Spawning and Early Development of Capelin (*Mallotus villosus*) at Bellevue Beach, Trinity Bay in 1999

by

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Introduction

In 1990 we began to monitor spawning times, egg deposition and development, larval emergence and various environmental variables (e.g. 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 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, Trinity Bay.

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, a minimum of 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 when emergence was peaking, otherwise only one tow was collected. Larval density was expressed as larvae per m^3.

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 1999 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 1999 spawning population consisted mainly of the 1996 yearclass (73%) followed by the 1997 yearclass (17%). The proportion of age 2 fish is considerably higher for females than for males (Table 1). The 1995 yearclass was proportionally low in abundance. This is the second year that age 4 fish were scarce, especially so for females in 1999.

Mean weights and lengths of females and males and the samples in general are presented in Table 2. Average size appears to be increasing.

Spawning Time

In 1999 spawning began on June 28, which was marginally earlier than in 1998 (Table 3), and all eggs were deposited by July 12(Fig. 2). Unlike other years that the beach has been monitored, there was only one major spawning run. Consequently the time of egg deposition on Bellevue Beach was protracted (Table 3).

Egg Density and Development

One major spawning mode was observed in early July (July 4-8) (Fig. 2). Egg densities on Bellevue Beach were one of the highest estimated in the series (Table 3). This suggests that for this area, the mature population spawning on the beach sediment was abundant relative to other years in the 1990s.

Observations during the spawning period indicated that strong wave action near the end of the spawning period washed many of the eggs high up on the beach. When evaluating eggs for development staging, we noticed a high proportion of opaque and abnormal eggs in the samples, similar to 1998 (Nakashima and Slaney 1999). Also many of the eggs that began development, failed to survive beyond stage IV, 4-6 days after fertilization.

Pre-emergent Larval Estimates

The majority of pre-emergent larvae observed in beach sediments at Bellevue Beach in 1999 occurred July 20-22 (Fig.3) which was 11 days earlier than the first major sign of pre-emergent larvae in 1998 (Nakashima and Slaney 1999: July 31-Aug. 4). The density of pre-emergent larvae was the lowest in the series and comparable to 1998(Table 3). This indicates that egg mortalities in beach sediments have been very high in 1998 and in 1999. The 1999 yearclass is one of the weakest produced from beach spawning at Bellevue Beach in the 1990s.

Emergent Larvae

Emergent larval densities were very low in 1999 with no strong peak as in other years. The highest amount released was on July 22 at night (Fig. 4). However, the actual amount was very low (8000/m^3) and the lack of multiple releases suggest larval production from Bellevue Beach sediments was very poor in 1999. Like the pre-emergent larvae, the results indicate the 1999 yearclass is one of the weakest in the series, similar to the 1991 yearclass (Table 3).

Summary

The results indicate that there was a high mortality of eggs in Bellevue Beach sediments in 1999 resulting in low densities of pre-emergent larvae. This also affected the potential production of emergent larvae. Another contributor to low production was the presence of only one spawning episode. Despite the high egg deposition, the results suggest that having all the eggs deposited at once resulted in poor survival due to adverse conditions experienced during incubation in the sediments. Consequently the 1999 yearclass produced from Bellevue Beach was relatively weak.

Acknowledgements

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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
	1999	4.0	81.0	15.0	<.1	0	273
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
	1999	32.0	65.0	3.0	0	0	253
Combined	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	
	1999	17.0	73.0	13.0	<.1	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
1999	29.6	171	19.4	153	24.7	162

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
1999	374.4	4.2	38.9	181-195

[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.

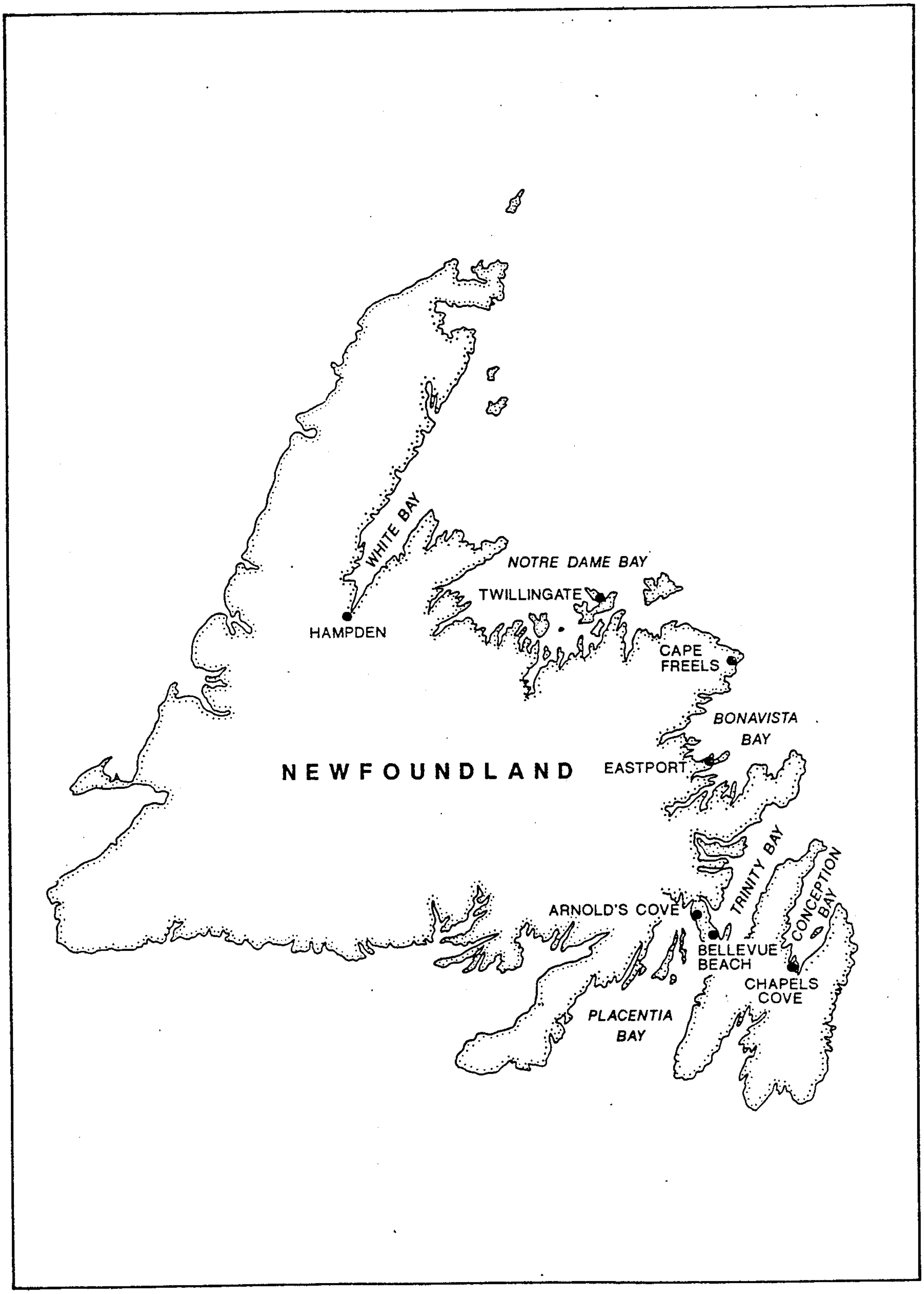

Fig. 1. Sampling sites.

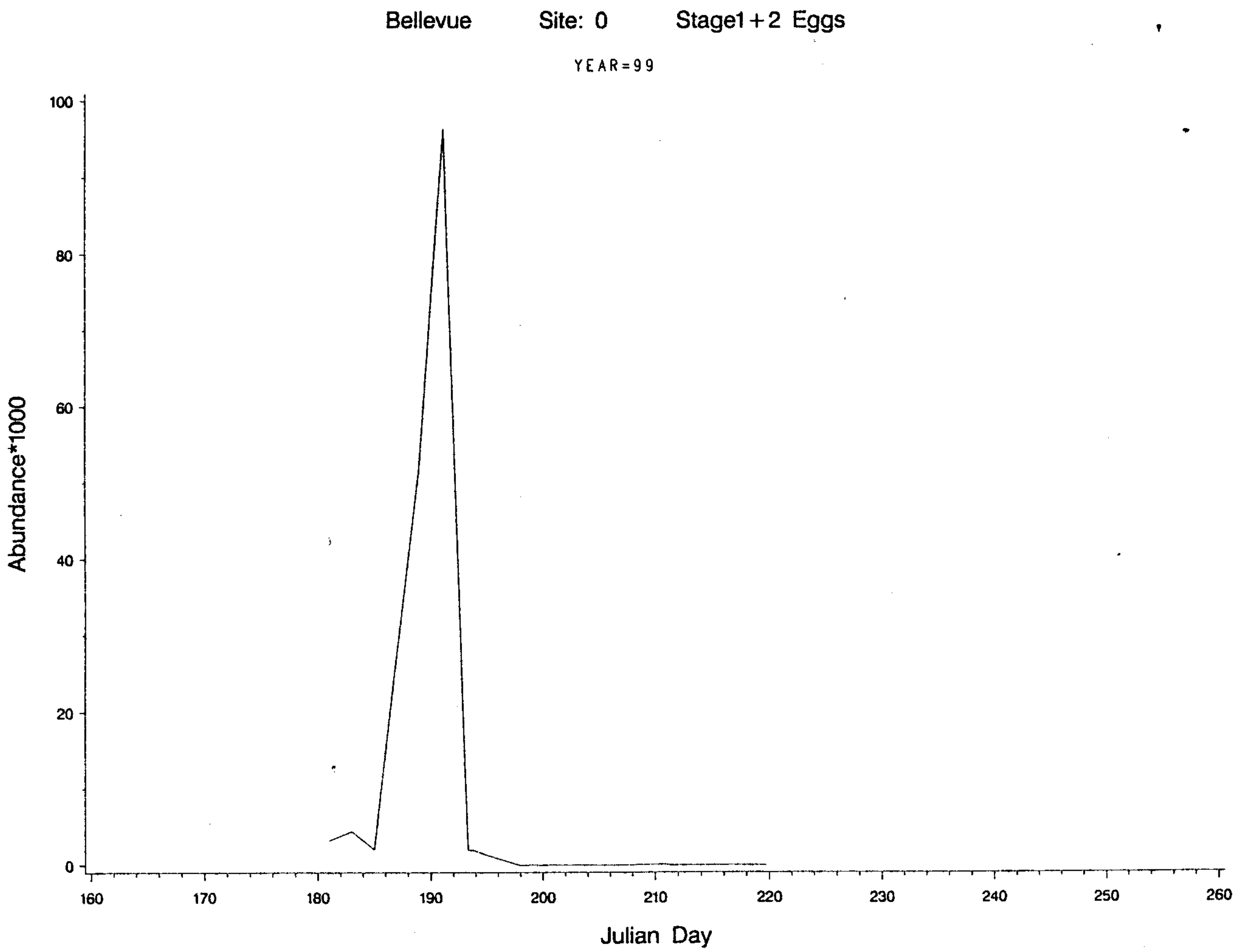

Fig. 2. Seasonal pattern in egg deposition on Bellevue Beach in 1999.

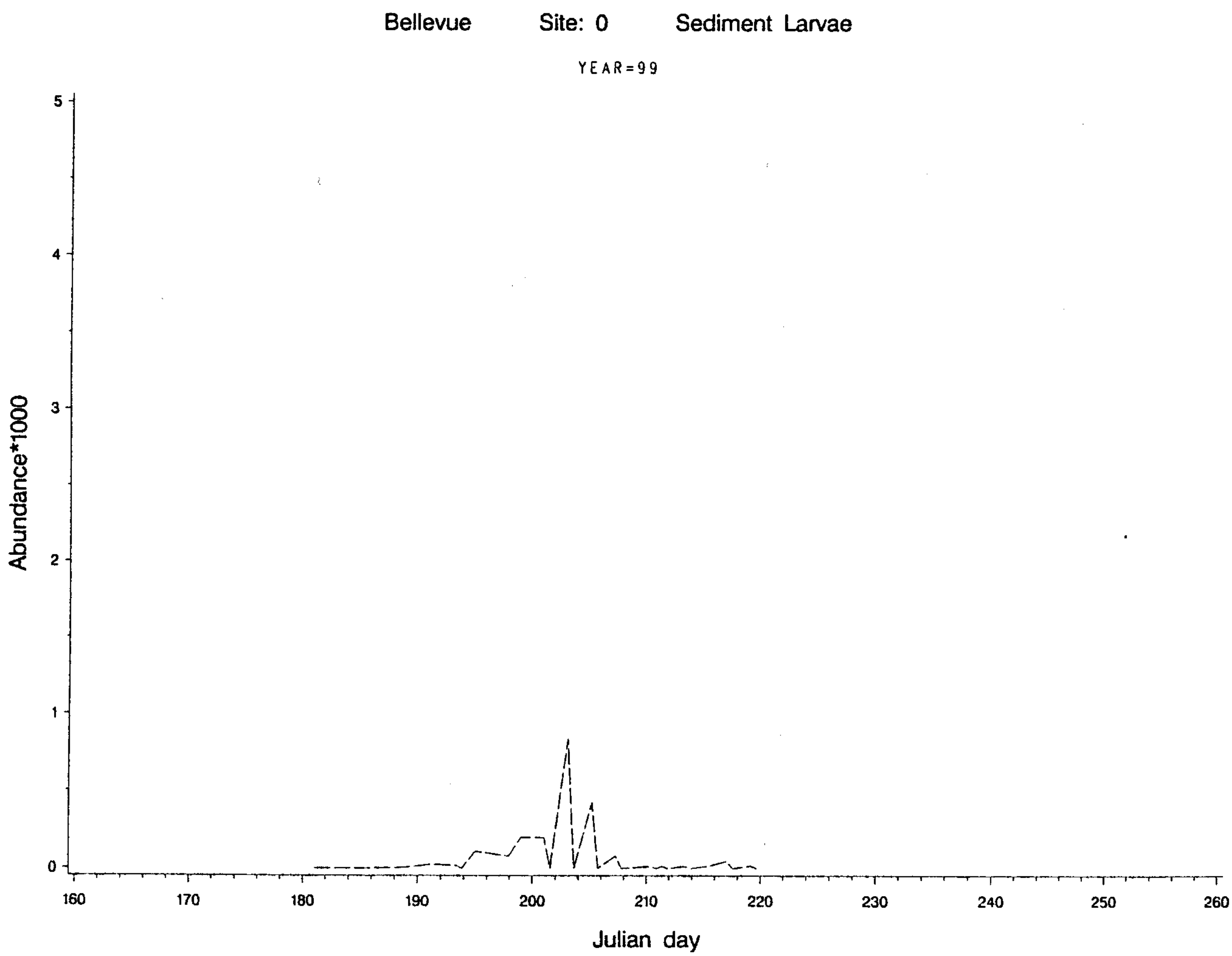

Fig. 3. Seasonal pattern in pre-emergent larvae in Bellevue Beach in 1999.

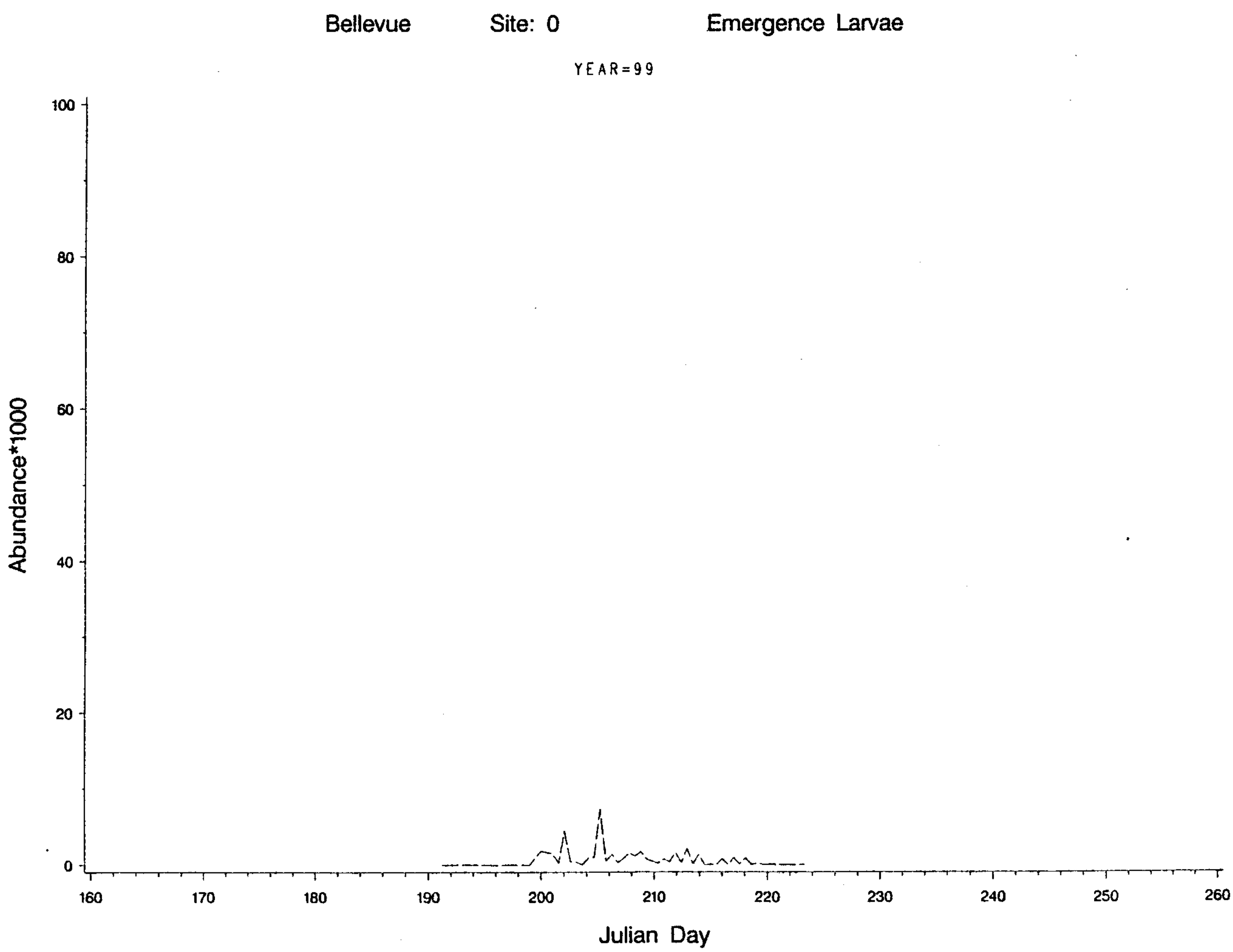

Fig. 4. Seasonal pattern in larval emergence from Bellevue Beach in 1999.

Results from a 1999 Field Study on:
1) the distribution and biomass of capelin, and
2) the classification of substrates at Bellevue, Trinity Bay

by

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Introduction

Bellevue Beach, Trinity Bay, is one of many important capelin spawning locations along the northeast coast of Newfoundland. The area has been the focus of inshore capelin research studies within the Newfoundland region for many years. It forms a part of the flight path of an aerial survey which has been conducted annually since 1982 to estimate the relative abundance of pre-spawning capelin (Anon. 1997). It has also been the site of an annual capelin egg and larval production study since 1990 (Anon. 1997). Results from these studies have been important as indices of abundance for capelin in the inshore area.

For the past three years, an additional component has been added to the research studies in the Bellevue area. In 1997, a preliminary acoustic survey was conducted to examine the distribution and biomass of pre-spawning capelin in the near coastal zone off Bellevue Beach. In 1998, this research was expanded to include daily acoustic surveys of a pre-selected area throughout the spawning season. A second component was added to map the densities of individual capelin schools detected by the aerial survey (Wheeler and Nakashima 1999). In 1999, daily acoustic surveys were again conducted through the spawning season. Underwater video was also used to classify bottom substrates within the survey area and to examine for the occurrence of off beach spawning.

This paper documents the results of the acoustic and underwater video research conducted during the 1999 field season. Daily density and biomass estimates are provided and these are compared with results from 1998. The results of the substrate classification are also presented.

Methods

1) Distribution and Biomass

Acoustic surveys in 1998 and 1999 were conducted from the 7 m vessel *Topaz* equipped with a BioSonics Model 105 sounder and a Femto Model 9001 acoustic data acquisition system. A 120 kHz single beam transducer was mounted in a V-fin towed body and was deployed at a depth of approximately 1 m abeam of the survey vessel.

This acoustic system is calibrated annually. The following parameters, from a calibration conducted in September 1999, were used in the analysis of the 1999 data:

Source Level / Receive Sensitivity :	42.25 dB
Fixed Receiver Gain:	11.31 dB
TVG Gain:	20 log R
Attenuation Coefficient:	0.03470 dB/m
Pulse Length:	0.4 ms
Average Beam Factor:	-29.4 dB

Based upon preliminary acoustic surveys conducted in 1997, a survey area was defined in the coastal zone off Bellevue Beach (Figure 1). The survey area was 5.4 km^2 and included the area from Green Head in the northwest to ‘The Gut’ in the southeast. The inner boundary of the area was defined by the minimum navigable depth of the survey vessel (~3 m). The outer boundary was defined by the coastal distribution of capelin detected during the preliminary surveys in 1997, which, through much of the survey area, was approximately 1 km from the shoreline. The area was divided into five geographically based strata. Stratum ‘E’ was defined to be a subset of stratum ‘D’ and was designed to allow for more detailed acoustic sampling along Bellevue Beach.

A zig-zag survey through each stratum was deemed to be the most efficient survey design as it maximized acoustic sampling and minimized the time required to conduct each survey. Differential GPS and *Infonav* navigational software were used to ensure that the same transects were covered during each survey. A detailed log record was maintained during each survey of the area.

The acoustic data were subsequently edited using the Femto acoustic data editing system. Due to the irregular nature of the bottom topography throughout the survey area, a variable bottom removal algorithm was used. Only those concentrations considered to be capelin, based upon visual examination of the echograms, were included for analysis.

Acoustic back-scatter (m^2/sr) was converted to fish density (g/m^2) using a fixed target strength of -34 dB/g (Anon. 1997).

A single density estimate (g/m^2) was derived for each stratum based upon the series of zig-zags within the stratum. This was extrapolated to the stratum area to estimate stratum biomass. Strata estimates were summed to calculate total biomass for the survey area.

In each survey, the larger of the biomass estimates for strata ‘D’ and ‘E’, ie. overlapping strata, was used in calculating total biomass of the total area.

For the purpose of plotting capelin distributions, mean densities (g/m^2) were calculated per ten second interval along each transect.

2) Substrate Classification

An underwater video system was used in 1999 to classify bottom substrates and to examine for the occurrence of off beach spawning. The camera was attached to a tripod which when lowered to the ocean floor kept the camera at a fixed distance of 1 m from the bottom. Video images were calibrated using a metre stick placed beneath the tripod. Video data were viewed in real time on a monitor aboard the *Topaz*; data were also recorded to tape in Hi8 format.

Video data were recorded from 168 locations within the survey area (Figure 6). These sites were chosen systematically to map as much of the acoustic survey area as possible. The location of each sampling site was determined by differential GPS. The depth of the sampling sites was restricted to 20 m and less, ie. the length of the power cable on the video camera.

In addition to being able to identify substrate particle sizes, the video camera could distinguish the presence of capelin eggs on the substrate. However, as the resolution of the video images were insufficient to estimate egg densities, only the presence or absence of capelin eggs at each location was recorded.

The video data were analysed using *Mocha* image analysis software. A single video frame from each sampling site was digitized. A selection of ten substrate particles were measured from each digitized frame and mean particle size was calculated.

Results

1) Distribution and Biomass

A total of 10 acoustic surveys were conducted in the Bellevue survey area during the 1999 field season (Figures 2 and 3). Peak densities and biomass were detected during the first survey on July 7th (Table 1 and Figure 4). Biomass estimates declined subsequent to this, increased again on July 14th and then declined continuously throughout the spawning season. During the period of peak abundance, from July 7th to July 15th, the largest biomass estimates were derived from strata A, B and C, along the western shore. It was only during periods of low abundance (July 19th and 29th) that biomass estimates were larger along Bellevue Beach.

The peak biomass estimate in 1999 (3310 t) was 65% larger than the peak (2002 t) in 1998 (Figure 5). The peak abundance in 1999 was also detected two weeks earlier than in 1998. The abundance of capelin in 1999 was consistently higher than in 1998; biomass estimates from two surveys (July 7th and 9th) were larger than the peak estimate in 1998, and estimates from two other surveys (July 13th and 14th) were comparable to the peak in 1998. The duration of high abundance in 1999 was approximately one week (July 7th - 15th); in 1998, it was more protracted over a two to three week period from mid-July onward.

2) Substrate Classification

For substrate classification within the survey area, mean particle sizes were divided into six groups ranging from sand to boulder (Figure 6). Sand was the most common substrate component, occurring at 24% of the sampled locations. Gravel and pebble (2 - 30 mm) occurred in 27% of the sampling sites; medium to large rock and boulders (60 - 201 mm) occurred at 42% of the sites. It was impossible to determine the substrate component at 8% of the sites due to the presence of a thick layer of capelin eggs.

Sand predominated off Bellevue Beach in particular towards the western end of the beach (Figure 6). Gravel and pebble occurred in pockets from Green Point to Bellevue Beach and also off the beach in particular towards the eastern end of the beach. Larger rock predominated in stratum C to the west of Bellevue Beach and in stratum D off the western end of Bellevue Island.

Capelin eggs were detected at 19% of the sampled sites (Fig. 7). However, they were only detected at gravel or pebble sites; none were detected at sites with sand or larger rock. The eggs were widely distributed geographically through the sampled area, from Green Point in the west to the eastern end of Bellevue Beach. They were also distributed widely where gravel or pebble occurred, being detected at 52% of the gravel sites and 39% of pebble sites. This was even more pronounced in the western part of the sampled area (strata A, B, and C) where eggs were detected at all of the sites where gravel occurred.

The capelin eggs were detected from sites that were videotaped between July 14th and July 21st. Capelin densities detected acoustically on July 7th were overlaid on the same map (Fig. 8). With very few exceptions, the distribution of capelin on July 7th was very similar to the subsequent distribution of capelin eggs.

Discussion

The peak biomass estimate from the acoustic surveys in1999 was 65% larger than in 1998. Some of this increase can be accounted for by increased fish size. Biological samples of capelin from Bellevue Beach indicated that the mean weight of fish increased by 17% from 1998 to 1999 (Nakashima 2000). Assuming that peak abundances were estimated in each of the years, this suggests an actual increase in fish abundance of approximately 50% from 1998 to 1999.

In 1999, peak densities and biomass were detected during the first acoustic survey of the field season (July 7th). This leads one to question whether this represents the actual peak for the season. On July 5th, an acoustic survey was attempted but could not be completed due to an computer malfunction. However, the survey vessel *Topaz* did complete a run through the survey area. Observations recorded in the acoustic log indicated that there was a narrow 'band' of capelin along the western portion of Bellevue Beach and several smaller concentrations of capelin along the western shore to Green Head. This suggests that the high densities of capelin detected on July 7th moved into the survey area in the intervening period. However, it still does not indicate if the peaks detected on July 7th were the actual peaks for the spawning season. There may have been higher densities and a larger biomass within the area prior to July 5th.

Results from the 1999 Bellevue Beach egg and larval study (Nakashima 2000) indicate that peak beach spawning occurred from July 4th - 8th and that very few eggs were deposited subsequent to this. The acoustic results indicate that there were in excess of 2500 t of capelin in the survey area after beach spawning had occurred. Although no biological samples were taken, echograms and videotape indicate that these were pre-spawning fish. If these fish spawned in the area, then they must have done so sub-tidally (off-beach). The data support this conclusion as the incidence of capelin eggs at bottom sampling sites was widespread throughout the survey area and the distribution of capelin on July 7th relative to the location of these eggs was almost identical. It is also supported by the distribution of fish during the period of peak abundance. Most of the fish occurred in strata A and B along the western shore and not along the beach. Subsequently, eggs were detected at all of the sites with gravel in these strata.

The results indicate that off-beach spawning was widespread in the Bellevue area in 1999. In fact, based upon acoustic biomass estimates, it is conceivable that more capelin spawned off-beach (sub-tidally) in 1999 than spawned entirely in 1998. The implications of this in relation to larval emergence and the larval index from the egg and larval production study (Nakashima 2000) are uncertain. Larval tows, conducted adjacent to the beach as part of the egg and larval production study, would be unlikely to detect larvae from off-beach spawning. However, there were no larval tows directed beyond the off-beach spawning sites. This will be investigated further in 2000.

The percentages of capelin that spawned on the beach and off-beach in the Bellevue area in 1999 are unknown as acoustic biomass estimates were not available prior to beach spawning. Consequently, it is unknown what biomass produced the eggs that were deposited on the beach from July 4th to 8th. This aspect can be investigated further in 2000 by commencing the acoustic surveys earlier in the season.

Summary

- The peak biomass of capelin in the Bellevue survey area in 1999 was at least 50% greater than in 1998.

- Suitable capelin spawning substrate exists in depths to at least 20 m in the Bellevue survey area.

- Off-beach (sub-tidal) spawning was widespread in the Bellevue area in 1999 and more capelin may have spawned sub-tidally in 1999 than spawned entirely in 1998.

- It is unknown if the relative proportion of beach spawning and off-beach spawning in 1999 differed from previous years.

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Table 1. 1999 Bellevue capelin densities and biomass estimates, by stratum, and date.

	Densities (grams per square meter)					Biomass (t)					
Date	Strat. A	Strat. B	Strat. C	Strat. D	Strat. E	Strat. A	Strat. B	Strat. C	Strat. D	Strat. E	All Strata
07-Jul	832.29	1163.01	419.69	187.25	328.66	972.9	1582.8	391.1	363.3	260.9	3310.0
08-Jul											
09-Jul	850.64	633.91	455.74	127.39	146.88	994.3	862.7	424.7	247.1	116.6	2528.9
10-Jul											
11-Jul	169.99	273.20	313.51	26.28	153.41	198.7	371.8	292.1	51.0	121.8	984.5
12-Jul											
13-Jul	425.63	577.37	277.23	54.43	81.81	497.5	785.8	258.3	105.6	64.9	1647.2
14-Jul	354.71	881.05	7.02	54.03	19.42	414.6	1199.1	6.5	104.8	15.4	1725.0
15-Jul	123.44	309.81	82.05	31.11	18.88	144.3	421.6	76.5	60.4	15.0	702.7
16-Jul	18.28	133.79	112.95		6.89	21.4	182.1	105.3	0.0	5.5	314.2
17-Jul											
18-Jul											
19-Jul	21.51	19.48	40.28	114.53	94.80	25.1	26.5	37.5	222.2	75.3	311.4
20-Jul											
21-Jul											
22-Jul	64.43	78.65	6.24		0.00	75.3	107.0	5.8	0.0	0.0	188.2
23-Jul											
24-Jul											
25-Jul											
26-Jul											
27-Jul											
28-Jul											
29-Jul	24.09	21.90	0.00	21.98	15.93	28.2	29.8	0.0	42.6	12.6	100.6

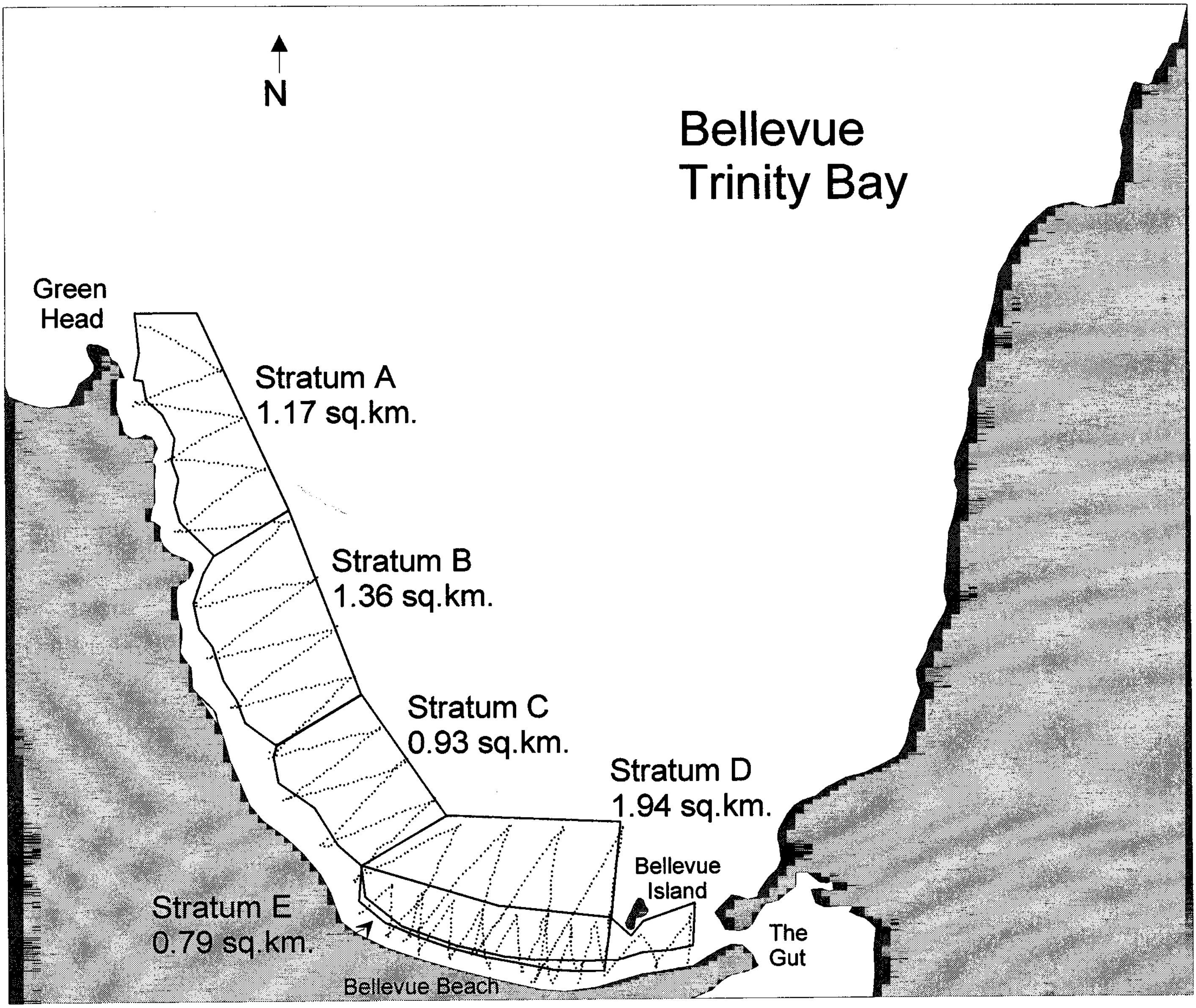

Figure 1. Acoustic survey strata and transects, Bellevue, Trinity Bay.

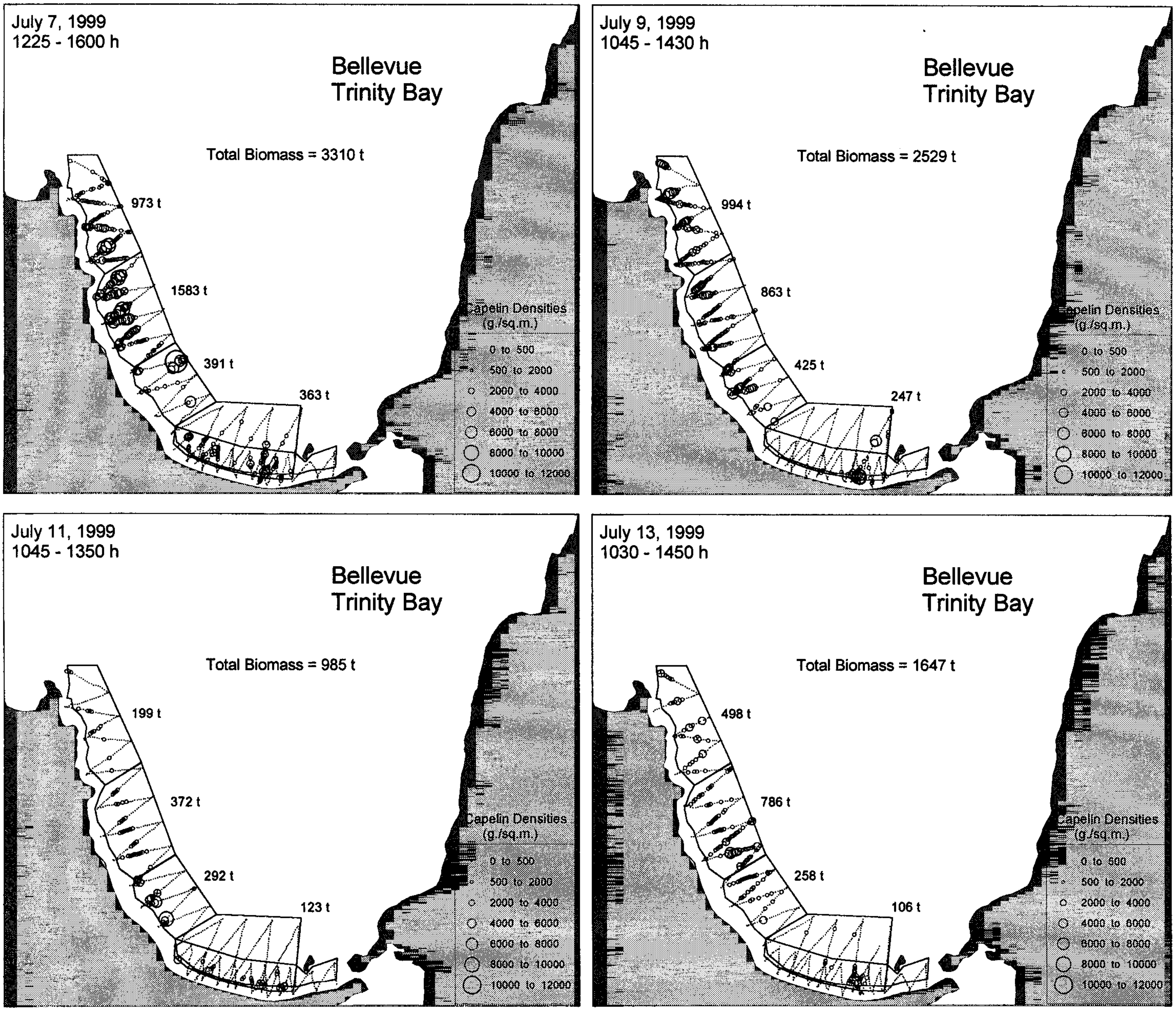

Figure 2. Bellevue capelin densities and biomass estimates, by stratum, July 7 - 13, 1999.

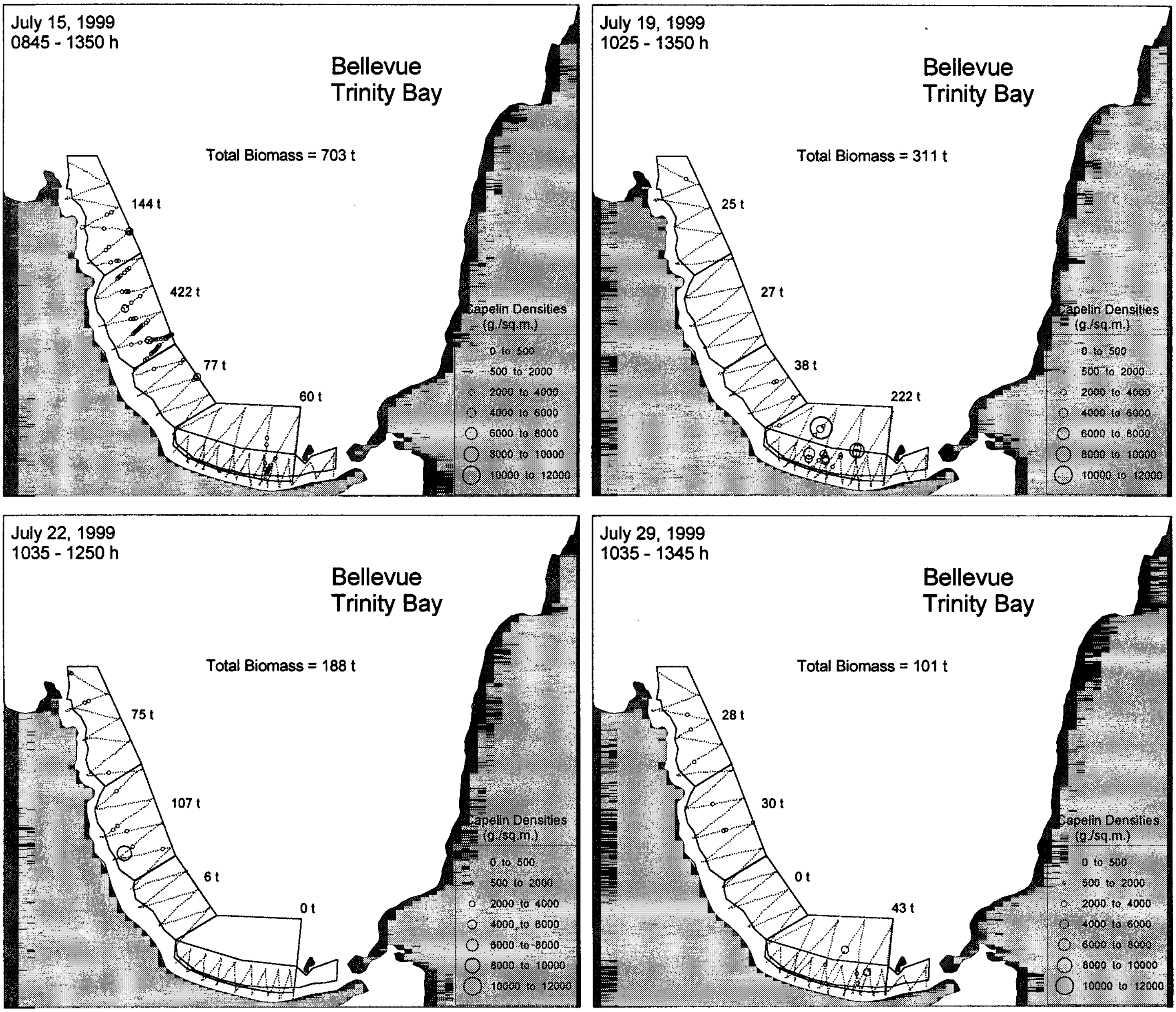

Figure 3. Bellevue capelin densities and biomass estimates, by stratum, July 15 - 29, 1999.

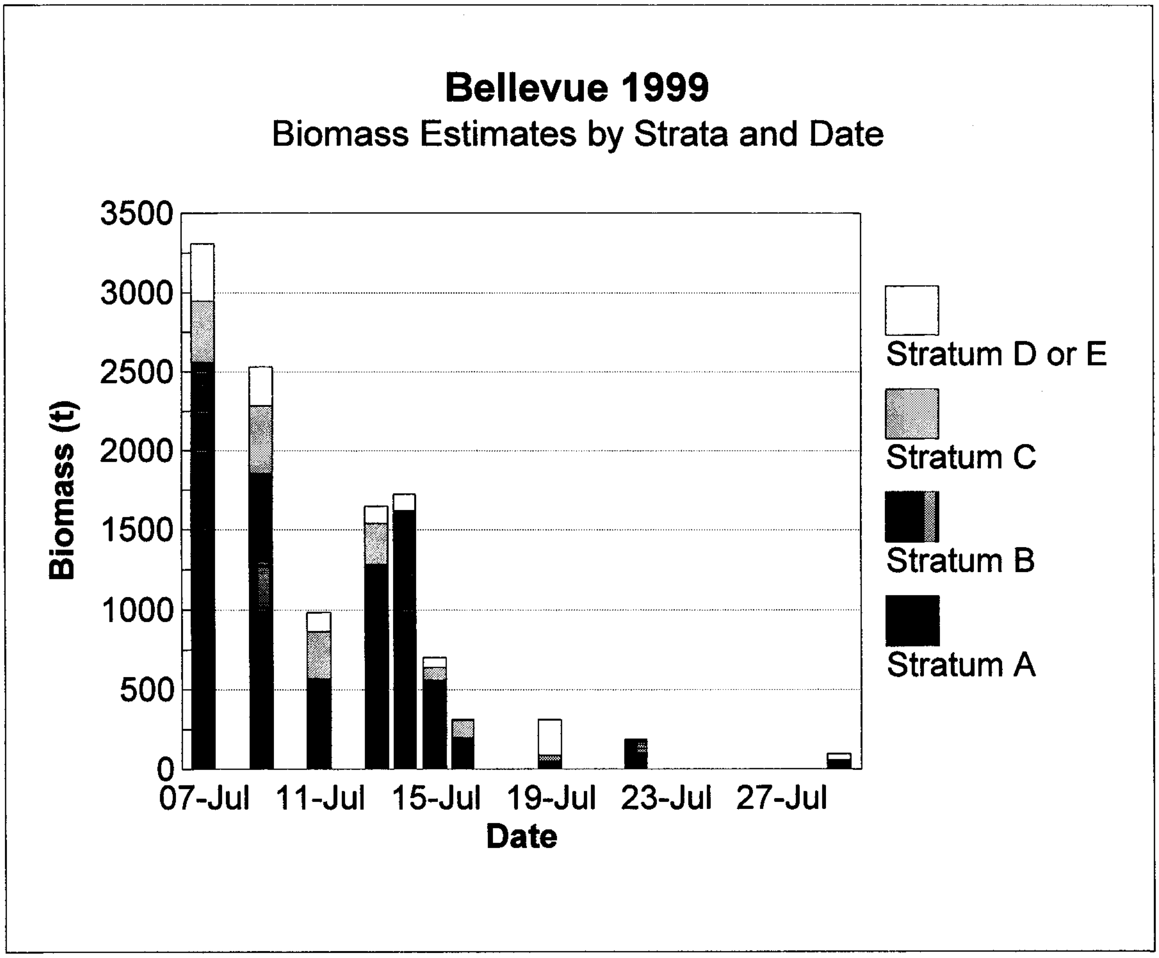

Figure 4. 1999 Bellevue capelin biomass estimates by stratum and date.

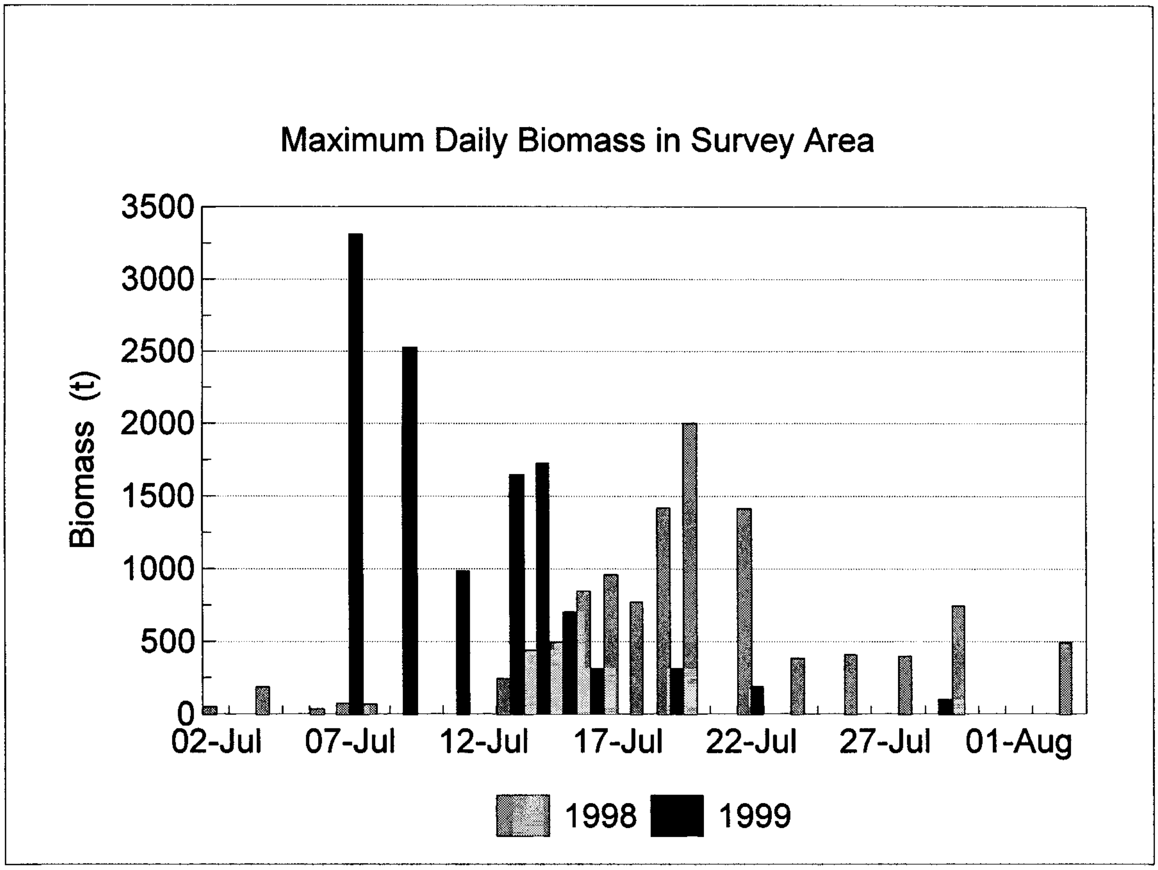

Figure 5. Comparison of maximum daily capelin biomass estimates within the Bellevue survey area in 1998 and 1999.

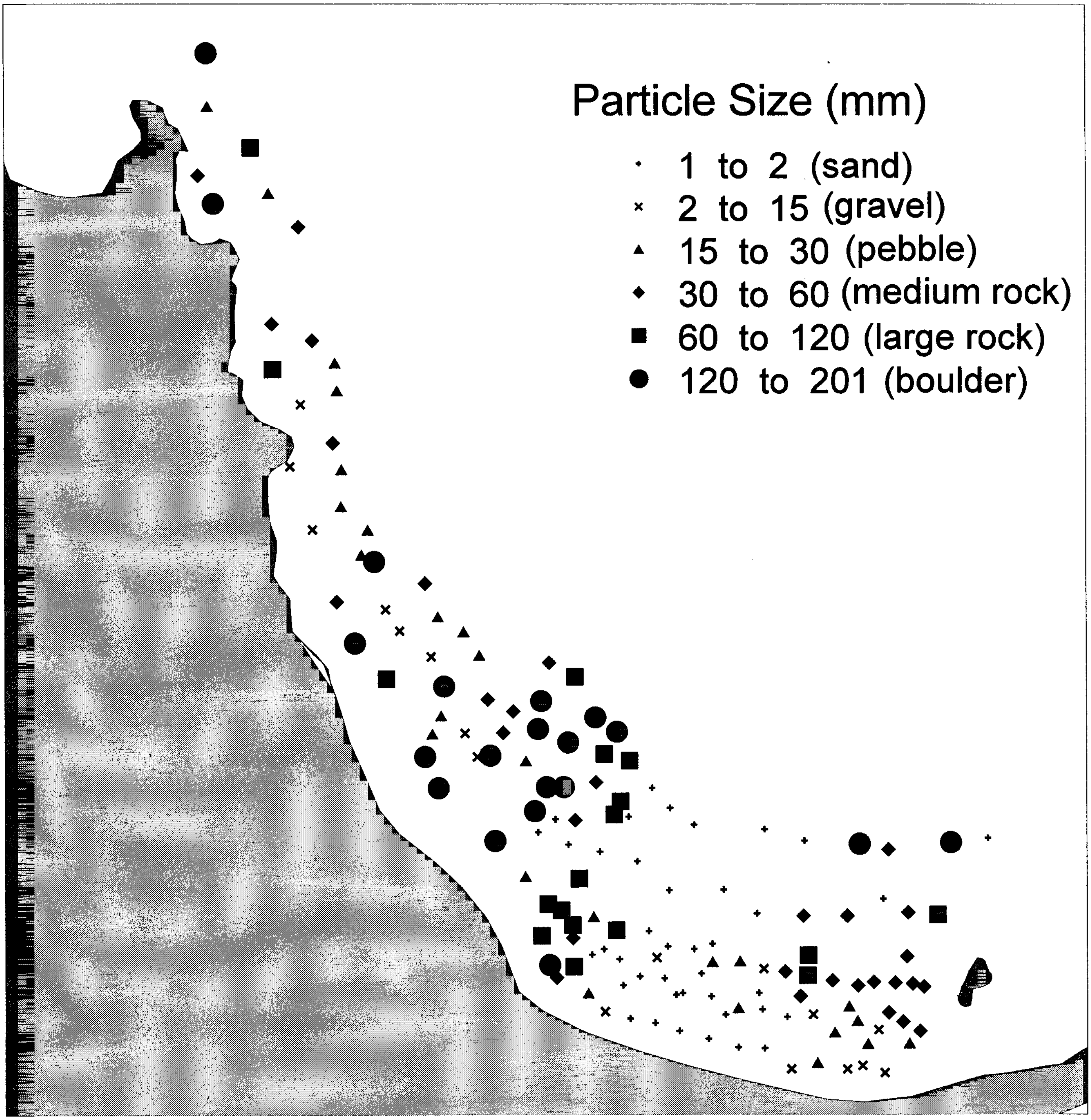

Figure 6. Mean particle size of bottom substrate at selected sites in Bellevue, Trinity Bay, as calculated from video images.

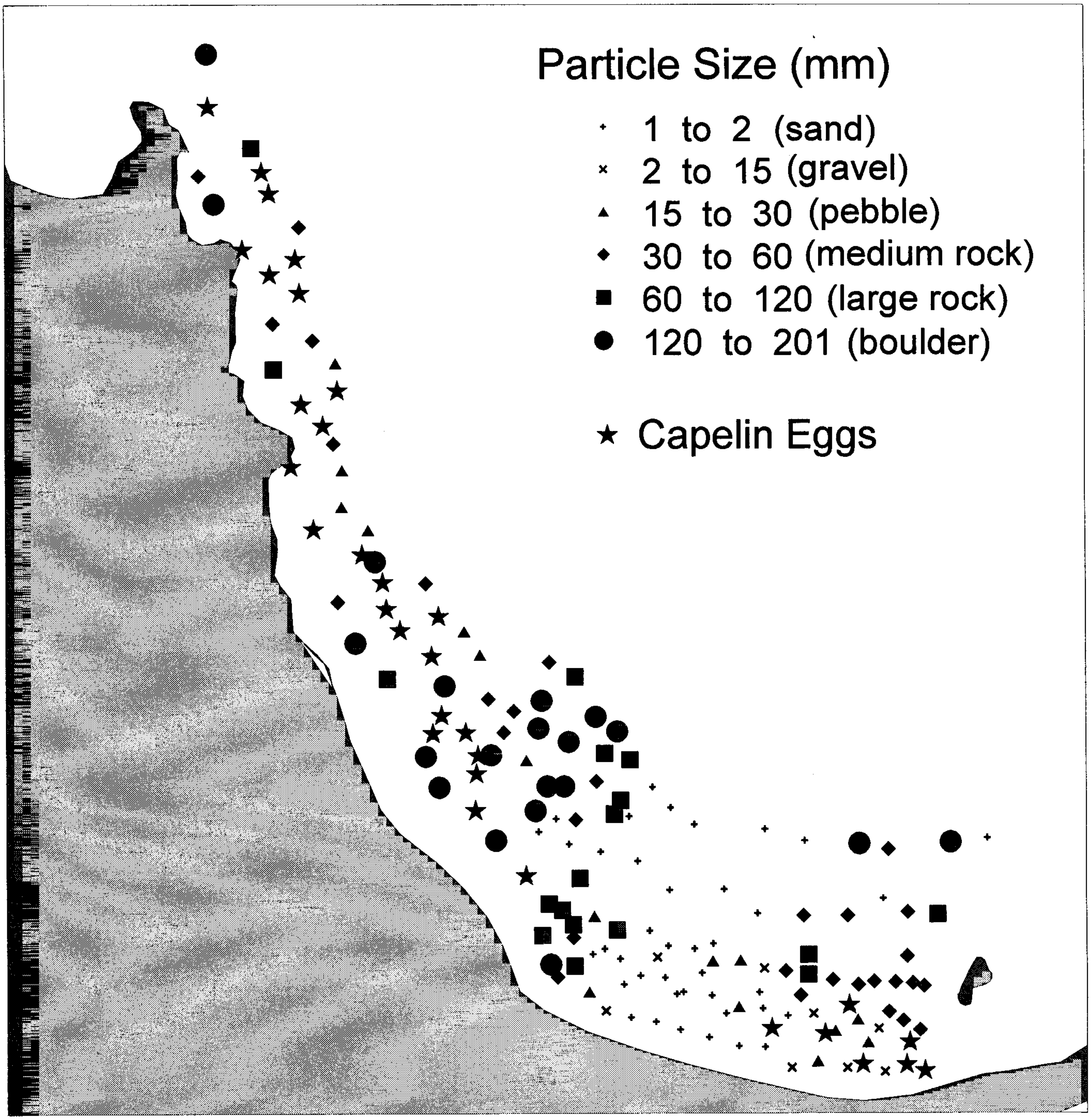

Figure 7. Mean particle size of bottom substrate at selected sites and locations where capelin eggs were detected, as determined from video images.

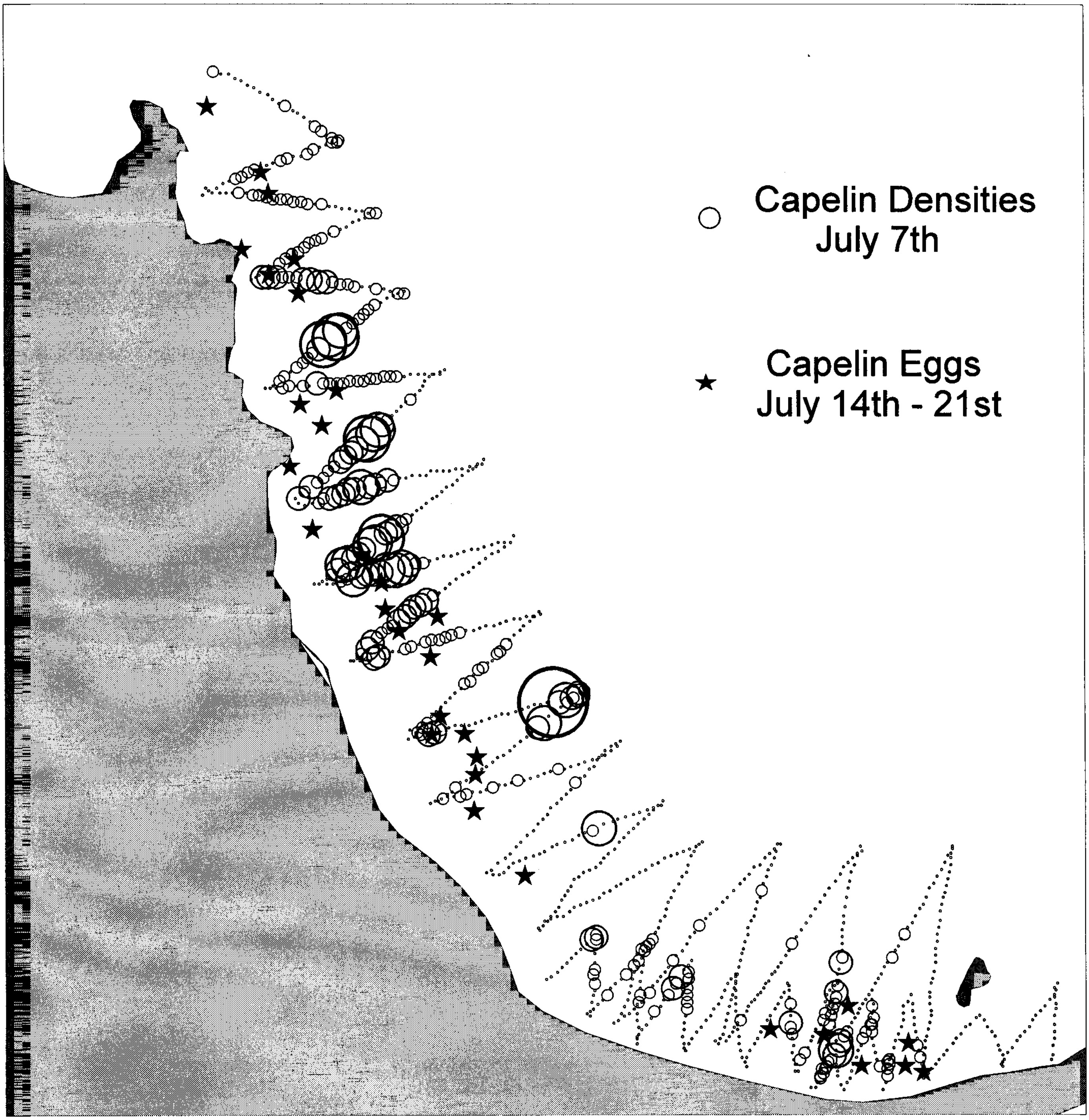

Figure 8. Location of capelin detected acoustically and subsequent locations of capelin eggs detected from video images.

Acoustic surveys for capelin in Placentia Bay, June 1998-1999

by

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Abstract

The abundance, distribution and biological composition of capelin (*Mallotus villosus*) in Placentia Bay was assessed during an acoustic survey in June 1999. Capelin biomass in outer Placentia Bay and a portion of 3Ps was estimated as 20,000 tons. This was a substantial decrease from June 1998, when 203,000 tons of capelin was detected in the same area. The acoustic survey in 1999 was 2-3 weeks earlier than in 1998 and it is possible that capelin had not yet migrated into the survey area. Approximately half of the capelin sampled were maturing. Immature capelin were concentrated in an area to the south of the Burin Peninsula, while mature capelin were caught throughout the bay. Capelin from Placentia Bay were smaller-at-maturity and smaller-at-age than capelin from Trinity Bay (3L) or Labrador (2J). The length of 50% maturity was 120mm for females and 140mm for males.

Introduction

Acoustic surveys for cod and capelin are conducted regularly in Placentia Bay (NAFO Div. 3Ps) by the Fisheries Conservation group at Memorial University of Newfoundland. O'Driscoll & Rose (1999) summarised the results from four surveys in 1998-99, and showed that distribution and abundance of capelin in Placentia Bay varied seasonally. Capelin biomass was highest in June 1998, when over 130,000 tons were detected in the outer part of the bay. In this paper, we present a more spatially extensive estimate of capelin abundance from June 1998, including a portion of 3Ps out to the edge of the St. Pierre and Green Banks. We compare this new estimate with capelin biomass in the same region from our June 1999 survey. We also present biological data on capelin growth and maturity in Placentia Bay.

Methods

Surveys were conducted from the research vessel *Teleost* during June 19-25 1998 (Teleost 65) and June 1-4 1999 (Teleost 79). Acoustic data was collected using a calibrated Simrad EK500 split-beam 38-kHz echo-sounder (Table 1), and analysed using custom FASIT (Fisheries Assessment and Species Identification Toolkit) software. We distinguished signals from capelin based on signal characteristics and information from fishing sets.

For biomass estimation, we integrated acoustic data from 11m below the surface to the bottom in 100-m horizontal bins and scaled by acoustic target strength to give estimates of areal density of capelin (fish m^{-2}) in each 100-m bin. Mean target strengths for each survey (Table 2) were calculated from fishing set length-frequency data using the relationship TS = 20logL – 73.1 where L = fish length in centimetres (Rose 1998).

The area surveyed included the outer part of Placentia Bay and a corridor straddling the edges of St. Pierre and Green Banks out to the shelf edge (Fig. 1). Ten blocks were used as the basis for the survey and transects were run across the blocks (Fig. 1). These blocks are identical to those used in calculation of cod biomass from the same surveys (e.g. Rose & Lawson 1999).

Only data collected along transects were used to estimate biomass, although all data, including inter-transect segments are shown in Fig. 1. Capelin biomass was estimated independently for each block from the equation:

$$B_i = w\ A_i d_i$$

where B_i is the biomass of capelin in block i (kg)
w is the average weight of capelin from fishing sets (kg)
A_i is the area of block i (m^2)
d_i is the mean areal density of capelin in block i (fish m^{-2})

Acoustic data in 100-m bins were significantly autocorrelated. To estimate sampling uncertainty we used a bootstrapping method (Robotham & Castillo 1990) for each block based on repeated 10% sampling of the 100-m binned data (100 times). There was usually no significant autocorrelation in the 10% sampled data. The 100 sample means were used to calculate the bootstrapped mean density (d_i) and 95% confidence intervals for each block (Tables 3-4).

Fishing sets with Campelen bottom and IYGPT mid-water trawls were carried out in support of the acoustic surveys (Fig 2). Length composition of capelin was determined from a random sample of 200 fish per set in 1998 and 1999. Detailed biological analyses were also carried out on a length-stratified sub-sample (10 capelin in each 1-cm length class) of fish from each set in June 1999 (Table 5). We compare biological characteristics of capelin from Placentia Bay with fish sampled during the same cruise in Trinity Bay (NAFO 3L) and southern Labrador (NAFO 2J).

Results

The acoustic estimate of capelin biomass in our survey area in June 1999 was 20,000 tons (95% confidence intervals 12,000-29,000t) (Table 4). This was an order of magnitude lower than the equivalent biomass estimate from June 1998 of 203,000 tons (135,000-303,000t) (Table 3).

Spatial distribution of capelin was also different between 1998 and 1999 (Fig. 1). In June 1998 highest densities of capelin were observed in the northern part of the study area (blocks b and c). In June 1999 highest densities were in block g to the south of Placentia Bay.

Mean lengths of capelin from Placentia Bay were similar in 1998 (125mm) and 1999 (124mm) (Fig. 3). However, a lower proportion of large capelin (>130mm) were observed in 1999. Approximately 50% of capelin sampled were sexually mature in 1999. A mix of mature and immature capelin was captured in all fishing sets (Fig. 2). Immature capelin were most abundant in sets to the south of the Burin Peninsula in block g and in the north-eastern part of the survey area in block a (Fig. 2).

Capelin from Placentia Bay matured at smaller size than capelin from Labrador or Trinity Bay (Fig. 4). Length at 50% maturity was 120mm for females and 140mm for males, compared to 130mm for females and 150mm for males from

Trinity Bay and Labrador. There was no evidence that capelin in Placentia Bay were maturing at younger ages than capelin in the other areas (Fig. 5). At age two 24% of males and 55% of females were mature in Placentia Bay, compared to 29% of males and 83% of females in Labrador and 31% of males and 49% of females in Trinity Bay. Rather, mature capelin from Placentia Bay seemed to be smaller at age than capelin from Labrador and Trinity Bay (Fig. 6). This difference in growth was particularly apparent for females (Fig. 6).

Discussion

O'Driscoll & Rose (1999) showed that capelin abundance and distribution varied seasonally in Placentia Bay. Biomass estimates in a "common area" of outer Placentia Bay (bounded by co-ordinates: 47°23'N, 54°29'W; 47°20'N, 54°01'W; 46°45'N, 55°31'W; 46°43'N, 54°19'W) were highest in June 1998 and lowest in January 1999 (Fig. 7). Estimated capelin biomass in this common area in June 1999 was 4,500t, which was ten times greater than biomass in January 1999, but much less than biomass in January and June 1998 (Fig. 7). Our survey was ~18 days earlier in 1999 than in 1998. The southward distribution of capelin in 1999 suggests that all fish may not yet have migrated into our study area. However, independent acoustic surveys for cod in fall 1999 (Luiz Mello pers. comm.) and discussions with local residents (Byron Adams pers. comm.) indicate that the abundance of capelin in Placentia Bay was much lower in 1999 than in 1998.

The reduction of capelin biomass between June 1998 and June 1999 also reflects relative year-class strength. Most (86%) capelin sampled in June 1999 were age two (1997 year-class). If the same age structure was present in Placentia Bay in 1998 as in 1999, capelin biomass in June 1998 would have been dominated by the strong 1996 year-class. The 1997 year-class we observed in June 1999 is thought to be much weaker (Anderson *et al.* 1999).

No biological sampling of capelin was carried out in June 1998. Because of the small size of the capelin sampled, O'Driscoll and Rose (1999) assumed that almost all capelin in Placentia Bay in June 1998 were immature. Our results from 1999 indicate that this is incorrect. Using the maturity-at-length data from 1999 (Fig. 4) and the length frequencies observed in 1998 (Fig. 3) we calculated that 53% of capelin observed in June 1998 were pre-spawning adults. Hence, there would have been substantial spawning mortality of the larger capelin (>120mm) between 1998 and 1999.

The low length-at-maturity and apparent slow growth of capelin in Placentia Bay compared to capelin from Trinity Bay and Labrador was an unexpected result. Winters (1982) observed a north-south cline in capelin growth, where growth was more rapid further south. He attributed this cline to warmer water temperatures in the south. Winters (1982) did not sample capelin from Placentia Bay, but capelin from Grand Beach in Fortune Bay exhibited a similar growth pattern to fish from Trinity Bay and grew faster than capelin from Labrador. Work on the growth and feeding behaviour of capelin in this area is ongoing.

Acknowledgements

We thank the sea-going scientific staff and crew of the "CGSS Teleost" and Phil Eustace who aged the capelin samples. Funding for this work came from the NSERC Industrial Chair in Fisheries Conservation and from a New Zealand Foundation for Research, Science and Technology Post-Doctoral Fellowship held by the first author.

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Table 1. Specifications for EK500 on Teleost surveys in June 1998 and 1999.

	1998	1999
Frequency	38kHz	38kHz
Ping Interval	1s	1s (250m range) 2s (500m)
Pulse length	1.0ms	1.0ms
Bandwidth	3.8kHz	3.8kHz
Transmit Power	2000W	2000W
Absorption Coefficient	10dB km^{-1}	10dB km^{-1}
2-Way Beam Angle	-20.6 dB	-20.6 dB
Sv Transducer Gain	25.60 dB	26.00 dB
TS Transducer Gain	25.60 dB	25.82 dB
TVG	20logR	20logR
Angle Sensitivity Along.	21.9	21.9
Angle Sensitivity Athw.	21.9	21.9
3 dB Beamwidth Along.	7.1 dg	7.0 dg
3 dB Beamwidth Athw.	7.1 dg	7.0 dg
Along. Ship Offset	0.00 dg	-0.13 dg
Athw. Ship Offset	0.00 dg	-0.15 dg
Range of Raw Sv data collection	250m or 500m	250m or 500m
Vertical Sampling Resolution	0.1m	0.1m
Bottom Removal	none on raw data	none on raw data
Vessel Speed	8 knots	8 knots

Table 2. Capelin target strength calculated from length-frequency data for surveys in Placentia Bay in June 1998 and 1999.

Survey	Mean σ (m^2)	Mean TS (dB)	Mean length (mm)	Mean weight (g)
June 1998	9.846E-05	-51.06	125	10.34
June 1999	9.485E-05	-51.22	124	9.50

Table 3. Capelin abundance and biomass estimates for survey June 19-25 1998 (see Fig. 1 for block boundaries).

Survey Block	No. of 100-m bins	Mean capelin density m^{-2} (d_i) (95% CI)	Transect area (*10^6 m^2)	Stratum abundance (millions) (95% CI)	Stratum biomass (tons) (95% CI)
a	340	2.63 (0.75-5.01)	170	448 (127-852)	4633 (1316-8813)
b	370	4.60 (3.30-6.34)	396	1820 (1310-2510)	18830 (13521-25940)
c	553	4.94 (2.75-7.91)	462	2280 (1270-3660)	23621 (13137-37841)
d	503	3.15 (1.38-5.41)	390	1230 (537-2110)	12689 (5549-21828)
e	617	3.65 (2.59-4.79)	1050	3820 (2710-5020)	39479 (28018-51931)
f	777	1.98 (1.46-2.34)	1630	3230 (2390-3830)	33389 (24719-39569)
g	1003	1.12 (0.80-1.76)	4230	4730 (3380-7420)	48950 (34944-76703)
h	710	0.48 (0.31-0.78)	3700	1780 (1150-2890)	18461 (11918-29846)
i	642	0.004 (0.002-0.008)	3940	18 (6-32)	183 (65-335)
j	1094	0.08 (0.04-0.27)	3630	287 (140-978)	2972 (1450-10117)
Total			19600	19600 (13000-29300)	203208 (134636-302923)

Table 4. Capelin abundance and biomass estimates for survey June 1-4 1999 (see Fig. 1 for block boundaries).

Survey Block	No. of 100-m bins	Mean capelin density m^{-2} (d_i) (95% CI)	Transect area ($*10^6$ m^2)	Stratum abundance (millions) (95% CI)	Stratum biomass (tons) (95% CI)
a	328	0.007 (0.001-0.016)	170	1 (0.2-3)	12 (2-26)
b	405	0.007 (0.002-0.017)	396	3 (1-7)	28 (9-63)
c	474	0.022 (0.009-0.048)	462	10 (4-22)	95 (41-210)
d	476	0.013 (0.006-0.038)	390	5 (2-15)	48 (2-139)
e	676	0.012 (0.007-0.019)	1050	13 (7-20)	119 (68-187)
f	754	0.132 (0.068-0.233)	1630	215 (111-379)	2045 (1056-3604)
g	1048	0.282 (0.157-0.405)	4230	1190 (665-1710)	11314 (6313-16272)
h	2402	0.165 (0.119-0.207)	3700	609 (441-763)	5781 (4186-7251)
i	884	0.009 (0.005-0.014)	3940	36 (20-54)	339 (191-509)
j	2235	0.011 (0.003-0.031)	3630	39 (11-112)	373 (103-1060)
Total			19600	2120 (1260-3090)	20154 (11970-29321)

Table 5. Biological sample sizes from June 1999 cruise.

Set Number	Gear Type	Catch	Number measured	Number LWSM	Number aged
3	Campelen	2455	200	45	20
5	Campelen	2405	200	39	4
6	Campelen	8591	200	49	0
7	Campelen	4503	200	46	0
8	Campelen	48	48	18	8
9	Campelen	468	200	59	0
10	Campelen	201	201	50	0
11	Campelen	1491	200	56	19
12	IYGPT	8522	200	50	12
13	IYGPT	568	200	63	5
14	Campelen	12085	200	56	16
15	Campelen	2323	200	60	10
17	Campelen (mid-water)	619	200	56	4
Total		44279	2449	647	98

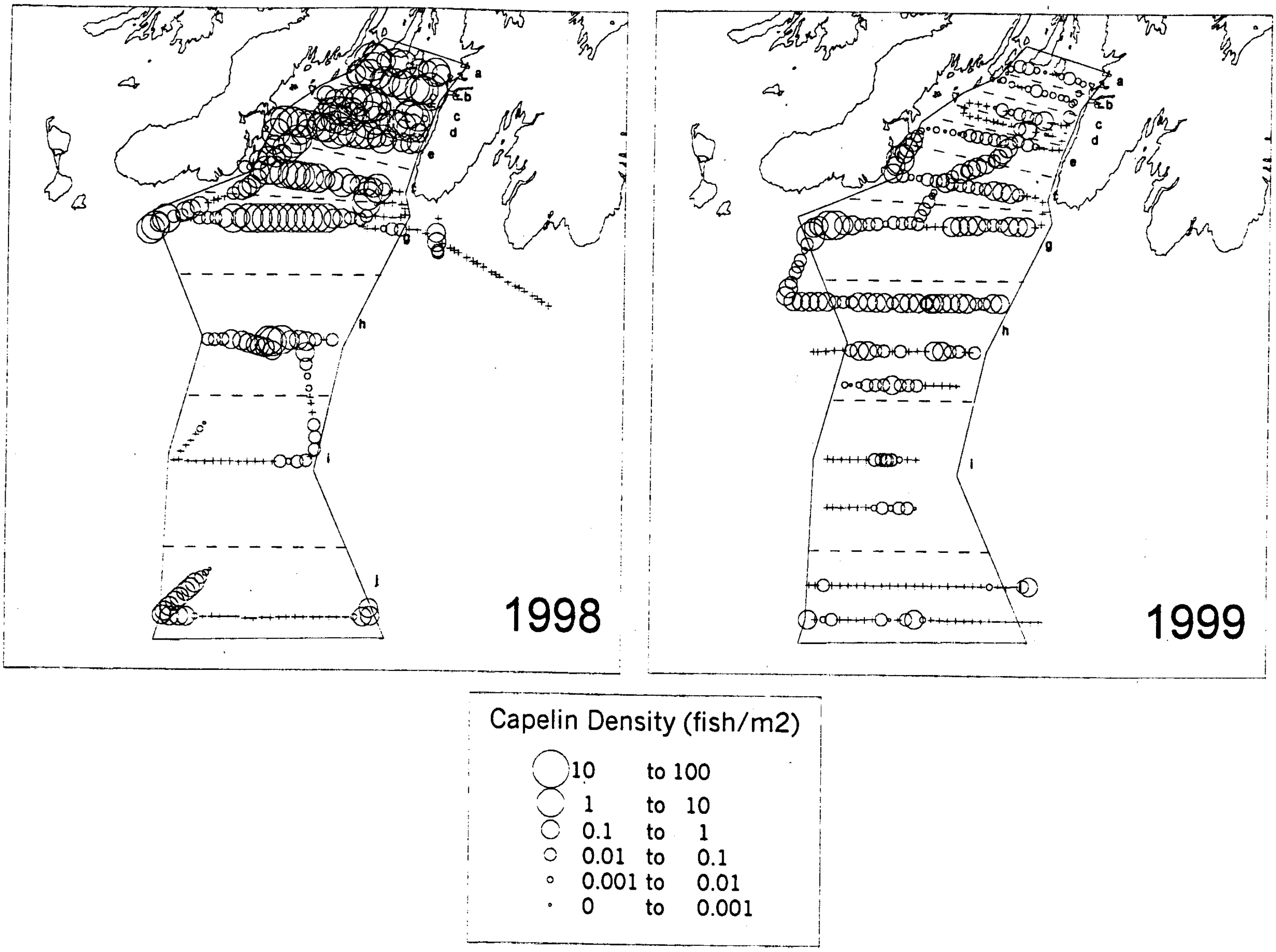


Fig. 1. Expanding symbol plot showing capelin distribution in Placentia Bay and a portion of 3Ps during surveys in June 1998 and 1999. Acoustic data were averaged into 5-km bins for the purpose of display. '+' symbol indicates no capelin were detected in that bin. Blocks used for estimating biomass are indicated and lettered.

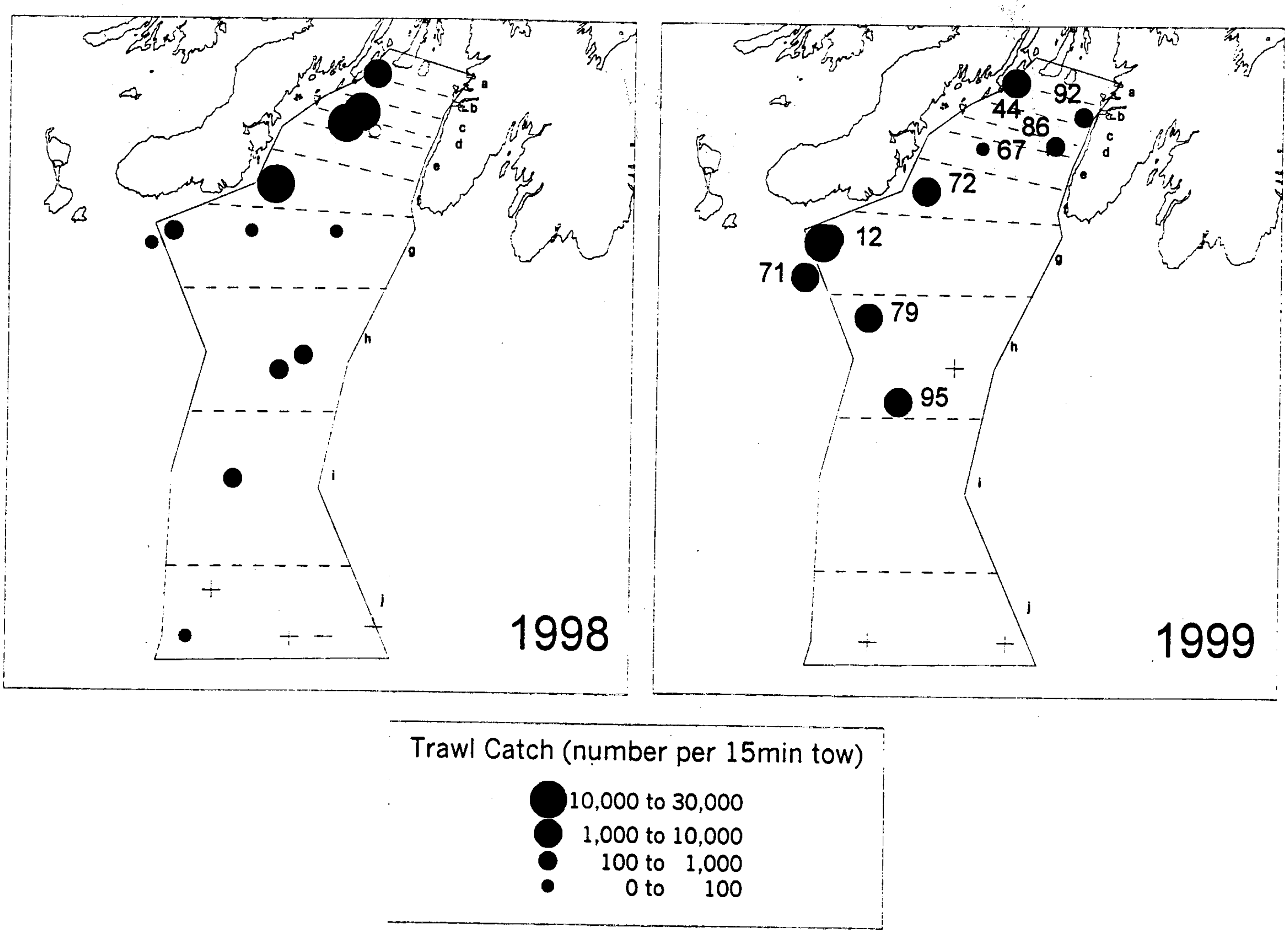


Fig. 2. Locations of fishing sets during surveys in June 1998 and 1999. Circle size is proportional to catch. Open circles show IYGPT mid-water trawls. Closed circles show Campelen bottom trawls. '+' symbol indicates no capelin were caught. Numbers next to symbols in 1999 indicate proportion of capelin in each set that were sexually mature.

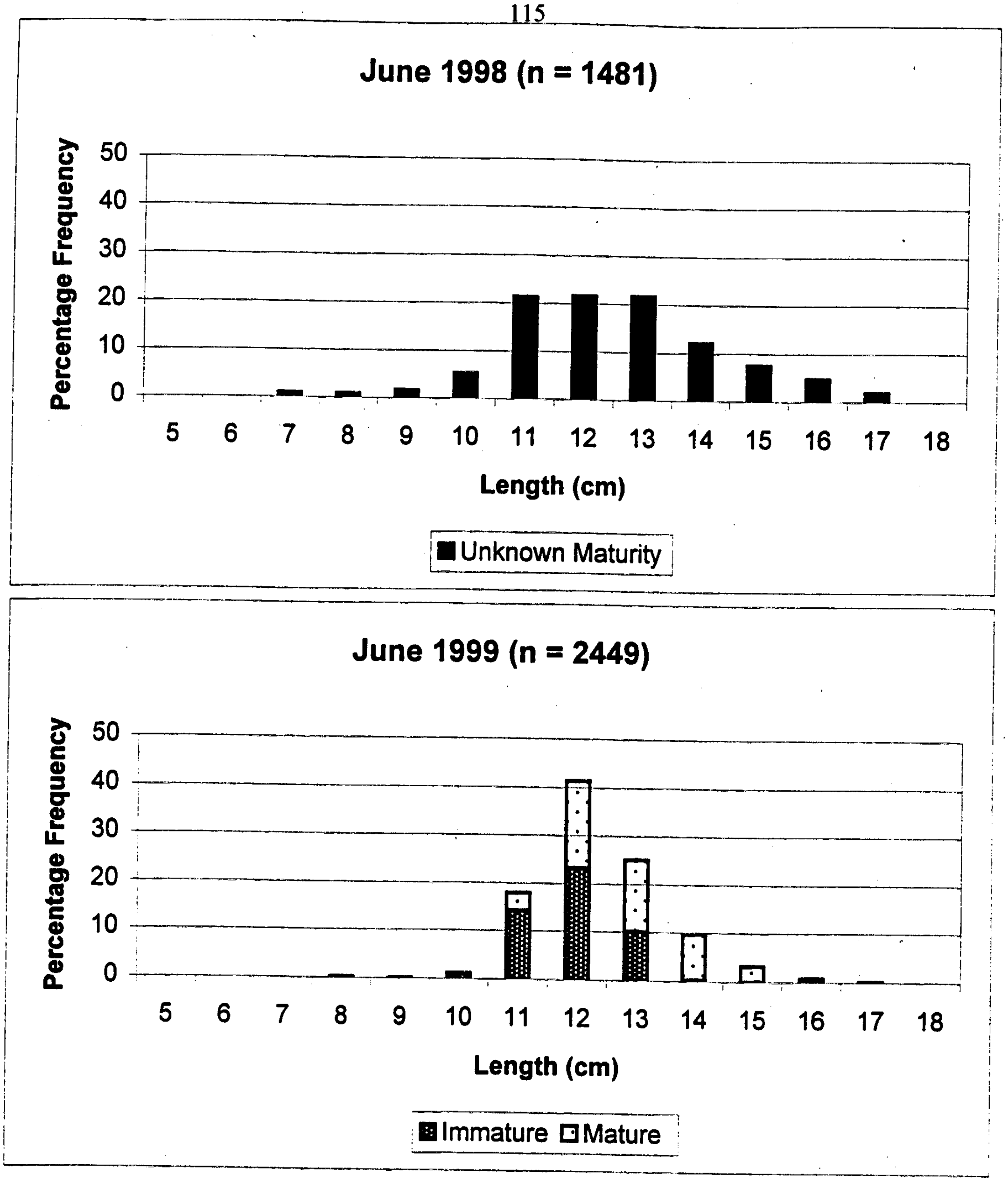


Fig. 3. Length frequency distributions of capelin sampled during acoustic surveys. The total number of fish measured (n) is given.

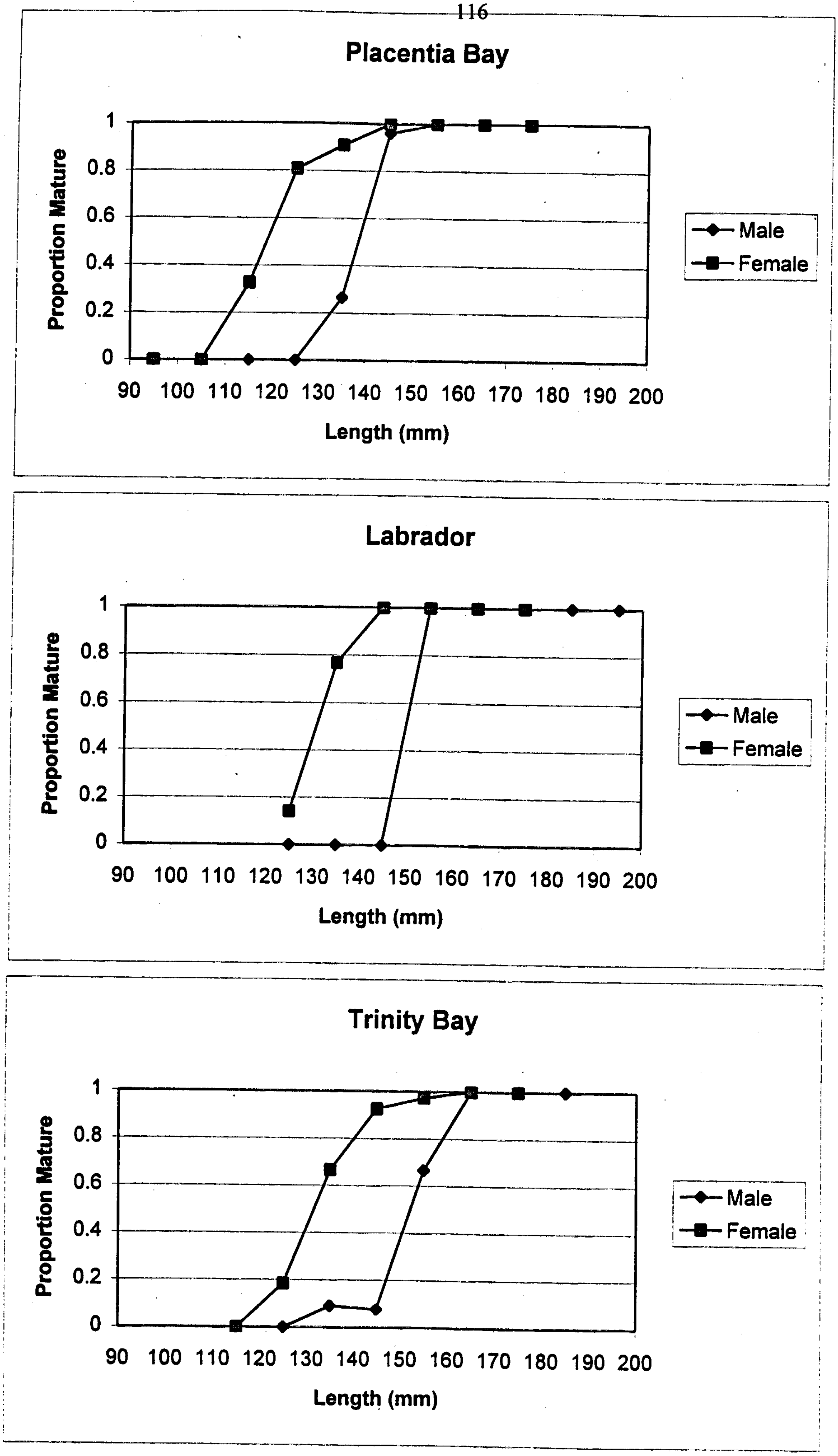


Fig. 4. Comparison of proportion mature at length for capelin sampled in Placentia Bay, Labrador and Trinity Bay.

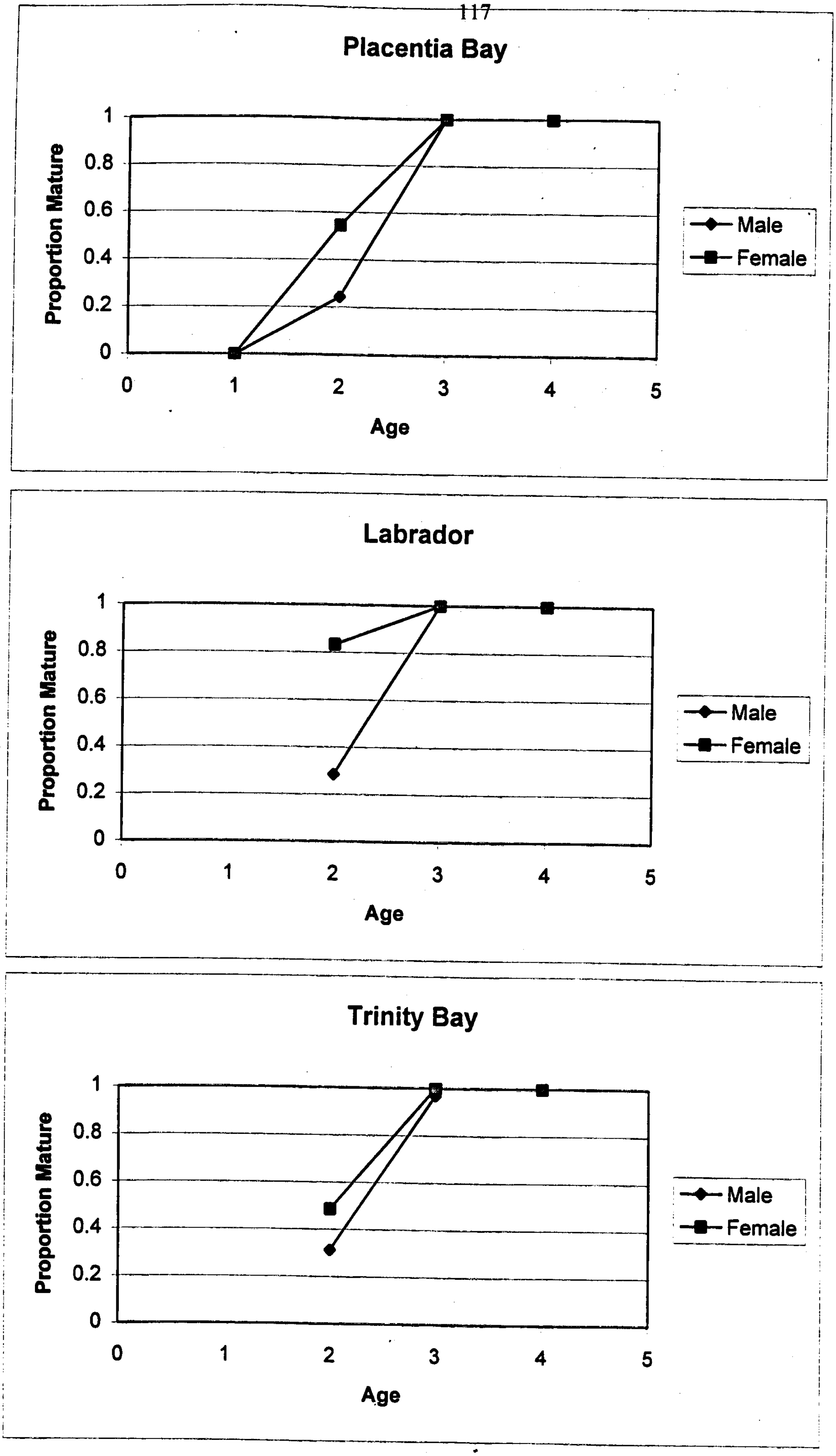
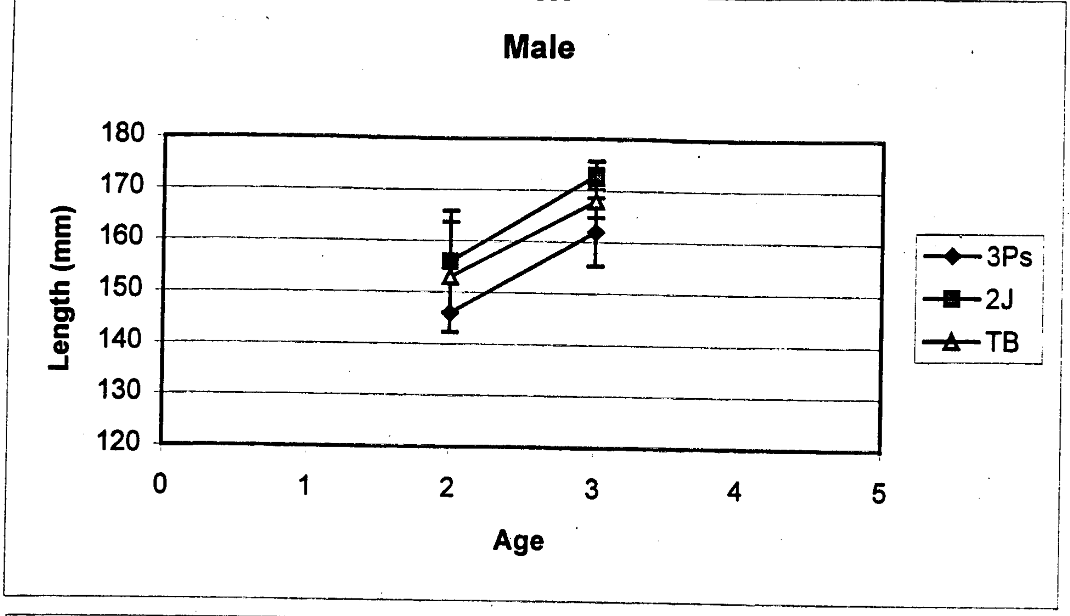


Fig. 5. Comparison of proportion mature at age for capelin sampled in Placentia Bay, Labrador and Trinity Bay.



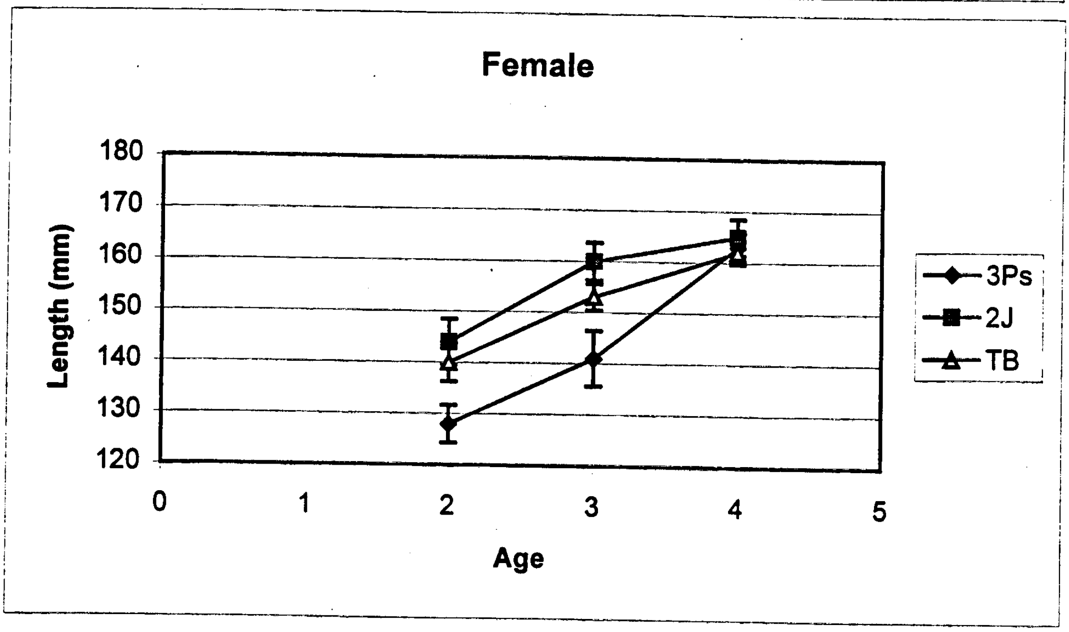


Fig. 6. Comparison of mean length at age of mature capelin sampled in Placentia Bay (3Ps), Labrador (2J) and Trinity Bay (TB). Error bars show +/- 2 standard errors.

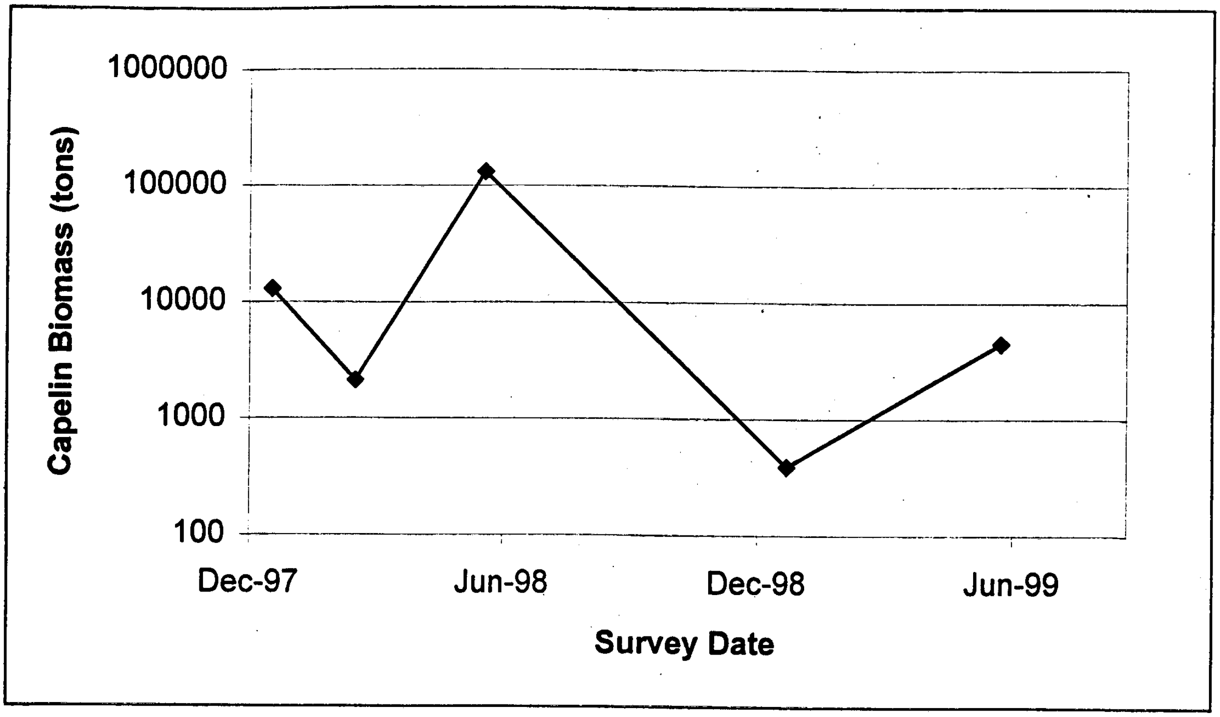


Fig. 7. Change in acoustic estimates capelin biomass for a "common area" of outer Placentia Bay surveyed in January, March and June 1998, and January and June 1999. Note capelin biomass is presented on a logarithmic scale.