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Acoustic Surveys in Placentia Bay and 3Ps, June 1996-1998

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Abstract

Index acoustic/trawl surveys for cod during the spawning season have been conducted in June in Placentia Bay and a portion of 3Ps since 1996. The 1996 survey indicated the presence of approximately 9 Kt of cod primarily of the 1990 and 1992 year-classes. A similar survey in June of 1998 indicated the presence of 72 Kt of cod again dominated by the 1990 and 1992 year-classes, but also containing large numbers of 1993 and 1994 year-class. Cod were more widely distributed in 1998 than in 1996 and occurred at higher densities, with the major biomass located in the Oderin Bank area. A higher proportion of younger fish was found on the shelf than in the Bay. An inner Bay survey also conducted in June 1998 indicated an additional 3 Kt, with similar age structure to the outer Bay. Bay-only surveys in the spring of 1997 indicated the presence of approximately 45 Kt of cod in the inner and outer parts of Placentia Bay (ca. 40 Kt at Perch Rock, 4 Kt at Bar Haven, and 6 Kt at Oderin Bank).

Résumé

Des relevés acoustiques indices de la morue, pendant la saison du frai, ont été effectués en juin dans la baie Placentia et dans une partie de 3Ps depuis 1996. Le relevé de 1996 indiquait la présence de 9 kt environ de morue, surtout des poissons des classes d'âge de 1990 et 1992. Un relevé semblable effectué en juin 1998 a montré la présence de 72 kt de morue, aussi dominée par les classes d'âge de 1990 et 1992, mais on a aussi décelé un nombre important de poissons des classes de 1993 et 1994. La répartition des morues était plus étendue en 1998 qu'en 1996 et les densités étaient plus élevées, la principale biomasse se trouvant dans la région du banc Oderin. La proportion de jeunes poissons était plus importante sur le plateau que dans la baie. Un relevé effectué dans le fond de la baie en juin 1998 a permis de déceler la présence de 3 kt supplémentaires, la structure des âges étant semblable à celle notée dans la partie extérieure de la baie. Des relevés limités à la baie réalisés au printemps de 1997 ont montré la présence de 45 kt environ de morue dans le fond et l'entrée de la baie Placentia (40 kt à Perch Rock, 4 kt à Bar Haven et 6 kt au banc Oderin).

Introduction

Acoustic surveys for cod and capelin were first conducted in Placentia Bay in the winter of 1995 (Rose 1996). Since then, several surveys have taken place in conjunction with research on spawning areas and cod ecology. Conducting any form of fisheries survey in Placentia Bay is difficult. Most of the bottom is not trawlable and bathymetry and behavior related detectability issues (Lawson and Rose 1999) create problems for acoustic methods. Nevertheless, acoustic methods are thought to be the best available method to survey the abundance of these species. The shelf portion of 3Ps is more amenable to both trawl and acoustic surveying. However, the vertical distribution of cod well off the bottom at this time of year tends to favor acoustic surveying.

Acoustic surveys employing an EK500 split-beam system (38 kHz) were conducted in June, 1996, and June, 1998, from the CGSS Teleost, across a portion of 3Ps that included the outer part of Placentia Bay and a strip that ran to the shelf edge (Fig. 1).

Acoustic surveys were also undertaken in the inner portions of Placentia Bay and parts of the outer Bay using small vessels (Innovation and Mares) and a BioSonics DT4000 digital echosounding system. Surveys conducted in June 1996, May 1997, and June 1998 are reported here (closest in timing to the Teleost surveys).

Methods

The outer part of Placentia Bay and a sample block straddling the edges of St. Pierre and Green Banks to the shelf edge was surveyed acoustically from the Teleost in June 1996 and June 1998. In both surveys, similar methods were used. Ten blocks were used as the basis for the survey (Fig. 1 and 2). Transects were run across the blocks. Depths < 50 m cannot be surveyed adequately from the Teleost because of the likelihood of avoidance. Survey conditions were excellent in all years (e.g. Fig 3). In both surveys a calibrated EK500 38 kHz split-beam system was used with settings as indicated in Table 1. Calibrations were undertaken by the Hydroacoustics Section at NWAFC prior to each trip. Digital data were collected using the EP software package (Simrad) using the full dynamic range available with no threshold. In 1996 only low resolution data (1 m) was collected, in 1998 both low and high resolution (0.1 m) data were collected and high resolution data was used for all analyses.

Inner Bay and spawning surveys were conducted in the springs of 1997 and 1998 from the Innovation and Mares (10 and 16 m) using the BioSonics DT4000 single beam digital system (38 kHz in 1997 and 120 kHz in 1998). In most cases a regular grid was run over most of the Bay, and special grids were run over spawning areas. These vessels can survey into very shallow waters (10 m). Digital data was stored and analyzed at very high resolution (1.5 cm) (Table 1). This system was calibrated routinely in Clattice Harbour, Placentia Bay, during these surveys.

Inner Bay survey blocks were arranged by area (Fig. 4). Within blocks, sub-blocks were allocated according to depth (>150 m and >150 m). Only the sub-blocks > 150 m were surveyed in 1998 as a consequence of having the 120 kHz sounder available.

Editing and analysis for both EK500 and DT4000 data was done using the FASIT software package (Memorial University of Newfoundland) for PC's (LeFeuvre et al., 1999). Bottom tracking was performed manually at the highest resolution available (Table 1). FASIT uses standard integration algorithms as specified by Simrad (Simrad EK500 manual), with the exception that Sa units are not given in m^2 nautical $mile^{-2}$. Here, FASIT output Sa values in units of $m^2.m^{-2}$ each 100 m.

To estimate sampling uncertainty, autocorrelation functions were examined for the Sa from each transect. Autocorrelation was significant only over the first few lags in almost all cases. Hence, for each block, a bootstrapping method was employed to estimate uncertainty, based on repeated 25% sampling of the data (25 times). There was no significant autocorrelation in the 25% sampled data. The 25 sample means were then used to calculate the bootstrapped mean density and 95% CI's. Note that the uncertainty included in these estimates is only that associated with within block sampling and likely underestimates a fuller treatment of uncertainty (Rose et al., submitted.).

Frequency	EK500 38 kHz	DT4000 38 kHz	DT4000 120 kHz
Transmit power	4 kW	1 kW	0.25 kW
Bandwidth	3.8 kHz	5.0 kHz	5.0 kHz
Pulse width	1.0 ms	0.4 ms	0.4 ms
Pulse rate	1 s^{-1}	1 s^{-1}	1 s^{-1}
Absorption coef.	10 dB km^{-1}	10 dB km^{-1}	38 dB/km
Sv gain	26.5 dB	na	na
TS gain	26.5 dB	na	na
2-way EBA	-20.6 dB		
Raw Sv	250 or 500 m	Bottom 133 m at –130 dB threshold	Bottom 133 m to max. 150 m
Sampling resolution	1 m in 1996; 10 cm in 1998	1.5 cm	1.5 cm
Bottom removal	None on raw data	None on raw data	None on raw data
Vessel speed	5 knots	4 knots	4 knots

Table 1. Specifications for EK500 on Teleost and DT4000 on Innovation/Mares for surveys in June 1996 and 1998.

Sa was then scaled by TS (sigma) and a detectability coefficient as follows:

For block i, total Sa_i = mean Sa_i * block $area_I$

Sa_i was decomposed by 4 cm length groups, the proportions determined from the catch. The model used as the basis for the length scaling was TS (dB) = 20 Log length (cm) – 67.5 (Rose, unpublished), which is similar to the ICES model of TS (dB) = 20 Log

length (cm) –67.6 and the general model for gadoid-type fishes (Foote, 1987). Accordingly, if abundance of length group l in block I is A_{il}:

A_i (#/area$_i$) = Sa_i / [Sigma$_l$ * P_l] * D^{-1}

Note that we follow the Norwegian and European nomenclature for these terms (Sa is areal backscatter and Sigma = [10^(TS/10)]*4pi.

A_{il} (#$_l$/area$_i$) = A_i * P_l

Note that densities may be calculated in the same way by substituting mean Sa_i for total Sa_i. The 95% CI's are calculated by inserting a 2 SE range above and below the S_{ai} and repeating the calculations (for each calculation there are actually 3 computations, one for the mean and one each for the high and low CI).

Calculation of biomass for each block and length group (B_{il}) was done by scaling the abundance of each length group (A_{il}) by the mean weight of that group as determined from the best fit model of the catch data following: $Wt = K * L^3$.

$B_{il} = A_{il} * W_l$

Abundance at age was calculated from the total abundance by proportioning the totals by the age structure of the catch (P_a is the proportion of the catch of age a). Note that no correction for catchability by size or age can be made – so interpretations of results should keep that in mind.

$A_{ia} = A_i * P_a$

Biomass at age was calculated by multiplying the abundance at age by a mean weight at age (W_a) determined from the logistic model which best fit the catch data.

$B_{ia} = A_{ia} * W_a$

Year	Area	K ($W=KL^3$)	R^2	u	B0	B1
96	outer	0.00892	0.95	25	5.201	0.717
98	outer	0.00995	0.96	25	6.962	0.667
98	Bay	0.00908	0.97	25	3.127	0.751

Table 2. Weight at length and weight at age coefficients used to scale the abundance estimates.

Fishing sets were conducted with both the Campelen 1800 bottom trawl and the IGYPT mid-water trawl from the Teleost (Figs. 5 and 6). Fishing was done with feather hooks from the small vessels.

Experiments to empirically determine D were conducted during both the 1996 and 1998 surveys, as recommended by Lawson and Rose (1999). The strategy was to test during survey conditions the proportion of the total fish "missed" by the echosounder in the bottom shadow zone. **These estimates have not as yet been incorporated into the analyses.** A value of D = 0.93 based on experiments in June 1998 in Smith Sound has been used as an interim estimate.

Results

June 1996

Outer Bay and Shelf

The acoustic estimate was 6.2 million cod (4.0-8.5 CI) comprising 8.7 Kt (5.6-11.9 CI) (Table 3a). The fish were concentrated on the western side of the Bay near Oderin Bank (blocks d and e) with lesser concentrations offshore in blocks g and j (Table 3b).

Six year-old fish (1990 y class) were the most numerous at 2.5 million fish, and seven year-olds (1989 y class) were second at 1.2 million fish (Table 3c). There were also 1.1 million four year-olds (1992 y class).

Table 3. Survey summary for June 1996, a) overall estimates, b) by block, and c) by age.

a)

Mean abundance (10^6; 95% CI)	6.2 (4.0-8.5)
Mean biomass (10^3 t; 95% CI)	8.8 (5.6-11.9)

b)

Block	Mean abundance (10^6; 95% CI)	Mean biomass (t; 95% CI)
A	0.02 (0.01-0.03)	26 (18-34)
B	0.04 (0.03-0.05)	59 (46-72)
C	0.21 (0.14-0.28)	296 (199-392)
D	3.33 (2.57-4.09)	4682 (3617-5746)
E	1.46 (0.44-1.46)	2053 (625-3482)
F	0	0
G	0.40 (0.34-0.46)	561 (481-642)
H	0.02 (0.01-0.03)	26 (9-44)
I	0.18 (0.11-0.25)	252 (159-346)
J	0.32 (0.58-0.84)	818 (456-1179)
Total	6.2 (4.0-8.5)	8773 (5600-12000)

c)

Age	Mean abundance (10^6; 95% CI)	Mean biomass (t; 95% CI)
2	0.04 (0.02-0.05)	14 (9-19)
3	0.13 (0.08-0.18)	67 (43-91)
4	1.14 (0.73-1.55)	806 (515-1097)
5	0.63 (0.40-0.86)	617 (395-840)
6	2.49 (1.59-3.39)	2137 (3342-4547)
7	1.24 (0.80-1.69)	2282 (1459-3106)
8	0.36 (0.23-0.49)	902 (577-1227)
9	0.16 (0.10-0.22)	543 (347-739)
10	0.013 (0.008-0.017)	56 (35-75)
11	0.025 (0.016-0.034)	144 (92-196)

June 1997

No survey of the full study area could be undertaken in 1997. However, we surveyed portions of the area in Placentia Bay from the small vessels. These include the Bar Haven, Perch Rock, and Oderin Bank spawning areas (Table 4). Full analyses of these data is incomplete but a preliminary total estimate is between 40 and 50 Kt (the majority of this at Perch Rock ca. 40 Kt). At Bar Haven the 1992 year-class was strongest and the 1990 year-class next strongest (0.6 and 0.4 million fish, respectively). It is noteworthy that a large Perch Rock spawning aggregation was observed only in 1997.

Table 4. Perch Rock spawning ground acoustic survey results, May 1997.

Transect	Mean density (/m^2)	Area (km^2)	Abundance (10^6)	Biomass (t)
1	0.053	3.4	0.18	410
2	0.444	4.6	2.04	4620
3	0.310	4.5	1.41	3183
4	0.464	7.1	3.29	7439
5	0.403	6.6	2.65	5990
6	0.279	7.9	2.21	4988
7	0.598	6.9	4.11	9288
8	0.186	6.4	1.18	2676
9	0.112	6.6	0.74	1667
Total		54.0	17.8	40261

June 1998

Outer Bay and Shelf

The acoustic estimate was 34.3 million cod (22.0-46.5 CI) comprising 72.0 Kt (45.9-98.0 CI) (Table 5a). The fish were more widespread than in 1996 but concentrated on the western side of the Bay near Oderin Bank (blocks d and f) with lesser concentrations offshore in blocks h and j (Table 5b).

Eight year-old fish (1990 y class) were the most numerous at 9.7 million fish, and six-year olds (1992 year class) were second at 8.6 million fish (Table 5c).

A higher proportion of younger fish were located offshore than in the Bay.

Table 5. Survey summary for June 1998, a) overall estimates, b) by block, and c) by age.

a)

Mean abundance (10^6; 95% CI)	34.3 (22.0-46.5)
Mean biomass (10^3 t; 95% CI)	72 (46-98)

b)

Block	Mean abundance (10^6; 95% CI)	Mean biomass (t; 95% CI)
A	1.31 (1.10-1.51)	3096 (2611-3582)
B	0.42 (0.30-0.54)	1000 (714-1286)
C	0.49 (0.35-0.62)	1150 (821-1479)
D	14.67 (10.32-19.02)	34712 (24427-44997)
E	0.16 (0.13-0.19)	375 (300-450)
F	7.87 (3.44-12.30)	18628 (8149-29106)
G	0.73 (0.59-0.88)	1021 (817-1225)
H	6.42 (3.85-8.98)	8928 (5357-12500)
I	0.06 (0.03-0.09)	84 (46-122)
J	2.13 (1.89-2.37)	2961 (2628-3294)
Total	34.3 (22.0-46.5)	71954 (45870-98040)

c)

Age	Mean abundance (10^6; 95% CI)	Mean biomass (t; 95% CI)
2	0.37 (0.24-0.50)	177 (113-241)
3	1.25 (0.82-1.68)	750 (487-1012)
4	3.43 (2.30-4.55)	2557 (1714-3400)
5	4.08 (2.69-5.47)	4640 (3047-6233)
6	8.60 (5.50-11.69)	14055 (8982-19127)
7	2.93 (1.85-4.00)	6370 (4037-8704)
8	9.70 (6.11-13.29)	27380 (17251-37509)
9	2.96 (1.88-4.04)	11102 (7083-15121)
10	0.76 (0.48-1.03)	3729 (2394-5064)
11	0.10 (0.07-0.14)	662 (428-897
12	0.07 (0.05-0.10)	533 (335-731)

Inner Bay

The inner Bay area contained approximately 1 million fish in 1998 (Table 4). The 1990 year-class was the most numerous in the 1998 survey followed by the 1992 and 1993 year classes.

Discussion

The overall numbers of cod located in June within the study area in Placentia Bay and outwards towards the shelf edge increased by a factor of 7 from 1996 to 1998 (Fig. 7). An initial comparison of the absolute numbers by year-class suggests that either the detectability in 1996 was much less than in 1998 (a so-called year effect), or, there was a marked immigration of cod into the area prior to 1998. Local growth cannot account for this increase. A test of the variability is possible with the data on hand but these analyses have not been completed as yet. We note that if there was a movement of cod into the study region between 1996 and 1998, then the movement came from a region where age structure was similar to that of the study region prior to the movement.

The 1997 estimate does not have identical spatial coverage as 1996 and 1998. Nevertheless, the estimate falls in between the low 1996 and high 1998 totals (Fig. 7).

Fishing set data lend support to the increase in abundance observed in the acoustic data. Mean Campelen CPUE standardized to 15 minutes at 3 knots in 1998 was approximately 4-times the 1996 CPUE (243 and 61, NS difference). Trawl differences would not be expected to be as great as acoustic differences because of the semi-pelagic nature of cod at this season.

There is consistency between the surveys in relative year-class strength. The 1990 year class has been the strongest of the past decade, with the 1992 year class also strong. The 1991 year-class is weak. Although too soon to know for certain, the 1993 and 1994 year-classes look promising.

It is noteworthy that the age class structure of cod in this region appears to be near identical to that of Smith Sound (see Rose WP99), at least until 1995.

The present results indicate that acoustic/trawl survey methods are tenable for cod in springtime in this region. Further work is needed on variability in detectability and in catch selectivity from trawls and other gear. Better estimates of these factors will likely improve the acoustic estimates.

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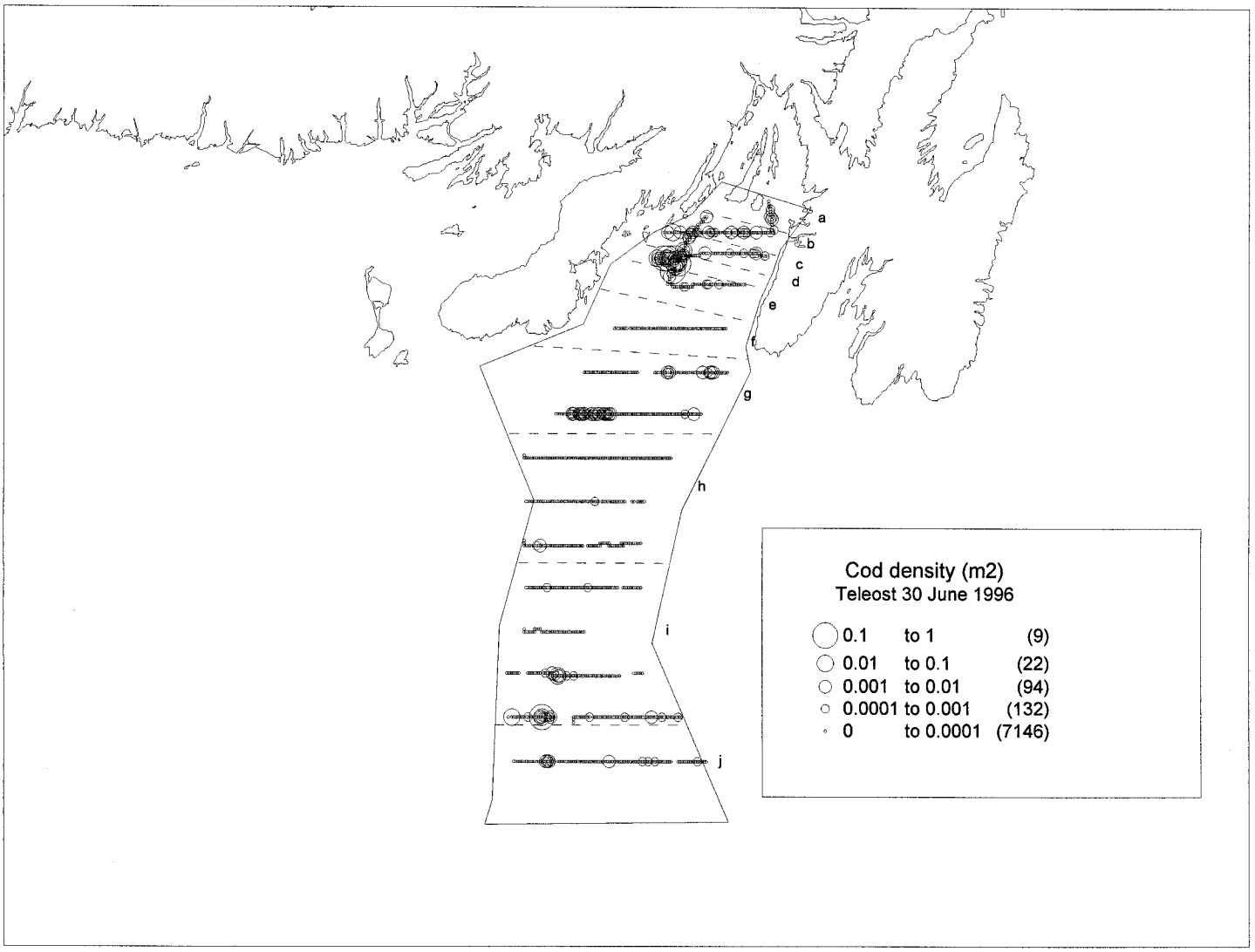


Fig. 1. Map of study area and blocks and acoustic transects and cod densities in June 1996 (Teleost 30).

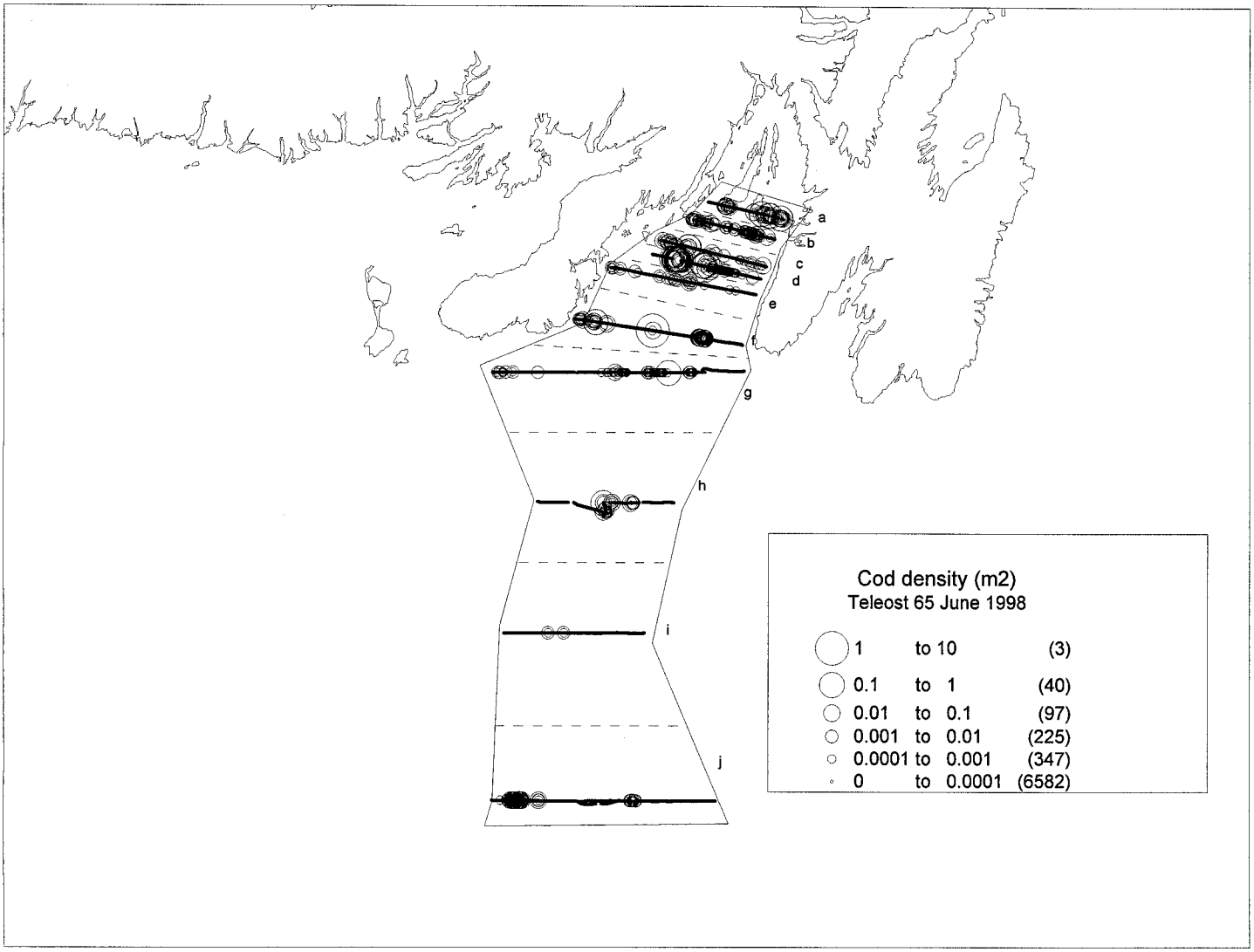
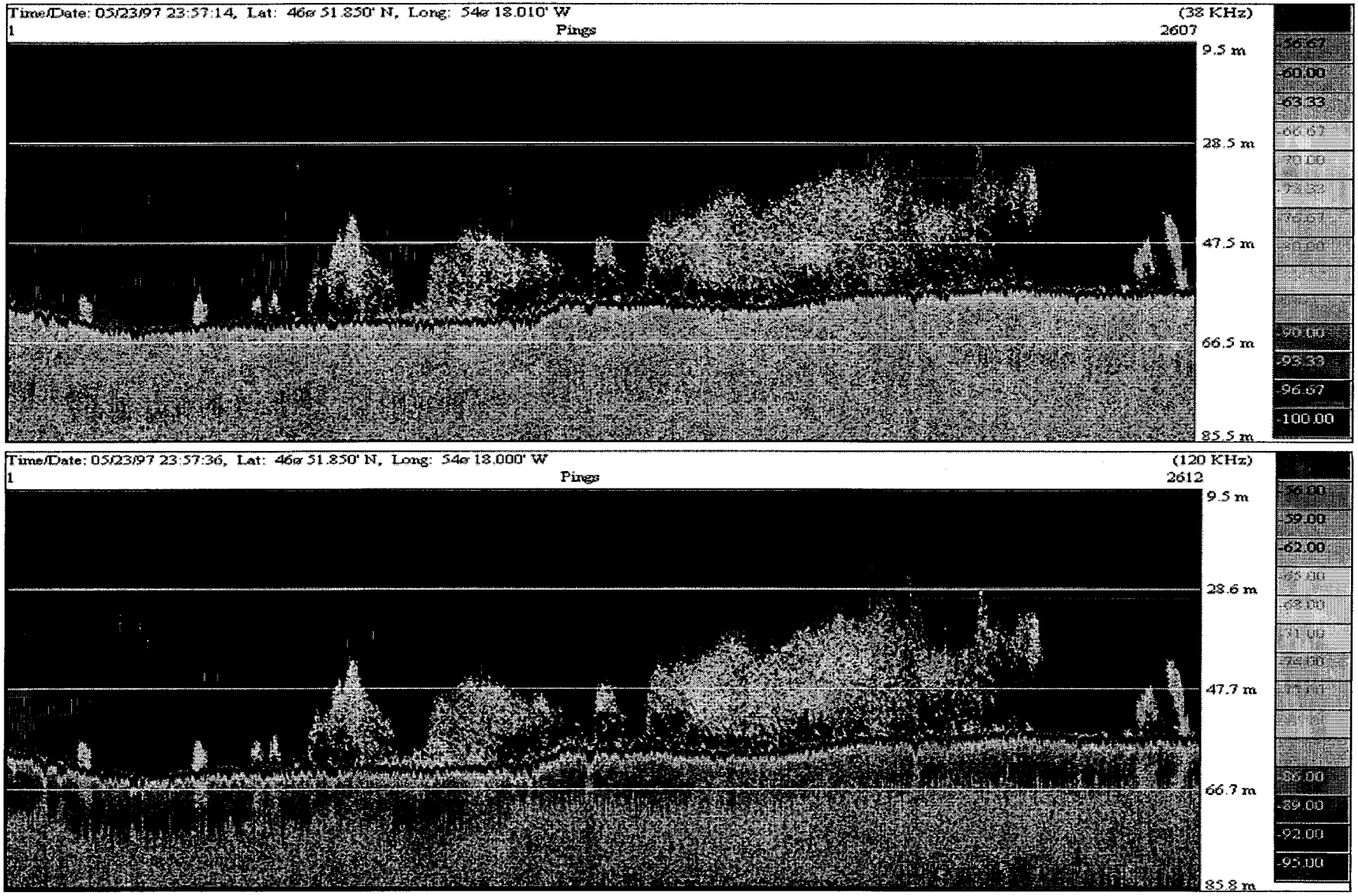


Fig. 2. Map of study area and blocks and acoustic transects and cod densities in June 1998 (Teleost 65).

Fig. 3. Digital echograms of cod spawning aggregation, block f, 1997 at 38 (top) and 120 kHz (bottom).



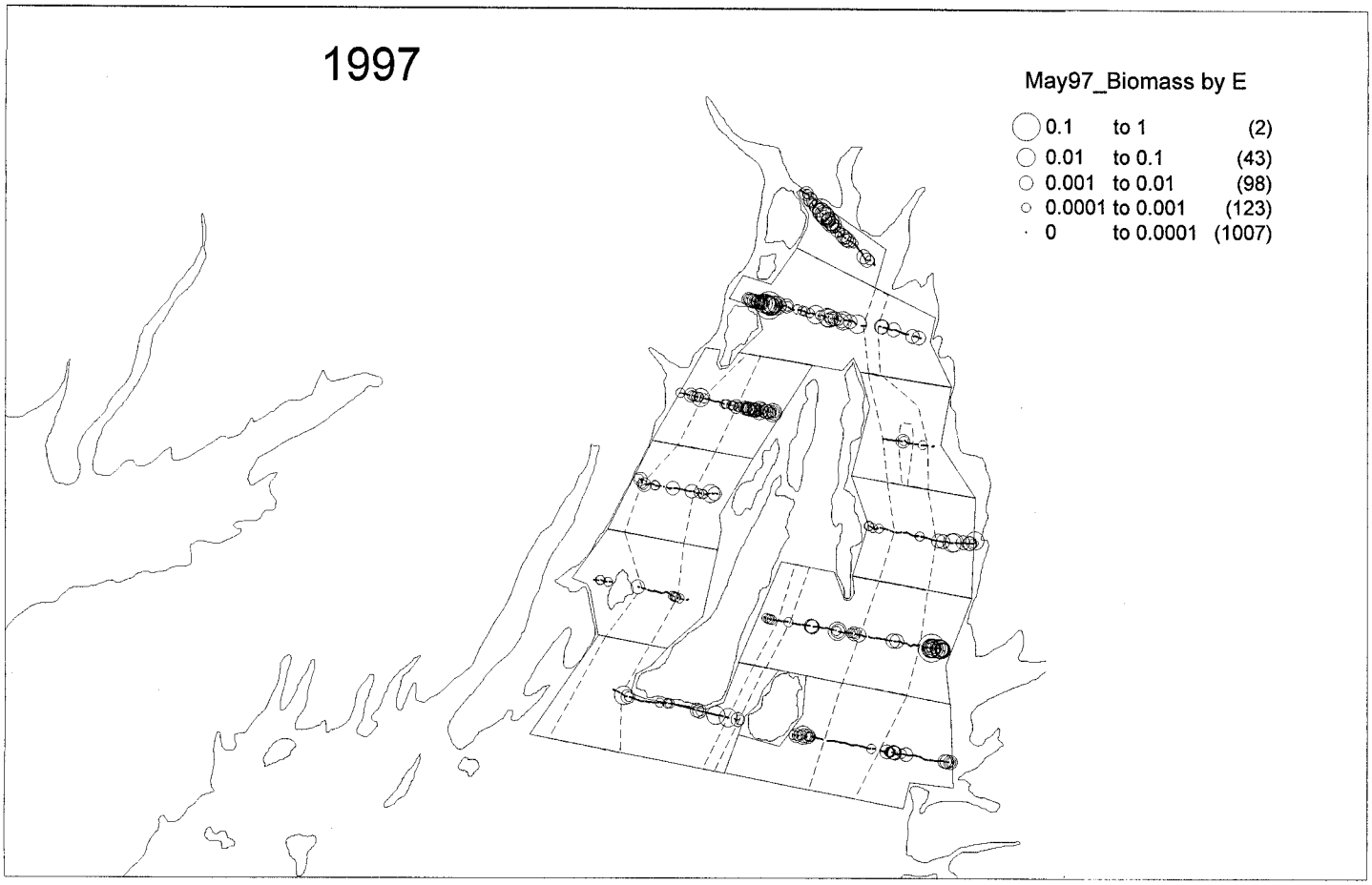
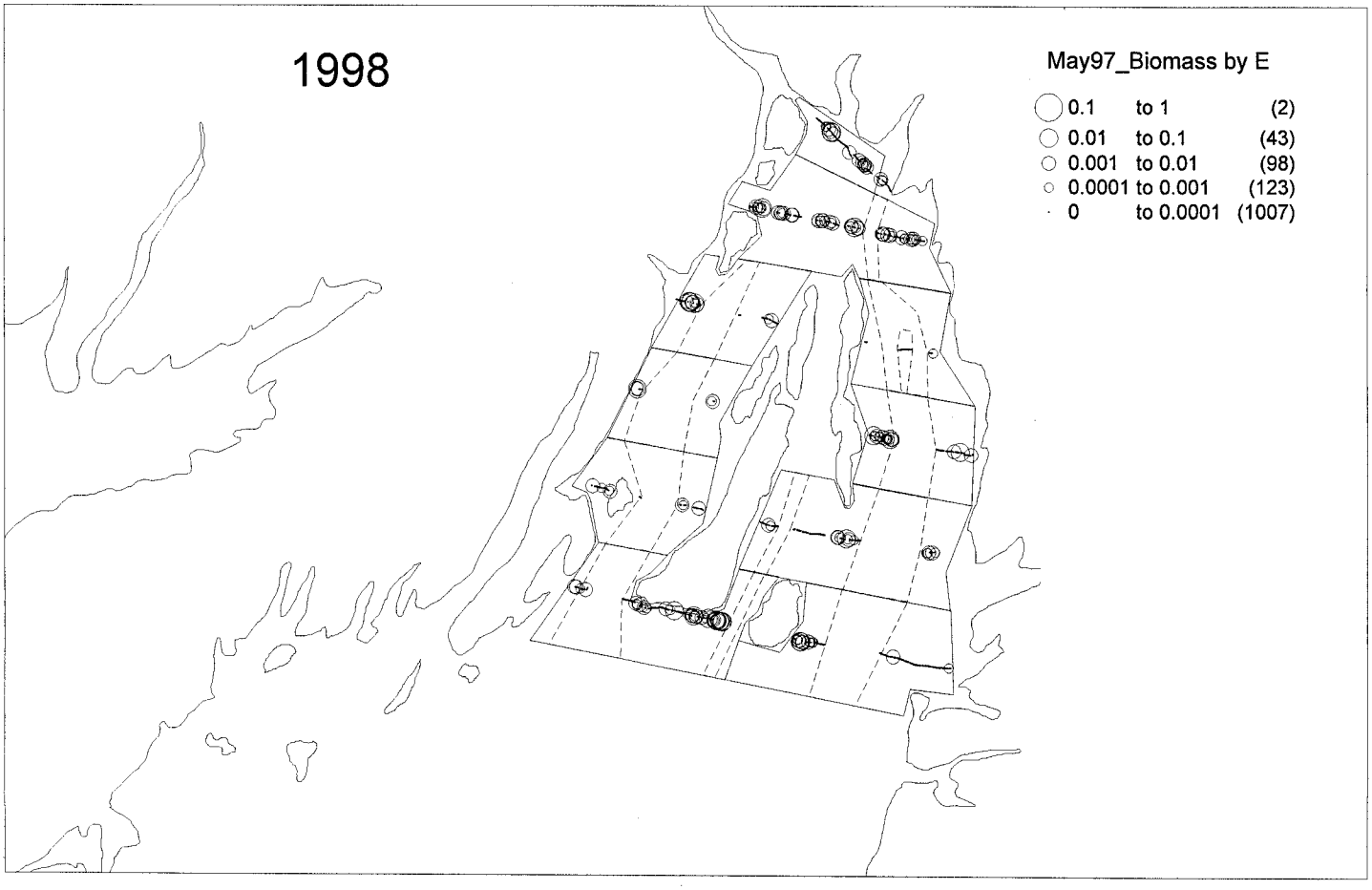


Fig. 4. Inner Placentia Bay blocks and acoustic transects and cod densities in June 1997 and 1998. The broken line represents the 150 m contour.



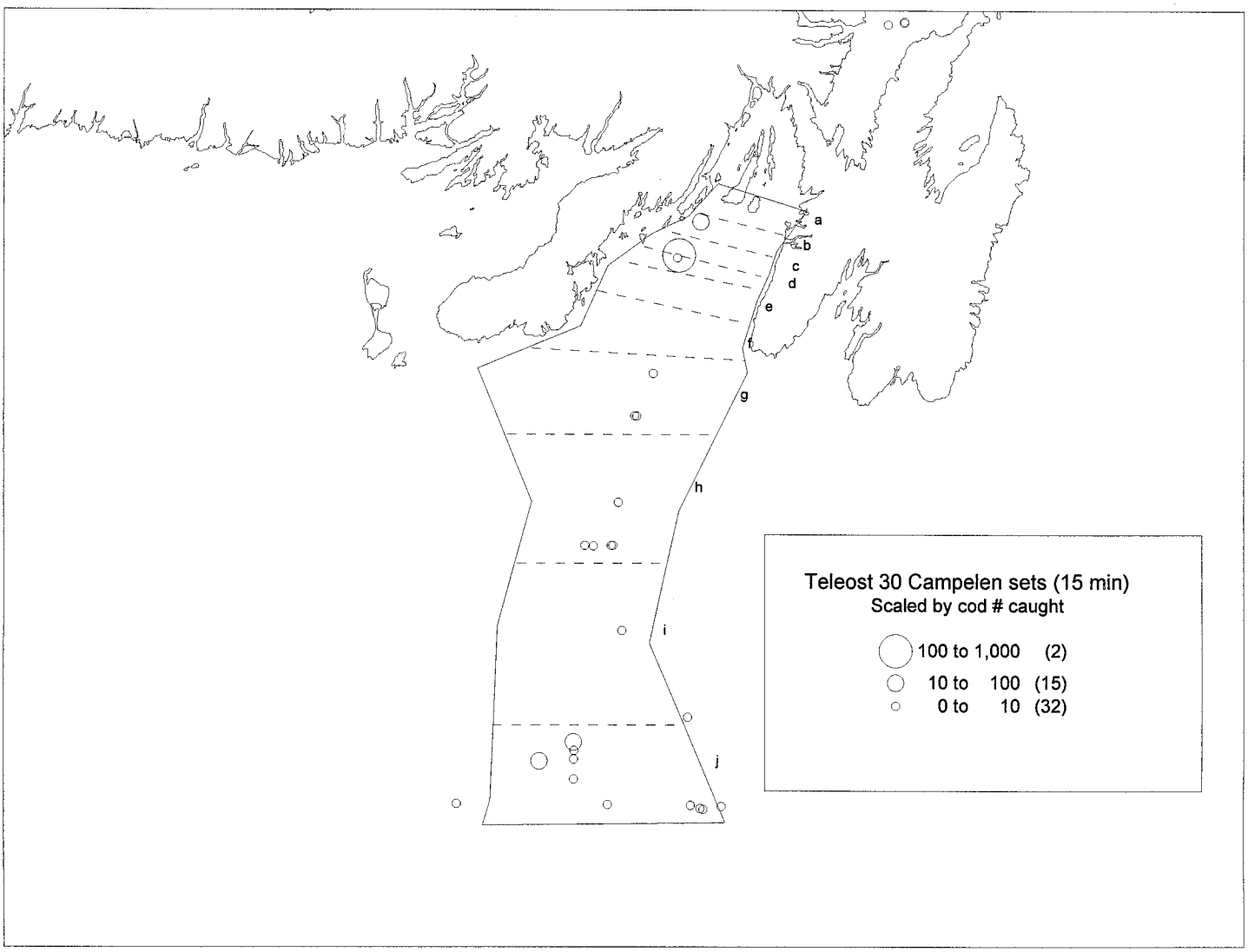


Fig. 5. Set locations scaled by catch (#'s) for cod during acoustic/trawl survey in June 1996 (Teleost 30).

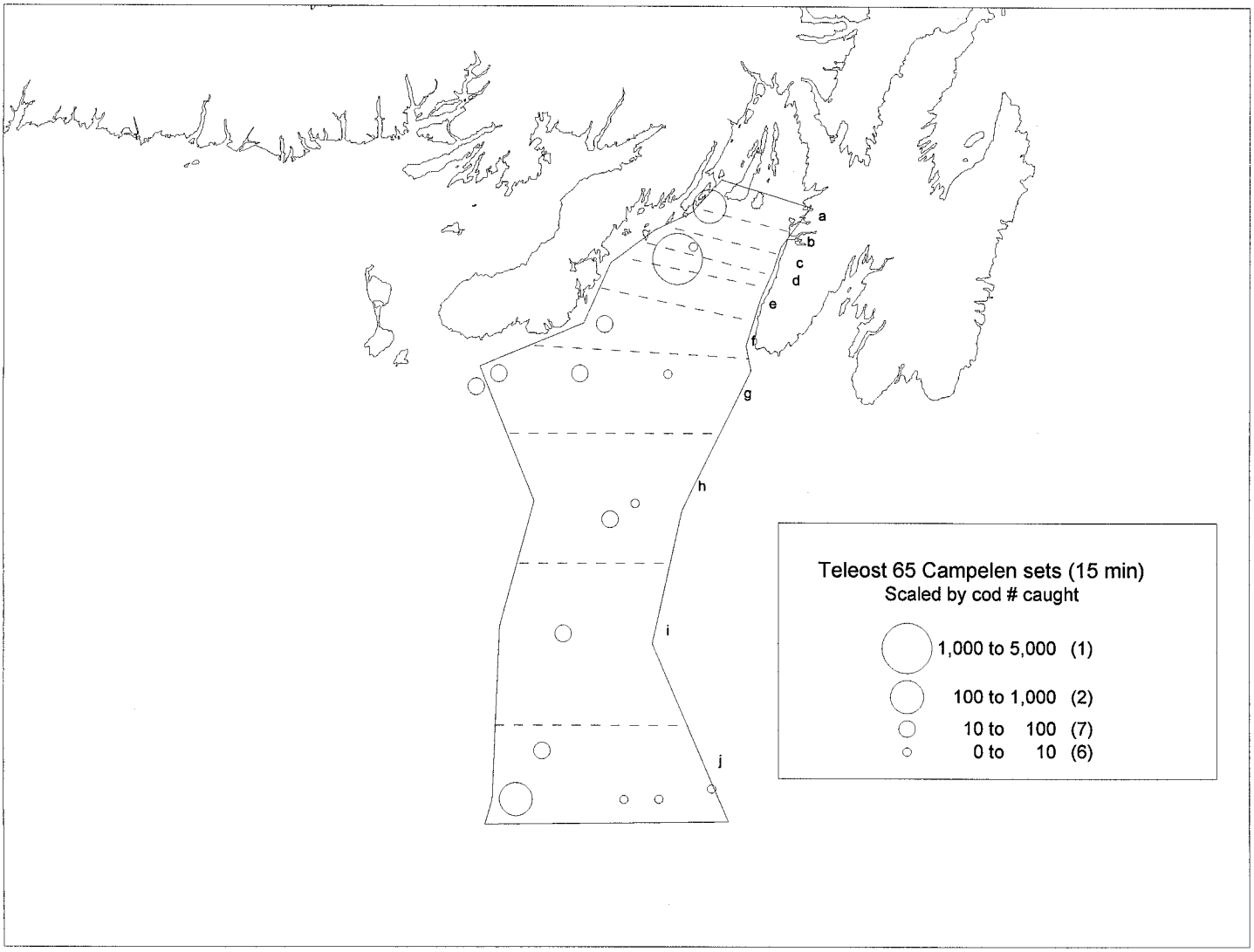


Fig. 6. Set locations scaled by catch (#'s) for cod during trawl/acoustic survey in June 1998 (Teleost 65).

Fig. 7. Total biomass for Placentia Bay - 3Ps acoustic/trawl index survey area, June, 1996-1998.