest in 1992 and in 1983 (Fig. 4).

The Spearman rank correlation analysis showed that density estimates were significantly correlated with depth in 10 out of 11 years; negatively correlated in 8 years and positively correlated in 2 yrs, 1991 and 1992 (Table 1). In general, density estimates were greater at shallower depths in many years (Fig. 5).

Significant deep and shallow differences occurred in all years except 1990 and 1991. The mean rank of shallow density estimates were greater than those of deep density estimates in eight out of nine significant analyses (Table 2).

DISCUSSION

From 1982 to 1992, capelin were distributed at relatively shallow depths at night and at deeper depths during the day. The extent of diel vertical migration varied among years and capelin were dramatically deeper in 1992 and 1983. Acoustic estimates of density (g/m^2) were greater at shallower depths (typically nighttime) than at deeper depths (typically daytime). Shallow/deep differences in density were statistically significant in nine out of eleven years using the Bonferroni test for simultaneous inference.

Depth-related biasses would not be consistent among years due to inter-annual variability in diel migration patterns. If an average TS was calculated empirically over a wide range of conditions and was negatively related to depth, then density estimates would be underestimated during the day when fish migrate to deeper depths, and overestimated at night, when fish migrate to shallower depths. Such a depth-related bias in density estimate would be minimized if fish consistently migrate on a diel basis. In effect, inter-annual variability in diel migration patterns, and the depth at which capelin are distributed may obscure inter-annual comparisons of biomass.

It is essential to know whether annual changes in estimates of abundance are due to variations in fish behaviour or reflect real changes in year-class strength. Carscadden *et al.* (in press) showed that biomass projections of mature capelin, derived from acoustic estimates, were significantly correlated with inshore aerial survey and catch rate indices of capelin from 1982 to 1989. Thus, the magnitude of bias caused by depth-related densities did not obscure general patterns of population abundance during that time period.

In the 1982 to 1992 acoustic series, the greatest inter-annual change in biomass was a 70-fold decline between 1990 and 1991 (Miller, 1992); yet no such decline was detected in the inshore indices (Carscadden, 1992). We considered whether a depth-related bias in density estimate could account for the decline in 1991, and have determined it unlikely. The ratios of densities (median shallow density: median deep density) range from 0.292 to 10.79 in the 11 year time series. That ratio was 0.35 in 1990 and 0.43 in 1991. Further, vertical distributions were average in 1990 and 1991. Thus, a depth-related bias in density estimates and/or radical changes in depth distribution cannot account for the low densities observed in 1991. That is, densities were low at all depths in 1991.

If we assume that a dynamic TS causes density estimates to vary at different depths, then the question is whether such variation is due to modification of swimbladder volume or orientation. In our analysis, large density estimates, comparable to those at shallow depths, occurred at deeper depths most noticeably in 1990 (Fig. 5). Further, in 1992 capelin vertical distribution was deeper, capelin did not surface at night as in former years yet deep density estimates were significantly greater than shallow density estimates. Thus we hypothesize that the observed depth-related differences in density are caused largely by a change in orientation and less by a modification of swimbladder volume.

Although we have not measured TS values, it is possible to determine the likely maximum change in TS using literature values and the ratios of median densities at shallow and deep depths. Olsen and Angell (1983) showed that a 10 degree change in tilt angle as capelin swam downwards resulted in a TS reduction of 1-2 dB. We estimated from Fig. 3 of Halldorsson and Reynisson (1983) a 2-5 dB reduction in TS as capelin swam to deeper depths. Decibels (dB) are expressed on a logarithmic scale, and a change of 3 dB results in a doubling of the density estimate (Rose 1992). The average ratio of median densities in our study was 3.53. Thus if the ratios in median densities resulted from a change in TS only, the average TS change was between 4 and 5 dB.

We have shown that density estimates are related to depth which translated into significant differences between shallow and deep categories in nine out of eleven years. Both day-night changes in depth and inter-annual variability in average vertical depth can lead to a change in TS. The resultant bias in density estimates illustrates the need for regular measurement of *in situ* TS (cf. Miller 1985). Although the current use of TS= -34dB/kg is considered appropriate for the range of observed capelin sizes, Miller (1985) recognized that the accuracy of estimating capelin abundances relied upon accurate estimates of TS which can vary significantly as fish behaviour changes. A high variability of *in situ* TS would necessitate calculating an average TS from a large number of measurements over a wide range of condition. Alternatively, *in situ* TS could be repeatedly estimated so that necessary adjustments could be made throughout a survey (Rose 1992). It is likely that TS variation will have to be quantified over several years to determine whether an average TS for an entire assessment survey is acceptable or whether a variable TS under different conditions (e.g. day-night) is more appropriate. In any event, accurate hydroacoustic stock assessment of this important commercial and a principal forage species depends on examining behaviour-induced error variability.

ACKNOWLEDGEMENTS

We are grateful to the pelagic technical staff of the Department of Fisheries and Oceans (DFO) and the crew of the *Gadus Atlantica* for their expertise while conducting the acoustic surveys. Financial support for computer facilities and for NLS was provided by the *Northern Cod Science Program* (DFO). The constructive and thoughtful comments of B. Nakashima, G. Rose and J. Hutchings greatly improved the manuscript.

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Table 1. Spearman Rank correlation coefficients of density (g/m^2) and vertical depth. Rank correlations are significant at 0.05 unless marked "ns" which denotes not significant.

Year	r_{Sp}	N	
82	-0.650	200	
83	-0.281	162	
84	-0.581	312	
85	-0.442	280	
86	-0.435	375	
87	-0.496	261	
88	-0.300	316	
89	-0.244	355	
90	0.085	307	ns
91	0.237	309	
92	0.338	340	

Table 2. Non-parametric test of independent means (Kruskal-Wallis one-way analysis of variance) between deep and shallow densities(g/m^2) in each year; sample size (N). Depth category (1) refers to shallow and (2) refers to deep. P values are significant (using the sequential Bonferroni method to maintain a table-wide error rate of 0.05) unless marked "ns" which denotes not significant.

Yr	Depth Category	N	Mean Rank	Mann-Whitney U-Test Statistic	P
82	1	48	151.61	1194.5	<0.0001
	2	152	84.36		
83	1	17	116.24	642.0	0.0013
	2	145	77.43		
84	1	133	204.30	5546.0	<0.0001
	2	179	120.98		
85	1	139	170.10	5685.0	<0.0001
	2	141	111.32		
86	1	182	218.67	11980.5	<0.0001
	2	193	159.08		
87	1	108	163.70	4730.5	<0.0001
	2	153	107.92		
88	1	193	180.11	7698.5	<0.0001
	2	123	124.59		
89	1	204	191.65	12617.5	0.0036
	2	151	159.56		
90	1	132	143.42	10153.5	0.0697 ns
	2	175	161.98		
91	1	178	147	10235.5	0.0661 ns
	2	131	165.87		
92	1	125	133.26	8782 .5	<0.0001
	2	215	192.15		

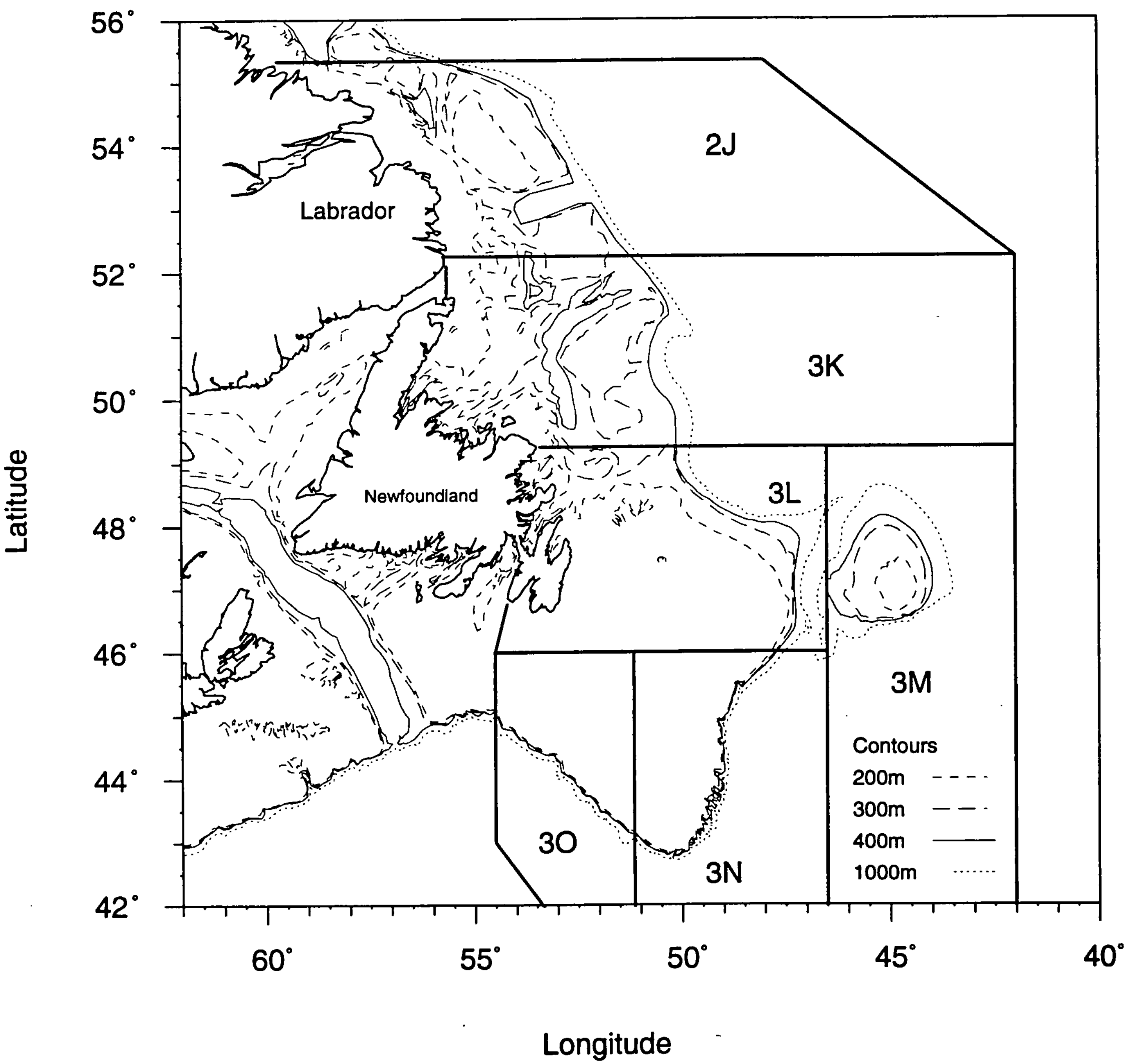
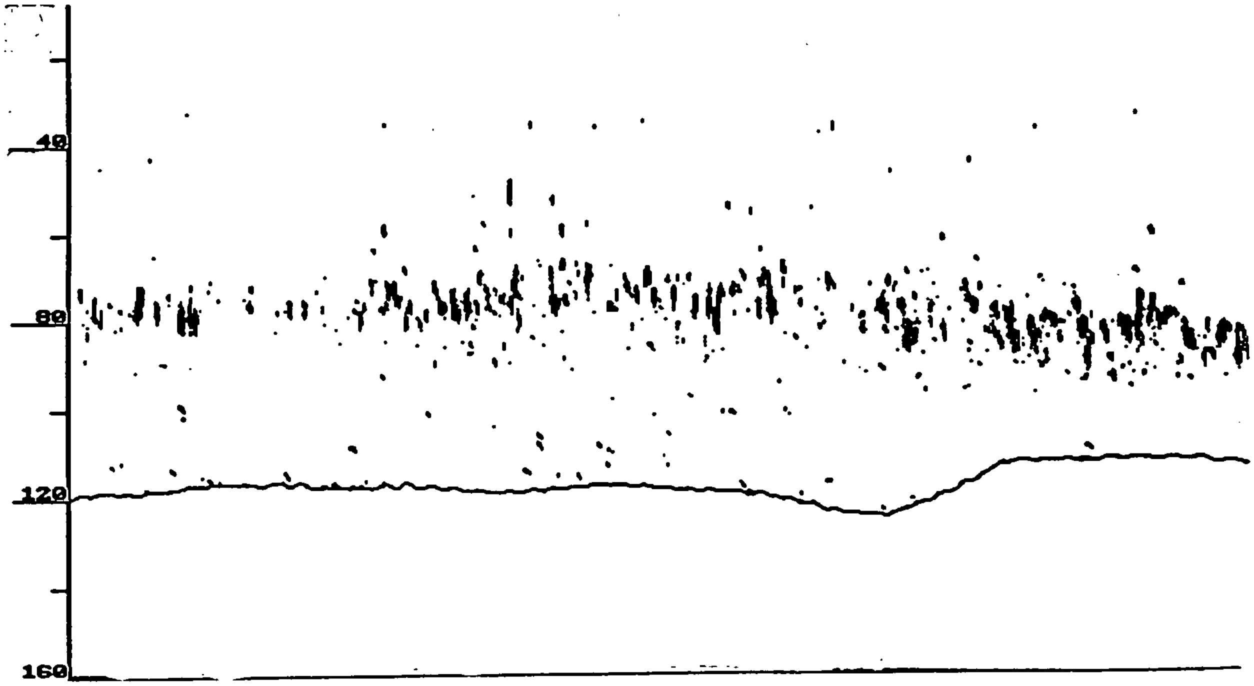


Fig. 1. Northwest Atlantic off the east coast of Newfoundland and Labrador. Letters (2J, 3K, 3L) refer to Northwest Atlantic Fisheries Organization Divisions. Div. 3L was site of annual spring acoustic/trawl surveys from 1982 to 1992. Approximate boundaries of spring survey area: 46°N to 49°N, 49°30′W to 52°45′W.



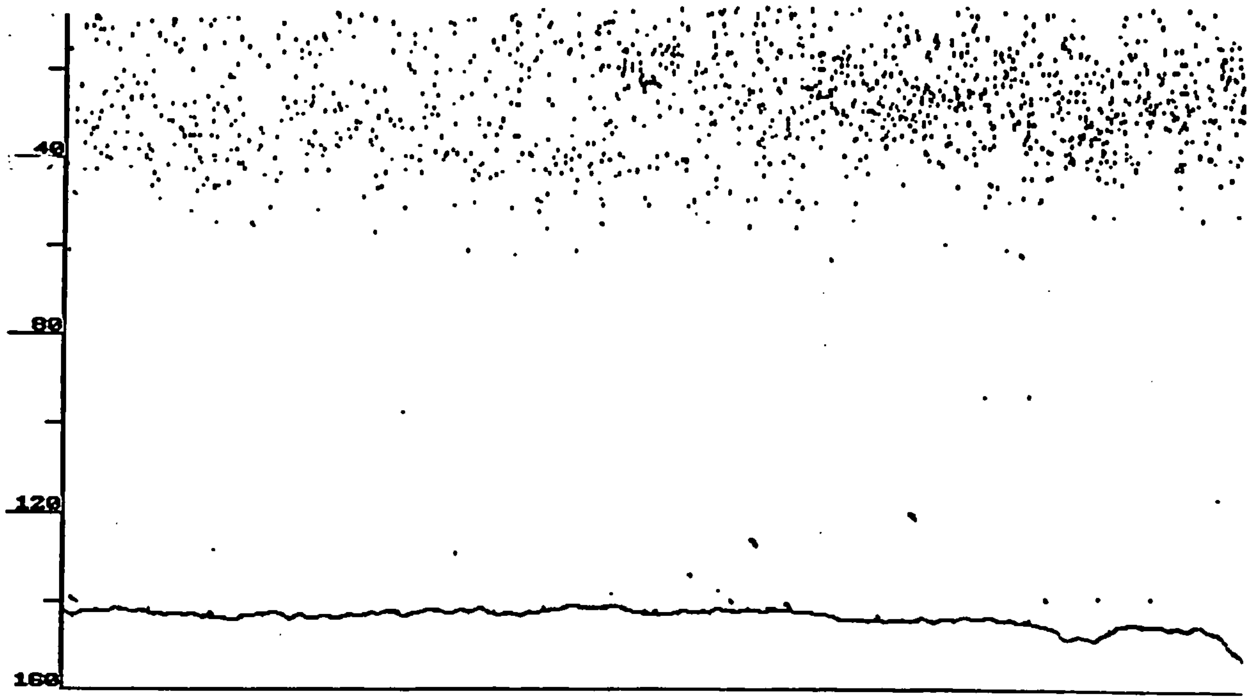


Fig. 2. Echograms illustrating distribution during the day (top panel) starting from 47°52′ N 50°20′W, and distribution at night (bottom panel) starting from 47°53′N 51°17W. Depth (m) is along Y-axis. Time/distance is along X, both echograms represent 9-10 minutes of acoustic data.

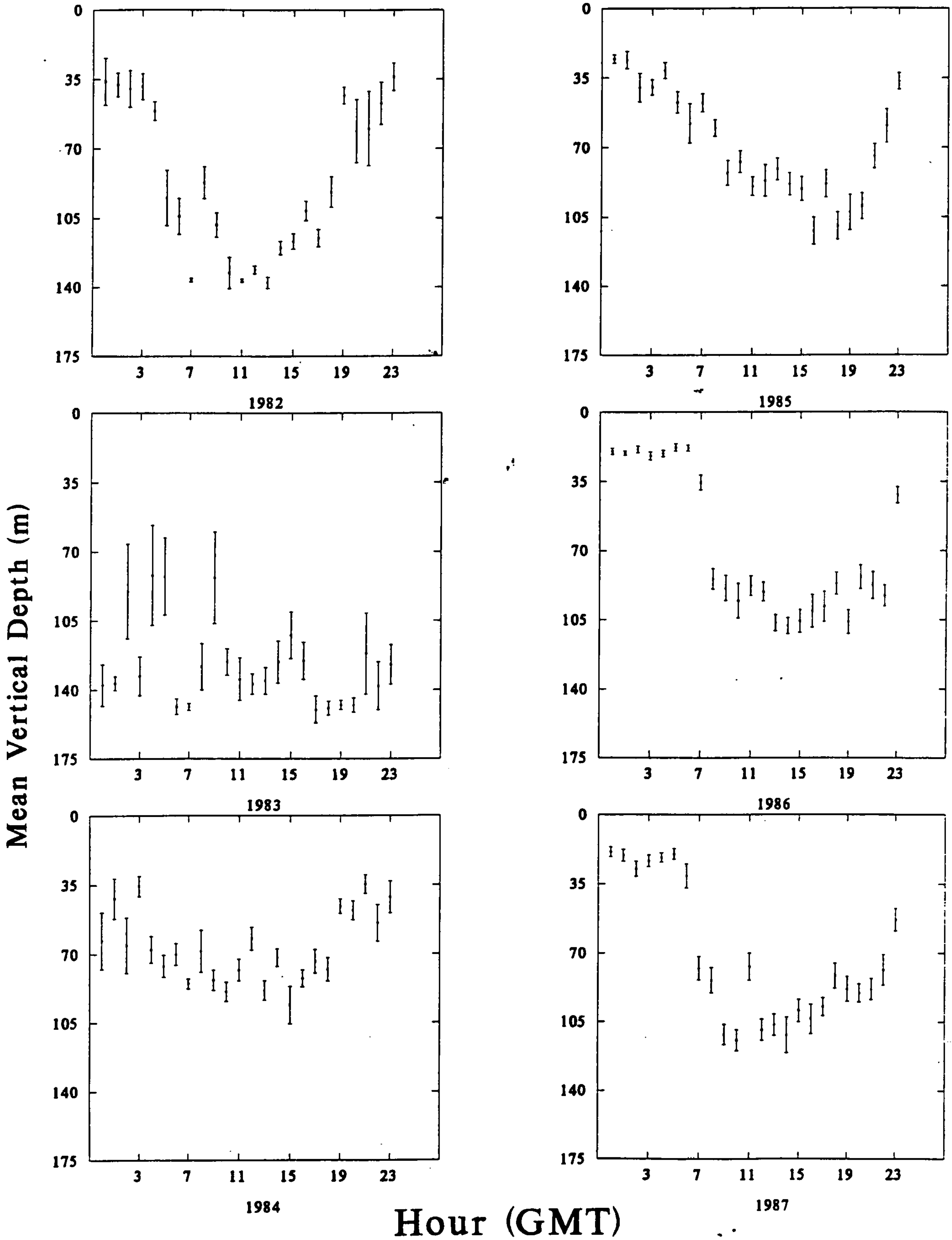


Fig. 3. Diel depth distribution (m) of capelin from 1982 to 1992. Depth is weighted by areal density and corrected for bottom depth (see text); Bars represent standard error of hourly means. GMT is Greenwich Mean Time (Local time= GMT- 2.5 hours)

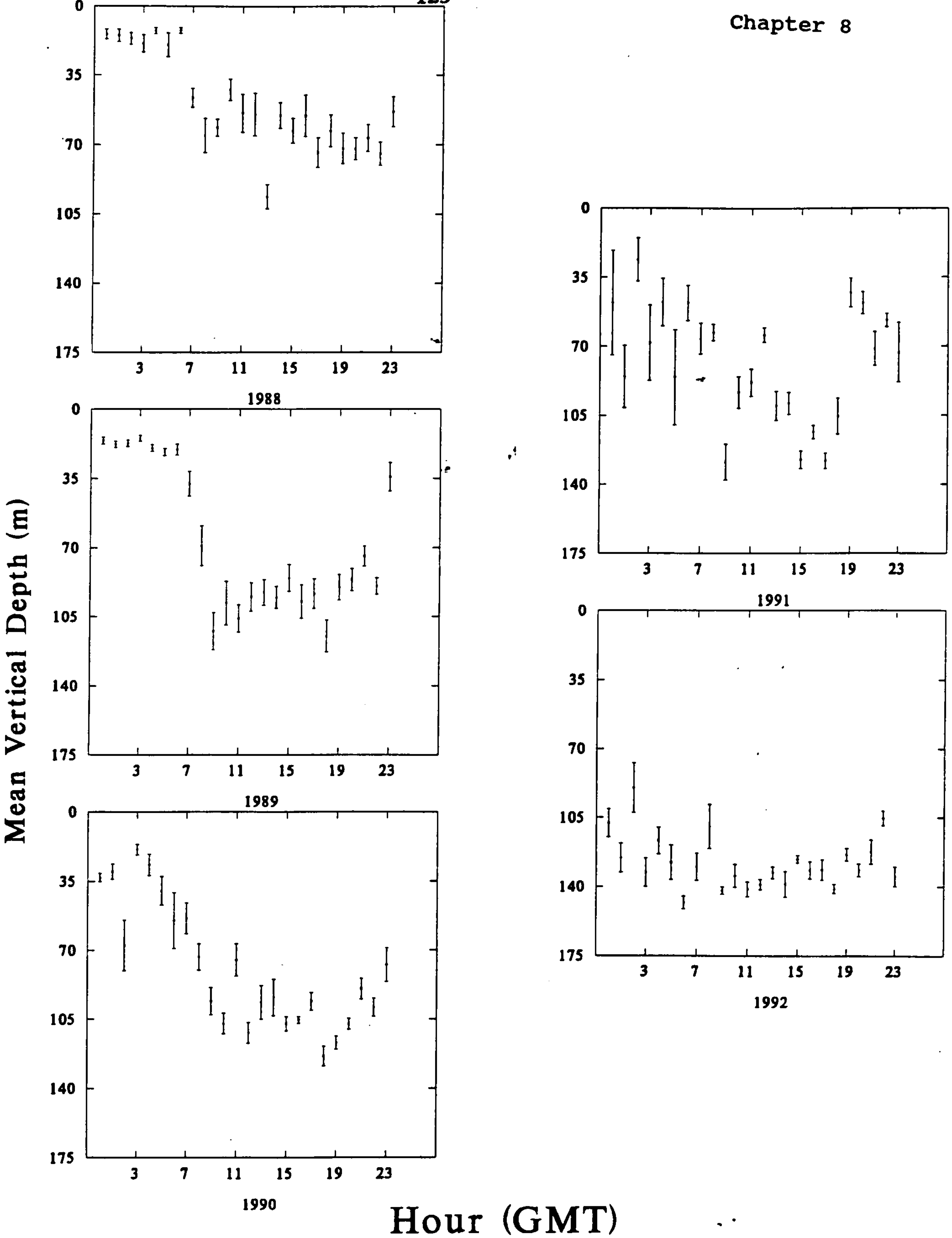


Fig. 3. Continued ...

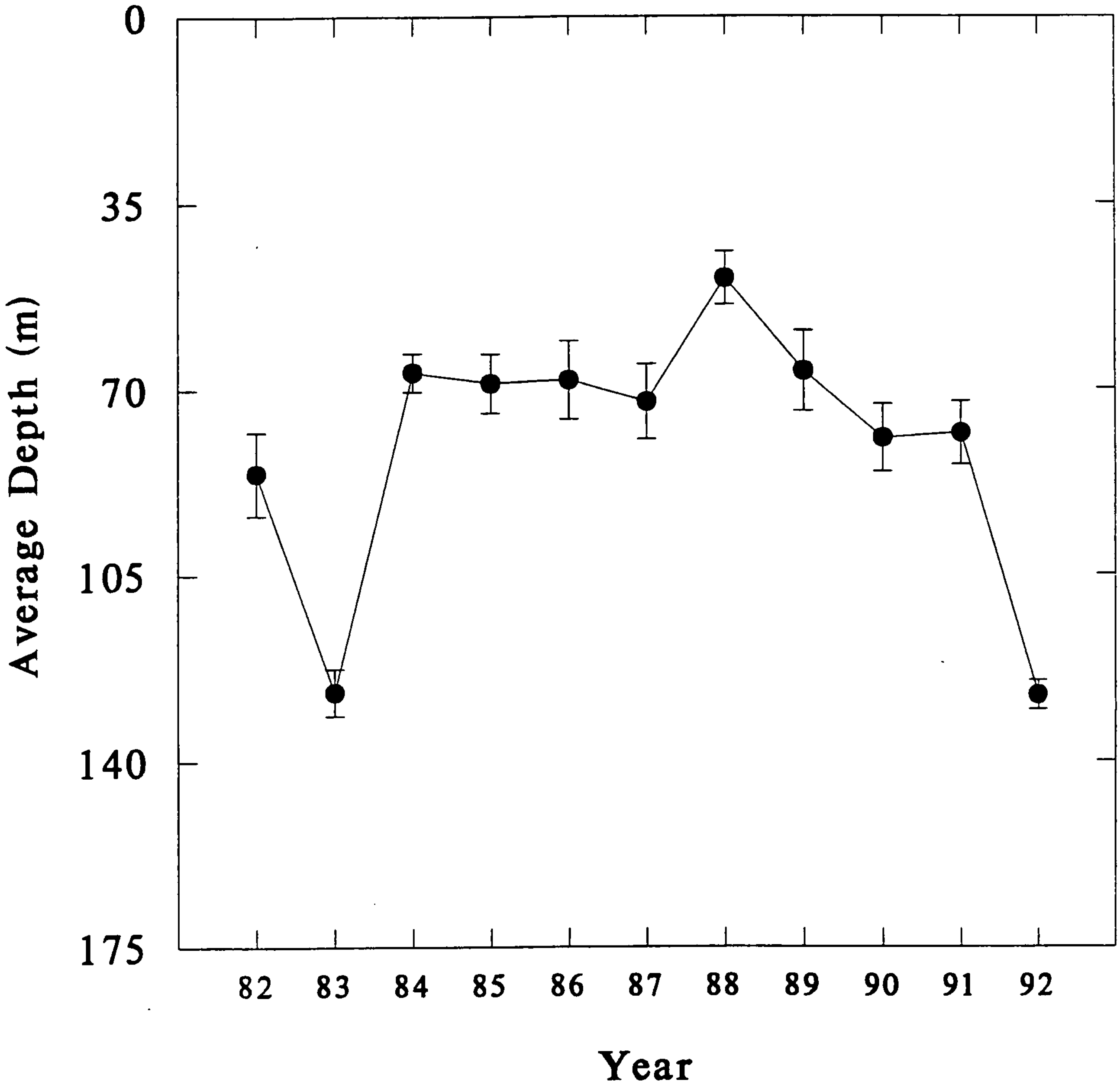


Fig. 4. Annual average vertical depth from 1982 to 1992. Vertical bars represent standard errors of the annual means.

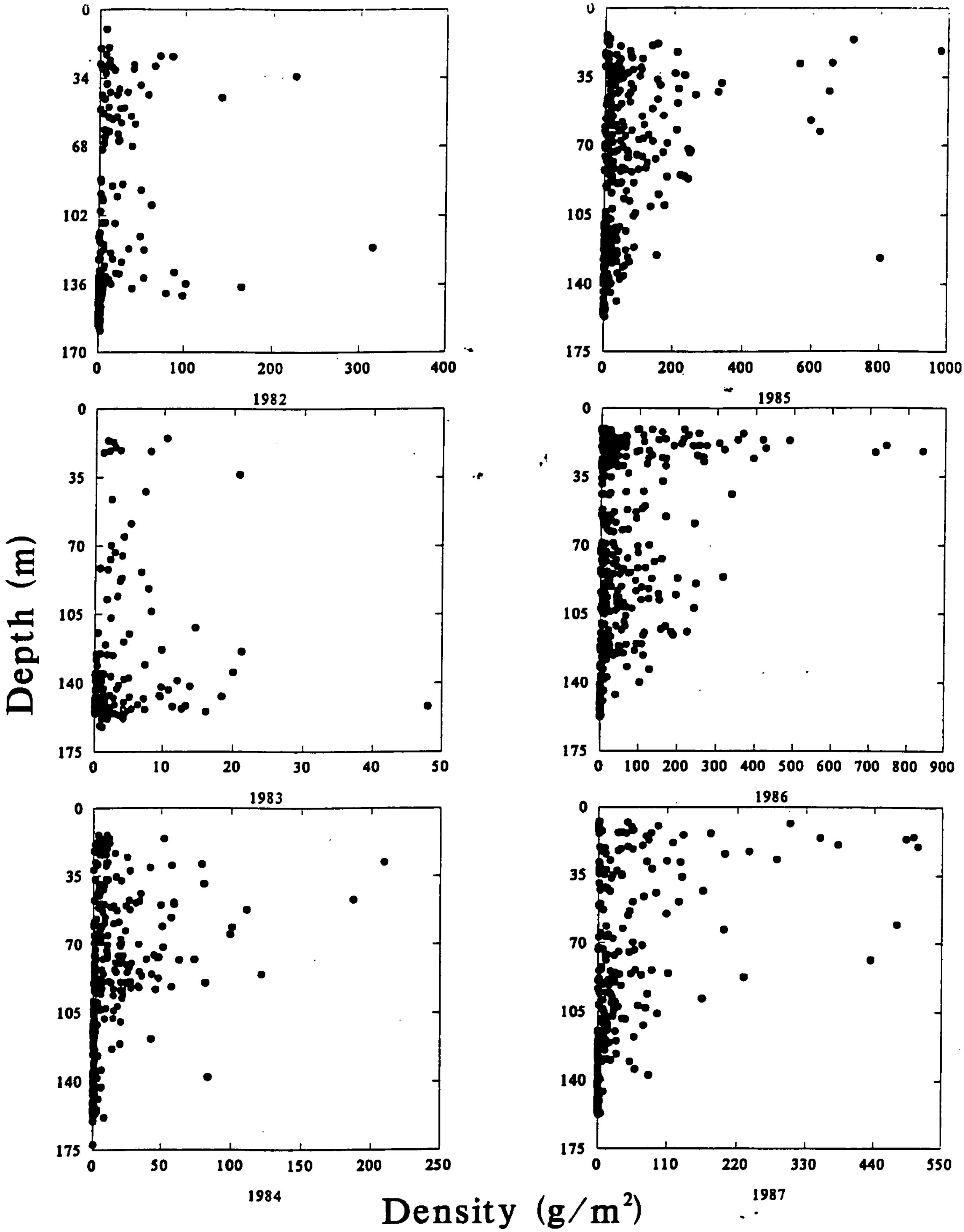


Fig. 5. Density (g/m^2) of capelin and depth (m) from 1982 to 1992. Depth is weighted by areal density and corrected for bottom depth (see text).

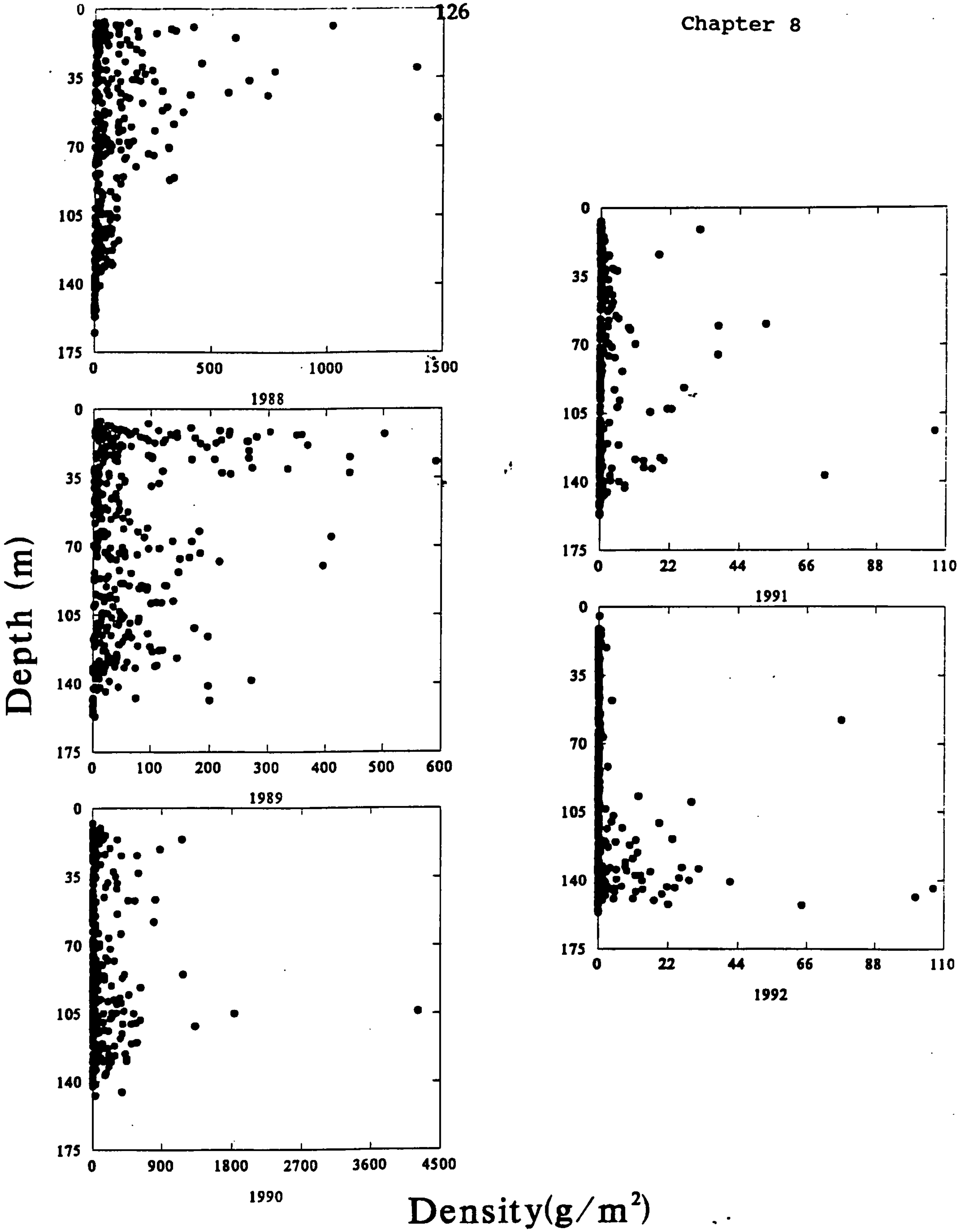


Fig. 5. Continued ...

Chapter 9

Capelin on Flemish Cap (Div. 3M)

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INTRODUCTION

Based on patterns of fisheries and the results of research vessel surveys, a general impression of capelin distribution in Div. 2J and Div. 3K during the fall period emerged for the 1970's and 1980's (reviewed in Lilly and Davis 1993). During the late summer and early fall, capelin occurred in Hamilton Bank and the coastal shelf. In late autumn, the capelin moved into Div. 3K. In many years during the 1980's, Canadian acoustic surveys conducted during October recorded high biomasses of capelin. During those same years, capelin were widely distributed in both Div. 2J and 3K during November and December as evidenced from bycatch in bottom trawl surveys and occurrence of capelin in cod stomachs. Exceptions occurred in 1986 and 1987 when the acoustic biomass estimates were relatively low and samples from the groundfish survey indicated that there were few capelin on Hamilton Bank (Div. 2J) but there were capelin on the central Northeast Newfoundland Shelf (Div. 3K) (Lilly and Davis 1993).

Acoustic estimates were very low during 1990-92 and in 1991 and 1992 there were virtually no capelin in Div. 2J; most of the capelin were distributed in the southeast portion of the survey area (Miller and Lilly 1991, Miller 1992, 1993). Results from the groundfish bycatch data and stomach content data support this observation except that capelin were even further east during 1990-92 (Lilly and Davis 1993). In 1993, the fall acoustic survey was expanded with the total survey area encompassing the zone from the Newfoundland shoreline to approximately 500 m, and from Hamilton Bank south to include Div. 3L. The biomass estimate was low and the capelin detected occurred in southern Div. 3K.

Capelin acoustic surveys were conducted during the spring in Div. 3L between 1982 and 1992. Although the estimates have been variable, they were very low during 1991 and 1992. The extremely low estimate in 1991 was unexpected because the 1990 estimate was the highest in the series and some of the same year-classes were expected to contribute in 1991. Furthermore, patterns of biomass projected from acoustic surveys had, prior to 1991, matched the patterns of indices of mature biomass measured inshore by commercial catch rates and aerial surveys. The inshore abundance indices have shown average or above average values during the 1990's, contrary to what would have been predicted from the offshore acoustic surveys.

At the same time that the discrepancies between the results from the offshore acoustic surveys have been occurring, the oceanographic environment in the Newfoundland area has been severe (Colbourne 1993) with water temperatures below normal especially during 1991.

The discrepancies between inshore and offshore abundance indices during a period of severe environmental conditions have raised the question of a change in distribution in capelin (see also Simon and Frank WP. Given the continuing average inshore indices compared to the dramatic decline in the offshore estimate and changes in distribution in Div. 2J and 3K, attention has been focused on the offshore distribution.

During 1993, new evidence arose which may help to address the question. Bycatches of capelin were reported from a new shrimp fishery that developed on Flemish Cap (Div. 3M), an area in which capelin were reported to be rare (Templeman 1976, Lilly 1987). Given the known eastward movement in capelin distribution during 1990-92 in Div. 3K and the possibility of a large-scale change in capelin distribution, these reports were pursued. In this paper, we provide a review of historical occurrence of capelin on Flemish Cap from bycatch from commercial fisheries and research vessel surveys, a review of feeding studies and summarize information available to date on the bycatch in the shrimp fishery.

Flemish Cap

The Flemish Cap is a relatively small bank (about 52 n mi x 424 n mi bounded by 200 m isobath) centred at about 47°N, 45°W. It is separated from the northern Grand Banks to the west by the Flemish Channel (Pass) which is over 1000 m deep (Templeman 1976). Templeman (1976) also noted that the dividing line (at 46°30'W) between Div. 3M and Div. 3N is inappropriate because a considerable portion of the Flemish Cap, in some places as shallow as 400 m, occurs in Div. 3LN (Fig. 1).

Flemish Cap is influenced by two major current systems. Cold, low-salinity water from the Labrador Current flows from the west and splits into two branches at the northwest corner of Flemish Cap. A southward flowing branch moves through the

Flemish Pass, between the Grand Bank and the Flemish Cap while the other branch flows east and then southeast around the northern and northeast slopes of the Flemish Cap. The North Atlantic Current, warmer and more saline than the Labrador Current flows east-northeast across the southern slopes of the Flemish Cap. There is a weak anticyclonic gyre over the central portion of the Flemish Cap (Lilly 1987) (Fig. 2).

Several authors (e.g. Templeman 1976, Drinkwater and Trites, 1986, Lilly 1987) have summarized the oceanographic conditions on the Flemish Cap. An examination of Drinkwater and Trites (1986) summary indicates that average temperatures at all depths are above 3°C. Lilly (1987) reported that on the central portion of Flemish Cap, temperatures at 100 m are fairly stable at 3-4°C year round. The temperature at 20 m varies from 4°C in spring (March-April) to 12°C in fall (September).

The above temperatures are average and individual temperatures can be lower (Templeman 1976). For example, Templeman (1976) reported that at Station 41, on the top of the Cap at 157 m, the bottom temperature range (1951-73) was 2.43°C to 4.84°C. The lowest temperature from surface to bottom (1951-72) was 2.42°C but in 1973 (a cold year), it was 1.01°C. Generally, the colder waters of the Labrador Current rarely reach the Cap, however, "in cold years, the cold part of the Labrador Current may extend further eastward after April, producing lower mid-water and water temperatures in July, especially on the western slope of the Cap" (Templeman 1976).

In terms of fish species, the Flemish Cap has supported major fisheries for cod and redfish (Templeman 1976, Lilly 1987). The abundance of other demersal species is low (Lilly 1987) while capelin occurrence is rare (Templeman 1976, Lilly 1987).

Commercial Fishery Bycatches in Div. 3M

There have been no directed commercial fisheries for capelin in Div. 3M and bycatches of capelin have not been reported to ICNAF/NAFO very often. In 1973, Poland reported catching 317 tons of capelin (2 tons in September, 110 tons in October and 205 tons in November) during the redfish fishery using stern otter trawler (TC > 2000). Templeman (1976) attributed this occurrence of capelin to unusually cold water on the Flemish Cap that year.

No other catches of capelin in the commercial fishery were reported until 1990 when Portugal reported 14 t bycatch in the redfish fishery during July using bottom otter trawl

(TC 1000-2000). During 1991, Cuba reported 6 t of capelin (4 t in July, 2 t in August), taken during the redfish fishery using midwater otter trawl (TC >2000). Cuba has also reported 6 t for 1992. There have been no bycatches reported for 1993 (however, see section later).

Capelin Bycatches in Bottom Trawl Surveys

Results of bottom trawl surveys are available from the late 1940's for Canada and from the early 1970's from USSR. I checked detailed catch records from INVESTIGATOR II surveys during 1949-58 and A.T. CAMERON surveys from 1961 to 1978 (Table 1). INVESTIGATOR II surveys were usually during the late June-July period while the timing of A.T. CAMERON trips was variable (Table 1). There were no capelin recorded in either the INVESTIGATOR II or A.T. CAMERON catches.

Wells and Baird (1989) did not report any capelin bycatches during GADUS ATLANTICA surveys conducted in the winter (January-February) 1978-85. Their database comprised 1010 sets, stratified over a depth range of 71-400 fathoms. Although groundfish were stated to be the objects of the study, results for 75 species were reported including other pelagic species such as barracudas, argentines and sharks. Presumably if capelin had occurred in the sets, they would have been reported.

Borovkov et al. (1989) summarized the results of spring-summer bottom trawl surveys for Div. 3LKM for the period 1971-88. The data were aggregated and although capelin were reported for Div. 3L and 3K (1.7% and 0.1% by weight respectively), there were no capelin reported for Div. 3M. Rare occurrences (less than 0.1% by weight) of species were noted with a + symbol in their tabular summary but this symbol did not occur for capelin in Div. 3M.

Capelin in Predator Stomachs

Lilly (1987) summarized the food of the two major species, redfish and cod, on the Flemish Cap from studies conducted up until 1986. More recent studies have confirmed his summary. The food of both species comes from the pelagic food web. Redfish consumed primarily pelagic invertebrates such as copepods, euphausiids, and hyperiid amphipods, shrimp and fish which were mainly myctophids. The major prey of cod were hyperiid amphipods and planktivorous fish consisting of juvenile redfish, myctophids and juvenile cod.

I checked several historical feeding studies and found that capelin rarely are reported as prey items. In a series of Soviet and Spanish studies (Table 2), capelin were reported as prey in only two studies. Noskov et al. (1962) reported that in summer 1962, concentrations of redfish were found on the northwestern and northeastern slopes of the Flemish Cap between 300 and 450 m. These redfish were feeding heavily on amphipods, shrimp, capelin and lantern anchovy. No quantitative estimates of feeding were given. In a study of feeding by Greenland halibut in Flemish Pass in 1992, capelin were found occasionally (<1% frequency of occurrence) in depths less than 1000 m (Paz et al. 1993). The actual feeding location may not have been in Div. 3M but rather Div. 3L since the study covered both Divisions. There was insufficient detail given in the study to determine the exact location.

There have been a number of Canadian cod feeding studies in Div. 3M (Lilly and Evans 1986). Details of these studies are found in Table 3. A recent check (G. R. Lilly, pers. comm.) of the data indicated that no capelin were found in the stomachs examined.

Thus, in summary, capelin have never been reported in cod and American plaice stomachs in Div. 3M. Capelin have not been reported in redfish stomachs since 1962 and the one report of capelin in Greenland halibut stomachs may have been from Div. 3L.

<u>The Shrimp Fishery on Flemish Cap</u>

The shrimp in Div. 3M were recently assessed in NAFO (Anon. 1993) and the following information is taken from that report.

Shrimp have been known to occur on Flemish Cap but no directed commercial effort was reported prior to 1993. A fishery began in late April 1993 when two Canadian vessels operated under exploratory permit. By late July, about 50 vessels from many countries were fishing shrimp. By late August, 21,000 t of shrimp had been taken and 18 vessels were still operating. Fishing effort was distributed around the western, northern and eastern portions of the Cap along the 400 m contour (Fig. 3). Bycatch was mostly small redfish (mode at 14 cm) representing 10-15% of the total catch weight April-June, and higher in July. By-catch of other commercial species was reported to be low (Table 4 from Parsons et al. 1993).

Based on information from groundfish surveys, STACFIS concluded that shrimp abundance had increased during 1991-93 compared to the 1988-90 period. The increase in biomass may have been attributable to the strong 1988 year-class. This year-class was female in 1993 and would have been at the sizes targeted by the 1993 fishery. STACFIS was unable to predict whether the present high abundance of shrimp on the Flemish Cap would continue.

Capelin Bycatch in the Flemish Cap Fishery

Information on capelin bycatch in the Canadian shrimp fishery on Flemish Cap was available for May, June and July. Capelin occurred in over 50% of the commercial fishery sets, however, the weight of capelin was low compared to both bycatch and shrimp (Table 5). The catch rate of capelin was generally low with most sets less than 2 kg/hr, however there were some higher catch rates between days 150 and 180 (roughly June and July) (Fig. 4). Because peak catch rates occurred at the end and beginning of May, June and July, mean monthly catch rates did not change substantially during the three months (Table 5).

Sets with capelin bycatch were made between 310 m and 495 m with mean depths of May = 347 m, June = 380 m, and July = 356 m. Bycatches occurred on the western-northwestern part of the Cap in May, extended around the northern, northeastern and eastern part of the Cap in June and the western, northwestern and northern part in July (Fig. 5).

Six samples were available for biological sampling. Age 3 fish predominated in all months although there was an increase in age 4 fish with time. The proportions of age 2 fish remained low during the three months (Table 6). Most of the capelin were judged to be maturing (stage 2), that is, that they would spawn during 1993. By July, a small proportion of fish were very close to spawning (stage 3) or spawning (stage 4) (Table 6). A comparison of roe contents (as a proportion of body weight) indicated that the capelin on Flemish Cap were in a spawning state similar to samples taken offshore during 1988 and 1989 in Div. 3NO (Fig. 6).

DISCUSSION

The available historical evidence appears to support the conclusions of Templeman (1976) and Lilly (1987) that capelin are rare on the Flemish Cap. Capelin have not appeared in thousands of bottom trawl research sets nor have they been recorded in cod stomachs. Capelin have been reported in redfish stomachs in only one report and Greenland halibut stomachs, although the location of the latter record may not have been the Flemish Cap. A bycatch in the redfish fishery was reported during 1973 and Templeman (1976) attributed this occurrence of capelin to the fact that 1973 was a cold year. Bycatches have also been reported in the 1990-92 redfish fishery and the 1993 shrimp fishery.

The occurrence of capelin on the Flemish Cap since 1990 coincides with cold water temperatures in the Northwest Atlantic. Colbourne (1993) reported that since the early 1970's, there have been three anomalous periods; the early 1970's, the mid 1980's, and the early 1990's. In a detailed examination of available data from the Flemish Cap, Colbourne (1993) concluded that the same anomalies also existed in this area as well. Temperatures have been about 2°C below normal in the upper 100 m since the late 1980's and have been about normal below 300 m. Based on the depth of capelin bycatches in the July 1993 shrimp fishery, these capelin would have occurred in temperatures of about 3.0-3.5°C (Colbourne 1993). Vertical migrations could take the capelin into water temperatures of 5-6°C. When compared to known spawning temperatures of capelin in the Northwest Atlantic (Carscadden et al. 1989), none of the surface to bottom temperatures, neither normal nor anomalous (Colbourne 1993), would be considered detrimental for capelin during the spawning season.

The capelin captured as bycatch were maturing and a small proportion were very close to spawning. Thus, some proportion of these fish would probably spawn on Flemish Cap.

Based on the available evidence, I conclude that there has not been a self-sustaining population of capelin on the Flemish Cap. Capelin occurring there since 1990 have probably been migrants from the Grand Banks area. Their occurrence on Flemish Cap during periods of cold water conditions in the Northwest Atlantic is consistent with the 1973 observation and as Templeman (1976) noted, during these cold periods, the cold part of the Labrador Current may extend further eastward and influence the western slope of the Cap.

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Table 1. Canadian bottom trawl surveys checked for presence of capelin as bycatch.

Vessel	Dates
INVESTIGATOR II	August 28-31, 1949 July 10-16, 1950 July 10-19, 1956 July 29-August 11, 1957 June 23-July 1, 1958
A. T. CAMERON	March 18-April 1, 1961 September 8-21, 1964 July 25-August 5, 1966 July 25-August 5, 1967 February 29-March 14, 1968 July 25-August 8, 1968 September 7-24, 1973 February 2-15, 1977 November 7-21, 1978
GADUS ATLANTICA	January 25-February 15, 1978 January 28-February 20, 1979 April 18-May 5, 1979 January 4-23, 1980 January 5-26, 1981 January 26-February 16, 1982 February 2-23, 1983 February 1-20, 1984 January 31-February 17, 1985

Table 2. Summary of predator feeding studies in Div. 3M that were checked for presence of capelin.

	Number of stomachs					
Study	Cod	Redfish	American plaice	Greenland halibut	Year(s)	Season(s)/ months(s)
1. Noskov et al. 1963	-	✓	-	-	1962	summer
2. Turuk and Postalaky 1980	783	741	627	42	1978	May-August
3. Turuk 1981	11712	-	-	-	1970-80	April-August, February/March
4. Konstantinov et al. 1985	10882 (1970-82)	10391 (1979-82)	2083	-	(see species)	all months except October and November
5. Albikovskaya & Gerasimova	9176	just under 11,000	-	-	1981-8	variable but included December to July except January
6. Paz Canalejo et al. 1989	468	203	320	-	1988	July
7. Paz et al. 1991	1182 (1989) 530 (1990)	-	-	-	1989 & 1990	July and August
8. Rodriguez-Marin & Punzon 1993	-	-	-	4987	1992	May-November (>720 m)

Table 3. Dates of sampling and numbers of Atlantic cod stomachs collected during winter stratified-random bottom trawl surveys and spring-summer ichthyoplankton surveys by the R.V. GADUS ATLANTICA on the Flemish Cap (NAFO Div. 3M) during the period 1978-84 (from Lilly and Evans SCR Doc. 86/109).

Year	Trip number	Sampling period	Number of[a] tows	Number of stomachs
1978	5	Jan. 28-Feb. 12	98	403
1979	17	Feb. 08-17	13	94
	19	Mar. 25-28	6	153
	20	Apr. 28-May 09	4	207
1980	30	Jan. 06-21	80	456
	35	Apr. 05	9	72
	37	May 19-28	8	135
1981	45	Jan. 08-21	83	484
	50	Apr. 29-May 10	5	71
	51	May 28-30	8	72
1982	61	Jan. 29-Feb. 14	92	519
1983	74	Feb. 05-20	103	878
1984	90	Feb. 02-13	97	989
TOTAL			606	4533

Table 4. Bycatch information from the Canadian fishery for shrimp on Flemish Cap, 1993, obtained by observers.

	April		May		June	
Species	Wt. (t)	%	Wt. (t)	%	Wt. (t)	%
Shark (NS)	.	.	.	.	0.25	0.10
Skate (NS)	0.00	0.18	0.44	0.16	0.58	0.22
Cod	0.00	0.06	0.16	0.06	0.08	0.03
Wolffish (NS)	.	.	1.29	0.46	0.60	0.23
Eelpouts (NS)	.	.	0.11	0.04	0.10	0.04
Redfish (NS)	1.40	82.55	32.47	11.49	38.09	14.51
G. Halibut	.	.	0.23	0.08	0.46	0.17
Shrimp (P.B.)	0.27	16.16	246.90	87.34	220.64	84.04
Other	0.02	1.06	1.09	0.39	1.76	0.67
TOTAL	1.70	100.00	282.70	100.00	262.55	100.00

Table 5. Details of shrimp fishing activity by Canadian vessels with observers, Div. 3M, 1993.

Month	Total sets	Total sets with capelin	Total shrimp catch (t)	Observed bycatch (t)	Total capelin bycatch (kg)	Capelin catch (kg/hr)
May	97	75	247.0	32.3	191	.85
June	459	235	864.8	177.2	770	1.0
July	184	121	213.9	208.5	438	.91

Table 6. Age-composition, mean length-at-age, and maturity composition by age for caplin captured as bycatch in the Div. 3M shrimp fishery, May, June and July 1993.

	Age				
	2	3	4	5	6
May (N = 1)					
Age-composition	2	98	0	0	0
$\bar{L}$	131	170	-	-	-
Maturity					
1 (Immature)	10	4			
2 (Maturing)		96			
3 (Ripe)					
4 (Partly spent)					
5 (Spent)					
June (N = 3)					
Age-composition	3.5	88.3	7.9	.3	
$\bar{L}$	142	172	176	193	
Maturity					
1 (Immature)	83.1	9.2	8.4		
2 (Maturing)	16.9	90.8	91.6	100	
3 (Ripe)					
4 (Partly spent)					
5 (Spent)					
July (N = 2)					
Age-composition	1.9	80.3	17.9		
$\bar{L}$	146	171	167		
Maturity					
1 (Immature)	83.3	23.9	43.5		
2 (Maturing)	10.0	65.1	46.7		
3 (Ripe)	3.3	9.2	8.7		
4 (Partly spent)	3.3	1.9	1.0		
5 (Spent)					
Overall					
Age-composition	2.7	87.9	9.2	.1	
$\bar{L}$	141	171	171	193	
Maturity					
1 (Immature)	85.6	11.9	27.9	0	
2 (Maturing)	13.1	85.3	66.7	100	
3 (Ripe)	.6	2.4	4.8		
4 (Partly spent)	.6	.5	.6		
5 (Spent)					

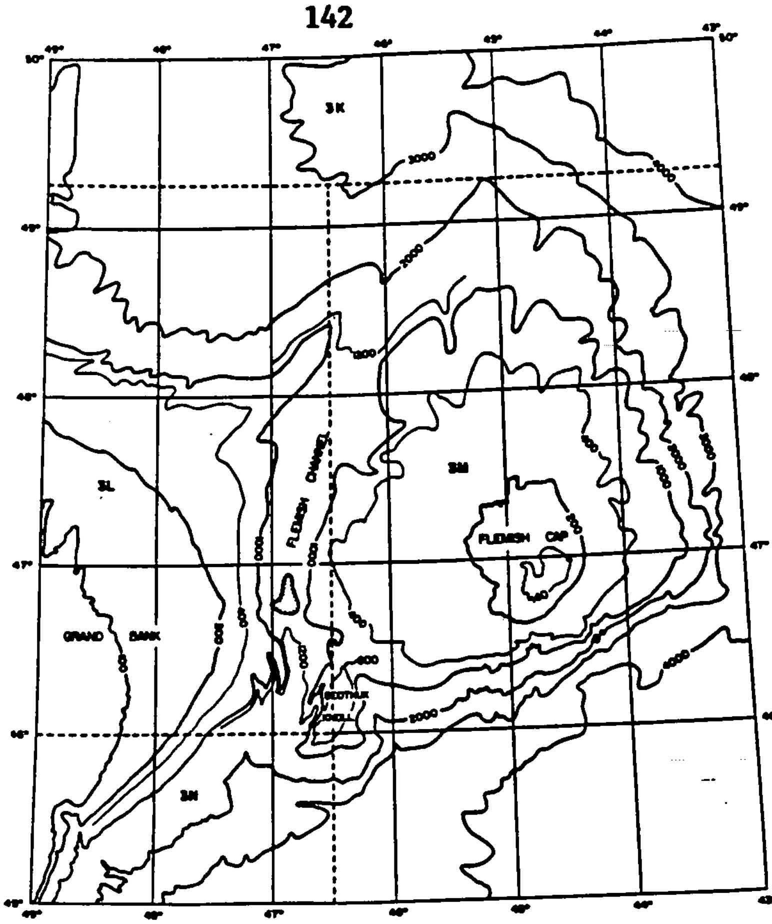

Fig. 1. Isobaths (m) for Flemish Cap and adjacent NAFO Divisions and banks.

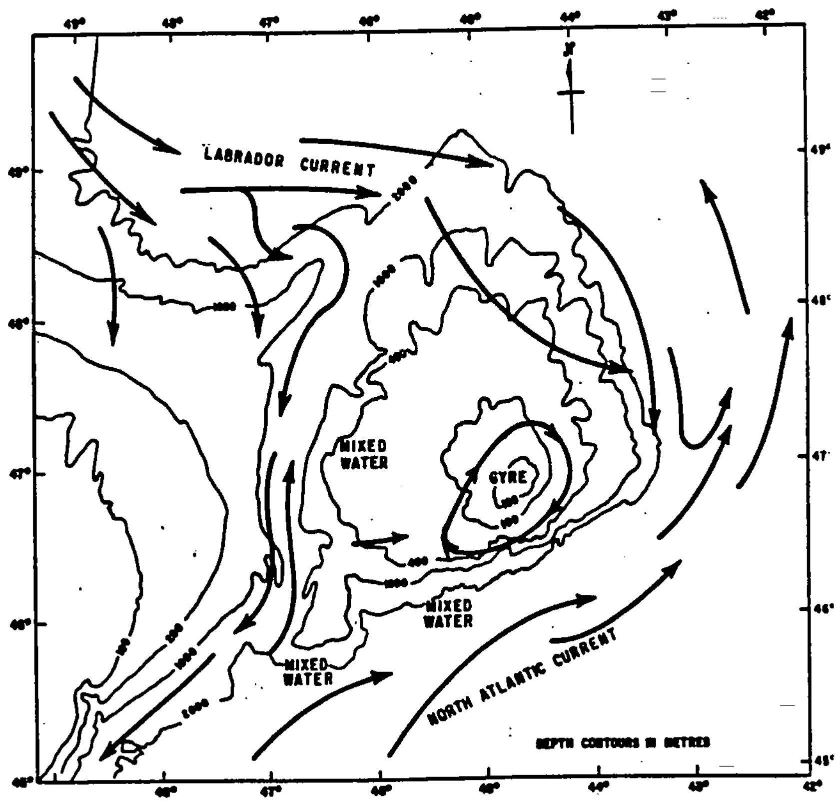

Fig. 2. General current regime on the Flemish Cap.

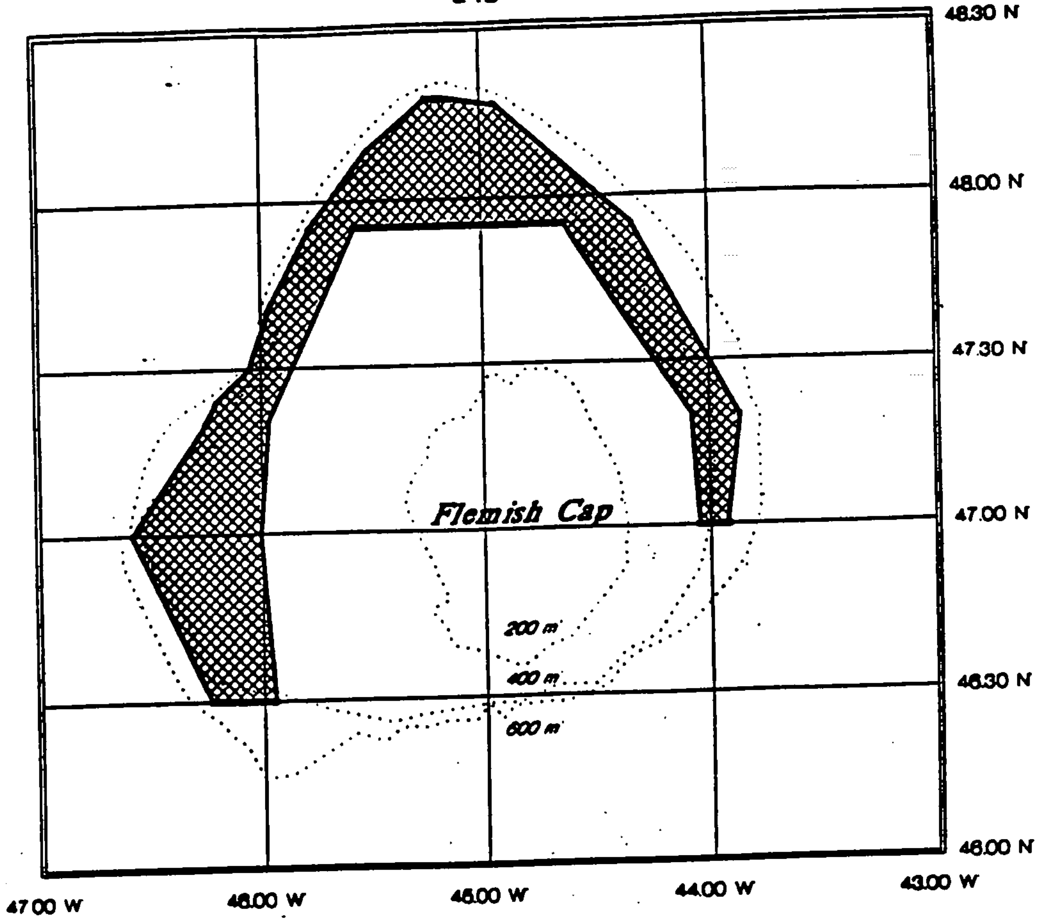

Fig. 3. Main shrimp area on Flemish Cap in May-August 1993.

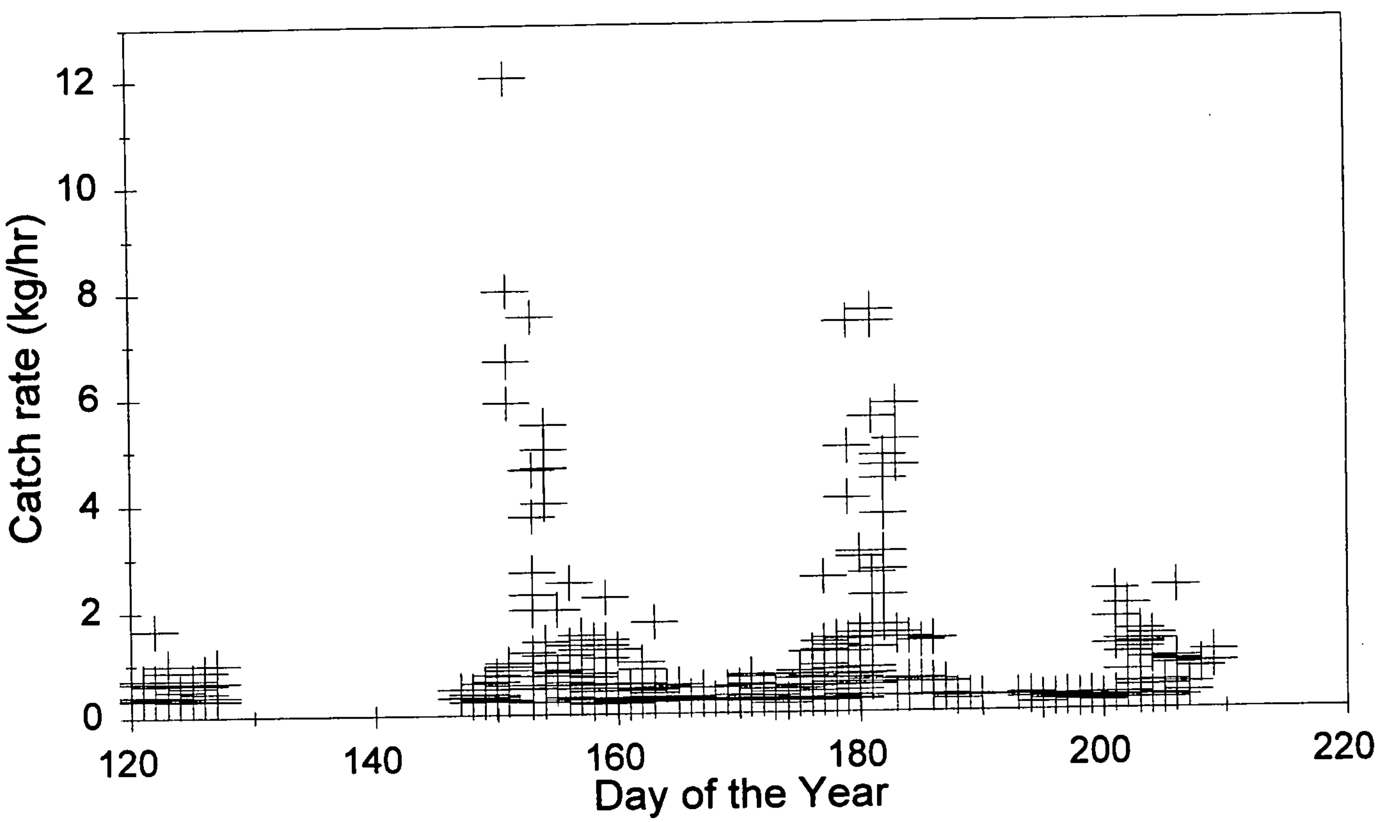

Fig. 4. Capelin daily bycatch rate (kg/hr) during Div. 3M shrimp fishery.

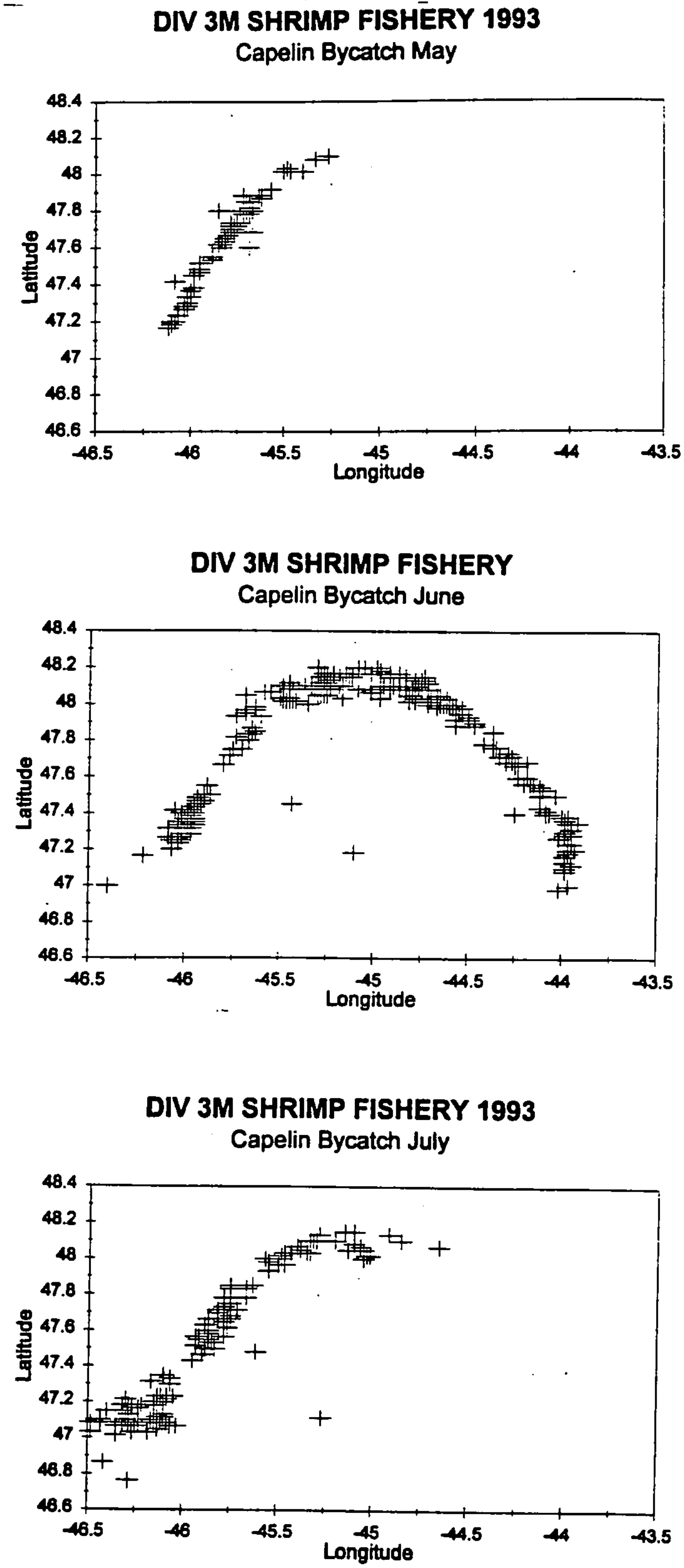

Fig. 5. Locations by set and month of capelin bycatch in Div. 3M shrimp fishery.

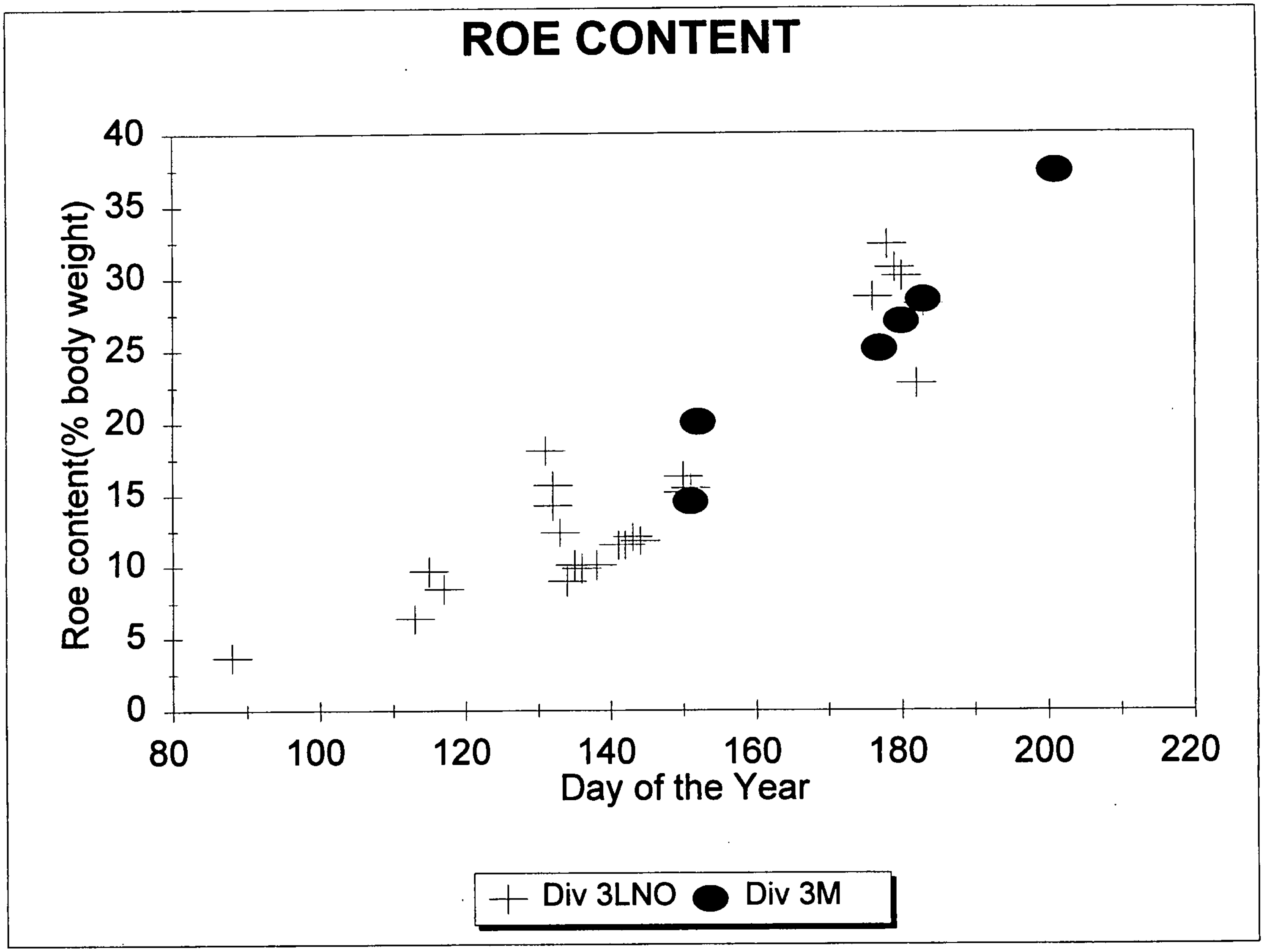

Fig. 6. Roe content: weight of roe (gm) as % of total body weight (gm) of capelin captured in Div. 3NO and Div. 3M. Div. 3NO samples are from the USSR capelin fishery in Div. 3O during 1988 and the Canadian acoustic survey in Div. 3N during June-July 1989. Div. 3M samples were bycatch in the 1993 shrimp fishery.

Chapter 10

Recent extension of capelin onto the eastern Scotian Shelf (NAFO Div. 4VW)

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INTRODUCTION

Unusual occurrences of marine fish have been frequently reported in the scientific literature. If a few individuals have been sighted then simple straying from the normal habitat may be involved. If large quantities are involved a major shift in the species distribution may have occurred (see review in Mearns 1987). A persistent change in distribution may indicate a range extension or establishment of a self-sustaining population in a new geographic area. It has been shown that large scale oceanographic processes (e.g. El Nino-Southern Oscillation) can alter the distribution and migration pattern of many marine fishes (Soule and Kleppel 1987). This has led to the notion that whenever unusual occurrences of marine fishes are observed they reflect anomalous oceanographic conditions.

In the Northwest Atlantic, between 1965 and 1968, great quantities of capelin (Mallotus villosus) were recorded in the Bay of Fundy herring weir fishery and it was suggested they were reproducing successfully there (Tibbo and Humphreys 1966; Jangaard 1974). This was a highly unusual occurrence because capelin are normally resident in waters around Newfoundland where five major stocks are generally recognized (Carscadden 1983). This situation did not persist, however, as capelin were not reported in the Bay of Fundy after 1968.

The presence of capelin in the Bay of Fundy coincided with a minima in ocean temperatures associated with a cooling trend from 1952 to 1967 (Fig. 1). Colton (1972) suggested that such cooling was a possible cause for the southward extension of capelin. In the Gulf of Maine and contiguous waters, changes in the composition of the subsurface water brought about by slope water displacement or modification of coastal waters of Labrador origin (relatively cold and fresh) was believed to be responsible for the cooling trend (Colton 1972). A recent study by Petrie and Drinkwater (1993) revealed that the transport of Labrador Current water increased between 1952 and 1967. The authors tested and confirmed the hypothesis that variation of the westward transport of the Labrador Current makes significant contributions to the observed temperature and salinity variability of the waters from the Gulf of St. Lawrence to the Gulf of Maine. If we assume this is an accurate physical description of the cooling trend then a mechanism may exist for the directed transport of capelin from the more northern latitudes to southern waters.

It is obviously an unusual event when significant quantities of capelin occur outside of their normal distributional range. In addition to the 1960's, substantial quantities of capelin occurred in the Bay of Fundy between 1915 and 1919 (Bigelow and Schroeder 1953) and around 1903 (Huntsman 1922). Both of these capelin observations occurred during periods of below normal water temperatures (Fig. 1). No accompanying recorded observations of capelin exist for the continental shelf waters due primarily to the lack of standard research vessel surveys prior to 1970.

It appears that we are now witnessing another southward extension of capelin, particularly on the eastern Scotian Shelf where during annual groundfish surveys an explosive increase in capelin abundance has been noted since 1988. This latest event coincides with the occurrence of atmospheric and oceanic extremes in the Labrador Sea/Newfoundland Shelf region and the Gulf of St. Lawrence. In general, cold air temperatures, heavy sea ice and cold water temperatures have prevailed in these regions during the past 3-5 years (Drinkwater 1993). Given that capelin is a reliable indicator of cold, coastal water masses in the NW Atlantic, it is possible that portions of the Scotian Shelf are now undergoing oceanic cooling.

This paper reports on the recent dramatic increase of capelin encountered during annual groundfish surveys of the Scotian Shelf. It is from this data that we evaluate the relative abundance and distribution of capelin on the Scotian Shelf from the initiation of the trawl surveys (1970) to present. Concurrent hydrographic data are also analyzed in relation to the trends in capelin abundance.

MATERIALS AND METHODS

Research vessel (RV) surveys of the Scotian Shelf have been conducted each spring since 1979 (NAFO Div. 4VsW) and each summer since 1970 (NAFO Divs. 4VWX) by Fisheries and Oceans, Canada. Both sampling and data analysis protocols are well documented (Halliday and Koeller 1981; Smith and Somerton 1981). The RV surveys provide reliable indices of abundance and distribution for the groundfish stocks on the Scotian Shelf using a stratified random survey design with strata based on depth boundaries of 91, 183 and 366 m (Fig. 2). Because the cod end of the bottom trawl is equipped with a 19 mm liner, by-catch of juvenile groundfish, pelagic fish, and small bodied fish species in general is common. For example, both juvenile and adult herring are routinely captured during summer groundfish surveys of the Scotian Shelf. Stephenson et al. (1990) have argued that this by-catch provides a meaningful abundance index of herring. Significant quantities of capelin are also captured during autumn groundfish trawl surveys in NAFO Div. 2J3K which Carscadden et al. (1989) suggested not only provided information on distribution but also possibly the relative abundance of capelin in this geographic region. On the basis of these results we consider the RV surveys capable of providing useful relative indices of distribution and abundance of capelin on the Scotian Shelf.

Hydrographic data was collected at the end of each trawling station. Before 1990, water temperature and salinity data were obtained from water samples collected with a reversing bottle from near-bottom. Water temperatures were measured in 1990-1993 using an internally recording Seabird model 19 (or 25) conductivity, temperature and depth (CTD) profiler. The near-bottom temperatures from each CTD profile were calibrated with the reversing thermometer estimates of temperature (Page and Losier, submitted).

Biological sampling of capelin included estimation of size (length frequency), total weight and numbers in each tow. Capelin distributions were generated from individual sets and plotted using ACON Version 5.02 (Black 1991). For each annual survey capelin abundance is expressed as stratified mean numbers per tow by division.

RESULTS

The spring and summer RV surveys both show a progressive increase in capelin abundance in Div. 4VW during the past six years (Fig. 3) with recent capelin catch rates during the summer survey among the highest ever observed. Throughout the remainder of the survey series capelin were not abundant except for the early 1970s when catch rates exhibited a minor peak (Fig. 3). By-catch levels of the magnitude recently observed in Div. 4VW are comparable to the capelin by-catch levels reported during groundfish surveys in Newfoundland waters (Div. 2J and 3K) where between 1981 and 1988, the stock biomass averaged 900,000 mt (Carscadden et al. 1989). It is unlikely that the capelin population on the Scotian Shelf is of comparable size to the Newfoundland stock because of its restricted geographic extent in southern waters (see below).

This recent episode of a southward capelin range extension appears to be confined to the offshore waters of the eastern Scotian Shelf, as revealed by the spring and summer RV surveys (Fig. 4). Very few capelin were encountered in the Bay of Fundy during the summer surveys and there have been no reports of capelin occurring in the herring weir fishery after 1968 (pers. comm. W. Dougherty, C. Monaghan; DFO port technicians, Biological Station, St. Andrews, N.B. E0G 2X0). It appears, therefore, that the present capelin invasion is not as extensive as in the past (e.g. 1960s as described by Tibbo and Humphreys 1966), with the leading edge of the current distribution just inside the eastern boundary of Division 4W. Because there were not offshore surveys of the entire Scotian Shelf before 1970 we do not know whether capelin were as abundant offshore as they were during the mid-1960s in the Bay of Fundy.

The composite size frequency distribution of capelin revealed that the majority of the fish captured ranged in size from 14-16 cm (Fig. 5). Based on age readings conducted by Tibbo and Humphreys (1966) of capelin from the Bay of Fundy, capelin $\geq$14 cm are 2+ years old. The occurrence of capelin both smaller than 14 cm and larger than 16 cm suggests that several age groups were co-occurring in this geographic area. Capelin <14 cm were probably not adequately sampled due to their extrusion through the meshes of the cod end. This was, in fact, the case as shown by monthly sampling conducted by the Ocean Production Enhancement Network of Western Bank (in Div. 4W) that began in March, 1991 using a rectangular mid-water trawl (1.6 mm mesh). Numerous 0-group capelin (20-40 mm) were encountered in the survey area during October-December 1991 and 1992 (pers. comm., L. Fortier, Laval University, Ste. Foy, PQ). The occurrence of 0-group capelin during this period may also suggest that these capelin originated on the eastern Scotian Shelf through local spawning. Capelin in this size range dominated mid-water trawl collections on the Southeast Shoal of the Grand Banks during November of 1987, 1988, and 1989 (K.T. Frank, unpublished data) and these larvae were known to have originated from the resident spawning stock.

As during previous southward extensions of capelin into Nova Scotian waters, recent water temperatures have been below normal and near record low levels. In Div. 4Vs, where recent capelin catch rates are highest (Fig. 4), near-bottom water temperatures have been declining since 1985 with average temperatures <2°C between 1989 and 1991 (Fig. 6). A similar temperature trend was evident in Div. 4Vn but near-bottom water temperatures did not drop below 2°C in recent years (Fig. 6). It should also be noted that the declining temperature trend seen during the early 1970s (Fig. 6) coincided with a minor peak in capelin abundance (Fig. 3). The time series of near-bottom salinity was quite variable with a slight downward trend (freshening) since the mid-1980s in both Div. 4Vs and 4Vn. Cooling is evident in Div. 4W but recent near-bottom temperatures may still be too warm for successful occupation of these waters by capelin (Fig. 7). The recent cooling of the near-bottom waters in Div. 4Vs and 4Vn was not apparent in Div. 4X (Fig. 7), which includes the southwestern Scotian Shelf and Bay of Fundy, and this may explain the absence of capelin in this area (Fig. 4).

The spatial distributions of near-bottom temperature matched closely the composite distribution of capelin depicted in Figure 4. Negative temperature anomalies generally characterized the sampling strata in Div. 4Vn, 4Vs and the eastern half of Div. 4W since 1987 (Table 1). This time series of bottom temperature anomalies strongly coincides with the leading edge of the current distribution of capelin.

Collectively, these data suggest that the eastern Scotian Shelf is experiencing a cooling trend and that capelin have responded positively to this change both in terms of increased local abundance and reproduction.

DISCUSSION

It is apparent that capelin can quickly respond to changing environmental conditions and that this species has the capacity to rapidly colonize locations outside of its normal geographic range. This may be a unique life history characteristic of capelin. We believe the time series of capelin catch rates derived from the annual groundfish surveys rule out the possibility of resurgence of a local population given the prolonged absence of capelin at various times on the Scotian Shelf. Rather, the recent situation appears to be due transport (or migration) of capelin onto the eastern Scotian Shelf (at an undetermined life stage) and eventual establishment of a reproducing population. This interpretation is consistent with that of Tibbo and Humphreys (1966) for the Bay of Fundy capelin episode in the mid-1960s.

In our examination of the various fish species collected during the RV surveys we were struck by the very few numbers of arctic/boreal species that responded similarly as capelin to the recent, and past, cold water conditions on the Scotian Shelf. Out of several species considered (see Simon and Comeau 1994 for a complete description), two showed a temporal pattern of abundance similar to capelin: Greenland halibut, <u>Reinhardtius</u>

hippoglossoides and checker eelpout, Lycodes vahlii (Fig. 8). Peak catch rates of Greenland halibut and checker eelpout were observed during the mid-1970s and during the 1990s, both of which correspond to periods of below normal water temperature on the eastern Scotian Shelf (Fig. 6). Although not shown, the distributional pattern of these two species is confined to the eastern Scotian Shelf, closely resembling the patterns depicted in Figure 4 for capelin. It should also be noted that the first occurrence of Greenland halibut in the Bay of Fundy was recorded in 1968 by Barrett (1968) and Boyar (1964) reported its occurrence off Boothbay Harbor in 1963, both records being associated with times of below normal water temperatures in the area of capture and with the major cooling event of the Scotian Shelf and Gulf of Maine during the mid-1960s (Fig. 1).

The limited number of species whose geographic distribution changes extensively on ecological time scales may ultimately be linked to the physiological capacity of the species. As Colton (1972) noted during the 1952 to 1967 cooling event of the continental shelf waters from Nova Scotia to Long Island, the distributional patterns of several groundfish species did not change extensively and it was suggested that spawning area and bottom type were the principal habitat requirements for species such as yellowtail flounder and haddock. Seasonal production of blood anti-freeze proteins among certain species (cod, winter flounder, eelpout) may allow individuals to remain in nearshore waters during winter time where water temperature drop below 0°C such as in the southern Gulf of St. Lawrence and coastal Newfoundland (Goddard et al. 1992).

Capelin are a major diet item of cod in several geographic areas (e.g. Newfoundland: Lilly 1991; Iceland: Magnusson and Palsson 1989; Norway: Hamre 1991). One would expect, therefore, that the resident cod stock on the eastern Scotian Shelf would benefit from the influx of new and abundant prey. Indirect evidence suggests that this has not occurred. Instead, cod abundance has declined dramatically and weight at age (an index of condition) shows a temporal decline since the mid-1980s (Frank et al. submitted). This situation can be attributed, in part, to excessive exploitation but we cannot rule out concurrent effects due to changes in the physical environment.

Finally, the question of how long capelin will persist on the eastern Scotian Shelf remains. Given the recent warming of the some of the deep basins in and around the Scotian Shelf (Cabot Strait and Emerald Basin) due to presumed changes in the slope water characteristics (see Drinkwater 1993) it is entirely possible that the capelin population will shortly dissappear. The mechanism(s) associated with such a disappearance is, however, as unapparent as their mode of establishment.

ACKNOWLEDGEMENTS

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Table 1. Near-bottom, stratum mean temperature anomalies from NAFO Div. 4VW between 1982 and 1992. Data collected during July research vessel survey of the Scotian Shelf. Key to cell entries are + : anomaly ≥ 0.45°C; - : anomaly ≤ -0.45°C; 0 : anomaly between -0.44 and 0.44. Baseline for long-term mean was 1970 to 1990.

Div.	Year	82	83	84	85	86	87	88	89	90	91	92
	40	0	-	0	0	0	-	0	0	0	0	0
4Vn	41	+	-	+	+	0	-	0	-	-	-	-
	42	0	0	0	-	-	-	+	-	-	0	-
	44	-	0	+	0	0	-	0	-	-	-	-
	46	0	-	+	+	+	0	0	0	-	0	0
	47	+	+	+	+	-	-	0	-	-	-	-
	48	0	0	+	0	0	-	0	-	-	-	-
4Vs	49	-	+	+	-	+	-	+	-	-	-	-
	50	-	-	+	-	+	-	0	-	-	-	0
	51	-	0	+	-	+	-	+	0	-	-	+
	52	-	-	+	+	0	-	+	-	-	0	+
	53	0	-	0	+	+	0	-	0	+	-	0
	54	-	0	+	+	+	-	-	+	-	-	0
	55	-	0	+	0	0	0	0	-	-	-	-
	56	-	-	+	-	+	+	0	-	-	+	-
	57	-	0	+	+	-	-	0	-	-	-	-
	58	-	-	+	-	+	-	+	-	+	-	-
	59	0	-	+	-	+	-	-	0	-	-	-
4W	60,	-	+	0	+	+	0	-	-	0	0	0
	61	-	0	0	+	+	+	-	0	+	0	0
	62	-	0	0	+	+	0	0	0	-	0	-
	63	-	+	0	+	-	-	-	0	+	+	0
	64	-	-	+		+	-	0	-	-	-	-
	65	-	-	+	+	+	-	0	0	0	-	+
	66	-	-	+		+	0	+	0	+	+	0

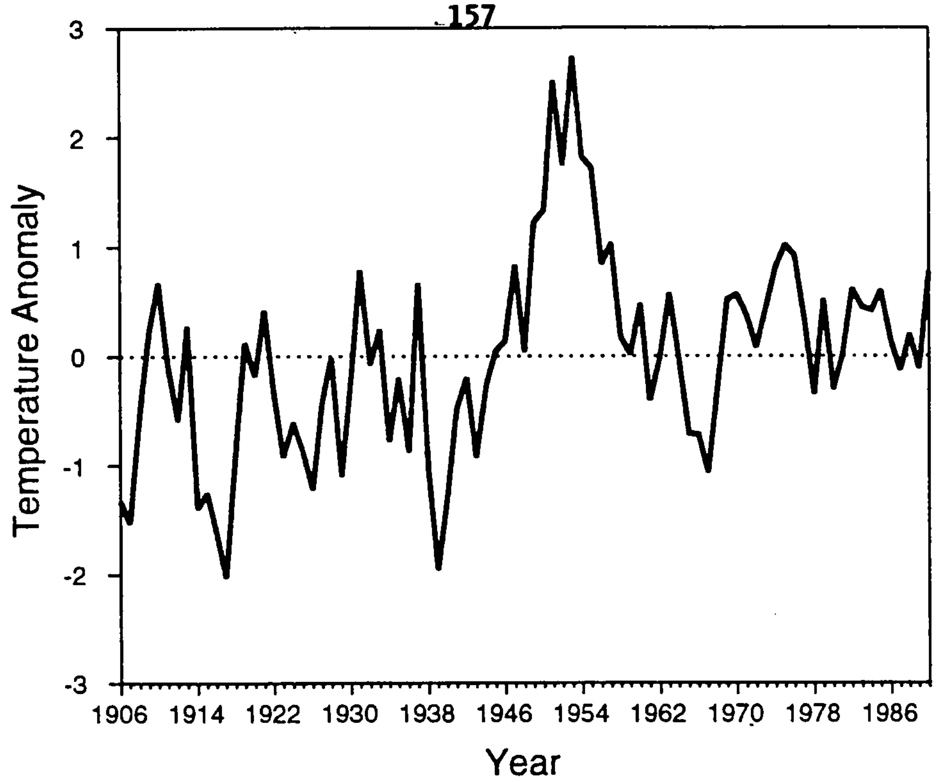


Figure 1. Annual mean sea surface temperature anomalies from Boothbay Harbor, Maine. Long-term annual mean temperature calculated for the period 1906-1990. This data series is generally representative of the low frequency temperature trends across the Gulf of Maine and Scotian Shelf (Petrie and Drinkwater 1993).

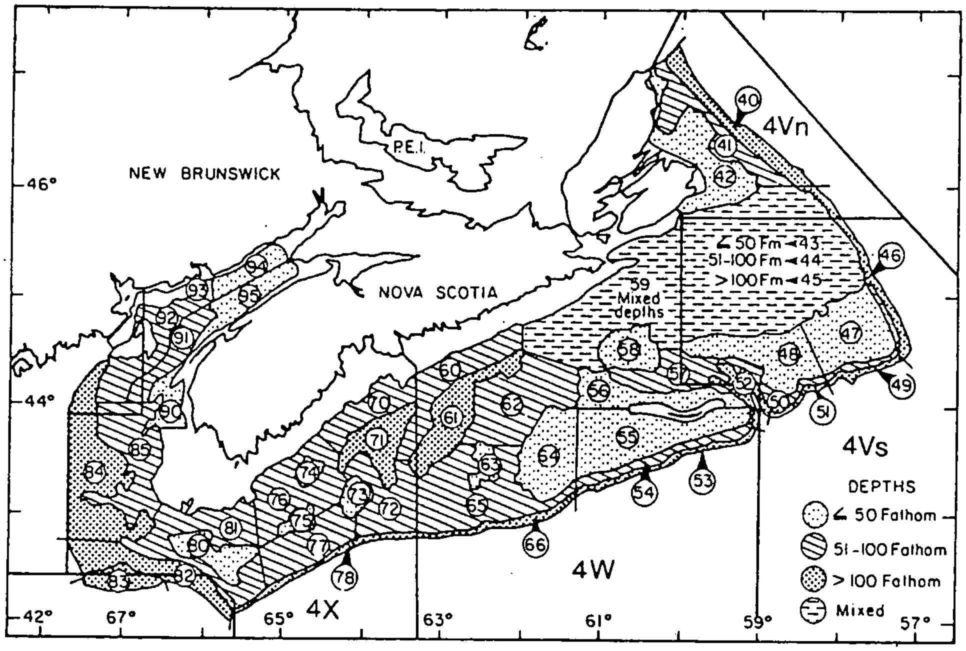


Figure 2. Depth stratification scheme used for annual groundfish surveys of the Scotian Shelf. NAFO Div. 4Vn includes strata 40-42, Div. 4Vs includes strata 43-52, Div. 4W includes strata 53-66, and Div. 4X includes strata 70-95.

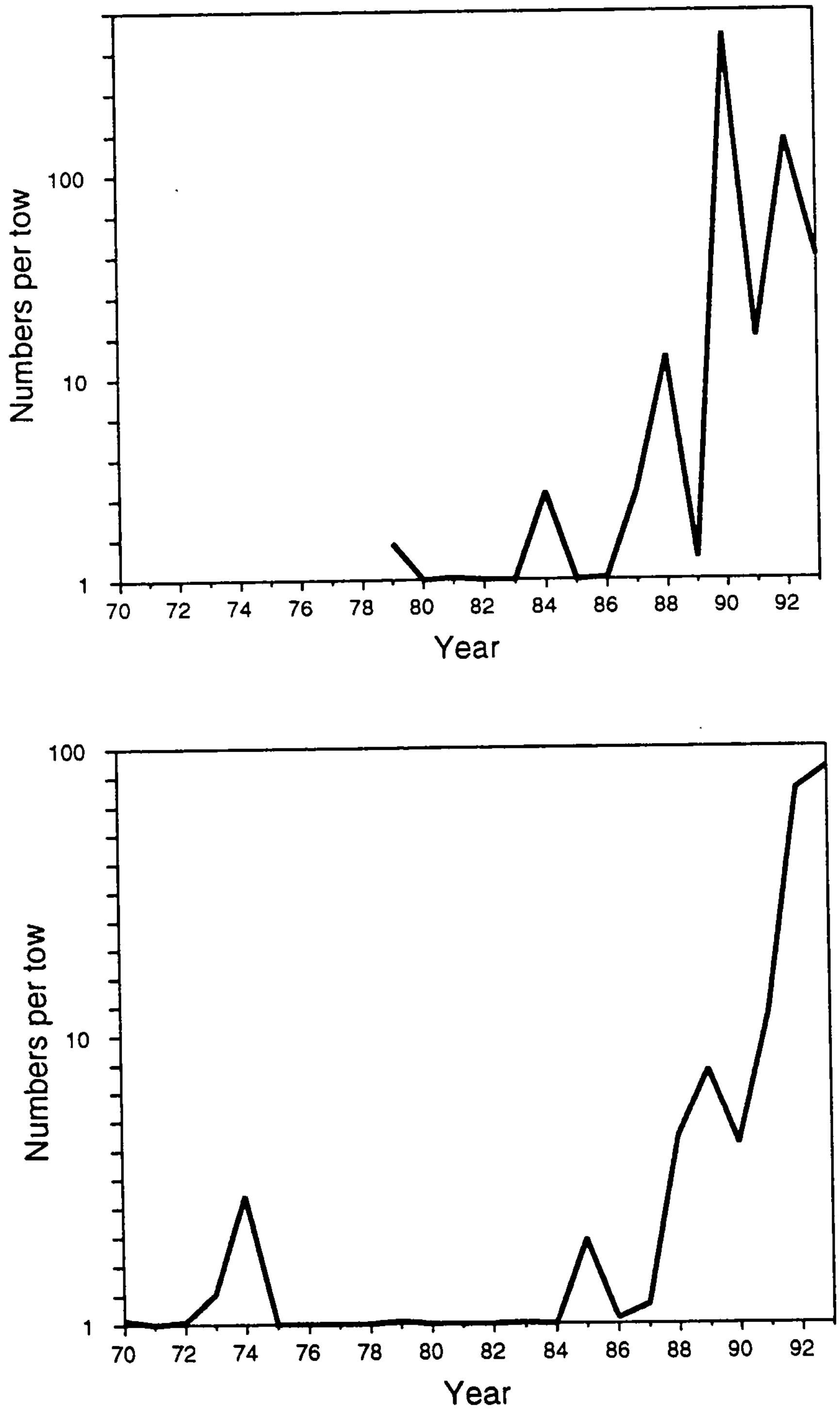
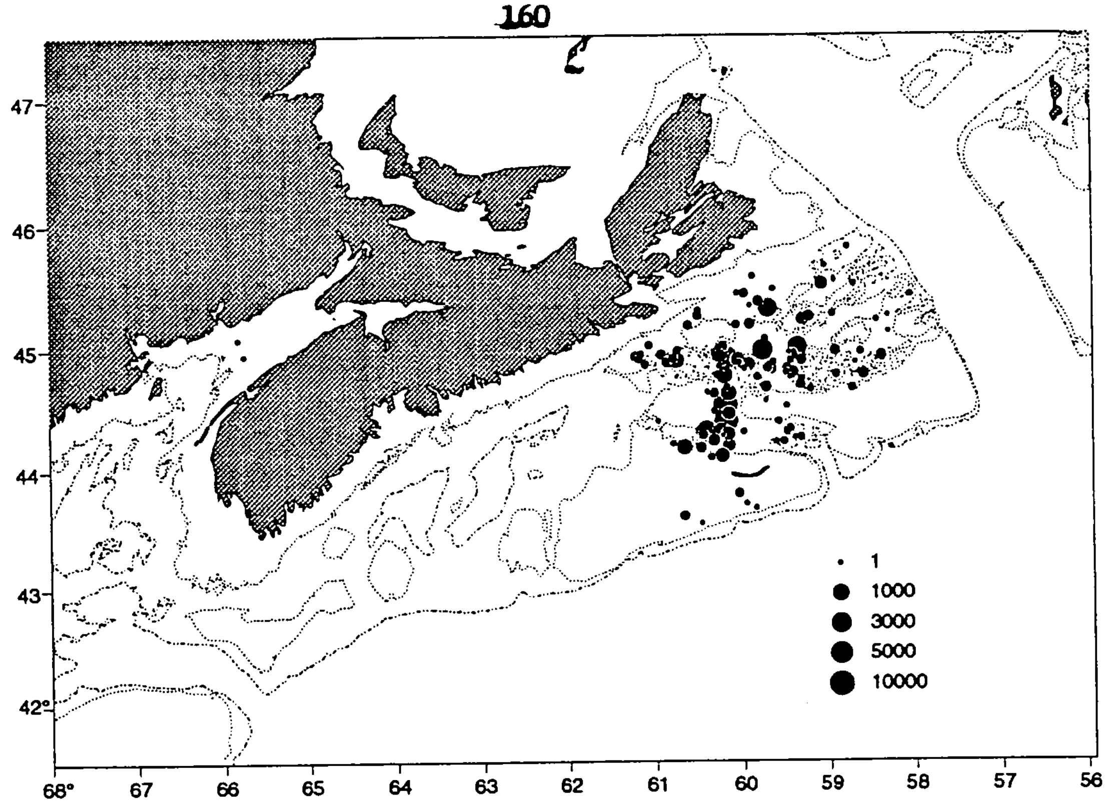


Figure 3. Mean numbers per tow of capelin for Div. 4VW during spring (A) and summer (B) RV surveys. Note that these catch rates represent only the eastern half of the Scotian Shelf because generally no capelin were collected in Div. 4X.



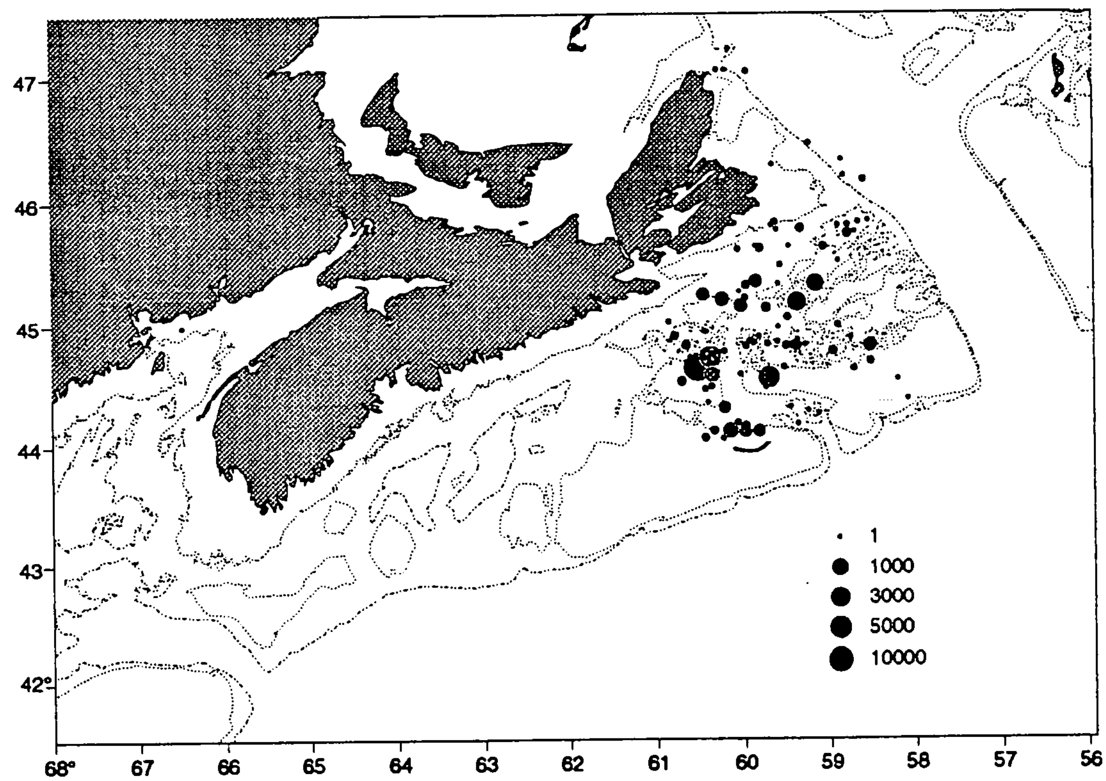


Figure 4. Geographic distribution of capelin on the Scotian Shelf depicted as expanding symbols of capelin catch per tow from the spring (A) and summer (B) RV surveys for all years combined. Note that the spring RV survey did not include Div. 4X.

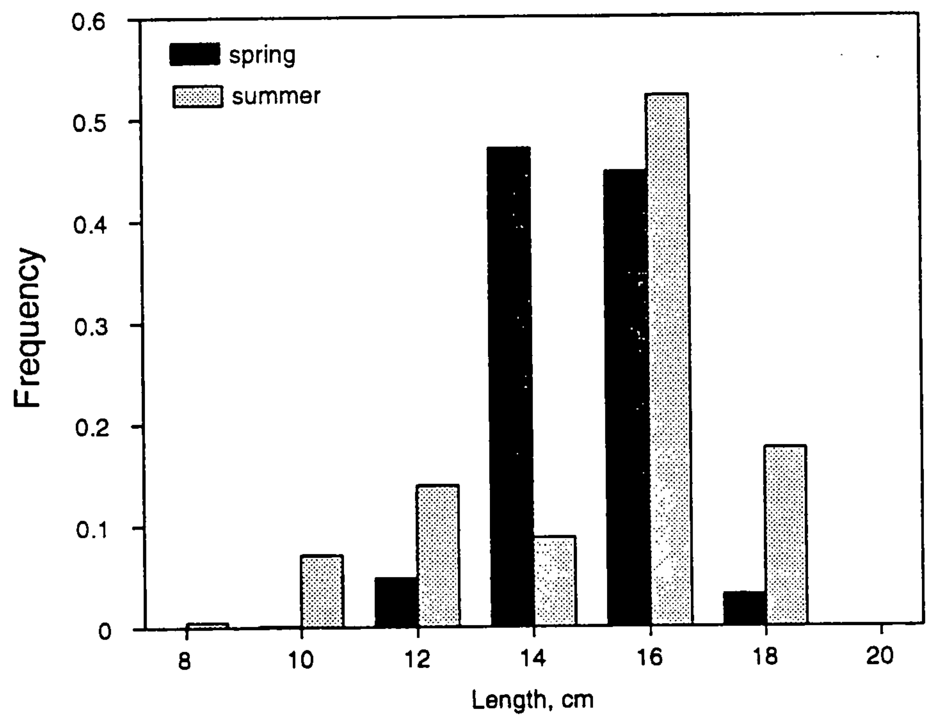


Figure 5. Length frequency distribution of capelin for all spring and summer RV surveys combined.

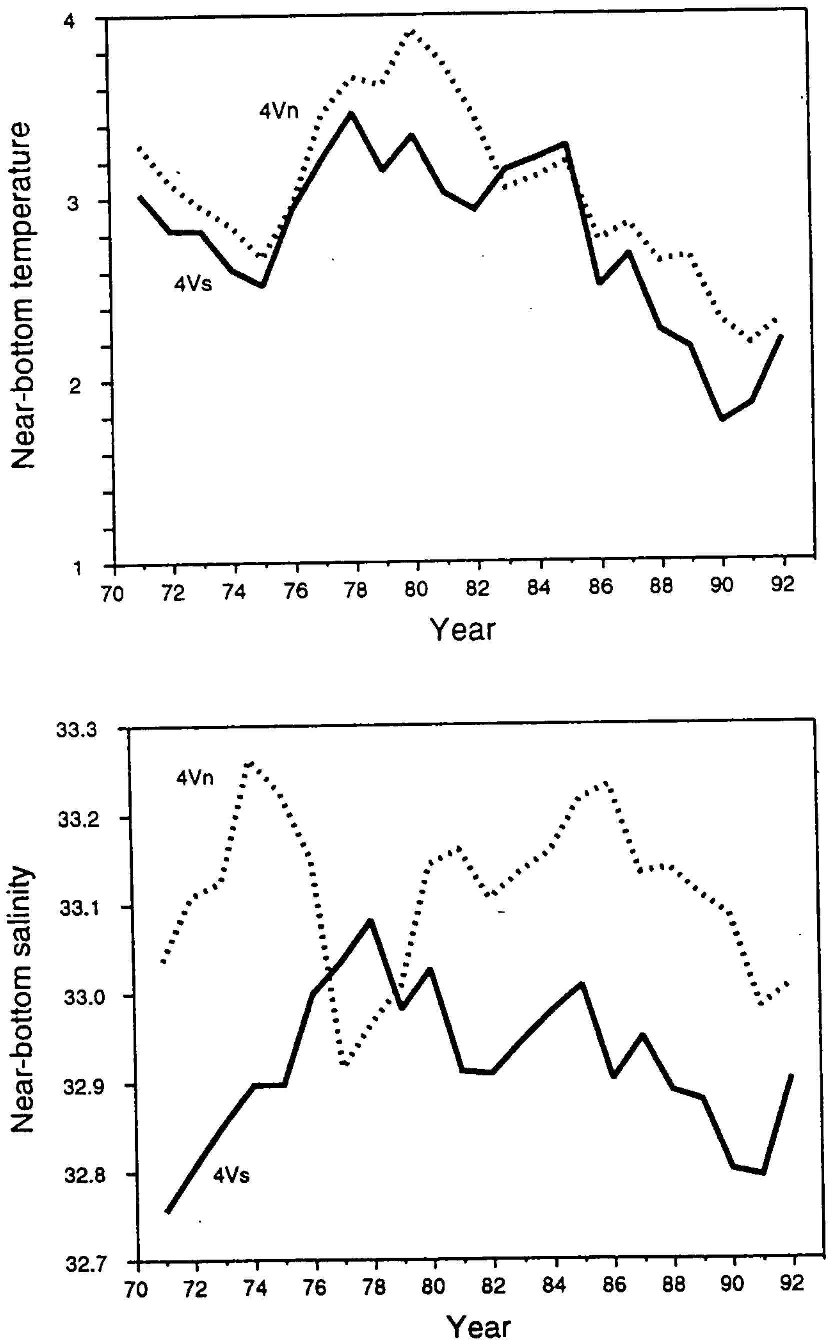
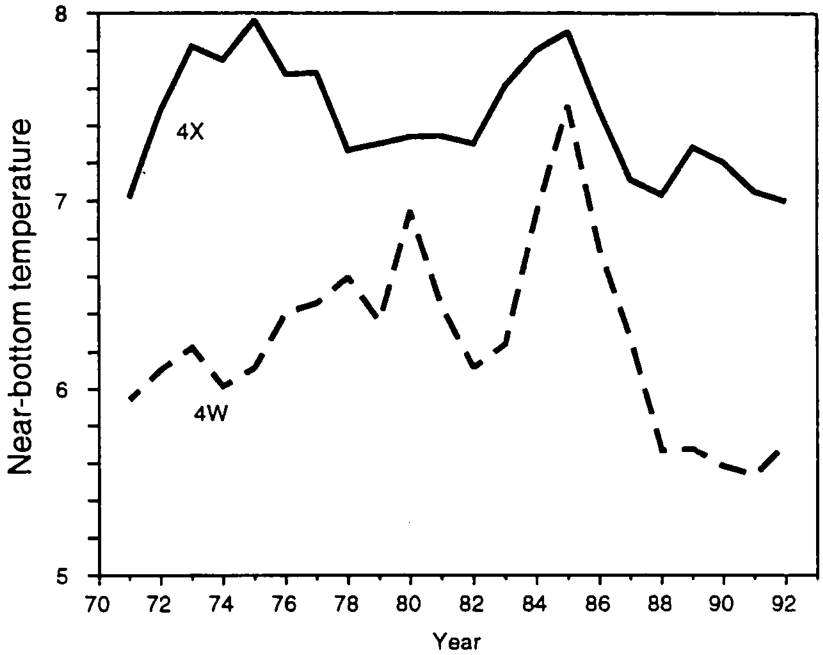


Figure 6. Average, near-bottom temperature and salinity time series from the summer RV survey in Div. 4Vn and 4Vs. Data were smoothed using a three year running mean.



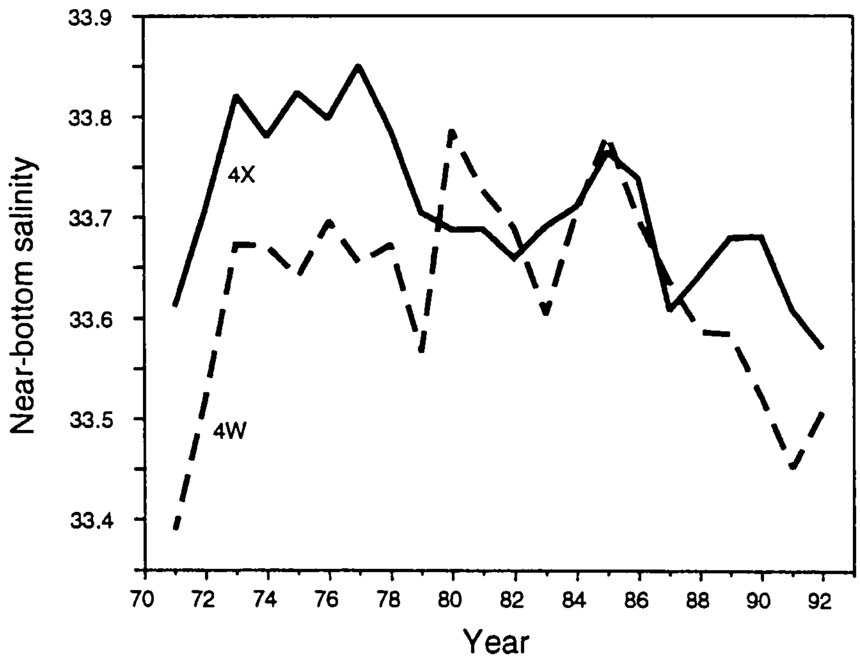


Figure 7. Average, near-bottom temperature and salinity time series from the summer RV survey in Div. 4W and 4X. Data was smoothed using a three year running mean.

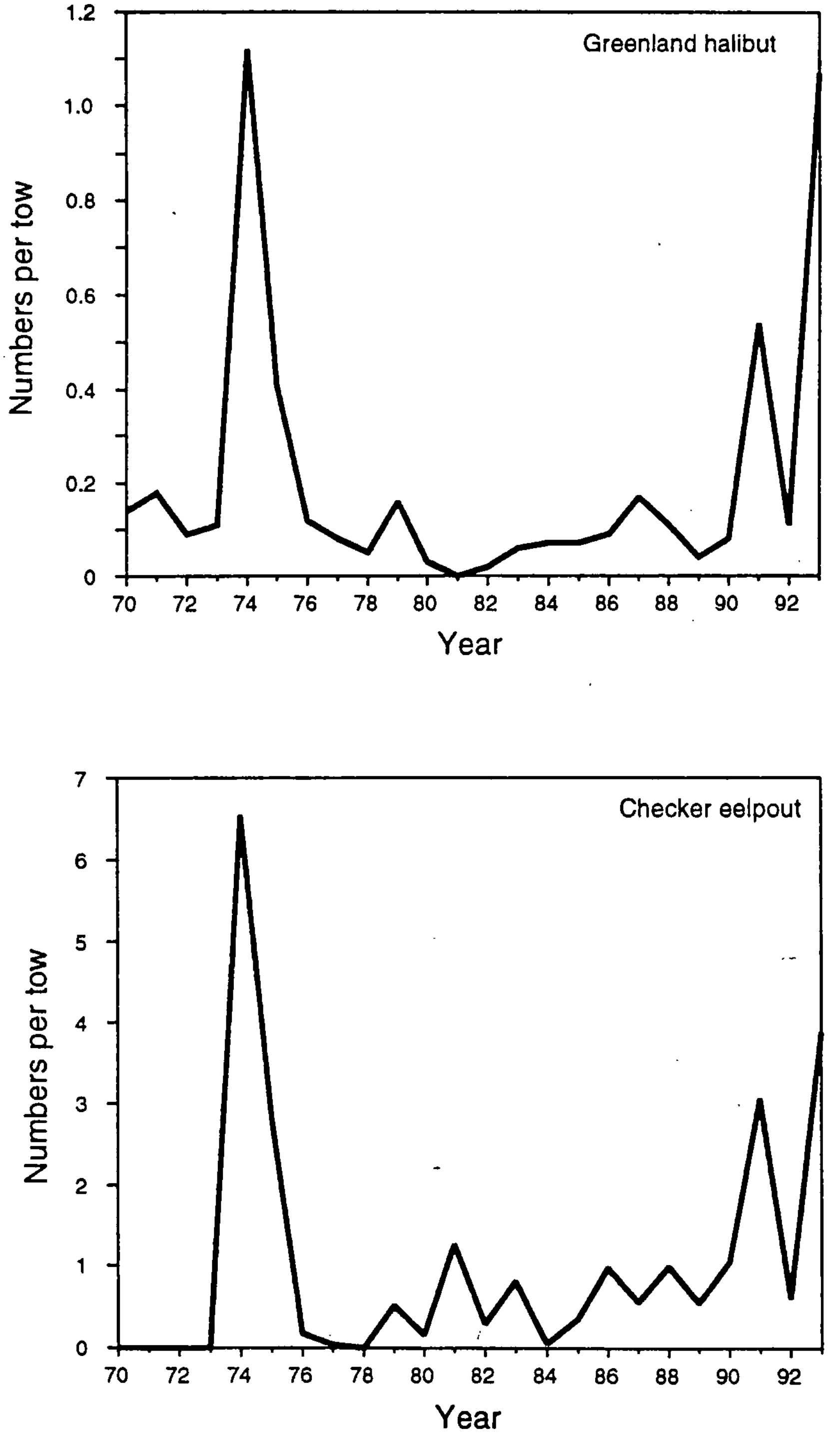


Figure 8. Mean numbers per tow of Greenland halibut and Checker eelpout for Div. 4Vw during summer RV surveys of the Scotian Shelf.