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An Acoustic Survey of Atlantic Cod (*Gadus morhua*) in Three Inshore Areas of Western Trinity Bay (NAFO Division 3L)

by

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Abstract

The results of an acoustic survey of cod conducted in three fjords (Smith Sound, Northwest Arm, and Southwest Arm) on the western side of Trinity Bay during 15-26 April 1996 are presented. Integrated density estimates were obtained using a Biosonics 102 system employing a dual beam 38Khz transducer from the *RV Shamook*. Data acquisition and signal processing were conducted with Biosonics ESP software. Each fjord was treated as a separate stratum and a series of equidistant (1nm apart) parallel transects perpendicular to the long axis of each fjord was run, with a randomly chosen starting point. A total of 52 transects totalling 44.85 nm miles were run in the surveyed area. Extensive biological sampling of cod was conducted, using an otter trawl, handlines, and gill nets. Cod were generally large and of similar mean length in each stratum (54.7-56.2 cm). Average lengths and weights of cod sampled within each stratum were used to calculate target strengths and to convert acoustic integrated backscatter to cod biomass. Targets classified as cod were detected on 36 (69.2%) of the transects. Average densities of cod on most transects were generally low (<0.1 mT/km^2), but relatively high densities (5.0-6.4 mT/km^2) were observed in three adjacent transects across a school of spawning cod in deep (>200m) water in the outer region of Smith Sound. Total estimated biomass for the three areas combined was 171.3 mT (CV 38.7%) Most of the cod (90.4%) were found in Smith Sound. Much of the area surveyed was characterized by rough bottom and steep sides making it difficult to detect cod close to the bottom; consequently, biomass for the surveyed area is possibly underestimated.

Introduction

Since the early 1990's the offshore components of the major cod stocks off the coast of Labrador (2J) and northeastern Newfoundland (3KL) have essentially disappeared. Annual and biannual stratified-random trawl surveys have not detected any major concentrations of adult cod in the offshore areas, in spite of the moratorium. In contrast, inshore acoustic surveys and tagging studies, as well as catch rates from the sentinel survey and food fishery, all indicate that there are aggregations of adult cod inhabiting many of the inshore bays off eastern and northeastern Newfoundland, particularly in Notre Dame Bay, Bonavista Bay, and Trinity Bay.

Accurate information on the size of these inshore aggregations is lacking. Additional inshore strata have been added to the trawl survey area as of fall 1996 to extend coverage as close as possible to the shoreline; however, much of the coastal area remains untrawlable due to rough bottom and alternative methods of quantifying inshore components are clearly required.

The present paper summarizes the results of an acoustic survey for cod conducted in three fjords in western Trinity Bay, Newfoundland, during April 1996. Age-length distributions of cod sampled during the survey are also given. Other biological characteristics of sampled cod, including length frequencies, maturities, condition, and parasites are presented in detail elsewhere (Brattey 1996). The survey was conducted mainly to provide information on the feasibility and logistics of conducting inshore acoustic surveys for cod, prior to planning more extensive inshore surveys.

Survey Area

The area surveyed encompassed three adjacent fjords 20-30 nautical miles (nm) long and 0.5-2.0 nm wide in the Random Island area on the western side of Trinity Bay (Fig. 1). Smith Sound and Southwest Arm have deep (>200 m) central channels that extend out into Trinity Bay, whereas Northwest Arm is shallower (approximately 160 m) and has a relatively shallow (70 m) sill near the entrance (Fig. 2).

Hydroacoustic equipment

A Biosonics model 102 echosounder and a dual beam 38Khz transducer were used to conduct the survey. The transducer was mounted on a Biofin tow-body deployed with a deck-mounted crane and suspended approximately 5 m below the surface off the rear starboard quarter of the vessel. Data acquisition and signal processing including integration were conducted with Biosonics echo signal processing (ESP) software, version 3.2.

Calibration

Prior to and during the trip a 38 mm tungsten-carbide standard target suspended 7.5 m below the transducer was used to calibrate and check the stability of the system. Measured TS (mean =-42.22) was consistent with the expected value (-42.1) and showed little variability, (variance 0.058; Fig. 3) at up to 4dB off axis. Measured standard TS values were also consistent with those obtained during previous calibrations.

Integrator calibration parameters were the same as those used during previous surveys and were provided by Biosonics (simultaneous 20logR(dB) = -145.80, beam pattern factor 0.0009136). Sounder and calibration parameters used during the acoustic survey are summarized in Table 1.

Survey Design

The survey design was based on that used for acoustic surveys of herring in the inshore of NAFO Divisions 3KL (Wheeler 1991). Each of the three areas surveyed is geographically discrete and was treated as a separate stratum. There is no historical time series of data on the distribution of cod in these areas to serve as a basis for partitioning effort among the strata, so each area was surveyed with the same sampling intensity. To assign transect positions, a perpendicular baseline was assigned to the head of each area as close to shore as the vessel could safely operate and the first mile was subdivided into a baseline plus ten parallel lines 0.1 nm apart; the position of the first transect was chosen randomly from these lines. Transect spacing was set at 1nm within each area and was based largely on logistic constraints (size of area, time available, and vessel speed) and resulted in 14-22 transects per stratum (Fig. 4, Table 2). Transects were run at approximately four knots during daylight hours.

Data collection and signal processing

During the survey a detailed log and a paper echogram were collected for each transect. The ping rate of the echosounder was set at one ping per second. At an average speed of approximately 4 knots this translates into a horizontal distance or "bin" of 10.2 m for each data report. On the vertical scale, data were collected from the surface to the bottom in 5 m primary "bins". Secondary bins for the bottom 10 m (bottom up) were set at 1 m. The acoustic data was edited to select for cod and to ensure that acoustic backscatter from the bottom was excluded. Due to the steep slopes in the surveyed area, it was necessary to set the bottom removal algorithm to exclude acoustic backscatter within 2 m of the detected bottom.

The average length of cod sampled within a stratum (Table 3) was converted to an average TS per fish using the following relationship derived specifically for cod by Rose and Porter (1996):

$$TS = 20 \log L - 65.5$$

where L=cod fork length in cm. The average TS's were similar within each stratum: -32.67 in

Smith Sound; -32.7 in Southwest Arm; -32.51 in Northwest Arm. Densities of cod in terms of numbers of individuals were obtained by dividing system voltages by the average TS; these were converted to weights (mT/km^2) by multiplying by the average weight of cod sampled within a stratum (Table 3).

Acoustic survey results

Integrated density estimates were calculated for the 52 transects run within the survey area (Tables 4-6). The formulas used to compute mean densities, variances, and biomass estimates within each stratum and overall biomass are described in Wheeler (1991). Biomass per stratum was obtained by multiplying the average stratum density by the stratum area. Stratum variances given in Tables 4-6 indicate the extent to which individual transect densities vary around the overall stratum mean. Estimates of biomass (±variance, in metric tons) for each stratum were as follows:

Area	Cod Biomass (mT)	Variance
Smith Sound	154.41	4319.72
Northwest Arm	9.89	24.15
Southwest Arm	6.96	3.20

Targets classified as cod were detected on 36 (69.2%) of the transects. Average densities of cod on most transects were generally low (<0.1 mT/km^2), but relatively high densities (5.0-6.4 mT/km^2) were observed in three transects across deep (>200m) water in the outer region of Smith Sound (Table 4). Cod in this area appeared to be spawning (Brattey 1996).

Acoustic estimates of biomass per transect (extrapolated to 0.5nm either side of the transect line) varied widely both among and within strata, with the highest estimates (22.1-65.7 mT) on transects in the outer portion of Smith Sound. Plots of acoustic estimates of biomass on individual transects suggested that cod were widely distributed in Smith Sound, restricted to the inner portion of Northwest Arm, and widely distributed in the central portion of Southwest Arm (Fig. 5) cod. Plots of cod distribution by depth from the acoustic data (Fig. 6) and from echograms (Figs. 7, 8, 9) indicated that cod were distributed over a wide range of depths in the survey area. However, depth distributions were not consistent among the three strata. In Smith Sound, highest densities were observed in deep water (>180m), but low densities were also recorded at depths as shallow as 20 m (Fig. 6). In Northwest Arm, the acoustic data suggested that cod were mostly at intermediate depths (35-80 m), whereas in Southwest Arm they were mostly in deep water (>180 m, Fig. 6). The echograms revealed widely differing vertical distributions; cod in the deep central channel of Smith Sound often extended 60 m up from the bottom (Fig. 7); however, those on the slopes in Smith Sound (and Northwest Arm) showed a narrow vertical distribution and tended to remain close to the bottom (Figs. 8). Cod in the deep central channel of Southwest Arm extended 50 m up from the bottom (Fig. 9) but were much less densely aggregated than those in Smith Sound.

Three additional transects were also run outside the survey area, in the main part of Trinity Bay eastward from the entrance to Smith Sound. Although detailed results are not reported here, no significant aggregations of cod were detected in these transects.

Biological sampling

Samples of fish were collected with the Yankee 36 otter trawl equipped with a small-mesh liner in areas where trawling was feasible. Hand-lines equipped with feathered hooks and jiggers were used in areas of rough or steep-sided bottom at depths <100 m. Gill nets (5.25 in mesh) were deployed elsewhere. Most cod were sampled for fork length, weight, sex, maturity, and gill parasites; otoliths were also taken from 719 fish for age determination. Fishing set locations are indicated in Fig. 10. Sampling was conducted widely throughout each stratum and over a wide range of depths (25-290 m), but two areas (shoreward ends of Smith Sound and Southwest Arm) were not sampled due to time constraints.

Cod were widely distributed in the survey area; they were caught in all three strata and in 23 of the 26 fishing sets conducted (Table 7). Catch weights and numbers of cod varied widely among sets, with the largest catch (442 fish weighing 826.6 kg) taken in Smith Sound. The only

other species caught in significant numbers was American plaice (Hippoglossoides platessoides); other species such as turbot (Reinhardtius hippoglossoides), witch (Glyptocephalus cynoglossus) and redfish (Sebastes sp.) were caught in small numbers.

Cod were generally large and mean lengths were similar among sets within each stratum (Table 3). The mean lengths for cod in each stratum, obtained by combining catches from all gears, varied by only a few cms and ranged from 54.7 cm in Southwest Arm (n=246) to 56.2 cm in Northwest Arm (n=253). Average weights of cod within each stratum ranged from 1.66 kg in Smith Sound and Southwest Arm to 1.85 kg in Northwest Arm.

An age-length key contructed using data from cod whose ages were known and applied to the length frequency of the total catch (Table 8) revealed a wide range of ages (2-25 yr) among cod in the survey area. However, the majority of cod sampled (76.2%) were 5-7 yrs old and 6 yr old fish (1990 year class) dominated the catch (Table 8).

Oceanographic data and further details of the biological characteristics of these cod, including maturities, condition, and parasite (Lernaeocera branchialis) infestation are summarized elsewhere (Morgan and Brattey 1996; Brattey 1996).

Discussion

The three areas covered during this survey are probably among the most difficult in which to conduct a hydroacoustic survey for demersal species such as cod. The fjords are extremely steep sided and contain areas of rough bottom making it difficult to detect fish that are within a few meters of the bottom. Consequently, we were forced to be conservative in our method of editing the acoustic data to ensure that backscatter from the bottom was not included in our estimates. However, this undoubtedly resulted in removal of some cod from our estimate.

Experience gained during this survey will be invaluable if future inshore acoustic surveys of cod are to be conducted. The ability to detect cod close to the bottom could probably be improved by collecting the acoustic data at a much higher level of resolution, both horizontally (higher ping rate) and vertically (smaller vertical "bins"). Better survey coverage (i. e. more transects miles per unit time) could also be achieved by using a larger and more stable tow-body that would enable the vessel to operate at faster speeds. The tow body we used became unstable at speeds greater than five knots, particularly in bad weather; consequently, our survey speed was restricted to four knots which limited the total number of transect miles that could be covered.

The use of two vessels, one for biological sampling and one for acoustic work, rather than only one as was available here would greatly extend the area that could be covered in two weeks and would be essential to cover larger inshore areas in a reasonable period of time. The use of two vessels has other advantages in that fishing can be conducted immediately after a transect has been run giving more accurate and timely information on the size distribution of fish in local areas. In our survey, fishing was usually conducted the day after transects were run or even later, which introduces the possibility of changes in the size composition between fishing and acoustics. However, for this survey this did not appear to be a problem as the size of the fish was remarkably similar throughout the surveyed area.

Our results suggest that the transect spacing of one nm was reasonable for surveying the area given that the aggregations of cod we detected tended to extend over at least a few miles, resulting in several transects per aggregation. Our results in conjunction with previous acoustic work in this area (Rose 1996) suggests that cod consistently spawn in the outer area of Smith Sound during April and it may be appropriate to designate this area as a separate stratum and assign a higher level of sampling intensity to this area, or to reduce the sampling other areas.

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Table 1. Summary of Biosonics 102 sounder and calibration parameters used during the acoustic survey.

Sounder Parameters	Value
Mode	F2/X2
Transmitter	0.00
Pulse Width	0.4ms
Control	Blank at Range
Range	500 M
Trigger	Internal
Trigger Interval	1 sec
Calibrator	Off
Receiver Gain(X2)	-6 db
Bandwidth	5 khz
Toggle Switch	40LogR
Toggle Switch	Salt Water
Channel 1	40logR(N)
Channel 2	40LogR(W)
Channel 3	20LogR (Simultaneous)

Calibration Tone Values	
Channel 1 @ 10 Khz	5.75(Vrms)
Channel 2 @ 10 Khz	5.47(Vrms)
Calibrator	-40db CW
Separation	1 M
Control	Normal

Calibration Parameters(38khz dual beam)	
Source Level(db)	223.50
Receiver Sensitivity (narrow beam) db	-187.00
Receiver Sensitivity (wide beam) db	-186.50
Wide Beam Roll Off	1.30
Simultaneous 20logR(db)	-145.80
Beam Pattern Factor	0.0009136

Table 2. Transect details (see Fig 4. for transect positions).

Stratum	Transect number	Start Latitude	Start Longitude	End Latitude	End Longitude	Speed (knots)	Duration (min)	Distance (nm)
Smith Sound	SS1	4812.66	5354.20	4812.91	5354.01	3.24	5.00	0.27
	SS2	4812.30	5352.89	4811.79	5353.15	4.63	7.00	0.54
	SS3	4811.46	5351.90	4810.61	5352.30	4.91	11.00	0.90
	SS4	4810.09	5351.28	4810.12	5351.21	3.85	19.00	1.22
	SS5	4810.33	5349.34	4811.75	5348.32	4.10	23.00	1.57
	SS6	4811.60	5346.80	4810.74	5347.40	4.75	12.00	0.95
	SS7	4810.69	5345.79	4811.43	5345.32	4.36	11.00	0.80
	SS8	4810.83	5344.12	4809.50	5344.80	4.42	19.00	1.40
	SS9	4808.90	5343.60	4810.00	5343.00	4.13	17.00	1.17
	SS10	4809.89	5341.40	4809.04	5342.00	4.48	13.00	0.97
	SS11	4809.60	5339.60	4810.30	5340.50	4.75	12.00	0.95
	SS12	4810.46	5338.88	4809.99	5338.39	3.67	9.00	0.58
	SS13	4810.49	5337.07	4811.00	5337.80	4.26	10.00	0.71
	SS14	4811.52	5336.42	4811.09	5336.04	2.50	12.00	0.50
	SS15	4811.57	5335.55	4812.05	5335.09	4.00	9.00	0.60
	SS16	4812.79	5333.97	4812.34	5333.30	3.72	10.00	0.62
	SS17a	4811.94	5331.18	4812.50	5335.09	4.47	11.00	0.82
	SS17b	4812.70	5332.06	4813.62	5333.11	4.89	14.00	1.14
	SS18	4813.99	5331.61	4813.25	5330.67	3.92	15.00	0.98
	SS19	4813.87	5329.63	4814.71	5330.46	4.04	15.00	1.01
	SS20	4814.39	5328.16	4815.21	5329.08	4.12	15.00	1.03
	SS21	4815.64	5338.12	4814.62	5326.80	3.52	23.00	1.35
Northwest Arm	NW0	4810.87	5357.28	4810.20	5356.70	4.10	6.00	0.41
	NW1	4809.12	5356.68	4809.41	5355.58	4.53	11.00	0.83
	NW2	4808.63	5354.93	4808.24	5356.38	3.90	16.00	1.04
	NW3	4807.31	5355.57	4807.59	5354.47	4.53	11.00	0.83
	NW4	4806.17	5355.73	4806.60	5354.21	3.81	17.00	1.08
	NW5	4805.11	5355.89	4806.86	5353.18	6.53	18.00	1.96
	NW6	4804.57	5351.61	4805.29	5351.65	3.42	10.00	0.57
	NW7	4805.23	5350.24	4804.63	5350.17	4.07	9.00	0.61
	NW8	4804.86	5348.71	4805.49	5348.68	3.78	10.00	0.63
	NW9	4804.89	5347.23	4805.58	5347.15	4.60	9.00	0.69
	NW10	4805.26	5345.66	4804.69	5345.68	4.87	9.00	0.73
	NW11	4804.85	5344.24	4805.99	5344.14	4.02	17.00	1.14
	NW12	4805.29	5342.77	4805.70	5342.74	3.42	7.00	0.40
	NW13	4804.61	5341.11	4805.57	5341.23	4.38	13.00	0.95
	NW14	4803.25	5339.76	4804.62	5339.53	3.74	22.00	1.37
	NW15	4804.53	5338.15	4803.62	5338.11	3.92	13.00	0.85

Stratum	Transect number	Start Latitude	Start Longitude	End Latitude	End Longitude	Speed (knots)	Duration (min)	Distance (nm)
Southwest Arm	SW0	4801.10	5356.20	4801.58	5356.11	2.82	10.00	0.47
	SW1	4801.43	5354.60	4800.77	5354.79	4.40	9.00	0.66
	SW2	4800.65	5353.25	4801.27	5353.91	3.78	10.00	0.63
	SW3	4801.10	5351.61	4800.47	5351.77	4.20	9.00	0.63
	SW4	4800.24	5350.29	4800.97	5350.21	4.04	11.00	0.74
	SW5	4800.84	5348.68	4800.00	5348.86	3.97	13.00	0.86
	SW6	4800.58	5346.55	4801.42	5347.20	4.52	13.00	0.98
	SW7	4801.47	5345.68	4800.86	5345.47	4.07	9.00	0.61
	SW8	4801.14	5343.70	4802.50	5344.29	3.96	15.00	0.99
	SW9	4802.45	5342.97	4801.41	5342.51	4.05	16.00	1.08
	SW10	4801.85	5340.87	4803.00	5341.81	3.77	21.00	1.32
	SW11	4803.22	5340.14	4802.47	5339.85	4.09	11.00	0.75
	SW12	4803.51	5338.68	4803.58	5338.45	3.83	8.00	0.51
	SW13	4803.88	5337.42	4803.42	5337.88	3.00	9.00	0.45

Table 3. Mean lengths and weights of cod sampled during Shamook trip 251 and used to convert acoustic integrated backscatter to cod density and biomass.

Area	Date	Set	Gear	No. cod	Catch weight (kg)	Mean Length (cm)	Mean Weight (kg)
Smith Sound	960416	1	Jigger	54	54.6	48.5	1.01
	960416	2	Trawl	7	15.8	61.3	2.26
	960417	3	Trawl	3	2.3	47.3	0.77
	960417	4	Trawl	442	826.6	58.6	1.87
	960418	5	Trawl	131	206.4	56.6	1.58
	960418	6	Trawl	0	0		
	960418	7	Trawl	293	483.8	55.3	1.65
	960420	8	Jigger	113	140.3	51.8	1.24
			Total	1043	1729.8	55.1	1.66
Northwest Arm	960420	9	Jigger	4	6.8	51.8	1.70
	960421	10	Jigger	70	153.0	59.3	2.19
	960421	11	Gill net	4	9.1	61.5	2.28
	960421	12	Gill net	1	2.4	67.0	2.40
	960421	13	Gill net	3	10.6	69.7	3.53
	960421	14	Trawl	9	6.5	35.4	0.72
	960421	15	Jigger	2	4.2	61.0	2.10
	960421	16	Jigger	128	228.5	56.4	1.79
	960422	17	Gill net	1	2.5	66.0	2.50
	960422	18	Gill net	2	5.5	67.0	2.75
	960425	26	Jigger	29	38.4	51.1	1.32
			Total	253	467.5	56.2	1.85
Southwest Arm	960423	19	Trawl	69	111.0	54.4	1.61
	960423	20	Trawl	78	133.4	55.0	1.71
	960423	21	Trawl	0			
	960423	22	Trawl	0			
	960424	23	Trawl	16	26.9	55.2	1.68
	960424	24	Trawl	23	34.5	58.1	1.50
	960424	25	Trawl	60	103.7	55.2	1.73
			Total	246	409.5	54.7	1.66
			Overall Total	1542	2606.8	55.3	1.69

Table 4. Summary of details for cod biomass estimate for Smith Sound.

Stratum	Stratum Area(km2)	Transect	Transect Len(m)	Transect Area(m2)	Weighting Factor	Density (mT/km2)	Weighted Den (mT/km2)	A (Den-mean wtd den)^2	B Wtd Fact^2	C A*B
Smith Sound	68.94686872	SS1	500.31	927074.43	0.295817	0.00E+00	0.00E+00	5.02E+00	0.087508	4.39E-01
		SS2	1000.62	1854148.86	0.591633	0.00E+00	0.00E+00	5.02E+00	0.350030	1.76E+00
		SS3	1667.70	3090248.10	0.986056	1.74E+00	1.72E+00	2.45E-01	0.972306	2.38E-01
		SS4	2260.66	4189002.98	1.336653	7.04E-01	9.41E-01	2.36E+00	1.786642	4.21E+00
		SS5	2909.21	5390766.13	1.720120	1.78E+00	3.06E+00	2.10E-01	2.958811	6.22E-01
		SS6	1760.35	3261928.55	1.040837	1.39E-01	1.45E-01	4.41E+00	1.083341	4.78E+00
		SS7	1482.40	2746887.20	0.876494	5.98E-02	5.24E-02	4.75E+00	0.768242	3.65E+00
		SS8	2594.20	4807052.60	1.533865	7.84E-01	1.20E+00	2.12E+00	2.352740	4.99E+00
		SS9	2168.01	4017322.53	1.281873	3.95E-01	5.06E-01	3.40E+00	1.643197	5.59E+00
		SS10	1797.41	3330600.73	1.062749	5.10E-01	5.42E-01	2.99E+00	1.129435	3.38E+00
		SS11	1760.35	3261928.55	1.040837	1.02E+00	1.06E+00	1.49E+00	1.083341	1.61E+00
		SS12	1074.74	1991493.22	0.635458	5.30E+00	3.37E+00	9.35E+00	0.403807	3.77E+00
		SS13	1315.63	2437862.39	0.777888	2.37E-01	1.85E-01	4.01E+00	0.605110	2.43E+00
		SS14	926.50	1716804.50	0.547809	3.15E-02	1.73E-02	4.88E+00	0.300094	1.46E+00
		SS15	1111.80	2060165.40	0.657371	0.00E+00	0.00E+00	5.02E+00	0.432136	2.17E+00
		SS16	1148.86	2128837.58	0.679283	3.15E-02	2.14E-02	4.88E+00	0.461425	2.25E+00
		SS17a	1519.46	2815559.38	0.898406	0.00E+00	0.00E+00	5.02E+00	0.807134	4.05E+00
		SS17b	2112.42	3914314.26	1.249004	5.50E+00	6.88E+00	1.07E+01	1.560011	1.66E+01
		SS18	1815.94	3364936.82	1.073705	1.91E+01	2.05E+01	2.84E+02	1.152843	3.27E+02
		SS19	1871.53	3467945.09	1.106574	6.39E+00	7.07E+00	1.72E+01	1.224505	2.11E+01
		SS20	1908.59	3536617.27	1.128486	9.23E-01	1.04E+00	1.73E+00	1.273481	2.21E+00
		SS21	2501.55	4635372.15	1.479084	6.59E-01	9.75E-01	2.50E+00	2.187688	5.47E+00
										9.09E-01

Sum	68946868.72
Average	3133948.58

Average	2.24E+00

Biomass (mT)	154.417
Variance	4319.722815

Table 5. Summary of details for cod biomass estimate for Northwest Arm.

Stratum	Stratum Area(km2)	Transect	Transect Len(m)	Transect Area(m2)	Weighting Factor	Density (mT/km2)	Wtd Den (mT/km2)	A (Den-mean wtd den)^2	B Wtd Fact^2	C A*B
Northwest Arm	48.37955081	NW0	759.73	1407779.69	0.465578	0.107300	5.00E-02	9.45E-03	0.216763	2.05E-03
		NW1	1537.99	2849895.47	0.942512	0.157250	1.48E-01	2.23E-03	0.888330	1.98E-03
		NW2	1927.12	3570953.36	1.180979	0.945350	1.12E+00	5.49E-01	1.394712	7.66E-01
		NW3	1537.99	2849895.47	0.942512	1.233950	1.16E+00	1.06E+00	0.888330	9.41E-01
		NW4	2001.24	3708297.72	1.226402	0.577200	7.08E-01	1.39E-01	1.504061	2.09E-01
		NW5	3631.88	6729873.64	2.225692	0.009250	2.06E-02	3.81E-02	4.953705	1.89E-01
		NW6	1056.21	1957157.13	0.647268	0.101750	6.59E-02	1.06E-02	0.418955	4.42E-03
		NW7	1130.33	2094501.49	0.692690	0.000000	0.00E+00	4.18E-02	0.479819	2.01E-02
		NW8	1167.39	2163173.67	0.715401	0.000000	0.00E+00	4.18E-02	0.511799	2.14E-02
		NW9	1278.57	2369190.21	0.783534	0.000000	0.00E+00	4.18E-02	0.613926	2.57E-02
		NW10	1352.69	2506534.57	0.828957	0.000000	0.00E+00	4.18E-02	0.687169	2.87E-02
		NW11	2112.42	3914314.26	1.294535	0.000000	0.00E+00	4.18E-02	1.675821	7.01E-02
		NW12	741.20	1373443.60	0.454223	0.000000	0.00E+00	4.18E-02	0.206318	8.63E-03
		NW13	1760.35	3261928.55	1.078779	0.000000	0.00E+00	4.18E-02	1.163765	4.87E-02
		NW14	2538.61	4704044.33	1.555713	0.000000	0.00E+00	4.18E-02	2.420244	1.01E-01
		NW15	1575.05	2918567.65	0.965224	0.000000	0.00E+00	4.18E-02	0.931657	3.90E-02
			Sum	48379550.81		Average	2.04E-01			1.03E-02
			Average	3023721.93						
							Biomass (mT)	9.893		
							Variance	24.15269239		

Table 6. Summary of details for cod biomass estimate for Southwest Arm and for entire survey area.

Stratum	Stratum Area(km2)	Transect	Transect Len(m)	Transect Area(m2)	Weighting Factor	Density (mT/km2)	Wtd Den (mT/km2)	A (Den-mean wtd den)^2	B Wtd Fact^2	C A*B
Southwest Arm	36.67094412	SW0	870.91	1613796.23	0.616105	3.62E-01	2.23E-01	2.97E-02	0.379585	1.13E-02
		SW1	1222.98	2266181.94	0.865169	1.88E-01	1.62E-01	4.38E-06	0.748517	3.28E-06
		SW2	1167.39	2163173.67	0.825843	0.00E+00	0.00E+00	3.60E-02	0.682016	2.45E-02
		SW3	1167.39	2163173.67	0.825843	0.00E+00	0.00E+00	3.60E-02	0.682016	2.45E-02
		SW4	1371.22	2540870.66	0.970037	0.00E+00	0.00E+00	3.60E-02	0.940973	3.39E-02
		SW5	1593.58	2952903.74	1.127341	5.15E-02	5.80E-02	1.91E-02	1.270897	2.43E-02
		SW6	1815.94	3364936.82	1.284644	2.89E-01	3.71E-01	9.83E-03	1.650311	1.62E-02
		SW7	1130.33	2094501.49	0.799625	6.82E-01	5.46E-01	2.43E-01	0.639401	1.55E-01
		SW8	1834.47	3399272.91	1.297753	4.37E-01	5.67E-01	6.10E-02	1.684162	1.03E-01
		SW9	2001.24	3708297.72	1.415730	2.08E-01	2.94E-01	3.18E-04	2.004292	6.37E-04
		SW10	2445.96	4532363.88	1.730337	2.04E-01	3.53E-01	2.10E-04	2.994066	6.30E-04
		SW11	1389.75	2575206.75	0.983146	5.81E-02	5.71E-02	1.73E-02	0.966576	1.67E-02
		SW12	945.03	1751140.59	0.668539	1.66E-02	1.11E-02	3.00E-02	0.446945	1.34E-02
		SW13	833.85	1545124.05	0.589888	2.32E-02	1.37E-02	2.77E-02	0.347967	9.64E-03
			Sum	36670944.12		Average	1.90E-01			2.38E-03
			Average	2619353.15						

Biomass (mT)	6.956
Variance	3.203

All strata combined:	**Biomass (mT)**	**171.266**
	Variance	**4347.079**
	Standard Error	**65.932**
	C.V.(%)	**38.497**

Table 7. Catch details for the five most abundant marine fish species caught during Shamook Trip 251,15-26 April 1996.

Area	Date	Set	Gear	Depth fished (m)		Cod		Plaice		Turbot		Witch		Redfish	
						No. fish	Weight (kg)	No. fish	Weight (kg)	No. fish	Weight (kg)	No. fish	Weight (kg)	No. fish	Weight (kg)
Smith Sound	960416	1	Jigger	30		54	54.6	0	.	0	.	0	.	0	.
	960416	2 [2]	Trawl	105		7	15.8	0	.	0	.	0	.	0	.
	960417	3 [2]	Trawl	260		3	2.3	12	2.6	0	.	0	.	0	.
	960417	4	Trawl	278		442	826.6	77	20.0	4	3.0	0	.	0	.
	960418	5	Trawl	215		131	205.4	106	31.4	0	.	0	.	0	.
	960418	6	Trawl	148		0	0.0	0	.	0	.	0	.	0	.
	960418	7	Trawl	158		293	483.8	650	150.0	0	.	3	2.1	2	1.2
	960420	8	Jigger	33		113	140.3	0	.	0	.	0	.	0	.
					Total	1043	1728.8	845	204.0	4	3.0	3	2.1	2	1.2
Northwest Arm	960420	9	Jigger	51		4	6.8	0	.	0	.	0	.	0	.
	960421	10	Jigger	30		70	153.0	0	.	0	.	0	.	0	.
	960421	11	Gill net	60		4	9.1	1	0.4	0	.	0	.	0	.
	960421	12	Gill net	56		1	2.4	1	0.2	0	.	0	.	0	.
	960421	13	Gill net	61		3	10.6	1	0.4	0	.	0	.	0	.
	960421	14	Trawl	105		9	6.5	175	35.0	0	.	0	.	0	.
	960421	15	Jigger	25		2	4.2	0	.	0	.	0	.	0	.
	960421	16	Jigger	31		128	228.5	0	.	0	.	0	.	0	.
	960422	17	Gill net	55		1	2.5	0	.	0	.	0	.	0	.
	960422	18	Gill net	70		2	5.5	0	.	0	.	0	.	0	.
	960425	26	Jigger	25		29	38.4	0	.	0	.	0	.	0	.
					Total	253	467.5	178	36.0	0	.	0	.	0	.
Southwest Arm	960423	19	Trawl	173		69	111.0	435	111.0	0	.	0	.	1	0.3
	960423	20	Trawl	268		78	133.4	411	108.0	3	1.5	7	1.5	0	.
	960423	21	Trawl	290		0	.	0	.	0	.	0	.	0	.
	960423	22 [3]	Trawl	162		0	.	0	.	0	.	0	.	0	.
	960424	23 [3]	Trawl	214		16	26.9	35	14.5	0	.	0	.	0	.
	960424	24	Trawl	168		23	34.5	277	74.0	0	.	0	.	0	.
	960424	25	Trawl	215		60	103.7	413	107.0	0	.	0	.	0	.
					Total	246	409.5	1571	414.5	3	1.5	7	1.5	1	0.3
					Overall Total	1542	2605.8	2594	654.5	7	4.5	10	3.6	3	1.5

[2] gear damaged.

[3] gear fouled.

Table 8. Age-length distribution of cod sampled from inshore areas of Trinity Bay during April 1996. Values were obtained by applying an age-length key from 719 aged samples to the length frequency of the entire catch.

	Ages												
Length (cm)	0	1	2	3	4	5	6	7	8	9	10	11	25
19			4										
22			3	3									
25				6	1								
28				6	1								
31				1	4								
34					10								
37					21								
40					19	3							
43					31	15	7						
46					11	48	13						
49					2	59	48	2					
52						55	85	11					
55						40	130	27	4				
58						4	132	42	11	4			
61							70	59	15	10	2		
64							27	41	18	1			
67							18	18	11	7	1		
70							9	15	7	4	4	1	
73								7	2	5	1		
76							1	2	4	4	1		
79								3	2	2			
130													1
Totals			7	15	101	223	538	228	76	37	9	1	1
Av/Len (cm)			20.29	25.99	39.83	49.82	56.25	61.55	64.42	67.14	68.95	70	129

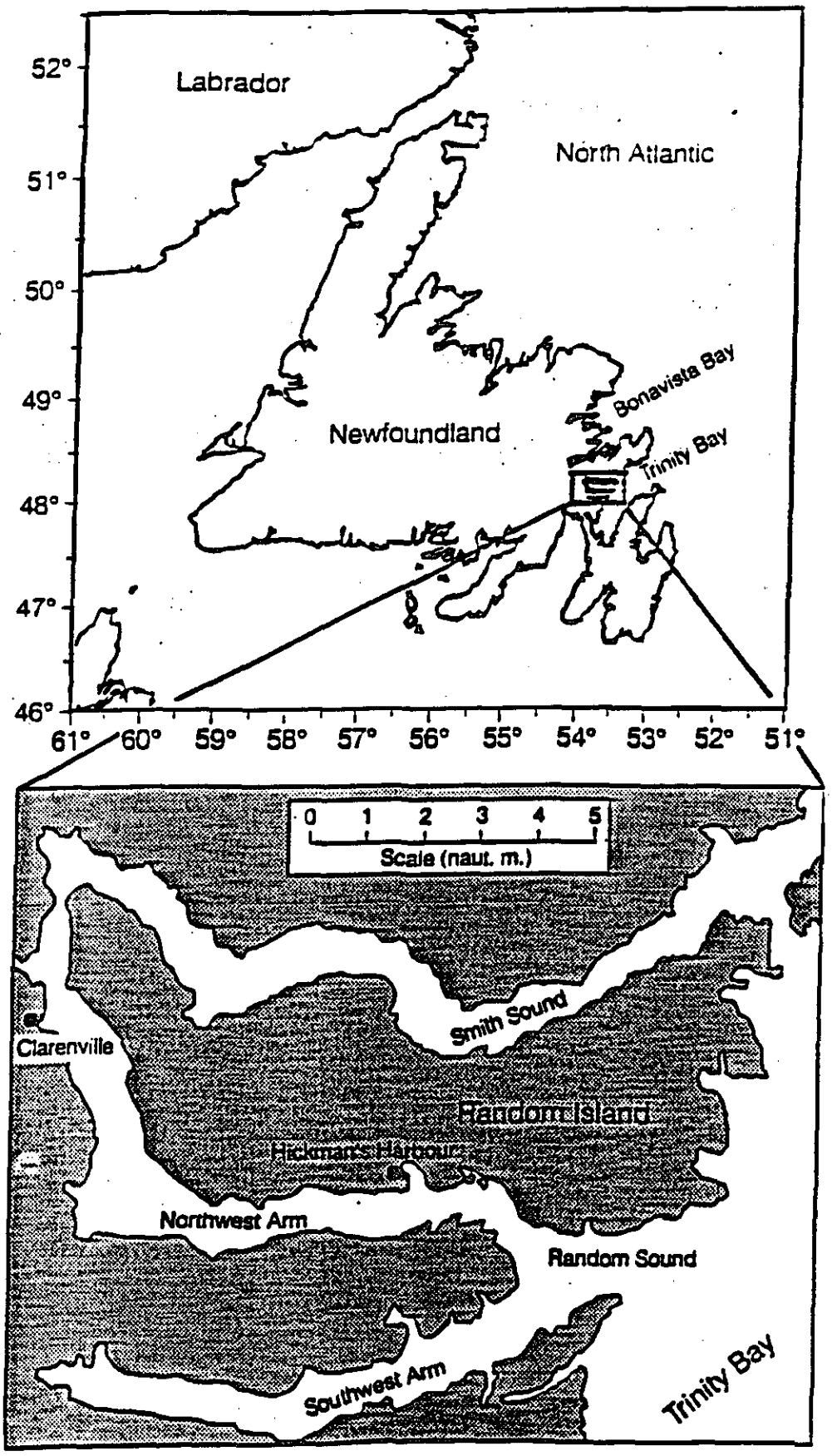


Fig. 1. Location of the area surveyed for cod during Shamook trip 251.

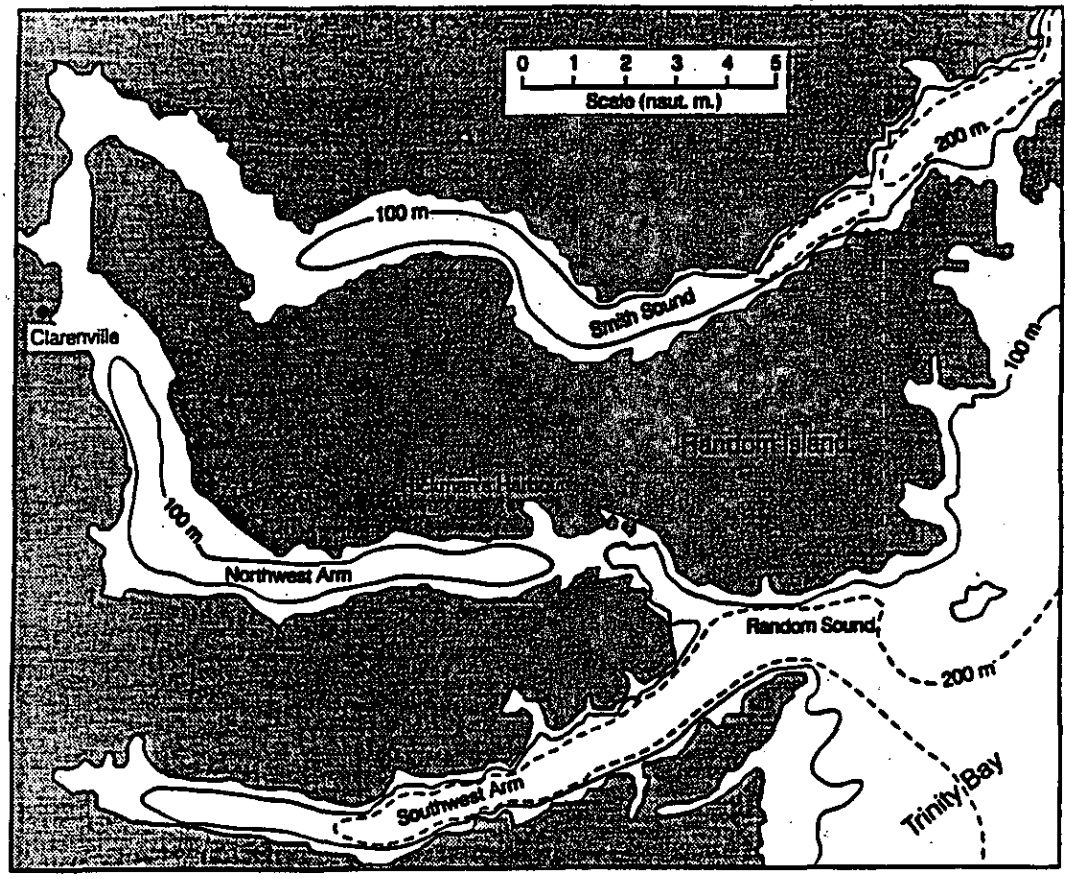


Fig. 2. Bathymetry of the survey area in western Trinity Bay, Newfoundland.

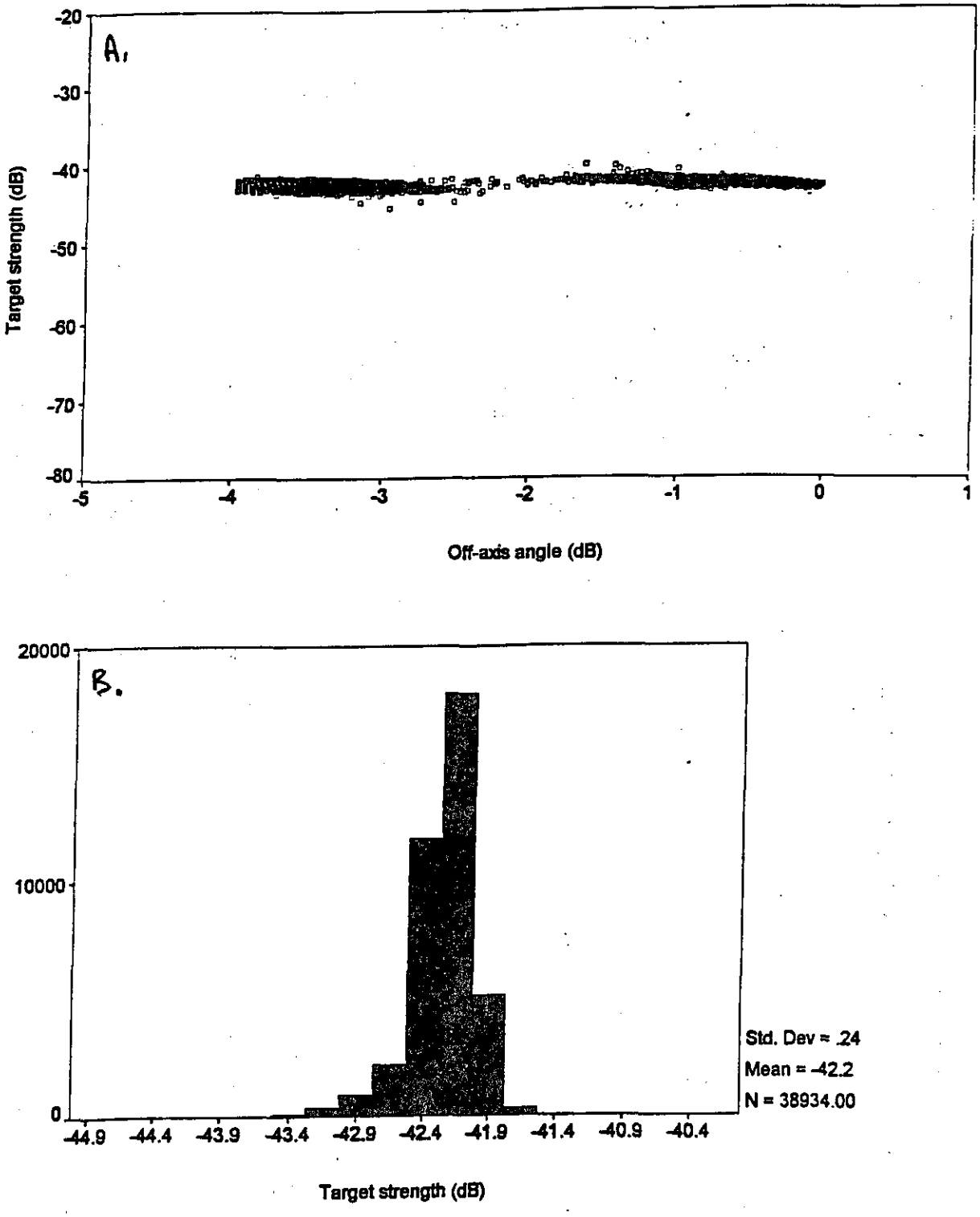


Fig. 3. Scatterplot and histogram of measured target stengths from calibrations using a standard target (38 *mm tungsten-carbide ball) suspended 7.5 m below the transducer.*

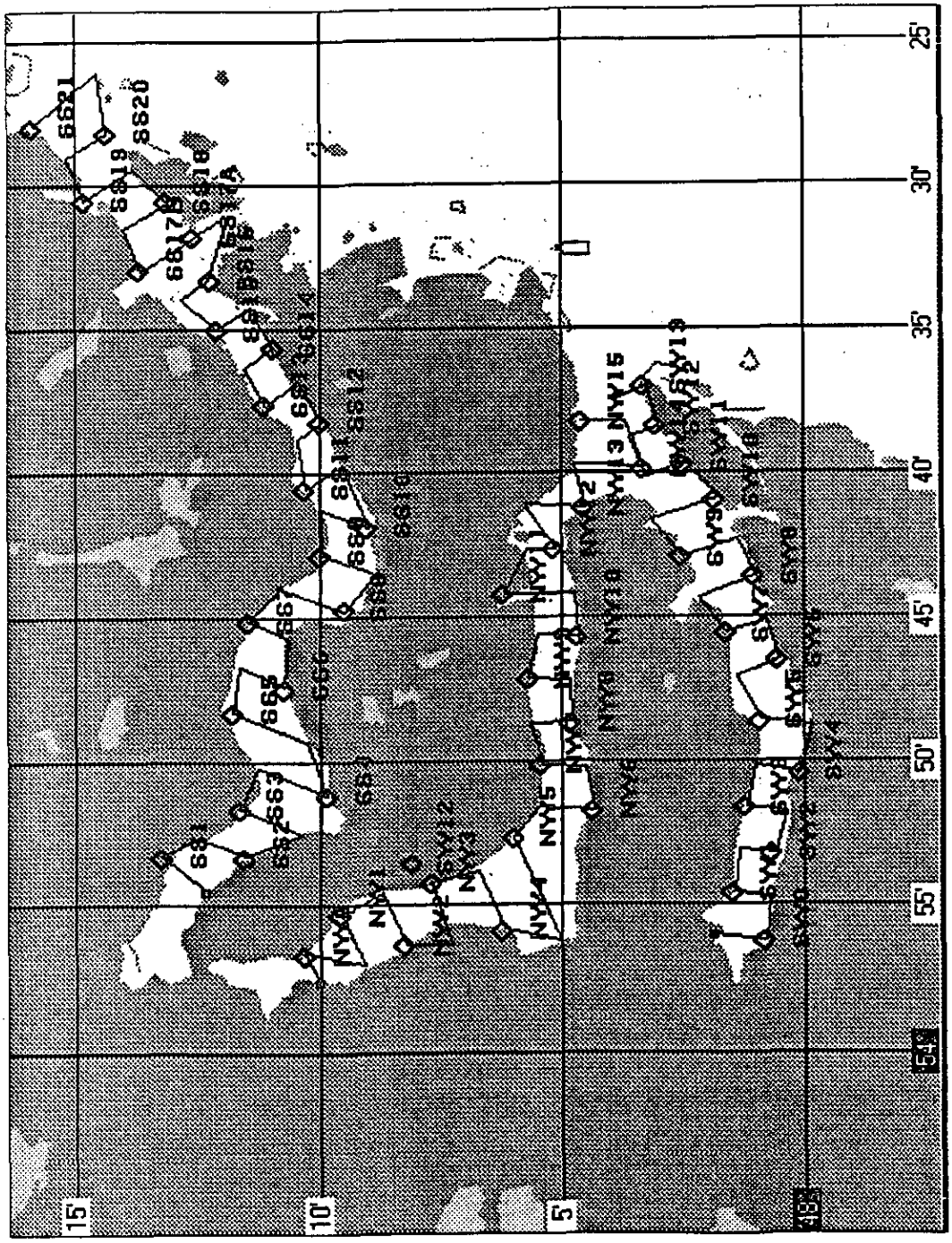
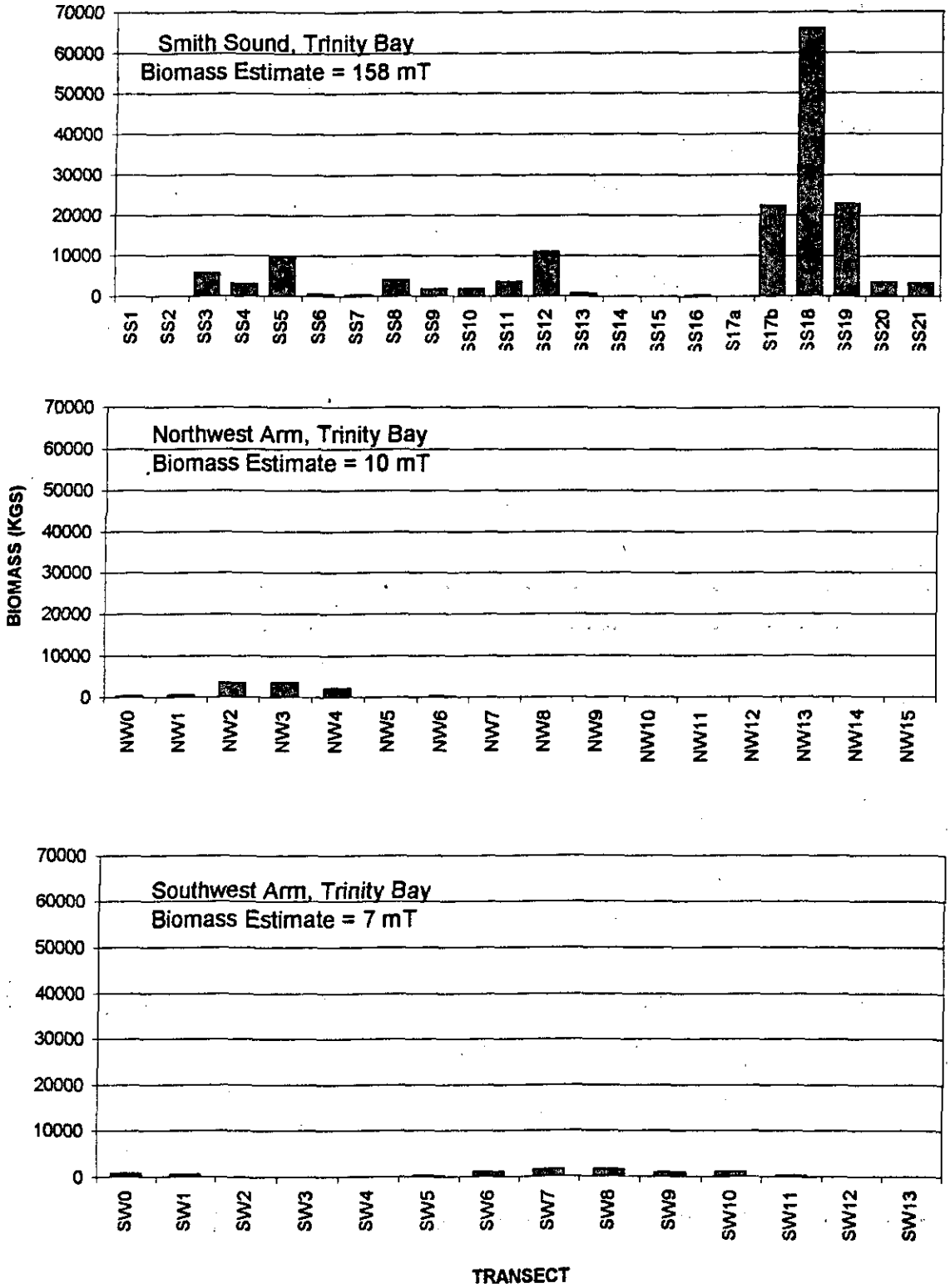


Fig. 4. Acoustic transect positions. Shamook trip 251, April 15-26th, 1996.

Fig. 5. Biomass estimate of cod by transect and stratum for three areas in western Trinity Bay surveyed during Shamook trip 251 (see Fig 4.for transect positions).



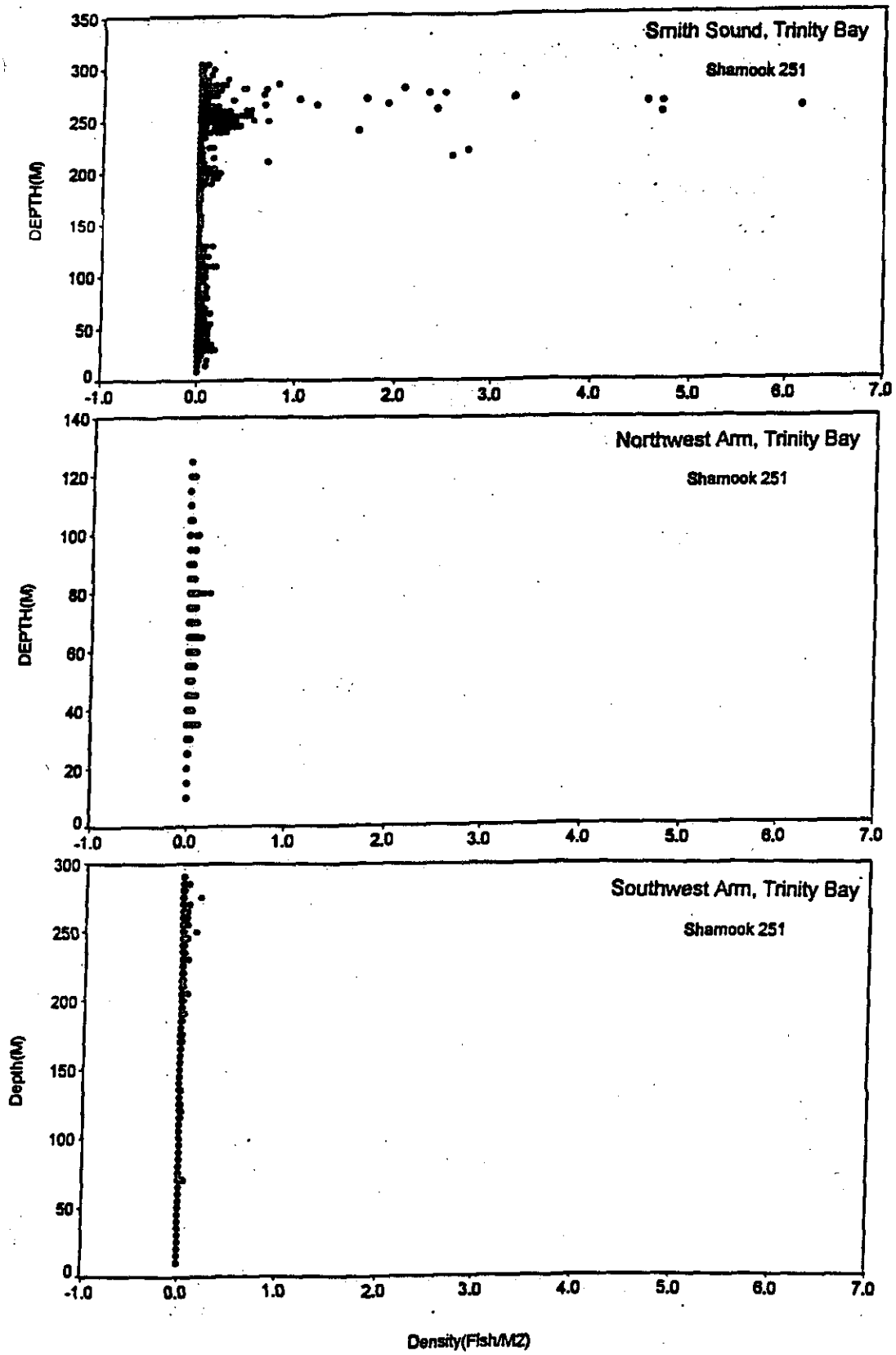


Fig. 6. Distribution of cod densities by depth as detected on acoustic transects during Shamook trip 251 (April 15-26th, 1996).

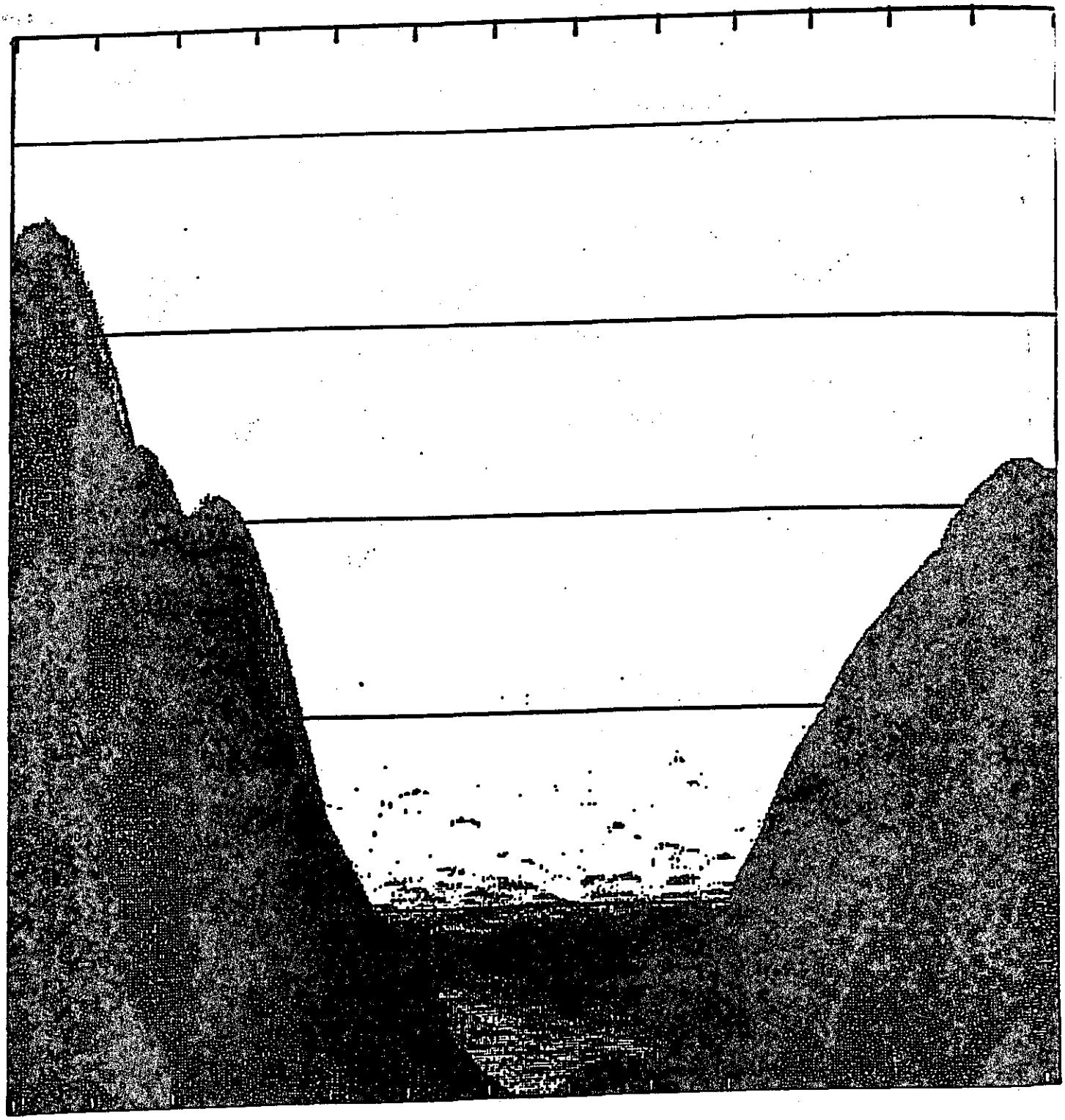


Fig. 7. Echogram from transect SS18 (outer Smith Sound). Horizontal lines are 50 m depth intervals. Note the dense aggregation of targets in the deepest section of the transect

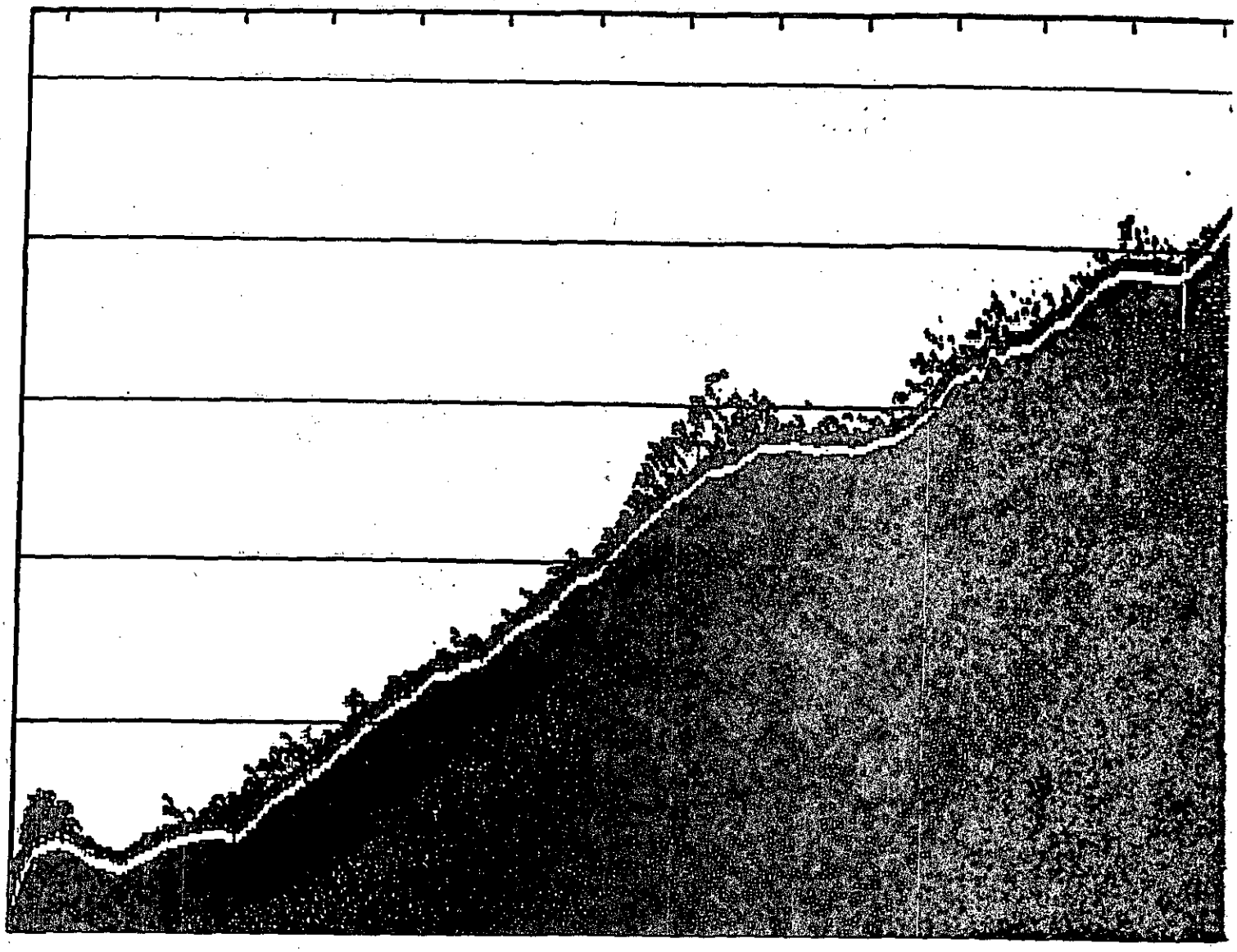


Fig. 8. Echogram from transect SS5 (inner Smith Sound). Horizontal lines are 50 m depth intervals. Note the aggregation of targets close to the bottom and extending down the slope throughout the depth range portrayed.

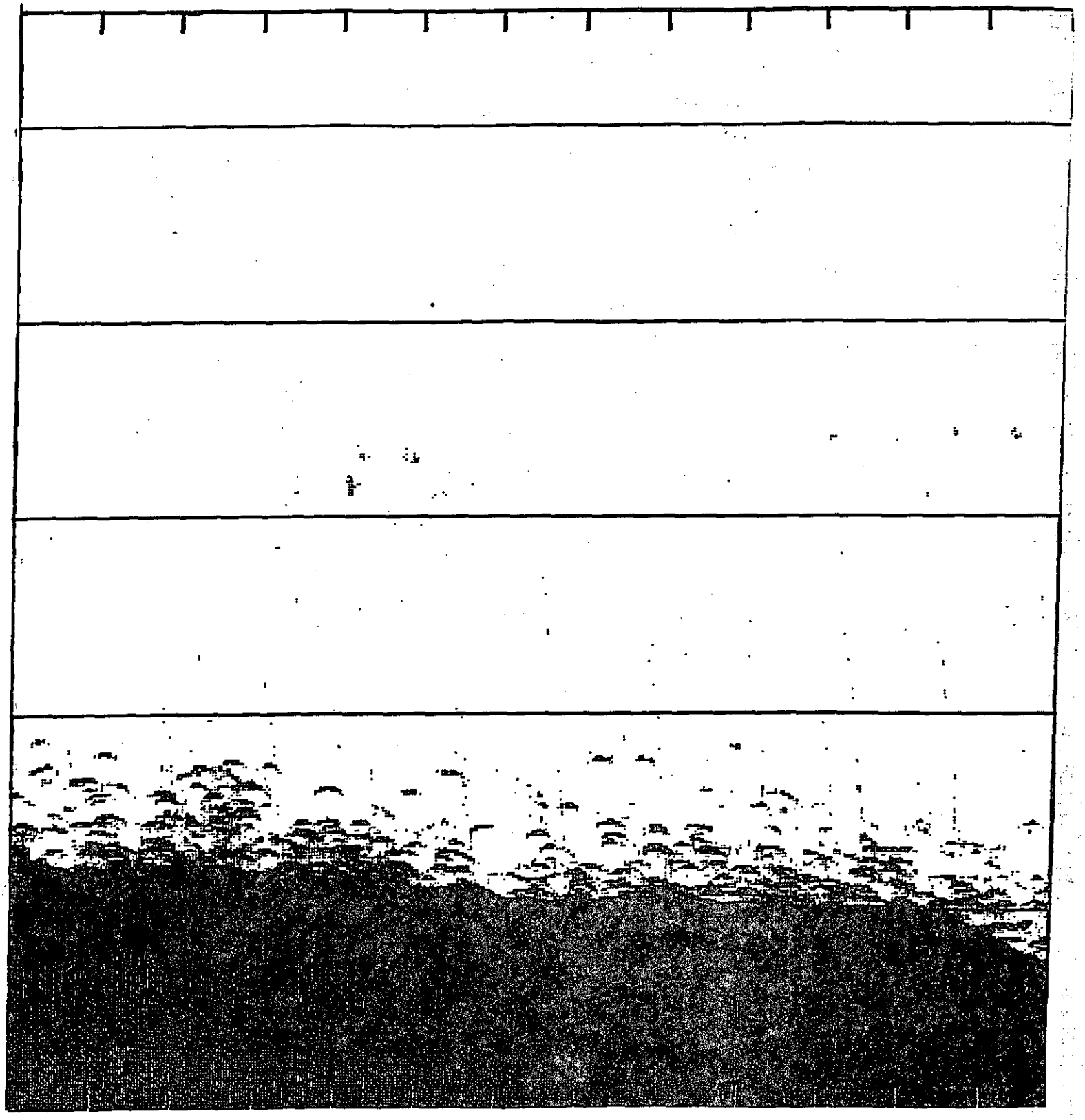


Fig. 9. Echogram from Southwest Arm. Horizontal lines are 50 m depth intervals. Note the low density of targets scattered up through the water column.

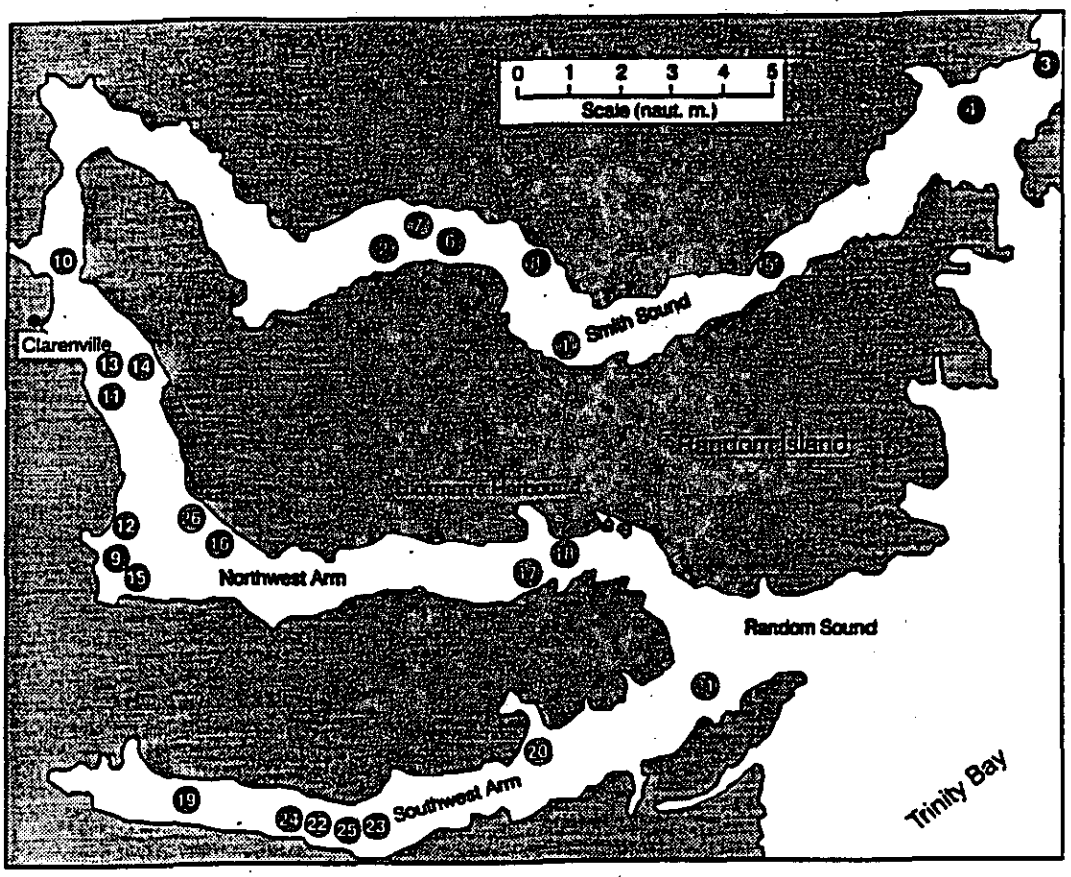


Fig. 10. Fishing set locations during Shamook trip 251