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Newfoundland Southeast Coast Herring - 1990 Acoustic Survey Results

by

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Abstract

The results of an acoustic survey of the Fortune Bay and St. Mary's Bay-Placentia Bay herring stock complexes, conducted during the winter 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. Foote's (1987) target strength/fish length relationship was used for the conversion of backscattering to biomass. Preliminary results of an experimental target strength study of herring using the 120 kHz system are also presented and suggest a substantial difference (+4.5 dB) in the target strength of 25.8 cm herring compared to that derived using Foote's relationship. The implications of the experimental target strength results are discussed and the objectives of future experimental target strength research are outlined.

Résumé

Le présent document expose les résultats d'un relevé acoustique des zones de stock de hareng des baies de Fortune, St. Mary's et Placentia réalisé au cours de l'hiver 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. On s'est servi du rapport de Foote (1987) entre l'index de réflexion d'un but et la longueur du poisson pour convertir la rétrodiffusion en biomasse. Les résultats préliminaires d'une étude de l'index de réflexion du hareng au moyen d'un système de 120 kHz sont également présentés; ils dénotent apparemment un important écart (+4,5 dB) entre l'index de réflexion du hareng de 25,8 cm et celui qui est déduit du rapport de Foote. On traite des conséquences des résultats de l'étude de l'index de réflexion et des objectifs des prochaines expériences fondées sur cet index.

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).

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.

The three northern stocks were surveyed during the fall of 1988, i.e. fiscal year 1988-89, and the results of the survey formed the basis of scientific advice in 1989 (Wheeler et al. 1989). This paper documents the results of an acoustic survey of the two southern stocks conducted from January 15, 1990 to March 2, 1990 (fiscal year 1989-90). Prior to 1990, the last acoustic survey of these two stocks was conducted in 1986 (Wheeler and Chaulk 1987).

Acoustic Survey Design

The survey commenced at Pass Island in Fortune Bay and terminated at St. Joseph's in St. Mary's 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, for the first time during a herring acoustic survey, the R.V. SHAMOOK was equipped with a midwater trawl to provide extra sampling capability. This was in response to a CAFSAC recommendation that measures be taken to ensure that sufficient samples are collected randomly to provide reliable estimates of population age structure.

Each of the two stock areas was divided into low and high density strata based upon distributional patterns observed during previous surveys. Fortune Bay was divided into 14 strata (Fig. 2-4) and St. Mary's Bay-Placentia Bay into 25 strata (Fig. 5-8). It was decided prior to the survey to allocate sampling intensity (total transect length) on a 2:1 ratio between high and low density areas, respectively.

The survey design consisted of a series of randomly selected parallel transects from shore to the 120 m depth contour, with a minimum of three transects in each stratum. Each transect was surveyed at a vessel speed of 6.0 K. Navigational error dictated that transects be spaced a minimum of 926 m (0.5 n mi) apart. Reference lines were drawn parallel to the coastline. Random transects were chosen perpendicular to these lines given the constraint of 926 m separation between transects. Due to the irregular nature of the coastline, transects within strata were of unequal length.

Biological Sampling

Biological sampling was good during the survey (Table 1), even though there were only ten successful sets, four purse seine and six midwater trawl, during the 31 survey days. Herring were caught in five of the ten successful sets. In Fortune Bay, herring were sampled from two strata only; however, these strata accounted for 98% of the stock biomass estimate. In Placentia Bay, research samples were obtained from one stratum; however, this stratum accounted for 88% of the biomass estimate. There was also a commercial sample from the stratum which accounted for the remaining 12% of the biomass estimate. This sample was obtained from a purse seine set by a commercial vessel on a school which had been integrated less than 24 hours earlier. There were no herring either integrated or sampled in St. Mary's Bay. However, there were four successful sets, three by purse seine and one by midwater trawl, in which immature capelin were caught.

In order to calculate mean fish lengths and weights, by stratum (Table 2), as is necessary for the fish length-target strength per kg relationship and for estimating population numbers at age, the research samples obtained from strata 9 and 11 in Fortune Bay were used for their respective strata. For the remaining strata in Fortune Bay in which herring were detected but for which samples were not available, means from samples collected in strata 9 and 11 combined, were used. Similarly, for Placentia Bay, research samples from stratum 11 were used to calculate mean fish lengths, weights, and population numbers at age for that stratum. The commercial samples collected from stratum 12 were used for that stratum, and a mean from both was used for other strata in which herring were detected.

In both of the stock areas surveyed, spring spawners were dominant (Fig. 9) and the percentages were comparable with those derived from the most recent acoustic survey conducted in 1986. Spring spawners also accounted for greater than 80% of the 1989 commercial catch in both stock areas (Wheeler et al. 1990).

For St. Mary's Bay-Placentia Bay, the 1982 year-class of spring spawners was dominant (by number) and accounted for 38% of the population estimate (Fig. 9). The 1987 and 1986 year-classes of spring spawners accounted for 13% and 10% of the population estimate respectively and the 1979 year-class of autumn spawners still represented 10% of the population total. In 1986, the 1982 year-class was also the largest and represented approximately 60-80% of the total. In Fortune Bay, two year-classes dominated (Fig. 9); 1987 spring spawners accounted for 39% of the population estimate by number and 1982 spring spawners for 33% of the estimate. The 1983 year-class of spring spawners also represented 13% of the total. In 1986, the 1982 year-class was the only dominant one and accounted for in excess of 60% of the total population numbers.

Acoustic Data Analysis

1) Species Identification

A two-staged process (Wheeler et al. 1989) was again used to identify herring concentrations for inclusion in data analysis. All fish schools, regardless of species, were first identified from chart recorder tracings and acoustic logbook observations recorded during the survey. Detected voltages from all other sources were eliminated prior to further analysis. The shape of the echo trace of each of the fish schools was then viewed with an oscilloscope to distinguish between herring, capelin, and other species. This method involves examination of peak voltage amplitudes, voltage peak to trough distances and distance between voltage peaks. The methodology is similar to that described by Rose and Leggett (1988) who used discriminant functions, for the identification of capelin, mackerel, and cod schools. Of the schools eliminated from the analysis (Table 3), most (89%) were identified as capelin. The majority (71%) of these concentrations were in St. Mary's Bay. The hydroacoustic backscatter of representative herring and capelin schools is shown in Figures 10 and 11. Herring schools are generally characterized by stronger total backscatter, shorter mean distance between voltage peaks and more well defined school edges. Capelin schools generate a weaker total backscatter, have greater inter-fish distances, and less well defined school edges. A data base of school integrated data is being developed for herring concentrations for which groundtruthing information is available. Once sufficient information is available, the data will be analyzed to determine if a discriminant function exists to distinguish herring from capelin, mackerel, cod, and other species.

2) Standard Target Calibration During 1990 Acoustic Survey

The hydroacoustic system used during the 1990 south coast acoustic survey was calibrated by BioSonics Inc. on December 8, 1989 immediately prior to the survey (Appendix 1). In addition, the system was calibrated with a standard target several times during the survey. The calibrated target strength provided with the standard sphere was -40.6 dB.

The results of the standard target calibrations during the survey (Fig. 12) were variable and high dependent upon soak time (i.e. the amount of time that the transducer and standard target were suspended in the water column prior to measurements being made). For soak times of less than two hours, target strength estimates for the sphere ranged from -47.2 dB to -36.5 dB. However, when soaked for greater than two hours, the range of target strength estimates was not as large, from -39.6 dB to -35.6 dB with a mean of -38.0 dB. It is hypothesized that this average difference, approximately 2.5 dB from the expected value, is caused by the cold water temperatures in which the system was operating. Surface water temperatures (Table 1) became progressively colder throughout the survey, from a high of 0.93°C in Fortune Bay to a low of -1.39°C in St. Mary's Bay. BioSonics Inc. engineers have speculated that at such low temperatures, the physical properties of the transducer's ceramics may have changed enough to produce a difference of 2.5 dB. It is further hypothesized that the greater variability of results for soak times less than two hours may have been caused by minute ice crystals forming on the face of the transducer when it was placed in such cold water temperatures. During the survey, the v-fin and transducer were stored on deck, subject to air temperatures ranging from -25°C to +0°C. A certain acclimation period is required for the transducer to equilibrate from the colder air to the warmer water.

Standard target calibration data collected over a seven hour period in Trinity Bay, October 1989, were also examined (Fig. 13). Although the first target strength estimate was not taken until the transducer and sphere had been in the water for one hour, the system had already stabilized. This is consistent with expectations, as air and water temperatures were approximately the same, 7°C. Results were also consistent over the seven hours, with a mean target strength of -40.8 dB. Similar consistent results were also obtained during the 1988 fall survey (Wheeler et al. 1989) when the system was operating in warmer water temperatures.

To ensure that the standard target calibration differences observed during the 1990 winter survey were environmentally induced and not a result of electronic instability within the hydroacoustic equipment, the system was recalibrated immediately after the survey by BioSonics Inc. on April 13, 1990 (Appendix 2). The source level for both pre and post survey system calibrations was identical, and receiving sensitivities for both receivers at 20 log R and 40 log R were within 0.3 dB. It was concluded that the 2.5 dB difference during the 1990 winter survey, was a real change, regardless of the source, and that as the total backscatter of herring schools would also be increased, this difference must be accounted for in the conversion from backscatter to biomass.

3) Calculation of Experimental Target Strength Estimates

At the annual meeting last year, CAFSAC 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. There were three objectives to the field experiment: 1) to determine, a target strength/fish length relationship, 2) to examine diurnal changes in target strength estimates, and 3) to examine the relationship between integrated estimates and actual fish numbers.

A sample of approximately 500 live herring was obtained from a commercial purse seiner and were transferred to a holding pound, measuring 2 m long, 4 m wide, and 4 m deep. Acoustic measurements were conducted in an experimental pound, which was 6 m long, 6 m wide, and 11 m deep. Both pounds were constructed of capelin seine twine, with 19 mm mesh. The bottom four corners of the experimental pound were anchored and the upper corners were moored to ensure that the shape of the pound remained rigid during experimentation. A video camera was suspended in one corner of the pound at a depth of 9 m and positioned to view horizontally towards the centre of the pound.

Acoustic measurements were conducted at specific intervals from 1100 h on October 8, 1989 to 1630 h on October 9, 1989. It was not possible to examine the target strength/fish length relationship over a range of fish lengths as all fish obtained from the seiner were of the 1987 year-class and the length range was limited, from 24.0 cm to 28.9 cm with a mean length of 25.8 cm. A sample of five fish was first placed in the experimental pound. Between 1100 h and 1600 h on October 8, this was increased to ten fish and then 20 fish and acoustic measurements were made for each sample size. Between 1600 h on October 8 and 0930 h on October 9, a sample of 40 herring was placed in the pound and acoustic measurements were made at approximately one hour intervals. A sample of 40 fish was used over this time period to examine diurnal changes in target strength on a consistent sample size. Between 0930 h and 1630 h on October 9, sample sizes were increased to 80, 160, and 360 fish and further acoustic measurements were made. Fish were given one hour to acclimatize after being placed in the pound before any acoustic measurements were made. Fish were added to the pound throughout the experiment, but none were removed; i.e. the sample of 360 fish at the end of the experiment included the five fish placed in the pound at the beginning of the experiment.

For each of the sample sizes (5, 10, 20, 40, 80, 160, 360 fish), target strengths were measured until a minimum of 300 targets had been isolated over the 2-10 m depth range within the enclosure. Results are summarized by depth (1 m intervals) and for all depths combined in Figure 14. In Figure 15, the same data are presented by sample size. However, rather than including separate plots for each of the sample sizes, the data have been grouped and results are presented for sample sizes of 5, 10, and 20 fish, for 40 fish, for 80, 160, and 360 fish, and for all fish combined.

From all observations combined over the duration of the experiment, the average target for herring with a mean length of 25.8 cm was -37.1 dB. This was very consistent over the entire depth range (Fig. 15) regardless of the number of fish within the pound, as long as sufficient targets were isolated. For all depths combined (Fig. 14), there was a diurnal change, the average target strength during the night decreasing to -39.2 dB and increasing again at dawn.

For each sample, there was a broad range from which the average target strength was derived, examples of which are given in Figure 16. The three examples, at 0926 h, 2105 h, and 0230 h were randomly chosen to illustrate the range of target strengths, -62 dB to -28 dB, from which the average was derived. The same range is evident when data from all depths for the entire experiment are combined (Fig. 16). Such broad ranges are not uncommon in experimental or in situ target strength studies. Rose and Leggett (1988) reported ranges from -54 dB to -22 dB for capelin, and -54 dB to -16 dB for cod. Similarly, Reynisson (1988) reported ranges from -64 dB to -23 dB for capelin, and Foote et al. (1986) reported ranges from -50 dB to -30 dB for herring. Videotape from the camera suspended within the pound showed all possible orientations of fish within the acoustic beam, from near vertical to horizontal. Such a distribution of tilt angles would account for the broad range in target strength estimates.

The results of this experimental target strength study show that for herring with a mean length of 25.8 cm, the average target strength derived during the night (-39.2 dB) is much larger than that derived using Foote's in situ (1987) relationship for fish of the same length:

$$T.S. = 20 \log (25.8 \text{ cm}) - 71.9 = -43.7 \text{ dB}$$

This 4.5 dB difference may be explained by a combination of factors. Foote's (1987) relationship is derived in situ from three separate experiments using 38 kHz acoustic systems (Degnbol et al. 1985, Lassen and Stoehr 1985, and Foote et al. 1986). In this experiment, a 120 kHz system was used. Degnbol et al. (1985) reported very little difference in the target strength of herring and sprat at 38 kHz and 120 kHz. However, they used a single beam transducer and determined target strengths by a cross section technique, rather than from a dual beam system as used in this experiment. Lassen and Stoehr (1985) documented a 2.6 dB difference in target strengths derived using the same cross correlation technique; however, the direction of the difference was opposite to that observed in this present experiment. There is still considerable debate as to potential differences between target strengths calculated using different frequencies and Foote (1987), therefore, restricted his analysis to 38 kHz as it is the most widely used surveying frequency. The applicability of his results to the 120 kHz dual beam system is questionable and is to be the focus of further experimentation in Trinity Bay this year. Differences in fish morphology between herring in the Northwest and Northeast Atlantic may also account for some of the differences between the Trinity Bay results and Foote's in situ relationship. The exponent of the length-weight relationship for herring in Newfoundland waters is consistently between 3.0 and 3.5 (Parsons and Hodder 1973, 1975; Moores 1980) whereas for herring from the Northeast Atlantic (Anon. 1988), the exponent is between 2.0 and 3.0. This may result in an increase in the size of the swim bladder per unit fish length. As the swim bladder accounts for 90-95% of the backscatter from an individual fish (Foote 1980), any increase in the size and volume of it will have a corresponding effect in the target strength estimate.

The 4.5 dB difference between the results of the Trinity Bay experiment and Foote's (1987) relationship, although large, is comparable to differences observed between other target strength studies. For example, Rose and Leggett (1988) using a 120 kHz dual beam system calculated an in situ target strength of -41 dB for capelin with a mean length of 16.5 cm. However, Halldorsson and Reynisson (1983) using a 38 kHz single beam system calculated a target strength of -49.1 dB for capelin of the same length, a difference of 8.1 dB.

The results presented in this document are preliminary; data from this experiment require further detailed analysis prior to primary publication. However, there is a substantial difference between the experimental target strength estimate and that derived from Foote's relationship, at least for one length of herring. If it is assumed that the difference is linear over the entire length range of the herring, and that the difference is in intercept and not slope, then the target strength/fish length relationship from the experiment would be:

$$T.S. = 20 \log L - 67.4$$

The use of a standardized slope (i.e. 20) follows the practice of Love (1977) who has shown the approximate proportionality between mean backscattering cross section and fish length squared.

The evidence from the Trinity Bay experiment is further substantiated by in situ target strength estimates collected in Long Harbour, Fortune Bay during the 1990 winter survey (Fig. 17). Target strengths were calculated from a sample of 5159 scattered targets along a transect, and provided a mean of -34.1 dB. Herring, with an average length of 27.2 cm were caught by midwater trawl (Table 2) immediately after in the same location and depth. When adjusted to account for differences in fish length and for the 2.5 dB difference described above, the average target strength estimate was identical to that derived experimentally in the enclosure. The range and distribution of target strength estimates used to derive the mean (Fig. 17) are also identical to those determined in the enclosure experiment, except for a shift to the right due to the difference in mean fish length and because of the 2.5 dB attributed to the cold water temperature.

As a target strength estimate is available for only one length group of herring from the Trinity Bay experiment, and results are still considered to be preliminary, CAFSAC recommended that Foote's (1987) target strength-fish length relationship continue to be used until the results of further experimental work to be conducted in 1990, are available. The two main objectives of the research to be conducted in 1990 are: 1) to determine an experimental target strength/length relationship within the net enclosure by acoustically measuring different length ranges of herring, and 2) to compare target strength estimates at different frequencies by simultaneously determining target strengths using a 38 kHz and

120 kHz acoustic system. In addition, as many of the potential factors which contribute to the differences between initial experimental results and those of Foote (1987) will be examined and quantified. It should be noted that if further research confirms the preliminary experimental results, then biomass estimates derived using Foote's (1987) relationship will be overestimated by a factor of 2.8.

Acoustic Survey Results

Integrated density estimates were calculated for the 303 transects surveyed. Mean fish lengths and weights by stratum (Table 2) were applied, using Foote's (1987) target strength/fish length relationship, to calculate a target strength (dB per kg) for each stratum. A 2.5 dB correction factor was also applied, due to the change observed during the survey which was attributed to the cold water temperatures. 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 Tables 4 and 5. These are summarized by stock area in Tables 6 and 7. In both stock areas, the majority of the biomass estimate is derived from two strata only; in Fortune Bay, 97.8% was detected in strata 9 and 11 and in St. Mary's Bay-Placentia Bay, 99.9% was detected in strata 11 and 12. In Fortune Bay, the biomass estimates in strata 9 and 11 were derived from nine herring schools (Table 3); however, most of the estimate was derived from a single large school in Bay L'Argent (stratum 11). Similarly, in Placentia Bay, the biomass estimates in strata 11 and 12 were derived from two schools only, one large school off Corbins Head and one smaller school off Harbour Buffett. Consequently, coefficients of variation, based upon survey design variance only, were high for both stock areas, 69% for Fortune Bay and 88% for St. Mary's Bay-Placentia Bay.

Mean biomass (t) estimates by stock area from the 1986 surveys and the 1990 survey are provided for comparison in the following text table:

	1986 surveys		1990 survey	
Stock area	Jan.-Mar.	Nov.-Dec.	Mean	C.V.
FB	17,200	9,100	37,000	0.69
SMB-PB	36,300	42,200	97,500	0.88

Populations numbers at age, by spawning type (Table 8), were adjusted to January 1990 from the 1990 acoustic biomass estimate. For comparison, the 1986 survey population numbers at age were also projected to January 1990. Projections were made assuming $M = 0.20$ and no fishing mortality. Population numbers at age were available only for the 1986 November-December survey in Fortune Bay as no fish were sampled in the January-March survey. There is no evidence of strong recruitment to either stock as the 1987 year-class, which is the only one of any consequence since 1982, is presently only equal to the 1982 year-class in Fortune Bay and approximately 30% that of the 1982 year-class in St. Mary's Bay-Placentia Bay.

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Table 1. SHAMOOK midwater trawl and MARINUS purse seine set details for the 1990 herring acoustic survey, Fortune Bay and St. Mary's-Placentia Bay.

Set no.	Date	Time	Location	Surface temp.	Bottom temp.	Results
S1	Jan. 18	0800	Northeast Arm, Hr. Breton Fortune Bay	-	-	Caught ctenophores and one capelin
S2	Jan. 22	1730	Long Harbour Fortune Bay	-	-	Caught 29 herring, mostly '87 year-class
S3	Jan. 22	1815	Long Harbour Fortune Bay	-	-	Caught 20 herring, mostly '87 year-class
S4	Jan. 23	1700	Long Harbour Fortune Bay	0.93	1.46	No catch, trawl twisted due to tide
S5	Jan. 23	1900	Long Harbour Fortune Bay	-	-	Caught approximately 60 kg herring, mixture of '87 year-class and '82 year-class
M1	Jan. 24	1710	Bay L'Argent Fortune Bay	0.50	1.36	No catch, fish were wild and seine was partially frozen
M2	Jan. 24	1850	Bay L'Argent Fortune Bay	-	-	Caught approximtely 9000 kg herring, mostly '82 year-class, '87 year-class & '83 year-class
M3	Feb. 16	1455	off Corbins Head Placentia Bay	-0.70	-0.58	No catch, fish were too deep for the seine
S6	Feb. 16	1555	off Corbins Head Placentia Bay	-	-	No catch, transducer on trawl malfunctioned
S7	Feb. 16	1650	off Corbins Head Placentia Bay	-	-	Caught approximately 500 kg herring, mostly '82 year-class, '87 year-class & '86 year-class
S8	Feb. 23	1105	Mussel Pond Point St. Mary's Bay	-	-	Caught approximately 25 kg immature capelin
M4	Feb. 23	1225	Mussel Pond Point St. Mary's Bay	-1.34	-0.48	Caught approximately 45,000 kg immature capelin
M5	Feb. 26	1310	Little Colinet Island St. Mary's Bay	-1.37	-1.11	Caught approximately 90 kg immature capelin
M6	Feb. 26	1530	Great Colinet Island St. Mary's Bay	-1.39	-1.00	Caught approximately 1800 kg immature capelin

Table 2. Biological samples used to calculate mean lengths, mean weights and population numbers at age from the 1990 herring acoustic survey, Fortune Bay and St. Mary's Bay-Placentia Bay.

Stock area	Survey strata	Survey dates	Sampling location	Sample strata	Sample dates	Sample type	# fish sampled	Mean lgt. (cm)	Mean wgt. (gm)
FB	3, 6, 7, 8	Jan. 19-22	Long Harbour	9	Jan. 22 & 23	Res. MWT	149	27.2	148.2
			Bay L'Argent	11	Jan. 24	Res. PS	200	31.8	264.7
	9	Jan. 22 & 23	Long Harbour	9	Jan. 22 & 23	Res. MWT	149	27.2	148.2
	10	Jan. 22 & 23	Long Harbour	9	Jan. 22 & 23	Res. MWT	149	27.2	148.2
			Bay L'Argent	11	Jan. 24	Res. PS	200	31.8	264.7
	11	Jan. 24 & 25	Bay L'Argent	11	Jan. 24	Res. PS	200	31.8	264.7
SMB-PB	9	Feb. 9-12	Corbins Head	11	Feb. 16	Res. MWT	200	32.6	296.3
			Harbour Buffett	12	Feb. 17	Comm. PS	100	33.1	308.4
	11	Feb. 16 & 17	Corbins Head	11	Feb. 16	Res. MWT	200	32.6	296.3
	12	Feb. 14 & 15	Harbour Buffett	12	Feb. 17	Comm. PS	100	33.1	308.4
	18	Feb. 16 & 17	Corbins Head	11	Feb. 16	Res. MWT	200	32.6	296.3
			Harbour Buffett	12	Feb. 17	Comm. PS	100	33.1	308.4

Table 3. Number of fish schools edited as non-herring prior to analysis of 1990 herring acoustic survey, Fortune Bay and St. Mary's Bay-Placentia Bay.

Stock area	Stratum	Herring schools analyzed	Schools edited	
			Capelin	Unidentified
FB	1	0	0	0
	2	0	2	0
	3	1	0	0
	4	-	-	-
	5	0	0	0
	6	1	1	0
	7	1	0	0
	8	2	0	0
	9	5	0	0
	10	2	1	1
	11	4	0	1
	12	0	1	0
	13	0	0	0
	14	0	0	0
SMB-PB	1	0	0	1
	2	0	0	0
	3	0	0	0
	4	0	1	0
	5	0	2	0
	6	0	0	0
	7	0	0	0
	8	0	4	0
	9	2	0	0
	10	0	2	0
	11	1	0	0
	12	2	0	0
	13	0	0	4
	14	-	-	-
	15	-	-	-
	16	-	-	-
	17	0	0	0
	18	2	2	0
	19	-	-	-
	20	0	~10	0
	21	0	~10	0
	22	0	~20	0
	23	-	-	-
	24	-	-	-
	25	-	-	-

Table 4. Biomass and backscatter estimates, for Fortune 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 TOTAL SCATTER (m2/sr)	WEIGHTED SCATT. COEFF. (/sr)	SET NUMBER	NUMBER OF FISH SAMPLED
FB	1	-33.24	1	0.90	1.543E+06	0	0.00000	0	0.000E+00		
			2	3.33	5.711E+06	0	0.00000	0	0.000E+00		
			3	2.15	3.687E+06	0	0.00000	0	0.000E+00		
			4	1.57	2.692E+06	0	0.00000	0	0.000E+00		
			5	3.53	6.054E+06	0	0.00000	0	0.000E+00		
			6	3.90	6.688E+06	0	0.00000	0	0.000E+00		
			7	3.43	5.882E+06	0	0.00000	0	0.000E+00		
			8	3.13	5.368E+06	0	0.00000	0	0.000E+00		
			9	2.12	3.636E+06	0	0.00000	0	0.000E+00		
			10	2.29	3.927E+06	0	0.00000	0	0.000E+00		
			11	1.77	3.035E+06	0	0.00000	0	0.000E+00		
			11		4.384E+06		0.00000		0.000E+00		
					4.822E+07						
	2	-33.24	12	0.75	1.286E+06	0	0.00000	0	0.000E+00		
			13	2.68	4.596E+06	0	0.00000	0	0.000E+00		
			14	1.78	3.053E+06	0	0.00000	0	0.000E+00		
			15	2.07	3.550E+06	0	0.00000	0	0.000E+00		
			16	1.20	2.058E+06	0	0.00000	0	0.000E+00		
			17	0.90	1.543E+06	0	0.00000	0	0.000E+00		
			18	0.90	1.543E+06	0	0.00000	0	0.000E+00		
			19	0.37	6.345E+05	0	0.00000	0	0.000E+00		
			20	0.53	9.089E+05	0	0.00000	0	0.000E+00	51	0
			21	0.60	1.029E+06	0	0.00000	0	0.000E+00		
			22	0.42	7.203E+05	0	0.00000	0	0.000E+00		
			11		1.902E+06		0.00000		0.000E+00		
					2.092E+07						
	3	-33.24	23	1.05	1.801E+06	0	0.00000	0	0.000E+00		
			24	1.62	2.778E+06	23	0.00648	11	3.072E-06		
			25	3.50	6.002E+06	0	0.00000	0	0.000E+00		
			3		3.527E+06		0.00216		1.024E-06		
					1.058E+07						
	5	-33.24	26	2.32	3.979E+06	0	0.00000	0	0.000E+00		
			27	0.85	1.458E+06	0	0.00000	0	0.000E+00		
			28	1.33	2.281E+06	0	0.00000	0	0.000E+00		
			29	2.15	3.687E+06	0	0.00000	0	0.000E+00		
			30	2.30	3.944E+06	0	0.00000	0	0.000E+00		
			31	1.33	2.281E+06	0	0.00000	0	0.000E+00		
			32	1.27	2.178E+06	0	0.00000	0	0.000E+00		
			33	1.98	3.396E+06	0	0.00000	0	0.000E+00		
			34	0.70	1.200E+06	0	0.00000	0	0.000E+00		
			9		2.712E+06		0.00000		0.000E+00		
					2.440E+07						
	6	-33.24	35	1.08	1.852E+06	0	0.00000	0	0.000E+00		
			36	1.70	2.915E+06	0	0.00000	0	0.000E+00		
			37	3.86	6.620E+06	0	0.00000	0	0.000E+00		
			38	1.49	2.555E+06	0	0.00000	0	0.000E+00		
			39	0.68	1.166E+06	0	0.00000	0	0.000E+00		
			40	2.72	4.665E+06	0	0.00000	0	0.000E+00		
			41	3.47	5.951E+06	0	0.00000	0	0.000E+00		
			42	1.98	3.396E+06	0	0.00000	0	0.000E+00		
			43	2.74	4.699E+06	12	0.00290	6	1.376E-06		
			44	4.12	7.066E+06	0	0.00000	0	0.000E+00		
			10		4.088E+06		0.00029		1.376E-07		
					4.088E+07						

Table 4 (cont.). Biomass and backscatter estimates, for Fortune 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 TOTAL SCATTER (m2/sr)	WEIGHTED SCATT. COEFF. (/sr)	SET NUMBER	NUMBER OF FISH SAMPLED
	7	-33.24	45	0.13	2.229E+05	0	0.00000	0	0.000E+00		
			46	1.28	2.195E+06	0	0.00000	0	0.000E+00		
			47	0.92	1.578E+06	0	0.00000	0	0.000E+00		
			48	0.73	1.252E+06	0	0.00000	0	0.000E+00		
			49	0.18	3.087E+05	0	0.00000	0	0.000E+00		
			50	1.35	2.315E+06	69	0.03452	33	1.637E-05		
			51	2.57	4.407E+06	0	0.00000	0	0.000E+00		
			52	1.68	2.881E+06	0	0.00000	0	0.000E+00		
			53	1.58	2.710E+06	0	0.00000	0	0.000E+00		
			9		1.986E+06		0.00384		1.819E-06		
					1.787E+07						
	8	-33.24	54	0.08	1.372E+05	0	0.00000	0	0.000E+00		
			55	0.25	4.287E+05	0	0.00000	0	0.000E+00		
			56	0.74	1.269E+06	0	0.00000	0	0.000E+00		
			57	0.13	2.229E+05	0	0.00000	0	0.000E+00		
			58	0.63	1.080E+06	0	0.00000	0	0.000E+00		
			59	0.15	2.572E+05	0	0.00000	0	0.000E+00		
			60	0.20	3.430E+05	0	0.00000	0	0.000E+00		
			61	1.66	2.847E+06	186	0.16358	88	7.758E-05		
			62	0.45	7.717E+05	0	0.00000	0	0.000E+00		
			63	0.88	1.509E+06	0	0.00000	0	0.000E+00		
			64	0.46	7.889E+05	0	0.00000	0	0.000E+00		
			65	0.53	9.089E+05	0	0.00000	0	0.000E+00		
			66	0.52	8.918E+05	0	0.00000	0	0.000E+00		
			67	0.58	9.947E+05	0	0.00000	0	0.000E+00		
			68	1.62	2.778E+06	0	0.00000	0	0.000E+00		
			69	0.28	4.802E+05	0	0.00000	0	0.000E+00		
			70	0.45	7.717E+05	8	0.00737	4	3.496E-06		
			71	2.32	3.979E+06	0	0.00000	0	0.000E+00		
			18		1.137E+06		0.00950		4.504E-06		
					2.046E+07						
	9	-32.42	72	0.47	8.060E+05	0	0.00000	0	0.000E+00		
			73	0.78	1.338E+06	440	0.25984	252	1.488E-04	S2,S3,S4,S5	149
			74	0.57	9.775E+05	0	0.00000	0	0.000E+00		
			75	0.60	1.029E+06	268	0.15857	154	9.083E-05		
			76	1.75	3.001E+06	4	0.00259	3	1.482E-06		
			77	1.62	2.778E+06	13	0.00790	8	4.524E-06		
			78	1.12	1.921E+06	0	0.00000	0	0.000E+00		
			7		1.693E+06		0.06127		3.510E-05		
					1.185E+07						
	10	-33.24	79	0.63	1.080E+06	0	0.00000	0	0.000E+00		
			80	0.52	8.918E+05	5	0.00654	3	3.099E-06		
			81	1.48	2.538E+06	0	0.00000	0	0.000E+00		
			82	0.86	1.475E+06	0	0.00000	0	0.000E+00		
			83	0.27	4.630E+05	0	0.00000	0	0.000E+00		
			84	0.25	4.287E+05	0	0.00000	0	0.000E+00		
			85	0.52	8.918E+05	14	0.01739	7	8.248E-06		
			86	0.42	7.203E+05	0	0.00000	0	0.000E+00		
			87	0.55	9.432E+05	0	0.00000	0	0.000E+00		
			88	0.20	3.430E+05	0	0.00000	0	0.000E+00		
			89	0.23	3.944E+05	0	0.00000	0	0.000E+00		
			90	0.43	7.374E+05	0	0.00000	0	0.000E+00		
			91	0.18	3.087E+05	0	0.00000	0	0.000E+00		
			92	0.13	2.229E+05	0	0.00000	0	0.000E+00		
			14		8.171E+05		0.00171		8.105E-07		
					1.144E+07						

Table 4 (cont.). Biomass and backscatter estimates, for Fortune 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 TOTAL SCATTER (m2/sr)	WEIGHTED SCATT. COEFF. (/sr)	SET NUMBER	NUMBER OF FISH SAMPLED
	11	-33.60	93	0.65	1.115E+06	0	0.00000	0	0.000E+00		
			94	0.21	3.601E+05	0	0.00000	0	0.000E+00		
			95	0.34	5.831E+05	0	0.00000	0	0.000E+00		
			96	0.18	3.087E+05	0	0.00000	0	0.000E+00		
			97	0.27	4.630E+05	0	0.00000	0	0.000E+00		
			98	0.25	4.287E+05	0	0.00000	0	0.000E+00		
			99	0.65	1.115E+06	0	0.00000	0	0.000E+00		
			100	1.57	2.692E+06	3	0.00203	1	8.848E-07		
			101	3.42	5.865E+06	17023	10.68235	7431	4.663E-03	M1,M2	200
			102	1.03	1.766E+06	0	0.00000	0	0.000E+00		
			103	1.33	2.281E+06	0	0.00000	0	0.000E+00		
			104	1.40	2.401E+06	0	0.00000	0	0.000E+00		
			105	0.78	1.338E+06	6	0.00355	2	1.550E-06		
			14		1.594E+06		0.82215		3.589E-04		
					2.072E+07						
	12	-33.24	106	0.99	1.698E+06	0	0.00000	0	0.000E+00		
			107	0.40	6.860E+05	0	0.00000	0	0.000E+00		
			108	0.90	1.543E+06	0	0.00000	0	0.000E+00		
			109	0.78	1.338E+06	0	0.00000	0	0.000E+00		
			110	0.63	1.080E+06	0	0.00000	0	0.000E+00		
			111	0.81	1.389E+06	0	0.00000	0	0.000E+00		
			6		1.289E+06		0.00000		0.000E+00		
					7.734E+06						
	13	-33.24	112	2.70	4.630E+06	0	0.00000	0	0.000E+00		
			113	2.50	4.287E+06	0	0.00000	0	0.000E+00		
			114	2.32	3.979E+06	0	0.00000	0	0.000E+00		
			115	2.62	4.493E+06	0	0.00000	0	0.000E+00		
			116	2.88	4.939E+06	0	0.00000	0	0.000E+00		
			117	3.11	5.334E+06	0	0.00000	0	0.000E+00		
			6		4.610E+06		0.00000		0.000E+00		
					2.766E+07						
	14	-33.24	118	1.68	2.881E+06	0	0.00000	0	0.000E+00		
			119	2.73	4.682E+06	0	0.00000	0	0.000E+00		
			120	1.73	2.967E+06	0	0.00000	0	0.000E+00		
			3		3.510E+06		0.00000		0.000E+00		
					1.053E+07						
				159.35							

Table 5. Biomass and backscatter estimates, for St. Mary's Bay - Placentia 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 TOTAL SCATTER (m2/sr)	WEIGHTED SCATT. COEFF. (/sr)	SET NUMBER	NUMBER OF FISH SAMPLED
SMB-PB	1	-33.86	121	5.28	9.055E+06	0	0.00000	0	0.000E+00		
			122	8.05	1.381E+07	0	0.00000	0	0.000E+00		
			123	5.73	9.827E+06	0	0.00000	0	0.000E+00		
			124	5.07	8.695E+06	0	0.00000	0	0.000E+00		
			125	5.13	8.798E+06	0	0.00000	0	0.000E+00		
			126	4.20	7.203E+06	0	0.00000	0	0.000E+00		
			127	4.95	8.489E+06	0	0.00000	0	0.000E+00		
			128	5.44	9.329E+06	0	0.00000	0	0.000E+00		
			129	5.30	9.089E+06	0	0.00000	0	0.000E+00		
			130	5.90	1.012E+07	0	0.00000	0	0.000E+00		
			131	4.83	8.283E+06	0	0.00000	0	0.000E+00		
			11		9.336E+06		0.00000		0.000E+00		
					1.027E+08						
	2	-33.86	132	5.02	8.609E+06	0	0.00000	0	0.000E+00		
			1		8.609E+06		0.00000		0.000E+00		
					8.609E+06						
	3	-33.86	133	5.75	9.861E+06	0	0.00000	0	0.000E+00		
			134	1.72	2.950E+06	0	0.00000	0	0.000E+00		
			135	5.02	8.609E+06	0	0.00000	0	0.000E+00		
			136	2.61	4.476E+06	0	0.00000	0	0.000E+00		
			137	5.97	1.024E+07	0	0.00000	0	0.000E+00		
			138	1.52	2.607E+06	0	0.00000	0	0.000E+00		
			139	1.47	2.521E+06	0	0.00000	0	0.000E+00		
			140	4.46	7.649E+06	0	0.00000	0	0.000E+00		
			141	4.87	8.352E+06	0	0.00000	0	0.000E+00		
			9		6.362E+06		0.00000		0.000E+00		
					5.726E+07						
	4	-33.86	142	4.99	8.558E+06	0	0.00000	0	0.000E+00		
			143	4.89	8.386E+06	0	0.00000	0	0.000E+00		
			144	0.37	6.345E+05	0	0.00000	0	0.000E+00		
			145	1.98	3.396E+06	0	0.00000	0	0.000E+00		
			146	2.12	3.636E+06	0	0.00000	0	0.000E+00		
			147	2.40	4.116E+06	0	0.00000	0	0.000E+00		
			148	3.07	5.265E+06	0	0.00000	0	0.000E+00		
			149	2.83	4.853E+06	0	0.00000	0	0.000E+00		
			150	3.73	6.397E+06	0	0.00000	0	0.000E+00		
			151	0.26	4.459E+05	0	0.00000	0	0.000E+00		
			10		4.569E+06		0.00000		0.000E+00		
					4.569E+07						

Table 5 (cont.). Biomass and backscatter estimates, for St. Mary's Bay - Placentia 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 TOTAL SCATTER (m2/sr)	WEIGHTED SCATT. COEFF. (/sr)	SET NUMBER	NUMBER OF FISH SAMPLED
	5	-33.86	152	0.99	1.698E+06	0	0.00000	0	0.000E+00		
			153	0.83	1.423E+06	0	0.00000	0	0.000E+00		
			154	0.12	2.058E+05	0	0.00000	0	0.000E+00		
			155	0.10	1.715E+05	0	0.00000	0	0.000E+00		
			4		8.746E+05		0.00000		0.000E+00		
					3.499E+06						
	6	-33.86	156	1.86	3.190E+06	0	0.00000	0	0.000E+00		
			157	1.43	2.452E+06	0	0.00000	0	0.000E+00		
			158	2.08	3.567E+06	0	0.00000	0	0.000E+00		
			159	1.35	2.315E+06	0	0.00000	0	0.000E+00		
			160	0.90	1.543E+06	0	0.00000	0	0.000E+00		
			161	0.71	1.218E+06	0	0.00000	0	0.000E+00		
			162	0.88	1.509E+06	0	0.00000	0	0.000E+00		
			7		2.256E+06		0.00000		0.000E+00		
					1.579E+07						
	7	-33.86	163	2.03	3.481E+06	0	0.00000	0	0.000E+00		
			164	2.21	3.790E+06	0	0.00000	0	0.000E+00		
			165	2.96	5.076E+06	0	0.00000	0	0.000E+00		
			166	1.49	2.555E+06	0	0.00000	0	0.000E+00		
			167	0.49	8.403E+05	0	0.00000	0	0.000E+00		
			168	2.79	4.785E+06	0	0.00000	0	0.000E+00		
			169	0.47	8.060E+05	0	0.00000	0	0.000E+00		
			170	0.16	2.744E+05	0	0.00000	0	0.000E+00		
			171	2.19	3.756E+06	0	0.00000	0	0.000E+00		
			172	0.32	5.488E+05	0	0.00000	0	0.000E+00		
			173	0.45	7.717E+05	0	0.00000	0	0.000E+00		
			174	0.98	1.681E+06	0	0.00000	0	0.000E+00		
			12		2.364E+06		0.00000		0.000E+00		
					2.837E+07						
	8	-33.86	175	0.60	1.029E+06	0	0.00000	0	0.000E+00		
			176	0.68	1.166E+06	0	0.00000	0	0.000E+00		
			177	1.64	2.813E+06	0	0.00000	0	0.000E+00		
			178	0.97	1.664E+06	0	0.00000	0	0.000E+00		
			179	1.74	2.984E+06	0	0.00000	0	0.000E+00		
			180	1.20	2.058E+06	0	0.00000	0	0.000E+00		
			181	1.36	2.332E+06	0	0.00000	0	0.000E+00		
			182	1.72	2.950E+06	0	0.00000	0	0.000E+00		
			183	2.23	3.824E+06	0	0.00000	0	0.000E+00		
			184	2.54	4.356E+06	0	0.00000	0	0.000E+00		
			185	1.25	2.144E+06	0	0.00000	0	0.000E+00		
			186	1.78	3.053E+06	0	0.00000	0	0.000E+00		
			187	2.18	3.739E+06	0	0.00000	0	0.000E+00		
			13		2.624E+06		0.00000		0.000E+00		
					3.411E+07						

Table 5 (cont.). Biomass and backscatter estimates, for St.Mary's Bay - Placentia 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 TOTAL SCATTER (m2/sr)	WEIGHTED SCATT. COEFF. (/sr)	SET NUMBER	NUMBER OF FISH SAMPLED
	9	-33.86	188	3.26	5.591E+06	0	0.00000	0	0.000E+00		
			189	3.88	6.654E+06	0	0.00000	0	0.000E+00		
			190	2.67	4.579E+06	32	0.01128	13	4.640E-06		
			191	1.43	2.452E+06	0	0.00000	0	0.000E+00		
			192	0.94	1.612E+06	0	0.00000	0	0.000E+00		
			193	1.68	2.881E+06	0	0.00000	0	0.000E+00		
			194	2.06	3.533E+06	0	0.00000	0	0.000E+00		
			195	4.23	7.254E+06	0	0.00000	0	0.000E+00		
			196	1.96	3.361E+06	0	0.00000	0	0.000E+00		
			197	3.03	5.196E+06	0	0.00000	0	0.000E+00		
			198	0.55	9.432E+05	0	0.00000	0	0.000E+00		
			199	0.35	6.002E+05	0	0.00000	0	0.000E+00		
			200	0.71	1.218E+06	0	0.00000	0	0.000E+00		
			201	1.00	1.715E+06	0	0.00000	0	0.000E+00		
			202	0.91	1.561E+06	0	0.00000	0	0.000E+00		
			203	0.73	1.252E+06	0	0.00000	0	0.000E+00		
			204	0.37	6.345E+05	0	0.00000	0	0.000E+00		
			205	0.32	5.488E+05	0	0.00000	0	0.000E+00		
			206	1.12	1.921E+06	0	0.00000	0	0.000E+00		
			19		2.816E+06		0.00059		2.442E-07		
					5.351E+07						
	10	-33.86	207	0.97	1.664E+06	0	0.00000	0	0.000E+00		
			208	0.73	1.252E+06	0	0.00000	0	0.000E+00		
			209	2.21	3.790E+06	0	0.00000	0	0.000E+00		
			210	1.80	3.087E+06	0	0.00000	0	0.000E+00		
			211	2.20	3.773E+06	0	0.00000	0	0.000E+00		
			212	0.92	1.578E+06	0	0.00000	0	0.000E+00		
			213	1.18	2.024E+06	0	0.00000	0	0.000E+00		
			214	2.10	3.601E+06	0	0.00000	0	0.000E+00		
			215	1.84	3.156E+06	0	0.00000	0	0.000E+00		
			216	0.92	1.578E+06	0	0.00000	0	0.000E+00		
			217	1.60	2.744E+06	0	0.00000	0	0.000E+00		
			218	1.07	1.835E+06	0	0.00000	0	0.000E+00		
			219	1.16	1.989E+06	0	0.00000	0	0.000E+00		
			272	1.44	2.470E+06	0	0.00000	0	0.000E+00		
			273	0.68	1.166E+06	0	0.00000	0	0.000E+00		
			15		2.380E+06		0.00000		0.000E+00		
					3.571E+07						
	11	-33.84	259	2.00	3.430E+06	31744	10.24708	13112	4.233E-03	M3,S6,S7	200
			264	1.85	3.173E+06	0	0.00000	0	0.000E+00		
			265	2.13	3.653E+06	0	0.00000	0	0.000E+00		
			266	2.40	4.116E+06	0	0.00000	0	0.000E+00		
			267	1.33	2.281E+06	0	0.00000	0	0.000E+00		
			268	1.73	2.967E+06	0	0.00000	0	0.000E+00		
			269	2.33	3.996E+06	0	0.00000	0	0.000E+00		
			270	2.71	4.648E+06	0	0.00000	0	0.000E+00		
			274	0.78	1.338E+06	0	0.00000	0	0.000E+00		
			275	1.68	2.881E+06	0	0.00000	0	0.000E+00		
			276	0.93	1.595E+06	0	0.00000	0	0.000E+00		
			11		3.098E+06		0.93155		3.848E-04		
					3.408E+07						

Table 5 (cont.). Biomass and backscatter estimates, for St.Mary's Bay - Placentia 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 TOTAL SCATTER (m2/sr)	WEIGHTED SCATT. COEFF. (/sr)	SET NUMBER	NUMBER OF FISH SAMPLED
	12	-33.88	220	0.14	2.401E+05	0	0.00000	0	0.000E+00		
			221	0.33	5.659E+05	0	0.00000	0	0.000E+00		
			222	0.33	5.659E+05	278	0.27116	114	1.110E-04		
			223	0.33	5.659E+05	0	0.00000	0	0.000E+00		
			224	0.48	8.232E+05	0	0.00000	0	0.000E+00		
			225	0.30	5.145E+05	0	0.00000	0	0.000E+00		
			226	0.47	8.060E+05	0	0.00000	0	0.000E+00		
			227	0.30	5.145E+05	0	0.00000	0	0.000E+00		
			228	0.19	3.258E+05	0	0.00000	0	0.000E+00		
			229	1.30	2.229E+06	0	0.00000	0	0.000E+00		
			230	0.56	9.604E+05	0	0.00000	0	0.000E+00		
			231	0.63	1.080E+06	0	0.00000	0	0.000E+00		
			232	0.48	8.232E+05	0	0.00000	0	0.000E+00		
			233	0.94	1.612E+06	0	0.00000	0	0.000E+00		
			234	0.30	5.145E+05	0	0.00000	0	0.000E+00		
			235	0.85	1.458E+06	0	0.00000	0	0.000E+00		
			236	1.42	2.435E+06	0	0.00000	0	0.000E+00		
			237	0.95	1.629E+06	0	0.00000	0	0.000E+00		
			271	0.41	7.031E+05	5310	5.18559	2173	2.122E-03	(COMM.)	100
			238	0.82	1.406E+06	0	0.00000	0	0.000E+00		
			239	0.41	7.031E+05	0	0.00000	0	0.000E+00		
			240	0.43	7.374E+05	0	0.00000	0	0.000E+00		
			241	0.61	1.046E+06	0	0.00000	0	0.000E+00		
			242	1.35	2.315E+06	0	0.00000	0	0.000E+00		
			24		1.024E+06		0.22736		9.305E-05		
					2.458E+07						
	13	-33.86	277	1.08	1.852E+06	0	0.00000	0	0.000E+00		
			278	0.59	1.012E+06	0	0.00000	0	0.000E+00		
			279	0.98	1.681E+06	0	0.00000	0	0.000E+00		
			280	0.95	1.629E+06	0	0.00000	0	0.000E+00		
			281	1.38	2.367E+06	0	0.00000	0	0.000E+00		
			282	0.77	1.321E+06	0	0.00000	0	0.000E+00		
			283	0.93	1.595E+06	0	0.00000	0	0.000E+00		
			284	1.07	1.835E+06	0	0.00000	0	0.000E+00		
			285	0.77	1.321E+06	0	0.00000	0	0.000E+00		
			286	0.41	7.031E+05	0	0.00000	0	0.000E+00		
			287	0.98	1.681E+06	0	0.00000	0	0.000E+00		
			11		1.545E+06		0.00000		0.000E+00		
					1.700E+07						
	17	-33.86	243	0.82	1.406E+06	0	0.00000	0	0.000E+00		
			244	1.07	1.835E+06	0	0.00000	0	0.000E+00		
			245	1.02	1.749E+06	0	0.00000	0	0.000E+00		
			246	1.90	3.258E+06	0	0.00000	0	0.000E+00		
			247	0.95	1.629E+06	0	0.00000	0	0.000E+00		
			248	1.08	1.852E+06	0	0.00000	0	0.000E+00		
			249	1.08	1.852E+06	0	0.00000	0	0.000E+00		
			250	1.06	1.818E+06	0	0.00000	0	0.000E+00		
			8		1.925E+06		0.00000		0.000E+00		
					1.540E+07						

Table 5 (cont.). Biomass and backscatter estimates, for St. Mary's Bay - Placentia 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 TOTAL SCATTER (m2/sr)	WEIGHTED SCATT. COEFF. (/sr)	SET NUMBER	NUMBER OF FISH SAMPLED
	18	-33.86	251	4.80	8.232E+06	9	0.00195	4	8.030E-07		
			252	4.32	7.409E+06	0	0.00000	0	0.000E+00		
			253	3.66	6.277E+06	5	0.00115	2	4.726E-07		
			254	4.13	7.083E+06	0	0.00000	0	0.000E+00		
			255	4.20	7.203E+06	0	0.00000	0	0.000E+00		
			256	2.13	3.653E+06	0	0.00000	0	0.000E+00		
			257	1.80	3.087E+06	0	0.00000	0	0.000E+00		
			258	1.49	2.555E+06	0	0.00000	0	0.000E+00		
			260	0.83	1.423E+06	0	0.00000	0	0.000E+00		
			261	1.31	2.247E+06	0	0.00000	0	0.000E+00		
			262	0.84	1.441E+06	0	0.00000	0	0.000E+00		
			263	1.05	1.801E+06	0	0.00000	0	0.000E+00		
			12		4.367E+06		0.00026		1.063E-07		
					5.241E+07						
	20	-33.86	297	1.99	3.413E+06	0	0.00000	0	0.000E+00		
			298	1.59	2.727E+06	0	0.00000	0	0.000E+00		
			2		3.070E+06		0.00000		0.000E+00		
					6.140E+06						
	21	-33.86	299	2.28	3.910E+06	0	0.00000	0	0.000E+00		
			300	2.38	4.082E+06	0	0.00000	0	0.000E+00		
			301	2.07	3.550E+06	0	0.00000	0	0.000E+00	M6	capelin
			302	1.49	2.555E+06	0	0.00000	0	0.000E+00		
			4		3.524E+06		0.00000		0.000E+00		
					1.410E+07						
	22	-33.86	288	1.43	2.452E+06	0	0.00000	0	0.000E+00	S8,M4	capelin
			289	1.28	2.195E+06	0	0.00000	0	0.000E+00		
			290	1.30	2.229E+06	0	0.00000	0	0.000E+00		
			291	1.52	2.607E+06	0	0.00000	0	0.000E+00		
			292	1.70	2.915E+06	0	0.00000	0	0.000E+00		
			293	1.80	3.087E+06	0	0.00000	0	0.000E+00		
			294	0.37	6.345E+05	0	0.00000	0	0.000E+00		
			295	0.74	1.269E+06	0	0.00000	0	0.000E+00		
			296	0.58	9.947E+05	0	0.00000	0	0.000E+00		
			9		2.043E+06		0.00000		0.000E+00		
					1.838E+07						
				330.8							

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

Stock area	Stratum	Target strength (dB kg^{-1})	Stratum area (m^2)	Stratum biomass density (kgm^2)	Total biomass (t)		Stratum area scattering Coeff. (sr^{-1})	Total backscattering (m^{2}sr^{-1})	
					Mean	S. E.		Mean	S.E.
FB	1	-	1.972×10^8	0.00000	0	-	0.000	0	-
	2	-	7.170×10^7	0.00000	0	-	0.000	0	-
	3	-33.24	7.260×10^7	0.00216	157	181	1.024×10^{-6}	74	86
	4	-	3.181×10^8	-	-	-	-	-	-
	5	-	9.240×10^7	0.00000	0	-	0.000	0	-
	6	-33.24	9.080×10^7	0.00029	26	26	1.376×10^{-7}	12	12
	7	-33.24	3.390×10^7	0.00384	130	131	1.819×10^{-6}	62	62
	8	-33.24	4.660×10^7	0.00950	443	394	4.504×10^{-6}	210	187
	9	-33.24	2.920×10^7	0.06127	1789	1323	3.510×10^{-5}	1025	758
	10	-33.24	2.840×10^7	0.00171	49	72	8.105×10^{-7}	23	34
	11	-33.60	4.180×10^7	0.82215	34366	25111	3.589×10^{-4}	15001	10964
	12	-	5.680×10^7	0.00000	0	-	0.000	0	-
	13	-	3.110×10^8	0.00000	0	-	0.000	0	-
	14	-	1.847×10^8	0.00000	0	-	0.000	0	-
Combined			1.575×10^9		36959	25150		16407	10991

Table 7. Biomass and backscatter estimates, by stratum, for St. Mary's-Placentia Bay, from the 1990 herring acoustic survey.

Stock area	Stratum	Target strength (dB kg^{-1})	Stratum area (m^2)	Stratum biomass density (kgm²)	Total biomass (t)		Stratum area scattering Coeff. (sr^{-1})	Total backscattering ($m^2 sr^{-1}$)	
					Mean	S. E.		Mean	S.E.
SMB-PB	1	-	6.149×10^8	0.00000	0	-	0.000	0	-
	2	-	6.565×10^8	0.00000	0	-	0.000	0	-
	3	-	3.773×10^8	0.00000	0	-	0.000	0	-
	4	-	4.057×10^8	0.00000	0	-	0.000	0	-
	5	-	4.340×10^7	0.00000	0	-	0.000	0	-
	6	-	6.950×10^7	0.00000	0	-	0.000	0	-
	7	-	9.390×10^7	0.00000	0	-	0.000	0	-
	8	-	9.630×10^7	0.00000	0	-	0.000	0	-
	9	-33.86	1.484×10^8	0.00059	88	86	2.442×10^{-7}	36	36
	10	-	9.000×10^7	0.00000	0	-	0.000	0	-
	11	-33.84	9.240×10^7	0.93155	86075	85590	3.848×10^{-4}	35553	35355
	12	-33.88	4.970×10^7	0.22736	11300	10984	9.304×10^{-5}	4625	4496
	13	-	7.420×10^7	-	-	-	-	-	-
	14	-	8.370×10^7	-	-	-	-	-	-
	15	-	6.870×10^7	-	-	-	-	-	-
	16	-	9.790×10^7	-	-	-	-	-	-
	17	-	1.287×10^8	0.00000	0	-	0.000	0	-
	18	-33.86	2.234×10^8	0.00026	58	36	1.063×10^{-7}	24	15
	19	-	5.241×10^8	-	-	-	-	-	-
	20	-	6.000×10^8	0.00000	0	-	0.000	0	-
	21	-	1.247×10^8	0.00000	0	-	0.000	0	-
	22	-	7.030×10^7	0.00000	0	-	0.000	0	-
	23	-	2.384×10^8	-	-	-	-	-	-
	24	-	5.154×10^8	-	-	-	-	-	-
	25	-	6.433×10^8	-	-	-	-	-	-
Combined			6.031×10^9		97521	86292		40238	35637

Table 8. Comparison of population numbers at age, projected to January 1990, as estimated from the 1986 (i) January-March and ii) November-December and 1990 acoustic surveys, for Fortune Bay and St. Mary's Bay-Placentia Bay.

	Fortune Bay			
	Autumn spawners ($x10^6$)		Spring spawners ($x10^6$)	
Year-class	1986ii	1990	1986ii	1990
1989	-	0.0	-	0.0
1988	-	0.0	-	0.0
1987	-	0.3	-	56.7
1986	0.0	0.0	0.0	5.4
1985	0.0	0.0	0.0	0.7
1984	0.0	0.7	0.0	0.7
1983	0.0	1.3	0.0	17.9
1982	0.3	1.3	9.8	47.6
1981	0.0	0.7	0.3	2.0
1980	0.2	0.0	1.0	2.0
≤1979	1.1	0.0	3.4	5.3
Totals	1.6	7.5	14.5	138.1

	St. Mary's Bay-Placentia Bay					
	Autumn spawners ($x10^6$)			Spring spawners ($x10^6$)		
Year-class	1986i	1986ii	1990	1986i	1986ii	1990
1989	-	-	0.0	-	-	4.3
1988	-	-	0.0	-	-	7.2
1987	-	-	5.7	-	-	42.4
1986	-	0.0	4.7	-	0.0	32.0
1985	0.0	0.0	0.4	0.0	0.0	6.1
1984	0.0	0.0	3.6	0.2	0.0	2.2
1983	0.0	2.7	1.8	0.0	0.4	10.8
1982	8.9	0.9	1.1	40.8	32.8	121.5
1981	1.8	4.6	4.3	4.7	0.4	11.1
1980	0.5	0.0	0.0	2.1	0.4	10.8
≤1979	5.6	5.5	31.3	4.7	0.0	17.3
Totals	16.9	13.7	58.0	48.9	34.0	265.7

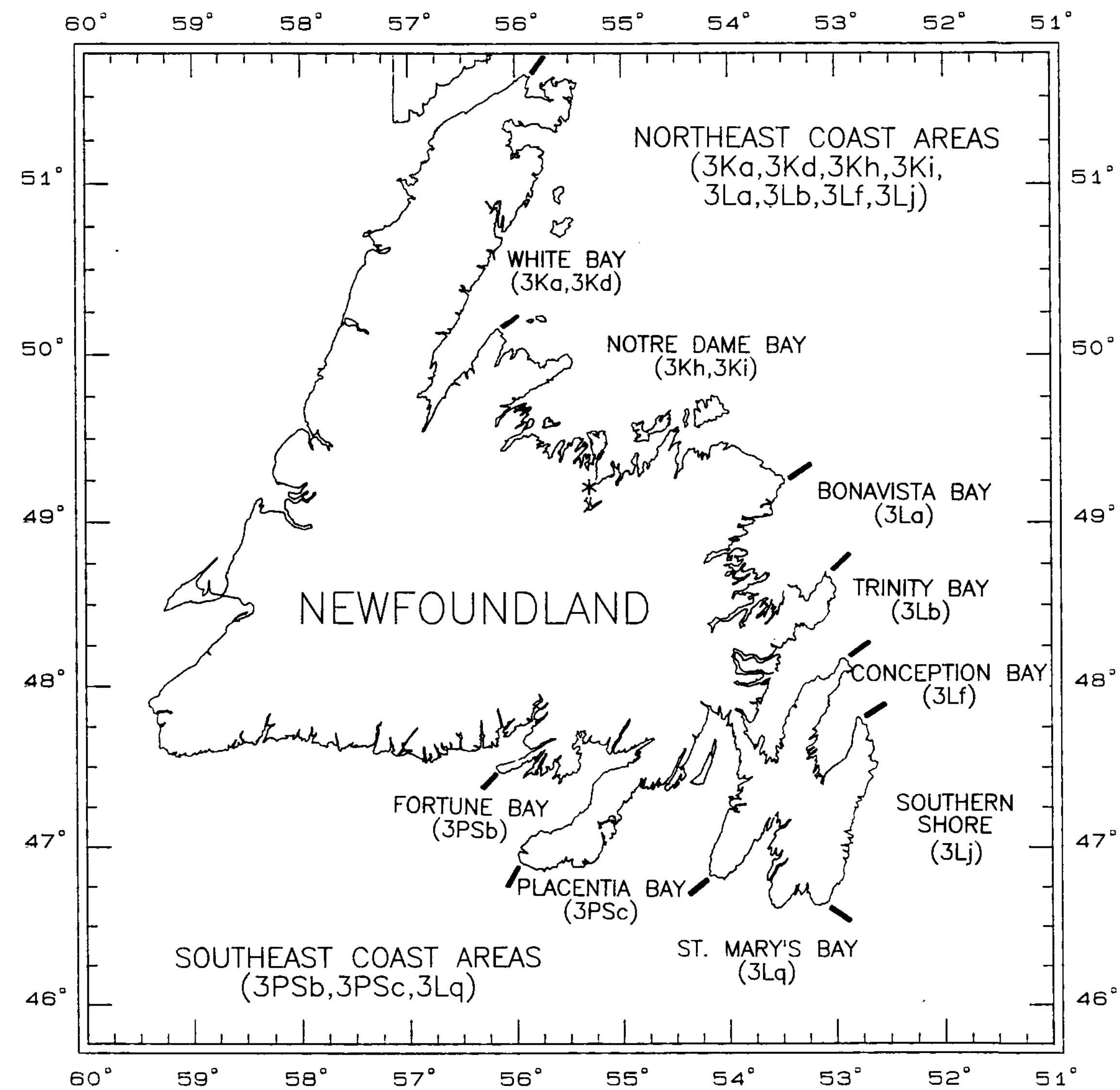

Fig. 1. Area map indicating the five herring stock complexes within the Newfoundland region: White Bay – Notre Dame Bay, Bonavista Bay – Trinity Bay, Conception Bay – Southern Shore, St. Mary's Bay – Placentia Bay, and Fortune Bay.

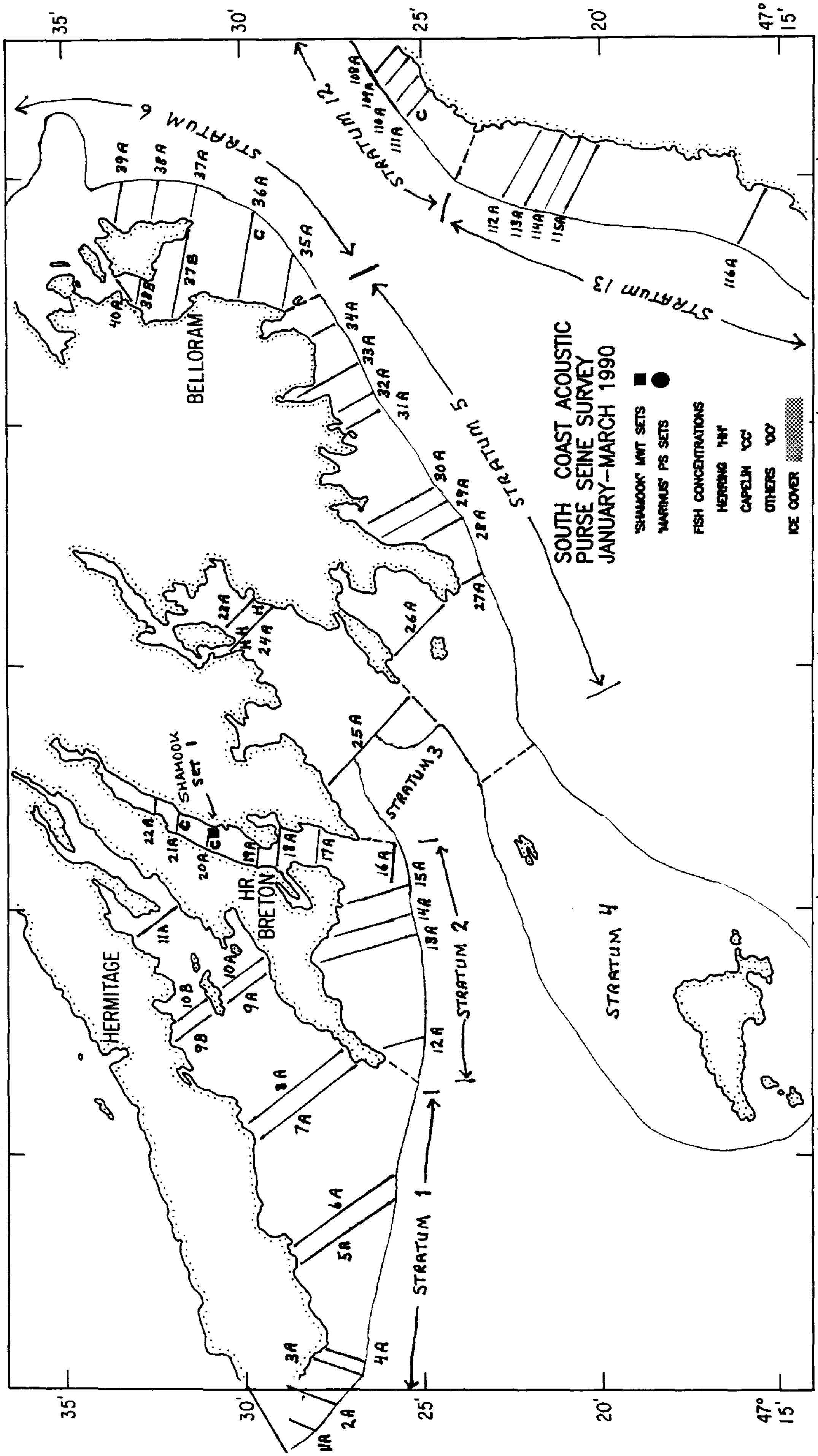

Fig. 2. Transects and set locations, acoustic purse seine survey, outer portion of Fortune Bay, 1990.

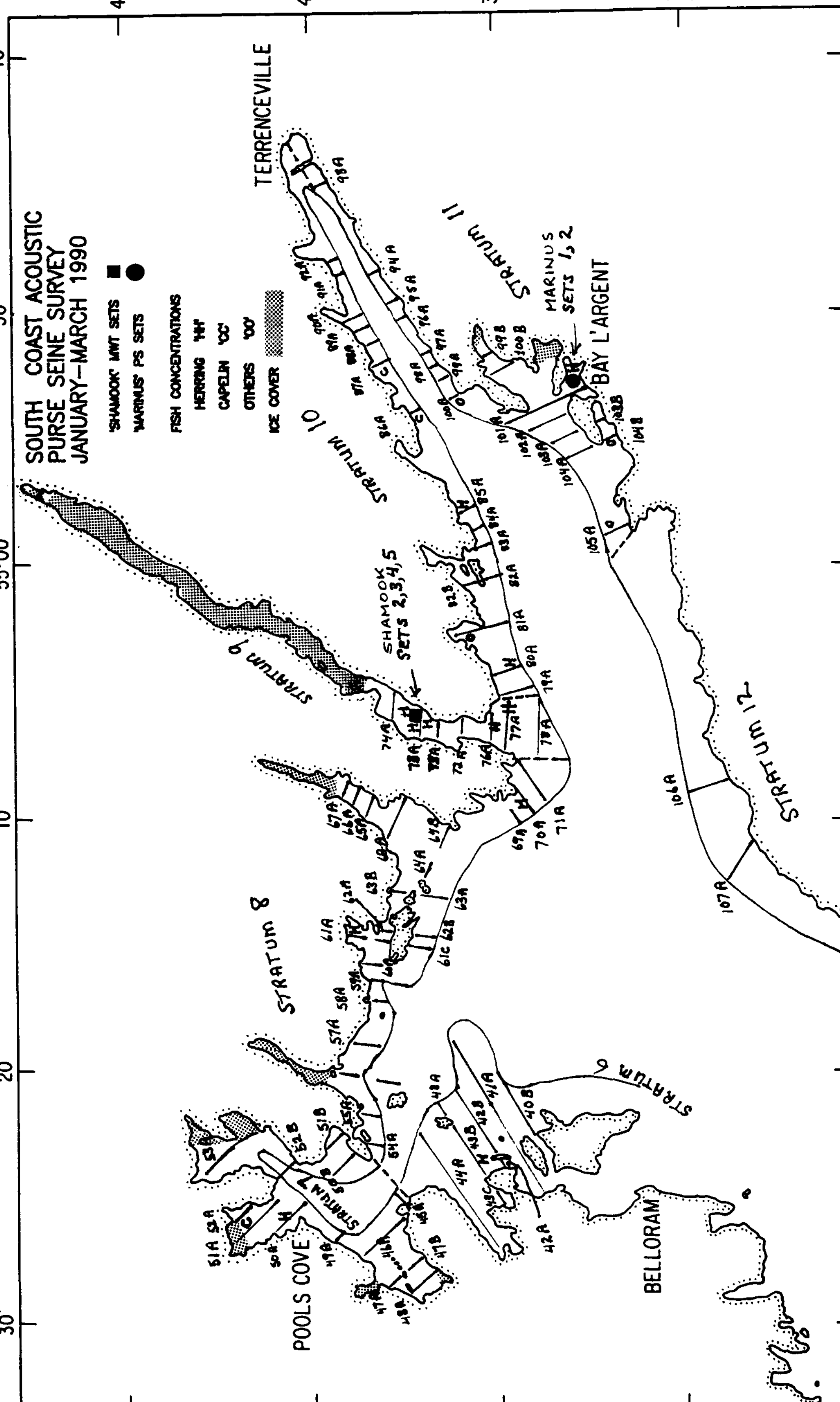

Fig. 3. Transects and set locations, acoustic purse seine survey, inner portion of Fortune Bay, 1990.

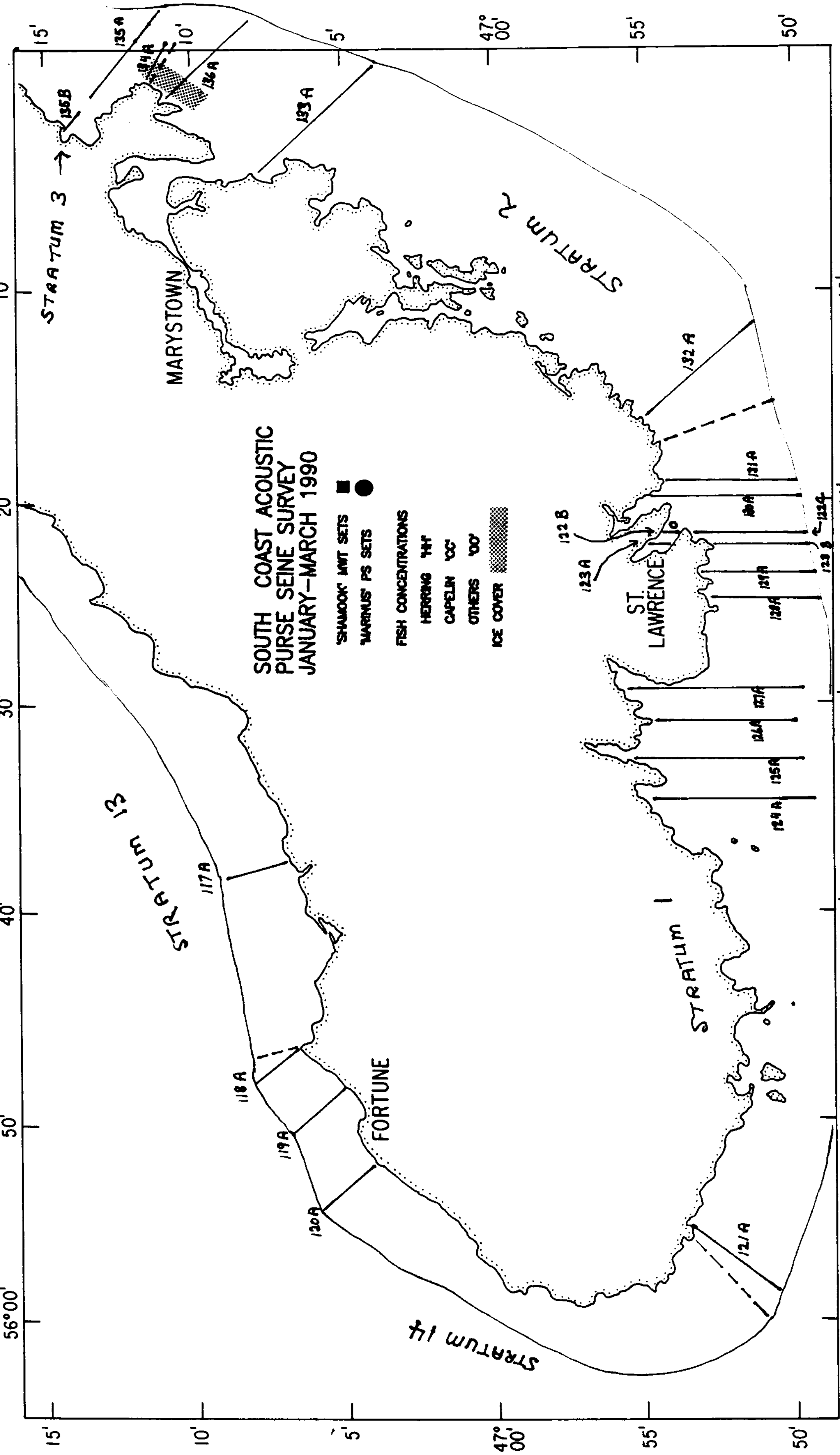

Fig. 4. Transects and set locations, acoustic purse seine survey, Fortune to Marystown, 1990.

Fig. 5. Transects and set locations, acoustic purse seine survey, west side of Placentia Bay, 1990.

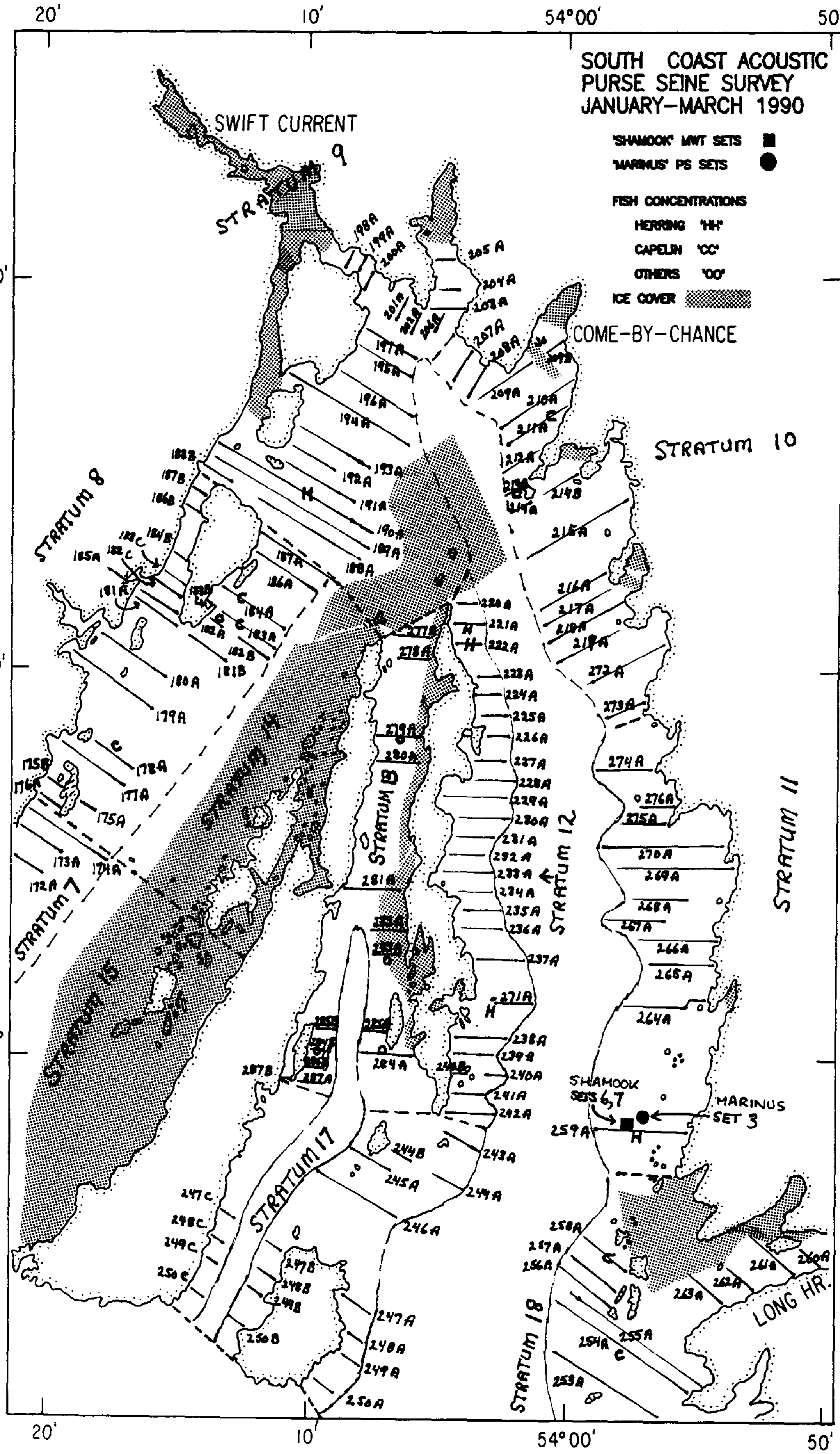

Fig. 6. Transects and set locations, acoustic purse seine survey, inner portion of Placentia Bay, 1990.

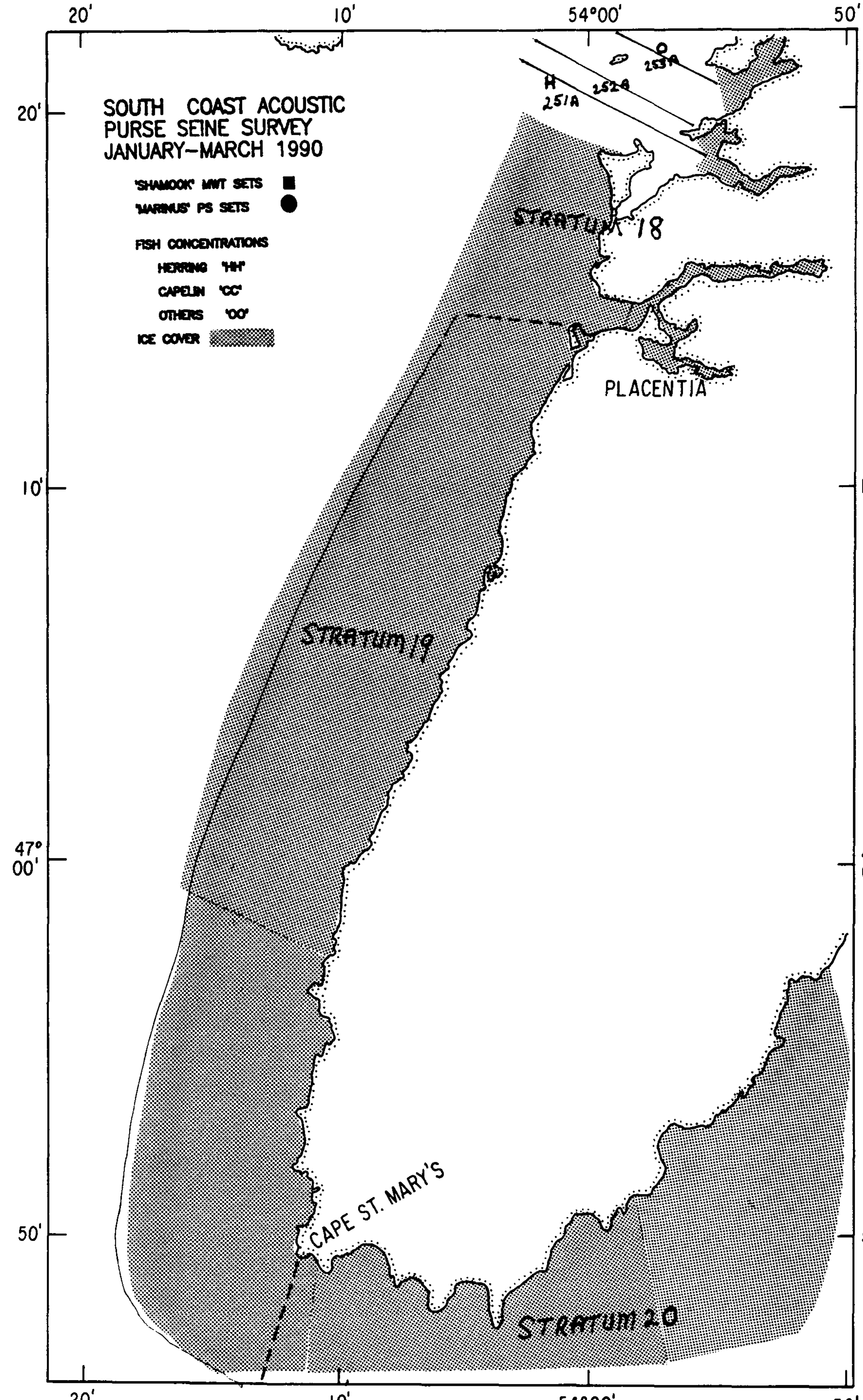

Fig. 7. Transects and set locations, acoustic purse seine survey, east side of Placentia Bay, 1990.

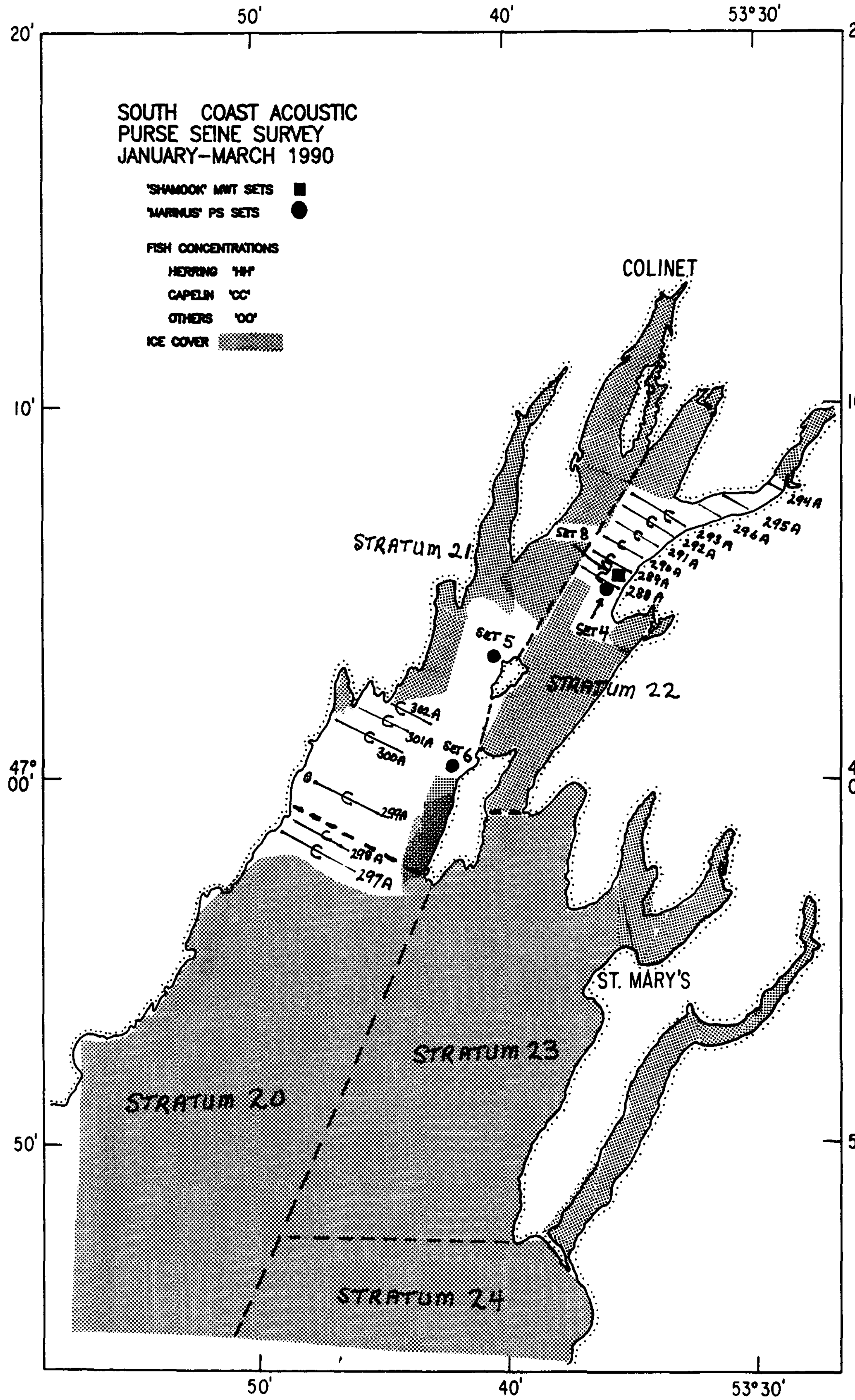

Fig. 8. Transects and set locations, acoustic purse seine survey, St. Mary's Bay, 1990.

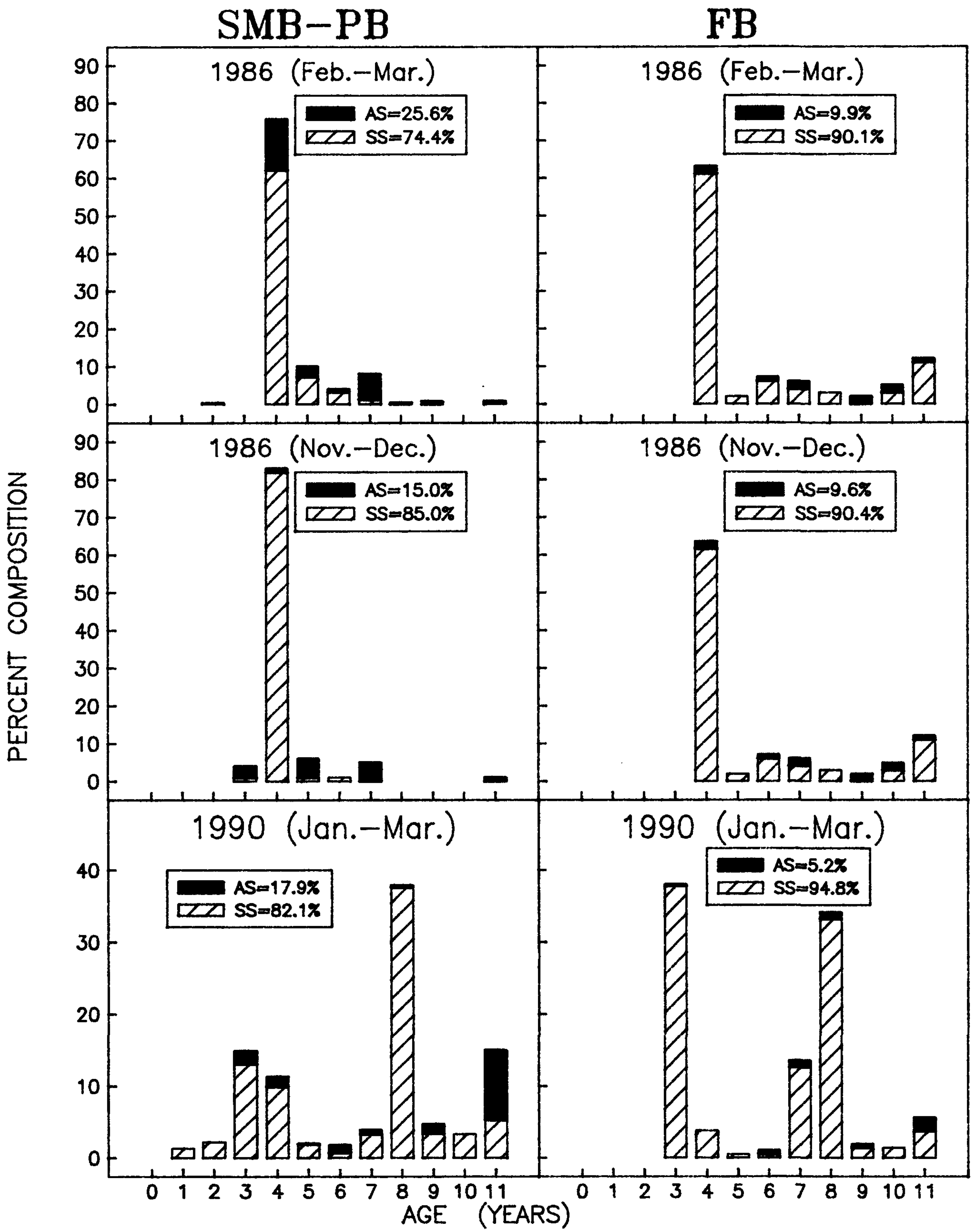

Fig.9. Stock age composition of herring from acoustic purse seine surveys, 1986 and 1990, for St. Mary's Bay-Placentia Bay (SMB-PB), and Fortune Bay (FB).

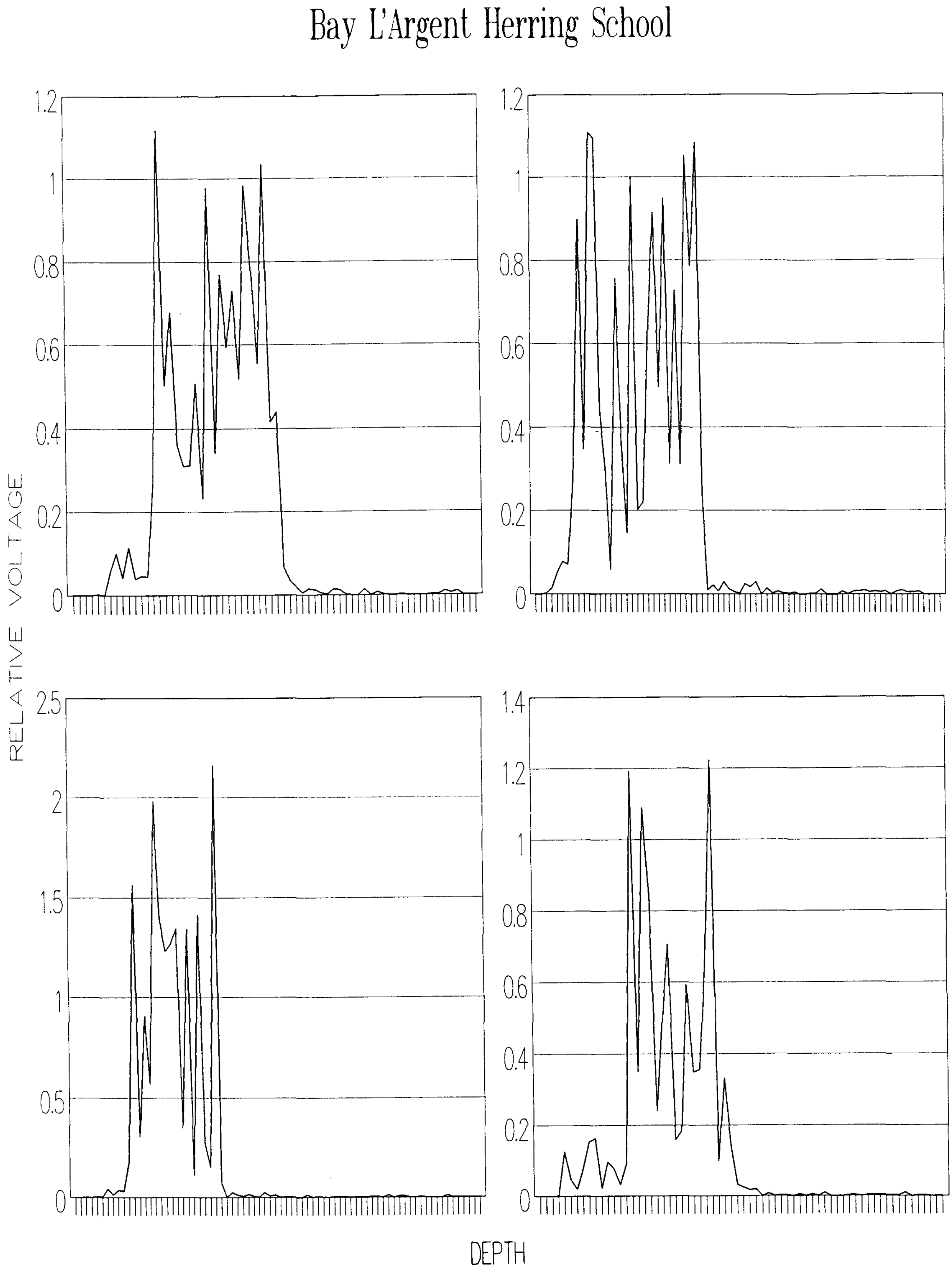

Fig. 10. Oscilloscope tracings illustrating relative voltage vs. school depth from a herring school detected in Bay L'Argent, Fortune Bay, January 1990.

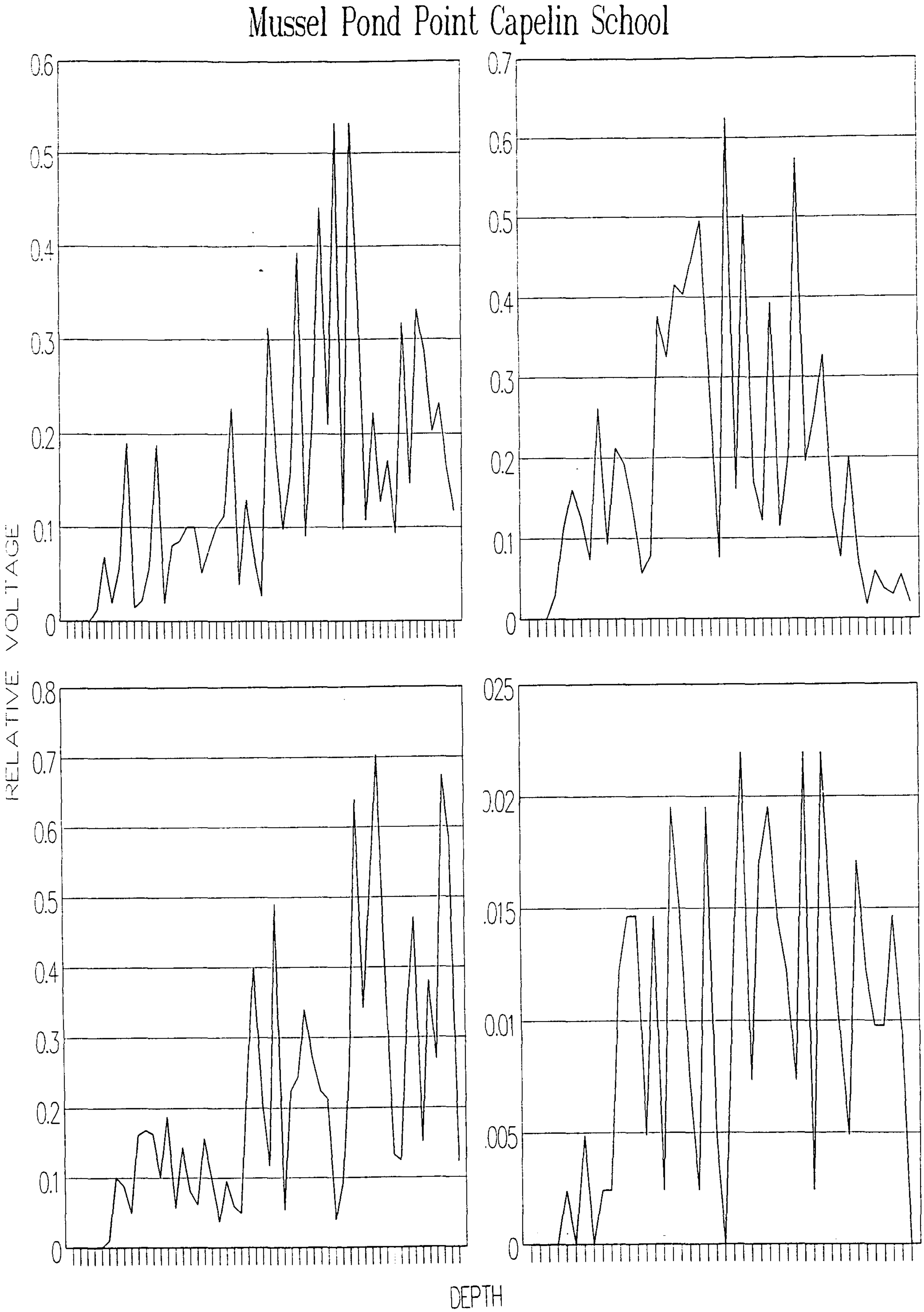

Fig. 11. Oscilloscope tracings illustrating relative voltage vs. school depth from a capelin school detected off Mussel Pond Point, St. Mary's Bay, February 1990.

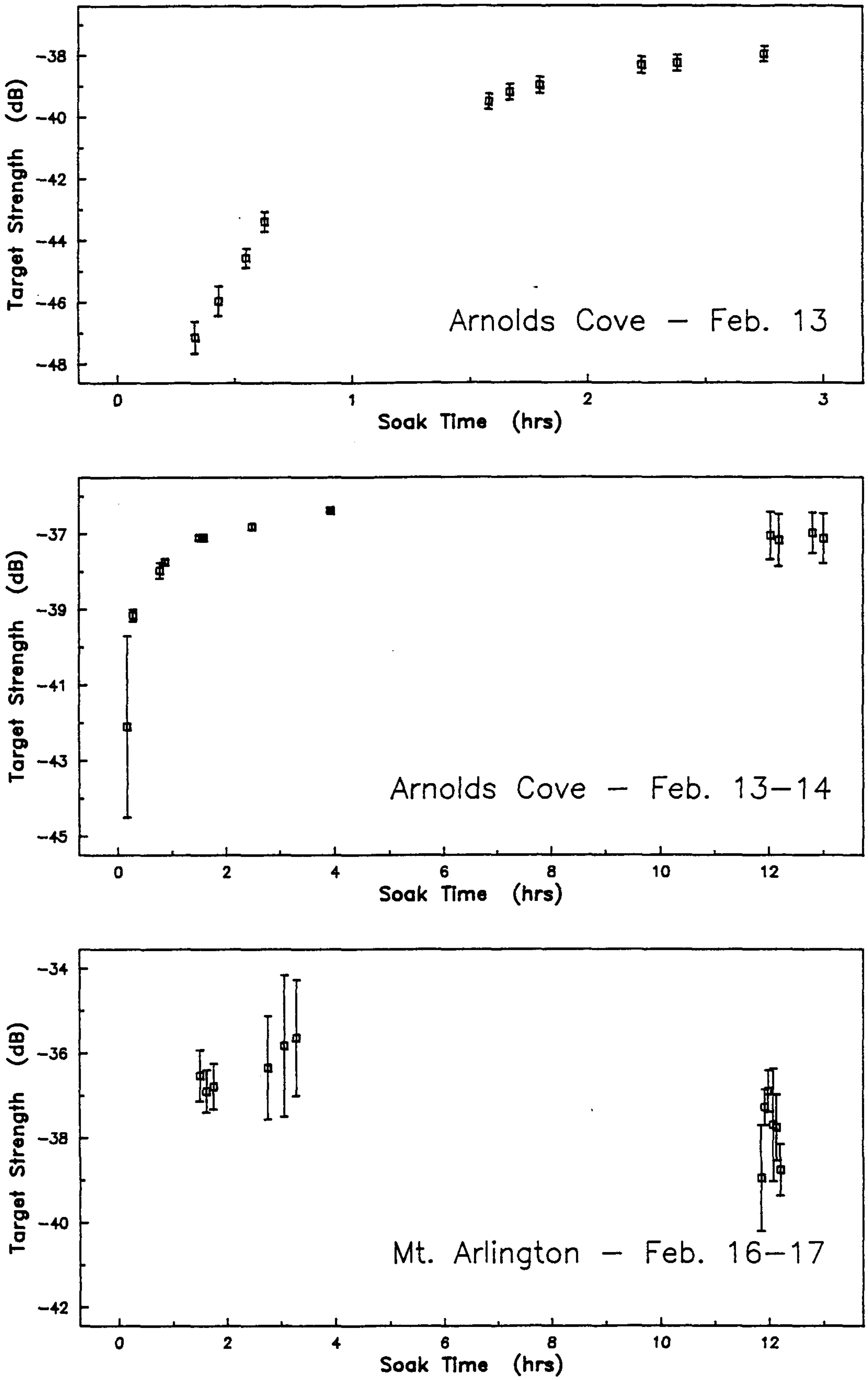

Fig. 12. Average target strength of standard target sphere vs. soak time as measured during the 1990 southeast coast acoustic survey.

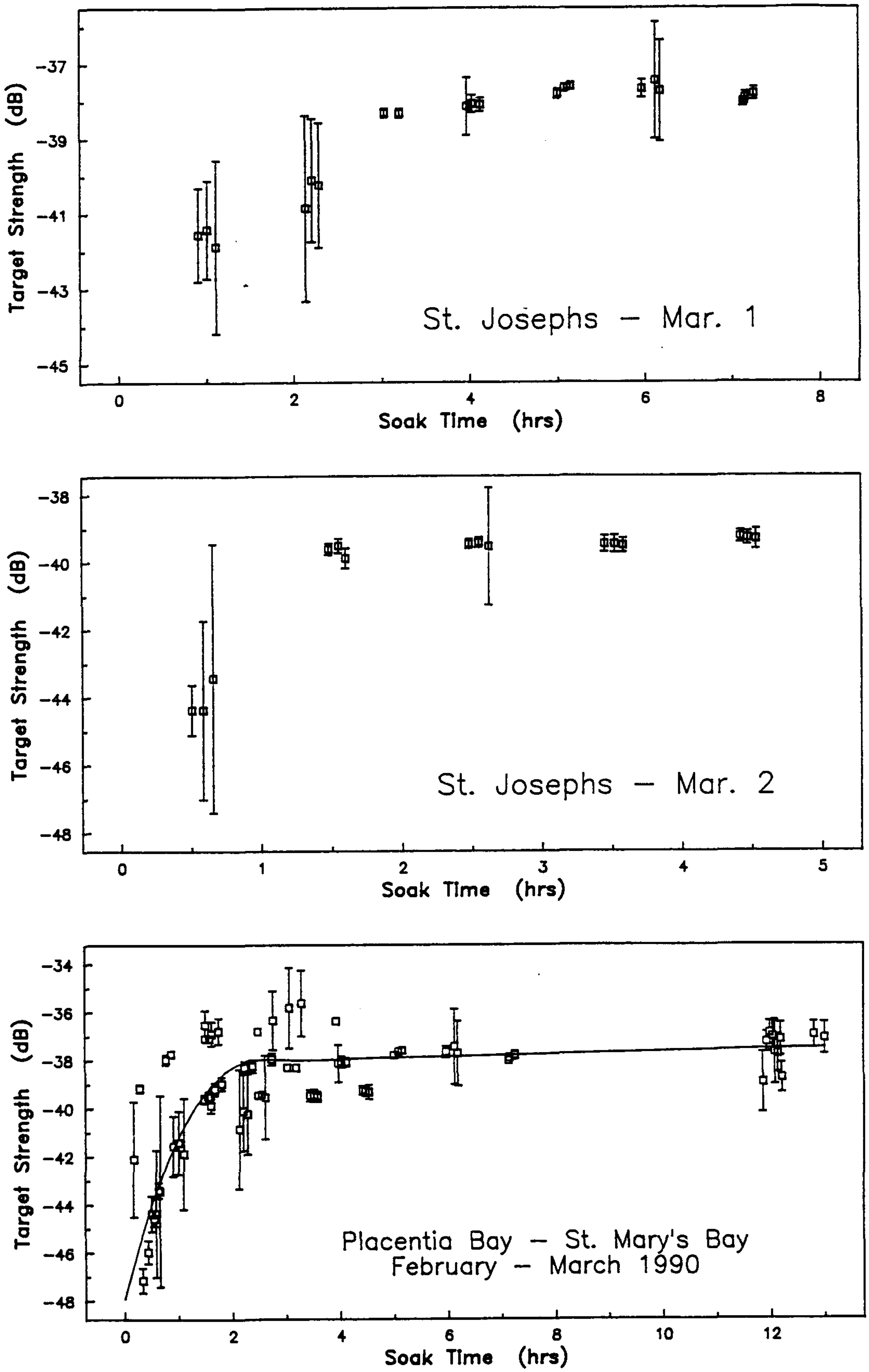

Fig. 12. Continued ...

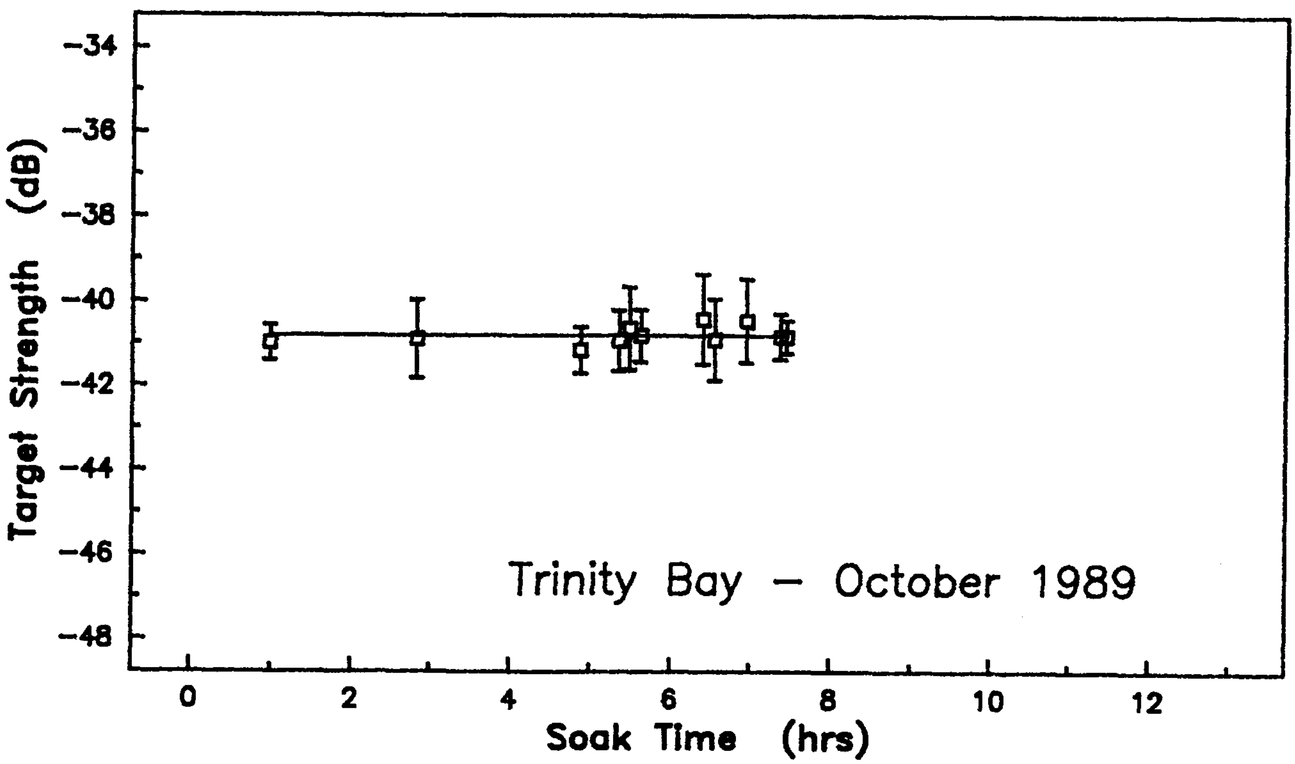

Fig. 13. Average target strength of the standard target sphere vs. soak time as measured in Smith Sound, Trinity Bay, October 1989.

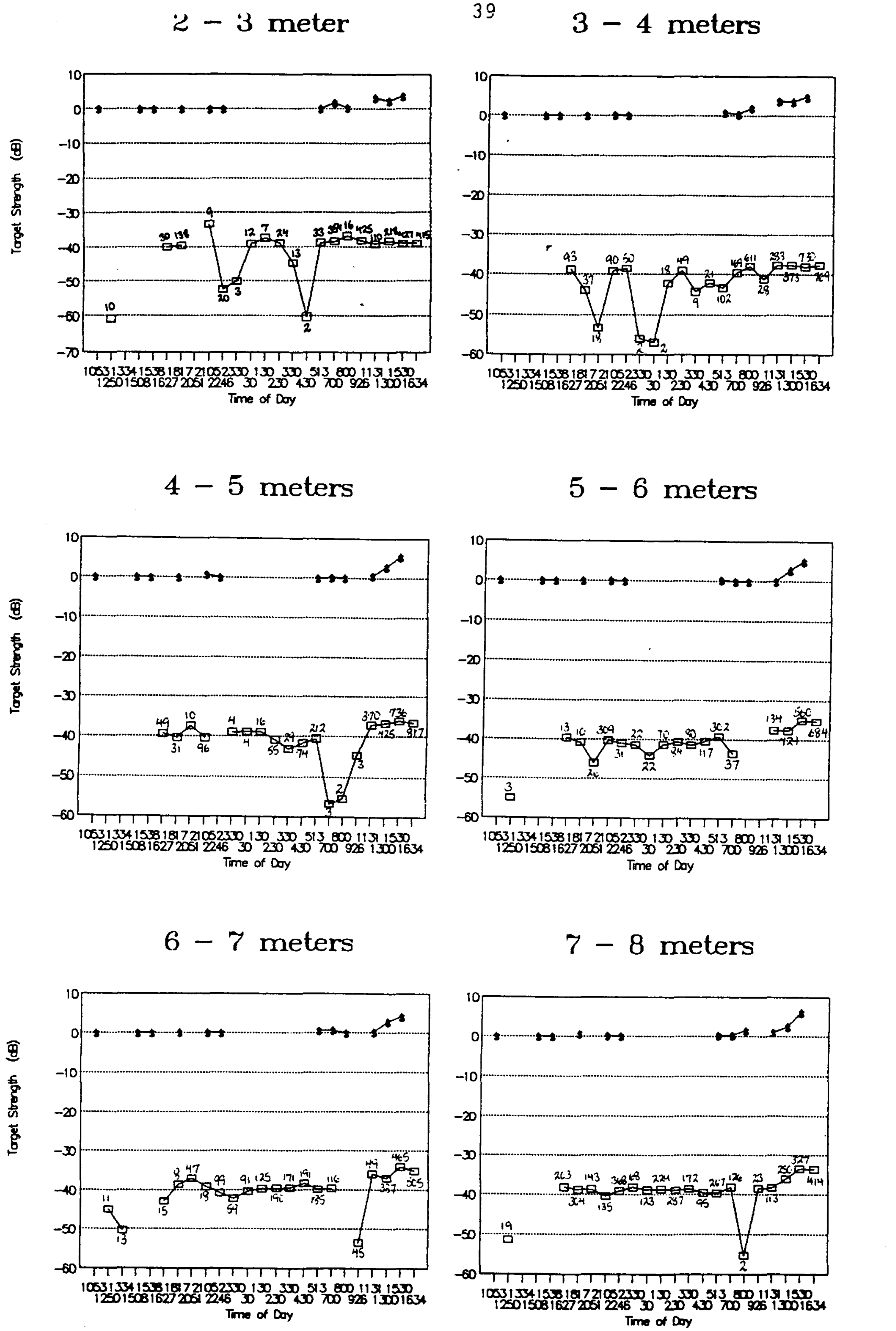

Fig. 14. Temporal changes in average target strengths of herring (mean length 25.8 cm) at one meter depth intervals, measured in situ in Trinity Bay, October 1989.

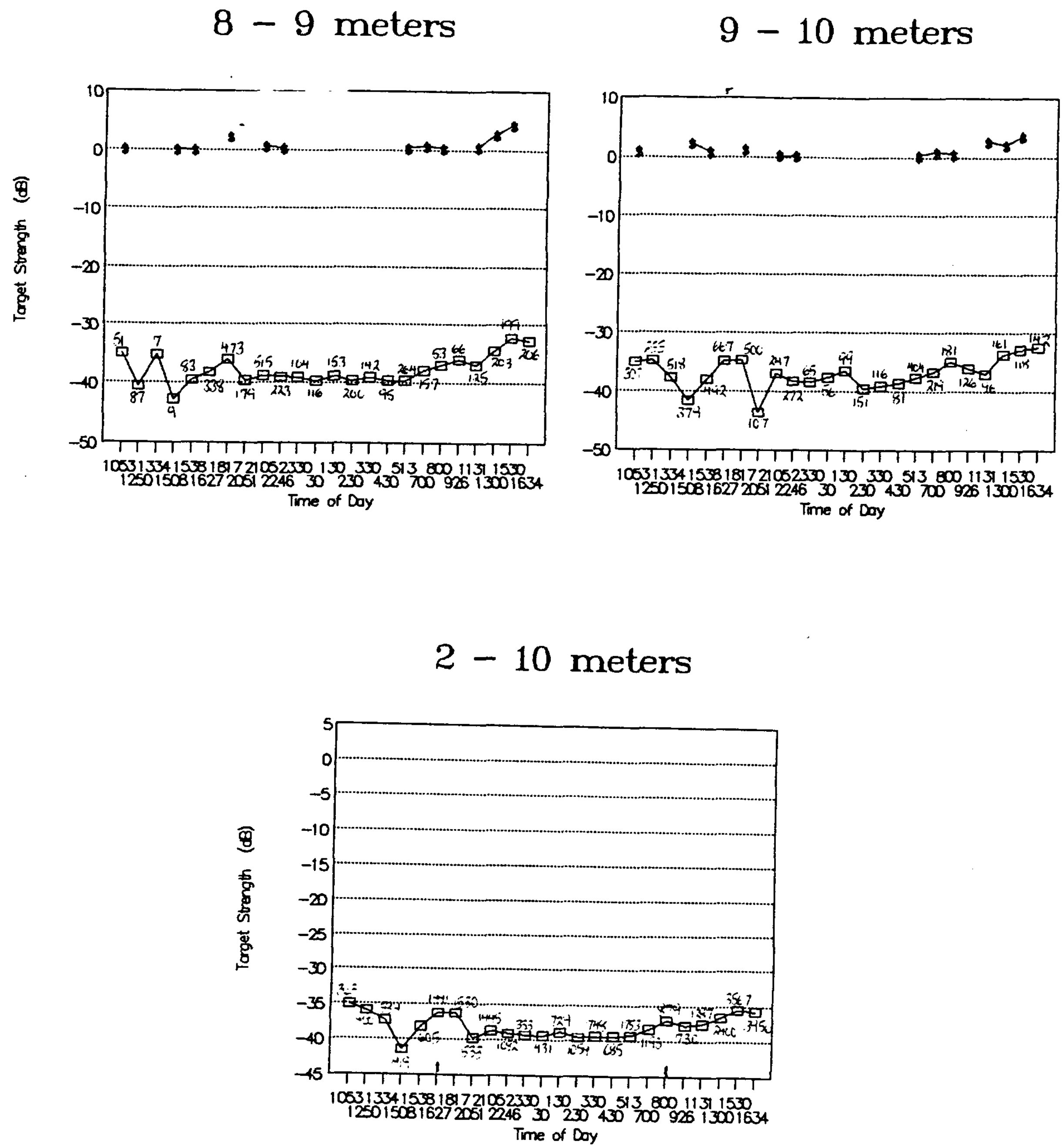

Fig. 14. Continued ...

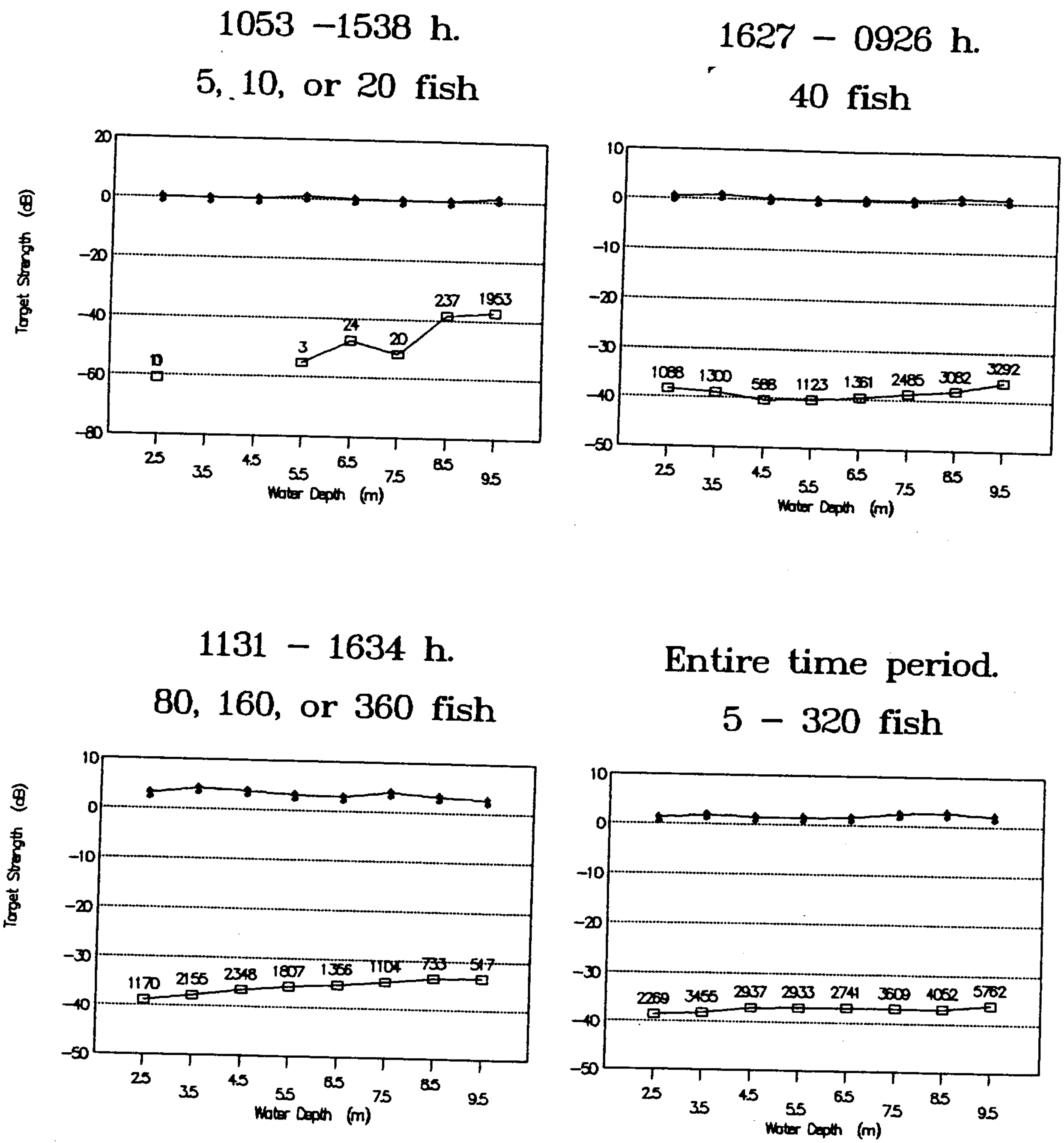

Fig. 15. Average target strengths of herring (mean length 25.8 cm) by depth, measured in situ in Trinity Bay, October 1989.

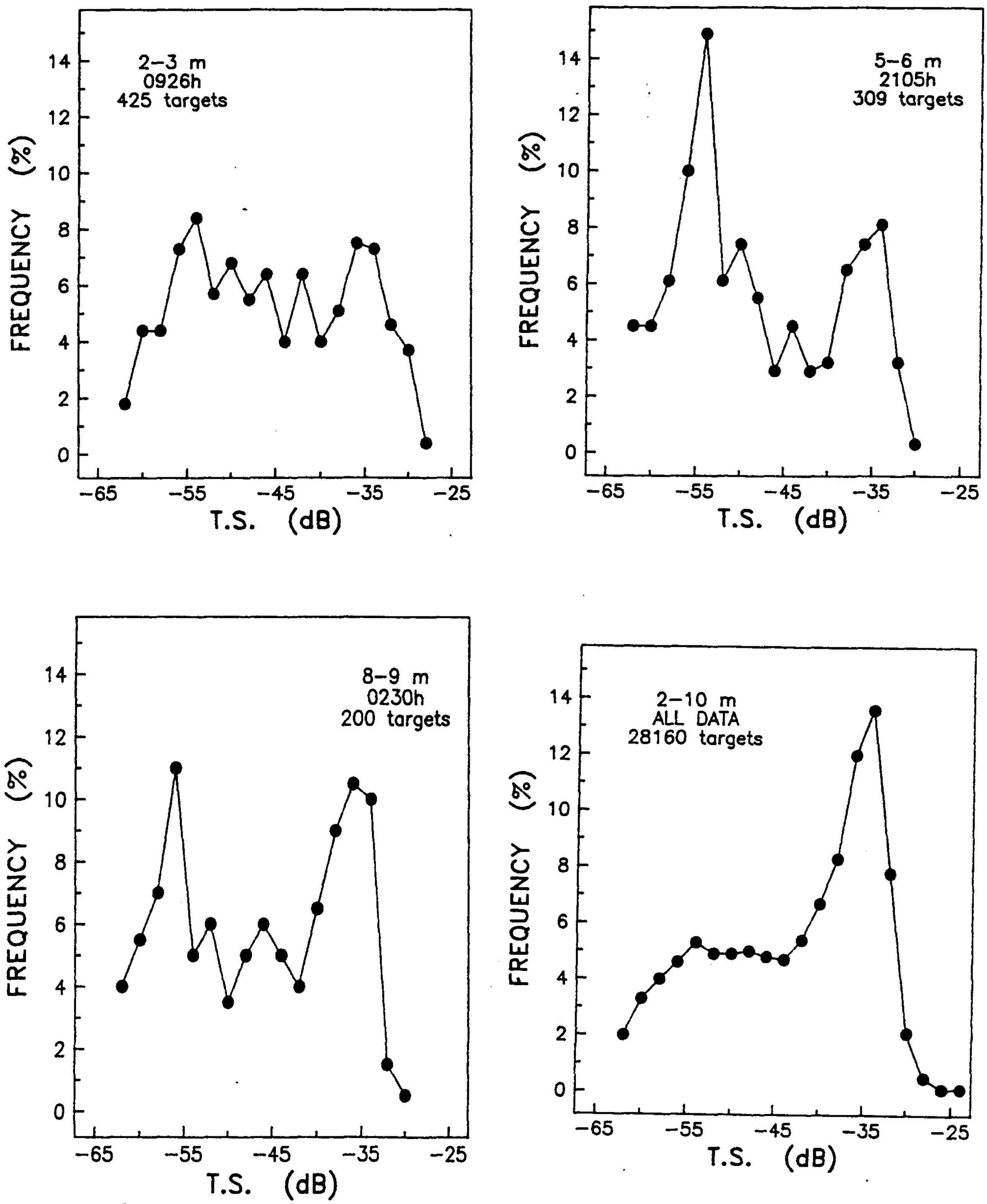

Fig. 16. Frequencies of target strengths as measured at specific depths and times, in Trinity Bay, October 1989.

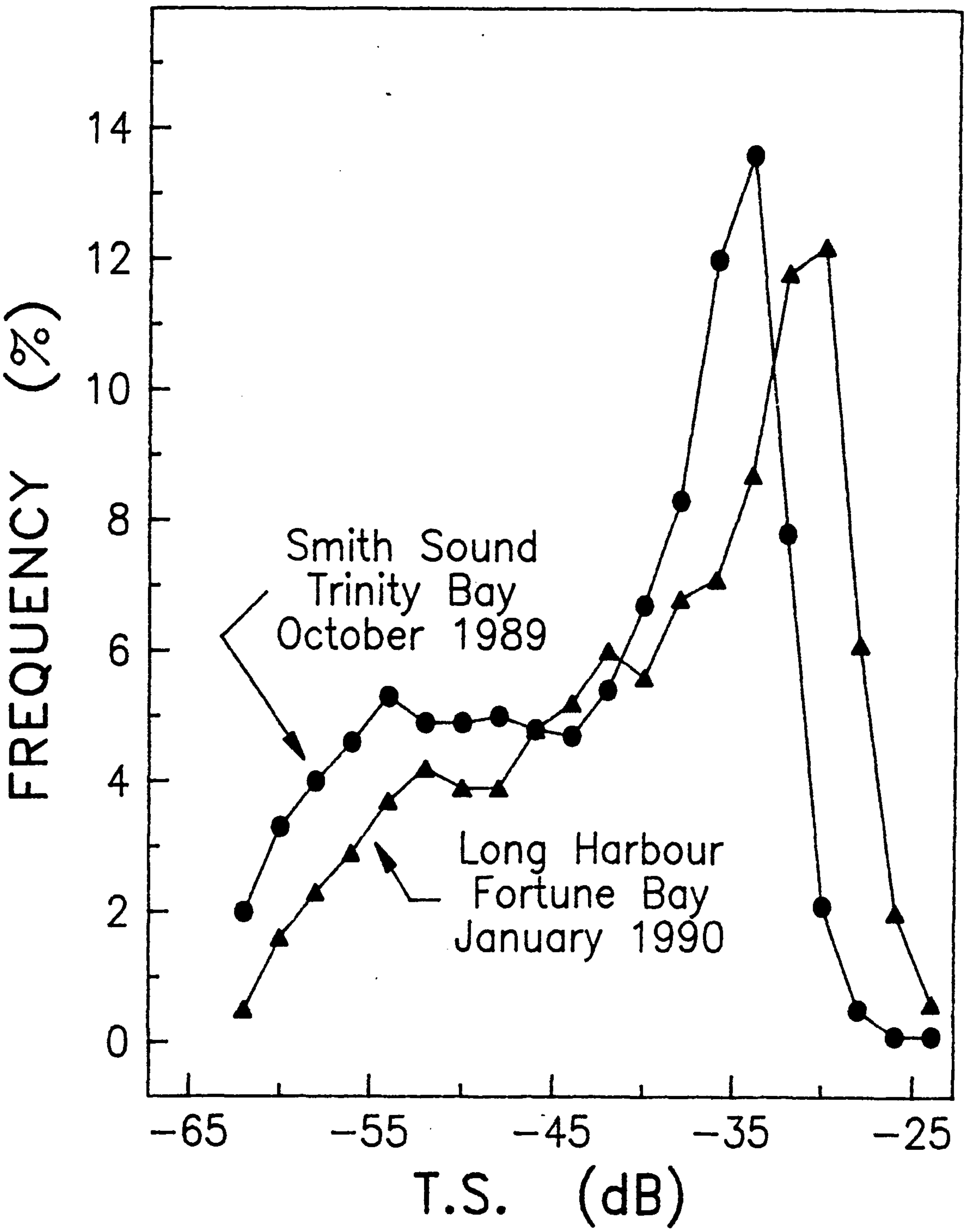

Fig. 17. Comparison of target strengths measured in situ in Trinity Bay, October 1989 on herring with mean length of 25.8 cm and in Fortune Bay, January 1990 on herring with mean length of 27.2 cm.

Appendix 1. Calibration parameters for the BioSonics hydroacoustic system, calibrated on December 8, 1989, and used during the 1990 southeast coast herring acoustic survey.

105-87-025 / 32-120-1025-026
Sounder / Transducer

BioSonics
SYSTEM CALIBRATION

Page 1 of 2

Customer Name: DFO Atlantic Fisheries Date: 12/8/89
(Company or Agency
Newfoundland Region, St Johns Newfoundland Project #:

BioSonics Contact Person: Russ Thynes Calibrator: Russ Thynes

Echo Sounder
Model # 105 Serial # 025 Frequency 120 kHz
Rec. Gain (RG) +6 dB Bandwidth 5 kHz (α) FRESH WATER
Blanking Distance na m Calibration Range, (R_{CAL}) 20 m = 26.85 ms
Total TVG Range 2.0 to 200 m 20/40 log R cross. dist. 16.2 m

Transducer & Cable Transducer S/N: Beam width
Cable Length 100' tow, 100' deck (200ft = 61 M) Cable Type B10 standard Cable S/N 141-89-520 deck, 147-89-051 tow

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) 1.185 m, Water Temperature 15 °C

CALIBRATION - SYSTEM RECEIVING SENSITIVITY

Transmission Loss, $TL = 20 \log R + \alpha R$ = 1.47 dB ($R = R_s$ meters)

TVG gain, G_{TVG40} 52.04 dB ($40 \log R_{CAL} + 2\alpha R_{CAL}$)
G_{TVG20} 26.02 dB ($20 \log R_{CAL} + 2\alpha R_{CAL}$)

Voltage into Standard, v_s = 50.4 mv V_s = −25.95 dBv (RMS)
Acoustic Level, $L = Ts + Vs - TL$ = 121.2 dB µPa
(at receiving transducer)

Receiver #1 40 log R*
Voltage out of Receiver, v_{det} = 2.642 V_{det} 8.44 dBv *

Receiving Sensitivity, $Gx = V_{det} - L$ = −118.7 dBv/µPa @ R_{CAL} meters

$G_1 = G_x - G_{TVG40} - RG$ = −170.8 dBv/µPa @ 1 m

Receiver #1 20 log R*
Voltage out of Receiver, v_{det} = 2.134 V_{det} 6.58 dBv *

Receiving Sensitivity, $Gx = V_{det} - L$ = −120.6 dBv/µPa @ R_{CAL} meters

$G_1 = G_x - G_{TVG20} - RG$ = −146.6 dBv/µPa @ 1 m

Appendix 1. Continued ...

BioSonics
SYSTEM CALIBRATION

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

Simultaneous 20 log R

Voltage out of Receiver, v_{det} = 2.696 V_{det} 8.61 dBv *

Receiving Sensitivity, $Gx = V_{det} - L$ = -118.5 dBv/µPa @ R_{CAL} meters

$G_1 = G_x - G_{TVG20} - RG$ = -142.6 dBv/µPa @ 1 m

Receiver #2 40 log R*

Voltage out of Receiver, v_{det} = 2.614 V_{det} 8.35 dBv *

Receiving Sensitivity, $Gx = V_{det} - L$ = -118.8 dBv/µPa @ R_{CAL} meters

$G_1 = G_x - G_{TVG40} - RG$ = -170.8 dBv/µPa @ 1 m

Receiver #2 20 log R*

Voltage out of Receiver, v_{det} = 2.110 V_{det} 6.49 dBv *

Receiving Sensitivity, $Gx = V_o - L$ = -120.7 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) = 0.1 dB

CALIBRATION SOURCE LEVEL

Transmission Loss, $TL = 20 \log R_s + \alpha R_s$ = 1.47 dB

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

Pulse Width 0.4 ms

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

TRANSMITTER SETTING	V_{out} STANDARD XDUCER		V_{so}	-Ss + TL	SL SOURCE LEVEL
dB	Vpp	Vrms	dBv	dBv	dB µ Pa @ 1 m.
na	17.00	6.01	15.58	197.4	+ 212.9
					+
					+
					+
					+

Comments * CORRECTED FOR RECEIVER GAIN SET FOR +6 dB

Appendix 1. Continued ...

BioSonics
4520 Union Bay Place NE
Seattle, Washington 98105
(206) 527-0905

Transducer Data Sheet

CUSTOMER: DFO / ST JOHNS'

DATE: 5-11-89 **INITIALS:** JB

Transducer Serial #: 33-120-1025-026 Frequency in kHz: 120

Nominal Beamwidth: 10°/25°

• • • Integrator Factors • • •

Angle Range — Narrow Beam: 0-30 Wide Beam: 0-30

Directivity Index — Narrow Beam: 26.55 dB Composite: 23.81 dB

Beam Pattern Factor $\left(\bar{b}^2_{av}\right)$ — Narrow Beam: 0.2048 E-2

Beam Pattern Factor — Composite Beam: 0.3459 E-2

• • • Dual Beam Factors • • •

Angle Range:

Wide Beam Dropoff d: 1.234 dB

A: 2.276

B: 0.579

The narrow (B_n) and wide (B_w) directivity functios in dB are related as follows:

$$B_n = d\,(B_n - B_w)$$

The equation relating narrow beam directivity (B_n) and angle of axis (θ) is:

$$\theta = A \cdot B_N^B$$

θ = Angle in degrees

B_n = Value of narrow beam directivity in dB

Appendix 2. Calibration parameters for the BioSonics hydroacoustic system, calibrated April 13, 1990, after the 1990 southeast coast herring acoustic survey.

105-87-025 / 33-120-1025-028
Sounder / Transducer

BioSonics
SYSTEM CALIBRATION

Page 1 of 2

Customer Name: Dept. of Fisheries and Oceans of Canada (Company or Agency)
Date: 4/13/90
Project #: SR-712
BioSonics Contact Person:
Calibrator: Russ Thymes

Echo Sounder
Model # 105 Serial # 025 Frequency 120 kHz
Rec. Gain (RG) 0 dB Bandwidth 5 kHz (α) Fresh water
Blanking Distance na m Calibration Range, (R_{CAL}) 20.0 m
Total TVG Range 2.0 to 200 m 20/40 log R cross. dist. m

Transducer & Cable Transducer S/N: 029 Beam width 10° / 25°
Cable Length 180' Tow / 100 Deck Cable Type 8/0 Std. Cable S/N 141-89-520 / 147-89-051

Standard Transducer Serial # 102 Type EDO
Ts 198.58 dB μPa/Vrms @ 1 meter Ss -195.9 dBv/μPa

Tank Parameters
Transducer separation, (R_s) 1.18 m, Water Temperature 15 °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 = 100.8 mV V_s = -19.93 dBv (RMS)
Acoustic Level, L = Ts + Vs - TL = 127.2 dB μPa
(at receiving transducer)

Receiver #1 40 log R*
Voltage out of Receiver, v_{det} = 2.594 V_{det} 8.28 dBv

Receiving Sensitivity, Gx = V_{det} - L = -118.9 dBv/μPa @ R_{CAL} meters

G_1 = G_x-G_{TVG40} - RG = -170.9 dBv/μPa @ 1 m

Receiver #1 20 log R*
Voltage out of Receiver, v_{det} = 2.070 V_{det} 6.32 dBv

Receiving Sensitivity, Gx = V_{det} - L = -120.9 dBv/μPa @ R_{CAL} meters

G_1 = G_x-G_{TVG20} - RG = -146.9 dBv/μPa @ 1 m

Appendix 2. Continued ...

105-87-025 / 33-120-1025-02
Sounder / Transducer

BioSonics
SYSTEM CALIBRATION

Page 2 of 2

Simultaneous 20 log R

Voltage out of Receiver, v_{det} = 2.192 V_{det} 6.82 dBv

Receiving Sensitivity, $Gx = V_{det} - L$ = -120.4 dBv/µPa @ R_{CAL} meters

$G_1 = G_x - G_{TVG20} - RG$ = -146.4 dBv/µPa @ 1 m

Receiver #2 40 log R*

Voltage out of Receiver, v_{det} = 2.440 V_{det} 7.75 dBv

Receiving Sensitivity, $Gx = V_{det} - L$ = -118.9 dBv/µPa @ R_{CAL} meters *

$G_1 = G_x - G_{TVG40} - RG$ = -171.0 dBv/µPa @ 1 m

Receiver #2 20 log R*

Voltage out of Receiver, v_{det} = 1.956 V_{det} 5.83 dBv

Receiving Sensitivity, $Gx = V_o - L$ = -120.8 dBv/µPa @ R_{CAL} meters *

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

Gain Difference

40 Log R gain difference G_1 (CH 1) - G_1 (CH 2) = .5 dB

CALIBRATION SOURCE LEVEL

Transmission Loss, $TL = 20 \log R_s + \alpha R_s$ = 1.47 dB

Source Level, $SL = V_{so} - Ss + TL$ Pulse Width 0.4 ms

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

TRANSMITTER SETTING	V_{out} STANDARD XDUCER		V_{so}	-Ss + TL	SL SOURCE LEVEL
dB	Vpp	Vrms	dBv	dBv	dB µ Pa @ 1 m.
—	17.00	6.01	15.58	197.4	+ 212.9
					+
					+
					+
					+

Comments * CORRECTED FOR GAIN DIFFERENCE OF 0.5 dB

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/m²) for block i in stratum h

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

5) the mean density (kg/m²) per unit area for stratum h

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

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

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