

Trends in Yearclass Strength of Capelin (Mallotus villosus)

by

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## Introduction

The multiplicative model provides an objective framework for combining indices from a variety of sources into a single compromise index (see Myers et al. 1993). This approach is particularly attractive for extraction of the yearclass effect because multiple estimates from several abundance indices can be combined over a life-span. The multiplicative approach was applied to capelin for the first time in the 1995 assessment (Anon. 1995) with indices receiving equal weight. For the 1999 assessment, a weighted multiplicative model was employed to estimate a standardized index of cohort strength (Nakashima and Evans 1999). For the 2000 assessment indices previously excluded, i.e. Canadian acoustic surveys, were included in the evaluation.

## Methods

The multiplicative cohort model assumes that the various types of abundance indices to be integrated remain proportional to population abundance (and therefore each other) throughout the time series so that gaps and missing values can be filled in through standardization into a combined index.

The general multiplicative model took the form:

$$N_{ijkt} = I C_k S_j A_i \epsilon$$

where I = intercept

$C_k$  = cohort effect

$S_j$  = survey effect for  $j = 1 \dots 13$

$A_i$  = age effect for  $i = 0 \dots 5$

$\epsilon$  = residuals from fitted model

and  $N_{ijkt}$  = number at age  $i$  from survey  $j$  belonging to cohort  $k$  in year  $t$ .

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

A multiplicative analysis was performed as in Anon. (1995). The variance of each index about the combined estimate was computed. For the group of indices comprising 1/3 of the total that had the smallest variances, their variances were replaced by the largest variance in the group. Thus exceptionally, possibly accidentally small variances were ignored. The multiplicative analysis was then repeated with each index weighted by the reciprocal of its variance.

For the most recent yearclass, a probability distribution for yearclass strength was developed combining the empirical distributions for expected yearclass strength and expected catchability of the few available indices, using Bayes rule (Evans 2000).

To develop a standardized cohort index for the 2000 assessment, a multiplicative model was applied to thirteen indices. Seven indices were chosen as the basis for the 1995 assessment, i.e. catch rates from purse seines and traps, the aerial survey index, egg deposition, the Russian 2J3K CPUE, and Canadian 2J3K and 3L fall bycatch indices from offshore groundfish surveys. Five indices that were the basis of a standardized recruitment index in the 1998 assessment (Nakashima 1998) were combined with the original seven indices for the 1999 assessment (Nakashima and Evans 1999). For this assessment we excluded the Bellevue Beach sediment larval index because of worries that it is not independent of the Bellevue Beach larval index and included two Canadian acoustic surveys because discrepancies would be accounted for in weighting.

## Results and Discussion

### Indices

The multiplicative model was applied to the following indices to estimate a standardized cohort index for the 2000 assessment of 2J3KL capelin (Appendix A):

1. aerial survey index 1982-98, excluding 1991;
2. egg deposition index 1990-99;
3. purse seine catch rate index 1981-93, 1996;
4. integrated trap catch rate index 1981-93;
5. groundfish 3L fall bycatch 1985-94;
6. groundfish 2J3K fall bycatch 1985-94;
7. Russian 2J3K fall commercial catch rate index 1972-91;
8. Conception Bay sediment larval index 1987, 1989-93;
9. Bellevue Beach emergent larval index 1990-96, 1998-99;
10. Offshore Div. 2J3KLNO 0-group index 1994-99;

11. Offshore Div. 2J3KLNO age 1 index 1994-99.
12. Canadian Div. 3L spring acoustic survey 1982-91, 1996;
13. Canadian Div. 2J3KL fall acoustic survey 1981, 1983-94.

(a) Aerial survey index

No aerial survey was conducted in 1999.

(b) Egg deposition index

Egg deposition (stages I-II, integrated for each beach) has been estimated since 1990 for several beaches on the northeast coast. For the 1999 assessment we used the Bellevue Beach data series (Nakashima and Slaney 2000a). To estimate the number of females we divided egg deposition by the mean female weight in gm. The estimate was then partitioned for the cohort model using the female age composition from biological samples collected at Bellevue Beach (Nakashima and Slaney 2000a). The egg deposition time series was first adopted as an index in the 1996 assessment (Winters 1996) and serves as an indirect measure of female spawner escapement. Retention of the index in the analysis assumes that observations at Bellevue Beach are indicative of an overall trend in beach spawning for Div. 3KL.

(c) Purse seine index

Data were available to estimate a purse seine catch rate (catch per fishing day) for the 1999 mobile fishery. Details concerning the purse seine fishery in 1999 are in Nakashima and Slaney (2000b). The purse seine catch rate for 1999 was not used in the standardized cohort model this year. The low number of returns reflecting the low participation in the fishery and nature of the fishery created difficulties in evaluating the relevance of the recent catch rates to those in the early part of the series.

(d) Integrated trap index

Data were unavailable from the research logbook survey to estimate an integrated trap index for 1999. The monitoring program to determine area openings and marketing constraints have changed fishing practices. Only 20 research logbook fishers participated in the fishery. Most of the data came from White Bay and Trinity Bay and no fishery took place on the Southern Shore or in St. Mary's Bay (Nakashima and Slaney 2000b). No acceptable method was available to make the 1999 estimate compatible with estimates earlier in the time series. Therefore no estimate for 1999 was used in the analysis.

(e) Offshore indices

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

(f) Inshore 0-group indices

The inshore indices were based on very early estimates of 0-group fish. Sediment larvae are newly hatched capelin larvae resident in beach sediments for 1-5 days. When larvae are released from beach sediments into the water column they are then termed emergent larvae. Sediment larvae were estimated from 15 Conception Bay beaches in 1987 and 1989-93 (Winters et al. 1996). Emergent larvae were enumerated at several northeast coast beaches including Bellevue Beach since 1990. The Conception Bay sediment larval index and the Bellevue Beach emergent larval index were used in the 1999 assessment (Nakashima and Evans 1999). The Bellevue Beach sediment larval index used in the 1999 assessment was excluded from the 2000 assessment. Estimates of sediment larvae and emergent larvae were highly correlated (Fig. 1) and the two life stages were less than 21 days apart raising concern that they were not independent. Consequently for this assessment only the Conception Bay sediment larval index and the Bellevue Beach emergent larval series were considered.

(g) Offshore 0-group and age 1 indices

An 0-group index and an age 1 index from annual offshore surveys conducted in August-September since 1994 (Anderson and Dalley 2000) were incorporated into the multiplicative cohort model for the first time in the 1999 assessment (Nakashima and Evans 1999). 0-group capelin were collected by bongos and age 1 capelin were collected using an IGYPT trawl during the offshore 0-group survey (Anderson and Dalley 2000).

(h) Canadian acoustic survey indices

Canadian acoustic surveys were conducted in the spring in Div. 3L from 1982-90, 1992, and 1996 and in the fall in Div. 2J3K from 1981, 1983-94. During initial development of the multiplicative model the spring (Winters 1995) and fall (Winters 1996) acoustic survey series were considered and their lack of correspondence to other series especially in the 1990s led to their rejection for inclusion in the original multiplicative model. With the development of the weighted model, these indices were included in the current run allowing the weightings to determine their influence on the multiplicative index rather than

the more subjective determination used in the mid 1990s (Winters 1995, 1996).

### Model Development

Indices used in the weighted model are displayed in Figure 2. A Bayes update to better estimate the most recent yearclass (2000 in this example) is shown in Figure 3. Weightings are in Table 1. The final cohort model in Fig. 4 displays considerable variation, especially in recent years.

### Summary

For the 2000 assessment, the weighted model was adopted to estimate standardized cohort abundance trends (Fig. 4). The relative size of the 1996 yearclass shows this yearclass to be relatively strong. Even at the lower 95% confidence interval the estimate is one of the highest in the series. However, there is considerable variation and therefore uncertainty about the estimate.

Based on the weighted multiplicative analysis, the 1996 yearclass is comparable to the 1986 yearclass but not as strong as the 1983 yearclass. The 1997 and 1998 yearclasses are weaker than the 1996 yearclass and appear to be of average strength. The 1999 yearclass will not be part of the 2000 spawning biomass, however, early indications from 0-group estimates suggest this yearclass may be one of the weaker yearclasses in the 1990s. The high variation surrounding the estimates, especially since 1993 partly reflects a reduction in the number of indices available to estimate relative yearclass size.

Besides the problems and assumptions associated with each of the indices in this analysis, there are other assumptions that have not been evaluated but may be important to interpreting the model results. For example, some indices do not use an independently derived age composition. Since 1996 the egg deposition and aerial survey indices use the same age composition derived from Bellevue Beach spawners. The results of the multiplicative analysis must be considered with caution in light of these and other assumptions whose effects have not been evaluated.

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Table 1. Weightings used in the multiplicative model.  
Survey symbols refer to indices in Appendix A.

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Age	Survey	Weight
2	A	1.50
3	A	2.16
4	A	1.22
5	A	2.16
2	B	0.66
3	B	2.15
4	B	1.77
5	B	1.44
2	C	0.44
3	C	2.16
4	C	2.16
5	C	0.83
2	D	0.33
3	D	2.16
4	D	2.16
5	D	1.63
2	E	1.44
3	E	1.61
4	E	2.16
5	E	1.93
2	F	2.16
3	F	2.16
4	F	1.54
1	G	2.16
2	G	2.16
3	G	1.04
0	H	2.16
1	J	1.27
0	K	2.16
0	M	2.16
1	N	0.17
2	N	0.34
3	N	0.46
4	N	0.45
5	N	0.51
1	O	0.31
2	O	0.45
3	O	0.34
4	O	0.41
5	O	0.61

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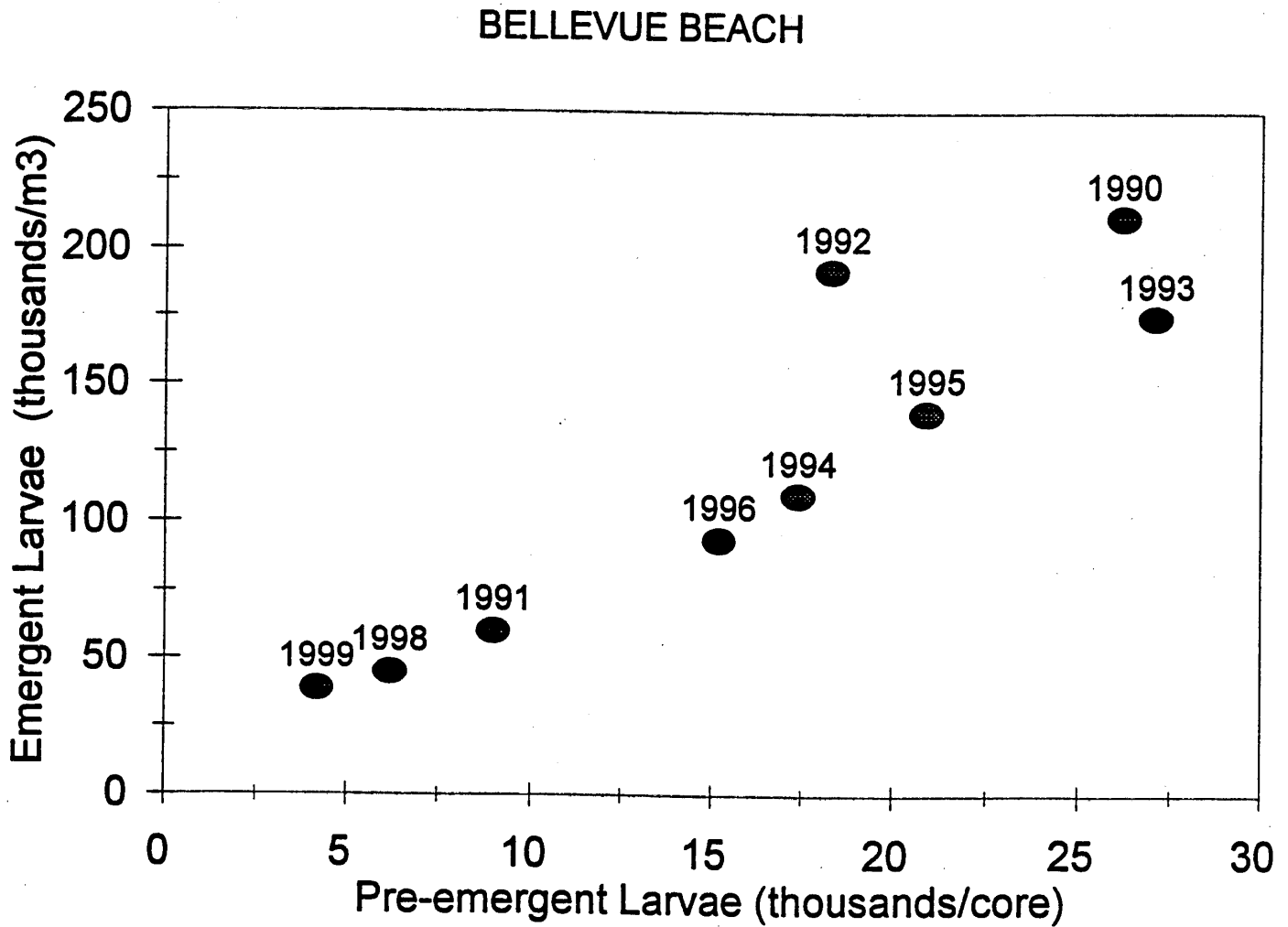


Fig. 1. Scatterplot of annual estimates of pre-emergent larvae and emergent larvae at Bellevue Beach (data from Nakashima and Slaney 2000a).

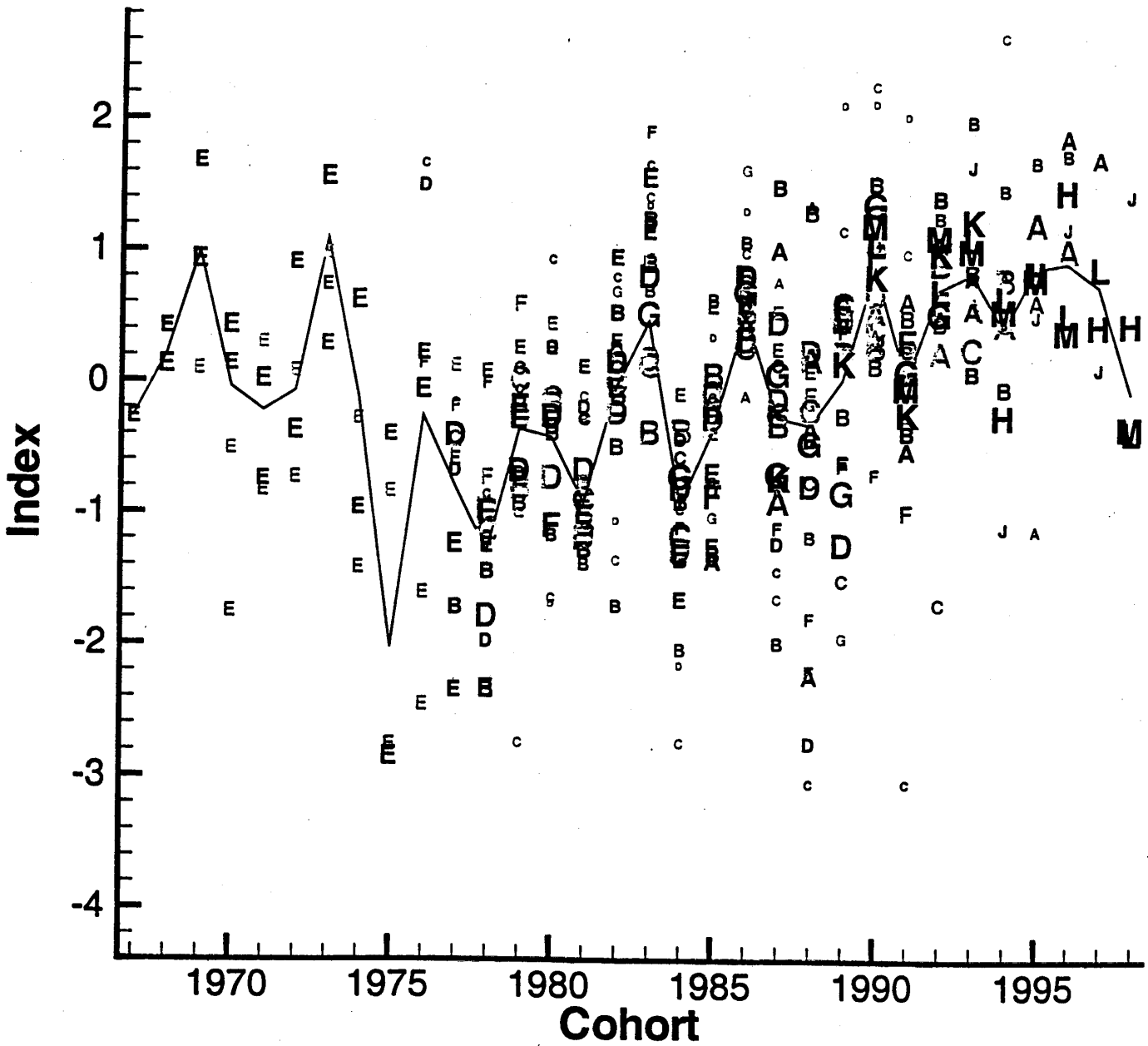


Fig. 2. The scatter of all indices used in the weighted multiplicative analysis. The letters refer to the indices in Appendix A. The larger the letter symbol the greater its contribution to the overall trend.

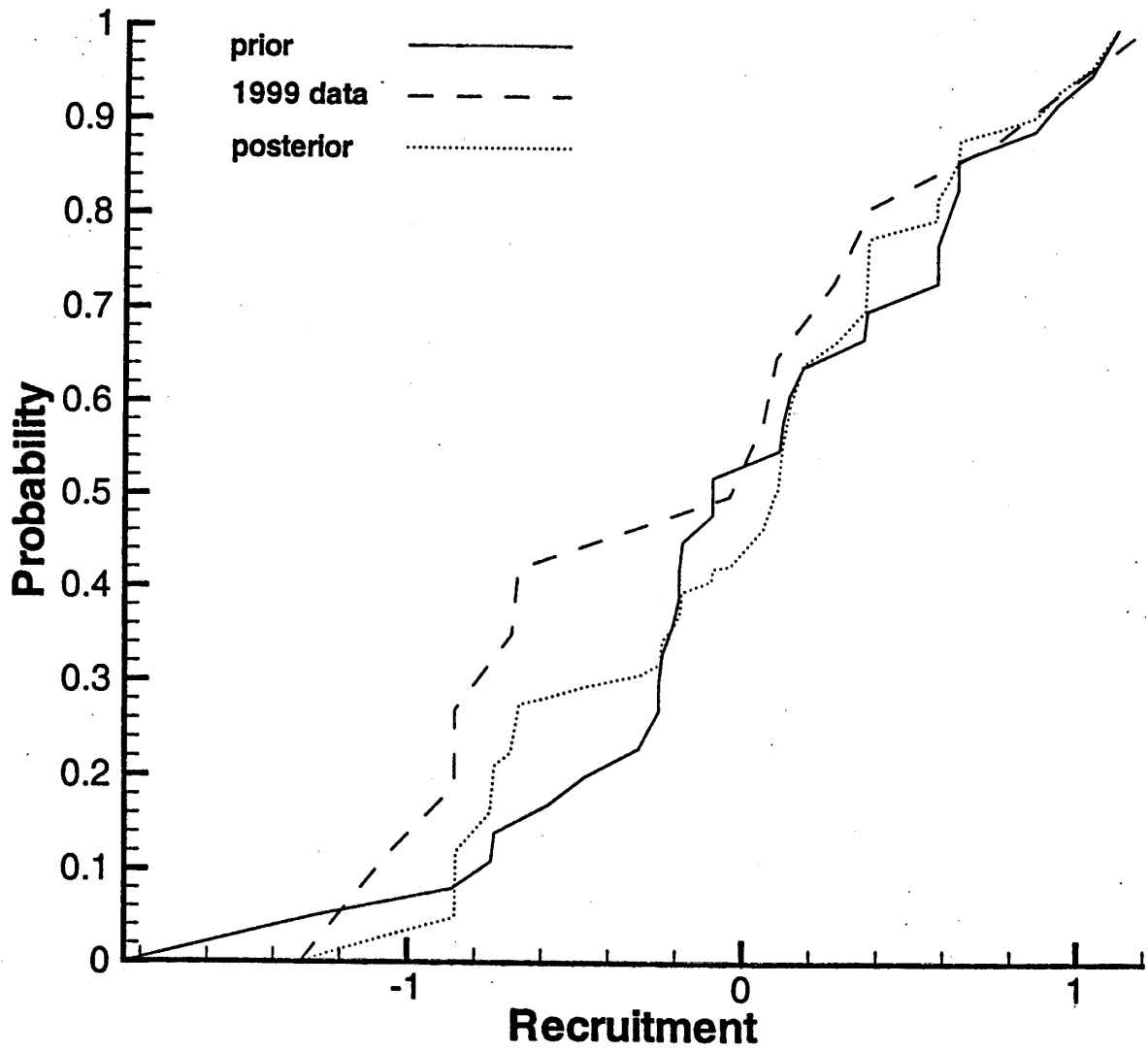


Fig. 3. Bayes update of the 1999 yearclass for the weighted multiplicative analysis.

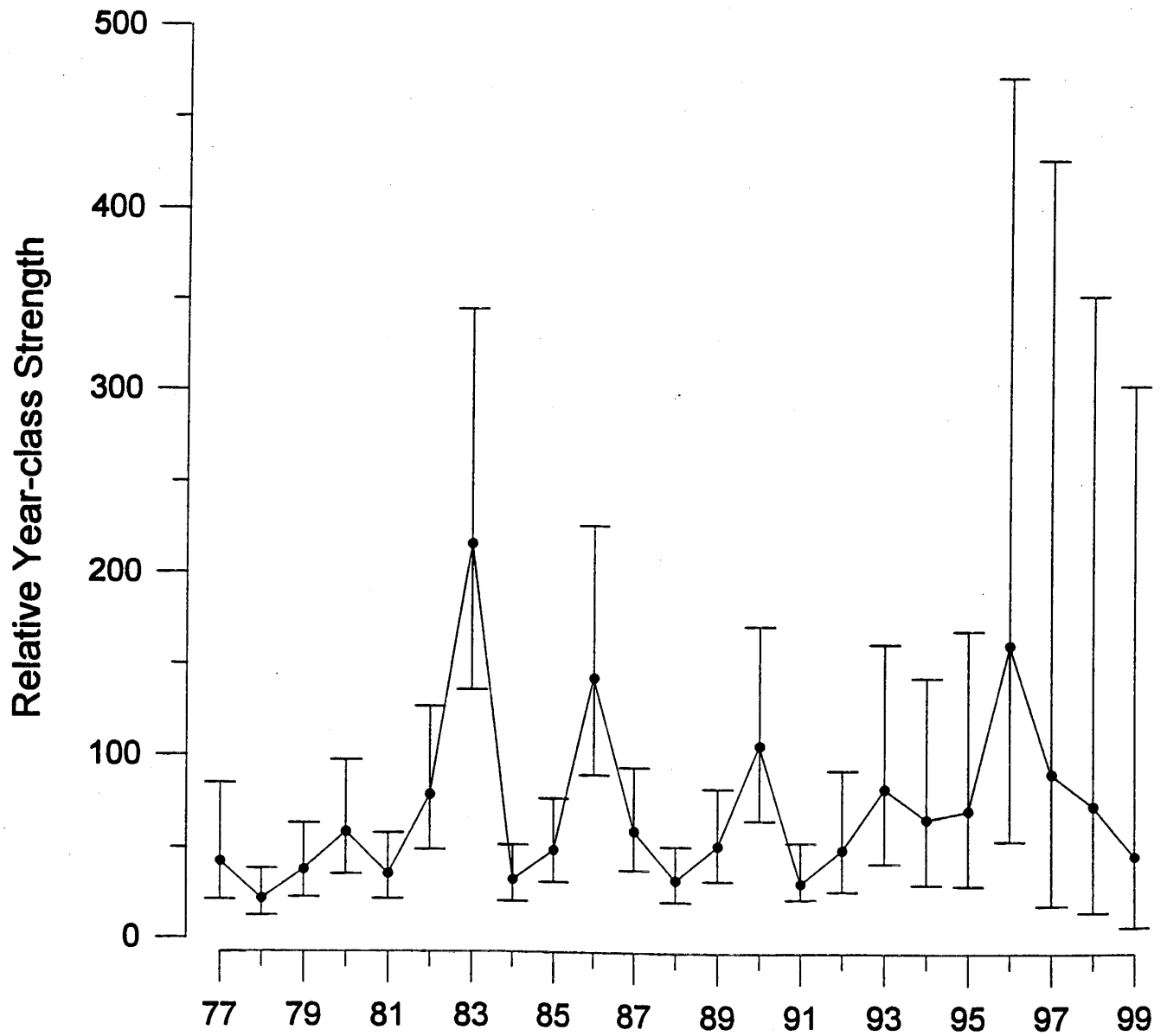


Fig. 4. Standardized estimates of cohort abundance of capelin with 2 standard errors using a weighted multiplicative model.

## Appendix A. Indices used in the standardized cohort abundance model.

Year	Age					
	0	1	2	3	4	5
Egg Deposition Index (A)						
1990	-	-	12	184	156	12
1991	-	-	179	544	374	84
1992	-	-	152	563	669	129
1993	-	-	213	1353	354	33
1994	-	-	186	519	253	80
1995	-	-	255	572	132	82
1996	-	-	187	806	287	28
1997	-	-	210	716	380	135
1998	-	-	729	1537	395	82
1999	-	-	618	1254	56	-
Aerial Survey Index (B)						
1982	-	-	55	939	125	36
1983	-	-	44	1783	1095	47
1984	-	-	32	712	885	79
1985	-	-	354	1775	582	143
1986	-	-	23	1438	803	56
1987	-	-	332	1456	4521	339
1988	-	-	515	2247	527	500
1989	-	-	24	3637	1011	52
1990	-	-	54	1524	1987	54
1991	-	-	-	-	-	-
1992	-	-	505	2660	4798	887
1993	-	-	226	2803	1013	130
1994	-	-	625	2678	1480	328
1995	-	-	1297	5227	2143	913
1996	-	-	768	5514	2074	137
1997	-	-	944	4662	3041	820
1998	-	-	1000	4745	1255	217
Purse Seine Catch Rate Index (C)						
1981	-	-	1	123	124	112
1982	-	-	3	395	58	18
1983	-	-	14	341	210	9
1984	-	-	4	158	248	20
1985	-	-	64	386	143	54
1986	-	-	1	441	215	16
1987	-	-	14	120	643	47
1988	-	-	42	358	107	111
1989	-	-	3	510	163	8
1990	-	-	10	304	413	10
1991	-	-	50	315	219	36
1992	-	-	150	705	89	5
1993	-	-	42	590	42	1
1994	-	-	-	-	-	-
1995	-	-	-	-	-	-
1996	-	-	217	500	35	1

## Appendix A. Continued ...

Year	Age					
	0	1	2	3	4	5
Trap Catch Rate Index (integrated) (D)						
1981	-	-	1	941	943	831
1982	-	-	16	1908	237	95
1983	-	-	67	1202	719	26
1984	-	-	30	766	1095	93
1985	-	-	334	1998	731	245
1986	-	-	10	3013	1674	155
1987	-	-	124	697	3216	243
1988	-	-	323	2271	634	615
1989	-	-	38	3447	1083	122
1990	-	-	55	2198	3200	83
1991	-	-	723	3180	2248	365
1992	-	-	730	4056	648	55
1993	-	-	665	4902	413	12
Russian 2J3K Fall Commercial Catch Rate Index (E)						
1972	-	-	33	181	59	8
1973	-	-	83	99	132	16
1974	-	-	92	223	80	56
1975	-	-	400	179	53	12
1976	-	-	46	437	36	5
1977	-	-	12	124	248	26
1978	-	-	38	71	97	14
1979	-	-	105	14	3	4
1980	-	-	206	185	49	7
1981	-	-	248	49	15	13
1982	-	-	247	61	5	1
1983	-	-	215	256	39	3
1984	-	-	262	77	39	5
1985	-	-	464	200	19	10
1986	-	-	128	419	50	4
1987	-	-	340	150	248	27
1988	-	-	430	112	14	33
1989	-	-	248	332	26	2
1990	-	-	208	281	95	3
1991	-	-	104	18	0	0

## Appendix A. Continued ...

Year	Age					
	0	1	2	3	4	5
Groundfish 2J3K Fall Bycatch Index (F)						
1980	-	-	34	31	7	-
1981	-	-	77	26	5	-
1982	-	-	31	97	6	-
1983	-	-	-	-	-	-
1984	-	-	-	-	-	-
1985	-	-	-	-	-	-
1986	-	-	-	-	-	-
1987	-	-	39	23	41	-
1988	-	-	131	37	2	-
1989	-	-	-	-	-	-
1990	-	-	-	-	-	-
1991	-	-	166	49	2	-
1992	-	-	248	29	1	-
1993	-	-	128	87	9	-
1994	-	-	173	20	3	-
Groundfish 3L Fall Bycatch Index (G)						
1985	-	44	220	28	-	-
1986	-	-	-	-	-	-
1987	-	-	-	-	-	-
1988	-	45	261	5	-	-
1989	-	57	140	71	-	-
1990	-	-	-	-	-	-
1991	-	352	56	12	-	-
1992	-	99	466	2	-	-
1993	-	154	125	66	-	-
Offshore 0-group Index (H)						
1994	89987	-	-	-	-	-
1995	271008	-	-	-	-	-
1996	499665	-	-	-	-	-
1997	179281	-	-	-	-	-
1998	181884	-	-	-	-	-
1999	215480	-	-	-	-	-
Offshore age I Index (J)						
1994	-	21256	-	-	-	-
1995	-	1344	-	-	-	-
1996	-	6743	-	-	-	-
1997	-	13247	-	-	-	-
1998	-	4543	-	-	-	-
1999	-	16877	-	-	-	-

## Appendix A. Continued ...

Year	Age					
	0	1	2	3	4	5
Conception Bay Sediment Larval (K)						
1987	61	-	-	-	-	-
1988	-	-	-	-	-	-
1989	147	-	-	-	-	-
1990	285	-	-	-	-	-
1991	99	-	-	-	-	-
1992	340	-	-	-	-	-
1993	432	-	-	-	-	-
Bellevue Emergent Larval Index (M)						
1990	212	-	-	-	-	-
1991	61	-	-	-	-	-
1992	193	-	-	-	-	-
1993	175	-	-	-	-	-
1994	110	-	-	-	-	-
1995	140	-	-	-	-	-
1996	94	-	-	-	-	-
1997	-	-	-	-	-	-
1998	45	-	-	-	-	-
1999	39	-	-	-	-	-
Canadian 3L Spring Acoustic Survey (N)						
1982	-	.1	9.7	16.2	2.4	.9
1983	-	.1	3.4	1.9	.8	.1
1984	-	.1	21.0	6.2	3.1	.5
1985	-	.2	369.5	80.5	3.8	2.3
1986	-	.03	59.4	158.1	21.3	1.0
1987	-	.3	88.1	18.3	38.9	4.0
1988	-	13.6	380.4	65.7	9.7	16.8
1989	-	3.4	314.8	96.2	11.0	1.4
1990	-	18.9	353.2	169.0	55.6	1.9
1991	-	-	-	-	-	-
1992	-	-	19.0	6.5	.7	.1
1993	-	-	-	-	-	-
1994	-	-	-	-	-	-
1995	-	-	-	-	-	-
1996	-	.1	3.0	1.7	.1	.03



## Appendix A. Continued ...

Year	Age					
	0	1	2	3	4	5
Canadian 2J3K Fall Acoustic Survey (O)						
1981	-	67.8	59.3	7.4	2.8	.7
1982	-	-	-	-	-	-
1983	-	2.6	2.5	1.3	.2	.03
1984	-	6.2	34.7	7.1	4.1	.4
1985	-	1.5	54.0	13.5	1.5	.6
1986	-	.1	6.6	12.1	1.1	.2
1987	-	.7	4.4	.5	.6	.1
1988	-	15.8	96.0	13.6	2.0	3.9
1989	-	1.9	59.0	35.3	2.5	.5
1990	-	1.4	2.6	1.6	.6	.1
1991	-	4.7	2.5	.4	.1	.1
1992	-	.1	1.9	.2	.1	.03
1993	-	.2	1.0	.3	.1	.03
1994	-	.3	.5	.1	.1	.03

**Abundance and Biomass of Juvenile and Adult Capelin in the  
Newfoundland Region (NAFO 2J3KL) Estimated from the Pelagic  
Juvenile Fish Surveys, 1994-1999**

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### **Introduction**

The status of capelin (*Mallotus villosus*) within the Newfoundland Region (NAFO 2J3KL) is of interest to scientists and managers for many reasons. These include setting catch limits as part of the capelin management plan. Currently, a multiplicative model has been developed from a number of indices modelled over many years to assess the abundance of capelin. Results from the model indicate the population is similar to, or possibly larger than, the absolute estimates of capelin biomass available from the 1980's (Nakashima 1998). However, the model output does not agree with opinions of fixed gear fishermen (Anon. 1999a) and a number of the model assumptions appear to be violated (Anon. 1999b). These factors have brought into question the accuracy of the model output and highlighted the question, how many capelin are there?

Capelin are arguably the single most important component of the marine ecosystem off Newfoundland and Labrador, existing as the primary link between plankton production and piscivore consumption. Capelin are the primary prey of important apex predators, such as harp seals (*Phoca groenlandica*) and Atlantic cod (*Gadus morhua*) (Bundy et al. 2000). Total annual consumption of capelin could be on the order of 4.7 Mt. Capelin are also the primary consumer of production from the lower, primary and secondary producers, consuming on the order of 42 Mt annually (op. cit.). Current estimates of harp seal consumption within the Newfoundland region indicate that 710,000 t of capelin are consumed annually (Hammill and Stenson 2000) while consumption by cod may be only on the order of 100,000 t annually (Carscadden et al. 2001).

The purpose of this paper is 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 1994-1999 (Anderson et al. 2000). This survey extends from southern Labrador to the southern Grand Bank, including the inshore areas along the northeast coast of Newfoundland. We compare our estimates to an independent estimate based on acoustics (O'Driscoll et al. 2000) and evaluate our results in the context of the marine ecosystem.

## Materials and Methods

The absolute abundance of capelin was estimated from the standardized catch 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;  $\leq$  140 mm. These size ranges are thought to approximate the size ranges of age one, two and three year old capelin. The survey design is described in Anderson and Dalley (1997). 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. Abundance offshore was based on the standardized catch rates at each station, as

$$N_1 = \sum_{i=1}^k q^{-1} \cdot A \cdot C_i \cdot D_i$$

where  $N_1$  is the absolute number of capelin offshore,  $q$  is the trawl catchability,  $A$  is the area represented by each station ( $2.92 \times 10^9 m^2$ ),  $C_i$  is the density of capelin estimated at each station ( $m^{-3}$ ),  $D_i$  is the maximum tow depth (m), and  $i$  represents the number of stations sampled offshore. For all inshore areas absolute abundance was estimated, as

$$N_2 = \sum_{j=1}^m q^{-1} \cdot B_j \cdot \sum_{i=1}^k E_i \cdot D_i$$

where  $N_2$  is the absolute abundance inshore,  $q$  is the trawl catchability,  $B_j$  is the total area of each inshore area ( $m^2$ ),  $E_i$  is the mean density of capelin for all stations sampled within each inshore area ( $m^{-3}$ ),  $D_i$  is the mean maximum tow depth (m),  $i$  represents the number of stations within each inshore area, and  $j$  represents the inshore areas. The inshore areas were estimated using a high resolution shoreline to define the inner boundary, while the outer boundary was defined arbitrarily to include an outer extension of each bay onto the adjacent shelf. Area was estimated using Surfer (1999). Total abundance for the entire area was simply  $N_1 + N_2$ . 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 (Sundby et al. 1989; Koslow et al. 1997).

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. 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). However, the night/day ratio varied without a consistent pattern, both among length groups and among years. As an average across all size groups within year, the ratio varied from a low of 4.87 in 1995 to a high of 25.64 in 1998. As an average for each size group across all years, the ratio was 19.22, 10.99, and 13.14 for size groups LG1, LG2 and LG3, respectively.

Mean length and weight of capelin within the three size groups tended to be greater beginning in 1997 (Table 2). Mean weight for all three size groups increased from 7.1 g in 1994-1996 compared to 9.1 g in 1997-1999. Among year abundance summed for all three size groups varied from a low of  $6.6 \times 10^{10}$  capelin in 1995 to a high of  $9.4 \times$

$10^{11}$  in 1994, based on a catchability coefficient of 0.14 (Table 3). Mean abundance was  $5.6 \times 10^{11}$  for all years, and ranged from  $3.1 \times 10^{11}$  to  $7.9 \times 10^{11}$ , based on high (0.25) and low (0.10) catchabilities respectively. Similarly, among year biomass ranged from 0.2 Mt in 1995 to 4.2 Mt in 1998, with a mean biomass estimate of 2.3 Mt, based on a catchability coefficient of 0.14 (Table 3). Mean biomass across all years ranged from 1.3 Mt to 3.2 Mt, based on high (0.25) and low (0.10) catchabilities (Table 3).

The year of highest abundance, 1994, was driven by the relatively strong 1993 year-class at age one. The 1996 year-class was also strong within the LG1 (age one) size group and this was particularly true for the LG2 (age two) size group in the 1998 survey. However, the very high value estimated at age two for the 1996 year-class was primarily due to the high night/day ratio applied (see Table 1). This in turn resulted in a high abundance and biomass estimate for the LG2 size group and ultimately the highest annual biomass estimate when all groups were combined (Table 3).

## Discussion

There appear to be at least three different factors that determine the abundance and biomass estimates based on the mid-water trawl catches. Abundance each year appears to be determined primarily by year-class strength, where the 1993, 1996 and 1998 year-classes were relatively strong (Anderson et al. 2000). These strong year-classes resulted in the largest biomass estimates at age one (LG1), in excess of 2 Mt, which contributed the most to annual estimates of biomass.

A second effect appears to result from the night/day ratios, where relatively high ratios were applied for different length groups in some years. This effect appears to be most pronounced for all size groups in 1995 and for the LG2 size group in 1998. In 1998 for the LG2 size group, the largest night/day ratio in the series was applied to the relatively strong 1996 year-class at age two. This resulted in a LG2 biomass estimate of 2.3 Mt, an order of magnitude greater than estimated for any other year. We believe the high LG2 ratio applied to this relatively strong year-class resulted in an over estimate of population abundance and biomass in 1998. The night/day ratio for LG2 ranged from 1.65 to 17.2 for the other years, averaging 8.1. If this mean night/day ratio is applied to LG2 in 1998, abundance drops to  $8.9 \times 10^{10}$  from  $2.8 \times 10^{11}$  and the total biomass summed for all three size groups drops to 2.7 Mt, from 4.3 Mt. Similarly, if the mean night/day ratios estimated for all years are applied to the three length groups in 1995 then total abundance is estimated as  $3.9 \times 10^{11}$  and we calculate a total biomass of 1.3 Mt. Applying these simple corrections to the night/day ratios, it would appear that the total biomass of capelin estimated during the trawl surveys might range from 0.9 to 2.9 Mt during the period 1994-1999.

A third factor affecting the biomass estimates is the increase in mean weight of capelin 1994-1996 compared 1997-1999. The increase was approximately 30%, which explains in part the higher biomass estimates during the final three years.

During the 1999 pelagic juvenile fish survey an acoustic survey was carried out to estimate the spatial distribution of capelin between survey stations and throughout the water column (O'Driscoll et al. 2000). Total acoustic biomass estimated from this survey was only 43,000 t to 69,000 t, depending on the target strength model used (op. cit.). These acoustic estimates represent only 2-3% of the biomass estimate based on the trawl survey. Recently, Carscadden et al. (2001) estimated that approximately 1.9 Mt of capelin

would be consumed annually in the 1990's based on a set of predators that included harp seals (710,000 t), cetaceans (700,000 t), seabirds (240,000 t), Greenland halibut (150,000 t) and Atlantic cod (100,000 t). For this level of predation to exist, we should expect in excess of 2 Mt of capelin to occur on average. Therefore, the acoustic estimate appears to be a significant under-estimate of the true biomass of capelin that must occur in the waters off Newfoundland.

The application of night/day ratios to our capelin catches is based on the simple assumption that capelin undergo diurnal migrations into the trawl zone (< 60 m) during night. Characteristically, capelin occur in layers near the surface at night and form schools in midwater and near the bottom during the day (O'Driscoll et al. 2000). We know there are interannual variations in diurnal behaviour (Shackell et al. 1994) as well as seasonal (O'Driscoll and Rose 1999) and that behaviour can vary spatially within the survey (O'Driscoll et al. 2000). 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). Our survey results support these observations, with the additional caveat that diurnal variation also appears to vary among size classes (i.e. ages). However, the application of our ratios to correct for day catches appears to be too simplistic a solution to apply in all cases. We believe that a more direct method utilizing acoustics is necessary to properly correct for the amount of capelin within the trawl zone.

Our estimates of absolute abundance and biomass should compare most closely to the acoustic survey estimates carried out in fall 1983-1994, where both surveys were post-spawning and covered a wide area of the shelf from southern Labrador to the northern Grand Bank. However, our estimates appear to be closer to the spring acoustic survey than the fall (Figure 1). In general, we should expect our abundance estimates to be higher than the previous fall acoustic estimates due to our greater potential to capture one year old juvenile capelin. In addition, our estimates include the inshore areas which were not surveyed by previous acoustic surveys. On average, the inshore areas represented about 40% of all capelin captured within the 2J3KL zone.

It appears that the Pelagic Juvenile Fish Survey holds promise as a basis for estimating the absolute abundance and biomass of capelin off Newfoundland. Our estimate that approximately 0.9 Mt to 2.9 Mt of capelin have occurred in recent years is similar to, and generally greater than, fall acoustic estimates in the 1980's. Limitations imposed by sampling the surface layer can be addressed by simultaneously using acoustics, as carried out in 1999 (O'Driscoll et al. 2000). Diurnal behaviour of capelin must be addressed by a comprehensive research program, both as this behaviour affects trawl catchabilities and diurnal corrections and as it affects acoustic detectability. Finally, questions regarding the inshore distribution of capelin and the assumption that the present survey design is adequately sampling capelin must also be addressed. Incorporating acoustics within the existing survey design, combined with separate sampling programs directed at identified concentrations inshore and offshore should result in our capability to realistically assess the status of capelin within the Newfoundland region.

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Table 1. Ratio of night to day capelin densities (number m<sup>-3</sup>) for each year and each size group, where LG1 is 55-119 mm, LG2 is 120-139 mm and LG3 is  $\geq 140$  mm.

<b>Year</b>	<b>LG 1</b>	<b>LG 2</b>	<b>LG 3</b>
<b>1994</b>	9.62	12.03	4.10
<b>1995</b>	2.96	7.96	3.68
<b>1996</b>	53.38	17.20	4.91
<b>1997</b>	2.15	1.65	14.96
<b>1998</b>	4.26	25.42	49.24
<b>1999</b>	44.97	1.65	1.95

Table 2. Mean length (mm) and weight (g) of capelin within three size categories sampled by the IYGPT in the Pelagic Juvenile Fish Surveys, 1994-1999. LG1 – length group 55-119 mm; LG2 – length group 120-139 mm; LG3 – length group  $\geq 140$  mm; WG1, WG2, WG3 – weight for LG1, LG2, LG3. Sample numbers are in parentheses.

<b>Year</b>	<b>LG1</b>	<b>LG2</b>	<b>LG3</b>	<b>WG1</b>	<b>WG2</b>	<b>WG3</b>
<b>1994</b>	92.6 (389)	127.6 (85)	152.1 (36)	2.9	7.6	12.5
<b>1995</b>	99.7 (239)	127.7 (61)	142.0 (4)	3.2	7.3	8.8
<b>1996</b>	90.9 (330)	131.1 (27)	149.0 (33)	2.5	8.4	11.1
<b>1997</b>	97.9 (331)	129.9 (122)	149.5 (79)	3.5	8.9	14.9
<b>1998</b>	101.9 (226)	129.3 (139)	149.4 (78)	3.7	8.3	15.4
<b>1999</b>	96.4 (292)	128.3 (62)	154.7 (38)	3.3	8.8	14.8



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, 1994-1999.

Q=0.14								
Year	Group 1		Group 2		Group 3		Total Po	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	981,481	6.07E+11	4,255,211
1999	7.23E+11	2,385,900	2.57E+10	226,160	3.12E+09	46,176	7.52E+11	2,658,236
							<b>Mean</b>	<b>5.61E+11 2,275,235</b>

Q=0.10								
Year	Group 1		Group 2		Group 3		Total Po	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	1,374,073	8.50E+11	5,957,295
1999	1.01E+12	3,340,260	3.60E+10	316,624	4.37E+09	64,646	1.05E+12	3,721,530
							<b>Mean</b>	<b>7.85E+11 3,185,328</b>

Q=0.25								
Year	Group 1		Group 2		Group 3		Total Po	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	549,629	3.40E+11	2,382,918
1999	4.05E+11	1,336,104	1.44E+10	126,650	1.75E+09	25,859	4.21E+11	1,488,612
							<b>Mean</b>	<b>3.14E+11 1,274,131</b>

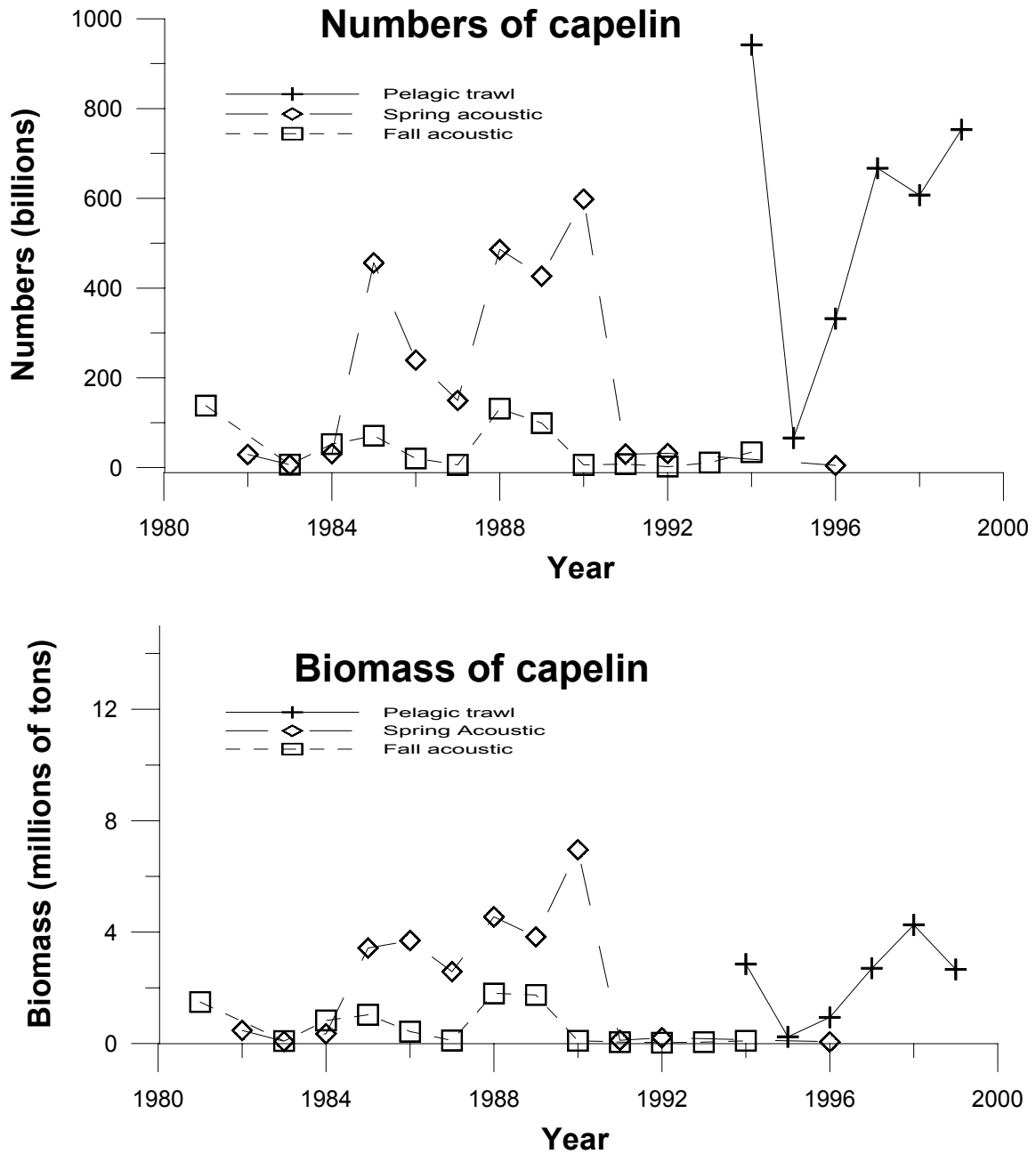


Figure 1. Estimates of capelin abundance (top) and biomass (bottom) based on acoustic surveys in spring (1982-92, 1996) and autumn (1981-94) and pelagic trawl surveys (1994-99), in the Newfoundland Region.

**Year-Class Strength of Northwest Atlantic Capelin (2J3KLNO)  
Estimated as 0-Group (larval), 1-Group and 2+-Group Stages from the  
Pelagic Juvenile Fish Surveys, 1994-1999**

by

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**Abstract**

**Introduction**

Research trawl surveys to estimate the year-class strength of capelin within NAFO Divisions 2J3KLNO have been carried out since 1991 (Anderson and Dalley 1995, 1996, 1997, 1998, 1999). Two gear types are used to sample larval and juvenile capelin in the upper water column. This is a multi-species survey carried out at the end of August and early September, timed to sample pelagic juvenile cod before they settle to the bottom and to sample larval capelin released from beach and bottom sediments following the primary spawning period in June and July.

The purpose of this paper is to report on the abundance and distribution of larval and juvenile capelin from the 1999 survey, and to compare these results to the previous surveys carried out 1994-1998. In addition, we examined the relationship between abundance measured at the larval stage to abundance measured for age one (1-group) and two (2+-group) juvenile capelin. Materials and methods used in this project have been previously described by Anderson and Dalley (1995, 1996, 1997, 1998) and Anderson et al. (1999b).

**Results & Discussion**

**1999 Survey**

The survey was conducted from August 23 to September 19, 1999 (Table 1). In 1999, 129 stations were sampled with the bongo and IYGPT samplers. These stations covered the inshore areas along the northeast coast of Newfoundland and six offshore areas over the Northeast Newfoundland Shelf and on the Grand Banks (Figure 1). The 1999 survey was again plagued by ship problems, where the Templeman was unavailable

due to refit problems until September 12. The Teleost sampled the northern portion of the survey area, from Bonavista Peninsula north, and then proceeded to sample the southern portion of the survey, working from Trinity Bay and Conception Bay then from north to south on the Grand Banks. The Templeman sampled only the southern Grand Bank area. Due to time constraints, the outer northern portion of the Grand Bank was not sampled in 1999 (Nose Index Area, Figure 1).

### **Abundance Indices Ages 0 and 1 and 2+ Capelin**

Abundance indices are reported for larval capelin captured in the bongo sampler as well as for length groups corresponding to one year old capelin (1-group) and capelin which are two years of age and older (2+-group) for all index areas and then summarized for inshore, offshore and all areas combined. In addition, we report for the first time an abundance index for 0-group capelin captured by the IYGPT. Due to strong night/day differences observed in juvenile capelin captured in the IYGPT, we applied a correction to all day samples based on the night/day ratio estimated each year (Anderson et al. 1999a). Both corrected and non-corrected indices are reported (Tables 2 and 3). Bonavista Bay was not sampled in 1998, due to the early recall of the research ship Teleost.

Previously, Bonavista Bay has been an important index area for capelin at both the larval stage and at the juvenile stages. We compared the ratio of abundance measured in Bonavista Bay to the total for the other inshore areas (Conception Bay, Trinity Bay, Notre Dame Bay, White Bay) for the previous four survey years, 1994-1997. For larvae, the mean ratio was 0.183 (Std Dev 0.0628, CV 34.4%). We felt this ratio was stable enough over the previous four years that it could be used to estimate the abundance of capelin larvae in the Bonavista Bay Index Area for 1998. Therefore, we have used this ratio in the estimate for the WIA (Table 3). Compared to the overall (i.e. total) estimate where Bonavista Bay was left not sampled, the predicted value increased the total WIA for 1998 by 7.0%. This increase had the effect of increasing the 1998 larval abundance index to a value similar to the 1997 year-class.

For age one capelin (LG1), the ratio of Bonavista Bay to the other inshore areas averaged 15.84 (range 0.007-77.6). The huge range among years indicates that estimating abundance in Bonavista Bay in 1998 based on the mean ratio would increase the total abundance estimate by 31.2%. However, this increase would not change the year-class strength ranking, where the 1997 year-class at age one would still rank fourth. Similarly for age 2+ capelin (LG2), the ratio of Bonavista Bay to the other inshore areas averaged 3.12 (range 0.003-15.34). Applying this ratio to estimate Bonavista Bay abundance in 1998 results in an increase of total abundance by 9.1% and has no overall effect on year-class ranking. We have chosen to correct for capelin abundance in Bonavista Bay in 1998 for the LG1 and LG2 size classes based on the mean abundance measured in the other four inshore areas in 1998. This is a conservative estimate, increasing the total abundance estimates by 2.3% and 2.8%, respectively. These estimates have no effect on year-class strength ranking, yet the correction moves the total estimates for the inshore and total abundance values more closely to what it might have been if we had actually sampled Bonavista Bay in 1998.

Abundance of larval capelin sampled by the bongo was marginally higher in 1999 than 1997 and 1998, but much lower than the maximum value reported in 1996 (Figure

2). The inshore index was notably higher than the offshore index in 1999, as compared with previous years. Abundance of larval capelin captured in the IYGPT was one to two orders of magnitude greater than previous years (Figure 3). When the bongo and IYGPT larval indices were added the total index was marginally greater in 1995 and 1997 and more than doubled in 1999 (Figure 3). Few larvae were taken in the IYGPT in the other three years.

Abundance estimated for 1-group capelin in 1999 was the second highest in the time series for year-classes 1993-1998 (Figure 4). The notable difference in 1999 was the highest index for the inshore area. Offshore, abundance for the 1998 year-class was similar to that for 1996, but much lower than that estimated for the 1993 year-class.

Comparison of the larval index to the 1-group index demonstrated a very close relationship for the 1994-1998 year-classes for non-corrected data (Figure 5). The relationship was also quite good for the corrected data with the exception of the 1998 year-class that was estimated to be much higher at age one than measured as larvae. This deviation suggests that the night/day correction for 1998 may be in error, where we have over estimated the abundance by the correction factor. These relationships are statistically significant explaining 77.3% and 99.7% of the variation, respectively.

The larval index also demonstrated a highly significant relationship to abundance estimated for the 2+ length group for the 1994-1997 year-classes (Figure 6). Previously, it has been demonstrated that capelin > 120 mm length are comprised primarily of two year old capelin, with variable mixtures of age one, three and even four year old capelin. The close relationship between the larval index with the 2-group index implies that year-class strength established early in life carried through to age two capelin. Here we assume that the abundance of the 2+ length group is primarily determined by age two capelin. There was no difference in the relationship between larval and age two capelin for corrected and non-corrected data. Again, the relationships are statistically significant explaining 89.1% and 89.3%, respectively.

Together, these comparisons demonstrate that year-class strength in capelin was established early in life, within days to weeks of larval release from beach sediments. These observations are consistent with the prediction of Leggett et al. (1984) and Carscadden et al. (2000) that release from beach sediments and early survival as larvae are important determinants of survival and ultimately year-class strength in northwest Atlantic capelin.

### **Size of Capelin**

Mean length of capelin in the bongos was 13.2 mm, range 5-29 mm, which was larger than mean lengths of 8.9-11.7 mm, 1994-1998 (Figure 7). If growth rates were not different among years, then a larger length implies an earlier spawning time. Prior to 1999, small numbers of larval capelin were captured in the IYGPT. In 1999, large numbers were caught with a mean length of 28.5 mm, ranging from 14 mm to 47 mm (Figure 7). This is smaller than previous years when mean length ranged from 34-35 mm in 1995 and 1997 for sample sizes of 262 and 43 fish, respectively. Mean length was 33.7 mm in 1994 and 42.8 mm in 1996, although these are based on sample sizes of only 4 fish each year. Previously, we demonstrated that bongos sampled larval capelin up to about 23 mm in length and the IYGPT sampled larval capelin down to about 25 mm in

length (Anderson and Dalley 1995). The split in the apparent bimodal distribution occurred within the length range not well sampled by either gear. Therefore, the length frequency distribution of larval capelin may in fact be unimodal. The combined data sets clearly demonstrate that spawning and larval release occurred much earlier in 1999 than any previous year in the 1990's, given the previous assumption of similar growth rates.

### **Distribution of Larvae and Juveniles and Adults**

Capelin larvae were distributed along the northeast coast of Newfoundland, as in previous years, with some larvae observed offshore on the northern Grand Bank (Figure 8). Larval capelin were captured only at one station on the southern Grand Bank in 1999, although we note that two stations directly north of the southern Grand Bank area, which might have contained larvae, were not sampled in 1999 due to poor weather. The presence of capelin on the southern Grand Bank is consistent with spawning in this area, although at a very low level. No capelin were observed off southern Labrador, in contrast to 1998 when small numbers of larvae were encountered there (Anderson et al. 1999).

Large larval capelin, primarily 20-40 mm, were more widely distributed in 1999 than in previous years (Figure 9). Previously, these large larval capelin were observed sporadically inshore with occasional small catches offshore and these distributions were always embedded within the broader distribution of larval capelin sampled by the bongo. In 1999, the presence of a fairly continuous distribution of large larval capelin offshore in the vicinity of Funk Island Bank is indicative of spawning to the north, possibly including coastal Labrador. The biggest concentration of these large larvae occurred in the Avalon Channel which would be consistent with spawning along the northeast coast and a southward drift of larvae in the Labrador Current.

Juvenile capelin, primarily age one, occurred most abundantly offshore on the northern Grand Bank and on Funk Is. Bank (Figure 10). The largest single catch occurred in Conception Bay and high abundance also occurred in Notre Dame Bay. A small concentration was observed on the SE Shoal of the southern Grand Bank. 1-group capelin were also observed off southern Labrador at relatively high abundance compared to previous years. Failure to sample the outer northern Grand Bank (i.e. the Nose) prevents any interpretation of how far offshore the distribution of 1-group capelin extended. Overall, the impression is one of a wider offshore distribution in 1999 extending from the northern Grand Bank to southern Labrador.

The distribution of 2-group capelin was decidedly northward and offshore compared to previous years, where highest abundance occurred over Funk Is. Bank (Figure 11).

### **Spawning Times**

The presence of large larval capelin at relatively high abundance in 1999 indicates there was a significant early spawning in 1999. If we assume growth rates of  $0.25 - 0.35 \text{ mm d}^{-1}$  (Jacquaz et al. 1977, Frank and Carscadden 1989), then these larval capelin averaged 70-100 days age. Based on a mid survey date of day 148, this would back calculate to release from beach sediments between days 148-177, which corresponds roughly to the last week of May through to the third week of June. Depending on beach

incubation temperatures, this implies spawning from early May through to early June. As it is unlikely that a significant spawning occurred along the coast in early May, we suspect that the lower growth rate is inappropriate for these capelin. The presence of larval capelin in the IYGPT trawls in previous years indicates that some early spawning has occurred during the period 1994-1998. However, the extent of early spawning was much greater in 1999. Similarly for capelin larvae sampled in the bongo, which averaged 13.2 mm length, release from beach sediments would have occurred between days 209-220, which corresponds to the end of July into the first two weeks in August. Therefore, if we restrict the back calculation estimates to the higher growth rates, we estimate that release from beach sediments occurred primarily from the third week of June to the second week of August.

The mean velocity of the Labrador Current at the surface is  $0.2 \text{ m sec}^{-1}$  while velocities off Bonavista Bay averaged  $0.3 \text{ m sec}^{-1}$  over a one month period (Petrie and Anderson). Velocity over the Grand Bank is typically weak, ranging from  $0.02\text{-}0.1 \text{ m sec}^{-1}$  (op. cit.). At drift speeds of  $0.2 \text{ m sec}^{-1}$  and times since release of 70 days, then these larvae could have drifted on the order of 1,200 km at the time of capture. Therefore, large larvae sampled offshore on Funk I. Bank and the northern Grand Bank could have spawned far to the north.

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Table 1. Summary of Pelagic Juvenile Fish Surveys conducted, 1994-1999. Bongo – refers to the number of stations sampled with a bongo plankton net; IYGPT – refers to the number of stations sampled with an IYGPT mid-water trawl; DoY – refers to the calendar day of the year.

Year	Ship-Trip	Dates	DoY Start	DoY End	DoY Middle	Bongo	ITYGPT
1994	TEM157/GAD247	22 Aug-3 Sep	234	246	241	99	99
1995	TEM175/TEL018	5 Sep -22 Sep	248	264	257	139	139
1996	TEM193/TEL034	19 Aug-6 Sep	231	249	241	147	147
1997	TEM210/TEL050	11 Aug-29 Aug	223	241	233	148	148
1998	TEM226/TEL069	24 Aug-10 Sep	236	253	244	132	132
1999	TEM242/TEL081	23 Aug-19 Sep	234	261	248	129	127

Table 2. Abundance indices of Northwest Atlantic capelin (2J3KLNO) based on the two-ship surveys, 1994-1999, using the Weighted Index Area method (number  $m^{-3}$   $10^3$  Bongo and  $10^5$  IYGPT). \* - indicates estimated value, see text for details.

Area	Sampling Year 1994				Sampling Year 1995				Sampling Year 1996			
	0-Group Bongo	0-Group IYGPT	1-Group	2+-Group	0-Group Bongo	0-Group IYGPT	1-Group	2+-Group	0-Group Bongo	0-Group IYGPT	1-Group	2+-Group
Inshore												
CB	7865.39	0.00	2151.19	89.54	27825.12	0.00	8.62	1.33	59170.22	0.00	0.42	0.21
TB	3797.05	0.00	258.49	11.19	13760.88	0.11	8.46	1.04	35682.76	0.00	24.29	6.50
BB	4615.81	0.00	1067.86	5.82	13439.82	0.39	7.74	1.36	37952.82	0.19	3216.28	249.38
NDB	18803.24	0.00	45.93	2.21	19478.60	59.47	234.63	6.19	45499.36	0.00	12.04	0.34
WB	17589.24	0.19	34.44	0.69	7671.55	0.12	1.58	5.15	57695.52	0.18	4.70	9.21
SUM	52670.73	0.19	3557.91	109.45	82175.97	60.09	261.03	15.07	236000.68	0.37	3257.73	265.64
Offshore												
HB					0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
ISN					4311.18	0.98	0.00	17.57	0.00	0.00	0.16	0.16
ISS	28081.33	0.50	50.95	0.00	34173.79	0.00	14.64	5.16	196751.14	0.40	10.82	9.17
BIBI					0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
BIBO												
FIBI					5805.14	0.00	8.31	5.71	3201.03	0.39	1798.45	7.65
FIBO												
NGB	9181.50	0.31	16834.73	275.27	143567.73	11.22	718.82	144.38	63705.86	0.00	1675.37	33.70
SA	8064.32	0.00	219.38	63.95					14021.44	0.00	16.95	0.48
SGB	53.28	0.00	812.65	85.35	973.80	0.00	341.09	12.71	0.00	0.00	0.00	0.00
NOSE									0.00	0.00	606.74	0.66
TAIL												
SGBO												
WD												
SUM	37316.11	0.81	17698.33	360.62	188831.64	12.20	1082.86	185.53	263658.03	0.79	3484.80	50.68
TOTAL	89986.84	1.00	21256.24	470.07	271007.61	72.29	1343.89	200.60	499658.71	1.16	6742.53	316.32

Table 2. (continued...)

Area	Sampling Year 1997				Sampling Year 1998				Sampling Year 1999			
	0-Group Bongo	0-Group IYGPT	1-Group	2+-Group	0-Group Bongo	0-Group IYGPT	1-Group	2+-Group	0-Group Bongo	0-Group IYGPT	1-Group	2+-Group
Inshore												
CB	18101.30	0.00	15.18	0.67	18203.82	0.06	14.64	6.06	15323.49	1.11	3613.16	24.15
TB	13363.79	9.66	1676.25	241.96	1801.22	0.05	23.72	32.95	26131.84	8.65	11.02	0.00
BB	17749.19	5.52	3079.55	23.40	11830.7*	0.17*	20.66*	44.94*	61713.93	0.19	59.89	0.08
NDB	17034.89	2.65	2.00	0.91	30448.79	0.41	30.14	138.12	16813.33	7.64	4570.15	1.37
WB	23459.91	17.46	1022.81	1.03	14383.76	0.17	14.12	2.63	15636.53	0.31	129.70	0.66
SUM	89709.08	35.29	5795.79	267.97	76668.29	0.86	103.28	224.70	135619.12	17.90	8383.92	26.26
Offshore												
HB	0.00	0.00	0.00	0.39	4404.30	0.00	0.00	0.00	0.00	0.00	0.00	0.20
ISN	286.38	0.00	52.80	159.73	6041.34	0.00	1.66	11.16	0.00	1.64	532.48	21.45
ISS	76000.98	2.29	1.34	85.95	65324.17	0.00	68.54	2177.05	38462.34	2.03	1391.15	40.00
BIBI	0.00	0.00	0.20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	10.06	0.00
BIBO												
FIBI	0.00	0.00	3.32	21.24	5560.74	0.20	408.08	85.60	5161.35	65.11	4480.24	448.20
FIBO												
NGB	12943.71	0.00	7392.86	667.89	11740.84	2.50	3922.34	5519.45	36619.72	277.92	2043.01	26.34
SA	21928.66	0.00	1126.22	0.00					3484.92	75.84	14.38	0.26
SGB	340.81	0.00	0.62	1.54	16548.69	0.00	59.25	166.64	617.51	0.00	36.52	1.47
NOSE	0.00	0.17	51.78	2.28	776.38	0.00	1638.66	165.44				
TAIL												
SGBO												
WD												
SUM	89571.88	2.29	7451.14	936.35	105215.78	2.70	4459.87	7959.90	80860.92	346.70	8493.46	537.46
TOTAL	179280.96	37.58	13246.93	1204.32	181884.07	3.56	4563.15	8184.60	216480.04	364.60	16877.38	563.72

Table 3. Abundance indices adjusted for night/day differences of for Northwest Atlantic capelin (2J3KLNO) based on the two-ship surveys, 1994-1999, using the Weighted Index Area method (number  $m^{-3}$   $10^3$  Bongo and  $10^5$  IYGPT). \* - indicates estimated value, see text for details.

Area	Sampling Year 1997				Sampling Year 1998				Sampling Year 1999			
	0-Group B	0-Group I	1-Group	2+-Group	0-Group B	0-Group I	1-Group	2+-Group	0-Group B	0-Group I	1-Group	2+-Group
<b>Inshore</b>												
CB	18101.39	0.00	15.18	0.67	18203.87	0.06	8.36	2.44	15323.52	1.11	3613.16	17.00
TB	13363.66	9.66	1676.20	241.35	1801.23	0.05	8.76	3.90	26131.83	4.41	2.16	0.00
BB	17749.11	0.27	1619.62	8.07	11830.7*	0.15*	15.08*	27.60*	61713.89	0.08	16.51	0.08
NDB	17034.98	0.58	2.00	0.48	30448.79	0.41	29.84	101.41	16813.15	3.42	97.42	0.97
WB	23459.99	17.46	1022.71	0.59	14383.69	0.09	13.34	2.63	15636.43	0.18	53.43	0.49
<b>SUM</b>	<b>89709.13</b>	<b>27.97</b>	<b>4335.71</b>	<b>251.16</b>	<b>76668.29</b>	<b>0.76</b>	<b>75.38</b>	<b>137.98</b>	<b>135618.82</b>	<b>9.20</b>	<b>3782.68</b>	<b>18.54</b>
<b>Offshore</b>												
HB	0.00	0.00	0.00	0.39	4404.27	0.00	0.00	0.00	0.00	0.00	0.00	0.20
ISN	286.46	0.00	27.64	55.08	6041.57	0.00	1.66	7.17	0.00	0.68	516.28	15.16
ISS	76001.02	2.29	0.89	85.95	65323.84	0.00	67.28	2157.89	38462.16	1.73	1238.70	28.64
BIBI	0.00	0.00	0.20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.39	0.00
BIBO												
FIBI	0.00	0.00	3.32	21.24	5561.07	0.20	357.53	8.76	5161.23	65.11	134.80	371.32
FIBO												
NGB	12943.87	0.00	7117.45	494.74	11741.37	2.16	3018.02	3254.46	36619.84	195.69	1598.83	18.55
SA	21928.65	0.00	1126.03	0.00					3485.11	31.34	14.38	0.18
SGB	340.83	0.00	0.43	1.54	16548.80	0.00	15.42	9.48	617.66	0.00	18.21	1.04
NOSE	0.00	0.17	51.43	1.92	776.52	0.00	1601.55	91.90				
TAIL												
SGBO												
WD												
<b>SUM</b>	<b>89572.18</b>	<b>2.29</b>	<b>7149.93</b>	<b>658.55</b>	<b>105216.65</b>	<b>2.36</b>	<b>3459.91</b>	<b>5437.76</b>	<b>80860.89</b>	<b>263.21</b>	<b>3507.21</b>	<b>434.71</b>
<b>TOTAL</b>	<b>179281.31</b>	<b>30.26</b>	<b>11485.64</b>	<b>909.71</b>	<b>181884.94</b>	<b>3.12</b>	<b>3535.29</b>	<b>5575.74</b>	<b>216479.71</b>	<b>272.41</b>	<b>7289.89</b>	<b>453.25</b>

Table 3. (continued...)

Area	Sampling Year 1994				Sampling Year 1995				Sampling Year 1996			
	0-Group B	0-Group I	1-Group	2+-Group	0-Group B	0-Group I	1-Group	2+-Group	0-Group B	0-Group I	1-Group	2+-Group
<b>Inshore</b>												
CB	7865.34	0.00	2151.19	89.54	27825.09	0.00	3.33	0.28	59170.29	0.00	0.42	0.21
TB	3796.99	0.00	246.35	11.19	13760.61	0.11	6.80	0.18	35682.66	0.00	24.29	4.62
BB	4615.73	0.00	1067.86	5.22	13439.94	0.09	7.74	1.60	37952.85	0.09	3216.28	248.31
NDB	18803.16	0.00	38.19	1.39	19478.79	38.79	230.60	6.19	45499.30	0.00	1.10	0.34
WB	17589.26	0.19	10.02	0.06	7671.45	0.12	1.39	2.63	57695.33	0.09	0.18	0.72
<b>SUM</b>	<b>52670.48</b>	<b>0.19</b>	<b>3513.61</b>	<b>107.40</b>	<b>82176.08</b>	<b>39.11</b>	<b>249.86</b>	<b>10.88</b>	<b>236000.43</b>	<b>0.18</b>	<b>3242.27</b>	<b>254.20</b>
<b>Offshore</b>												
HB					0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
ISN					4311.25	0.25	0.00	11.67	0.00	0.00	0.16	0.16
ISS	28080.99	0.50	23.65	0.00	34173.86	0.00	14.64	5.16	196751.12	0.40	0.42	9.17
BIBI					0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
BIBO												
FIBI					5805.49	0.00	8.31	3.85	3200.62	0.39	92.39	0.97
FIBO												
NGB	9181.63	0.31	4192.09	121.69	143567.83	2.94	699.07	115.59	63706.31	0.00	1003.84	23.82
SA	8064.13	0.00	219.38	63.95					14021.44	0.00	8.69	0.48
SGB	53.15	0.00	119.96	8.89	973.97	0.00	132.68	3.33	0.00	0.00	0.00	0.00
NOSE									0.00	0.00	199.60	0.66
TAIL												
SGBO												
WD												
<b>SUM</b>	<b>37315.77</b>	<b>0.81</b>	<b>4335.70</b>	<b>130.58</b>	<b>188832.40</b>	<b>3.19</b>	<b>854.70</b>	<b>139.60</b>	<b>263658.05</b>	<b>0.79</b>	<b>1096.81</b>	<b>34.12</b>
<b>TOTAL</b>	<b>89986.25</b>	<b>1.00</b>	<b>7849.31</b>	<b>237.98</b>	<b>271008.48</b>	<b>42.30</b>	<b>1104.56</b>	<b>150.48</b>	<b>499658.48</b>	<b>0.97</b>	<b>4339.08</b>	<b>288.32</b>

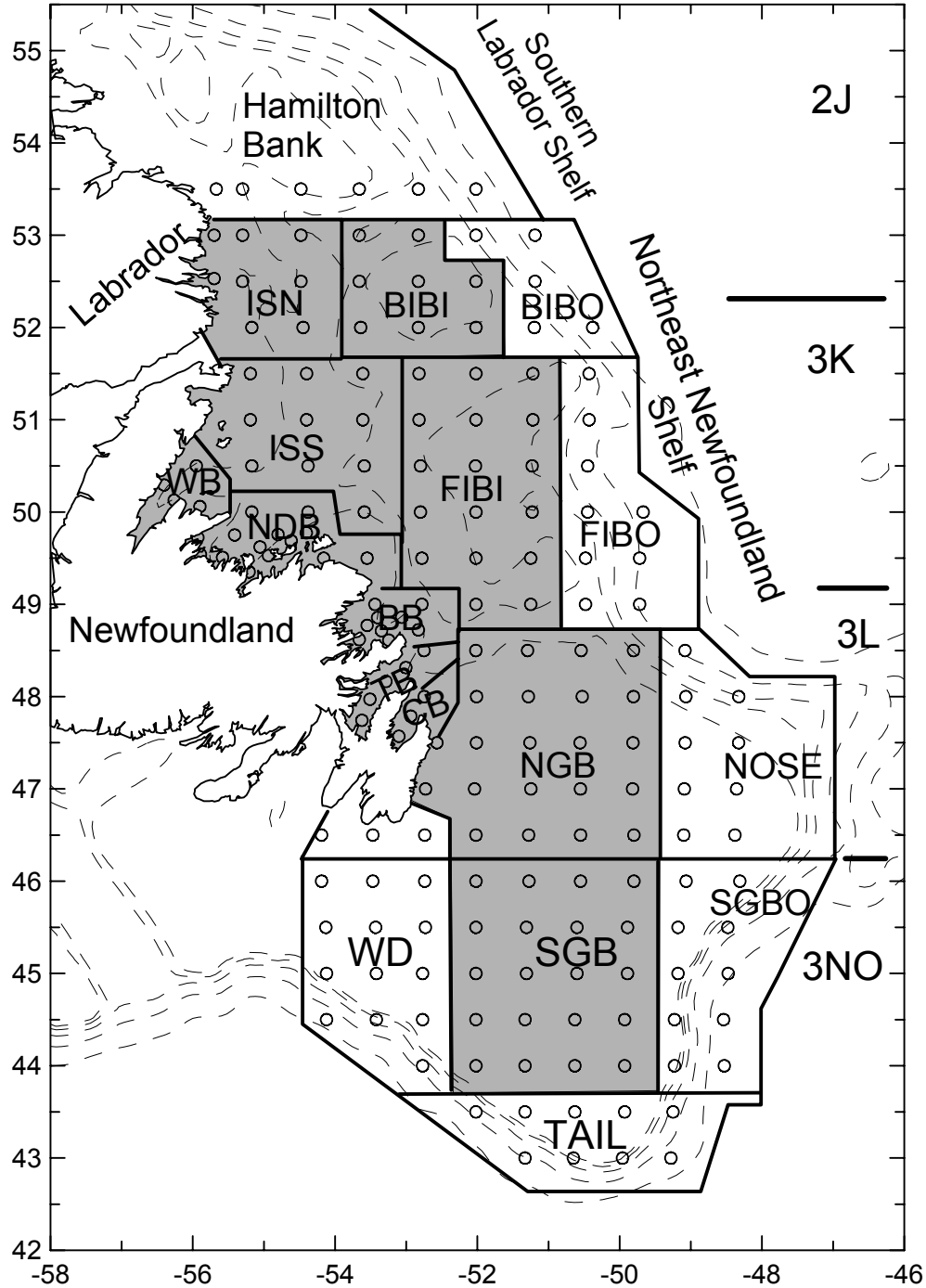


Figure 1. Pelagic Juvenile Fish Survey area, showing sample locations (indicated by 'o') and Index Areas. The shaded areas represent the Index Areas used in the calculation of annual abundance indices.

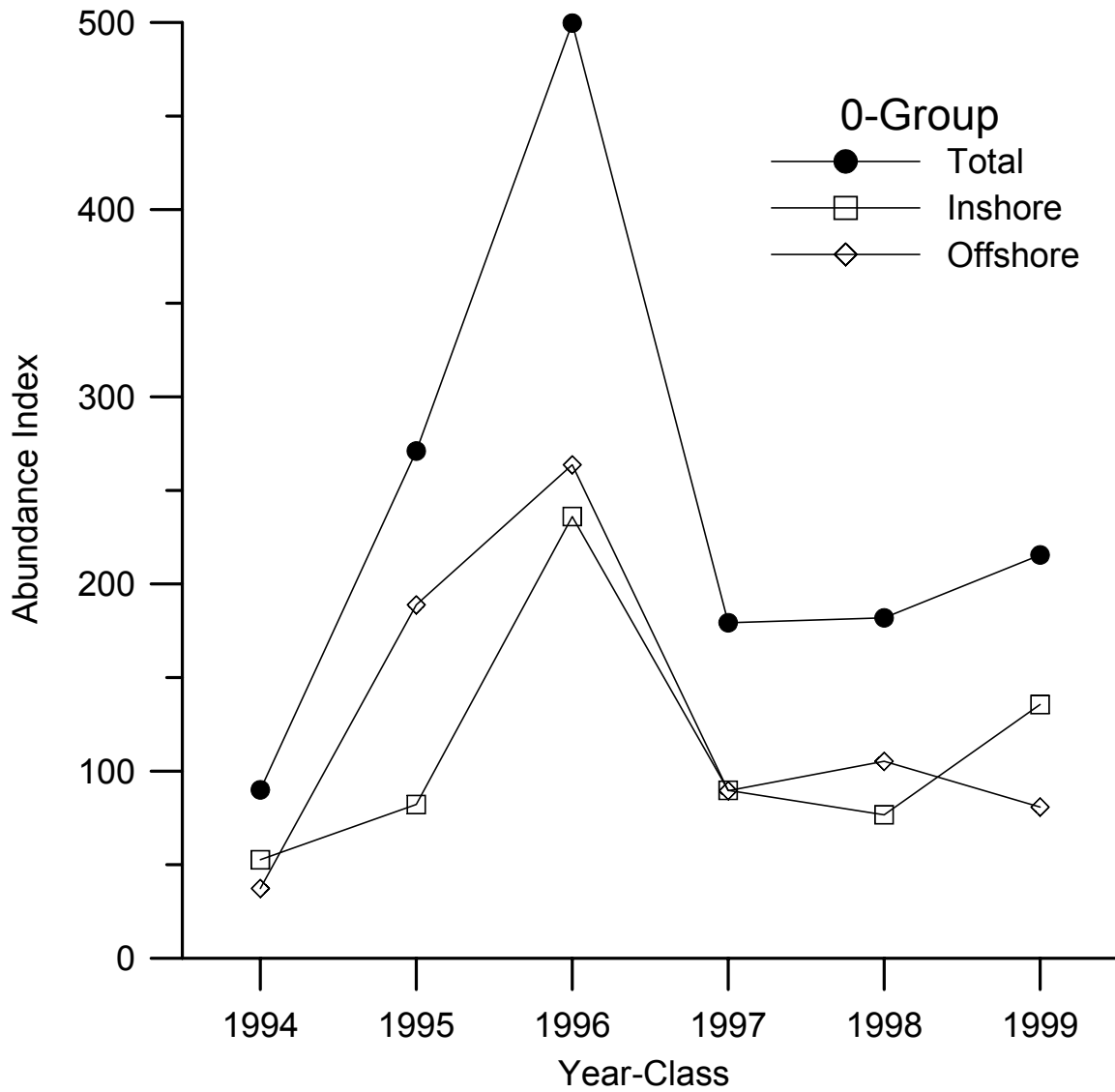


Figure 2. Year-class abundance index for 0-group (larval) capelin for inshore, offshore and both areas combined, 1994-1999 based on night/day corrections.

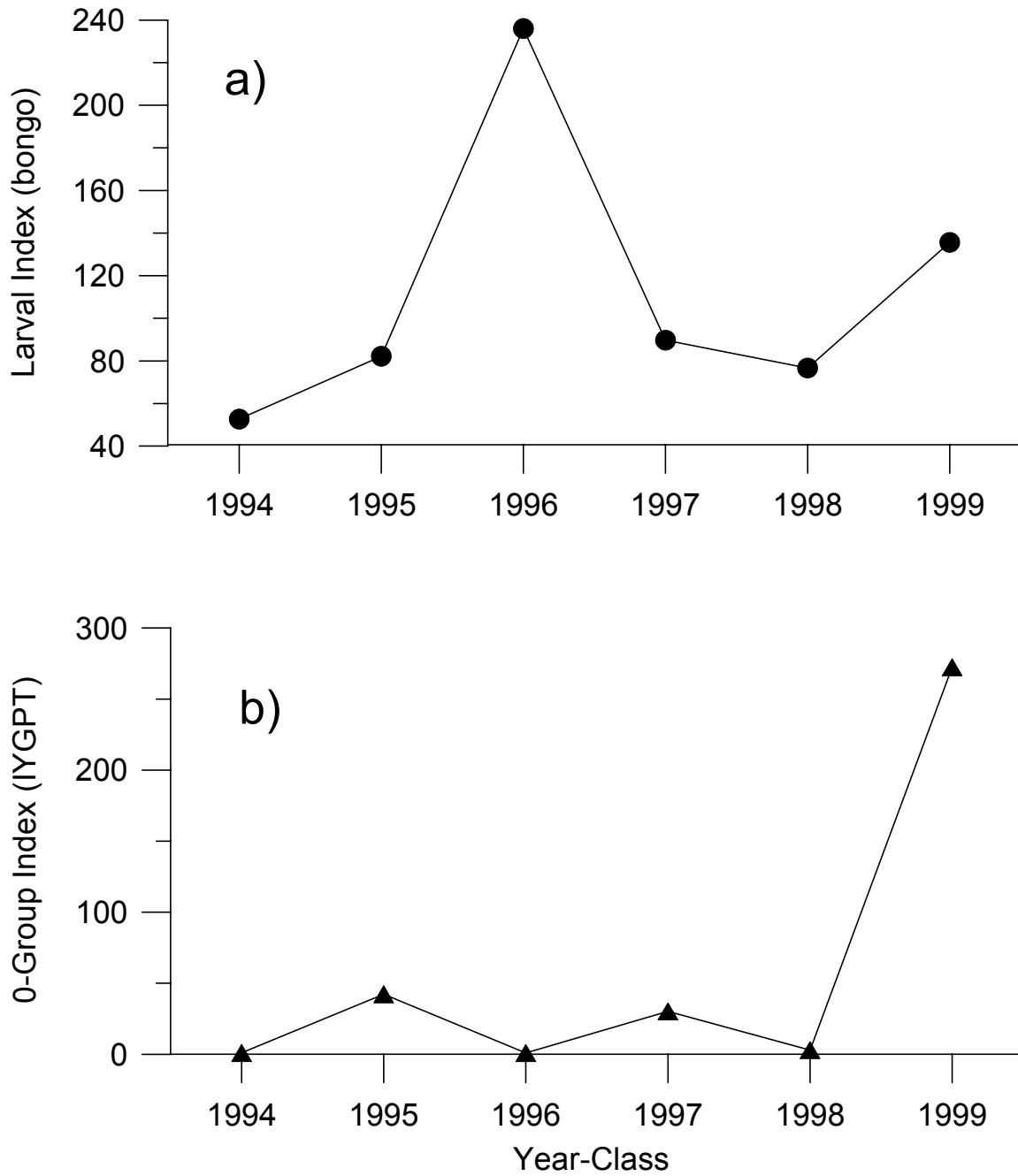


Figure 3. Year-class abundance indices for (a) larval capelin captured in the bongo and (b) 0-group capelin captured in the IYGPT. Each index is based on the Weighted Index Area method for night/day corrected data and both indices are considered relative within each time series.



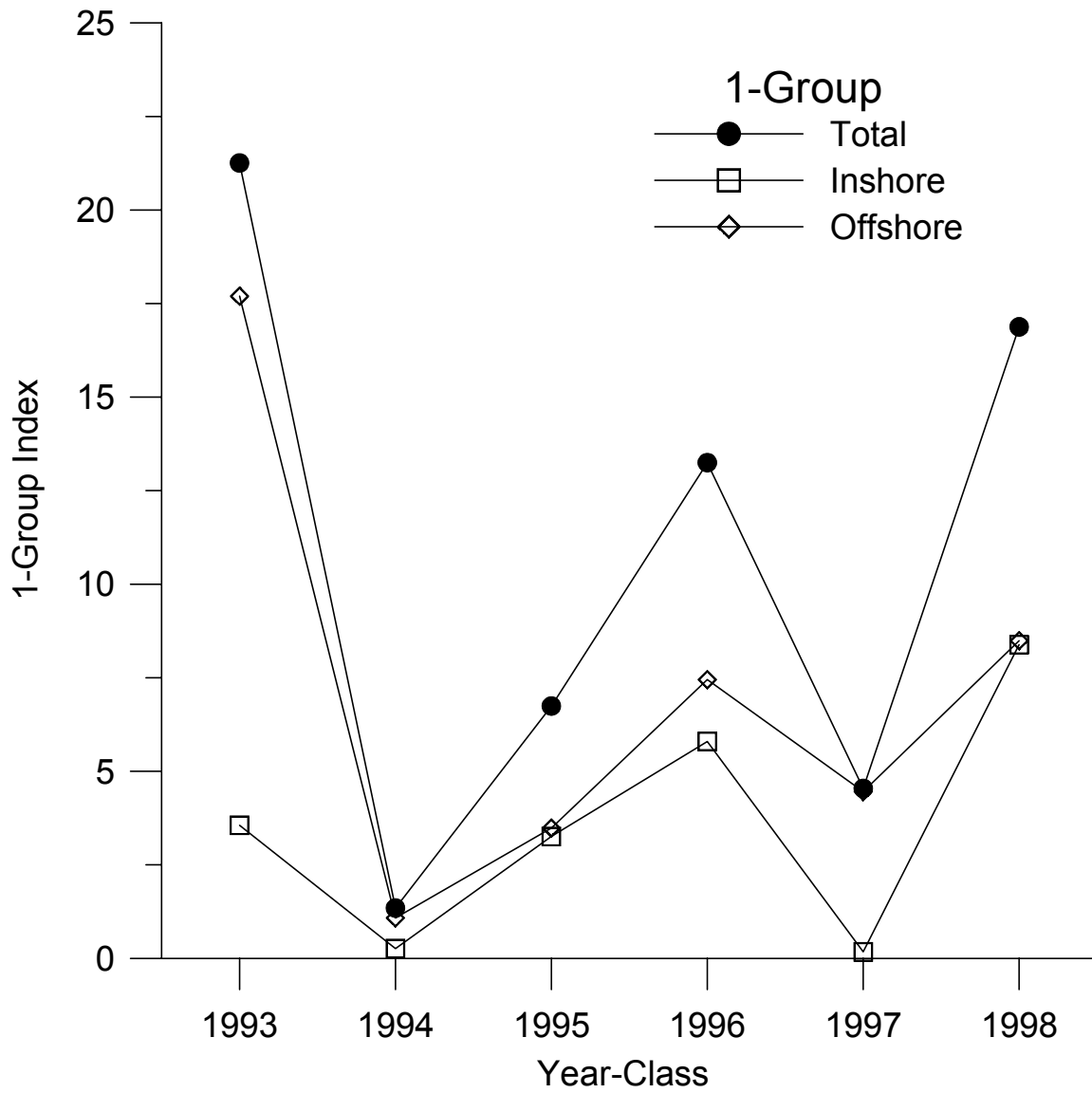


Figure 4. Year-class abundance indices for 1-group capelin sampled inshore, offshore and both areas combined.

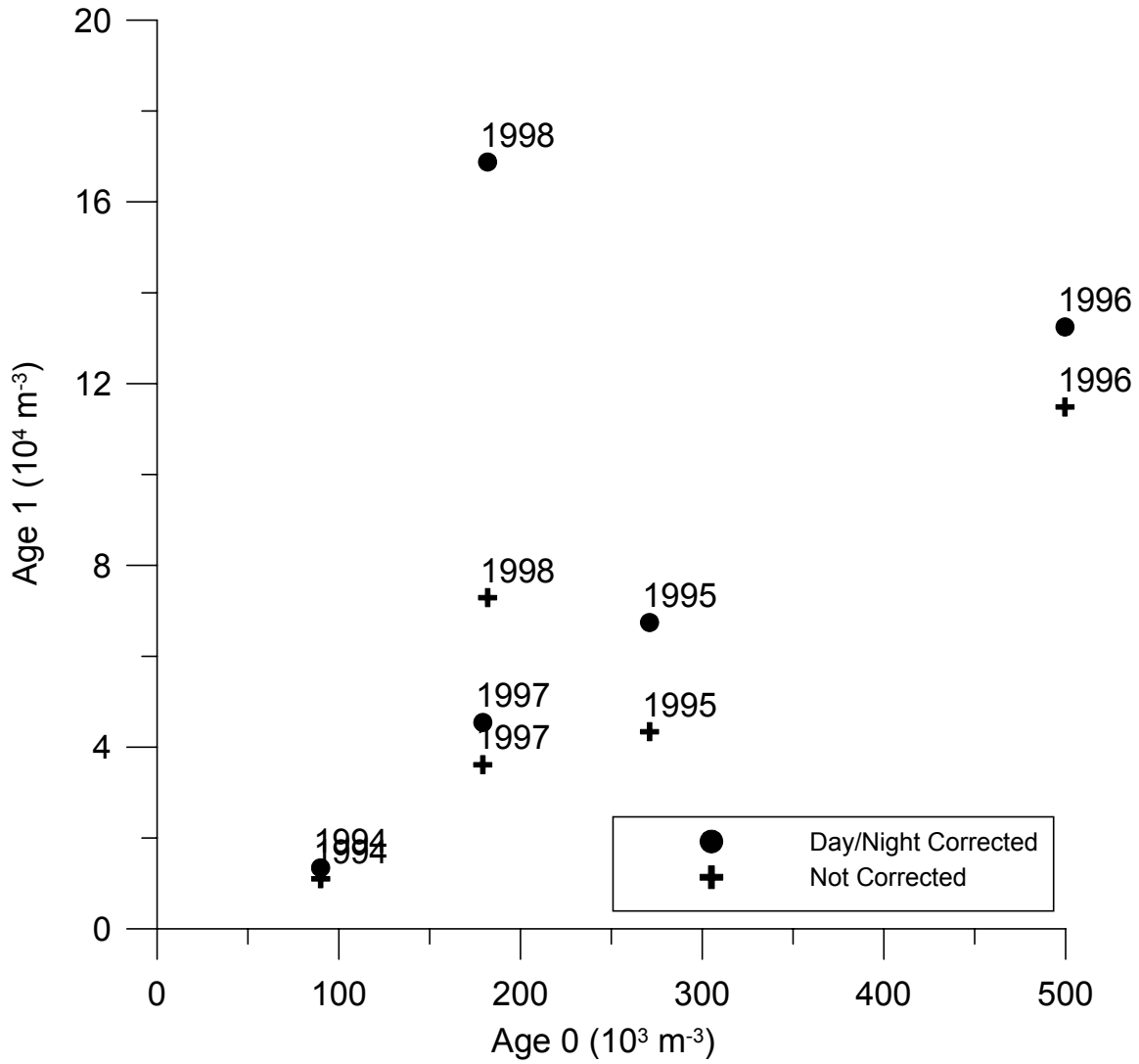


Figure 5. Year-class abundance indices for 0-group (larval) and 1-group capelin. The data point labels reference year-class.

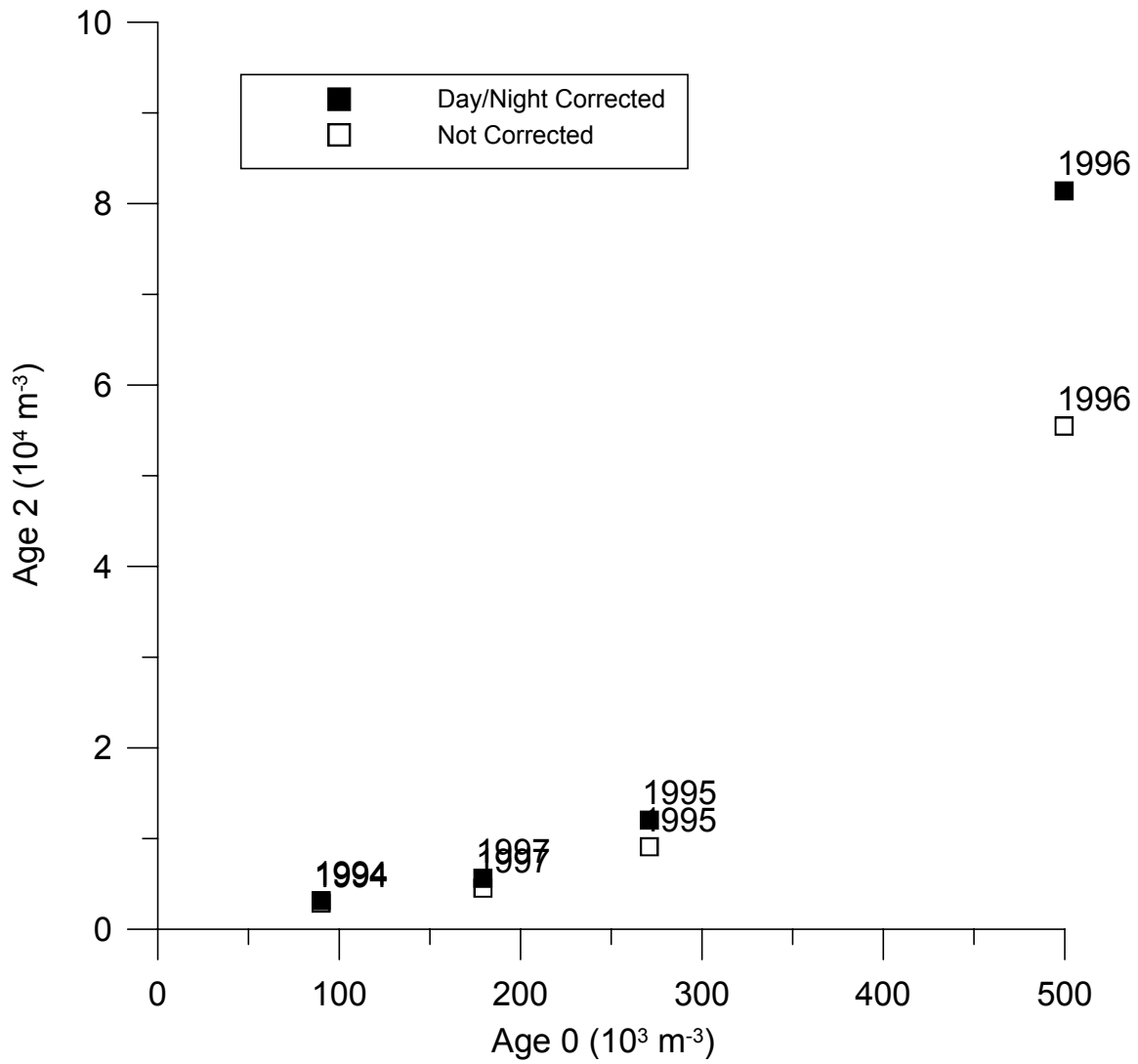


Figure 6. Year-class abundance indices for 0-group (larval) and 2-group capelin. The data point labels reference year-class.

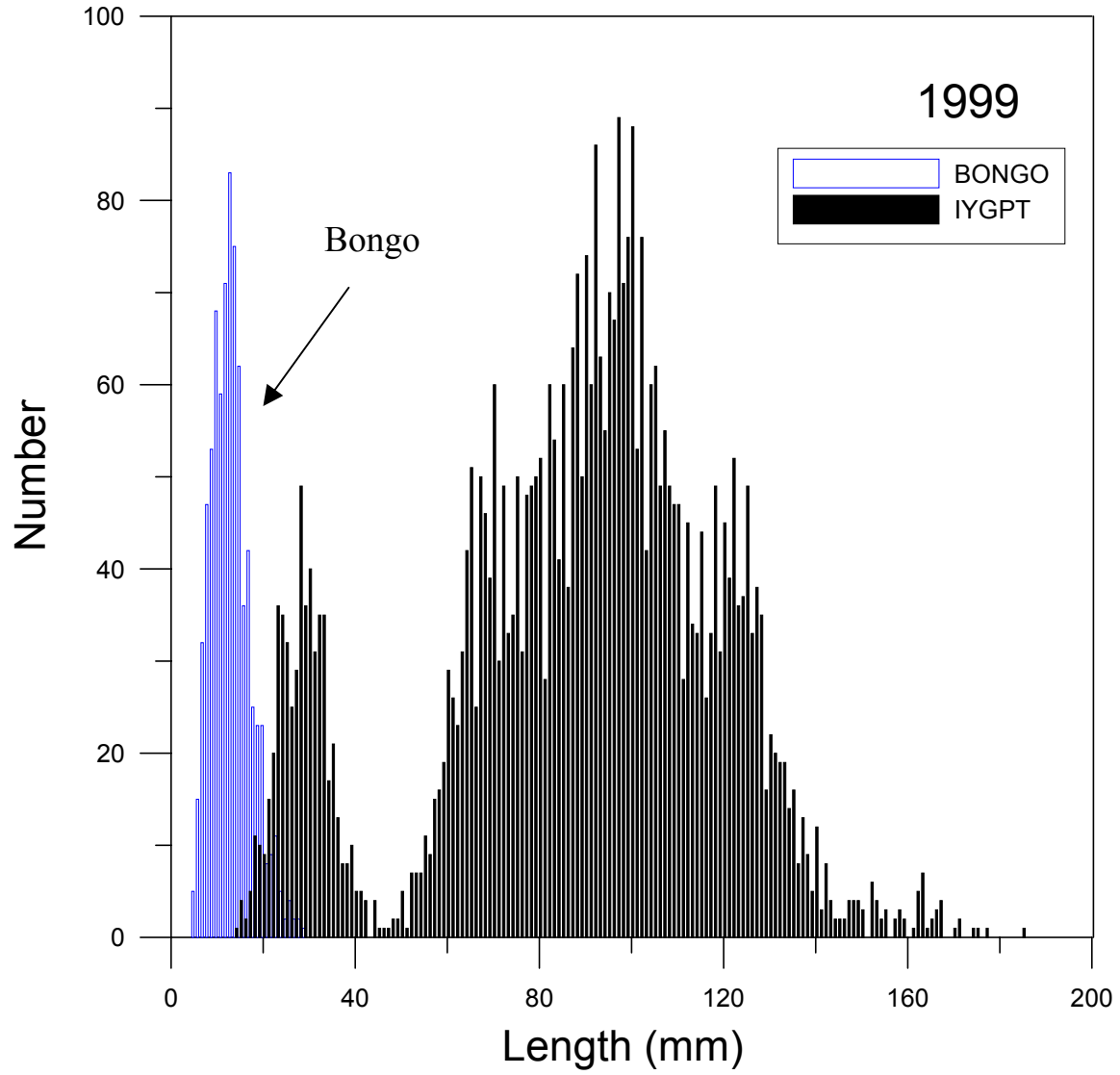


Figure 7. Length frequency distributions from the bongo and IYGPT samplers in 1999.

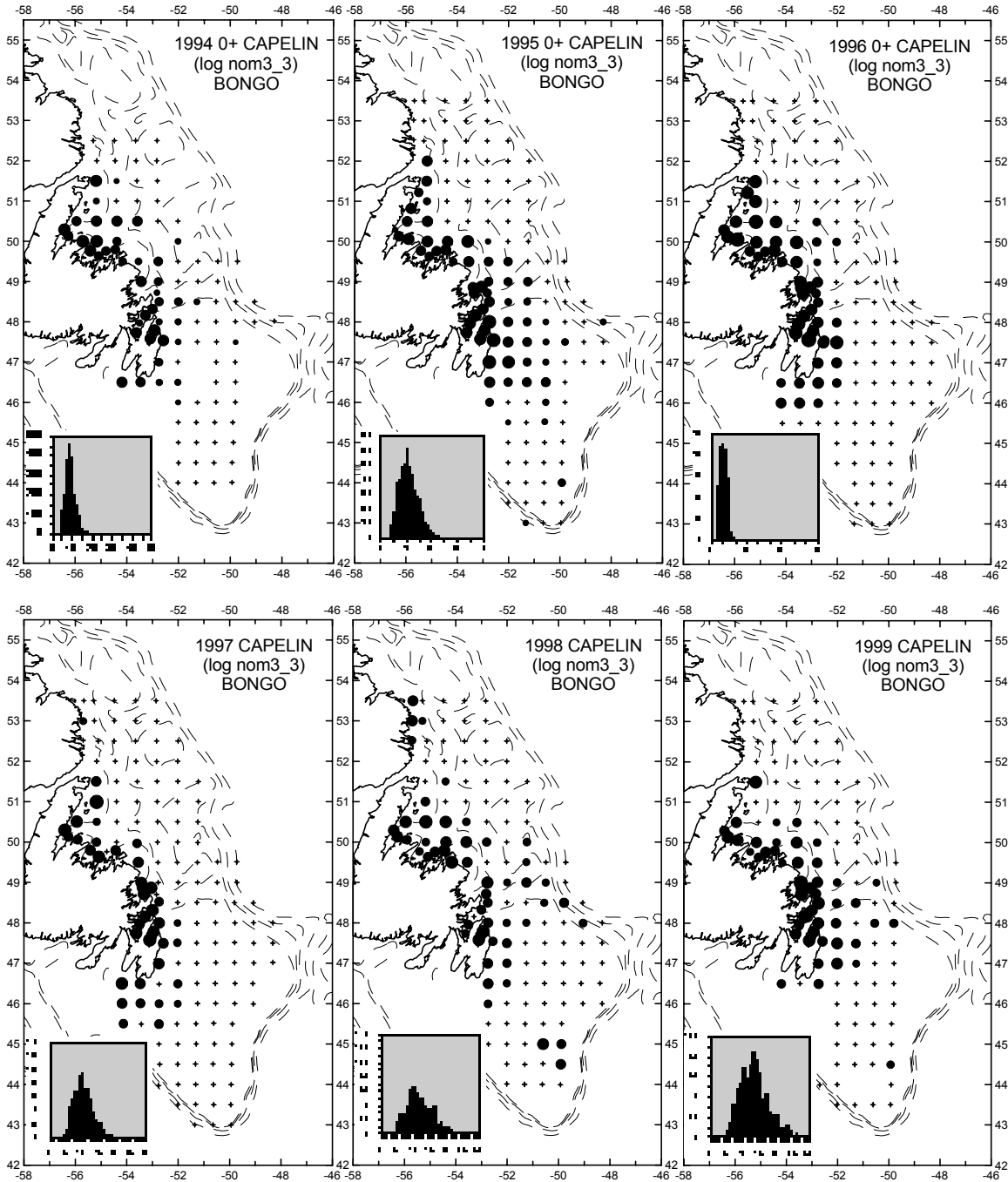


Figure 8. Distribution of larval capelin sampled by the bongo 1994-1999. Abundance ( $\log_{10}$  number  $m^{-3}$ ) at each station is represented by an expanding symbol, where values were standardized to a common scale among years. Crosses (+) represent stations where capelin were not caught.

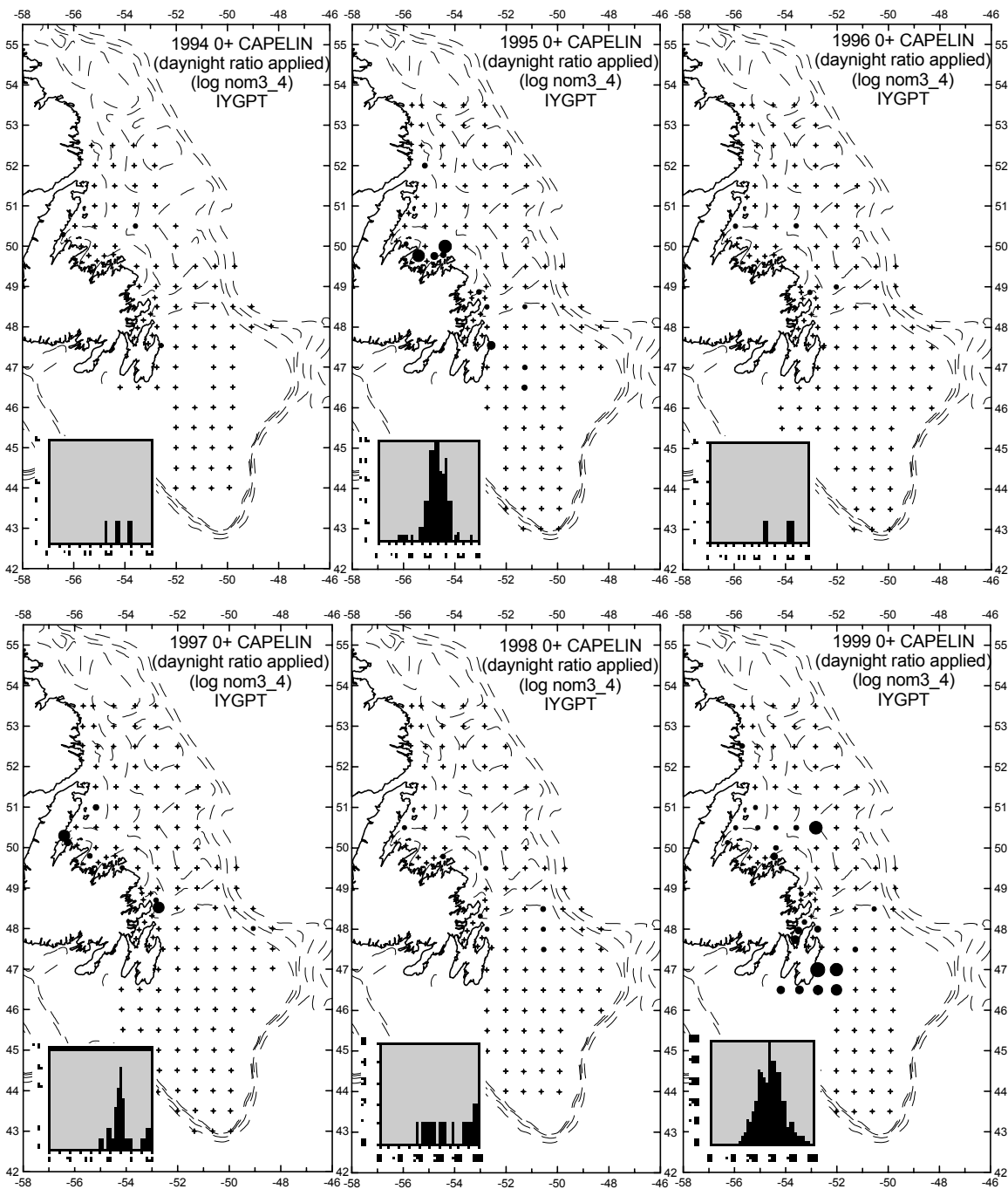


Figure 9. Distribution of 0-group capelin sampled by the IYGPT 1994-1999. Abundance ( $\log_{10}$  number  $\text{m}^{-3}$ ) at each station is represented by an expanding symbol, where values were standardized to a common scale among years. Crosses (+) represent stations where capelin were not caught.

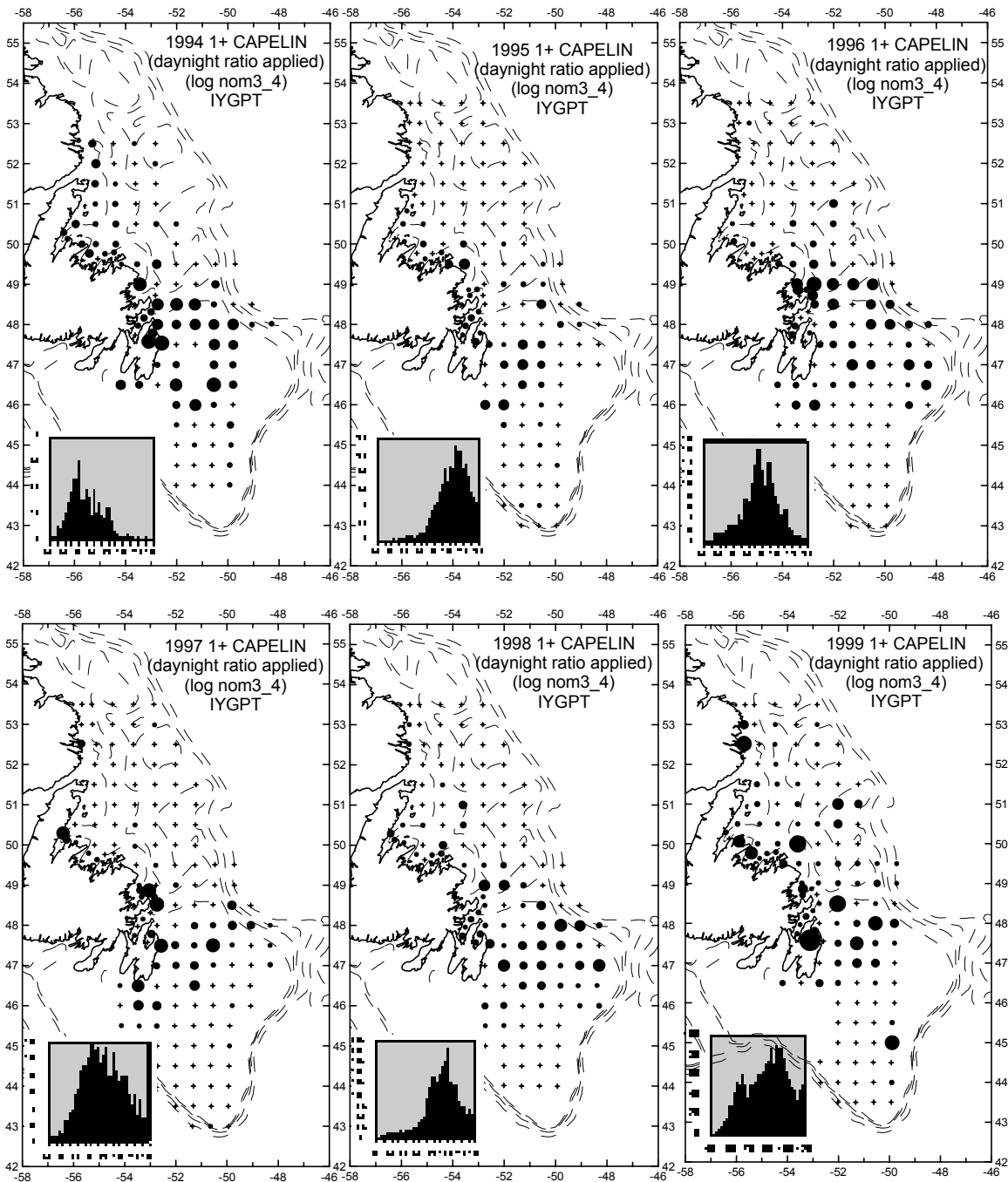


Figure 10. Distribution of 1-group capelin sampled by the IYGPT 1994-1999. Abundance ( $\log_{10}$  number  $m^{-3}$ ) at each station is represented by an expanding symbol, where values were standardized to a common scale among years. Crosses (+) represent stations where capelin were not caught.

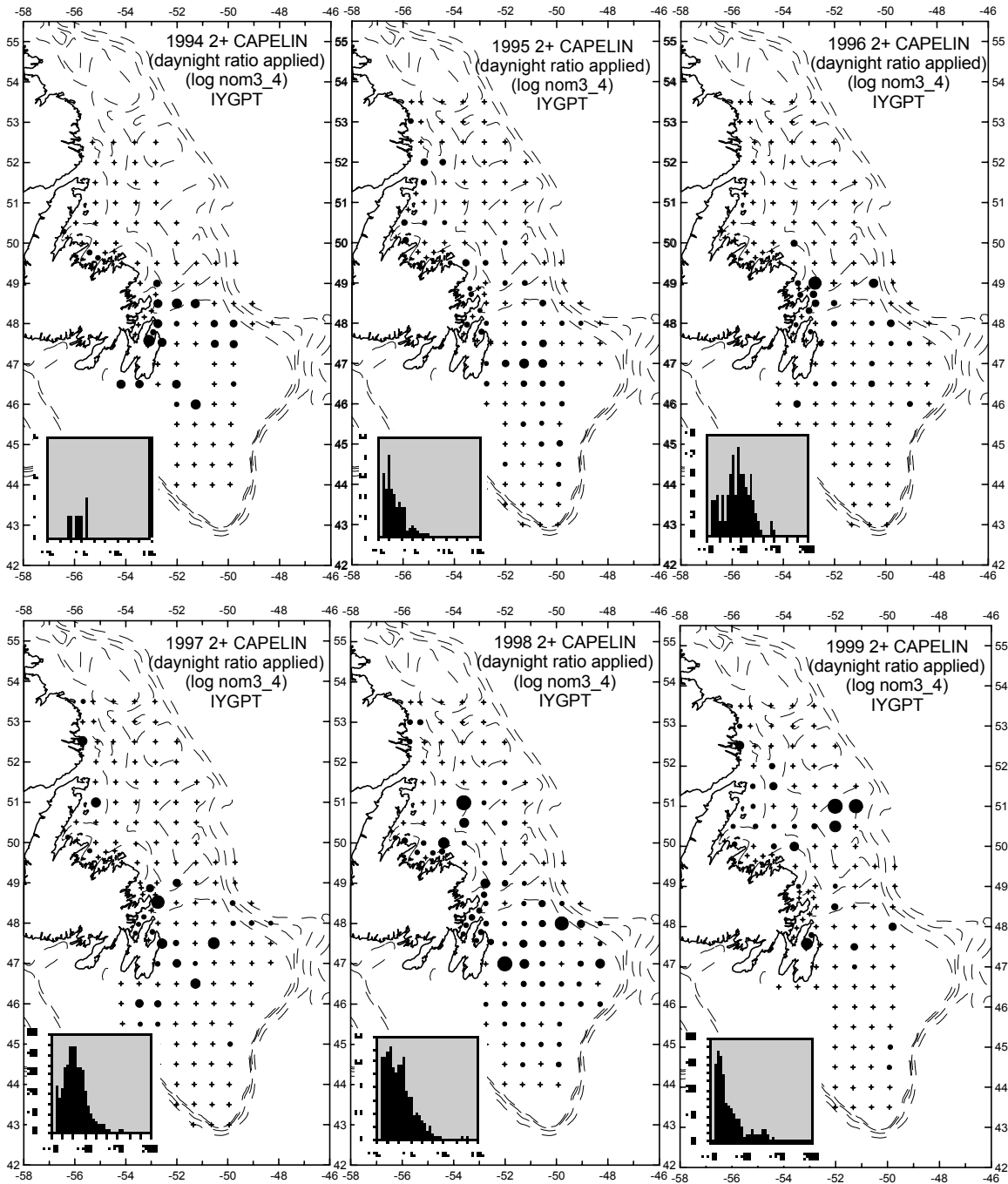


Figure 11. Distribution of 2-group capelin sampled by the IYGPT 1994-1999. Abundance ( $\log_{10}$  number  $m^{-3}$ ) at each station is represented by an expanding symbol, where values were standardized to a common scale among years. Crosses (+) represent stations where capelin were not caught.