Results of the 1998 Aerial Survey of Capelin (Mallotus villosus) Schools

by

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Introduction

Area estimates of capelin (Mallotus villosus) schools conducted since 1982 have been used as an index of inshore abundance of mature capelin in NAFO Div. 3L (eg. Nakashima 1996). From 1982 to 1989 school areas were measured from aerial photographs (Nakashima 1990). From 1990 to 1996 school areas were estimated from digital imagery data collected with the Compact Airborne Spectrographic Imager (CASI) (Borstad et al. 1992, Nakashima 1997). In 1997-98 imagery was collected using a video camera. This report presents the results of the 1998 capelin aerial survey.

Materials and Methods

Instrument Operation

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

Area Calibration

Three fixed objects were identified at widely dispersed locations along the two transects. The surface area of the three targets was measured (219, 847 and 1340 m^2) and for every flight at least one target was recorded at the video camera settings and altitudes flown to collect that flight's data.

Survey Method

Particulars of previous aerial surveys including aircraft type, equipment used, survey time, and altitudes flown are listed in Table 1. The optimal altitude for video surveys was 610 m (3000') which was largely governed by the resolution of the videocamera. Flights were limited to early morning and early evening hours similar to conditions imposed by aerial photography. At this altitude maintaining a flight line was more problematic on poor weather days due to turbulence and to local fog conditions. The survey covered two transects as often as possible; the inside of Trinity Bay from Masters Head to Hopeall Head and the inside of Conception Bay from Bryant's Cove to Portugal Cove (Fig. 1). The survey is limited to the inner portions of two bays, covering only a small portion of the coastal habitat occupied by mature capelin schools.

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

Analytical Methods

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

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

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

Aerial/Acoustic Experiment

Approximately 7 hours spread out over 5 days were used to collect aerial/acoustic data of schools in the Bellevue-Chance Cove area. Using hand held marine VHF units the aircraft and acoustic vessel coordinated runs over the same capelin schools. In some instances multiple estimates of surface area were made of the same school.

Results and Discussion

In 1998, the aerial survey provided frequent coverage of Conception Bay and Trinity Bay. Complete coverage in Trinity Bay occurred eight times (Table 2) and six times in Conception Bay (Table 3). The total number of hours flown in 1998 was comparable to 1996 and less than in 1997. The less frequent coverage in 1998 can be attributed to poorer flying conditions,low amounts of capelin observed, especially in Conception Bay, and fewer survey days. Eleven days (June 28-29, July 1-3, 5-6, 10-12, 18) were not flown because of poor weather or rough sea conditions.

In Trinity Bay the highest school area estimate was observed on July 8 which was earlier than the last three years (Table 2). The time is about 14 days before the major period (July 22-Aug. 1) of egg deposition on Bellevue Beach in 1998(Fig. 2) (Nakashima and Slaney 1999). In Conception Bay the highest total school area was observed on July 14, the same day as in 1997 (Table 3). For daily estimates prior to 1991 see Nakashima (1995). The peak estimate in Trinity Bay was higher than the long-term geometric mean of 225,516 and for Conception Bay the 1997 estimate of the inside transect was lower than the long-term geometric mean of 153,066 m^2 (Table 4, Fig. 3). Both exclude the 1991 and 1998 estimates.

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

Using school area as a relative abundance index assumes density/abundance of a school is related to its surface area. Misund et al. (1992) have shown that herring, sprat, and saithe biomasses are correlated to school area and to school volume. Multiple runs over the same school tended to yield consistent estimates of school area for a few schools in 1997 (Nakashima 1998). Acoustic/aerial estimates were made of more capelin schools in 1998. Further experients are planned to define the nature of the area vs volume relationship for spawning aggregations of capelin.

Acknowledgments

Special thanks to Gene Ploughman of Thorburn Aviation for providing the Cessna 185 at short notice and outfitting it for the video camera setup. Jed Samson, the pilot, was invaluable in completing the survey and getting so much accomplished. Digitization and school area measurements were conducted by Borstad Associates Ltd., Sidney, B.C. M. Y. Farrell assisted in the preparation of the manuscript.

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Table 1. Summary of aerial surveys.

Year	Aircraft	Camera	Survey period	Altitude (m)	Flight time hrs)
1982	Piper Aztec	RC 10	Jun 18-Jul 5	150-160	?
1983	Aero-Commander RC 10	Wild	Jun 19-Jul 9	460	25.9
1984	Cessna 310 RC 10	Wild	Jun 17-Jul 7	460	38.5
1985	Aero-Commander 500 B	Wild RC 10	Jun 18-Jul 3	290-610	28.6
1986	Aero-Commander 500 B	Wild RC 10	Jun 19-Jul 5	380-580	13.4
1987	Piper Aztec RMK	Zeiss	Jun 16-Jul 3	460	37.0
1988	Piper Navajo Piper Aztec	Zeiss RMK	Jun 15-Jul 5	305-490	33.0
1989	Piper Navajo RMK	Zeiss	Jun 16-27 Jun 30-Jul 4	435-730	26.0
1990	Piper Aztec RMK CASI	Zeiss	Jun 17-Jul 6	570-1260	27.0
1991	Piper Navajo	CASI	Jun 21-25 Jul 3-17	1220	27.3
1992	Cessna 185	CASI	Jun 21-Jul 14	275-1280	34.6
1993	De Havilland Beaver	CASI	Jun 30-Jul 16 Jul 19-22 Jul 26-28	365-1220	46.2
1994	De Havilland Beaver	CASI	Jul 2, 7-19 Jul 24-27 Aug 2-4	1220	43.8
1995	De Havilland Beaver	CASI	Jul 5-21, Jul 27-29	915-1340	42.4
1996	de Havilland Beaver	CASI	Jun 25-Jul 9, Jul 13-16	1060-1260	22.6
1997	Cessna 185	SONY CCD-TR500 HANDYCAM	Jun 29-Jul 24	610-975	41.7
1998	Cessna 185	SONY CCD-TR500	Jun 28-Jul 18	455-970	22.6

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

Date		No. of schools	Surface total area (m^2)	School size (m^2) Mean	SD	Median	Survey time (hr)
1991	Jun 23	0	0				1.6
	Jun 24	0	0				1.1
	Jul 5	139	170681	1228	1827	535	2.5
	Jul 14	54	64598	1196	1894	567	1.4
	Jul 16	33	93680	2839	5562	800	1.3
1992	Jun 25	29	40836	1408	1591	1078	1.4
	Jun 29	71	97424	1372	1510	679	1.4
	Jul 6	70	97565	1394	4273	267	2.3
	Jul 8	124	173219	1397	3862	370	2.7
	Jul 13	50	67889	1358	4008	263	1.7
1993	Jul 3	27	CASI data unavailable				1.5
	Jul 12	31	30502	1006	1747[a]	515	1.3
	Jul 14	14	58786	4199	2847	3976	1.1
	Jul 21	22	9760	451	611[a]	260	0.9
1994	Jul 2	0	0				0.3
	Jul 7	14	4311	308	408	220	1.1
	Jul 9	39	65179	1671	2081	846	1.6
	Jul 13	79	522964	6620	18249	577	1.8
	Jul 15	77	539207	7003	24606	706	1.6
	Jul 17	66	377255	5716	18303	1221	1.5
	Jul 19	57	296029	5193	19751	511	1.6
	Aug 2	9	16240	1804	1577	1115	1.0
1995	Jul 8		Transect coverage incomplete				1.0
	Jul 11	39	80225	2057	2575	1045	2.4
	Jul 13	73	(150198)[b]	2058	4700	503	2.7
	Jul 15	184	330010	1794	4751	514	2.5
	Jul 18	59	62737	1063	2955	318	1.1
	Jul 29	8	4460	558	444	492	1.0
1996	Jun 25	28	CASI unavailable				0.8
	Jul 8	119	478888	4024	14210	1000	2.0
	Jul 13	109	562977	5165	11268	1519	2.3
	Jul 15	50	98292	1966	2230	1382	2.8
1997	Jul 6	71	93393	1315	2398	424	1.4
	Jul 7	97	213060	2196	8131	388	1.1
	Jul 8	118	309246	2621	10044	313	1.8
	Jul 10	68	234180	3444	9862	625	1.4
	Jul 12	91	383255	4212	16694	484	1.3
	Jul 13/14	84	384610	4637	9026	1004	1.6
	Jul 17	88	310544	3529	16242	487	1.7
	Jul 19	39	165912	4254	4197	2853	1.0
	Jul 22	73	119727	1640	2611	713	1.3
1998	Jun 30	9	2069	230	224	128	1.3
	Jul 4	86	151603	1763	2135	778	1.6
	Jul 7	56	201565	3599	12587	692	1.5
	Jul 8	82	310569	3787	17254	512	1.2
	Jul 9	52	142609	2742	9735	796	1.5
	Jul 13	117	278876	2384	6745	573	2.4
	Jul 15	50	83342	1667	2249	631	2.3
	Jul 16	43	102412	2382	7165	468	1.8

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

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

	Date	No. of schools	Surface total area (m^2)	School size (m^2) Mean	SD	Median	Survey time (hr)
1991	Jul 8		Few schools observed - no CASI data				1.1
	Jul 11	56	15577	278	359	124	1.2
	Jul 17	8	8453	1057	531	875	1.1
1992	Jun 24	8	4772	597	328	468	0.9
	Jun 27	7	11726	1675	3478	133	0.4
	Jul 5	12	24263	2708	2880	2143	1.1
	Jul 6	23	10775	468	620	272	1.7
	Jul 9	30	45748	1525	1865	792	1.3
	Jul 13	63	148629	2359	3294	981	1.0
	Jul 14	143	350988	2454	6098	751	2.6
1993	Jul 2	16	CASI data unavailable				1.9
	Jul 4	45	CASI data unavailable				2.3
	Jul 11	60	102645	1867	4904[a]	440	2.0
	Jul 13	53	44184	910	1247[a]	455	1.7
	Jul 15	18	9670	551	681[a]	323	1.7
	Jul 20	73	69246	984	1357[a]	385	2.5
	Jul 21	72	98938	1390	3678	309	1.9
	Jul 27	69	198968	2884	5960	587	1.6
	Jul 28	35	41844	1196	1521	546	1.2
1994	Jul 2	5	CASI data unavailable				0.5
	Jul 7	9	11368	1263	1614	378	1.6
	Jul 9-10	16	79949	4997	10291	1609	1.8
	Jul 12-13	67	98926	1476	2607	333	1.7
	Jul 14	13	17110	1316	1624	416	1.3
	Jul 15	8	8678	1085	1089	868	0.7
	Jul 16	23	40575	1764	4753	576	1.0
	Jul 18	35	61500	1757	2294	1176	1.6
	Jul 26	0	0				0.9
	Aug 3	0	0				
1995	Jul 5	18	12242	680	813	337	1.1
	Jul 8	47	180070	3831	8506	1051	2.9
	Jul 12	5	717	143	59	120	1.5
	Jul 15	13	56285	4330	5147	1389	1.5
	Jul 21	75	51352	685	1161	284	2.8
	Jul 28	65	64918	999	2539	272	1.8
1996	Jun 25	12	CASI unavailable				0.8
	Jul 8-9	120	196509	1605	2829[a]	742	1.7
	Jul 13	8	12533	1567	1368	1002	1.6
1997	Jul 3	1	772	772	-	772	1.3
	Jul 7	0	0				1.0
	Jul 9	4	1572	393	204	429	1.1
	Jul 12	69	134150	1944	2470	898	1.5
	Jul 14	93	159485	1715	3298	341	1.7
	Jul 18	56	58898	1052	1888	518	1.7
	Jul 22	11	28296	2572	2718	1250	1.3
1998	Jun 30	1	1590	1590		1590	1.2
	Jul 4	5	5486	1097	1003	537	1.5
	Jul 8	13	5928	456	511	271	1.5
	Jul 9	25	22575	903	1084	563	1.4
	Jul 14	52	109021	2097	6152	973	1.7
	Jul 17	25	47154	1886	3409	801	1.7

[a] calculation excludes capelin in traps

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

Year	Trinity Bay	Inner Conception Bay	Outer Conception Bay
1982	62,397	151,214	6,577
1983	199,373	97,595	51,838
1984	43,245	63,891	65,956
1985	195,659	43,228	69,166
1986	95,898	31,574	132,455
1987	399,026	205,846	184,307
1988	112,863	201,642	87,534
1989	84,349	187,311	266,878
1990	141,122	128,743	88,759
1991	(170,681)[a]	(15,577)[a]	(6,374)[a]
1992	173,219	350,988	225,838
1993	58,786[b]	198,968	77,202
1994	539,207	98,926	28,339
1995	330,010	180,070	126,670
1996	562,977	196,509	77,650
1997	384,610	159,485	-
1998	310,569	109,021	-

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

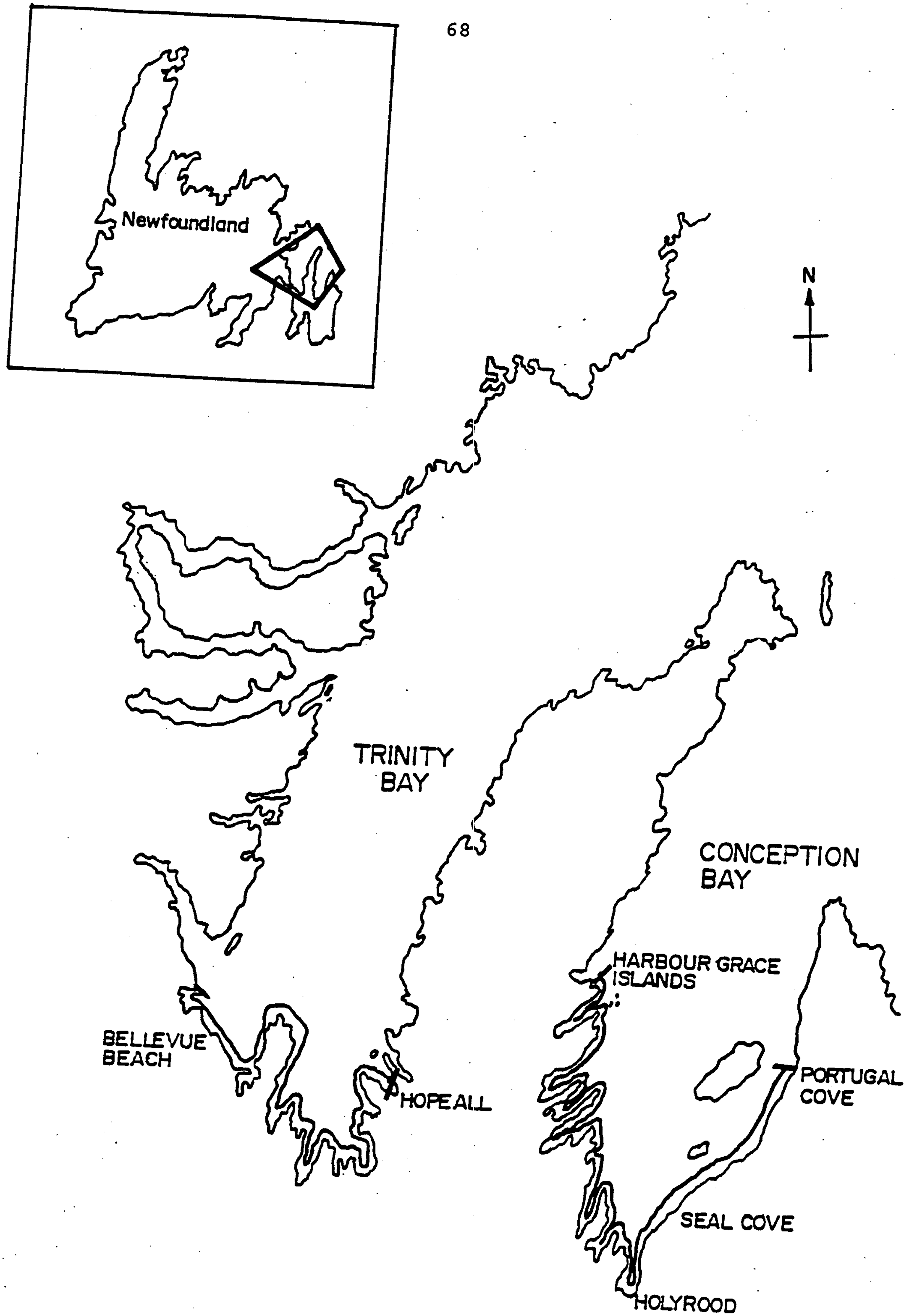

Fig. 1. Transects flown during the aerial survey.

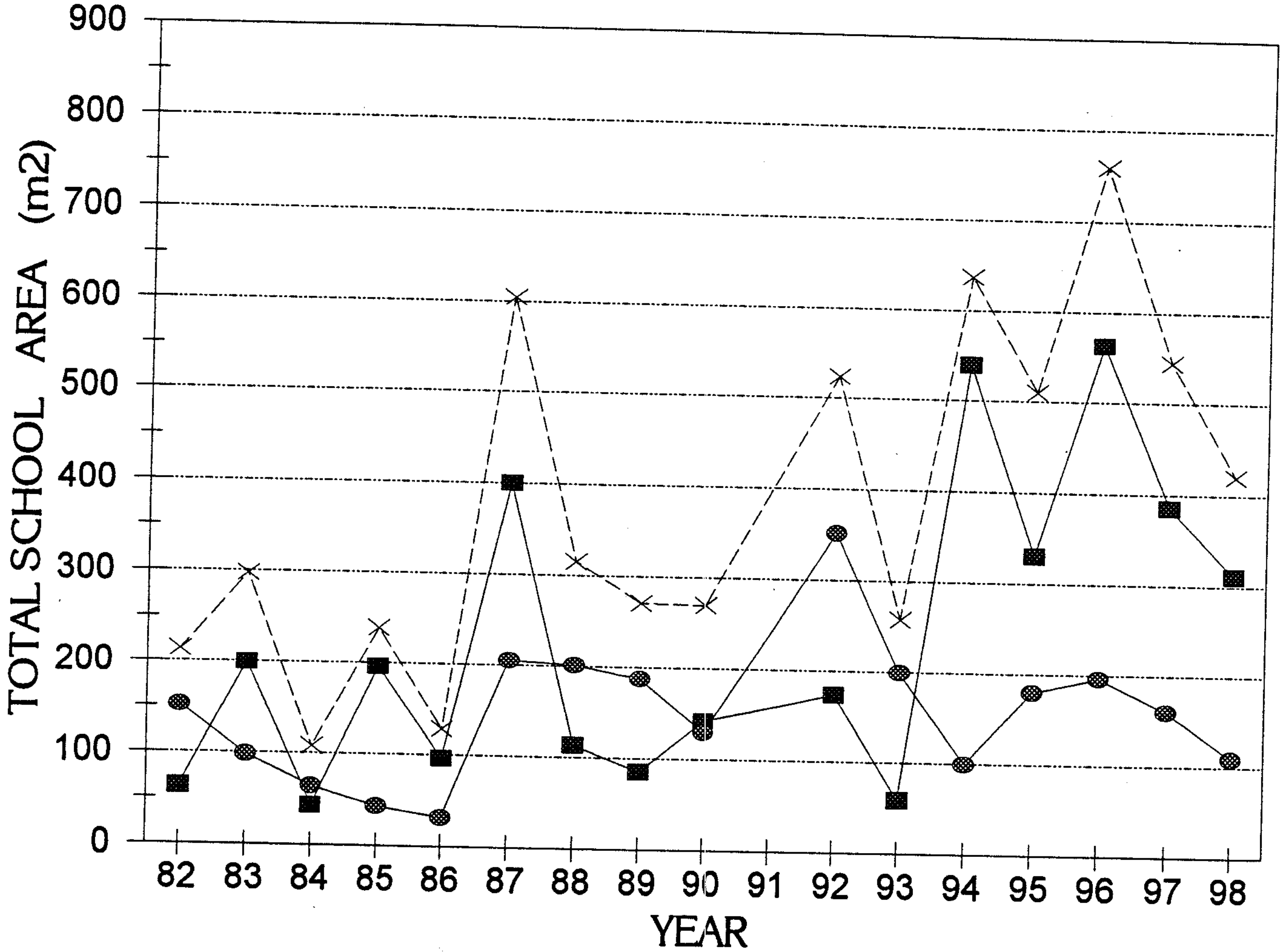

Fig. 3. Annual trends in school surface area for Trinity Bay (squares), Conception Bay (circles), and the two transects combined (X).

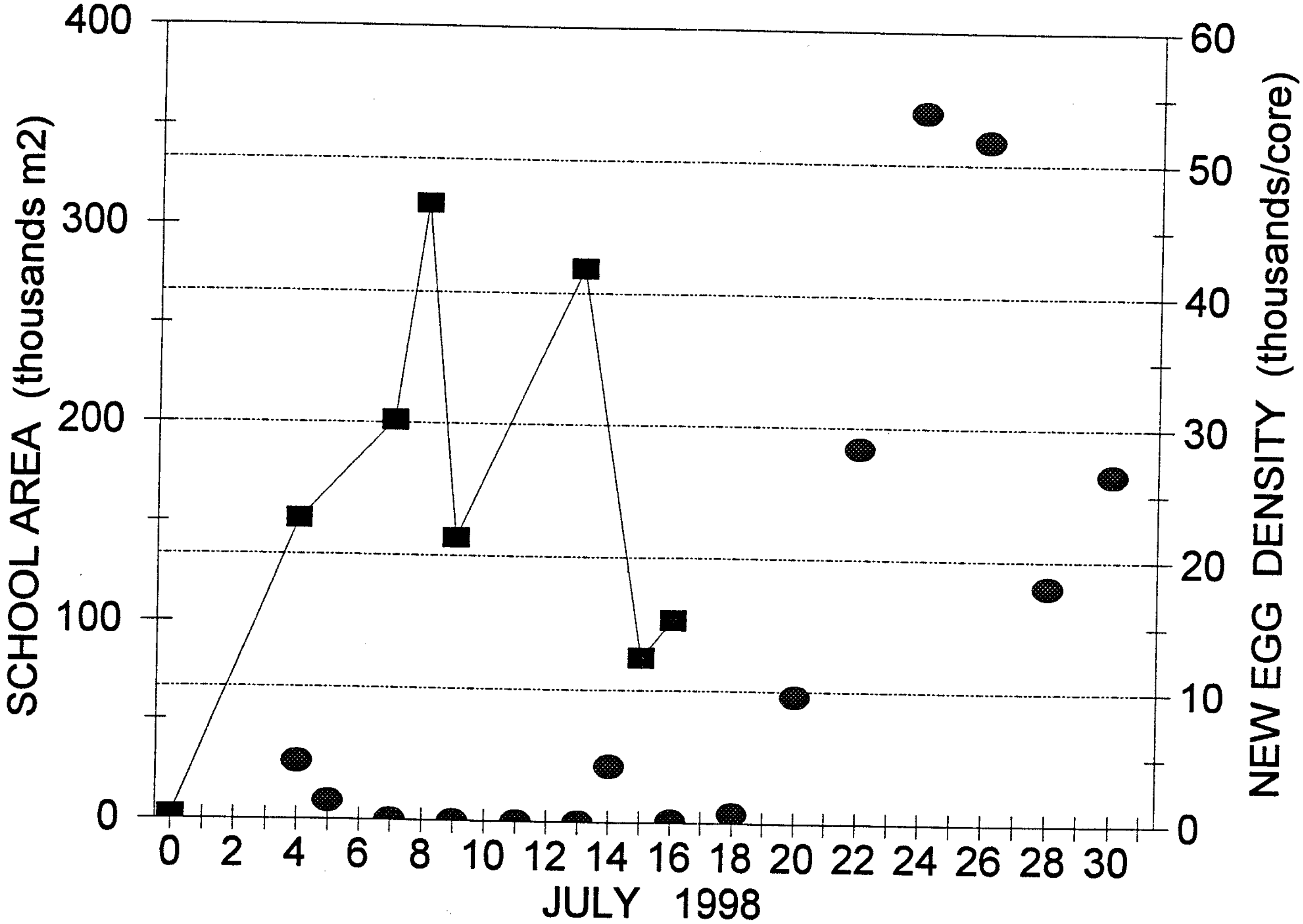

Fig. 2. Daily pattern of school areas in Trinity Bay (squares) and egg deposition at Bellevue Beach (circles) in July 1998.

Chapter 4

Spawning and Early Development of Capelin (*Mallotus villosus*) from Bellevue Beach, Trinity Bay in 1998

by

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Introduction

In 1990 we began to monitor spawning times, egg deposition and development, larval emergence and various environmental variables (eg. sunlight hours, wind direction and speed, air temperature, water temperature, precipitation, beach sediment temperatures, beach disturbance) on two capelin spawning beaches located at Arnold's Cove in Div. 3Ps and at Bellevue Beach in Div. 3L (Fig. 1). The number of sites was expanded in 1991 to include five additional beaches at Chapels Cove, Eastport, Cape Freels, Twillingate, and Hampden in Div. 3KL (Fig. 1). In 1995 Chapels Cove and Bellevue Beach were sampled. Information from these other sites can be found in Nakashima and Winters (1997). Since 1996 Bellevue Beach has been the only monitored site. In this report we present information on age, length, and weight of spawners, spawning times, egg densities, and pre-emergent and emergent larval estimates from Bellevue Beach in Div. 3L. The approach differs from past reports that presented data from all sites monitored in Div. 3KL (e.g. Nakashima et al 1998).

Materials and Methods

Adult Samples

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

Egg and Larval Sampling

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

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

Newly emerging larvae were collected in the intertidal zone at high tide conditions generally twice a day. A 165 um plankton net was towed for 40 m parallel to the beach, rinsed, and the contents preserved in 4% formalin and seawater solution buffered with sodium borate. Two tows were conducted each time but only one sample was counted. Larvae were categorized as in 'good' or 'bad' condition based on visual inspection. Larval density was expressed as larvae per m3.

Trapezoidal Integration

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

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

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

Egg and Larval Densities

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

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

The daily average density of emergent larvae was assumed to be the mean of the two high tide estimates. Total larval density per m^3 was then estimated using the trapezoidal integration method.

Results and Discussion

Spawner Characteristics

Age compositions of spawning fish from 1990 to 1998 were dominated by age 3 fish in all years except 1992 when age 4's were most abundant (Table 1). Our age composition data show that the 1998 spawning population consisted mainly of the 1995 yearclass (66%) followed by the 1994 yearclass (17%). The proportion of age 2 fish is considerably higher for females than for males. The 1997 yearclass with sexes combined as age 2 represented 14% of the overall mature population spawning in the vicinity of Bellevue Beach (Table 1).

Mean weights and lengths of females and males and the population in general are presented in Table 2.

Spawning Time

The extent and timing of the spawning period in 1998 was similar to 1991 and 1992 and earlier than in 1997 (Table 3). However, most of the eggs had been deposited by July 23 in 1997

(Fig. 3: Nakashima et al 1998) compared to a later time in 1998(Fig. 2).

Egg Density

One major spawning mode was observed in late July (July 21-31) (Fig. 2) with a few small modes on either side. Egg densities on Bellevue Beach were the highest in the series (Table 3). This suggests for this area the mature population spawning on the beach sediment was considerably higher than in 1997.

Pre-emergent Larval Estimates

The majority of pre-emergent larvae observed in beach sediments at Bellevue Beach in 1998 occurred July 31-Aug. 4 and Aug. 12-20 (Fig. 3). The density of pre-emergent larvae was the lowest in the series (Table 3). This implies that the 1998 year class is the weakest one produced at Bellevue Beach in the 1990s.

Emergent Larvae

Emergent larval densities were very low in 1998 with one distinct peak on August 12 at night (Fig. 4). Similar to the pre-emergent larvae the results indicate the 1998 year-class is the weakest in the series and comparable to the 1991 year-class (Table 3).

Summary

The results suggest that there was a high mortality of eggs in Bellevue Beach sediments in 1998 resulting in low densities of pre-emergent larvae. This also affected the potential production of emergent larvae. When evaluating eggs for development staging we noticed a higher proportion of opaque and abnormal eggs in the samples than in recent years.

Acknowledgements

Pelagic Fish Section staff and summer students collected the field data. Core and emergence samples were processed by C. Coady, J. Croft, and A. Powell. Eggs were counted by D. Joy and S. Flynn. R. Clarke, Chance Cove collected capelin samples throughout the spawning season and performed frequent CTD casts. M. Y. Farrell assisted in the preparation of the manuscript.

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Table 1. Age composition by numbers for mature capelin from Bellevue Beach, Trinity Bay combined. In 1990 only females were sampled.

Sex	Year	Age 2	3	4	5	6	Sample size
M	1991	9.7	40.3	45.0	5.0	0	300
	1992	3.5	30.0	58.0	8.5	0	200
	1993	1.0	68.0	29.0	2.0	0	300
	1994	9.3	56.5	28.8	5.1	0.3	375
	1995	7.3	54.0	27.4	11.0	0.3	328
	1996	4.4	67.6	26.5	1.3	0.3	321
	1997	5.3	48.5	37.7	8.0	0.6	324
	1998	2.0	74.8	20.2	3.0	0	396
F	1990	4.9	49.8	42.1	3.2	0	247
	1991	15.1	45.8	31.5	7.1	0.4	238
	1992	10.0	37.0	44.0	8.5	0.5	200
	1993	11.0	70.0	17.3	1.7	0	300
	1994	17.9	49.9	24.3	7.7	0.3	375
	1995	24.5	55.0	12.7	7.9	0	229
	1996	14.2	61.3	21.8	2.1	0.7	289
	1997	14.5	49.4	26.2	9.3	0.6	324
	1998	26.6	56.1	14.4	3.0	0	369
Combine	1991	12.1	42.8	39.0	6.0	0.2	
	1992	6.8	33.5	51.0	8.5	0.3	
	1993	6.0	69.0	23.2	1.8	0	
	1994	13.6	53.2	26.5	6.4	0.3	
	1995	14.4	54.4	21.4	9.7	0.2	
	1996	9.0	64.6	24.3	1.6	0.5	
	1997	9.9	48.9	31.9	8.6	0.6	
	1998	13.9	65.8	17.4	3.0	0	

Table 2. Mean weights (W in gms) and mean lengths (L in mm) of males, females and sexes combined from samples of spawners collected at Bellevue Beach.

Year	Males		Females		Sample	
	W	L	W	L	W	L
1990	-	-	24.9	160	-	-
1991	31.8	173	20.4	156	26.7	165
1992	25.2	165	17.2	150	21.2	158
1993	27.5	167	17.5	150	22.5	159
1994	26.0	167	18.6	153	22.3	160
1995	24.3	161	14.8	141	20.4	153
1996	28.2	169	18.5	154	23.6	162
1997	24.6	163	18.1	149	21.4	156
1998	25.5	165	16.5	149	21.2	157

Table 3. Annual estimates derived from trapezoidal integration of egg deposition, pre-emergent larvae, and emergent larvae and range of spawning dates for Bellevue Beach, Trinity Bay.

Year	Egg deposition Stages I-II eggs ('000 eggs/core)	Pre-emergent Larvae ('000 larvae/core)	Emergent larvae ('000 larvae/m^3)	Spawning Dates (Julian Day)
1990	92.2	26.2	212.1	175-207
1991	242.2	9.0	60.5	185-234
1992	261.7	18.3	192.5	185-232
1993	337.6	27.1[a]	175.3[b]	182-242
1994	192.5	17.4	109.8	180-217
1995	153.8	20.9	140.1	192-218
1996	243.3	15.2	93.6	178-215
1997	263.5	21.5	-	191-224
1998	452.6	6.2	45.0	183-228

[a] Adjusted to account for sampling stopped before all eggs had hatched. Unadjusted estimate was 17.2.

[b] Adjusted to account for sampling stopped before all larvae had emerged from sediments. Unadjusted estimate was 111.0.

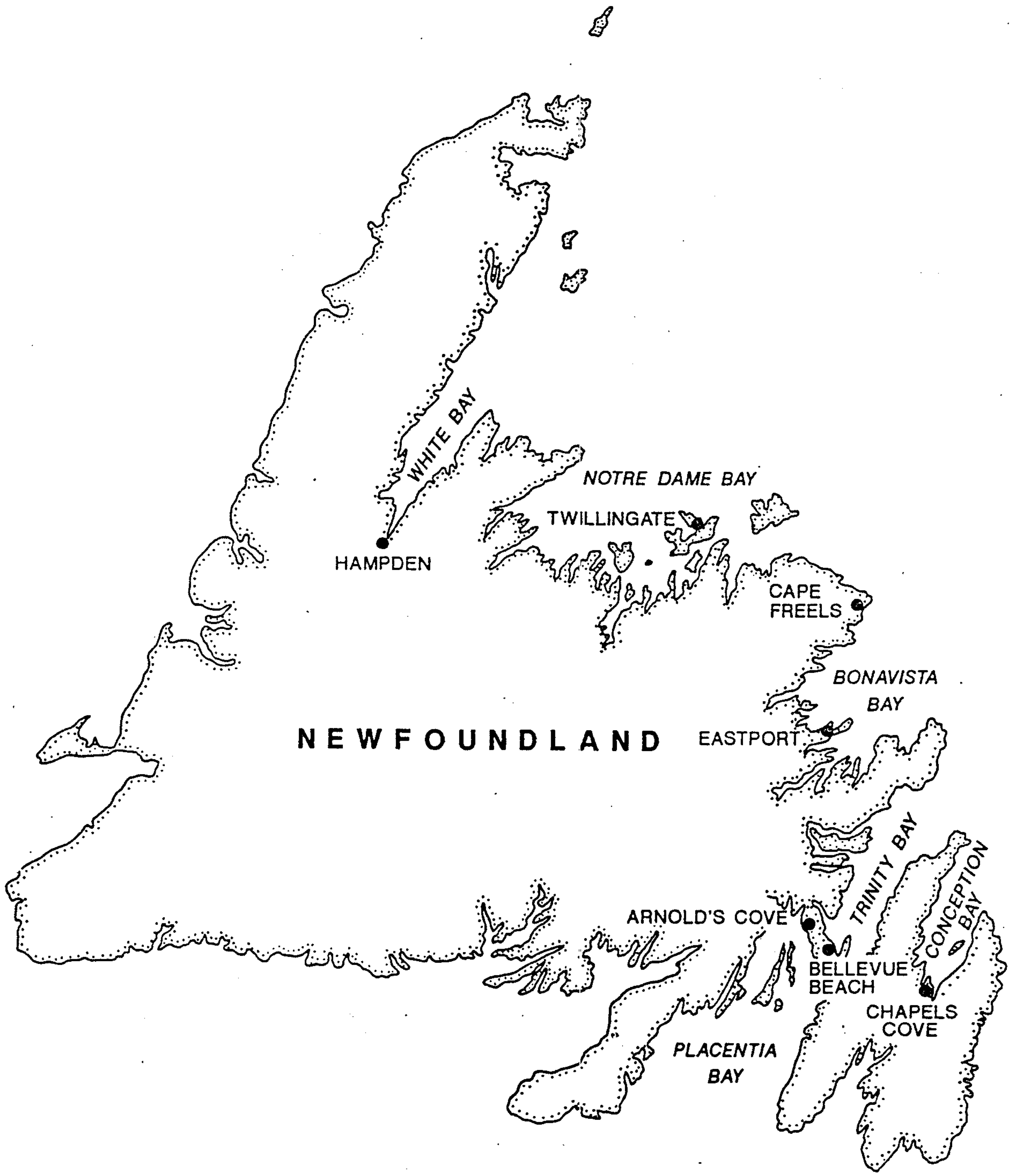

Fig. 1. Sampling sites.

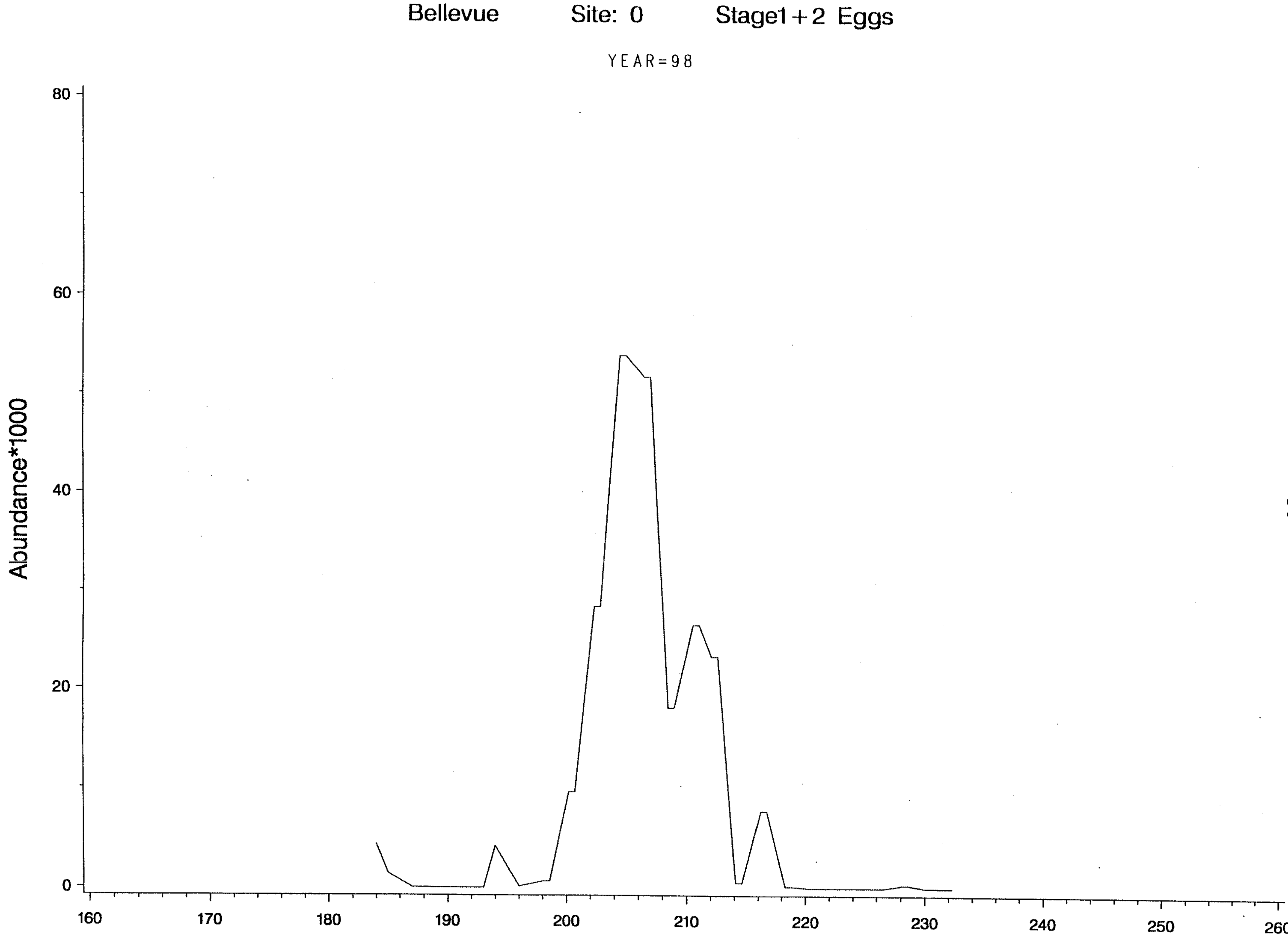

Fig. 2. Seasonal pattern in egg deposition on Bellevue Beach in 1998.

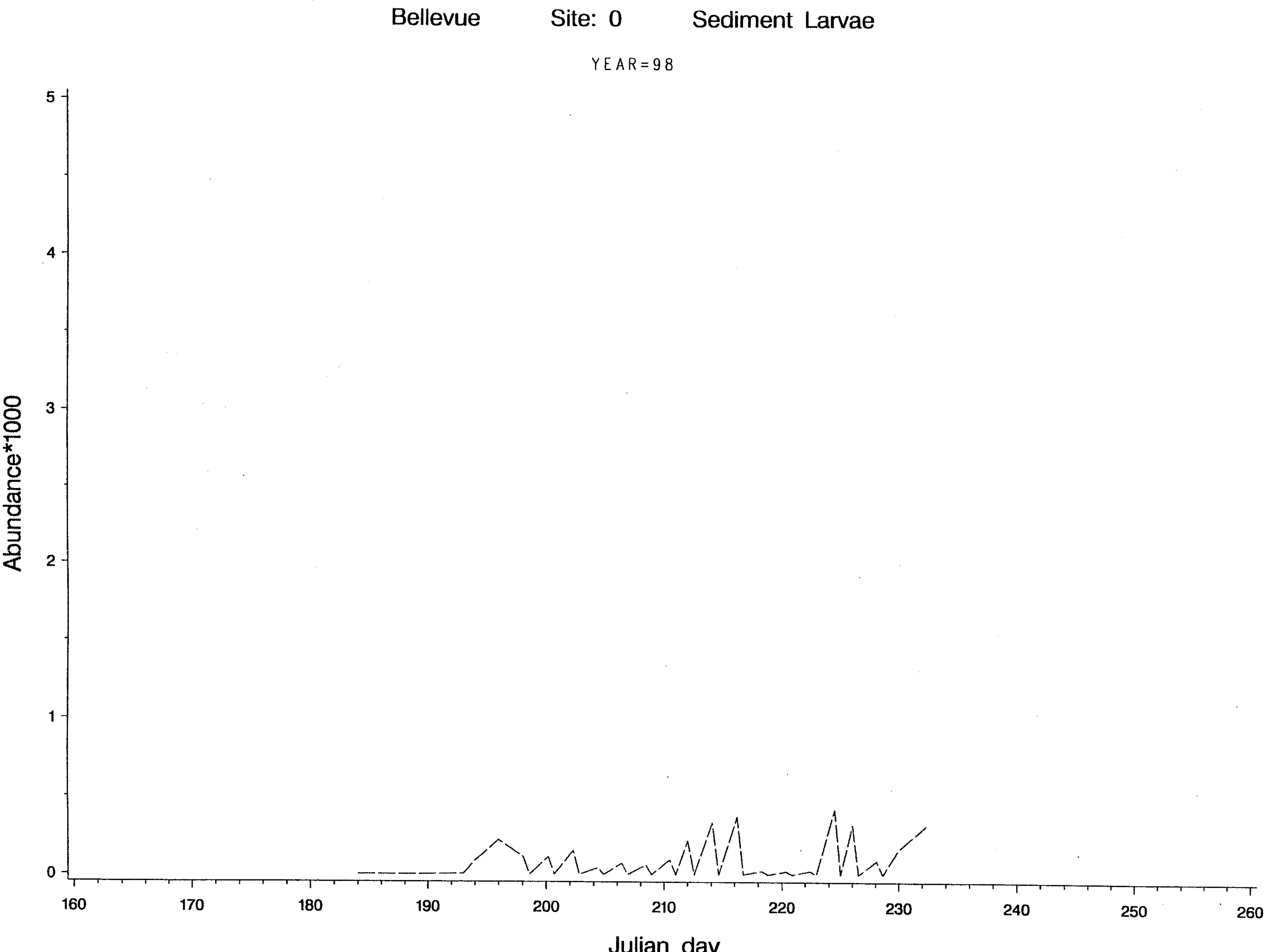

Fig. 3. Seasonal pattern in pre-emergent larvae on Bellevue Beach in 1998.

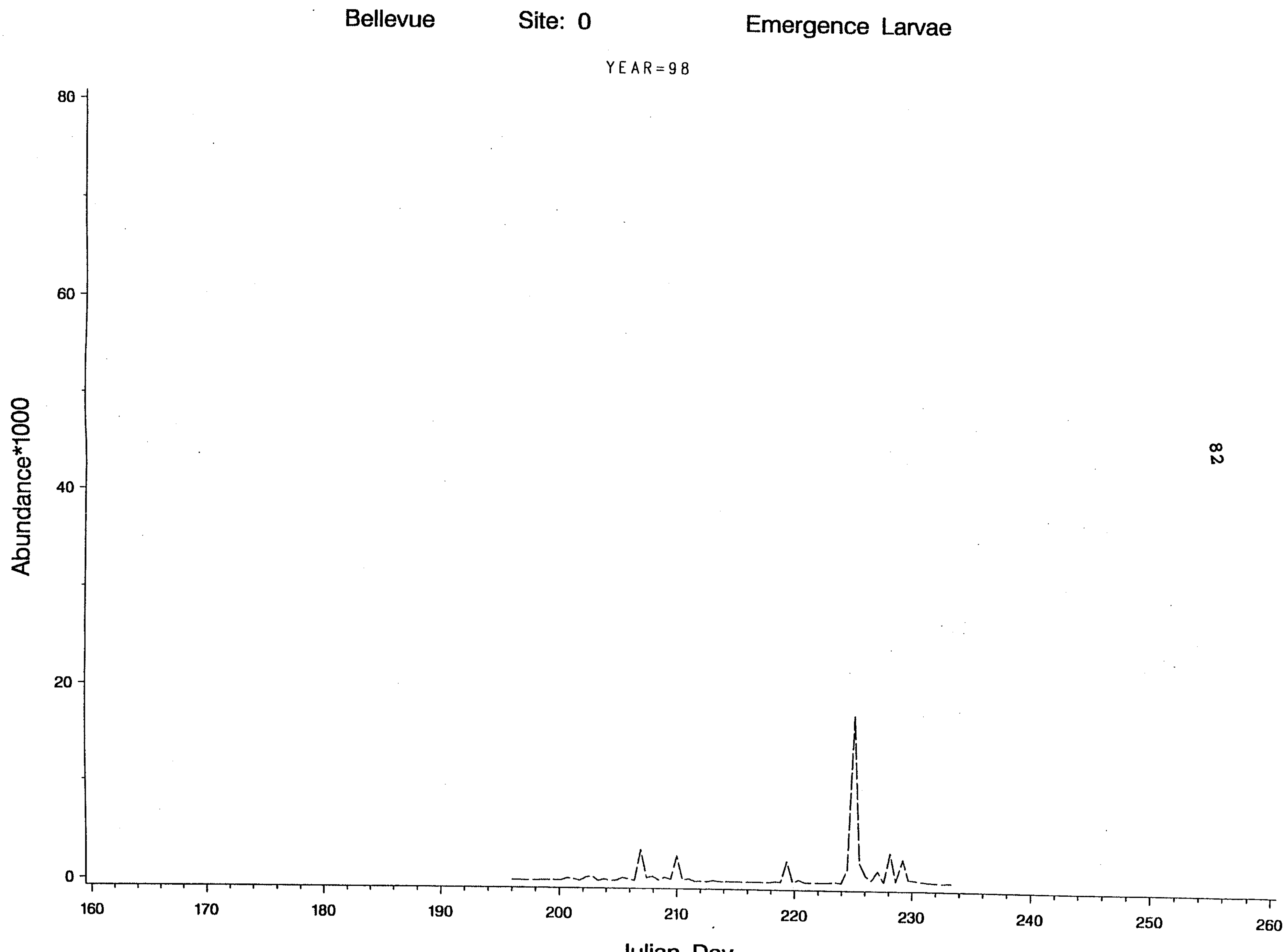

Fig. 4. Seasonal pattern in larval emergence from Bellevue Beach in 1998.

By-catches of capelin during spring and autumn bottom-trawl surveys in Divisions 2J3KL in 1998

by

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Introduction

Capelin (Mallotus villosus) are frequently caught during bottom-trawl surveys directed toward demersal fish off southern Labrador and eastern Newfoundland. The distribution and magnitude of capelin catches from the surveys in Div. 2J, 3K and 3L during the autumns of 1978-97 and the springs of 1972-97 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, Lilly and Davis 1993, Lilly 1994a, 1995ab) and to provide supporting data on changes in capelin distribution (Lilly and Davis 1993, Lilly 1994b, 1995c, 1996, 1997, 1998). There has also been interest in exploring the extent to which the frequency of occurrence of capelin in bottom-trawl catches might provide an index of capelin abundance. This chapter provides information on the distribution and frequency of occurrence of capelin during the trawl surveys in spring and autumn 1998. Capelin abundance and biomass, as estimated from areal expansion of the mean catch per tow, are also presented.

Materials and Methods

Surveys in Div. 2J3KL in autumn

Capelin were caught during random-stratified bottom-trawl surveys designed to assess the biomass of demersal fish during October-December 1978-98 (Table 1). All surveys in Div. 2J and 3K in 1978-94 were conducted with the 74 m stern trawler 'Gadus Atlantica'. Surveys in Div. 3L in 1981-83 and 1985-94 were conducted with the 51 m side trawler 'A. T. Cameron' (1981-82) and the sister 50 m stern trawlers 'Wilfred Templeman' (1983, 1985, 1987-94) and 'Alfred Needler' (1986). There were no autumn surveys in Div. 3L in 1978-80 and 1984. The 'Gadus Atlantica', 'Wilfred Templeman' and 'Alfred Needler' deployed an Engel 145 Hi-Lift trawl, whereas the 'A.T. Cameron' deployed a Yankee 41-5 trawl. In all instances, a 29 mm mesh liner was inserted in the codend. Tows were made at 3.5 knots for 30 min at each fishing station, and catches from the few tows of duration other than 30 min were appropriately adjusted. The variability in ships and bottom-trawls (McCallum and Walsh 1997) may have resulted in differences in catching efficiency, but this possibility has not been examined for capelin. Additional details regarding areas and locations of strata, and changes in survey pattern, are provided by Doubleday (1981), Lilly and Davis (1993), Bishop (1994) and Lilly et al. (1998). The most notable change in survey coverage was the addition of depths between 100 and 200 m in northwestern Div. 3K (St. Anthony Shelf and Grey Islands Shelf) in 1984 and subsequent years. Fishing in all Divisions and years was conducted on a 24-h basis.

The survey in autumn 1995 differed from that in previous years in several respects (Brodie 1996). The 'Gadus Atlantica' was replaced by the 63 m stern trawler 'Teleost', the Engel 145 Hi-Lift trawl was replaced with a Campelen 1800 shrimp trawl with rockhopper foot gear, tows were made at 3.0 knots for 15 min instead of 3.5 knots for 30 min, and the 'Wilfred Templeman' fished north of Div. 3L for the first time in the time-series. In 1996 the survey was extended to depths of 1500 m and new strata were added in the inshore (9 strata in Div. 3K and 16 in Div. 3L). The survey in 1997 was similar to that in 1996, except that some of the new inshore strata were modified and one stratum was added. The survey in 1998 was similar to that in 1997.

Surveys in Div. 3LNO in spring

Capelin were caught during random-stratified bottom-trawl surveys of Div. 3LNO during April-June 1971-98, excluding 1983 (Table 2). Surveys were conducted with the 51 m side trawler 'A. T. Cameron' (1971-82) and the sister 50 m stern trawlers 'Wilfred Templeman' (1985-98) and 'Alfred Needler' (1984). The 'A. T. Cameron' deployed a Yankee 41-5 trawl, and the 'Wilfred Templeman' and 'Alfred Needler' deployed an Engel 145 Hi-Lift trawl until 1995. In all instances, a 29 mm mesh liner was inserted in the codend. Tows were made at 3.5 knots for 30 min at each fishing station, and catches from the few tows of duration other than 30 min were appropriately adjusted. No adjustments were made for possible between-vessel differences in catching efficiency. Starting in spring 1996, the Engel 145 Hi-Lift trawl was replaced with the Campelen 1800 shrimp trawl with rockhopper foot gear and tows were made at 3.0 knots for 15 min.

Most surveys in Div. 3L in the 1970's and 1980's were conducted in May (Fig. 1). The 1971 survey was conducted entirely in June, and the 1981 survey was conducted primarily in April. The 1985 survey was part of special seasonal surveying, and was conducted by three consecutive trips of the 'Wilfred Templeman' over a period of 40 d. From the late 1980's to the mid-1990's the median date of fishing shifted from mid-May to mid-June. The 1998 median date of June 22 was the latest in the series.

Distributions

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

Estimation of frequency of occurrence of capelin

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

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

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

Estimation of capelin biomass and numbers

The biomass of capelin in each stratum was estimated as

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

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

Results

Capelin in Div. 2J3KL during autumn

Distribution

In Div. 2J3K during the autumn of 1998, capelin were recorded at 66% of the 233 fishing stations conducted at depths of 750 m or less (Table 3). This percentage is the highest since the surveys started in 1978. Catches (median = 2.2 kg; 95th percentile = 46 kg) were similar to those in 1995 and larger than in 1996 and 1997 (Table 3). Large catches occurred on the coastal shelfs off southern Labrador and northeastern Newfoundland and eastward to the western slopes of Belle Isle Bank and Funk Island Bank (Fig. 2). There were also good catches on the northern and northeastern slopes of Grand Bank. All of the large catches in the offshore occurred within the area covered by the acoustic survey in 1994, but the large catches in the inshore would have been shoreward of an acoustic survey, if one had been run using the survey blocks employed in 1994. In general, the distribution in 1998 was similar to that seen in several years during the 1980s, most notably 1986 and 1987 (Lilly 1995c). The distribution had been shifted to the southeastern part of the Northeast Newfoundland Shelf during 1991-96 (Lilly 1995c, 1996, 1997). A hint of a return toward the historic pattern was seen in 1997 (Fig. 3).

In Div. 3L, capelin were recorded at 59% of the 140 stations (Table 4). This is the third highest value since the introduction of the Engels trawl. Catches (median = 1.1 kg;

95th percentile = 19 kg) were similar to those in 1997 (Table 4). Capelin were caught mainly in northern and northeastern Div. 3L (Fig. 2). There were only a few small catches on the plateau of Grand Bank. The distribution in 1998 was broadly similar to that in 1995-97 (Fig. 3).

Frequency of occurrence

As reported by Lilly (1995a), the adjustment of the frequency of occurrence, to take into account the allocation of a relatively large number of sets to certain strata in 1991-94, did not substantially change the estimate of the frequency of occurrence, except in Div. 3L in 1992 (Table 5; Fig. 4). In Div. 2J3K, the adjusted frequency of occurrence increased, with irregular fluctuations, from 20-35% in the early 1980s to 40-50% in the 1990s. With the introduction of the Campelen trawl in 1995, the frequency of occurrence rose to a level higher than previously seen. The value declined in 1996 but increased again in 1997. The 1998 value was the highest in the time-series (unadjusted, 66%; adjusted, 70%). In Div. 3L, the frequency of occurrence fluctuated more widely than in Div. 2J3K. Low values of about 20% in 1990-91 were followed by high values of about 50% in 1992-93 and a decline to an intermediate level of about 40% in 1994. The value in 1995, following the change to the Campelen trawl, was the highest in the time-series. The value declined in 1996, increased in 1997 to the second highest in the time-series and declined in 1998 to the third highest in the time-series (unadjusted, 59%; adjusted, 61%).

Estimates of abundance and biomass

The minimum trawlable abundance and biomass were extremely low in 1978, relatively high in 1979-81, and fluctuated without trend from 1982 to 1994 (Fig. 5). The high levels in Div. 2J in 1978-81 were due almost entirely to a few very large catches on the plateau of Hamilton Bank (Carscadden et al. 1989). The estimates increased dramatically with the introduction of the Campelen trawl in 1995 (Fig. 6). Estimates declined in 1996 but increased in 1997 and 1998. The 1998 abundance estimate was the highest in the time-series and the 1998 biomass estimate equaled 1995 as the highest in the time-series. Biomass estimates, in thousands of tonnes, were as follows since the introduction of the Campelen trawl:

	2J	3K	3L	Total
1995	2.4	42.6	22.6	67.6
1996	0.3	16.7	12.3	29.3
1997	2.6	22.4	17.6	42.6
1998	14.0	36.5	17.2	67.7

Capelin in Div. 3LNO during spring

Distribution

In Div. 3L during the spring of 1998, capelin were recorded at 79% of the 163 fishing stations conducted at depths of 750 m or less (Table 6). This was the highest since the introduction of the Campelen trawl in 1996 and close to the maximum level recorded (80% in 1986). Catches were similar to those in 1996 (median = 2.8 kg; 95th percentile = 82 kg). The distribution was similar to that seen in many years, with largest catches in an arc from the northeast across the northern slope of Grand Bank and down through the Avalon Channel (Fig. 7). Catches were nil or very small in the northeast at depths greater than 300 m and on the plateau of the bank. The broad distribution of moderate to large catches in Div. 3L in 1996-98 is very different from observations in 1991-95, but similar to distributions observed in the mid to late 1980s. One notable difference from earlier years, such as 1986 and 1987, is the high frequency of occurrence of large catches in northern Div. 3L.

In Div. 3N and 3O the frequency of occurrence of capelin was equal to that in 1996 (54%) and much below that in 1997 (78%) (Table 2). However, there were many large catches, especially on the southern half of the plateau of the bank in Div. 3O.

Frequency of occurrence

The frequency of occurrence of capelin in sets at depths <750 m (unadjusted, 79%; adjusted 84%) was the highest in the time-series (Table 7; Fig. 8).

Estimates of biomass

The biomass estimated from areal expansion of mean catch per tow was 73 thousand tons (Table 7; Fig. 9). This was the second highest in the timeseries.

Discussion

Capelin in Div. 2J3KL in the autumn

The autumn distribution of capelin in Div. 2J and 3K changed in the early 1990s. In years prior to 1991 most of the capelin in Div. 2J and 3K were concentrated either in Div. 2J or in central Div. 3K, but after about 1990 or 1991 most of the capelin caught during the bottom-trawl surveys or found in stomachs of cod caught during those surveys came from southeastern Div. 3K (Lilly 1994b, 1995c). In 1997 the distribution was still concentrated toward the southeast but with some indication of a return to the west. In 1998 the distribution was similar to that seen in 1986 and 1987 (Lilly 1995c).

Capelin in Div. 3LNO in the spring

The extensive distribution and moderate to large catches of capelin in Div. 3L in the springs of 1996-98 contrast markedly with the very small catches in 1991-95. This may indicate an increase in the quantity of capelin in the survey area in 1996-98 compared with 1991-95, but the comparison is hampered by the change to the Campelen trawl in 1996.

The catches of capelin in Div. 3O in 1998 were frequent and large. Interpretation of these catches is difficult because of changes in gear and survey timing since the surveys were initiated in 1971 (Lilly 1995b). In some years (e.g. 1976, 1980, 1984, 1986) there were very few capelin caught on the southern Grand Bank, in other years (e.g. 1985, 1993) capelin were caught mainly toward the southern tip of the bank and in a few years (notably 1975 and 1998) there were large catches in central and southwestern 3O. The stock affinity of the capelin caught during these surveys is not clear. They could belong to either the 2+3KL stock or the 3NO stock. In some years capelin may have been intercepted during their migration across 3O to the spawning ground on the Southeast Shoal.

Bottom-trawl catches as indices of capelin status

The frequency of occurrence of capelin in bottom-trawl catches and the minimum trawlable biomass calculated from those catches have been presented for both the autumn survey series in Div. 2J3KL and the spring survey series in Div. 3L. The extent to which either of these metrics may serve as an index of capelin abundance or biomass is not known. It is useful to consider the question in two steps: (1) how well do the frequency of occurrence and the estimate of biomass reflect the quantity of capelin in the trawl survey area at the time of the survey and (2) how does the latter reflect the total abundance or biomass of the capelin stock? With respect to part (1), Lilly (1995b) found that both the frequency of occurrence and the trawlable biomass calculated for the spring series in Div. 3L were positively (but not significantly) related to the biomass of capelin estimated from the spring acoustic surveys. The lack of significance may be due in part to poor overlap in time and space between the acoustic survey and the bottom-trawl survey. More information is needed on the relationship between catches in a bottom trawl and the density and behaviour of capelin in the immediate vicinity as measured and observed with hydroacoustics. It is possible that a large catch of capelin in a bottom trawl indicates a high density of capelin near the bottom, especially since large catches are frequently taken close together, often in sequential sets. However, large catches could occur when the survey encounters capelin in relatively shallow water. For example, large catches of capelin on Hamilton Bank in 1979-81 (Carscadden et al. 1989) contributed to high estimates of trawlable biomass at a time when Soviet and Canadian acoustic surveys indicated that the abundance of the SA2+Div.3K capelin stock was low (Lilly 1994b). It is also possible that changes in the behaviour of capelin may change their vulnerability to a bottom trawl. For example, if capelin tend to stay near the bottom in both night and day, instead of migrating upward at night as has often been observed, then they may be captured more frequently and in greater quantities. Shackell et al. (1994b) reported that the capelin found during the acoustic survey of Div. 3L in spring 1992 were relatively deep and did not surface at night as in previous years. Such behaviour might result in an upward bias in the frequency of occurrence and the estimate of biomass.

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

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Table 1. Selected data for bottom-trawl surveys in Divisions 2J3KL in the autumns of 1977-1998. AN = ALFRED NEEDLER, ATC = A. T. CAMERON, GA = GADUS ATLANTICA, TE = TELEOST, WT = WILFRED TEMPLEMAN.

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

Table 1. (Cont'd.)

Year	Div.	Ship/Trip	Sampling dates (d/mo.-d/mo.)	Number of stations occupied: Phase 1	Number of stations occupied: Phase 2	Phase 1 stations with cod: No.	Phase 1 stations with cod: %	Phase 1 stations with capelin: No.	Phase 1 stations with capelin: %
1991	2J3K	GA 208-210	06/11-17/12	313		229	73	117	37
	3L	WT 114,115	08/11-02/12	219		168	77	45	21
1992	2J3K	GA 224-226	29/10-09/12	319		209	66	153	48
	3L	WT 129,130	05/11-29/11	215		146	68	80	37
1993	2J3K	GA 236-238	30/10-06/12	263		137	52	98	37
	3L	WT 145,146	12/11-04/12	153		94	61	76	50
1994	2J3K	GA 250-252	09/11-19/12	255		81	32	108	42
	3L	WT 161,162	08/11-07/12	200		68	34	83	42
1995	2J3K	TE 20-23 WT 180, 181	28/11-25/01	215		155	72	116	54
	3L	TE 23 WT 176, 178, 179	03/10-25/01	166		69	42	117	71
1996	2J3K	TE 39-41 WT 198	22/10-26/11	291		180	62	139	48
	3L	TE 41 WT 196-198	09/10-05/12	210		75	36	97	46
1997	2J3K	TE 54-57 WT 217	19/10-19/12	292		158	54	164	56
	3L	TE 57-58 WT 213-217	23/10-20/12	205		98	48	119	58
1998	2J3K	TE 72-75 WT 232	20/10-30/11	289		173	60	170	59
	3L	TE 75-76 WT 230-233	02/11-15/12	204		78	38	103	50

Table 2. Selected data for bottom-trawl surveys in Div. 3LNØ in the springs of 1971-98.

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

Table 2. Continued ...

Year	Div.	Ship/Trip	Sampling Dates (d/mo.-d/mo.)	No. of stations occupied	Stations with cod		Stations with capelin	
					No.	%	No.	%
1986	3L	WT 48	07/05-25/05	211	203	96	169	80
	3NØ	WT 47	18/04-04/05	203	160	79	21	10
1987	3L	WT 59, 60	14/05-01/06	181	169	93	53	29
	3NØ	WT 58, 59	23/04-14/05	190	168	88	56	29
1988	3L	WT 70, 71	05/05-24/05	154	142	92	108	70
	3NØ	WT 70	21/04-05/05	161	132	82	28	17
1989	3L	WT 82,83	06/05-28/05	205	189	92	157	77
	3NØ	WT 82	20/04-06/05	195	155	80	47	24
1990	3L	WT 96	18/05-04/06	156	137	88	108	69
	3NØ	WT 94-96	22/04-01/06	178	146	82	59	33
1991	3L	WT 106, 107	11/05-29/05	143	89	62	69	48
	3NØ	WT 105, 106	19/04-11/05	209	128	61	44	21
1992	3L	WT 120-122	13/05-07/06	178	51	29	92	52
	3NØ	WT 119, 120	22/04-13/05	185	90	49	54	29
1993	3L	WT 137, 138	18/05-10/06	181	55	30	93	51
	3NØ	WT 136, 137	27/04-18/05	166	77	46	67	40
1994	3L	WT 153, 154	22/05-10/06	160	18	11	75	47
	3NO	WT 152, 153	30/04-22/05	157	44	28	48	31
1995	3L	WT 169, 170	27/05-14/06	151	19	13	78	52
	3NO	WT 168, 169	03/05-27/05	174	51	29	42	24
1996	3L	WT 189-191	30/05-27/06	189	82	43	138	73
	3NO	WT 188, 189	07/05-30/05	168	100	60	91	54
1997	3L	WT 206-208	04/06-26/06	158	40	25	122	77
	3NO	WT 204-206	30/04-04/06	152	80	53	118	78
1998	3L	WT 223-224	06/06-30/06	163	51	31	129	79
	3NO	WT 221-222	12/05-04/06	181	101	56	97	54

Table 3. Statistics for by-catches of capelin during bottom-trawl surveys in NAFO Div. 2J3K during the autumns of 1978 to 1998.

Year	Number[a] of stations	Stations with capelin		Percentiles of capelin[b] catches (kg)			
		No.	%	50	75	95	Max.
1978	125	2	2	0.03			<<1
1979	124	42	34	0.09	0.3	9	185
1980	134	25	19	0.50	1.8	149	172
1981	214	53	25	0.30	1.0	234	345
1982	291	97	33	0.20	0.5	3	18
1983	248	58	23	0.10	0.3	2	24
1984	251	67	27	0.15	0.4	2	3
1985	297	127	43	0.12	0.4	3	10
1986	209	50	24	0.18	0.8	12	24
1987	276	94	34	0.20	1.0	18	117
1988	233	84	36	0.15	0.8	3	39
1989	273[c]	134	49	0.12	0.3	2	32
1990	232[c]	82	35	0.09	0.3	1	11
1991[d]	302	117	39	0.14	0.5	4	68
1992[d]	308	151	49	0.10	0.3	3	15
1993[d]	245	98	40	0.14	0.5	6	9
1994[d]	237	108	46	0.50	1.9	10	30
1995[e]	194	116	60	2.31	8.3	56	332
1996[e]	234	122	52	0.99	3.3	21	53
1997[e]	236	146	62	1.96	6.7	20	49
1998[e]	233	153	66	2.22	9.7	46	132

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

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

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

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

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

Table 4. Statistics for by-catches of capelin during bottom-trawl surveys in NAFO Div. 3L during the autumns of 1985 to 1998.

Year	Number[a] of stations	Stations with capelin		Percentiles of capelin[b] catches (kg)			
		No.	%	50	75	95	Max.
1985	232	80	35	0.33	0.8	6	16
1986	142	38	27	0.11	0.4	2	6
1987	165	38	23	0.10	0.5	2	4
1988	189	85	45	0.20	0.8	7	21
1989	174[c]	72	41	0.20	0.4	7	30
1990	161[c]	31	19	0.10	0.5	11	17
1991[d]	219	45	21	0.11	0.5	7	10
1992[d]	215	80	37	0.12	0.4	2	6
1993[d]	153	76	50	0.13	0.4	3	16
1994[d]	200	83	42	0.10	0.3	1	2
1995[e]	162	117	72	1.26	6.3	29	70
1996[e]	148	78	53	0.48	3.9	17	92
1997[e]	141	93	66	1.09	4.1	19	47
1998[e]	140	82	59	1.06	3.3	19	78

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

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

c Only stations from first-stage sampling are included.

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

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

Table 5. The frequency of occurrence of capelin in catches during the autumn bottom-trawl surveys in Div. 2J3K and Div. 3L in 1978-98. Div. 3L was not surveyed in 1978-80 and 1984. Only sets in 750 m or less are included. Sets in the inshore strata of Div. 3K and 3L are deleted. The method of adjustment is described in the text. For 1989 and 1990, the unadjusted value includes only sets from phase 1, whereas the adjusted value includes sets from phases 1 and 2. The tows in Div. 3L in 1981-83 were conducted with a Yankee 41-5 bottom trawl. All other tows prior to 1995 were conducted with an Engel 145 Hi-Lift bottom trawl. Tows in 1995-98 were conducted with a Campelen 1800 shrimp trawl.

Year	2J3K unadj.	2J3K adj.	3L unadj.	3L adj.
1978	1.6	1.3		
1979	33.9	35.0		
1980	18.7	18.4		
1981	24.8	26.4	13.4	14.1
1982	33.3	33.6	35.5	28.8
1983	23.4	24.8	34.9	30.6
1984	26.7	26.4		
1985	42.8	43.7	34.5	34.3
1986	23.9	26.1	26.8	27.0
1987	34.1	35.3	23.0	26.6
1988	36.1	36.9	45.0	45.5
1989	49.1	48.8	41.4	39.8
1990	35.3	35.2	19.3	21.0
1991	38.7	43.3	20.5	22.9
1992	49.0	53.0	37.2	52.1
1993	40.0	47.4	49.7	52.8
1994	45.6	46.7	41.5	38.7
1995	59.8	66.2	72.2	76.1
1996	52.1	54.2	52.7	56.6
1997	61.9	65.1	66.0	69.4
1998	65.7	70.0	58.6	61.2

Table 6. Statistics for by-catches of capelin during bottom-trawl surveys in NAFO Div. 3L during the springs of 1971 to 1998.

Year	Ship[a] and trip number	Number[b] of stations	Stations with capelin		Percentiles of capelin catches[c] (kg)			
			No.	%	50	75	95	Max.
1971	ATC 187	60	25	42	4.54	14.3	135	181
1972	ATC 199	38	16	42	1.24	4.5	9	9
1973	ATC 208,209	33	3	9	0.14	21.8	22	22
1974	ATC 222	70	17	24	1.13	9.3	58	58
1975	ATC 233	55	39	71	0.91	6.2	145	544
1976	ATC 246	64	30	47	1.86	6.0	17	18
1977	ATC 262	102	36	35	0.89	4.5	119	255
1978	ATC 276	95	8	8	0.07	0.3	<1	<1
1979	ATC 290	141	42	30	0.80	8.4	137	227
1980	ATC 304,305	115	20	17	0.48	1.6	12	13
1981	ATC 317,318	81	28	35	1.00	2.4	18	20
1982	ATC 329	103	44	43	0.50	2.9	27	48
1983								
1984	AN 28	37	18	49	3.25	11.5	190	190
1985	WT 28-30	221	94	43	0.30	1.4	8	24
1986	WT 48	211	169	80	2.00	6.0	72	483
1987	WT 59,60	181	53	29	4.50	17.0	69	167
1988	WT 70,71	154	108	70	0.30	1.7	12	33
1989	WT 82,83	205	157	77	0.80	2.1	18	32
1990	WT 96	156	108	69	0.98	3.2	52	175
1991	WT 106,107	143	69	48	0.14	0.5	5	24
1992	WT 120-122	178	92	52	0.04	0.1	1	4
1993	WT 137,138	181	93	51	0.09	0.4	5	26
1994	WT 153,154	152	74	49	0.11	0.3	2	4
1995	WT 169,170	151	78	52	0.08	0.3	6	12
1996	WT 189-191	189	138	73	3.92	15.1	78	625
1997	WT 206-208	158	122	77	1.37	5.5	17	40
1998	WT 223-224	163	129	79	2.77	10.8	82	468

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

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

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

Table 7. The frequency of occurrence and trawlable biomass of capelin in Div. 3L in the springs of 1977-98, as estimated from bottom trawl surveys. There was no bottom-trawl survey in 1983, and the survey in 1984 was incomplete. Tows were made with a Yankee 41-5 trawl in 1977-82, an Engel 145 Hi-Lift trawl in 1985-95, and a Campelen 1600 trawl in 1996-98.

	Frequency of occurrence (%)		Biomass ('000 tons)
Year	Unadj.	Adj.	Bottom trawl survey
1977	35.3	38.2	18.246
1978	8.4	5.9	0.025
1979	29.8	31.7	15.441
1980	17.4	15.6	0.492
1981	34.6	28.5	2.045
1982	42.7	47.9	6.005
1983			
1984			
1985	42.5	41.0	1.874
1986	80.1	79.7	33.864
1987	29.3	32.1	12.919
1988	70.1	69.8	4.007
1989	76.6	78.0	6.250
1990	69.2	71.5	15.546
1991	48.3	52.1	1.398
1992	51.7	54.1	0.259
1993	51.4	53.1	1.436
1994	48.7	48.6	0.432
1995	51.7	55.8	1.103
1996	73.0	77.7	94.695
1997	77.2	81.3	19.970
1998	79.1	83.6	73.363

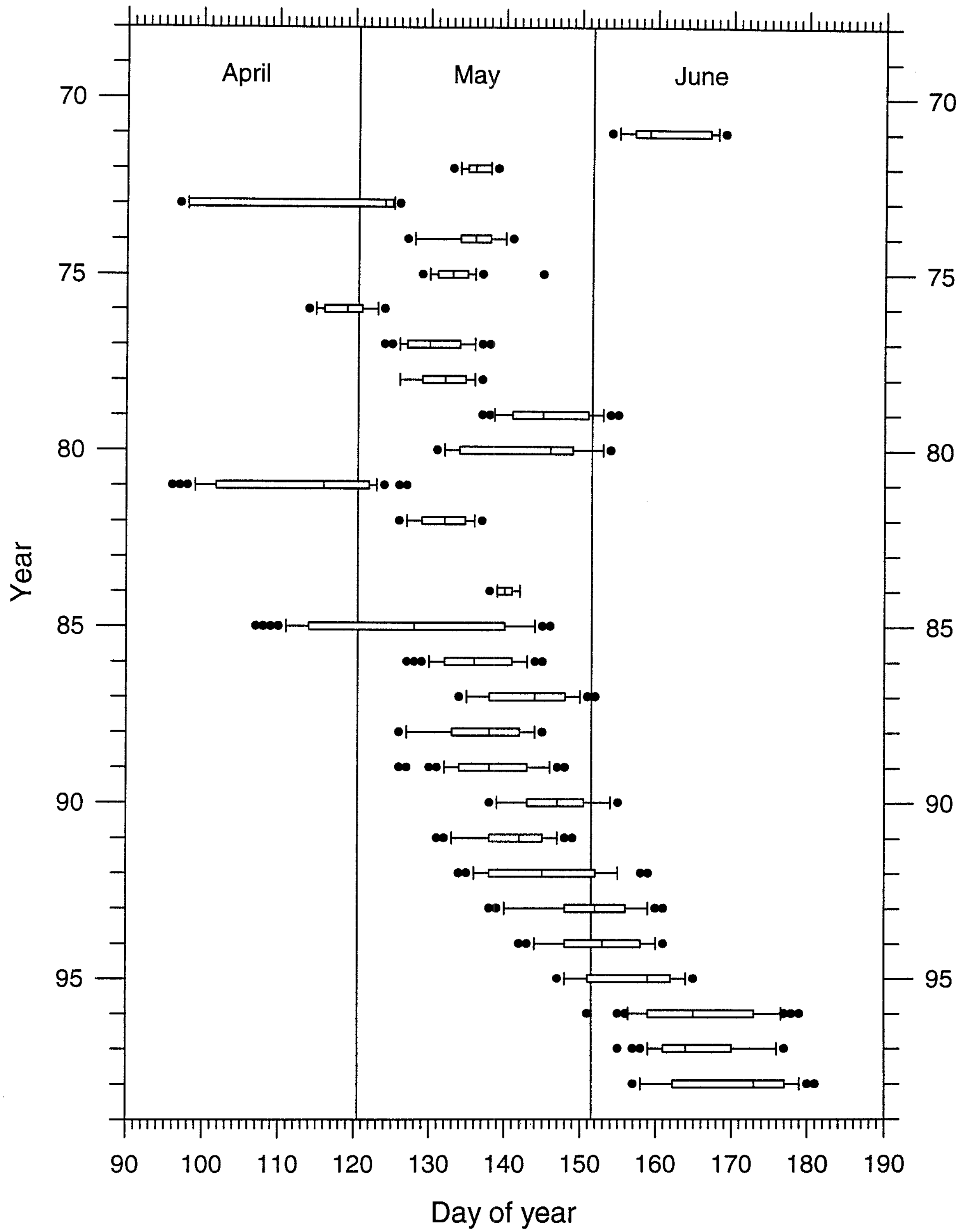

Fig. 1. Dates of fishing during stratified-random bottom-trawl surveys in Division 3L in 1971-1998. The box plot for each year illustrates the 10th, 25th, 50th, 75th and 90th percentiles, and all dates beyond the 10th and 90th percentiles.

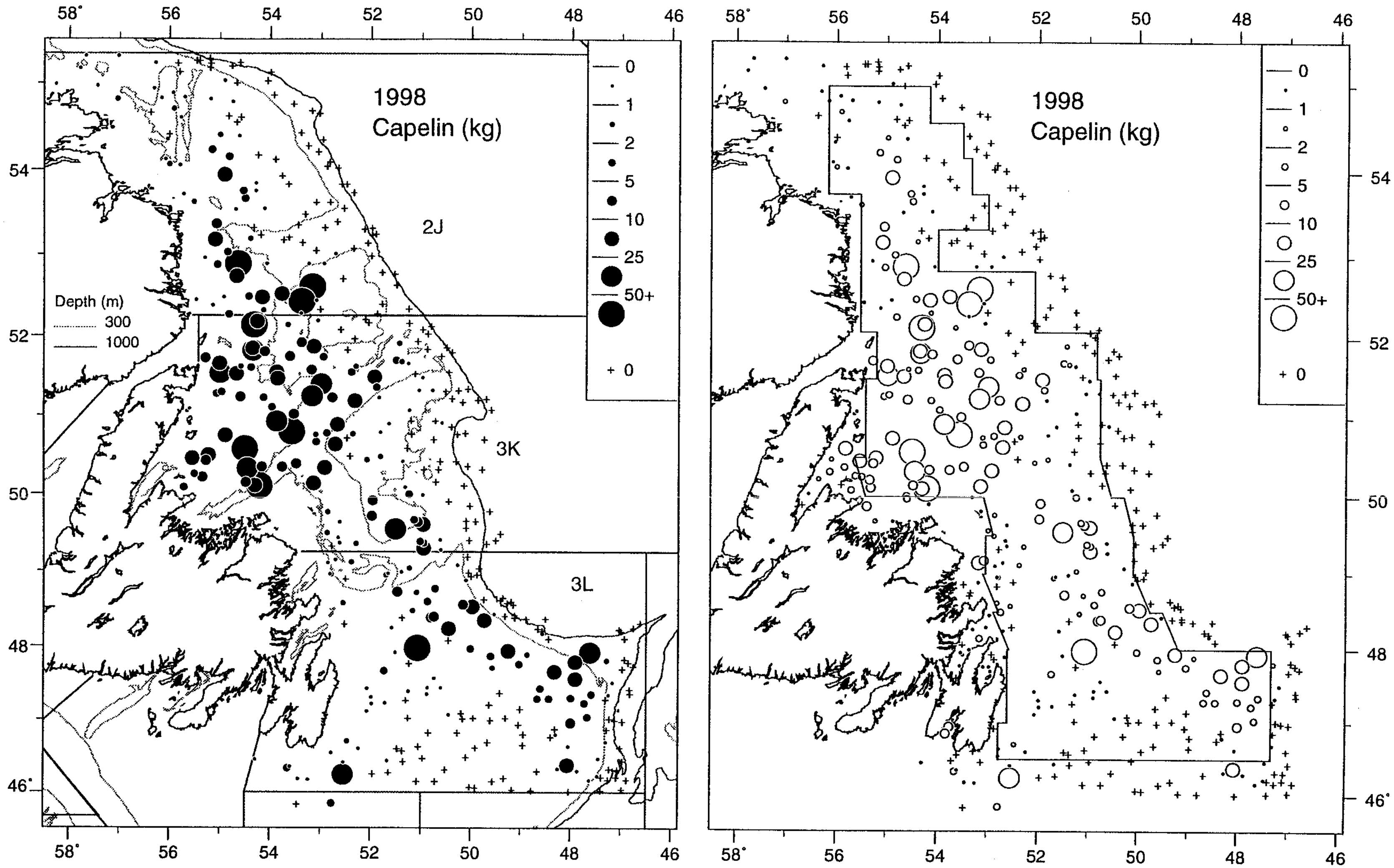

Fig. 2. Capelin catches (kg/15 min tow) during random-stratified bottom-trawl surveys in Divisions 2J3KL during autumn 1998. The left panel shows the 300 and 1000m isobaths. The right panel shows the boundary of the acoustic survey in 1994. Inshore stations are illustrated in the right panel only.

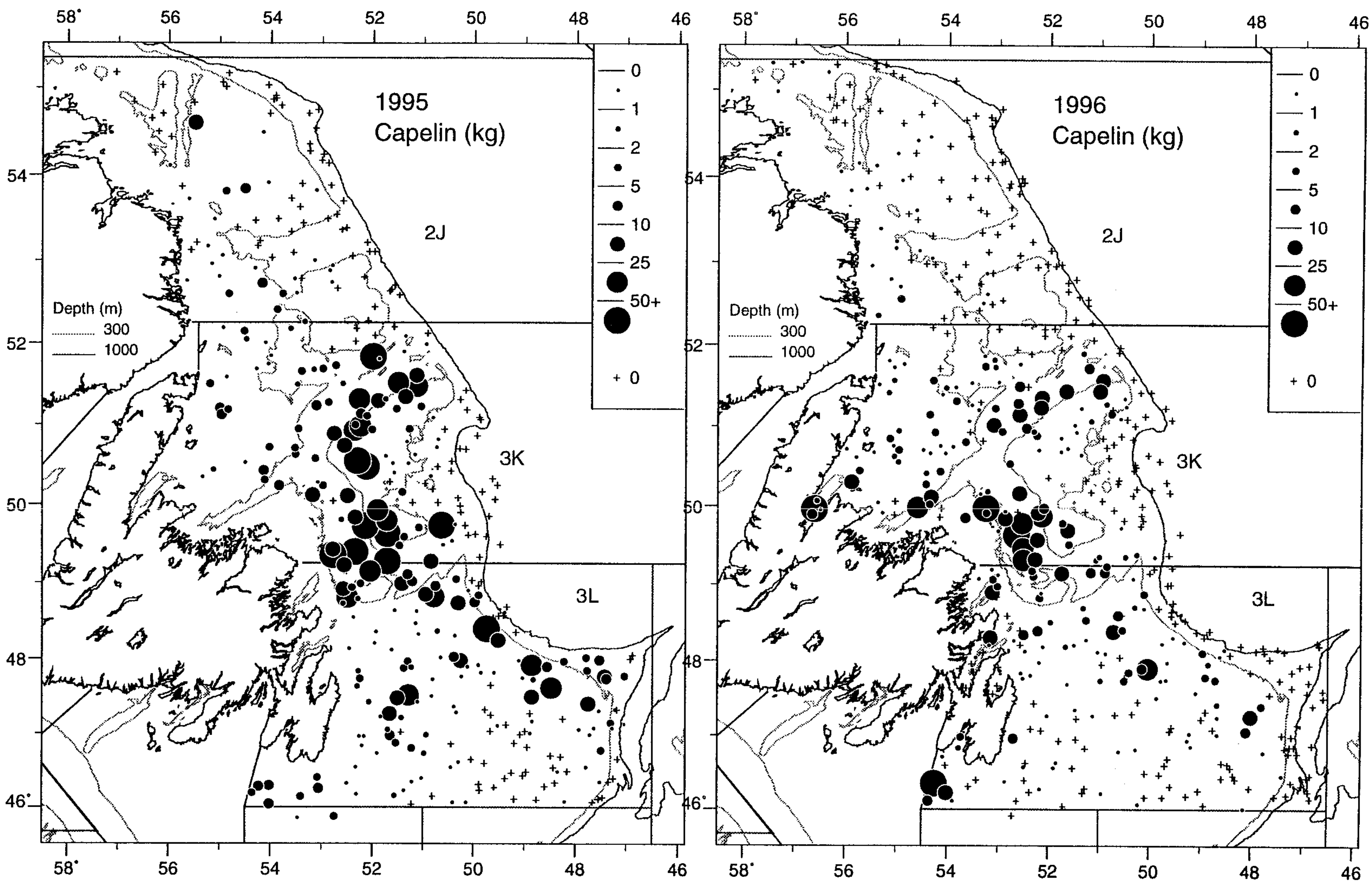

Fig. 3. Capelin catches (kg/15 min tow) during random-stratified bottom-trawl surveys in Divisions 2J3KL during the autumns of 1995-1998.

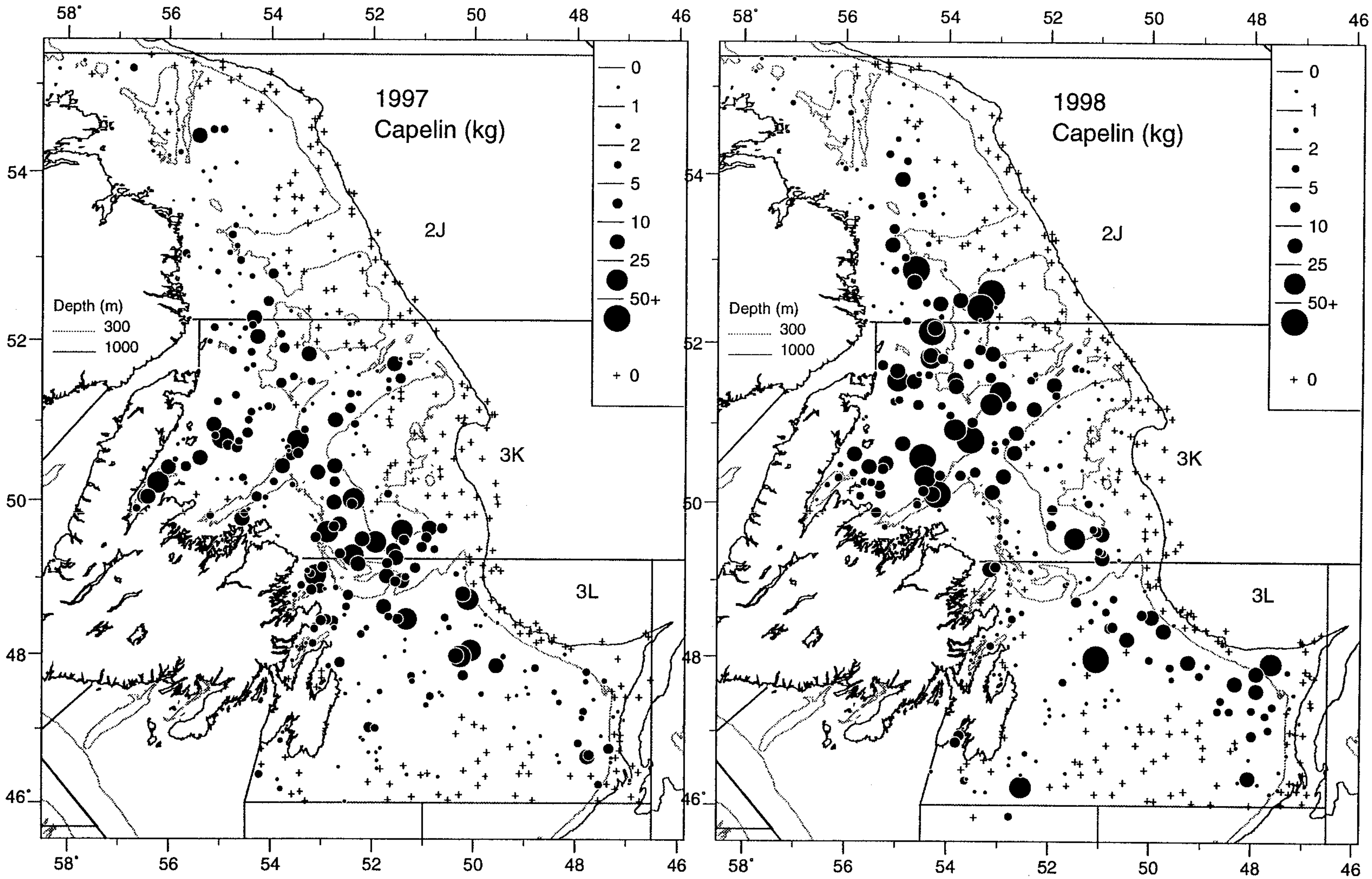
1997
Capelin (kg)
2J
3K
3L
0
1
2
5
10
25
50+
+ 0
Depth (m)
300
1000
1998
Capelin (kg)

Fig. 3 (cont'd)

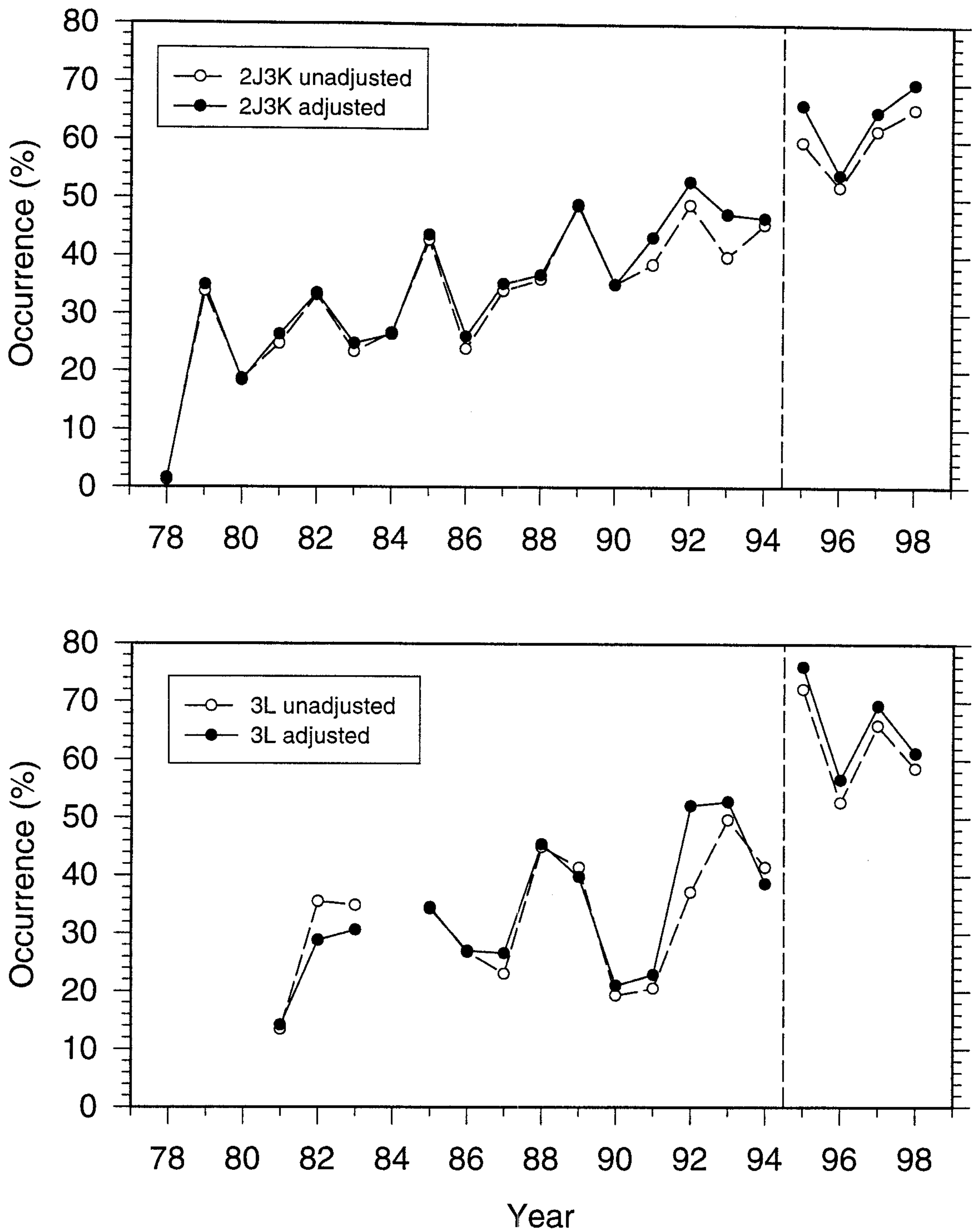

Fig. 4. The frequency of occurrence of capelin in catches during the autumn bottom-trawl surveys in Division 2J3K (upper panel) and Division 3L (lower panel) in 1978-1998. Division 3L was not surveyed in 1978-1980 and 1984. A Yankee 41-5 trawl was used in Division 3L in 1981-1983. An Engel 145 Hi-Lift trawl was used in Division 3L in 1985-1994 and in Division 2J3K in 1978-1994. A Campelen 1800 shrimp trawl was used in all Divisions in 1995-1998.

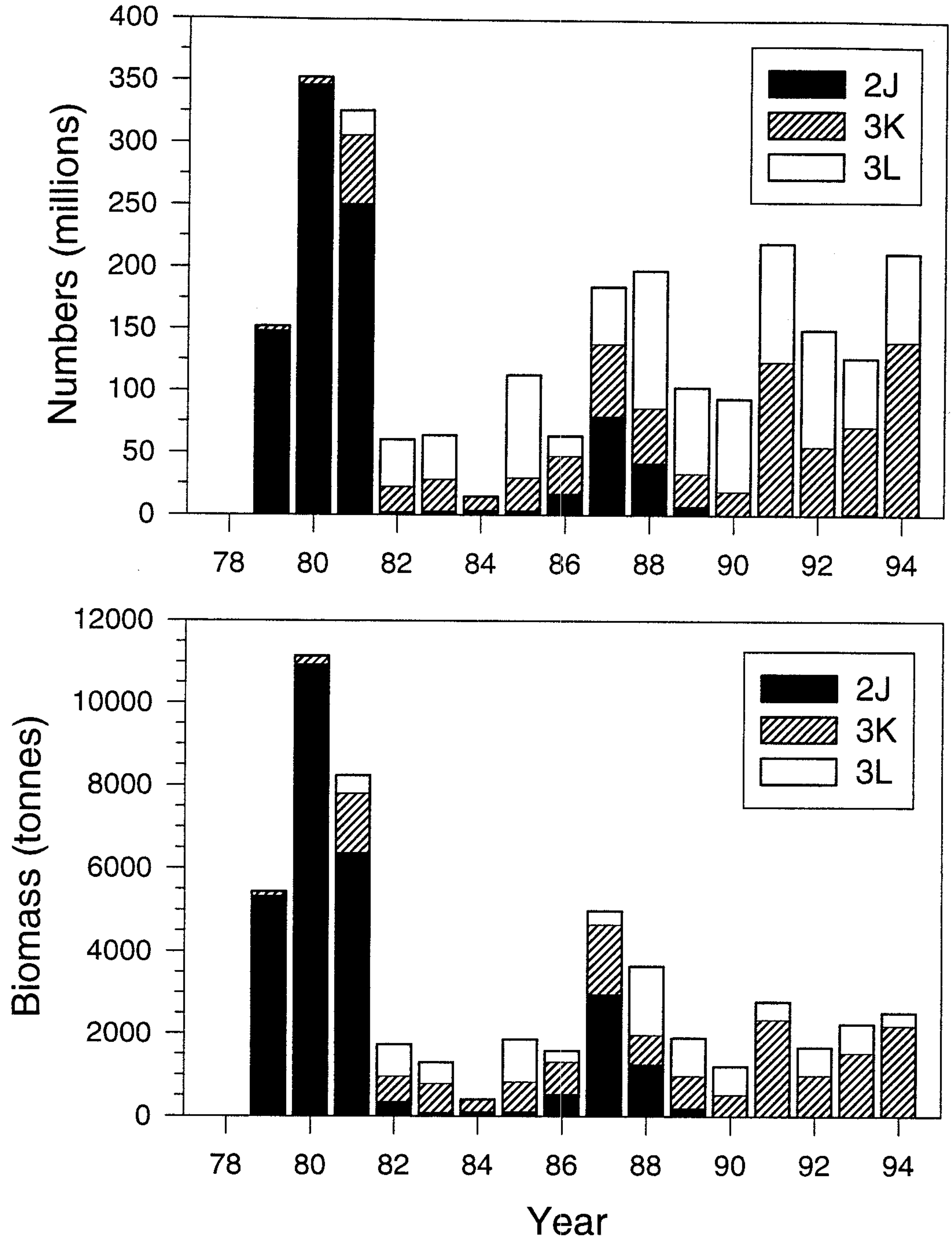

Fig. 5. Abundance and biomass of capelin by year and Division, estimated from areal expansion of stratified mean catch per tow during autumn surveys, for the years 1978-1994. There was a survey in Divisions 2J3K in 1978, but the estimated levels were too small to be distinguishable from the axis. Division 3L was not surveyed in 1978-1980 and 1984.

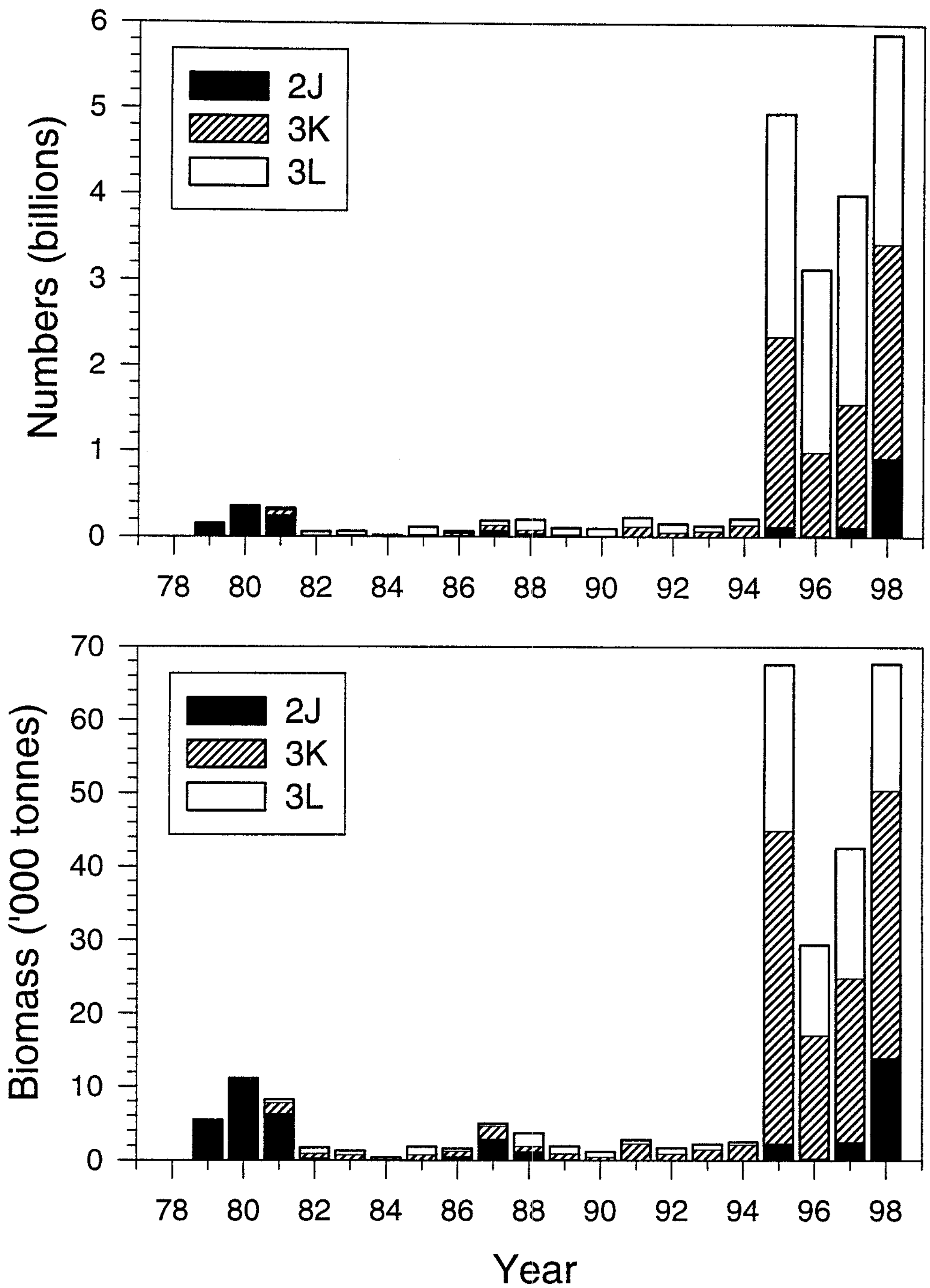

Fig. 6. Abundance and biomass of capelin by year and Division, estimated from areal expansion of stratified mean catch per tow during autumn surveys, for the years 1978-1998. There was a survey in Divisions 2J3K in 1978, but the estimated levels were too small to be distinguishable from the axis. Division 3L was not surveyed in 1978-1980 and 1984. A Campelen 1800 shrimp trawl was introduced in 1995.

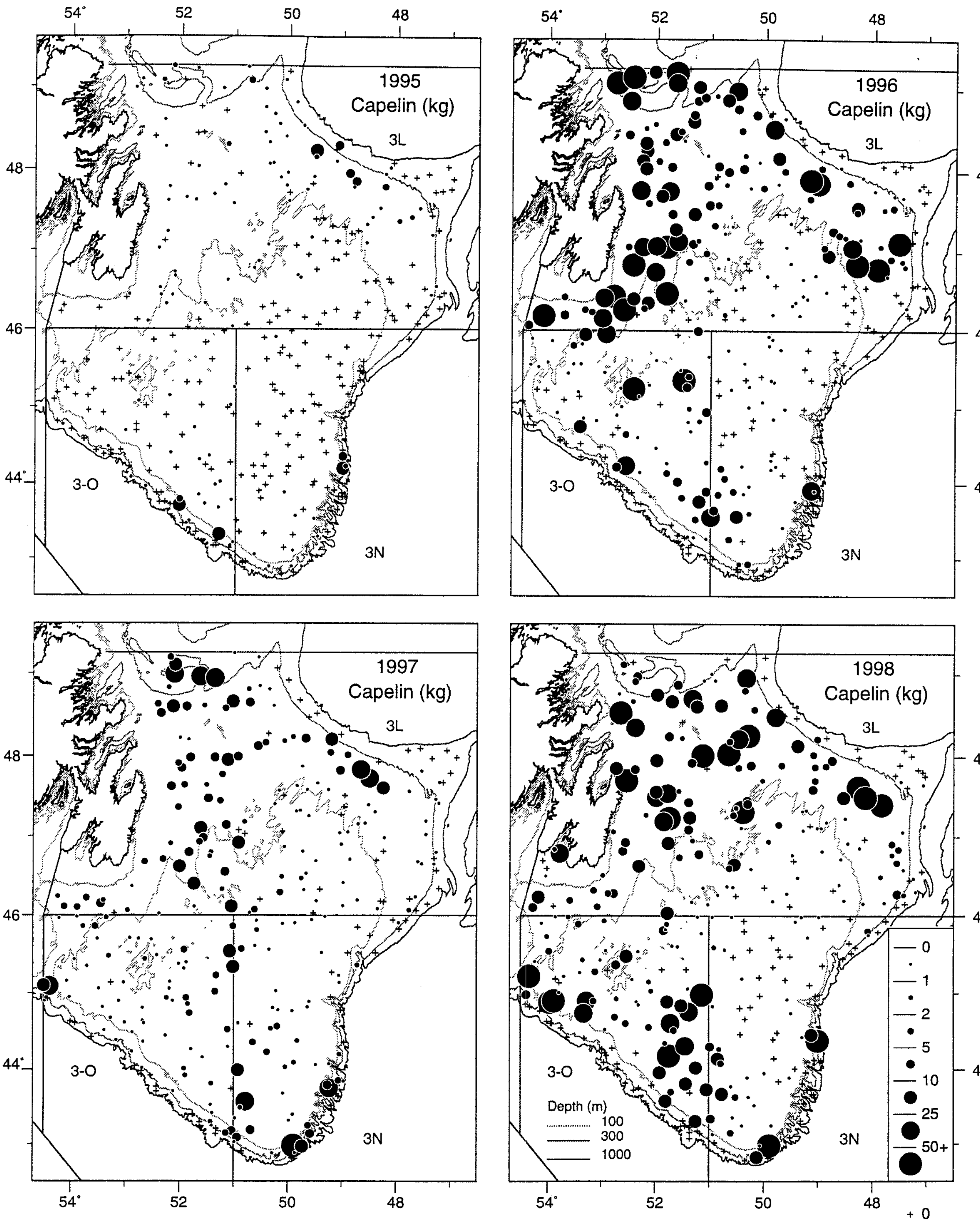

Fig. 7. Capelin catches during stratified-random bottom-trawl surveys in Divisions 3LNO during the springs of 1995-1998. Data from 1995 are kg/30 min tow with the Engels trawl and data from 1996-1998 are kg/15 min tow with the Campelen trawl. For plots of distributions in 1971-1994, see Lilly (1995b).

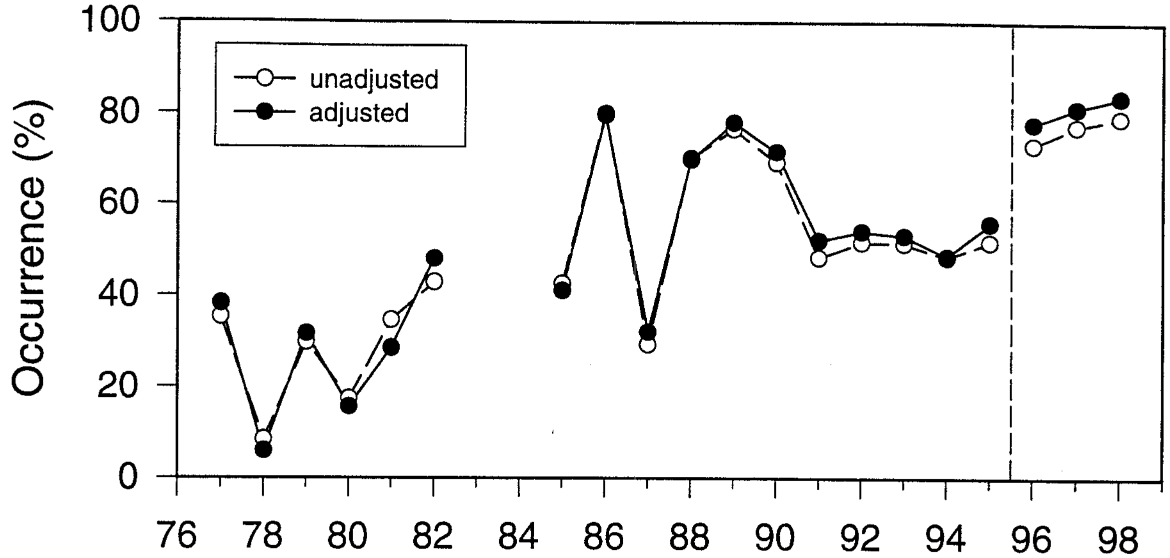

Fig. 8. The frequency of occurrence of capelin in catches during spring bottom-trawl surveys in Division 3L in 1977-1998. There was no survey in 1983 and coverage was inadequate in 1971-1976 and 1984. A Yankee 41-5 trawl was used until 1982, an Engels 145 Hi-Lift trawl was used in 1985-1995, and a Campelen 1600 shrimp trawl was used in 1996-1998.

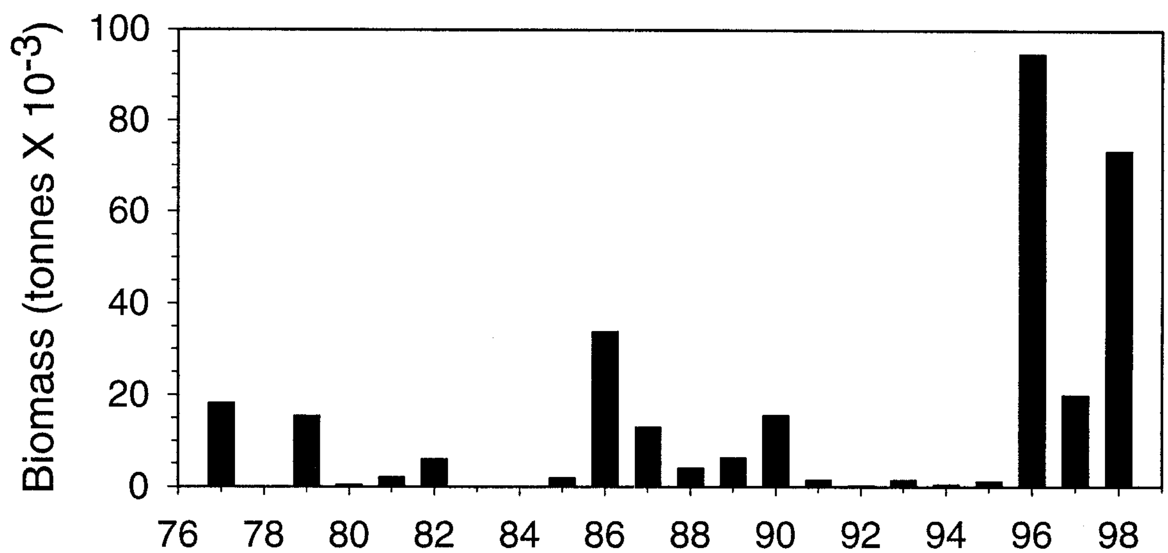

Fig. 9. The biomass of capelin as estimated from areal expansion of stratified mean catch per tow during spring bottom-trawl surveys in Division 3L in 1977-1998. There was no survey in 1983 and coverage was inadequate in 1971-1976 and 1984. A Yankee 41-5 trawl was used until 1982, an Engels 145 Hi-Lift trawl was used in 1985-1995, and a Campelen 1600 shrimp trawl was used in 1996-1998.

Absolute Abundance and Biomass of Juvenile and Adult Capelin (Mallotus villosus) in the Newfoundland Region (2J3KLNO) Estimated from the Pelagic Juvenile Fish Surveys, 1994-1998

by

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Introduction

The absolute abundance and biomass of capelin (Mallotus villosus) within the Newfoundland Region (NAFO 2J3KLNO) is of interest to scientists and managers for many reasons. These include setting catch limits as part of the capelin management plan. Currently, there is no direct estimate of capelin biomass, following the cancellation of the offshore capelin acoustic surveys previously carried out in spring and autumn. A multiplicative model developed from many indices and modelled over many years indicates that the abundance and biomass of capelin is similar to, or possibly larger than, the absolute estimates of capelin biomass available from the 1980's (Anon. 1998). Quantifying the multiplicative model is an important component in assessing the current stock status of capelin.

Capelin are an important component of the ecosystem and may be the key prey species determining the status of apex predators, such as harp seals (Phoca groenlandica) and Atlantic cod (Gadus morhua). Current estimates of harp seal consumption within the Newfoundland region indicate that consumption in 2J3KL alone was on the order of 805,856 t in 1996 (Hammill and Stenson 1997). Currently, there is no independent estimate of how important this predation pressure might be to the status of capelin and its possible impact on the marine ecosystem.

The purpose of this paper was to estimate the absolute abundance and biomass of capelin based on the mid-water IYGPT trawl used in the Pelagic Juvenile Fish Surveys carried out in 2J3KLNO 1994-1998 (Anderson et al. 1999).

Materials and Methods

The absolute abundance of capelin was estimated from the abundance of capelin caught at each station (number m^{-2}), correcting for IYGPT trawl catchability and night/day catch rate differences within three size categories of capelin: < 120 mm; 120-139 mm; ≤ 140 mm. The survey design is described in Anderson et al. (1997). These size ranges are thought to approximate the size ranges of age one, two and three year old capelin. Catchability, *q*, was based on published estimates of nekton catchability by the IYGPT trawl (Koslow et al. 1997). They estimated an overall trawl catchability coefficient of 0.14, where published estimates have typically ranged from 0.1 to 0.25. Night/day ratios were estimated for each survey and each size range of capelin where IYGPT tows were designated as either night or day depending on the start time of each tow. For stations offshore, the adjusted capelin abundances were spatially extrapolated to the area represented by each station (2.916×10^9 m^2). For the inshore (Anderson et al. 1997), the mean adjusted abundance for each inshore area was extrapolated to the total area, where was estimated using Surfer.

Biomass was estimated based on the mean weight of capelin within each of the three size groups for each survey year. These weights were based on capelin samples collected during each survey and processed in the laboratory (P. Eustace, Pelagics Section, NAFC). Biomass for a given size group, for a given year was a simple multiple of the absolute abundance by the mean weight. The total population biomass was a summation of the three length groups.

Results

Capelin were consistently caught at higher abundance during the night, compared to the day, over all size groups for all years (Table 1, Fig. 1). However, the night/day ratio varied without a consistent pattern, both among length groups and among years. The original data were examined for outliers and when these occurred, the data were removed from the night/day estimate. The night/day data indicate that there was no overall year effect across all length groups, nor was there an overall effect for any one length group.

The mean length and weights of capelin varied within the length groups among years. One year old capelin (< 120 mm) were smallest in 1994 and 1996 (i.e. the 1993 and 1995 year classes) and consequently weighed less (Table 2). There was much less variation in the mean size of the two larger length groups. However, the mean weights varied within these length groups over the five-year period, where the mid-length group (age 2) weighed more in the 1996-1998 surveys compared to the 1994-1995 surveys. In the largest length group (age 3+), capelin weighed the most during the more recent surveys in 1997 and 1998.

The absolute abundance of one year old capelin (length group 1) varied by a factor of 16.0 among years, being highest in 1994 (i.e. the 1993 year class) and lowest in 1995 (i.e. the 1994 year class) (Table 3). Over all years the absolute abundance of capelin varied from 6.6×10^{10} to 9.42×10^{11} fish; a factor of 14.3 times.

The total biomass of capelin varied by a factor of 17.4 times, from a low of 244,686 t in 1995 to a high of 4,255,848 t in 1998 (Table 3). The two largest year classes, 1993 and 1996, were largely responsible for determining the total population biomass over all age and size groups. This was particularly true for the 1996 year class that was abundant as age one capelin in the 1997 survey (< 120 mm length) and again as age two fish in the 120-139 mm length class (Table 3). In addition, the mean weight of the older, larger capelin increased in 1997 and 1998. Therefore, abundance and biomass were largely similar in trend until the 1998 survey when the abundance decreased marginally while biomass increased to the highest value in five years (Fig. 2).

The variance in our estimates of abundance and biomass due to uncertainty in the IYGPT catchability only varied by a factor of 2.5 times (Table 3). This range is considerably less than that observed in abundance and biomass over the five-year period. Based on this range in catchabilities, biomass was estimated to be as low as 137,024 t in 1995 and as high as 5,958,188 t in 1998.

It is difficult to track year-class strength among years for the three age groups, nominally regarded as age one, two and three years of age. At the larval (age 0) and one year old (age 1) stages for the 1991-1996 year classes, the ranking was: 1996 > 1993 = 1995 > 1994 > 1991 = 1992

(Anderson and Dalley 1998). The 1996 year class ranked second and first among years for age/length groups one and two, based on our estimate of absolute abundance (Table 3). Similarly, the 1994 year class ranked lowest in abundance for age/length groups one and two, but for age/length group three it ranked third. Therefore, we conclude there is some consistent in relative year-class strength among years. However, there is a lack of complete consistency among as capelin grow into the largest length groups. In addition, the magnitude of decline from age/length one to two exceeded 90% in three of four years and then it was 55%. Of greater concern was the observation that two of three year classes actually increased in abundance from age/length group two to three while in the third case abundance remained about equal.

Discussion

The two largest year classes at age one were 1993 and 1996. It is difficult to follow the 1993 year class at age two in the middle size group (120-139 mm), but the 1996 year class showed up as the largest over the five years. The absence of the 1993 year class as age two fish does not appear to be a result of slow growth and small size, such that it did not occur in the 120-139 mm length range, as the abundance of the smallest length group was the lowest observed.

The greatest source of uncertainty in our estimates appears to be the diurnal vertical migration of capelin into the trawl zone by night, 20-60 m layer, and out of it by day. There was no consistent pattern among years or among length groups. However, the high night/day ratios for a given length group within a year appear to accurately reflect the behaviour of capelin in that the ratios were determined by consistently high tows, and were not a result of one or two high catches. Previously, interannual differences in the diurnal vertical migrations of northwest Atlantic capelin were reported (Shackell et al. 1994). Diurnal catch rate differences result primarily from migration into surface waters by night and out by day, but are also due to dispersion at night and schooling by day and can vary with season (Bailey et al. 1977, O'Driscoll and Rose 1999).

The absolute abundance and biomass of capelin was previously estimated based on spring acoustic surveys, which were carried out prior to the migration and spawning of capelin. These surveys were carried out in May each year, 1985-1992 (Miller 1992). Total abundance ranged from 1.50 - 5.99 x 10^{11} capelin from 1985 to 1990, dropped by an order of magnitude to 0.30-0.31 x 10^{11} capelin in 1991 and 1992 and were estimated to be as low as 0.05 x 10^{11} capelin in May of 1996. From 1985-1990, the capelin biomass was estimated to have ranged from 2.58 - 6.96 x 10^{6} tonnes. In 1990 and 1991, biomass was estimated to have dropped to 0.11 - 0.21 x 10^{6}.

Our estimates of abundance and biomass of capelin are very similar to those estimated by the acoustic surveys, 1985-1992 (Fig. 3). (We have also plotted the results of the fall acoustic surveys (Miller 1995) for completeness although it should be noted that these results were generally not accepted as reliable indicators of stock status (Winters 1995).) A higher range of biomass, relative to abundance, estimated in the 1980's might be expected, where these surveys were conducted prior to spawning. Given that a high proportion of spawning capelin die, our survey would estimate a lower biomass, all else being equal.

The standardized biomass index of the multiplicative model ranged from 60-95 during the period 1985-1990, was approximately 75 in 1991 and 1992, and ranged from 72-118 during 1994-1997 (Anon. 1998). Therefore, the offshore estimates of abundance and biomass do not agree with the output from the multiplicative model, in that the surveys estimated higher biomass in the 1980's compared to the 1990's, whereas the multiplicative model is the reverse.

The total biomass estimated for capelin greatly exceeded the biomass of capelin consumed by harp seals in 1994, 1997 and 1998. During these years, harp seal consumption would only have amounted to 19% - 30% of the total biomass. However, in 1996 harp seal consumption would have comprised 86% of the total estimated biomass and in 1995 would have exceeded the capelin biomass. In addition, if harp seals consume primarily capelin age two and older, then the estimated consumption of capelin would exceed the available capelin biomass in all years except 1998.

There are many sources of uncertainty when trying to estimate the absolute abundance and biomass of capelin from the Pelagic Juvenile Fish Surveys, including: 1) varying catchability among years; 2) varying growth rates among years; 3) varying survival following spawning for age three and four year old capelin. There is some indication of varying catchability among years, where all three age groups ranked last in 1995. We assume that the 1994, 1993 and 1992 year classes were present in the 1995 survey, where the 1993 year class was one of the largest at ages 0 and 1 and the 1994 year class one of the smallest (Anderson and Dalley 1998). Therefore, the low total abundance and biomass estimate in 1995 should be regarded with caution.

Conversely, while the 1998 survey had the highest ranking for age/length groups two and three, these represented the 1996 and 1995 year classes which we regard as relatively strong, while the age/length one group ranked fourth. Therefore, there is no clear indication of necessarily higher catchability in the 1998 survey.

There is a clear indication that growth rate has changed in recent years, where the 1997 and 1998 surveys measured larger mean lengths for one year old capelin (length group 1) and higher mean weights for length groups two and three. The effect that varying growth rate may have on our designation of age within length group remains unknown. Similarly, varying survival following spawning will further bias our interpretation of year-class strength within the largest length group.

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Table 1. Ratio of night to day capelin densities (number m^{-3}) for each year and each size (age) group, where age 1 is < 120 mm, age 2 is 120-139 mm, and age 3 is ≥ 140 mm.

Year	Age 1	Age 2	Age 3
1994	9.62	12.03	4.10
1995	2.96	7.96	3.68
1996	53.38	17.20	4.91
1997	2.15	1.65	14.96
1998	4.26	25.42	49.24

Table 2. Mean length (mm) and weight (g) of capelin within three size categories sampled in the Pelagic Juvenile Fish Surveys, 1994-1998.

Year	Length			Weight		
	< 120 mm	120-139 mm	≥ 140 mm	< 120 mm	120-139 mm	≥ 140 mm
1994	92.6	127.6	152.1	2.9	7.6	12.5
1995	99.7	127.7	142.0	3.2	7.3	8.8
1996	90.9	131.1	149.0	2.5	8.4	11.1
1997	97.9	129.9	149.5	3.5	8.9	14.9
1998	101.9	129.3	149.4	3.7	8.3	15.4

Table 3. Absolute abundance and biomass (t) estimates for capelin length groups 1-3 caught in the IYGPT trawl during annual Pelagic Juvenile Fish Surveys in 2J3KLNO.

Year	Q=0.14 Group 1		Group 2		Group 3		Total Pop	Total Bio
	Population	Biomass (t)	Population	Biomass (t)	Population	Biomass (t)		
1994	9.20E+11	2,669,112	1.94E+10	147,247	2.67E+09	33,446	9.42E+11	2,849,806
1995	5.76E+10	184,306	7.65E+09	56,130	4.81E+08	4,249	6.57E+10	244,686
1996	3.19E+11	810,155	5.63E+09	47,444	7.54E+09	83,668	3.32E+11	941,267
1997	6.18E+11	2,151,376	2.87E+10	254,292	2.00E+10	296,534	6.67E+11	2,702,202
1998	2.65E+11	969,562	2.79E+11	2,304,168	6.37E+10	982,118	6.07E+11	4,255,848
						Mean	5.23E+11	2,198,762

Year	Q=0.10 Group 1		Group 2		Group 3		Total Pop	Total Bio
	Population	Biomass (t)	Population	Biomass (t)	Population	Biomass (t)		
1994	1.29E+12	3,736,757	2.71E+10	206,146	3.74E+09	46,825	1.32E+12	3,989,728
1995	8.06E+10	258,029	1.07E+10	78,582	6.74E+08	5,949	9.20E+10	342,561
1996	4.47E+11	1,134,217	7.89E+09	66,422	1.06E+10	117,135	4.65E+11	1,317,774
1997	8.65E+11	3,011,926	4.02E+10	356,009	2.79E+10	415,148	9.34E+11	3,783,082
1998	3.71E+11	1,357,386	3.90E+11	3,225,836	8.92E+10	1,374,965	8.50E+11	5,958,188
						Mean	7.32E+11	3,078,266

Year	Q=0.25 Group 1		Group 2		Group 3		Total Pop	Total Bio
	Population	Biomass (t)	Population	Biomass (t)	Population	Biomass (t)		
1994	5.15E+11	1,494,703	1.08E+10	82,458	1.49E+09	18,730	5.28E+11	1,595,891
1995	3.23E+10	103,212	4.28E+09	31,433	2.69E+08	2,380	3.68E+10	137,024
1996	1.79E+11	453,687	3.16E+09	26,569	4.22E+09	46,854	1.86E+11	527,109
1997	3.46E+11	1,204,770	1.61E+10	142,403	1.12E+10	166,059	3.73E+11	1,513,233
1998	1.48E+11	542,955	1.56E+11	1,290,334	3.57E+10	549,986	3.40E+11	2,383,275
						Mean	2.93E+11	1,231,307

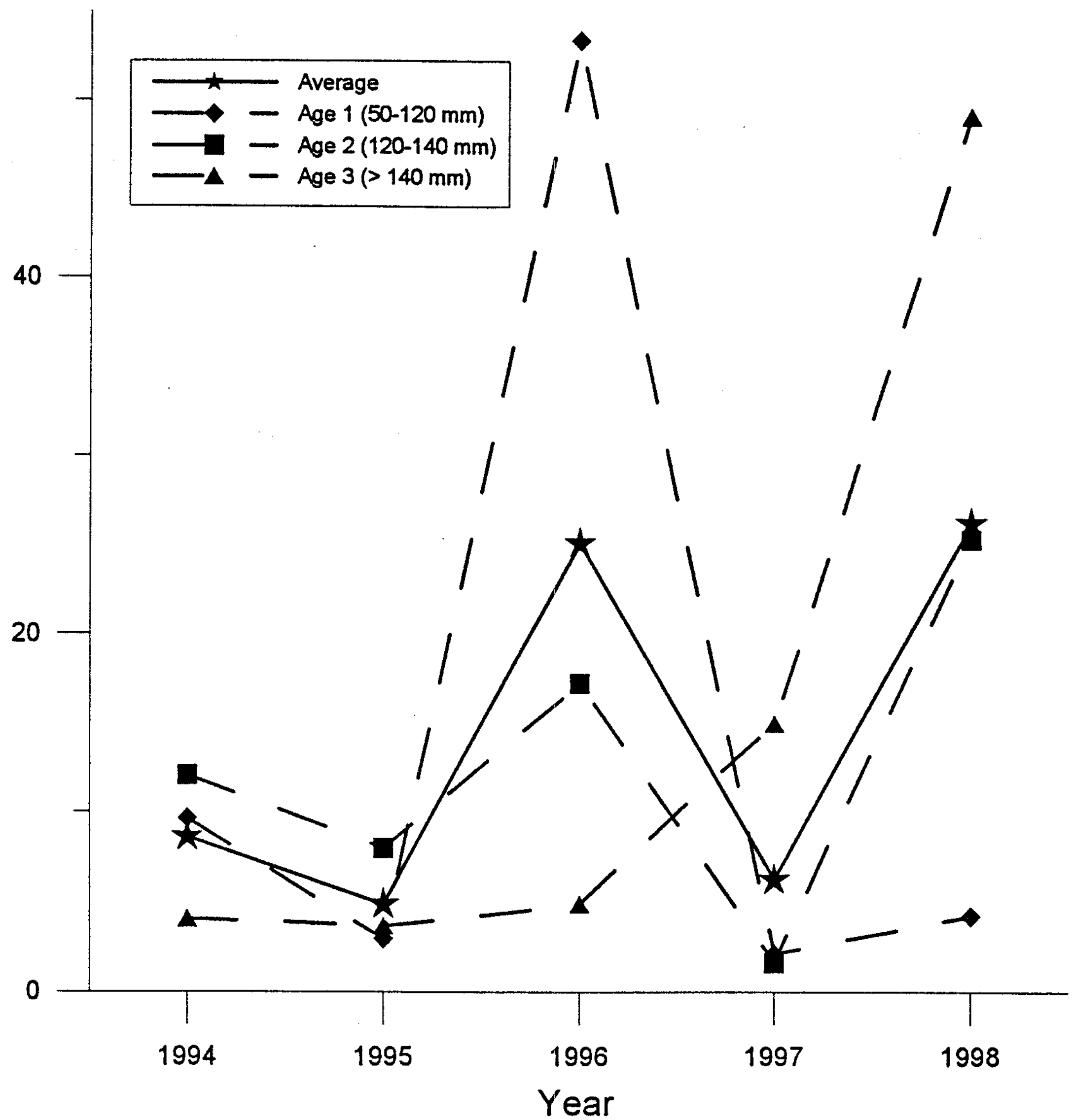


Figure 1. Day versus night abundance ratios for different age/size groups for each survey year. The average is for all age/size groups each year.

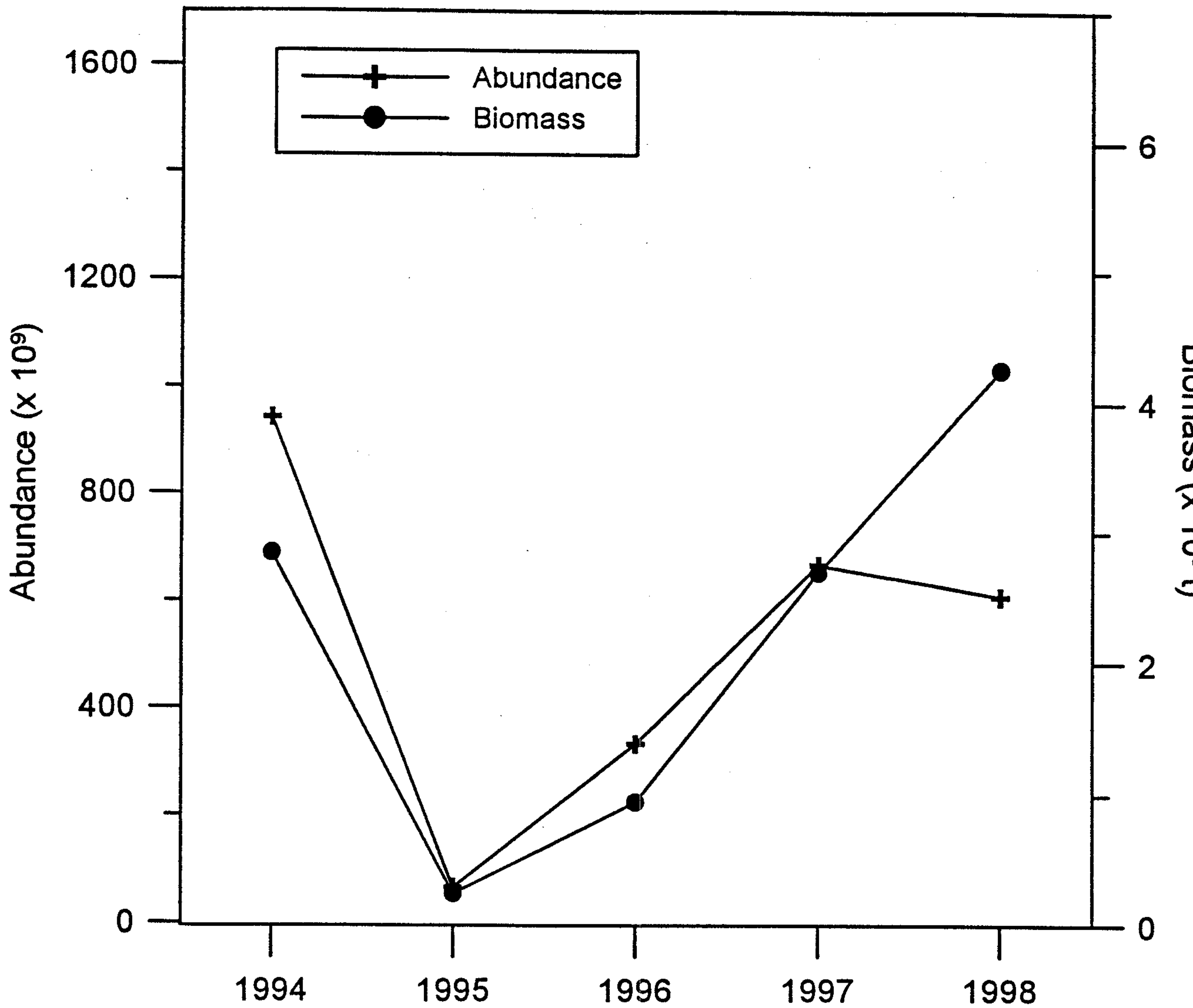
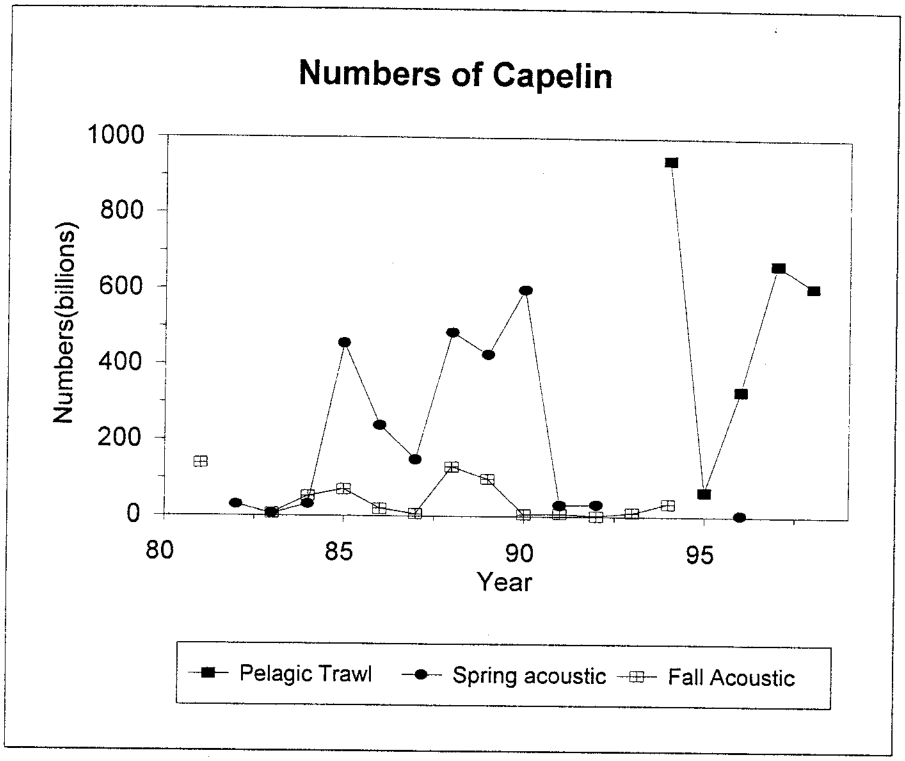


Figure 2. Absolute abundance and biomass of capelin in the Northwest Atlantic (2J3KLNO), as estimated from the Pelagic Juvenile Fish Surveys, 1994-1998.



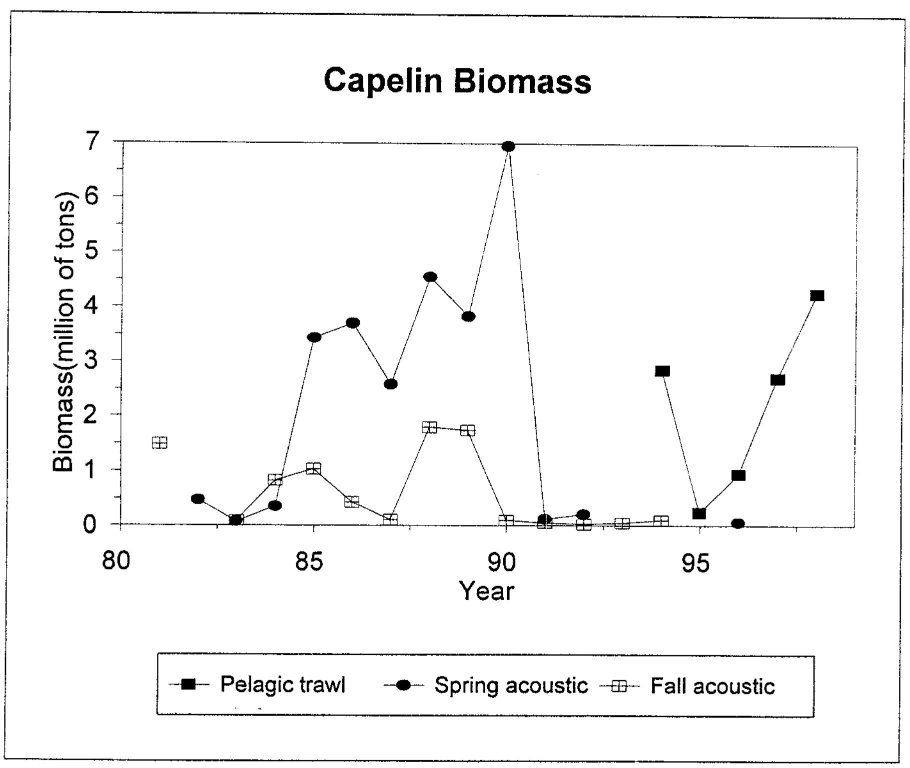


Fig. 3. Estimates of capelin abundance (a) and biomass (b) based on acoustic surveys in spring (1982-92, 1996) and autumn (1981-94) and pelagic trawls surveys (1994-98), in the Newfoundland Region.