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Newfoundland East Coast Herring
- 1990 Acoustic Survey Results

by

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Abstract

The results of an acoustic survey of the White Bay-Notre Dame Bay and Bonavista Bay-Trinity Bay herring stock complexes, conducted during the fall of 1990, are presented. Integrated density estimates were calculated using a 120 kHz hydroacoustic system, along a series of randomly selected parallel transects within each stock area. A target strength/fish length relationship calculated from net enclosed herring in Smith Sound, Trinity Bay was used for the conversion of backscattering to biomass. This relationship was then also used to convert backscattering to biomass for previous acoustic surveys conducted in 1988 and 1990.

Résumé

Le présent document expose les résultats d'un relevé acoustique des zones de stock de hareng des baies de White-Notre Dame et de Bonavista-Trinity au cours de l'automne 1990. Les estimations de densité intégrées ont été établies à l'aide d'un système hydro-acoustique de 120 kHz le long de bandes parallèles situées dans chaque zone de stock. Un rapport entre l'effectif visé et la longueur du poisson établi d'après des prises de hareng au filet dans le détroit Smith, baie de Trinity, a servi à convertir la rétrodiffusion en biomasse. Le même rapport a ensuite été utilisé pour convertir également en biomasse la rétrodiffusion obtenue dans les relevés acoustiques effectués en 1988 et 1990.

Introduction

Acoustic herring surveys have been conducted annually since 1983 to estimate the biomass of herring stocks within the Newfoundland Region. Prior to 1987, surveys were conducted using sonar and sounder to map schools and to estimate biomass (Wheeler and Chaulk 1987). Since then, a 120 kHz dual beam hydroacoustic system has been used to obtain integrated density estimates along acoustic transects (Wheeler et al. 1988, 1989, Wheeler 1990).

Due to the large distributional area of the five herring stock complexes assessed within the Newfoundland Region, it was decided in 1988 that acoustic surveys of the three northern stocks, (White Bay-Notre Dame Bay, Bonavista Bay-Trinity Bay, and Conception Bay-Southern Shore) and the two southern stocks, (St. Mary's Bay-Placentia Bay and Fortune Bay) (Fig. 1) would be conducted on an alternate fiscal year basis. The two southern stocks would be acoustically surveyed during the winter (January to March) when the herring are aggregated in overwintering concentrations. As ice cover precluded surveying the northern stocks during the winter, it was decided to survey these during the fall (October to December) as the herring migrate into the bays to overwinter.

This paper documents the results of an acoustic survey of the two northern stocks conducted from October 18, 1990 to November 29, 1990 (fiscal year 1990-91). Prior to 1990, the last acoustic survey of these two stocks was conducted during the fall of 1988 (Wheeler et al. 1989).

Acoustic Survey Design

The survey commenced at Cape Bauld in White Bay and terminated at Grates Point in Trinity Bay. A BioSonics 120 kHz dual beam hydroacoustic system was deployed from the R.V. SHAMOOK during the survey. The R.V. MARINUS, equipped with a herring purse seine, was attendant during the entire survey to collect biological samples. In addition, the R.V. SHAMOOK was equipped with a midwater trawl to provide extra sampling capability. An experienced commercial purse seine fisherman was hired under contract and was aboard the MARINUS for four weeks during the survey to aid the crew in detecting herring concentrations and in setting the purse seine. This was in response to a CAFSAC research recommendation that measures be taken to improve the efficiency of the MARINUS in collecting biological samples by purse seining in these surveys.

Each of the two stock areas was divided into low, medium, and high density strata based upon distributional patterns observed during previous surveys. White Bay-Notre Dame Bay was divided into 25 strata (Fig. 2-8) and Bonavista Bay-Trinity Bay into 21 strata (Fig. 9-15). It was decided prior to the survey to allocate sampling intensity (total transect length) on a 3:2:1 ratio between high, medium, and low density areas, respectively. The survey design was the same as in previous acoustic surveys (Wheeler et al. 1989, Wheeler 1990).

Biological Sampling

Herring were caught in fifteen sets during the survey (Table 1). Sampling was good in Bonavista Bay and average to poor in other areas. In White Bay-Notre Dame Bay, herring were detected in twelve strata and sampled in five strata which accounted for 60% of the biomass estimate. However, all fish sampled were of the 1990 year-class. In Bonavista Bay-Trinity Bay, herring were sampled in two strata only. However, these strata accounted for 87% of the biomass estimate and the samples from these strata also consisted of both immature and mature fish.

To calculate mean fish lengths and weights, by stratum (Table 2), necessary for the fish length-target strength per kg relationship and for estimating population numbers at age, a combination of research samples and commercial samples was used. The commercial samples were obtained from purse seine vessels fishing in the respective strata at the time of the acoustic survey. It was impossible to use this method for White Bay-Notre Dame Bay; only age 0 fish were caught in research samples whereas the commercial catch was multi-aged. There was no valid method to weight research and commercial samples. As this affected both the calculation of target strength per kg and population numbers at age, neither a biomass estimate nor a population age structure could be derived for White Bay-Notre Dame Bay from the acoustic survey. A biomass estimate and population age structure were derived for Bonavista Bay-Trinity Bay where there were adequate research samples with comparable age distributions to commercial samples.

In Bonavista Bay-Trinity Bay (Fig. 16), the 1987 and 1982 year-classes of spring spawners represented 60% and 17% of the population estimate, by number, respectively. The 1990 year-class, which was evident in White Bay-Notre Dame Bay, was not observed in Bonavista Bay-Trinity Bay.

Acoustic Data Analysis

1) Species Identification

The same process was used as in previous acoustic surveys (Wheeler et al. 1989, Wheeler 1990), to identify herring concentrations along transects for inclusion in data analysis. Of the 147 schools detected during the survey (Table 3), most (58%) were identified as herring.

2) Hydroacoustic Calibration During 1990 Acoustic Survey

The hydroacoustic system used during the 1990 east coast acoustic survey was calibrated by BioSonics Inc. on October 4, 1990 immediately prior to the survey (Appendix 1) and again on February 6, 1991 after the survey (Appendix 2). There was negligible change in system performance between the two calibrations. In addition, the system was calibrated with a standard sphere several times during the survey.

3) Calculation of Experimental Target Strength Estimates

CAFSAC has recommended that "Foote's (1987) target strength/fish length relationship be used for conversion of backscattering to biomass during acoustic surveys for herring until such time when in situ measurements become available for the various stocks in the Northwest Atlantic". In October 1989, a field program was initiated in Smith Sound, Trinity Bay to determine experimental target strength estimates for herring within the Newfoundland Region. Results of this initial experiment, presented to CAFSAC in May 1990 (Wheeler 1990) indicated that there was a substantial difference between the experimental target strength estimate and that derived from Foote's relationship, at least for one length of herring.

A second field experiment was conducted in Smith Sound in May 1990. The two objectives of the research were: 1) to determine an experimental target strength/fish length relationship to apply to acoustic survey results by acoustically measuring different length ranges of herring within a net enclosure, and 2) to compare simultaneous estimates of target strengths at 38 kHz and 120 kHz, as Foote's (1987) relationship was based upon measurements at 38 kHz whereas Newfoundland herring acoustic surveys utilize a 120 kHz hydroacoustic system. It was decided by CAFSAC to defer provision of advice for 1991 until the results of this research and the results of the 1990 fall acoustic survey were available for review.

A sample of approximately 1000 live herring was obtained from a commercial bar seine fisherman. The fish holding pound and experimental net enclosure were the same as in 1989 (Wheeler 1990). BioSonics 38 kHz (6°/16°) and 120 kHz (10°/25°) dual beam transducers were suspended from a wooden platform 0.5 m below the surface in the centre of the net enclosure.

Acoustic measurements were conducted over an eighty-two hour period from 2000 h on May 22, 1990 to 0600 h on May 26, 1990. Four separate length ranges of herring (Fig. 17) were identified from the sample of live fish, with mean lengths of 26.7, 31.8, 33.7, and 36.2 cm. A sample of approximately fifty fish of each length grouping was introduced separately into the experimental pound. Fish were given one hour to acclimatize after being placed in the pound before any acoustic measurements were made. Target strengths were then measured simultaneously at 38 kHz and 120 kHz. For two of the fish samples, mean lengths 26.7 cm and 33.7 cm (Table 4, Fig. 18-21) average daytime and nighttime target strengths were measured. For the remaining two samples, mean lengths 31.8 cm and 36.2 cm, only daytime target strengths were measured.

Key results of the experiment were as follows:

1) Average target strengths measured at 120 kHz were consistently larger (2.5-4.1 dB) than those measured at 38 kHz (Table 4, Fig. 20-21).

2) Average target strengths measured during the day, regardless of frequency were consistently larger (1.5-3.2 dB) than those measured during the night (Table 4, Fig. 18-19).

3) Average daytime target strengths and log fish length were linearly related over the observed length range:

   120 kHz $Y = 50.28 \log X - 107.9$ $r^2 = 0.77$

   38 kHz $Y = 48.12 \log X - 108.2$ $r^2 = 0.69$

   The slopes of these relationships (Fig. 21) were not significantly different but both were significantly different from that derived by Foote (1987).

4) Results from October 1989 (Wheeler 1990) and May 1990 experiments were consistent.

There are concerns as the applicability of target strengths measured within a net enclosure to acoustic survey results. Also, the range of average fish lengths, from which the experimental target strength-fish length relationship is derived, is relatively small (10 cm). The long-term goal is to derive in situ target strength measurements to convert backscatter to biomass. However, until such estimates are available, it was decided that the experimentally derived 120 kHz daytime relationship is more appropriate to apply to results (within the bounds of the regression) from the Newfoundland herring acoustic surveys which are conducted during the day with a 120 kHz hydroacoustic system, than is Foote's relationship, from 38 kHz in situ measurements at night.

The 120 kHz Smith Sound daytime target strength-fish length relationship was thus used to convert backscatter to biomass for the 1990 east coast fall acoustic survey results and for the previous 1990 south coast winter results (Wheeler 1990) and 1988 east coast fall survey results (Wheeler et al. 1989).

Acoustic Survey Results

Integrated density estimates were calculated for the 301 transects surveyed within both stock areas. For Bonavista Bay-Trinity Bay, mean fish lengths and weights by stratum (Table 2) were applied, using the Smith Sound experimental target strength/fish length relationship, to calculate a target strength (dB per kg) for each stratum. The formulas used to calculate mean densities, variances, and biomass estimates from the acoustic survey (Appendix 3) were derived from Jolly and Hampton (1989) and Jolly and Smith (1989).

Density estimates, by transect and stratum, are presented in Table 5 and are summarized by stock area in Table 6. In Bonavista Bay-Trinity Bay 92.9% of the herring biomass was detected in strata 27 and 28.

Mean biomass (t) estimates by stock area from the 1990 fall survey, the 1990 winter survey, and the 1988 fall survey are provided in the following text table:

	1988		1990	
Stock area	Mean	C.V.	Mean	C.V.
WB-NDB	14,581	0.314	-	-
BB-TB	15,734	0.472	34,601	0.522
SMB-PB	-	-	18,013	0.88
FB	-	-	7,730	0.690

A biomass estimate is not available for White Bay-Notre Dame Bay from the 1990 acoustic survey due to the previously discussed inadequacies of biological sampling during the survey. In addition, given the predominance of age 0 fish in the acoustic survey samples, target strength estimates would have to be predicted outside the bounds of the experimental target strength-fish length relationship.

Populations numbers at age, by spawning type (Table 7), were adjusted to January 1991 from the 1990 acoustic biomass estimates.

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Table 1. SHAMOOK midwater trawl and MARINUS purse seine set details for the 1990 herring acoustic survey, White Bay-Notre Dame Bay and Bonavista Bay-Trinity Bay.

Set no.	Date	Time	Location	Surface temp.	Bottom temp.	Results
S1	Oct. 25	1130	Great Cat Arm, White Bay	5.4	-0.1	Caught 35 small herring (40-60 mm) plus capelin and cod
M1	Oct. 25	1205	Great Cat Arm, White Bay	5.4	-0.1	Caught ~200 kg small herring (50-90 mm) plus capelin and squid
S2	Oct. 26	0750	Sops Arm, White Bay	6.3	0.7	Caught 60-70 small herring (40-90 mm)
M2	Oct. 26	0815	Sops Arm, White Bay	6.3	0.7	Caught ~200 kg small herring (80-110 mm)
M3	Oct. 29	0715	Cape St. John, Green Bay	4.1	0.7	No catch
S3	Oct. 29	0830	Cape St. John, Green Bay	4.1	0.7	Caught 55-60 small herring (70-100 mm)
S4	Oct. 29	1105	Cape St. John, Green Bay	4.1	0.7	Caught ~25 small herring (50-80 mm)
M4	Oct. 29	1220	Snooks Head, Green Bay	5.0	-0.2	Caught ~200 kg small herring (80-110 mm)
S5	Oct. 30	0620	Kings Point, Green Bay	-	-	No catch
S6	Nov. 8	0700	Swan Island, Bay of Exploits	5.0	-	Caught ~10 kg sticklebacks
M5	Nov. 8	1505	Thwart Island, Bay of Exploits	4.7	-	Caught ~90 kg small herring (100-125 mm)
S7	Nov. 11	1350	Gander Island, Hamilton Sound	4.8	-	Caught ~2 kg small herring (70-120 mm)
S8	Nov. 11	1610	Seal Islands, Hamilton Sound	4.8	4.6	Caught ~60 kg small herring (70-120 mm)
M6	Nov. 14	1245	Lewis Island, Bonavista Bay	2.6	1.7	No catch
S9	Nov. 14	1325	Lewis Island, Bonavista Bay	2.6	1.7	No catch
M7	Nov. 14	1455	Lewis Island, Bonavista Bay	2.6	1.7	Caught 4 small herring (50-75 mm) and ~50 stickleback
S10	Nov. 14	1500	Lewis Island, Bonavista Bay	2.6	1.7	No catch
S11	Nov. 14	1650	Lockers Reach, Bonavista Bay	4.0	-	Caught ~25 kg herring (28-38 cm)
M8	Nov. 15	0825	Trinity Gut, Bonavista Bay	4.1	4.0	No catch
S12	Nov. 15	1025	Lockers Flat Is., Bonavista Bay	-	-	No catch
M9	Nov. 15	1700	Hare Island, Bonavista Bay	3.5	2.9	Caught ~14,000 kg herring (20-34 cm)
M10	Nov. 19	1320	Wolf Island, Bonavista Bay	6.8	-0.1	No catch
M11	Nov. 20	1215	Morris Island, Bonavista Bay	5.6	3.3	No catch
M12	Nov. 20	1325	Morris Island, Bonavista Bay	5.6	3.3	Caught one herring (27 cm)
M13	Nov. 21	1500	Sweet Bay, Bonavista Bay	6.1	4.0	No catch
M14	Nov. 23	0825	Smith Sound, Trinity Bay	5.5	5.1	Caught 37 herring (22-32 cm)
S13	Nov. 23	0850	Smith Sound, Trinity Bay	5.5	5.1	Caught 6 herring (30-32 cm)
M15	Nov. 23	1045	Smith Sound, Trinity Bay	5.5	5.1	No catch
M16	Nov. 25	0915	Great Mosquito Cove, Trinity Bay	6.3	3.7	Caught ~200 kg juvenile cod
M17	Nov. 28	1210	Deer Harbour, Trinity Bay	5.3	2.3	Caught one each of juvenile cod, capelin and herring

Table 2. Biological samples used to calculate mean lengths and mean weights from the 1990 herring acoustic survey, White Bay-Notre Dame Bay and Bonavista Bay-Trinity Bay.

Stock area	Survey strata	Survey dates	Sampling location	Sample strata	Sample dates	Sample type	# fish sampled	Mean lgt. (cm)	Mean wgt. (gm)
WB-NDB	1-7	Oct. 19-29	Great Cat Arm	4	Oct. 25	Res. MWT & P.S.	129	6.30	1.44
			Jacksons Arm	4	Oct. 29	Comm. P.S.	50	34.49	346.12
			Sops Arm	5	Oct. 26	Res. MWT & P.S.	150	8.08	3.74
			Cape St. John	7	Oct. 29	Res. MWT	74	7.68	2.74
	8-21	Oct. 29-Nov. 11	Snooks Head	8	Oct. 29	Res. P.S.	100	9.07	4.95
			Springdale	11	Nov. 5	Comm. P.S.	100	34.30	354.00
			Roberts Arm	12	Nov. 14	Comm. P.S.	50	28.99	197.94
			Thwart Island	18	Nov. 8	Res. P.S.	100	10.99	10.52
	22-25	Nov. 11-12	Gander Island	23	Nov. 11	Res. MWT	150	9.53	5.67
			Cape Fogo	24	Nov. 9	Comm. P.S.	50	34.17	327.86
BB-TB	26-27	Nov. 13-14	Drake Island	27	Nov. 14	Comm. P.S.	100	31.0	251.0
	28	Nov. 14-16	Lockers Reach	28	Nov. 14	Res. MWT	50	30.7	245.0
			Hare Island	28	Nov. 15	Res. P.S.	100	28.2	185.0
	29	Nov. 16-19	Morris Island	29	Nov. 15	Comm. P.S.	100	33.0	303.0
	30-35	Nov. 19-21	Drake Island	27	Nov. 14	Comm. P.S.	100	31.0	251.0
			Lockers Reach	28	Nov. 14	Res. MWT	50	30.7	245.0
			Hare Island	28	Nov. 15	Res. P.S.	100	28.2	185.0
			Morris Island	29	Nov. 15	Comm. P.S.	100	33.0	303.0
	36-46	Nov. 22-29	Smith Sound	38	Nov. 23	Res. MWT & P.S.	42	25.2	146.0

Table 3. Number of fish schools edited as non-herring prior to analysis of 1990 herring acoustic survey, White Bay-Notre Dame Bay and Bonavista Bay-Trinity Bay.

Stock area	Stratum	Herring schools analyzed	Schools edited				
			Capelin	Mackerel	Cod	Sticklebacks	Unidentified
WB-NDB	1	0	0	1	0	0	0
	2	0	1	1	0	0	1
	3	3	1	2	0	0	4
	4	1	0	2	0	0	4
	5	2	0	0	2	0	2
	6	0	0	0	0	0	0
	7	3	0	0	0	0	2
	8	0	0	0	1	0	1
	9	1	0	0	1	0	3
	10	2	0	0	0	0	0
	11	0	0	0	0	0	0
	12	9	0	0	0	0	0
	13	0	0	0	0	0	0
	14	6	0	0	0	0	2
	15	0	0	0	0	0	1
	16	0	0	0	0	2	2
	17	3	0	0	0	1	1
	18	1	0	0	1	7	1
	19	1	0	0	0	1	0
	20	0	0	0	0	0	1
	21	0	0	0	0	0	0
	22	1	0	0	0	0	0
	23	9	0	0	0	0	1
	24	-	-	-	-	-	-
	25	-	-	-	-	-	-
BB-TB	26	0	0	0	0	0	0
	27	10	0	0	0	0	1
	28	12	0	0	0	0	0
	29	6	0	0	0	0	1
	30	2	0	0	0	0	0
	31	0	0	0	0	0	0
	32	0	0	0	0	0	0
	33	0	0	0	0	0	0
	34	0	0	0	0	0	0
	35	-	-	-	-	-	-
	36	1	0	0	0	0	0
	37	0	0	0	0	0	0
	38	6	0	0	0	0	1
	39	1	0	0	0	0	0
	40	0	0	0	0	0	0
	41	2	0	0	1	0	1
	42	2	0	0	0	0	3
	43	0	0	0	1	1	0
	44	0	0	0	0	0	1
	45	0	0	0	0	0	1
	46	1	0	0	0	0	0

Table 4. Average target strength estimates, day and night, measured at 120 kHz and 38 kHz, from net enclosed herring, Smith Sound, Trinity Bay, May 1990. (* October 1989)

Fish length (cm)	120 kHz Day Avg. T.S.	120 kHz Day N	120 kHz Night Avg. T.S.	120 kHz Night N	38 kHz Day Avg. T.S.	38 kHz Day N	38 kHz Night Avg. T.S.	38 kHz Night N	Foote 38 kHz night Pred. T.S.
25.80	-37.10*		-39.20*		-	-	-	-	-43.67
26.68	-35.77	570	-37.37	4243	-39.16	535	-40.63	2145	-43.38
31.83	-34.50	5087	-	-	-38.18	1530	-	-	-41.84
33.67	-28.50	4550	-31.65	13934	-32.62	6279	-34.14	1859	-41.36
36.16	-30.37	4805	-	-	-33.57	1835	-	-	-40.76

Table 5. Biomass and backscatter estimates, for Bonavista Bay-Trinity Bay, from the 1990 acoustic survey.

STOCK AREA	STRATUM	TARGET STRENGTH (dB/kg)	TRANSECT NUMBER	TRANSECT LENGTH (n.mi.)	TRANSECT AREA (m2)	TRANSECT BIOMASS (t)	WEIGHTED DENSITY (kg/m2)	TRANSECT TTL SCATTER (m2/sr)	WEIGHTED SCAT. COEF. (/sr)	SET NUMBER	NUMBER OF FISH SAMPLED
BB-TB	27	-26.93	159	4.23	7.254E+06	0	0.00000	0	0.000E+00		
			160	4.67	8.009E+06	0	0.00000	0	0.000E+00		
			161	2.75	4.716E+06	143	0.03167	289	6.421E-05		
			162	1.26	2.161E+06	0	0.00000	0	0.000E+00	M8	0
			163	1.90	3.258E+06	111	0.02455	224	4.976E-05	M6,M7,S9	0
			164	2.88	4.939E+06	13	0.00277	25	5.624E-06		
			165	0.70	1.200E+06	0	0.00000	0	0.000E+00		
			7		4.505E+06		0.00843		1.708E-05		
					3.154E+07						
	28	-27.50	166	2.99	5.128E+06	2609	0.75216	4637	1.337E-03	S11,S12	50
			167	1.70	2.915E+06	4	0.00101	6	1.794E-06	M9	100
			168	2.89	4.956E+06	3697	1.06575	6571	1.894E-03		
			169	2.93	5.025E+06	155	0.04477	276	7.959E-05		
			170	3.20	5.488E+06	192	0.05547	342	9.860E-05		
			171	1.58	2.710E+06	0	0.00000	0	0.000E+00		
			172	2.20	3.773E+06	0	0.00000	0	0.000E+00		
			173	3.05	5.231E+06	0	0.00000	0	0.000E+00		
			174	3.70	6.345E+06	0	0.00000	0	0.000E+00		
			175	0.52	8.918E+05	0	0.00000	0	0.000E+00		
			176	0.03	5.659E+04	0	0.00000	0	0.000E+00		
			177	0.82	1.406E+06	0	0.00000	0	0.000E+00		
			178	0.68	1.166E+06	67	0.01940	120	3.449E-05		
			13		3.469E+06		0.14912		2.651E-04		
					4.509E+07						
	29	-26.38	179	3.89	6.671E+06	34	0.00940	78	2.162E-05		
			180	1.93	3.310E+06	0	0.00000	0	0.000E+00		
			181	0.52	8.918E+05	0	0.00000	0	0.000E+00		
			182	1.49	2.555E+06	65	0.01800	149	4.139E-05		
			183	1.57	2.692E+06	0	0.00000	0	0.000E+00		
			184	1.18	2.024E+06	45	0.01257	104	2.891E-05		
			185	2.73	4.682E+06	0	0.00000	0	0.000E+00		
			186	3.40	5.831E+06	0	0.00000	0	0.000E+00	M11,M12	0
			187	4.27	7.323E+06	0	0.00000	0	0.000E+00		
			188	3.30	5.659E+06	79	0.02184	181	5.022E-05		
			189	1.23	2.109E+06	2	0.00061	5	1.407E-06		
			190	1.02	1.749E+06	0	0.00000	0	0.000E+00		
			191	0.72	1.235E+06	0	0.00000	0	0.000E+00	M10	0
			13		3.595E+06		0.00480		1.104E-05		
					4.673E+07						

Table 5. Continued.

STOCK AREA	STRATUM	TARGET STRENGTH (dB/kg)	TRANSECT NUMBER	TRANSECT LENGTH (n.mi.)	TRANSECT AREA (m2)	TRANSECT BIOMASS (t)	WEIGHTED DENSITY (kg/m2)	TRANSECT TTL SCATTER (m2/sr)	WEIGHTED SCAT. COEF. (/sr)	SET NUMBER	NUMBER OF FISH SAMPLED
	30	-27.05	192	2.65	4.545E+06	0	0.00000	0	0.000E+00		
			193	6.35	1.089E+07	0	0.00000	0	0.000E+00		
			194	2.72	4.665E+06	0	0.00000	0	0.000E+00		
			195	1.51	2.590E+06	14	0.00222	28	4.372E-06		
			196	5.30	9.089E+06	6	0.00087	11	1.705E-06		
			5		6.356E+06		0.00062		1.215E-06		
					3.178E+07						
	36	-29.10	218	7.40	1.269E+07	0	0.00000	0	0.000E+00		
			219	4.60	7.889E+06	19	0.00189	24	2.319E-06		
			2		1.029E+07		0.00094		1.159E-06		
					2.058E+07						
	38	-29.10	230	0.36	6.174E+05	0	0.00000	0	0.000E+00		
			231	0.41	7.031E+05	0	0.00000	0	0.000E+00		
			232	0.70	1.200E+06	0	0.00000	0	0.000E+00		
			233	0.78	1.338E+06	0	0.00000	0	0.000E+00	M15	0
			234	1.27	2.178E+06	0	0.00000	0	0.000E+00	M14	37
			235	1.17	2.006E+06	0	0.00000	0	0.000E+00	S13	6
			236	1.47	2.521E+06	0	0.00000	0	0.000E+00		
			237	0.76	1.303E+06	0	0.00000	0	0.000E+00		
			238	0.40	6.860E+05	0	0.00000	0	0.000E+00		
			239	0.24	4.116E+05	0	0.00000	0	0.000E+00		
			240	0.31	5.316E+05	22	0.02128	27	2.618E-05		
			241	0.33	5.659E+05	0	0.00000	0	0.000E+00		
			242	0.32	5.488E+05	4	0.00418	5	5.140E-06		
			243	0.69	1.183E+06	0	0.00000	0	0.000E+00		
			244	0.57	9.775E+05	0	0.00000	0	0.000E+00		
			245	0.50	8.575E+05	0	0.00000	0	0.000E+00		
			246	0.35	6.002E+05	0	0.00000	0	0.000E+00		
			247	0.19	3.258E+05	0	0.00000	0	0.000E+00		
			248	0.58	9.947E+05	0	0.00000	0	0.000E+00		
			19		1.029E+06		0.00134		1.648E-06		
					1.955E+07						
	39	-29.10	256	1.21	2.075E+06	2	0.00074	3	9.120E-07		
			257	1.51	2.590E+06	0	0.00000	0	0.000E+00		
			258	2.47	4.236E+06	0	0.00000	0	0.000E+00		
			3		2.967E+06		0.00025		3.040E-07		
					8.901E+06						

Table 5. Continued.

STOCK AREA	STRATUM	TARGET STRENGTH (dB/kg)	TRANSECT NUMBER	TRANSECT LENGTH (n.mi.)	TRANSECT AREA (m2)	TRANSECT BIOMASS (t)	WEIGHTED DENSITY (kg/m2)	TRANSECT TTL SCATTER (m2/sr)	WEIGHTED SCAT. COEF. (/sr)	SET NUMBER	NUMBER OF FISH SAMPLED
	41	-29.10	259	0.37	6.345E+05	0	0.00000	0	0.000E+00		
			260	0.18	3.087E+05	16	0.02275	19	2.798E-05		
			261	0.50	8.575E+05	0	0.00000	0	0.000E+00		
			262	0.29	4.973E+05	11	0.01569	13	1.930E-05		
			263	0.32	5.488E+05	0	0.00000	0	0.000E+00		
			264	0.77	1.321E+06	0	0.00000	0	0.000E+00		
			6		6.946E+05 4.167E+06		0.00641		7.880E-06		
	42	-29.10	265	2.65	4.545E+06	6	0.00143	8	1.756E-06		
			266	2.27	3.893E+06	0	0.00000	0	0.000E+00		
			267	2.33	3.996E+06	0	0.00000	0	0.000E+00		
			280	1.49	2.555E+06	0	0.00000	0	0.000E+00		
			281	3.61	6.191E+06	0	0.00000	0	0.000E+00		
			282	2.72	4.665E+06	0	0.00000	0	0.000E+00		
			283	3.73	6.397E+06	0	0.00000	0	0.000E+00		
			284	2.82	4.836E+06	0	0.00000	0	0.000E+00		
			285	0.80	1.372E+06	0	0.00000	0	0.000E+00	M17	0
			9		4.272E+06 3.845E+07		0.00029		1.951E-07		
	46	-29.10	294	1.09	1.869E+06	0	0.00000	0	0.000E+00		
			295	0.95	1.629E+06	0	0.00000	0	0.000E+00		
			296	1.21	2.075E+06	0	0.00000	0	0.000E+00		
			297	0.71	1.218E+06	0	0.00000	0	0.000E+00		
			298	1.13	1.938E+06	0	0.00000	0	0.000E+00		
			299	1.70	2.915E+06	0	0.00001	0	1.288E-08		
			300	1.70	2.915E+06	0	0.00000	0	0.000E+00		
			301	0.42	7.203E+05	0	0.00000	0	0.000E+00		
			8		1.910E+06 1.528E+07		0.00000		1.610E-09		

Table 6. Biomass and backscatter estimates, by stratum, for Bonavista Bay–Trinity Bay, from the 1990 herring acoustic survey.

Stock area	Stratum	Target strength (dB kg^{-1})	Stratum area (m^2)	Stratum biomass density (kg m^{-2})	Total biomass (t)		Stratum area scatt. coeff. (sr^{-1})	Total backscattering (m^2 sr^{-1})	
					Mean	S.E.		Mean	S.E.
BB–TB	26	–	4.00×10^{8}	0.00000	0	–	0.000	0	–
	27	–26.93	2.77×10^{8}	0.00843	2335	1561	1.708×10^{-5}	4733	3165
	28	–27.50	2.00×10^{8}	0.14912	29824	17961	2.651×10^{-4}	53013	31922
	29	–26.38	2.08×10^{8}	0.00480	999	458	1.104×10^{-5}	2297	1054
	30	–27.05	2.80×10^{8}	0.00062	173	145	1.215×10^{-6}	340	286
	31	–	1.20×10^{8}	0.00000	0	–	0.000	0	–
	32	–	7.20×10^{7}	0.00000	0	–	0.000	0	–
	33	–	6.60×10^{7}	0.00000	0	–	0.000	0	–
	34	–	1.34×10^{8}	0.00000	0	–	0.000	0	–
	35	–	2.97×10^{8}	–	–	–	–	–	–
	36	–29.10	7.71×10^{8}	0.00094	727	896	1.159×10^{-6}	894	1103
	37	–	1.41×10^{8}	0.00000	0	–	0.000	0	–
	38	–29.10	9.20×10^{7}	0.00134	123	109	1.648×10^{-6}	152	134
	39	–29.10	9.20×10^{7}	0.00025	23	26	3.040×10^{-7}	28	32
	40	–	7.70×10^{7}	0.00000	0	–	0.000	0	–
	41	–29.10	5.40×10^{7}	0.00641	346	277	7.880×10^{-6}	426	341
	42	–29.10	1.81×10^{8}	0.00029	52	30	1.951×10^{-7}	35	35
	43	–	1.11×10^{8}	0.00000	0	–	0.000	0	–
	44	–	1.64×10^{8}	0.00000	0	–	0.000	0	–
	45	–	9.50×10^{7}	0.00000	0	–	0.000	0	–
	46	–	1.86×10^{8}	0.00000	0	–	0.000	0	–
Combined			4.02×10^{9}		34601	18059		61918	32122

Table 7. Population numbers at age, projected to January 1991, as estimated from the 1990 fall acoustic survey for Bonavista Bay-Trinity Bay and from the 1990 winter acoustic survey for Fortune Bay and St. Mary's Bay-Placentia Bay.

	Bonavista Bay-Trinity Bay		Fortune Bay		St. Mary's Bay-Placentia Bay	
Year-class	AS ($x10^6$)	SS ($x10^6$)	AS ($x10^6$)	SS ($x10^6$)	AS ($x10^6$)	SS ($x10^6$)
1990	0.0	0.0	0.0	0.0	0.0	0.0
1989	0.0	7.6	0.0	0.0	0.0	0.7
1988	1.4	11.3	0.0	0.0	0.0	1.1
1987	2.9	99.6	0.1	10.7	0.9	6.7
1986	0.3	4.8	0.0	0.9	0.7	5.1
1985	0.0	2.1	0.0	0.1	0.1	1.0
1984	0.0	0.5	0.1	0.1	0.6	0.3
1983	0.0	0.8	0.2	3.0	0.3	1.7
1982	0.1	28.7	0.2	8.2	0.2	19.3
1981	0.0	0.1	0.1	0.3	0.7	1.8
≤1980	1.6	3.2	0.4	1.2	5.0	4.4
	6.3	158.6	1.3	24.6	9.1	42.1

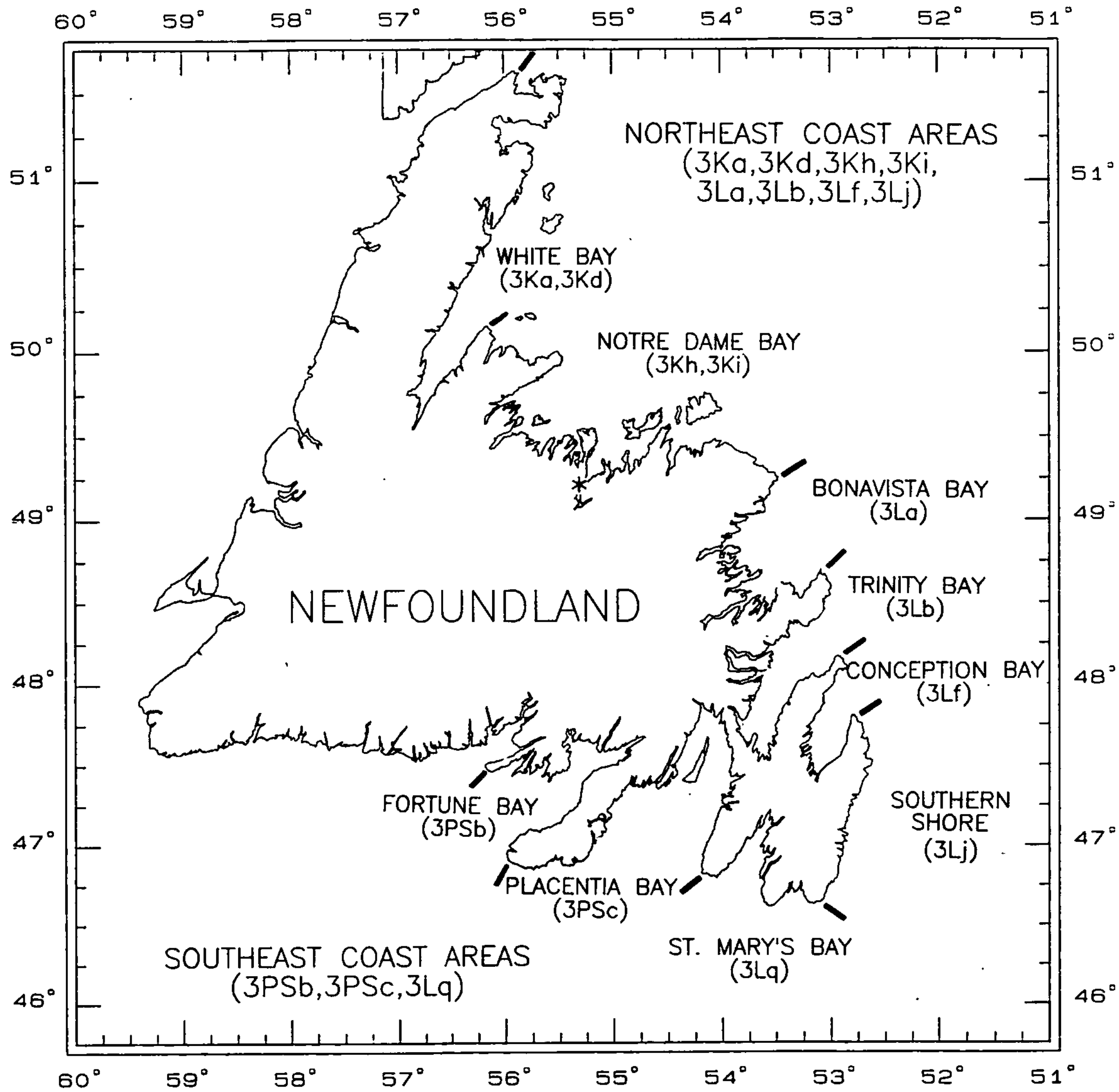

Fig. 1. Area map indicating the five herring stock complexes within the Newfoundland region: White Bay – Notre Dame Bay, Bonavista Bay – Trinity Bay, Conception Bay – Southern Shore, St. Mary's Bay – Placentia Bay, and Fortune Bay.

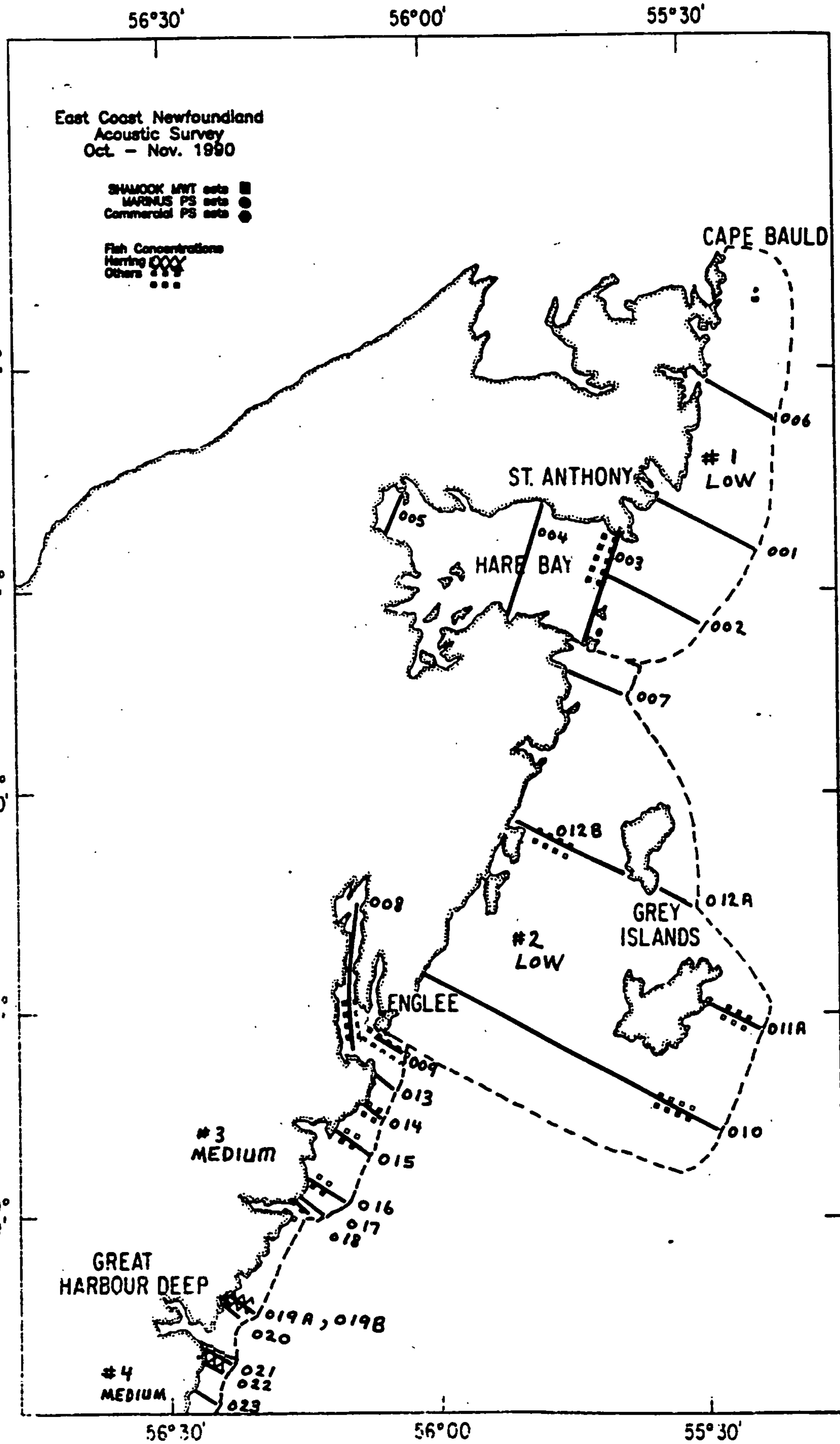

Fig. 2. Transects and set locations, acoustic purse seine survey, White Bay North, 1990.

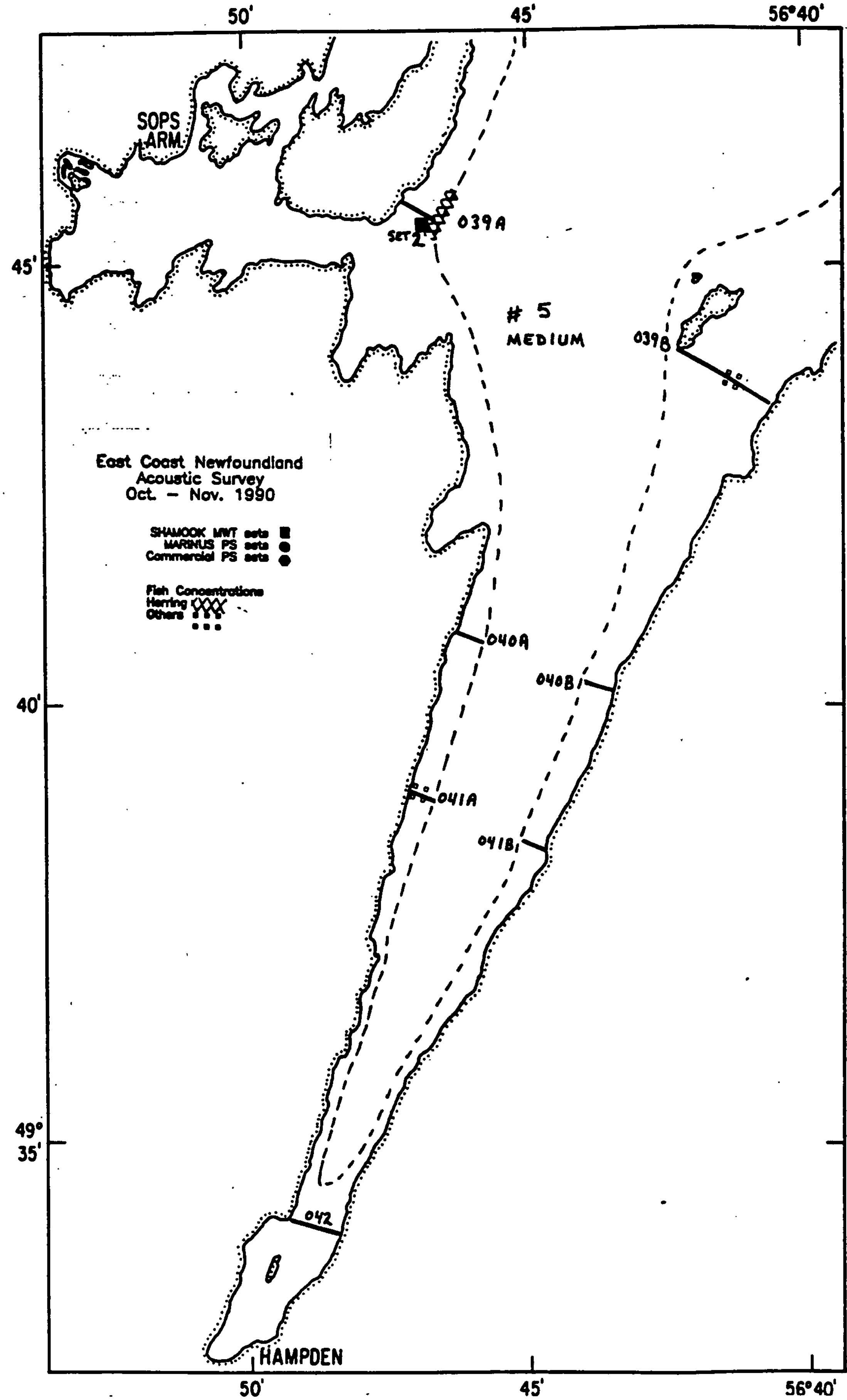

Fig. 3. Transects and set locations, acoustic purse seine survey, inner White Bay, 1990.

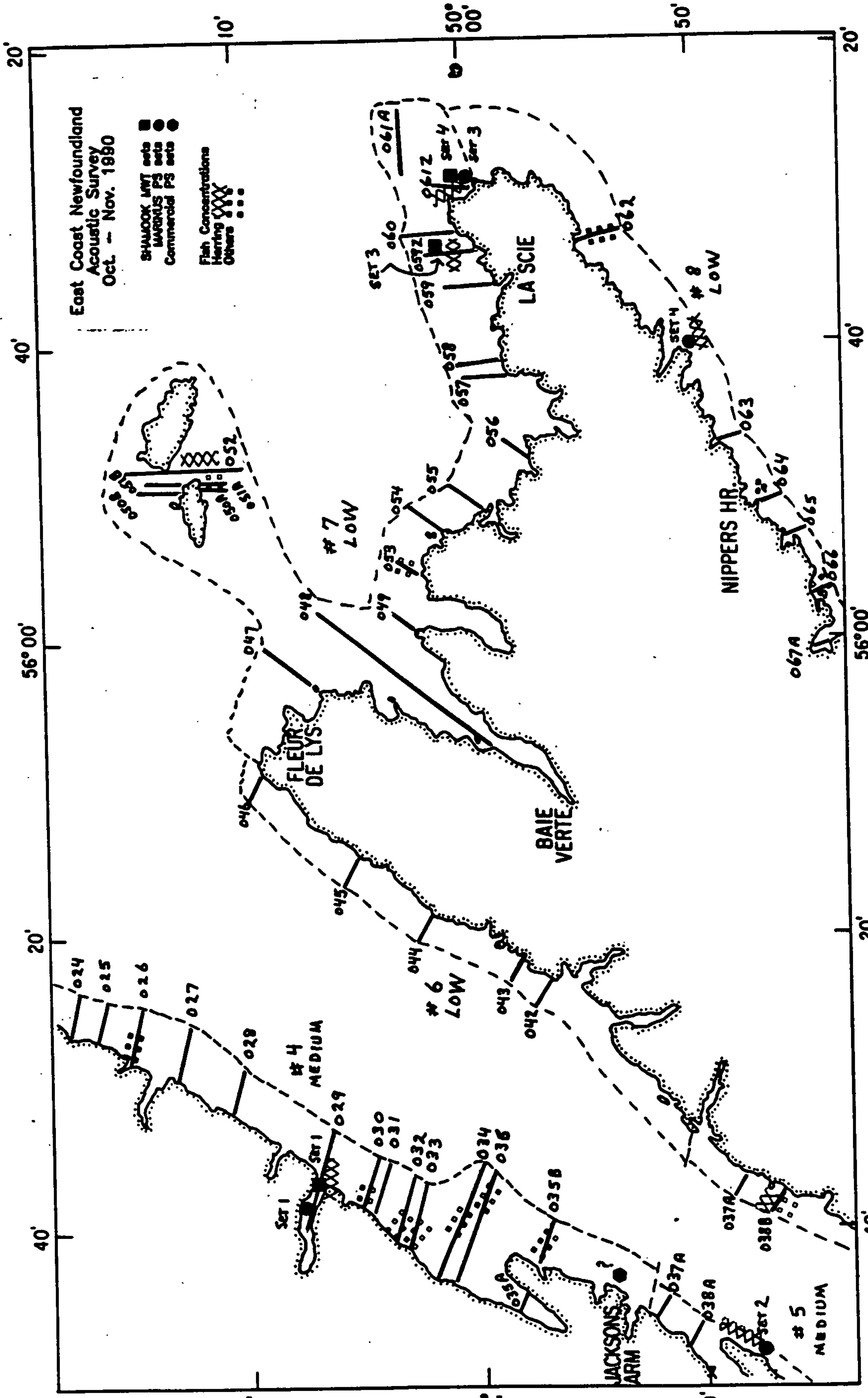

Fig. 4. Transects and set locations, acoustic purse seine survey, White Bay, 1990.

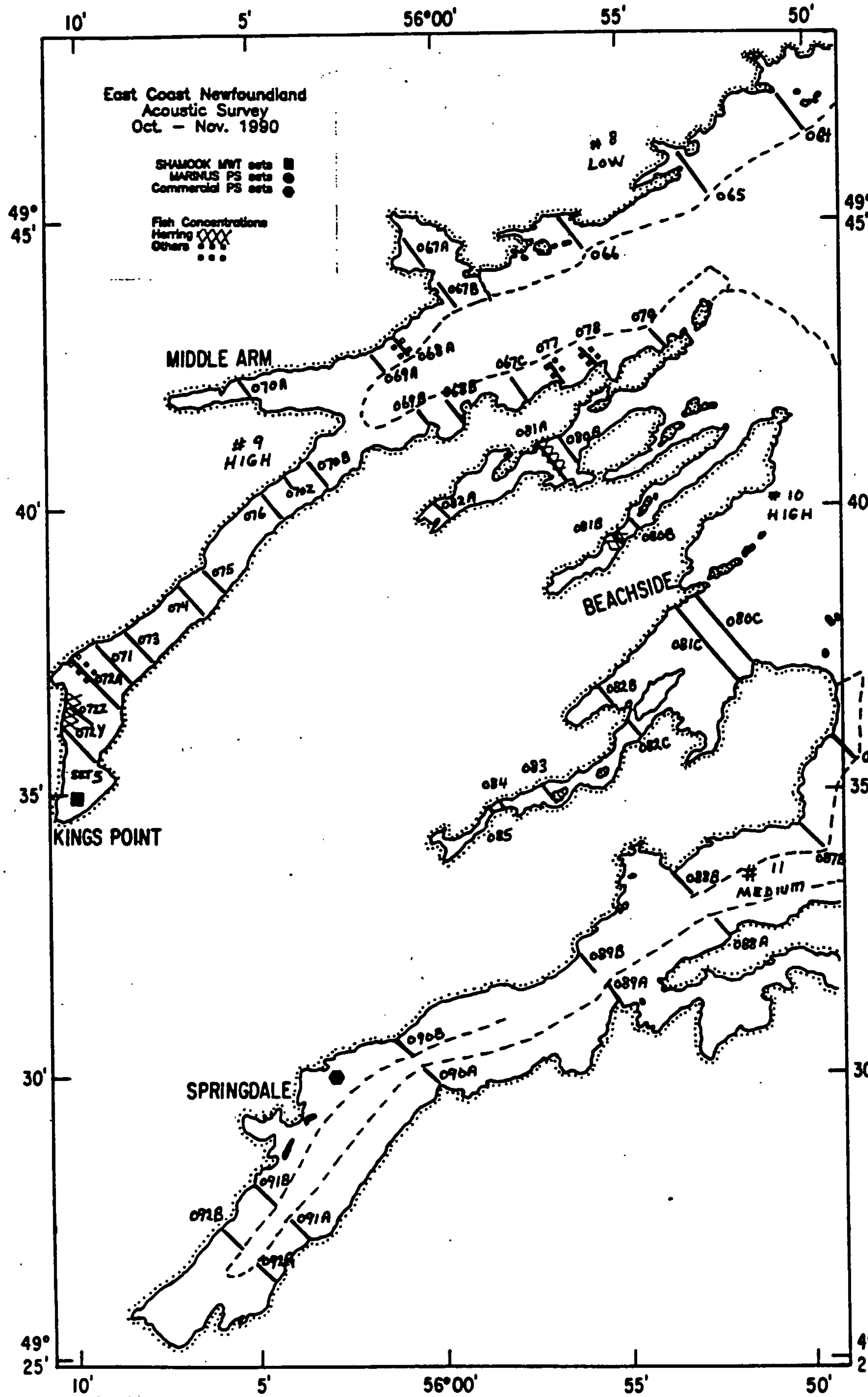

Fig. 5. Transects and set locations, acoustic purse seine survey, Green Bay - Halls Bay, 1990.

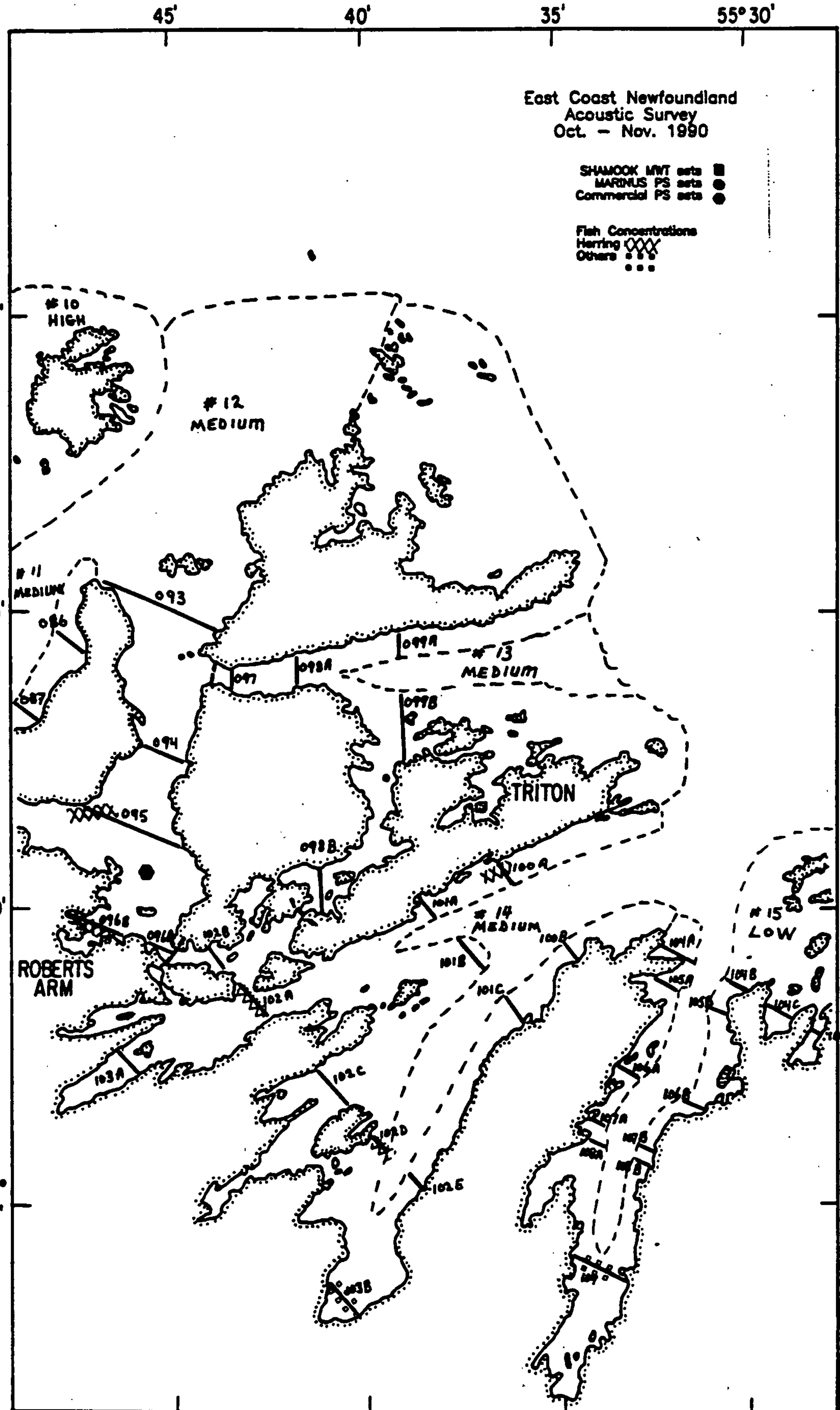

Fig. 6. Transects and set locations, acoustic purse seine survey, Badger Bay – Seal Bay, 1990.

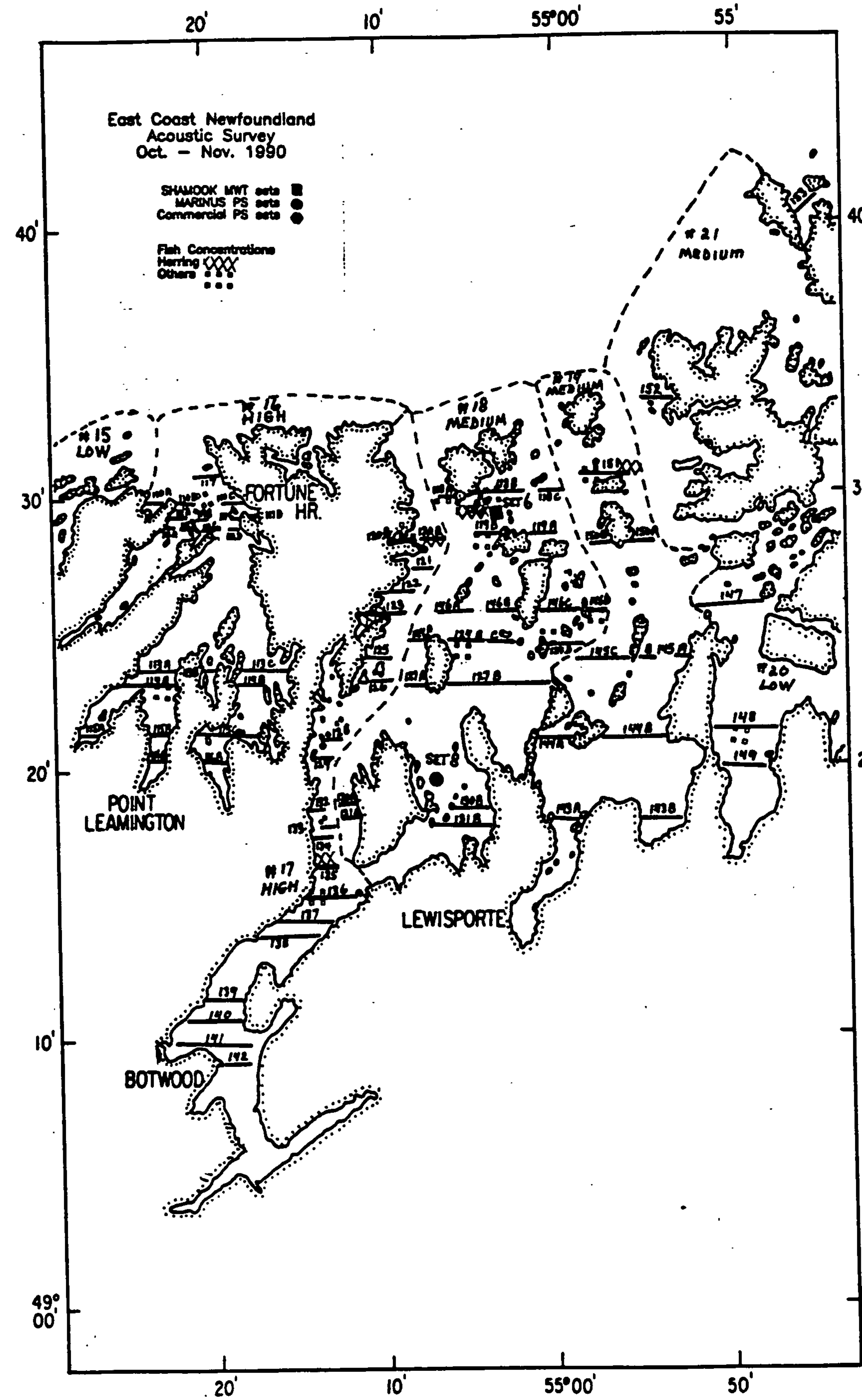

Fig. 7. Transects and set locations, acoustic purse seine survey, New Bay – Bay of Exploits, 1990.

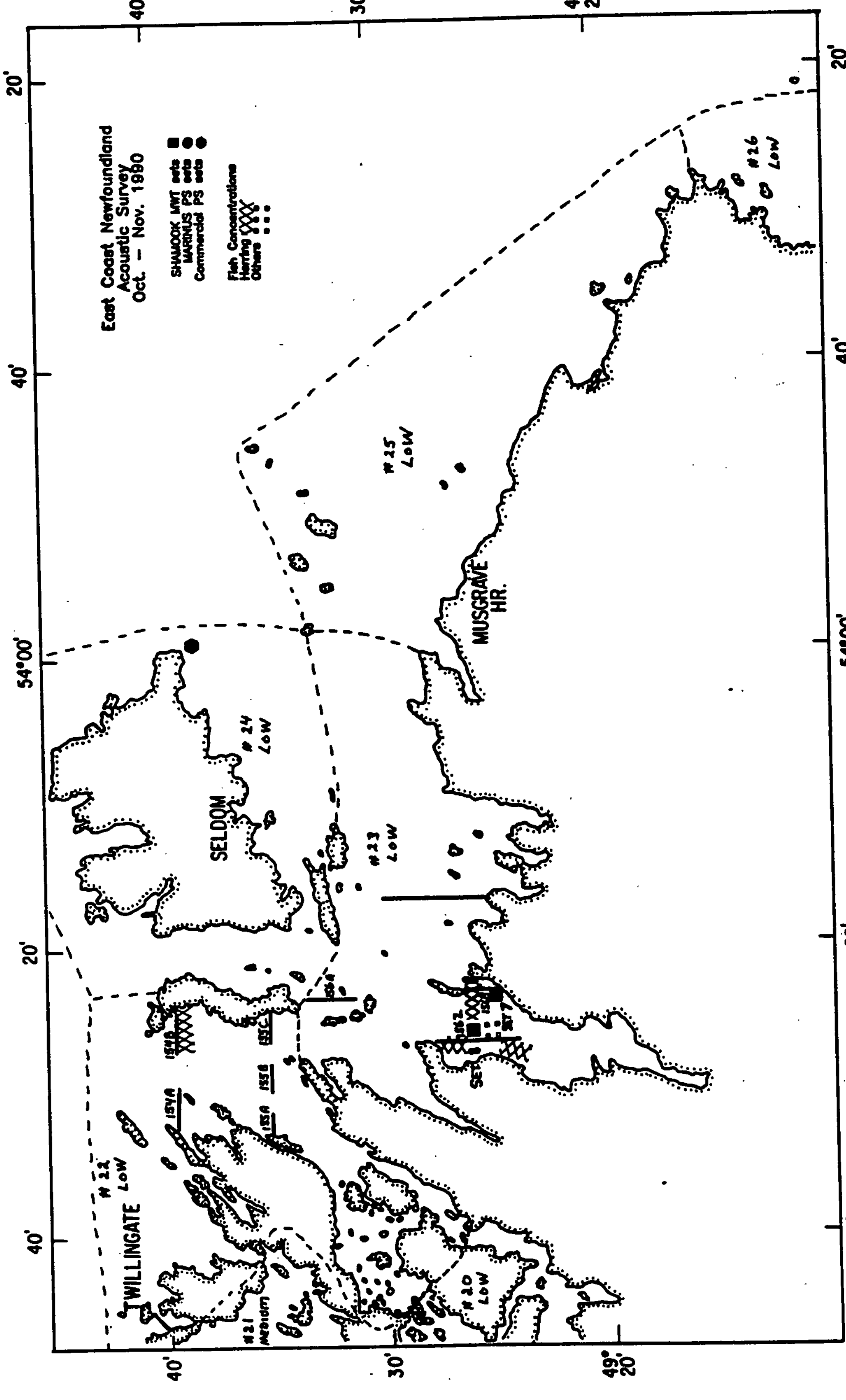

Fig. 8. Transects and set locations, acoustic purse seine survey, Hamilton Sound, 1990.

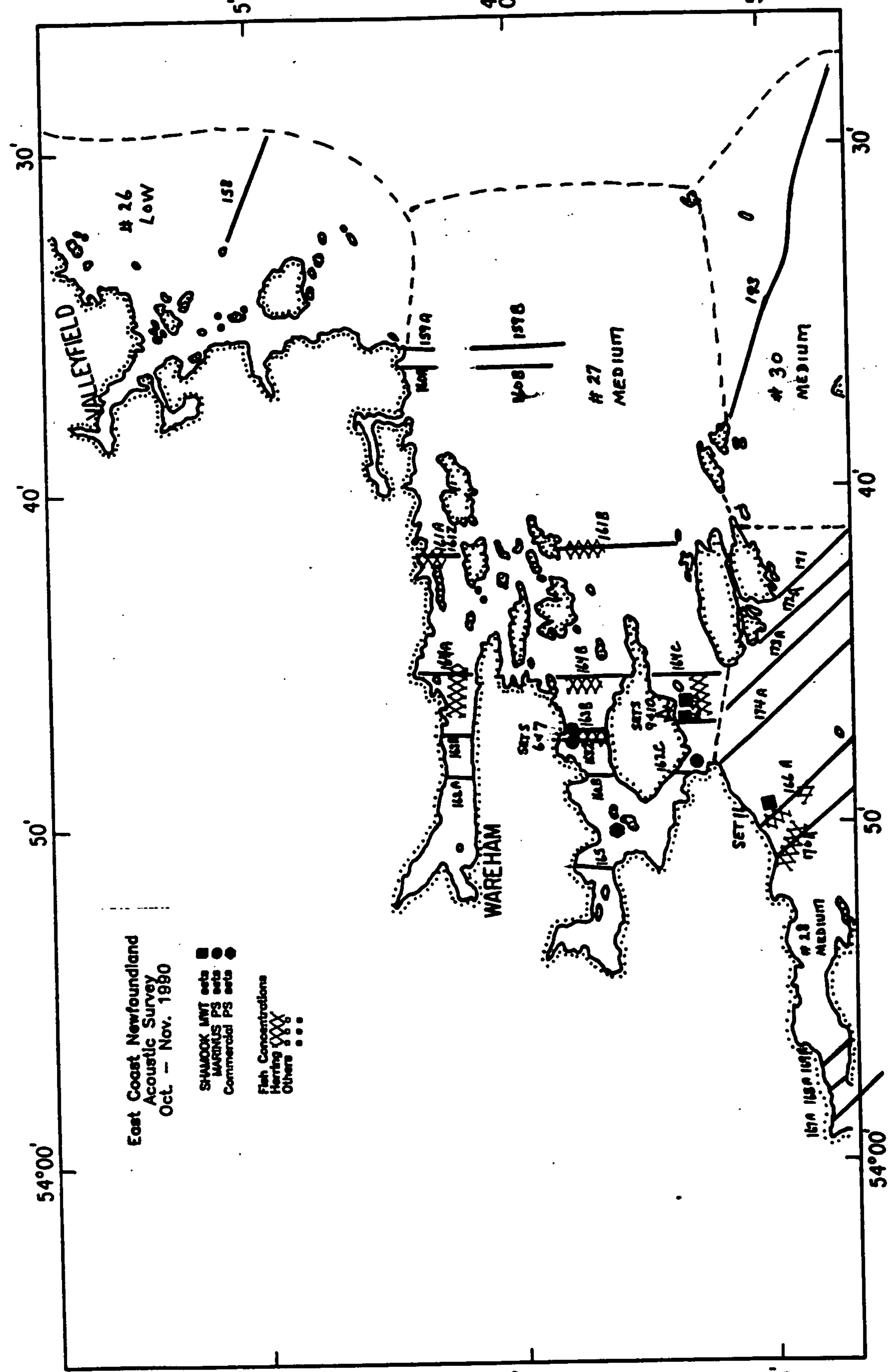

Fig. 9. Transects and set locations, acoustic purse seine survey, Bonavista Bay North, 1990.

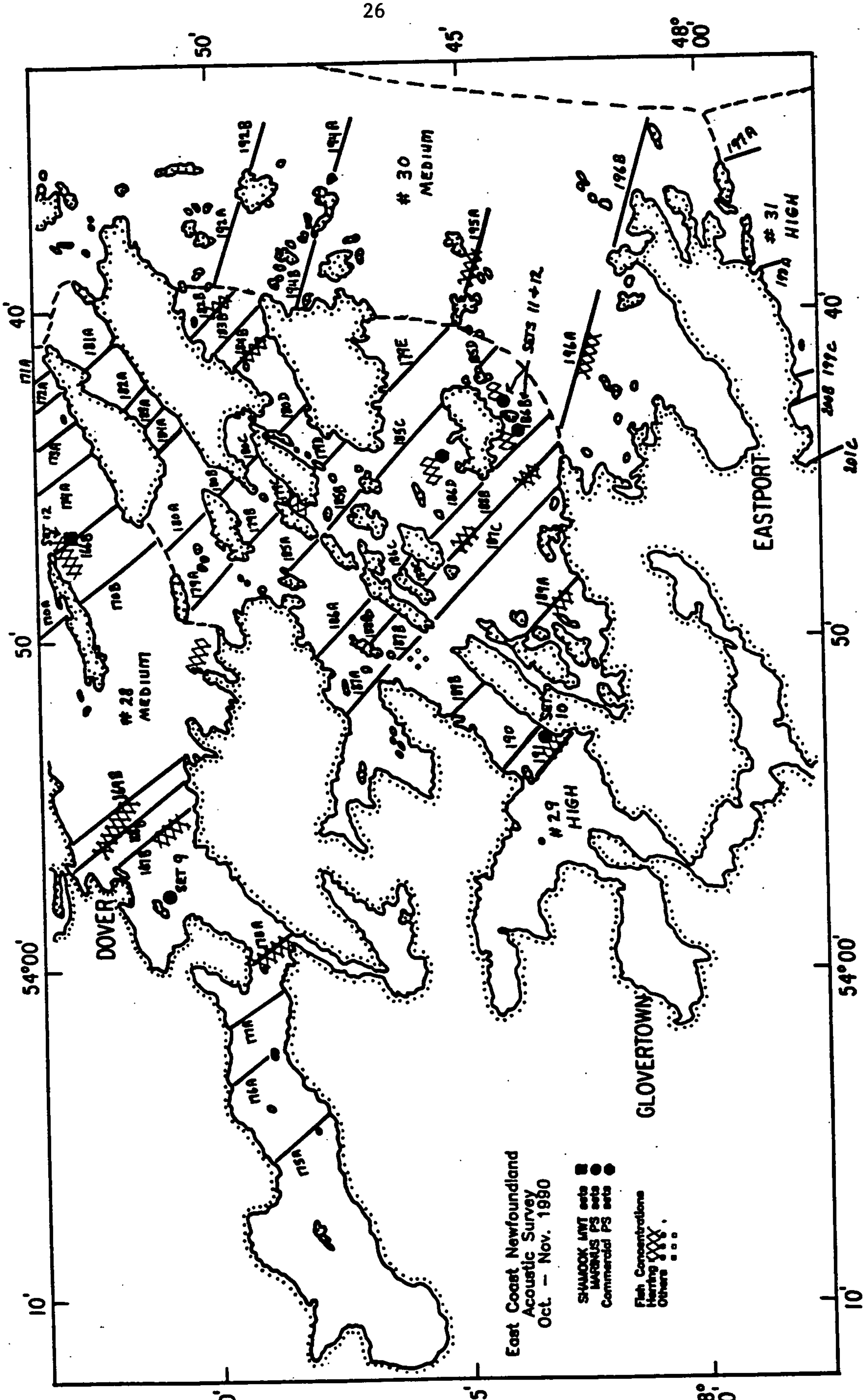

Fig. 10. Transects and set locations, acoustic purse seine survey, Bloody Reach B.B., 1990.

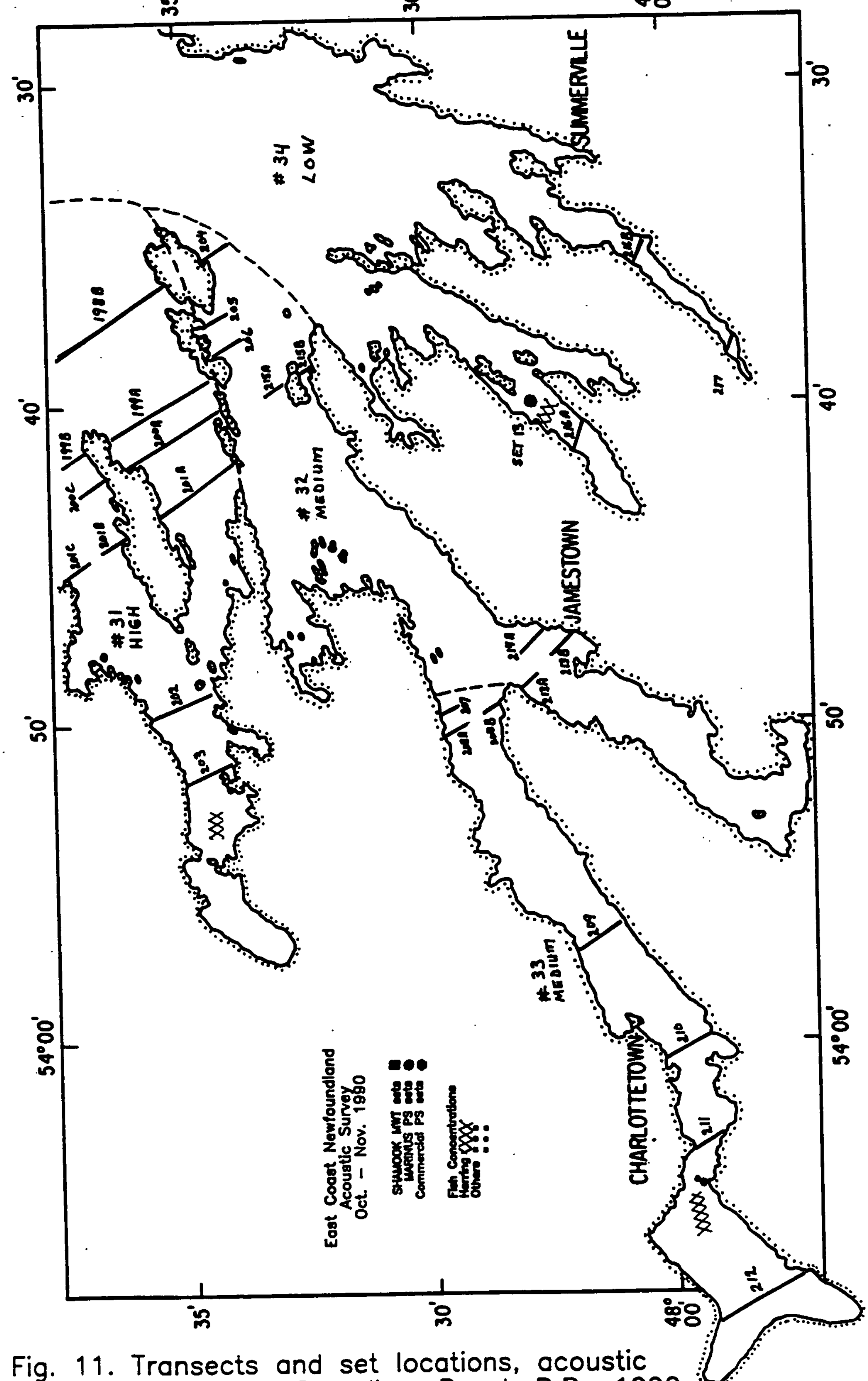

Fig. 11. Transects and set locations, acoustic purse seine survey, Chandlers Reach B.B., 1990.

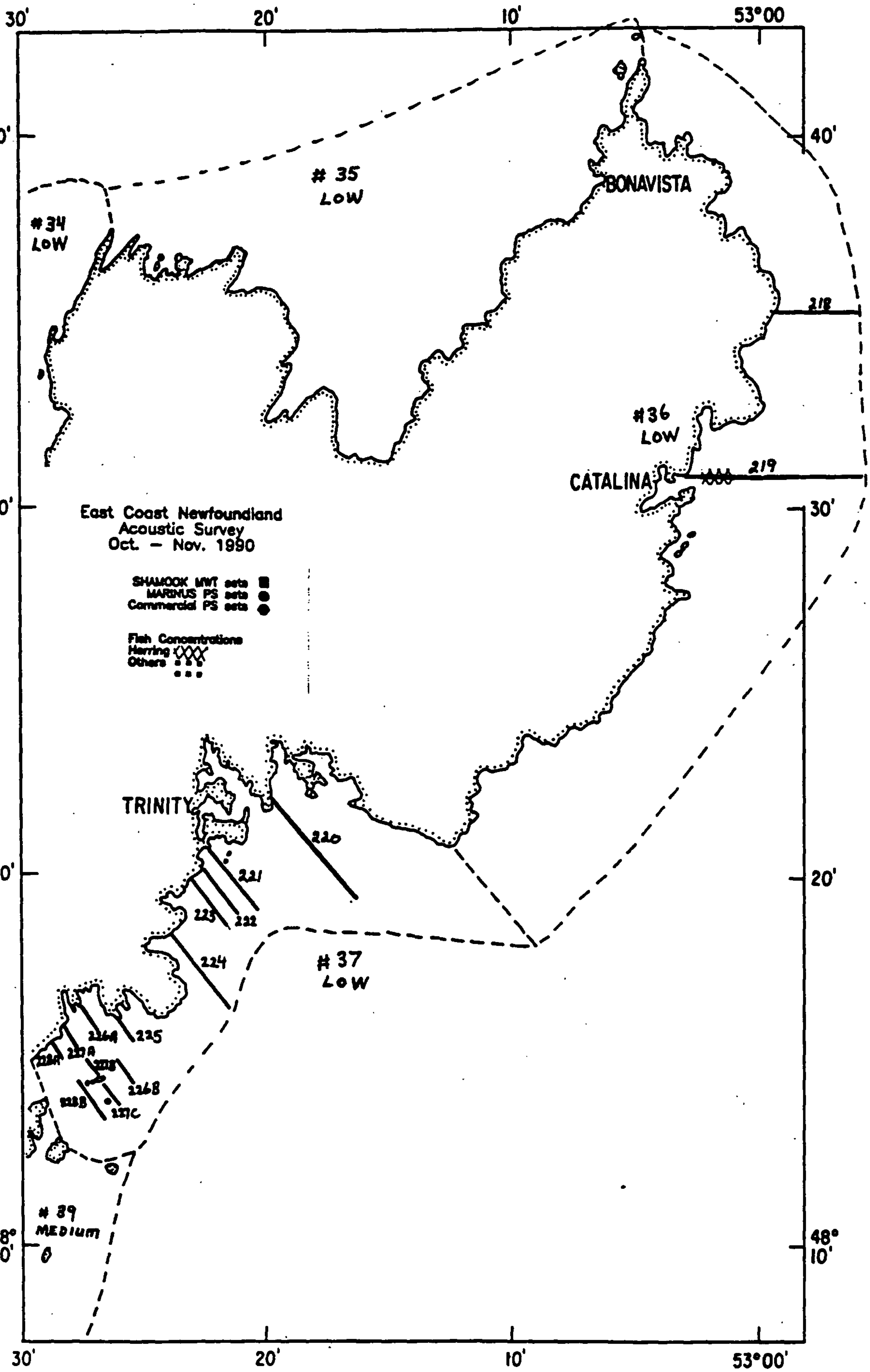

Fig. 12. Transects and set locations, acoustic purse seine survey, Bonavista – Trinity, 1990.

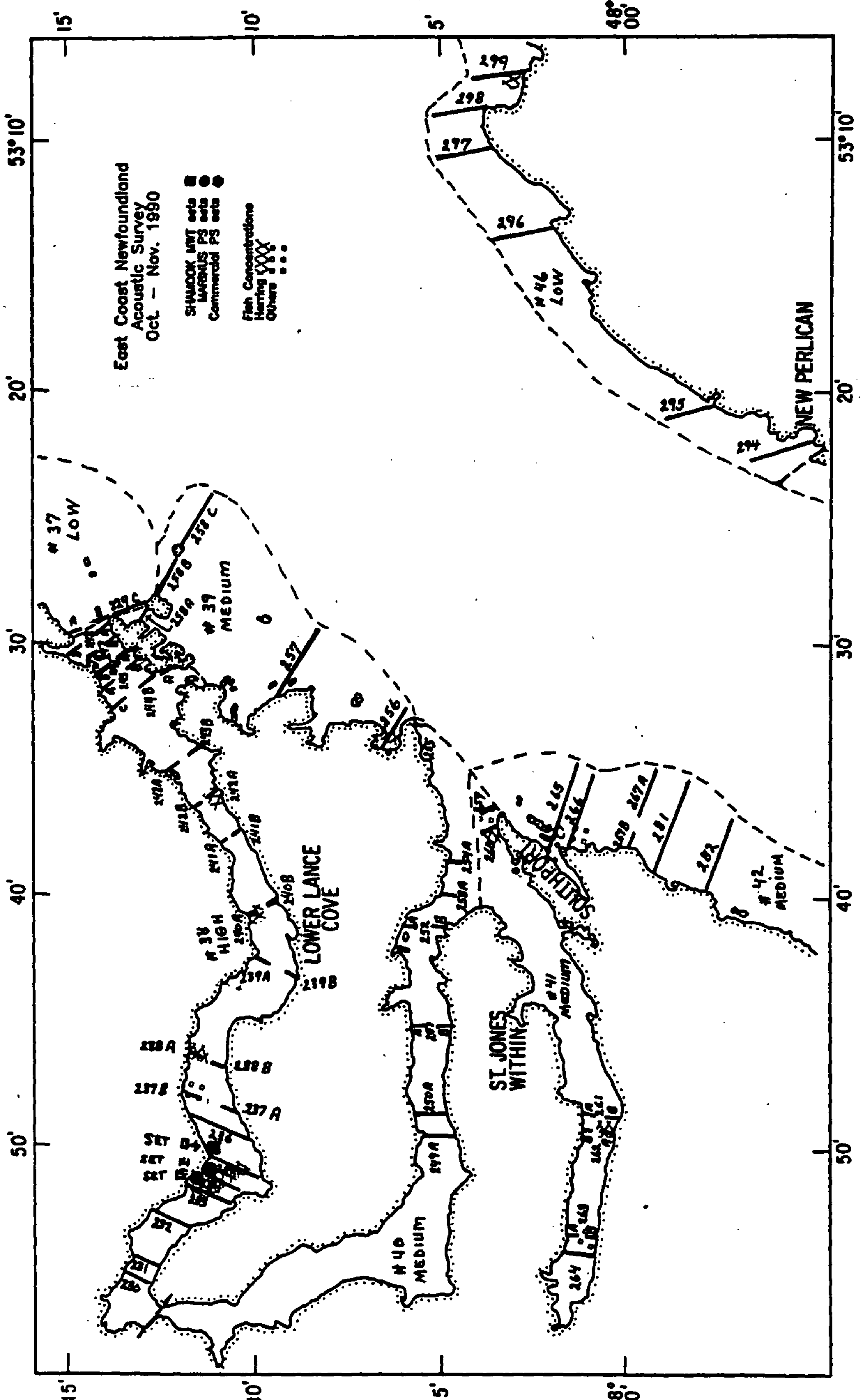

Fig. 13. Transects and set locations, acoustic purse seine survey, Smith and Random Sounds T.B., 1990.

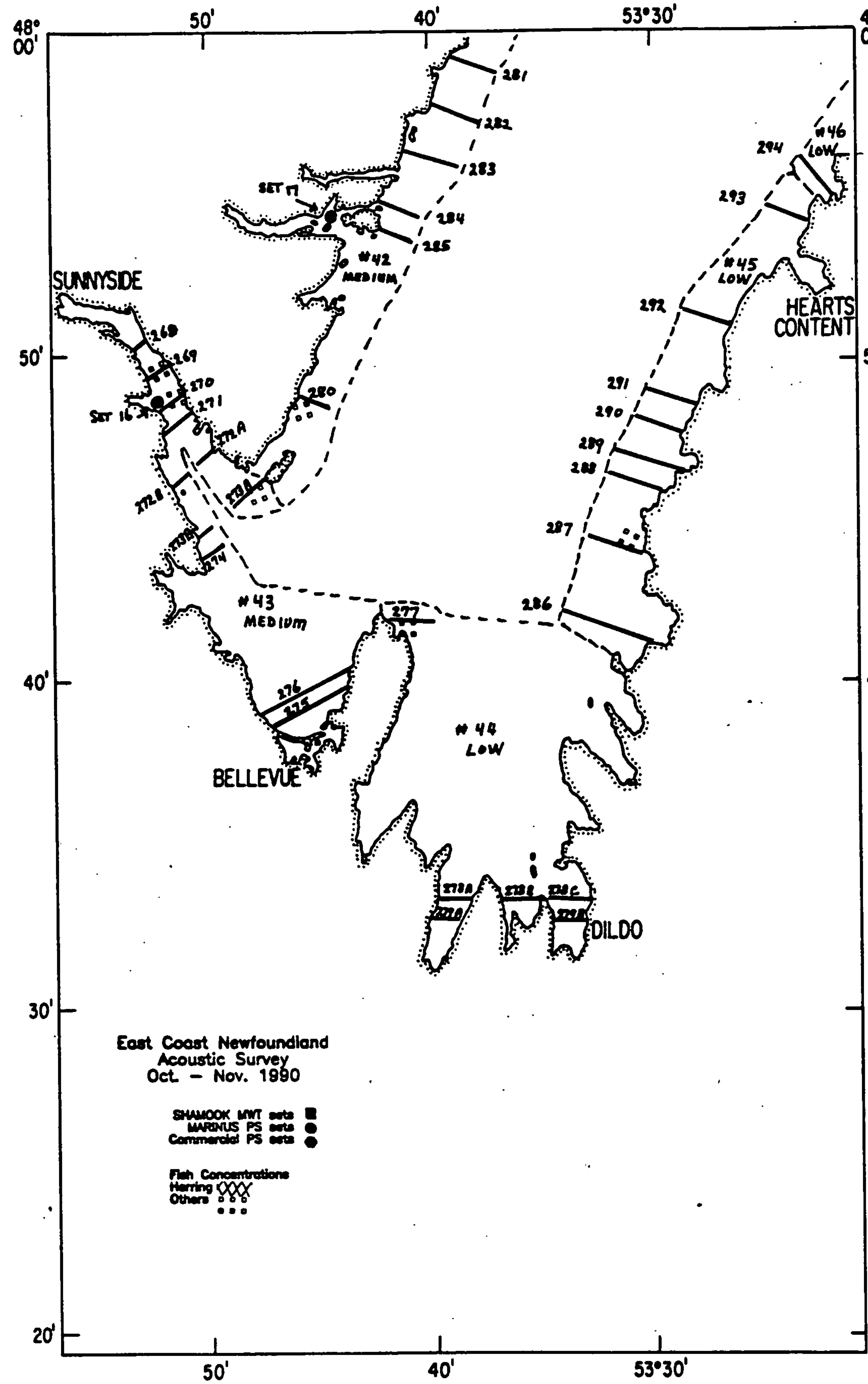

Fig. 14. Transects and set locations, acoustic purse seine survey, inner Trinity Bay, 1990.

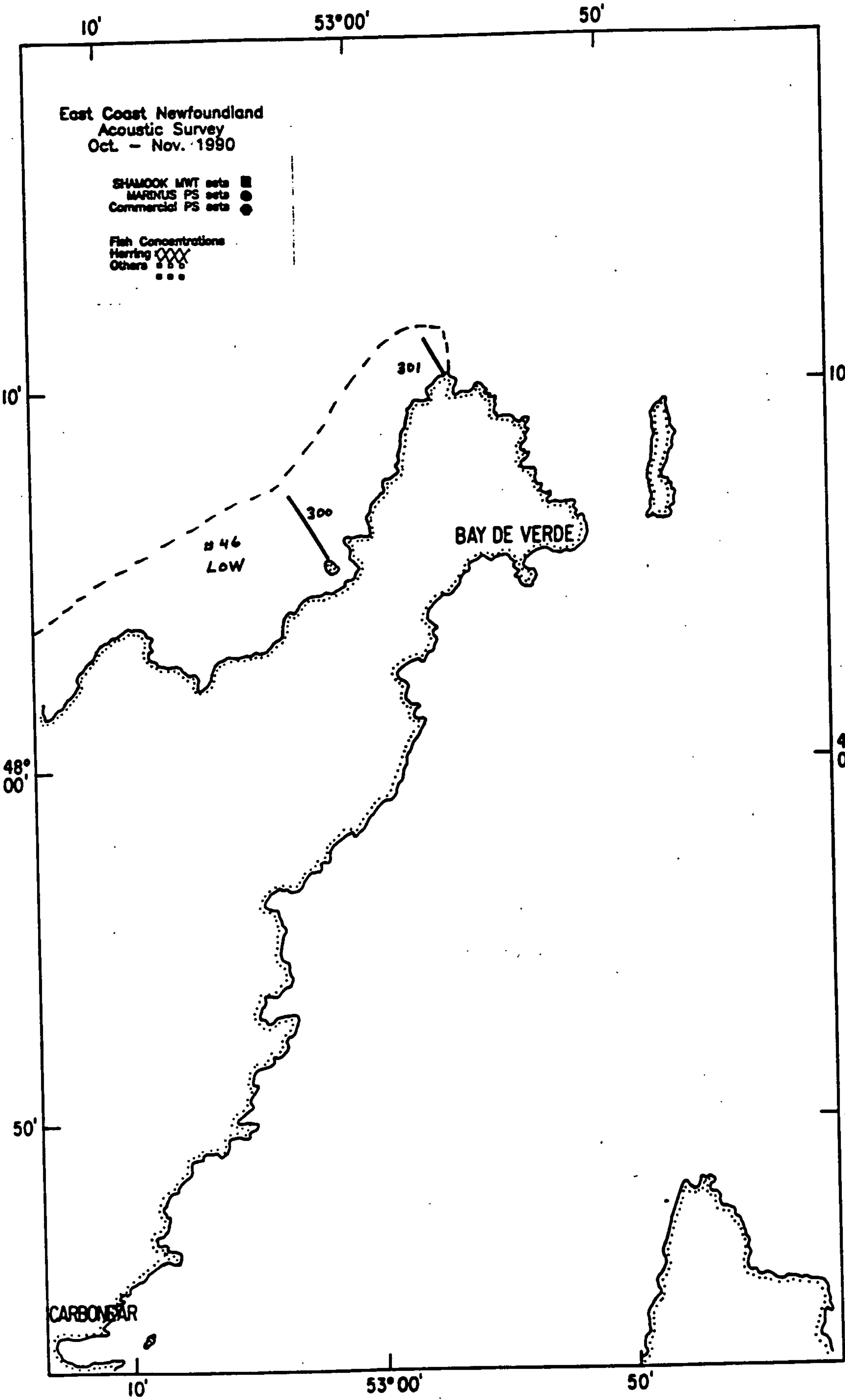

Fig. 15. Transects and set locations, acoustic purse seine survey, Trinity – Conception Bays, 1990.

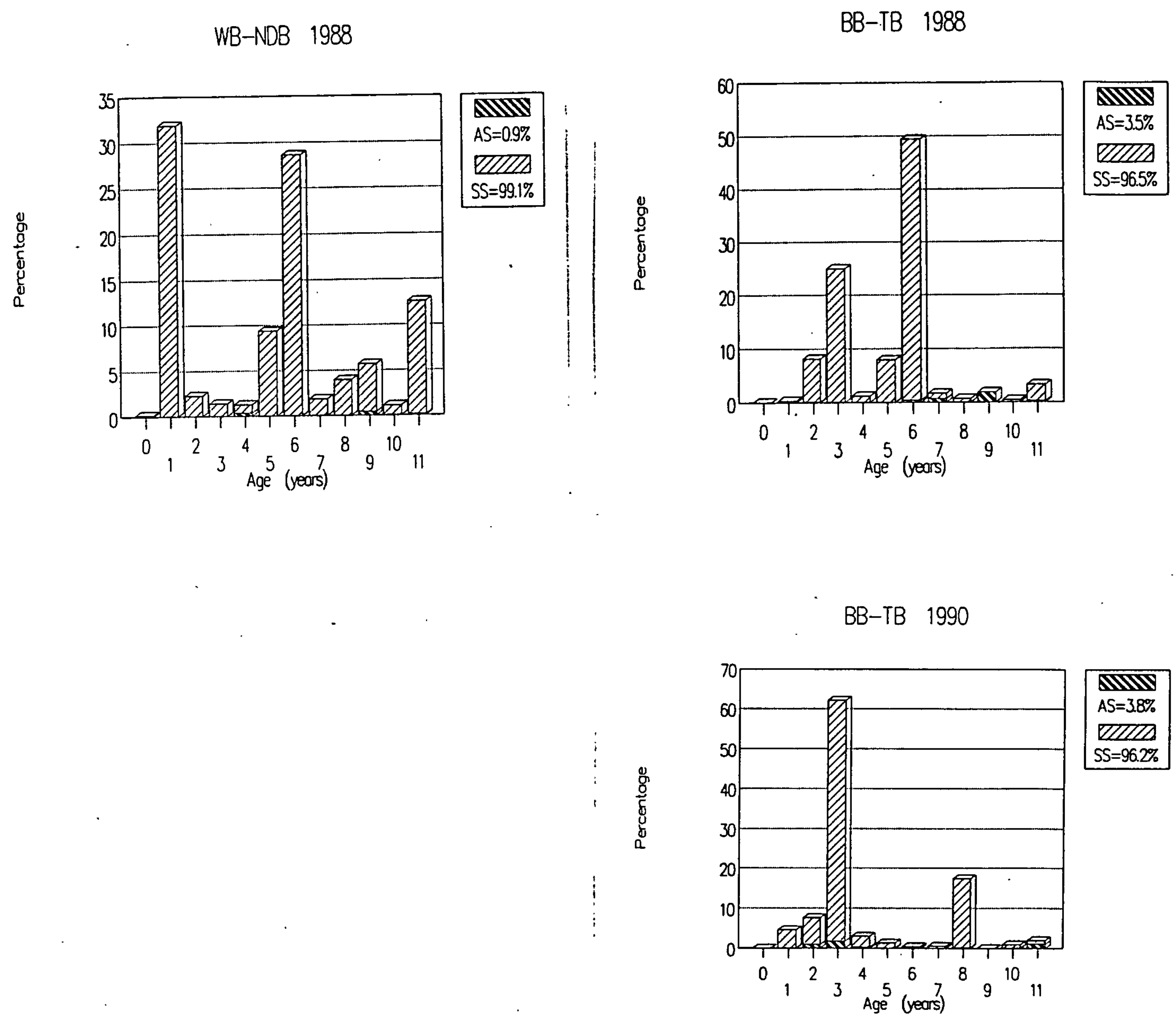

Fig. 16. Stock age composition of herring from acoustic purse seine surveys, 1988 and 1990, for White Bay-Notre Dame Bay (WB-NDB) and Bonavista Bay-Trinity Bay (BB-TB).

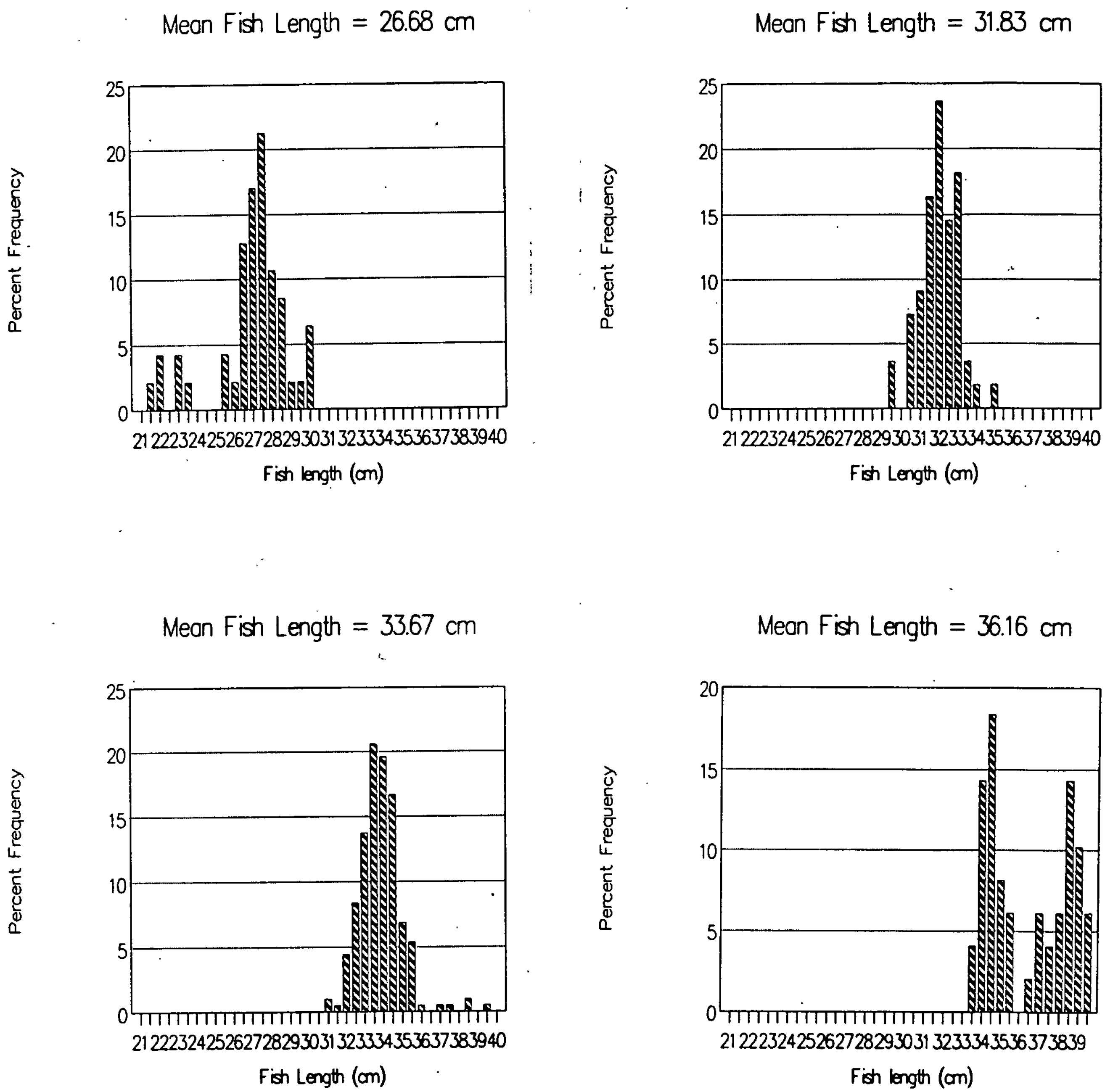

Fig. 17. Length distributions of the four herring samples used to determine target strength-fish length relationship within the net enclosure, Smith Sound, Trinity Bay, May 1990.

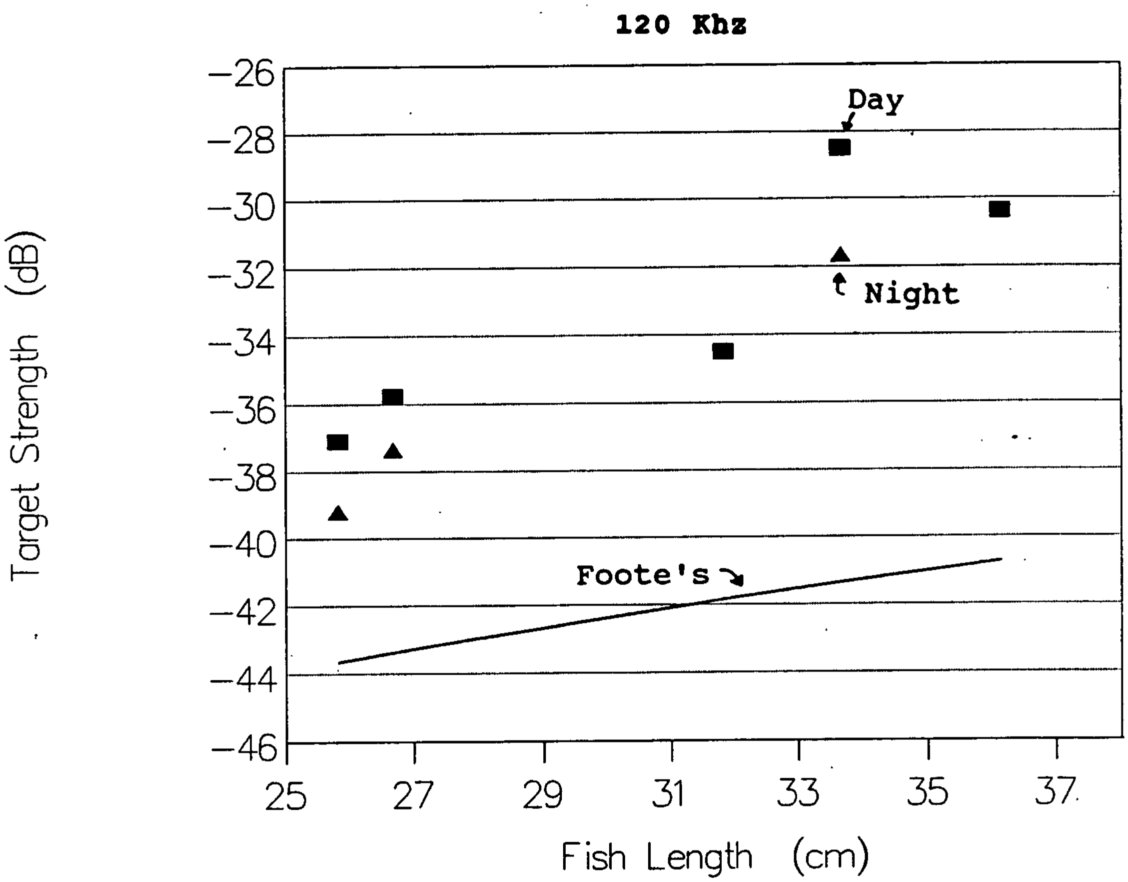

Fig. 18. Average target strengths measured at 120 kHz from net enclosed herring, Smith Sound, Trinity Bay, 1989 and 1990, where filled squares are average target strengths measured during the day and filled triangles are average target strengths measured during the night.

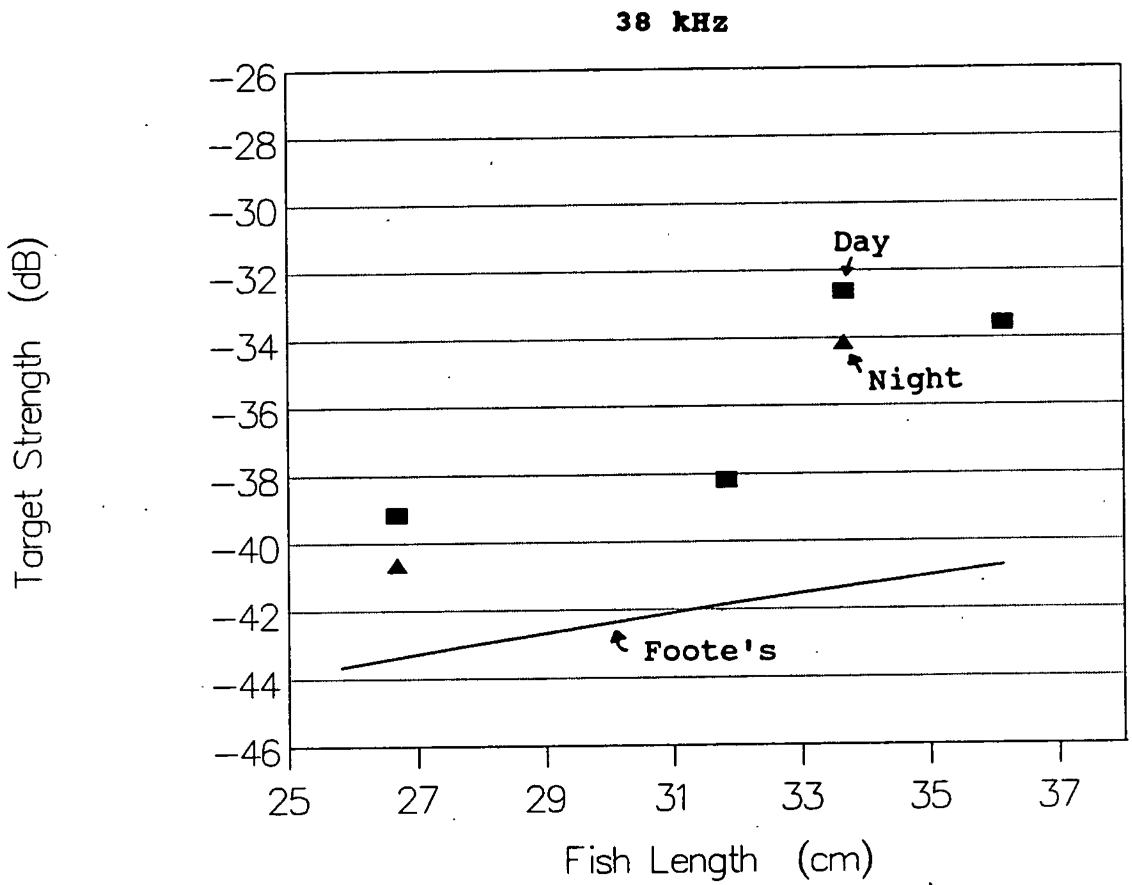

Fig. 19. Average target strengths measured at 38 kHz from net enclosed herring, Smith Sound, Trinity Bay, 1990, where filled squares are average target strengths measured during the day and filled triangles are average target strengths measured during the night.

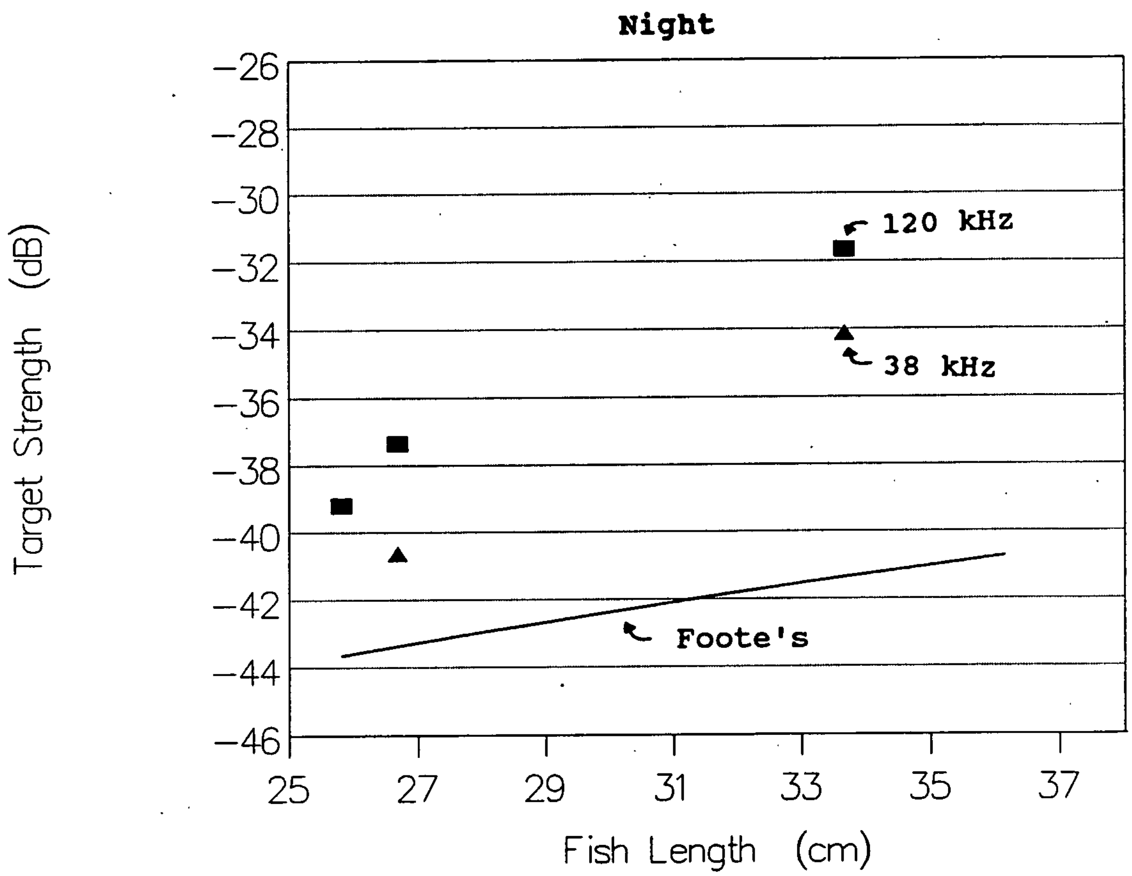

Fig. 20. Average target strengths derived from net enclosed herring, Smith Sound, Trinity Bay, 1989 and 1990, where filled squares are averages measured during the night at 120 kHz and filled triangles are averages measured during the night at 38 kHz.

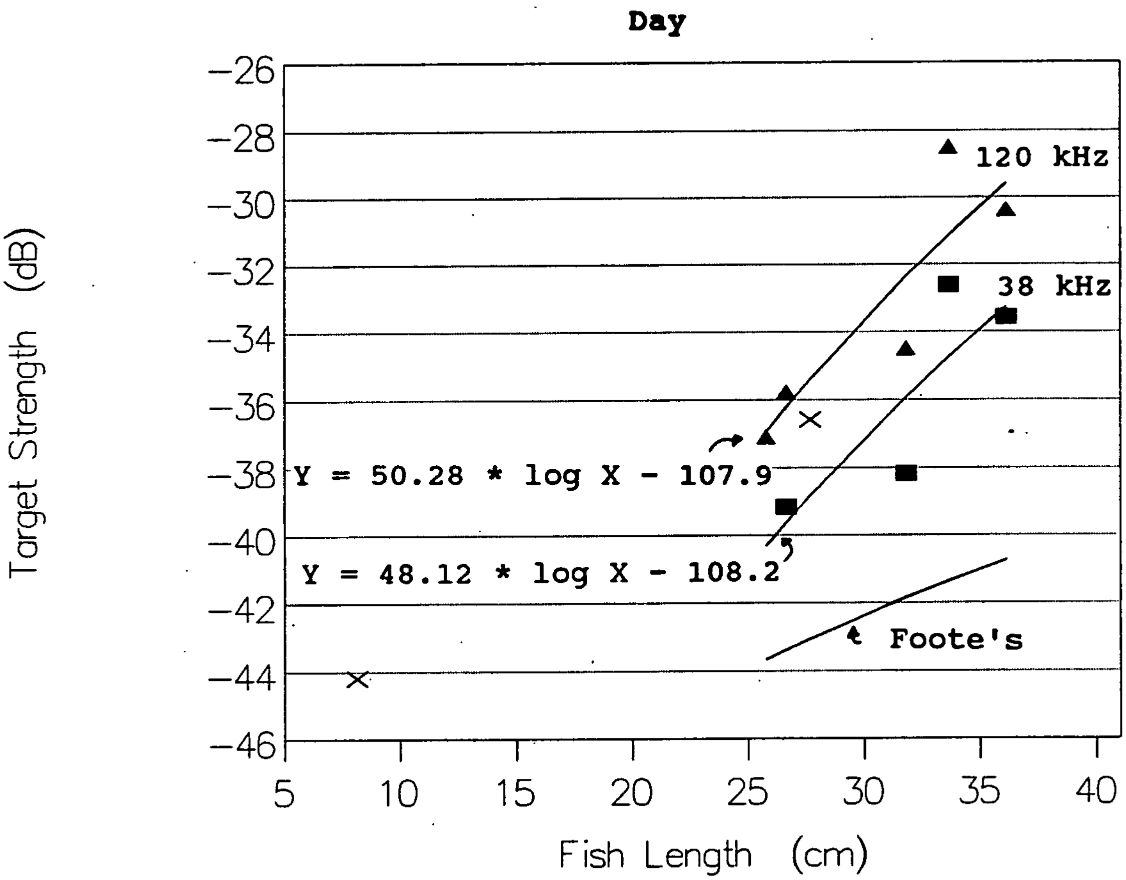

Fig. 21. Target strength-fish length relationships derived from net enclosed herring, Smith Sound, Trinity Bay, 1989 and 1990, where filled triangles are average target strengths measured during the day at 120 kHz, and filled squares are average target strengths measured during the day at 38 kHz. (The X's are in situ target strengths measured during 1990 acoustic surveys.)

Appendix 1. Calibration parameters for the BioSonics 120 kHz hydroacoustic system, calibrated on October 4, 1990 and used during the 1990 east coast herring acoustic survey.

105-87-025 / 33-120-1025-026

Sounder / Transducer

BioSonics
SYSTEM CALIBRATION

Page 1 of 2

Customer Name: DFO
(Company or Agency

Date: 10/4/90

Project #: SR-775

BioSonics Contact Person: Bob Johnson

Calibrator: RST

Echo Sounder

Model # 105 Serial # 025 Frequency 120 kHz

Rec. Gain (RG) 0 dB Bandwidth 5 kHz (α) FW

Blanking Distance NA m Calibration Range, (R_{CAL}) 20 m

Total TVG Range 2.0 to 200 m 20/40 log R cross. dist. m

Transducer & Cable

Transducer S/N: 026 Beam width 10°/25°

Cable Length 100' / 100' Cable Type Deck / Tow Cable S/N 141-89-520 / 147-89-051

Standard Transducer

Serial # 102 Type EDO-6846

Ts 148.58 dB µPa/Vrms @ 1 meter Ss -195.88 dBv/µPa

Tank Parameters

Transducer separation, (R_s) 1.18 m, Water Temperature 17 °C

CALIBRATION - SYSTEM RECEIVING SENSITIVITY

Transmission Loss, TL = 20 log R + αR = 1.47 dB (R = R_s meters)

TVG gain, G_{TVG40} 52.04 dB (40 Log R_{CAL} + 2 α R_{CAL})

G_{TVG20} 26.02 dB (20 Log R_{CAL} + 2 α R_{CAL})

Voltage into Standard, v_s = 119.7 mV V_s = -18.44 dBv (RMS)

Acoustic Level, L = Ts + Vs - TL = 128.7 dB µPa
(at receiving transducer)

Receiver #1 40 log R*

Voltage out of Receiver, v_{det} = 3.02 V_{det} 9.60 dBv

Receiving Sensitivity, Gx = V_{det} - L = -119.1 dBv/µPa @ R_{CAL} meters

G_1 = G_x-G_{TVG40} - RG = -171.1 dBv/µPa @ 1 m

Receiver #1 20 log R*

Voltage out of Receiver, v_{det} = 2.41 V_{det} 7.64 dBv

Receiving Sensitivity, Gx = V_{det} - L = -121.0 dBv/µPa @ R_{CAL} meters

G_1 = G_x-G_{TVG20} - RG = -147.0 dBv/µPa @ 1 m

BioSonics
SYSTEM CALIBRATION

105-87-025 / 33-120-1025-026
Sounder / Transducer

Page 2 of 2

Simultaneous 20 log R
Voltage out of Receiver, v_{det} = 3.02 V_{det} 9.60 dBv

Receiving Sensitivity, $Gx = V_{det} - L$ = -119.1 dBv/µPa @ R_{CAL} meters

$G_1 = G_x - G_{TVG20} - RG$ = -145.1 dBv/µPa @ 1 m

Receiver #2 40 log R*
Voltage out of Receiver, v_{det} = 2.78 V_{det} 8.88 dBv

Receiving Sensitivity, $Gx = V_{det} - L$ = -119.8 dBv/µPa @ R_{CAL} meters

$G_1 = G_x - G_{TVG40} - RG$ = -171.8 dBv/µPa @ 1 m

Receiver #2 20 log R*
Voltage out of Receiver, v_{det} = 2.24 V_{det} 7.00 dBv

Receiving Sensitivity, $Gx = V_o - L$ = -121.7 dBv/µPa @ R_{CAL} meters

$G_1 = G_x - G_{TVG20}$ = -147.7 dBv/µPa @ 1 m

Gain Difference
40 Log R gain difference G_1 (CH 1) -G_1 (CH 2) = 0.7 dB

CALIBRATION SOURCE LEVEL

Transmission Loss, $TL = 20 \log R_s + \alpha R_s$ = 1.47 dB
Source Level, $SL = V_{so} - Ss + TL$
V_{so} = 20 Log (vrms out of standard)

Pulse Width 0.4 ms

TRANSMITTER SETTING	V_{out} STANDARD XDUCER		V_{so}	-Ss + TL	SL SOURCE LEVEL
dB	Vpp	Vrms	dBv	dBv	dB µ Pa @ 1 m.
NA	16.50	5.83	15.32	197.4	+ 212.7
					+
					+
					+
					+

Comments SL + G_1 = 41.6 dB

Appendix 2. Calibration parameters for the BioSonics 120 kHz hydroacoustic system, calibrated February 6, 1991, after the 1990 east cost acoustic survey.

105-87-025 / 33-120-1025-026
Sounder / Transducer

BioSonics
SYSTEM CALIBRATION

Page 1 of 2

Customer Name: (Company or Agency) DFO (Wheeler)
Date: 2-6-91
Project #: SR-836
BioSonics Contact Person: Bob Johnson
Calibrator: RST

Echo Sounder
Model # 105 Serial # 025 Frequency 120 kHz
Rec. Gain (RG) 0 dB Bandwidth 5 kHz (α) Ø
Blanking Distance — m Calibration Range, (R_{CAL}) 20 m
Total TVG Range 2.0 to 200 m 20/40 log R cross. dist. 16 m

Transducer & Cable
Transducer S/N: 026 Beam width 10°/25°
Cable Length 100' Tow / 100' Deck Cable Type SB Cable S/N 147-89-051 / 141-89-520

Standard Transducer
Serial # 102 Type EDO-6846
Ts 148.85 dB µPa/Vrms @ 1 meter Ss -195.67 dBv/µPa

Tank Parameters
Transducer separation, (R_s) 1.2 m, Water Temperature 13 °C

CALIBRATION - SYSTEM RECEIVING SENSITIVITY

Transmission Loss, TL = 20 log R + αR = 1.58 dB (R = R_s meters)

TVG gain, G_{TVG40} 52.04 dB (40 Log R_{CAL} + 2 α R_{CAL})
G_{TVG20} 26.02 dB (20 Log R_{CAL} + 2 α R_{CAL})

Voltage into Standard, v_s = 100.7 mV V_s = -19.94 dBv (RMS)
Acoustic Level, L = Ts + Vs - TL = 127.3 dB µPa
(at receiving transducer)

Receiver #1 40 log R*
Voltage out of Receiver, v_{det} = 2.475 V_{det} 7.87 dBv

Receiving Sensitivity, Gx = V_{det} - L = -119.5 dBv/µPa @ R_{CAL} meters

$G_1 = G_x - G_{TVG40}$ - RG = -171.5 dBv/µPa @ 1 m

Receiver #1 20 log R*
Voltage out of Receiver, v_{det} = 1.985 V_{det} 5.96 dBv

Receiving Sensitivity, Gx = V_{det} - L = -121.4 dBv/µPa @ R_{CAL} meters

$G_1 = G_x - G_{TVG20}$ - RG = -147.4 dBv/µPa @ 1 m

Appendix 2. Continued ...

BioSonics
SYSTEM CALIBRATION

105-87-025 / 33-120-1025-026
Sounder / Transducer

Simultaneous 20 log R

Voltage out of Receiver, v_{det} = 2.510 V_{det} 7.99 dBv

Receiving Sensitivity, $Gx = V_{det} - L$ = -119.3 dBv/µPa @ R_{CAL} meters

$G_1 = G_x - G_{TVG20} - RG$ = -145.4 dBv/µPa @ 1 m

Receiver #2 40 log R*

Voltage out of Receiver, v_{det} = 2.390 V_{det} 7.57 dBv

Receiving Sensitivity, $Gx = V_{det} - L$ = -119.8 dBv/µPa @ R_{CAL} meters

$G_1 = G_x - G_{TVG40} - RG$ = -171.8 dBv/µPa @ 1 m

Receiver #2 20 log R*

Voltage out of Receiver, v_{det} = 1.925 V_{det} 5.69 dBv

Receiving Sensitivity, $Gx = V_o - L$ = -121.6 dBv/µPa @ R_{CAL} meters

$G_1 = G_x - G_{TVG20}$ = -147.7 dBv/µPa @ 1 m

Gain Difference

40 Log R gain difference G_1 (CH 1) - G_1 (CH 2) = .3 dB

CALIBRATION SOURCE LEVEL

Transmission Loss, $TL = 20 \log R_s + \alpha R_s$ = 1.58 dB

Source Level, $SL = V_{so} - Ss + TL$

V_{so} = 20 Log (vrms out of standard)

Pulse Width 0.4 ms

TRANSMITTER SETTING	V_{out} STANDARD XDUCER		V_{so}	-Ss + TL	SL SOURCE LEVEL
dB	Vpp	Vrms	dBv	dBv	dB µ Pa @ 1 m.
—	16.75	5.92	15.45	197.3	+ 212.7
					+
					+
					+
					+

Comments $SL + G_1 = 41.2$

Appendix 3. Formulas for calculating estimates of mean densities, variances, and total biomass for herring acoustic survey.

Given the following:

L - number of strata

l_{hi} - length (n mi) of transect i in stratum h

n_h - number of blocks sampled in stratum h

A_h - surface area (m²) of stratum h

y_{hi} - biomass (kg) of fish estimated in block i of stratum h

Then:

1) the area (m²) sampled for transect i in stratum h

$$L_{hi} = (l_{hi} * 1852 \text{ m}) * 926 \text{ m}$$

where due to navigational precision, the minimum distance between transects was predetermined to be 0.5 n mi (926 m)

2) the mean area (m²) for blocks sampled in stratum h

$$\bar{L}h = \frac{\sum_{i=1}^{n_h} L_{hi}}{n_h}$$

3) the weighting factor for sampled block i in stratum h

$$K_{hi} = \frac{L_{hi}}{\bar{L}_h}$$

to account for differences in the areas of each block sampled, i.e. due to different transect lengths

Appendix 3. Continued...

4) the density (kg/m^2) for block i in stratum h

$$x_{hi} = \frac{y_{hi}}{L_{hi}}$$

5) the mean density (kg/m^2) per unit area for stratum h

$$\bar{x}_h = \frac{\sum_{L=1}^{n_h} (K_{hi} * x_{hi})}{n_h} = \frac{\sum_{L=1}^{n_h} \frac{L_{hi}}{\bar{L}_h} * \frac{y_{hi}}{L_{hi}}}{n_h} = \frac{\sum_{L=1}^{n_h} \frac{(y_{hi})}{\bar{L}_h}}{n_h}$$

6) the total fish biomass (t) for stratum h

$$\hat{Y}_h = (A_h * \bar{x}_h)/1000$$

7) the variance estimate for stratum h

$$0^2 \hat{Y}h = \frac{\sum_{L=1}^{n_h} K_{hi}^2 (x_{hi} - \bar{x}_h)^2}{n_h (n_h - 1)}$$

8) the total fish biomass (t) for all strata

$$\hat{Y} = \sum_{h=1}^{L} \hat{Y}_h$$

9) the variance estimate for all strata

$$0^2 \hat{Y} = \sum_{h=1}^{L} A_h^2 * 0^2 \hat{Y}_h$$