Distribution and Acoustic Backscatter of Herring in NAFO Division 4T, November 1989

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ABSTRACT

The sixth annual acoustic survey for herring in the southern Gulf of St. Lawrence was conducted from 3 to 11 November 1989. Surveys in the western Gulf in and near the Bay of Chaleur produced herring biomass estimates of 11,249 tonnes. Most herring were found in the Newport and North Miscou strata. The 1989 estimate for the Chaleur area was only 5% of the 1988 estimate. The reduction in estimated biomass may have been due to an early migration from the western Gulf to wintering grounds in Sydney Bight. Surveys were not conducted in Sydney Bight because of a labour dispute.

RESUME

Le sixième relevé acoustique du hareng du sud du Golfe Saint- Laurent a été mené du 3 au 11 novembre 1989. Les relevés dans l'ouest du Golfe dans et près de la Baie des Chaleurs ont produit les estimés de biomasse de 11,249 tonnes. La plupart du hareng était retrouvée dans les strates de Newport et du Miscou du nord. L'estimé de 1989 n'était que 5% de celui de 1988. Cette réduction est possiblement due a une migration hâtive de l'ouest du Golfe vers les terrains d'hivernage dans l'Anse de Sydney. Du a un conflit de travail, les relevés n'ont pas été mené dans l'Anse de Sydney.

INTRODUCTION

Since 1984, the Department of Fisheries and Oceans has conducted acoustic surveys of late fall concentrations of herring (*Clupea harengus*) belonging to the southern Gulf of St. Lawrence stock complex (Shotton 1986, Shotton et al. 1987 a and b, Cairns et al. 1988 and 1989). Survey effort has concentrated in the Bay of Chaleur area, where NAFO Division 4T herring congregate in late fall, and the Sydney Bight area off Cape Breton Island, which is the wintering ground for many, and possibly all, 4T herring (W.T. Stobo and S. Courtenay, pers. comm.). Both of these areas are subject to purse seine fisheries in November.

The long-term objective of these surveys is to obtain an independent index of stock abundance for 4T herring which could be used as a means of calibrating virtual population analysis. This report presents acoustic backscatter estimates for herring in an area of the western Gulf centred around the Bay of Chaleur. Because the 1989 acoustic herring cruise was interrupted by a labour dispute, no data are available for the Sydney Bight area.

SURVEY AREA AND METHODS

Acoustic surveys were conducted using randomly-placed parallel transects within strata. The use of random parallel transects was recommended by CAFSAC following the special meeting of its Pelagic Subcommittee in August 1988 on acoustic survey design (O'Boyle and Atkinson 1989). Transect lines were randomly selected from a series of lines drawn perpendicular to the seaward boundary of a stratum and spaced 200 m apart. The 200 m spacing was used in place of the 926 m spacing recommended by O'Boyle and Atkinson (1989) because of the small size of the strata. Transect lines ran from the seaward stratum boundary inshore to approximately the 10 fathom line.

The 1989 survey covered only strata in the Chaleur area of the western Gulf of St. Lawrence. Strata and their boundaries (mapped in Figs. 1-5) were the same as those used in 1988 (Cairns et al. 1989).

Survey time was allocated among strata so that density of coverage (kilometers steamed per km^2 of stratum) varied with expected herring biomass. To determine time per stratum we first alotted available time so that survey intensity was directly proportional to the mean backscatter density recorded within strata in 1985-1988. Using this system, some strata merited very high or very low intensities of transect coverage. To ensure that all areas were adequately covered we adjusted the initial time alotments so that at least 7% but no more than 45% of potential transect lines were selected as transects in each stratum.

Because survey time may be unexpectedly restricted by weather or unforeseen events, we randomly assigned transect lines in most strata to two priority levels. In the A series, the number of transects per stratum was calculated so that cruising transects would use up about 60% of the planned survey period. Remaining transects were assigned to the B series, to be completed after the A series. In strata with only a few transects (Cap Bon Ami, Gaspé Bay, Gaspé Offshore, Malbaie), all transects were placed in the A series.

Transects were run 24 hours a day at 10 knots, except in poor weather when speed was reduced to 8-9 knots.

Acoustic transects were run from 3 to 11 November 1989. At 1000 on 7 November the *Alfred Needler* ran aground just off Paspebiac while completing a transect in the Shigawake stratum. The vessel got off at 1930 but transects were suspended until 0730 on 9 November because of hull inspection requirements. Transects were further suspended between 1250 and 1819 on 10 November as the ship was called to port for landline consultations. Transects continued until 0021 on 11 November when the cruise terminated because of a labour dispute. The vessel then headed for Dartmouth.

Completed transects are listed in Table 1. All prescribed transects were completed in the Cap Bon Ami, Gaspé Bay, Gaspé Offshore, and Malbaie strata. Only 10 of 28 A-series transects were completed in the East Miscou stratum. Consequently the southern part of that stratum was unsurveyed. Because coverage of the Shigawake stratum was interrupted by the grounding, the port call and the cruise termination, survey intensity varied in different parts of the stratum (Table 2). Twenty-six of 59 prescribed A-series transects were completed. In all other strata, all A-series transects were completed.

Acoustic estimates used the same equipment, procedures, and algorithms as in previous years. Acoustic equipment was calibrated by R. Dowd, L. Dickie and P. Boudreau by the method of narrow/wide beam axis comparison (Dickie and Boudreau 1987).

Calibration parameters are as follows:

Combined source level and receive sensitivity: 30.5 dB (These two parameters are combined as one unit because calibration is by standard target).

Receiver gain: 35 dB narrow beam and 43 dB wide beam.

Pulse length and bandwidth: 0.4 ms and 6 kHz.

Sampling threshold: 0.5 volts peak.

To select acoustic targets for integration, we examined paper sounder traces and identified marks as adult herring, small targets, or groundfish. Criteria for categorization of traces were derived from experience in

previous years with repeated trawl sampling and the same echosounding equipment. Solid black marks rising in pyramids or plumes in the water column were considered to be adult herring. Light speckles were taken as small targets, and heavy speckles, sometimes merging into nearly solid black, were taken as groundfish. We matched marks identified as adult herring schools with corresponding echo measurements recorded by the sounder on computer tape.

Echo strengths of herring schools were integrated on the Microvax II at the Gulf Fisheries Centre using software written by R. Shotton. This software rejects any voltage samples within 30 cm of the bottom (R. Shotton, pers. comm.). Methods of bottom detection are described by Shotton (unpubl.).

Calculation of mean and variance of acoustic and biomass estimates follows Jolly and Hampton (in press) and Jolly and Smith (1989), as presented by O'Boyle and Atkinson (1989) (Appendix 1). Foote's (1987) formula was used to calculate target strength from data on fish length and weight. Because no adult herring were taken in sets in 1989, mean lengths and weights of fish taken in the 1988 survey (Cairns et al. 1989) were used in target strength calculations.

Temperature profiles were measured with expendable bathythermographs (XBT's) which transmitted data to an HP-85 computer. Surface temperatures were taken by bucket thermometer. Temperature profiles were made in three lines across the Bay of Chaleur (Fig. 2).

Acoustic targets were sampled by sets made at two locations in the western Bay of Chaleur (Fig. 2), using an IYGPT trawl equipped with a headline transducer. Sets were not made elsewhere because schools showing on sounder traces were not judged to be sufficiently dense to provide a sample. All sets were made at night when herring appear to be easier to catch by trawl.

RESULTS

Distribution and backscattering of acoustic targets

The distribution of adult herring encountered during surveys in the Bay of Chaleur is mapped in Fig. 2 and total backscattering estimates are presented in Table 3. Marks identified as adult herring were found in only four strata. Most acoustic backscatter was found in Newport (57%) and North Miscou (39%) strata. Small quantities were also found in the Maisonnette and West Miscou strata.

Marks classified as small targets were found in the New Richmond, Shigawake, North Miscou and La Malbaie strata (Figs. 4 and 5).

No marks identified as groundfish were found on this survey.

Temperature profiles

Temperature profiles are presented in Fig. 6. Surface temperatures were in the 6-10^{o} range. Temperatures rapidly declined with depth in a narrow thermocline, then gradually decreased to about 2^{o} in deep water.

Size of herring samples

Marks judged sufficiently dense to set on were found only in the New Richmond stratum. The two sets made in that stratum (Fig. 2) obtained juvenile herring, mostly between lengths 21 and 27 cm (Fig. 6). Number (and %) spawning affinity of herring taken in these sets is given below:

Set no.	Spring	Spring-summer	Summer-fall	Fall	Total
1	17 (40)	5 (12)	2 (5)	18 (43)	42
2	35 (60)	1 (2)	1 (2)	21 (36)	58

Rainbow smelts (*Osmerus mordax*) were present in both sets but amounted to less than 1% of herring numbers.

Biomass estimates

We estimated biomass of herring schools encountered in Chaleur using Foote's (1987) formula for target strength (Tables 3-6). Because we were unable to obtain samples of adult herring in 1989, we used data on herring sizes from the November 1988 survey to perform the calculations in Foote's formula. Biomass estimates for Chaleur totaled 11249 tonnes (Table 4).

DISCUSSION

The biomass estimate from the 1989 survey was 11249 tonnes, which represents a 95.3% reduction from the 1988 estimate for the Chaleur area (Table 6, Fig. 7). If such a decrease is real a major population crash would be indicated.

The strike in November 1989 cut short the planned survey effort in the Chaleur area by about four days. Some A-series transects in Shigawake missed coverage because of the strike, but transect coverage was nevertheless sufficiently dense that it is unlikely that major herring schools would have been missed. Following the grounding, bridge officers turned the vessel at greater distances from the coast, leading to the possibility that fish may have been missed between the landward ends of the transects and the shore. The affected strata were Shigawake, New Carlisle, and New

Richmond. It is possible that concentrations of herring could have gone undetected in the southern portion of the East Miscou stratum where there was no transect coverage. This stratum had important herring concentrations in 1985 and 1987 (up to 23% of Chaleur area backscatter), although few herring were found in other survey years.

Any estimate based on complex electronic equipment is subject to instrument error. If herring were abundant in 1989 but were underestimated due to problems with the Ecolog sounder system, they should have been visible on the ship's hull-mounted sounder, which renders herring schools as dark traces. However, herring-like marks on the ship's sounder were light and infrequent in comparison with previous years.

An early departure of herring from the western Gulf could have caused the decrease in measured backscatter in 1989. Timing of the 1989 surveys was the earliest since the series began (Table 6), so migration would have to be substantially earlier than normal for herring to have been missed. If herring migrated early in 1989, a correspondingly greater quantity of herring should have been present in Sydney Bight. It is not possible to further evaluate this hypothesis because surveys were not conducted in Sydney Bight in 1989.

Acoustic backscatter estimates for 4T herring have shown marked variation since the inception of surveys in 1984 (Fig. 8). This variation is much greater than fluctuations in biomass and CPUE derived from sequential population analysis and the commercial fishery (Chadwick et al. 1989). The wide variation in acoustic results suggests that the present data series may not accurately reflect abundance of 4T herring.

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Dr. John A. Wright was tragically killed in a motor vehicle accident on 9 October 1990. The senior author would like to thank John for his friendship, professionalism, and unmatched devotion to duty. We will always remember him.

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Table 1. Estimates of total backscatter and biomass of herring encountered in acoustic transects in the Chaleur area, November 1989.

Stratum	Transect no.	November	Transect length (km)	Transect area (m^2)	Target strength (dB kg^{-1})	Sa (Area scattering coefficient) (sr^{-1})	Total backscattering (m^2 sr^{-1})	Biomass density (kg m^{-2})	Total biomass (t $transect^{-1}$)	Set number	Number of fish sampled
Cap Bon Ami	A1	5	7.289	1457796	-35.698	0.00000000	0.000000	0.00000	0.00		
	A2	5	8.008	1601599	-35.698	0.00000000	0.000000	0.00000	0.00		
	A3	5	7.844	1568868	-35.698	0.00000000	0.000000	0.00000	0.00		
	A4	5	7.682	1536444	-35.698	0.00000000	0.000000	0.00000	0.00		
	A5	5	8.737	1747332	-35.698	0.00000000	0.000000	0.00000	0.00		
Baie de Gaspé	A1	5	6.321	1264114	-35.698	0.00000000	0.000000	0.00000	0.00		
	A2	5	6.439	1287861	-35.698	0.00000000	0.000000	0.00000	0.00		
	A3	5	6.739	1347841	-35.698	0.00000000	0.000000	0.00000	0.00		
	A4	5	6.090	1217996	-35.698	0.00000000	0.000000	0.00000	0.00		
	A5	5	4.826	965299	-35.698	0.00000000	0.000000	0.00000	0.00		
	A6	5	2.723	544646	-35.698	0.00000000	0.000000	0.00000	0.00		
Gaspé Offshore	A1	5	5.577	1115408	-35.698	0.00000000	0.000000	0.00000	0.00		
	A2	5	7.956	1591280	-35.698	0.00000000	0.000000	0.00000	0.00		
	A3	5	12.359	2471759	-35.698	0.00000000	0.000000	0.00000	0.00		
	A4	5	10.346	2069232	-35.698	0.00000000	0.000000	0.00000	0.00		
	A5	5	7.272	1454328	-35.698	0.00000000	0.000000	0.00000	0.00		
American Bank	A1	5	3.167	633439	-35.698	0.00000000	0.000000	0.00000	0.00		
	A2	5	3.291	658228	-35.698	0.00000000	0.000000	0.00000	0.00		
	A3	5	8.914	1782834	-35.698	0.00000000	0.000000	0.00000	0.00		
	A4	5	8.830	1765965	-35.698	0.00000000	0.000000	0.00000	0.00		
	A5	5	5.749	1149780	-35.698	0.00000000	0.000000	0.00000	0.00		
	A6	5	3.585	716919	-35.698	0.00000000	0.000000	0.00000	0.00		
La Malbaie	A1	5	14.014	2802771	-35.698	0.00000000	0.000000	0.00000	0.00		
	A2	5	13.107	2621375	-35.698	0.00000000	0.000000	0.00000	0.00		
	A3	5	14.129	2825896	-35.698	0.00000000	0.000000	0.00000	0.00		
	A4	5	15.377	3075311	-35.698	0.00000000	0.000000	0.00000	0.00		
	A5	5	9.703	1940685	-35.698	0.00000000	0.000000	0.00000	0.00		
Anse-à-Beaufils	A1	5	10.099	2019789	-35.698	0.00000000	0.000000	0.00000	0.00		
	A2	5	10.476	2095135	-35.698	0.00000000	0.000000	0.00000	0.00		
	A3	5	10.499	2099841	-35.698	0.00000000	0.000000	0.00000	0.00		
	A4	4	10.286	2057146	-35.698	0.00000000	0.000000	0.00000	0.00		
	A5	4	9.000	1800096	-35.698	0.00000000	0.000000	0.00000	0.00		
Grande Rivière	A1	4	5.987	1197308	-35.698	0.00000000	0.000000	0.00000	0.00		
	A2	4	7.058	1411593	-35.698	0.00000000	0.000000	0.00000	0.00		
	A3	4	6.184	1236857	-35.698	0.00000000	0.000000	0.00000	0.00		
	A4	4	7.342	1468422	-35.698	0.00000000	0.000000	0.00000	0.00		
	A5	4	7.183	1436648	-35.698	0.00000000	0.000000	0.00000	0.00		
	A6	4	7.283	1456559	-35.698	0.00000000	0.000000	0.00000	0.00		
	A7	4	7.387	1477338	-35.698	0.00000000	0.000000	0.00000	0.00		
	A8	4	5.881	1176282	-35.698	0.00000000	0.000000	0.00000	0.00		
	A9	4	5.439	1087758	-35.698	0.00000000	0.000000	0.00000	0.00		
	A10	4	6.173	1234669	-35.698	0.00000000	0.000000	0.00000	0.00		
	A11	4	5.704	1140852	-35.698	0.00000000	0.000000	0.00000	0.00		
	A12	4	4.220	843922	-35.698	0.00000000	0.000000	0.00000	0.00		

Table 1 (con't)

Stratum	Transect no.	November	Transect length (km)	Transect area (m^2)	Target strength (dB kg^{-1})	Sa (Area scattering coefficient)z (sr^{-1})	Total backscattering (m^2 sr^{-1})	Biomass density (kg m^{-2})	Total biomass (t $transect^{-1}$)	Set number	Number of fish sampled
Newport	A1	4	8.181	1636291	-35.698	0.00001403	22.960788	0.05211	85.27		
	A2	4	9.814	1962778	-35.698	0.00000822	16.142826	0.03054	59.95		
	A3	4	9.753	1950532	-35.698	0.00000000	0.000000	0.00000	0.00		
	A4	4	8.685	1737090	-35.698	0.00002859	49.658790	0.10616	184.41		
	A5	4	7.937	1587414	-35.698	0.00000000	0.000000	0.00000	0.00		
	A6	4	7.723	1544689	-35.698	0.00002078	32.097273	0.07717	119.20		
	A7	4	7.698	1539543	-35.698	0.00000000	0.000000	0.00000	0.00		
	A8	4	5.287	1057329	-35.698	0.00000000	0.000000	0.00000	0.00		
Shigawake	A1	10	4.111	822140	-35.698	0.00000000	0.000000	0.00000	0.00		
	A2	10	5.844	1168720	-35.698	0.00000000	0.000000	0.00000	0.00		
	A7	10	5.998	1199604	-35.698	0.00000000	0.000000	0.00000	0.00		
	A8	10	5.980	1196014	-35.698	0.00000000	0.000000	0.00000	0.00		
	A11	10	6.312	1262338	-35.698	0.00000000	0.000000	0.00000	0.00		
	A12	10	6.803	1360587	-35.698	0.00000000	0.000000	0.00000	0.00		
	A13	10	6.354	1270797	-35.698	0.00000000	0.000000	0.00000	0.00		
	A27	10	6.089	1217768	-35.698	0.00000000	0.000000	0.00000	0.00		
	A29	10	5.987	1197472	-35.698	0.00000000	0.000000	0.00000	0.00		
	A31	10	5.981	1196107	-35.698	0.00000000	0.000000	0.00000	0.00		
	A40	10	4.519	903709	-35.698	0.00000000	0.000000	0.00000	0.00		
	A41	10	4.969	993855	-35.698	0.00000000	0.000000	0.00000	0.00		
	A44	10	3.676	735228	-35.698	0.00000000	0.000000	0.00000	0.00		
	A45	11	3.945	788979	-35.698	0.00000000	0.000000	0.00000	0.00		
	A48	10	2.842	568328	-35.698	0.00000000	0.000000	0.00000	0.00		
	A49	10	3.762	752437	-35.698	0.00000000	0.000000	0.00000	0.00		
	A50	10	3.532	706367	-35.698	0.00000000	0.000000	0.00000	0.00		
	A51	10	2.944	588787	-35.698	0.00000000	0.000000	0.00000	0.00		
	A52	10	2.612	522461	-35.698	0.00000000	0.000000	0.00000	0.00		
	A53	10	3.627	725446	-35.698	0.00000000	0.000000	0.00000	0.00		
	A54	10	3.652	730312	-35.698	0.00000000	0.000000	0.00000	0.00		
	A55	10	4.159	831831	-35.698	0.00000000	0.000000	0.00000	0.00		
	A56	10	3.774	754845	-35.698	0.00000000	0.000000	0.00000	0.00		
	A57	10	4.440	887967	-35.698	0.00000000	0.000000	0.00000	0.00		
	A58	10	4.213	842633	-35.698	0.00000000	0.000000	0.00000	0.00		
	A59	7	5.791	1158179	-35.698	0.00000000	0.000000	0.00000	0.00		
New Carlisle	A1	9	3.466	693294	-35.698	0.00000000	0.000000	0.00000	0.00		
	A2	9	1.821	364224	-35.698	0.00000000	0.000000	0.00000	0.00		
	A3	9	3.344	668797	-35.698	0.00000000	0.000000	0.00000	0.00		
	A4	9	3.439	687861	-35.698	0.00000000	0.000000	0.00000	0.00		
	A5	9	3.388	677568	-35.698	0.00000000	0.000000	0.00000	0.00		
	A6	9	3.935	787034	-35.698	0.00000000	0.000000	0.00000	0.00		
	A7	9	2.411	482192	-35.698	0.00000000	0.000000	0.00000	0.00		
New Richmond	A4	10	4.355	871009	-35.698	0.00000000	0.000000	0.00000	0.00		
	A5	10	4.814	962860	-35.698	0.00000000	0.000000	0.00000	0.00		
	A6	10	4.874	974754	-35.698	0.00000000	0.000000	0.00000	0.00		
	A7	10	4.048	809688	-35.698	0.00000000	0.000000	0.00000	0.00		
	A8	10	3.038	607584	-35.698	0.00000000	0.000000	0.00000	0.00	2	238
	A1	9	5.171	1034131	-35.698	0.00000000	0.000000	0.00000	0.00		
	A2	9	4.326	865282	-35.698	0.00000000	0.000000	0.00000	0.00		
	A3	9	4.108	821558	-35.698	0.00000000	0.000000	0.00000	0.00	1	264

Table 1 (con't)

Stratum	Transect no.	November	Transect length (km)	Transect area (m^2)	Target strength (dB kg^{-1})	Sa (Area scattering coefficient)z (sr^{-1})	Total backscattering (m^2 sr^{-1})	Biomass density (kg m^{-2})	Total biomass (t transect^{-1})	Set number	Number of fish sampled
Central Chaleur	A1	9	7.432	1486327	-35.698	0.00000000	0.000000	0.00000	0.00		
	A2	9	9.756	1951107	-35.698	0.00000000	0.000000	0.00000	0.00		
	A3	9	10.390	2078009	-35.698	0.00000000	0.000000	0.00000	0.00		
	A4	9	11.090	2218010	-35.698	0.00000000	0.000000	0.00000	0.00		
	A5	9	11.563	2312666	-35.698	0.00000000	0.000000	0.00000	0.00		
	A6	9	11.212	2242467	-35.698	0.00000000	0.000000	0.00000	0.00		
East Central Chaleur	A1	9	9.915	1982983	-35.698	0.00000000	0.000000	0.00000	0.00		
	A2	9	9.560	1911983	-35.698	0.00000000	0.000000	0.00000	0.00		
	A3	9	7.745	1548988	-35.698	0.00000000	0.000000	0.00000	0.00		
	A4	9	10.355	2070924	-35.698	0.00000000	0.000000	0.00000	0.00		
	A5	9	10.945	2189045	-35.698	0.00000000	0.000000	0.00000	0.00		
	A6	9	8.941	1788185	-35.698	0.00000000	0.000000	0.00000	0.00		
Maisonnette	A2	7	5.641	1128149	-35.698	0.00000000	0.000000	0.00000	0.00		
	A3	7	5.675	1135009	-35.698	0.00000000	0.000000	0.00000	0.00		
	A4	7	5.683	1136684	-35.698	0.00000184	2.095132	0.00684	7.78		
	A5	7	2.896	579229	-35.698	0.00000000	0.000000	0.00000	0.00		
	A6	7	5.294	1058753	-35.698	0.00000000	0.000000	0.00000	0.00		
	A7	7	4.662	932421	-35.698	0.00000000	0.000000	0.00000	0.00		
	A8	7	5.018	1003583	-35.698	0.00000000	0.000000	0.00000	0.00		
	A9	7	5.061	1012243	-35.698	0.00000000	0.000000	0.00000	0.00		
	A10	7	5.109	1021864	-35.698	0.00000000	0.000000	0.00000	0.00		
	A11	7	4.338	867643	-35.698	0.00000000	0.000000	0.00000	0.00		
	A12	7	4.901	980138	-35.698	0.00000000	0.000000	0.00000	0.00		
	A13	7	4.633	926627	-35.698	0.00000000	0.000000	0.00000	0.00		
	A14	7	5.909	1181733	-35.698	0.00000000	0.000000	0.00000	0.00		
	A15	7	4.566	913289	-35.698	0.00000000	0.000000	0.00000	0.00		
	A16	7	4.040	808039	-35.698	0.00000000	0.000000	0.00000	0.00		
	A17	7	4.523	904562	-35.698	0.00000000	0.000000	0.00000	0.00		
West Miscou	A1	3	9.768	1953696	-35.698	0.00000000	0.000000	0.00000	0.00		
	A2	3	9.635	1927091	-35.698	0.00000292	5.627876	0.01085	20.90		
	A3	3	10.498	2099530	-35.698	0.00000000	0.000000	0.00000	0.00		
	A4	3	10.654	2130745	-35.698	0.00000000	0.000000	0.00000	0.00		
	A5	3	11.025	2205098	-35.698	0.00000000	0.000000	0.00000	0.00		
	A6	3	11.271	2254175	-35.698	0.00000000	0.000000	0.00000	0.00		
	A7	3	10.037	2007339	-35.698	0.00000000	0.000000	0.00000	0.00		
	A8	3	9.910	1982079	-35.698	0.00000000	0.000000	0.00000	0.00		
	A9	3	10.475	2095100	-35.698	0.00000000	0.000000	0.00000	0.00		
	A10	3	9.807	1961494	-35.698	0.00000000	0.000000	0.00000	0.00		
	A11	3	9.361	1872129	-35.698	0.00000000	0.000000	0.00000	0.00		
	A12	3	9.725	1945007	-35.698	0.00000000	0.000000	0.00000	0.00		
	A13	3	9.330	1866037	-35.698	0.00000000	0.000000	0.00000	0.00		
	A14	3	9.117	1823452	-35.698	0.00000000	0.000000	0.00000	0.00		
	A15	3	9.157	1831496	-35.698	0.00000000	0.000000	0.00000	0.00		
	A16	3	9.578	1915611	-35.698	0.00000000	0.000000	0.00000	0.00		
	A17	4	2.908	581513	-35.698	0.00000000	0.000000	0.00000	0.00		
	A18	4	9.390	1877979	-35.698	0.00000000	0.000000	0.00000	0.00		
	A19	4	10.000	1999918	-35.698	0.00000000	0.000000	0.00000	0.00		
	A20	4	9.104	1820747	-35.698	0.00000000	0.000000	0.00000	0.00		
	A21	4	9.722	1944339	-35.698	0.00000000	0.000000	0.00000	0.00		
	A22	4	9.548	1909548	-35.698	0.00000000	0.000000	0.00000	0.00		

Table 1 (con't)

Stratum	Transect no.	November	Transect length (km)	Transect area (m^2)	Target strength ($dB\ kg^{-1}$)	Sa (Area scattering coefficient)z (sr^{-1})	Total backscattering ($m^2\ sr^{-1}$)	Biomass density ($kg\ m^{-2}$)	Total biomass ($t\ transect^{-1}$)	Set number	Number of fish sampled
West Miscou (con't)	A23	4	10.751	2150295	-35.698	0.00000000	0.000000	0.00000	0.00		
	A24	4	10.810	2162087	-35.698	0.00000000	0.000000	0.00000	0.00		
	A25	4	11.472	2294490	-35.698	0.00000000	0.000000	0.00000	0.00		
	A26	4	10.782	2156309	-35.698	0.00000000	0.000000	0.00000	0.00		
	A27	4	11.542	2308489	-35.698	0.00000000	0.000000	0.00000	0.00		
	A28	4	12.120	2423975	-35.698	0.00000000	0.000000	0.00000	0.00		
	A29	4	11.985	2396904	-35.698	0.00000000	0.000000	0.00000	0.00		
	A30	4	12.173	2434533	-35.698	0.00000000	0.000000	0.00000	0.00		
	A31	4	11.600	2320086	-35.698	0.00000000	0.000000	0.00000	0.00		
	A32	4	12.111	2422189	-35.698	0.00000195	4.721466	0.00724	17.53		
	A33	4	11.433	2286676	-35.698	0.00000000	0.000000	0.00000	0.00		
	A34	4	11.214	2242817	-35.698	0.00000372	8.348368	0.01382	31.00		
	A35	6	4.675	934913	-35.698	0.00000000	0.000000	0.00000	0.00		
	A36	6	5.102	1020310	-35.698	0.00000000	0.000000	0.00000	0.00		
	A37	6	11.770	2354096	-35.698	0.00000000	0.000000	0.00000	0.00		
	A38[a]	6	0.000	0	-35.698	0.00000000	0.000000	0.00000	0.00		
	A39	6	1.271	254124	-35.698	0.00000000	0.000000	0.00000	0.00		
	A40	6	8.001	1600194	-35.698	0.00000000	0.000000	0.00000	0.00		
	A41	6	7.269	1453816	-35.698	0.00000000	0.000000	0.00000	0.00		
	A42	7	7.055	1411089	-35.698	0.00000000	0.000000	0.00000	0.00		
	A43	7	6.596	1319111	-35.698	0.00000130	1.721123	0.00485	6.39		
	A44	7	6.420	1283972	-35.698	0.00000000	0.000000	0.00000	0.00		
	A45	7	6.111	1222255	-35.698	0.00000000	0.000000	0.00000	0.00		
	A46	7	6.553	1310680	-35.698	0.00000000	0.000000	0.00000	0.00		
	A47	7	6.766	1353244	-35.698	0.00000000	0.000000	0.00000	0.00		
	A48	7	6.788	1357623	-35.698	0.00000000	0.000000	0.00000	0.00		
North Miscou	A1	3	10.340	2068097	-35.698	0.00000000	0.000000	0.00000	0.00		
	A2	3	2.655	530918	-35.698	0.00000000	0.000000	0.00000	0.00		
	A3	3	13.883	2776594	-35.698	0.00000287	7.955935	0.01064	29.55		
	A4	3	12.669	2533873	-35.698	0.00000834	21.122424	0.03096	78.44		
	A5	3	12.456	2491226	-35.698	0.00000308	7.670074	0.01143	28.48		
	A6	3	4.933	986576	-35.698	0.00000000	0.000000	0.00000	0.00		
	A7	3	7.862	1572325	-35.698	0.00000000	0.000000	0.00000	0.00		
East Miscou	A17	6	24.967	4993444	-35.698	0.00000000	0.000000	0.00000	0.00		
	A18	6	25.649	5129768	-35.698	0.00000000	0.000000	0.00000	0.00		
	A19	6	25.688	5137574	-35.698	0.00000000	0.000000	0.00000	0.00		
	A20	6	25.687	5137324	-35.698	0.00000000	0.000000	0.00000	0.00		
	A21	6	25.955	5191076	-35.698	0.00000000	0.000000	0.00000	0.00		
	A22	6	25.107	5021493	-35.698	0.00000000	0.000000	0.00000	0.00		
	A23	6	25.394	5078881	-35.698	0.00000000	0.000000	0.00000	0.00		
	A24	6	25.567	5113385	-35.698	0.00000000	0.000000	0.00000	0.00		
	A25	6	25.231	5046277	-35.698	0.00000000	0.000000	0.00000	0.00		
	A26	6	25.829	5165845	-35.698	0.00000000	0.000000	0.00000	0.00		

[a]Acoustic data not recorded on tape because of equipment malfunction. No herring marks were seen on echogram during this transect.

Table 2. Schedule of transects in Shigawake stratum.

Transect	Time	Nov	Comments
A59	1000-1020	7	Begin transects at west end, ship runs aground.
A58-A46	0956-1250	10	Resume transects at west end, transect interrupted by port call.
A1-A2	1819-1854	10	Resume transect at east end.
A7,A8,All,A12	1906-2044	10	Start to do 14 transects which are randomly chosen from the 46 remaining.
A13,A27,A29,A31, A40,A41,A44	2047-2349	10	Because of time pressure, randomly delete 3 of 14 chosen transects.
A45	0400-0017	11	Continue transects until order given to return to port.

Table 3. Total backscattering and biomass estimates of herring encountered in acoustic strata in the Chaleur area, November 1989.

Stratum	Target strength (dB kg^{-1})	Stratum area (m^2)	Stratum area scattering coefficient (sr^{-1})	Total back-scattering (m^2 sr^{-1})		Stratum biomass density ($kg\ m^{-2}$)	Total biomass per stratum (tonnes $stratum^{-1}$)	
				Mean	SE		Mean	SE
Cap Bon Ami	-35.698	109800000	0.000000000	0	0	0.00000	0	0
Baie de Gaspé	-35.698	117600000	0.000000000	0	0	0.00000	0	0
Gaspé Offshore	-35.698	50000000	0.000000000	0	0	0.00000	0	0
American Bank	-35.698	187400000	0.000000000	0	0	0.00000	0	0
La Malbaie	-35.698	191200000	0.000000000	0	0	0.00000	0	0
Anse-à-Beaufils	-35.698	191900000	0.000000000	0	0	0.00000	0	0
Grande Rivière	-35.698	173800000	0.000000000	0	0	0.00000	0	0
Newport	-35.698	187000000	0.000009286	1736	745	0.03448	6448	2765
Shigawake	-35.698	323300000	0.000000000	0	0	0.00000	0	0
New Carlisle	-35.698	167000000	0.000000000	0	0	0.00000	0	0
New Richmond	-35.698	253600000	0.000000000	0	0	0.00000	0	0
Central Chaleur	-35.698	208400000	0.000000000	0	0	0.00000	0	0
East Central Chaleur	-35.698	235975050	0.000000000	0	0	0.00000	0	0
Maisonnette	-35.698	140000000	0.000000134	19	19	0.00050	70	69
West Miscou	-35.698	378000000	0.000000236	89	48	0.00088	331	176
North Miscou	-35.698	417800000	0.000002836	1185	560	0.01053	4400	2081
East Miscou	-35.698	2166535000	0.000000000	0	0	0.00000	0	0

Table 4. Total backscattering and biomass of herring encountered in the Chaleur area, November 1989.

Number of transects	Total backscattering (m^2 sr^{-1})		Biomass (tonnes)	
	Mean	CV	Mean	CV
186	3029	0.308	11249	0.308

Table 5. Total area backscatter estimates of herring surveyed in 4T and 4VN, 1984-1989. N means the number of transects run. A dash (-) indicates that the stratum was not surveyed in the indicated year. Data for 1984 from Shotton et al. 1987a, for 1985 from Shotton 1986, for 1986 from Shotton et al. 1987b, for 1987 from Cairns et al. 1988, and for 1988 for Cairns et al. 1989. Data for 1989 are from the present study (Tables 1 and 2).

Stratum	Total area backscatter (m^2 sr^{-1})												
	1984	1985		1986		1987		1988			1989		
	Mean	Mean	N	Mean	N	Mean	N	Mean	SE	N	Mean	SE	N
Chaleur													
Cap Bon Ami		0@	2	0*	3	0*	2	0*	0	3	0*	0	5
Baie de Gaspé		0@	2	23*	3	11*	2	0*	0	3	0*	0	6
Gaspé Offshore				0#	4	0*	3	0*	0	4	0*	0	5
American Bank		-		-		115*	3	0*	0	4	0*	0	6
La Malbaie		0@	3	0#	4	61*	3	0*	0	4	0*	0	5
Anse-à-Beaufils		1807@	3	535#	7	0*	4	0*	0	6	0*	0	5
Grande Rivière				25731*	7	3667*	9	101*	32	12	0*	0	12
Newport		4814	2	16275*	3	2713*	8	0*	0	13	1736*	745	8
Shigawake				18600*	3	8142*	8	48272*	11069	23	0*	0	26
New Carlisle		-		-		0*	3	218*	225	5	0*	0	7
New Richmond		-		-		258*	3	3209*	1720	14	0*	0	8
Central Chaleur		-		-		-		54	42	12	0*	0	6
East Central Chaleur		-		-		-		-			0	0	6
Maisonnette		-		-		-		12290	6716	12	19*	19	16
West Miscou		7964*	2	59*	3	141885*	3	558*	329	20	89*	48	48
North Miscou		0@	3	0*	3	1389*	3	0*	0	4	1185*	560	7
East Miscou		4464*	4	20*	4	28000*	2	4*	4	15	0*	0	10
Total Chaleur	28700	19048	21	61243	44	186241	56	64706	13067	154	3029	933	186
Prince Edward Island													
North Point	-	16	1	-		-		-			-		
Northeast P.E.I.	-	-		2346*	3	0*	2	-			-		
Beyond East Pt. (BP)	-	0	1	-		-		-			-		
East Point (EP)	-	0	1	-		-		-			-		
Cardigan Bay (CB)	-	0	1	-		-		-			-		
Total P.E.I.	-	16	4	2346	3	0	2	-			-		
West Cape Breton	10787	-		-		-		-			-		
Sydney Bight													
Aspy Bay		642*	1	174*	2	3484*	7	0*	0	5	-		
Neil Harbour		3630@	1	16310*	1	54672*	8	16122*	7841	23	-		
Wreck Cove		17246@	9	16755#	3	10066*	9	32994*	12082	14	-		
St. Ann's Bay		-		-		3257*	7	857*	787	14	-		
Haddock Bank		1133@	5	12*	4	412*	7	0*	0	2	-		
Sydney		2956*	4	0*	3	3970*	7	78*	77	9	-		
New Waterford		4572*	6	-		43268*	8	0*	0	15	-		
Donkin		703*	4	-		8080*	7	0*	0	4	-		
Total Sydney Bight	22318	30882	30	33251	13	127209	60	50051	14425	86	-		
Total all areas	61805	49946	55	96840	60	313450	118	114757		240	3029		186

@,#,* Years with similar symbols have the same stratum boundaries. Years with different symbols have different stratum boundaries.

Table 6. Acoustic biomass estimates for herring in the Southern Gulf of St. Lawrence and Sydney Bight, 1984-1989. Estimates are based on Foote's (1987) value for target strength. See Table 5 for data sources. A dash (-) means that no estimate is available.

Area and spawning affinity	Biomass estimate (tonnes)					
	1984	1985	1986	1987	1988	1989
Chaleur						
Spring			143179	153381	163881	
Fall			112498	563352	76413	
Total	104709	73599	255677	716733	240294	11249
Survey dates	7-12 Nov	7-13 Nov	17-28 Nov	4-11 Nov	12-18 Nov	3-11 Nov
Total transect length (km)	875*	1348**	1610***	2186	1371	1535
P.E.I.						
Total	-	62	9794	0	-	-
Survey dates		8-27 Nov	1-12 Dec	16-17 Nov		
West Cape Breton						
Total	36600					
Survey dates	17 Nov	-	-	-	-	-
Sydney Bight						
Spring				191844	47544	
Fall				251214	125342	
Total	75724	106865	127708	443058	172886	-
Survey dates	18-27 Nov	21-25 Nov	1-12 Dec	17-24 Nov	9-13 Dec	
All areas						
Spring				345225	211424	
Fall				814566	201756	
Total	217033	180464	383385	1159791	413180	11249
Survey dates	7-27 Nov	7-28 Nov	17 Nov-12 Dec	4-24 Nov	12 Nov-13 Dec	3-11 Nov

*Transect lengths in 1984 were derived from total times reported for strata. Total time on transect was estimated as total time in strata x 0.8 to account for set time and time steaming between transects. Steaming speed assumed to be 8 kt.

**Transect lengths in 1985 were calculated from total time on transect, assuming a steaming speed of 8 kt.

***Transect lengths in 1986 were calculated from total time on transect, assuming a steaming speed of 8.5 kt.

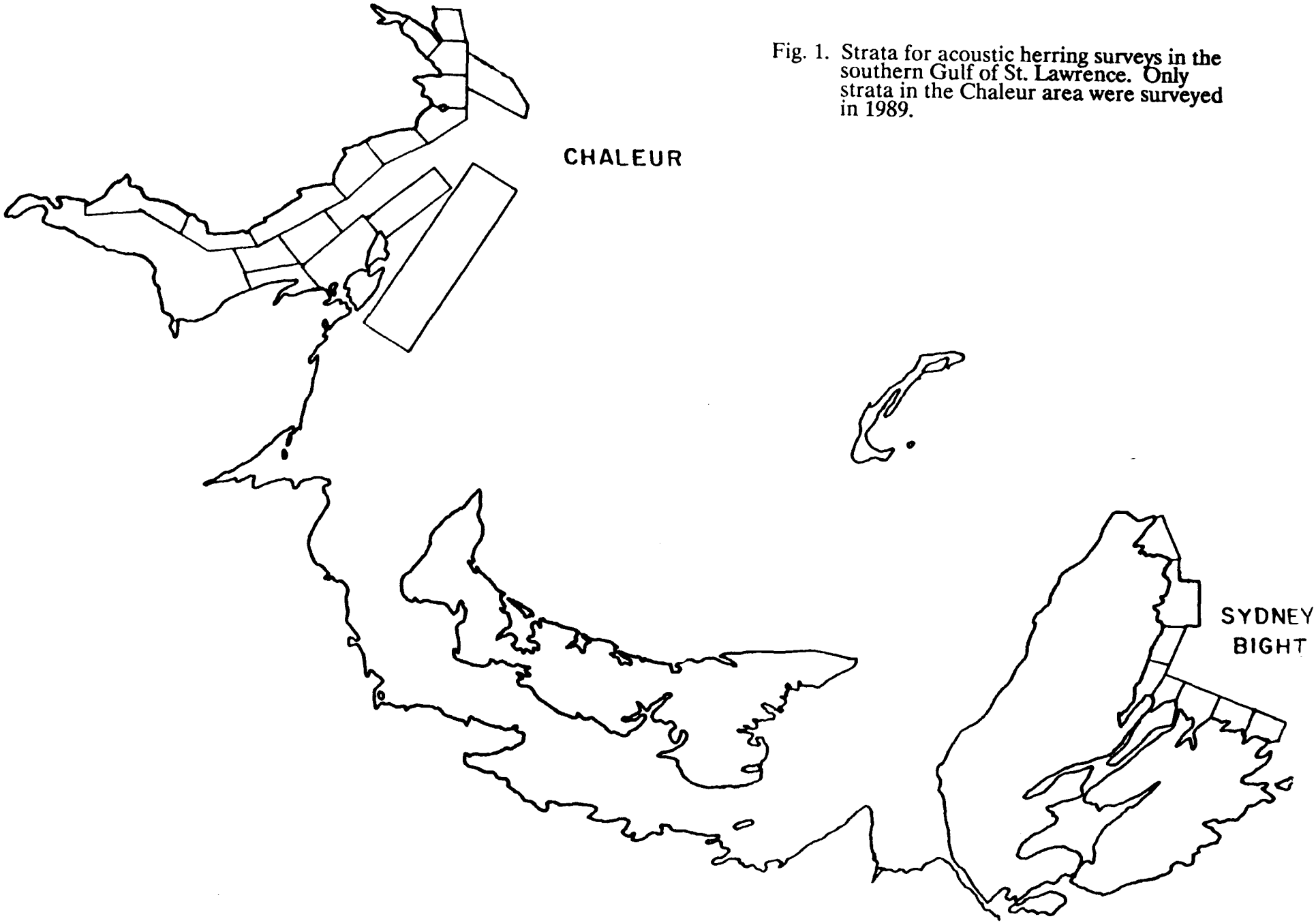
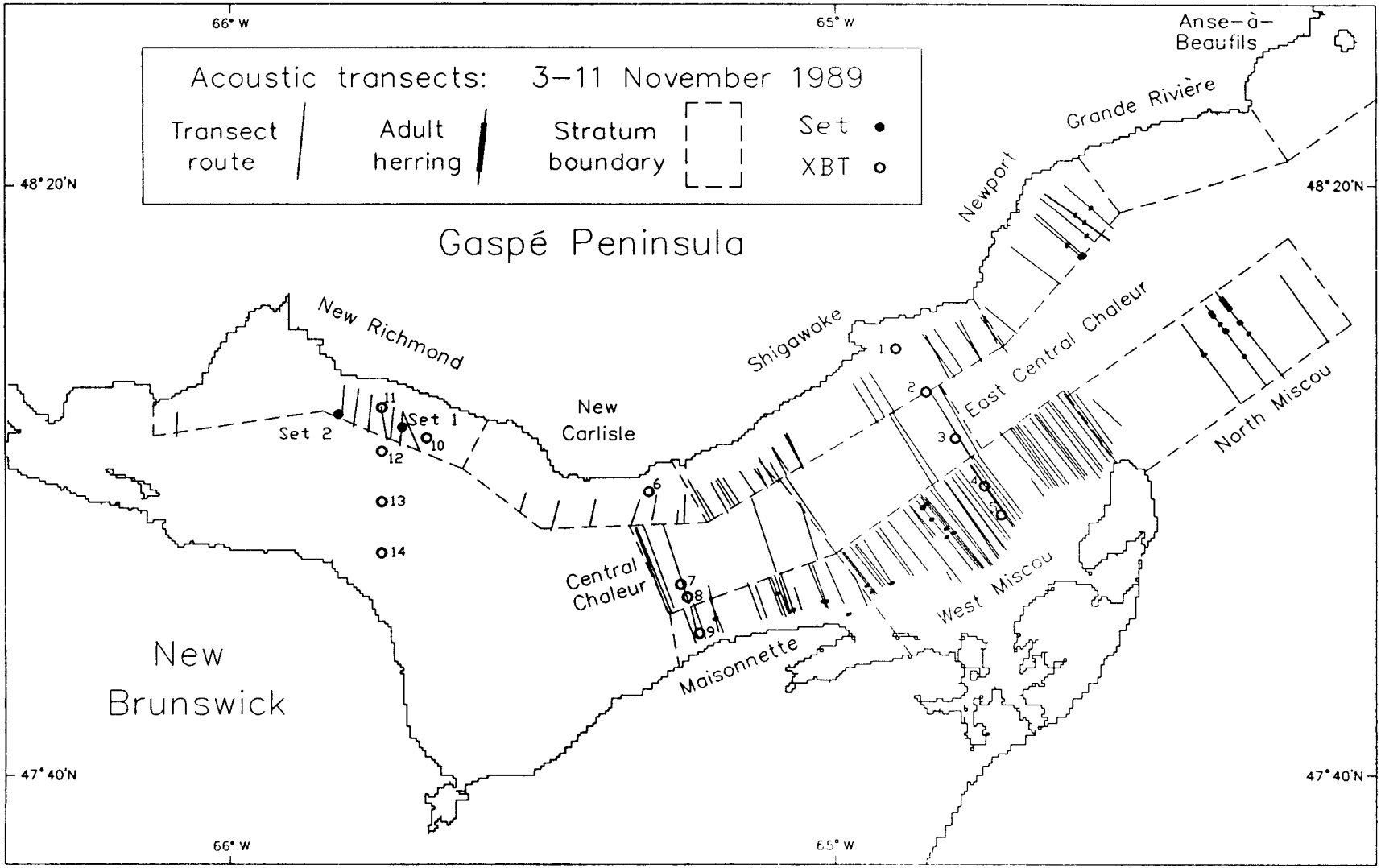


Fig. 1. Strata for acoustic herring surveys in the southern Gulf of St. Lawrence. Only strata in the Chaleur area were surveyed in 1989.

Fig. 2. Acoustic transects in the Bay of Chaleur, November 1989. Locations of sets and XBT casts are also shown.



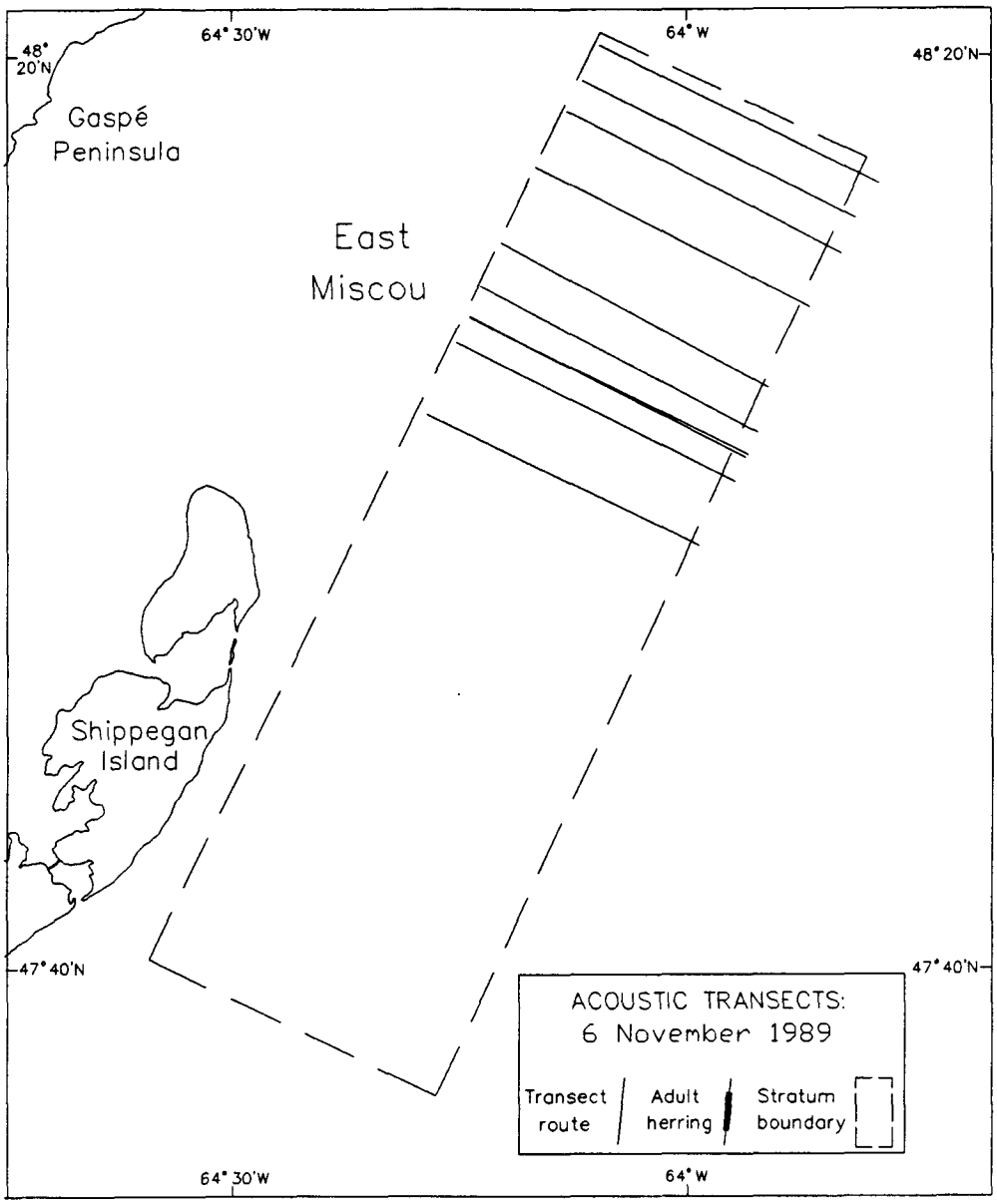


Fig. 3. Acoustic transects in the East Miscou stratum, November 1989. No acoustic targets were detected in this stratum.

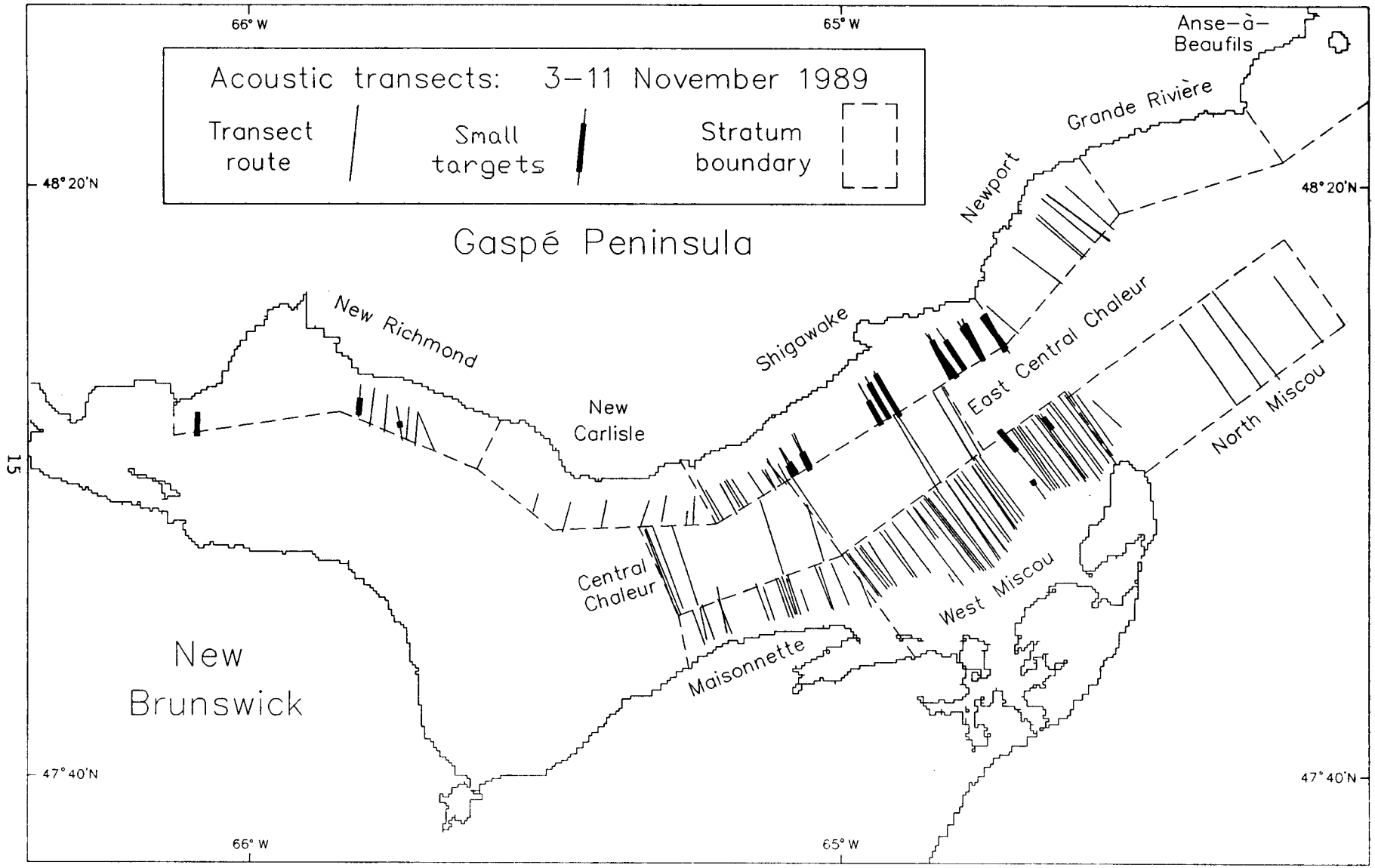


Fig. 4. Acoustic transects in the Bay of Chaleur, November 1989, showing locations where juvenile herring and other small targets were observed on the sounder.

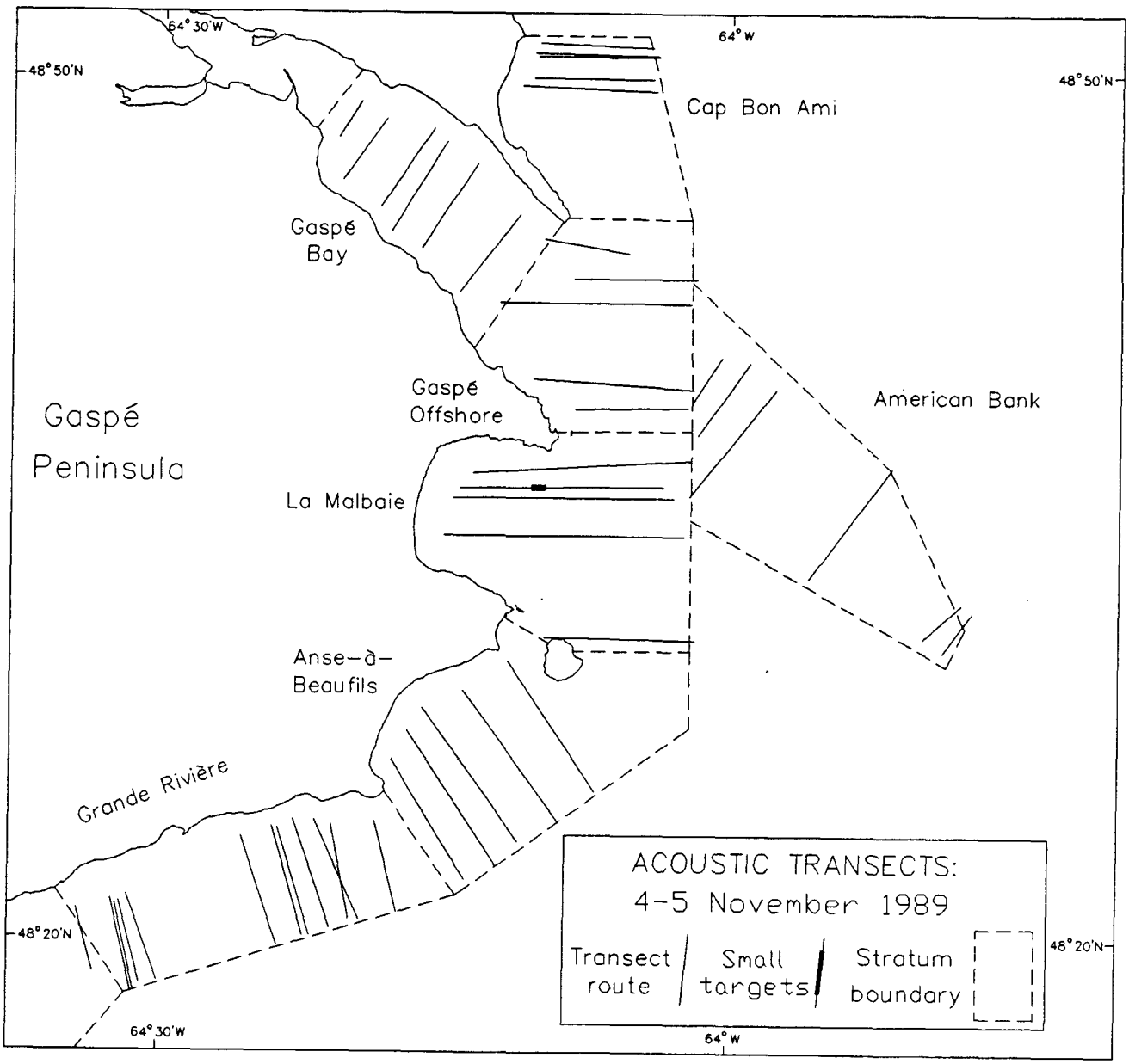


Fig. 5. Acoustic transects in the East Gaspé area, November 1989, showing locations where juvenile herring and other small targets were observed on the sounder.

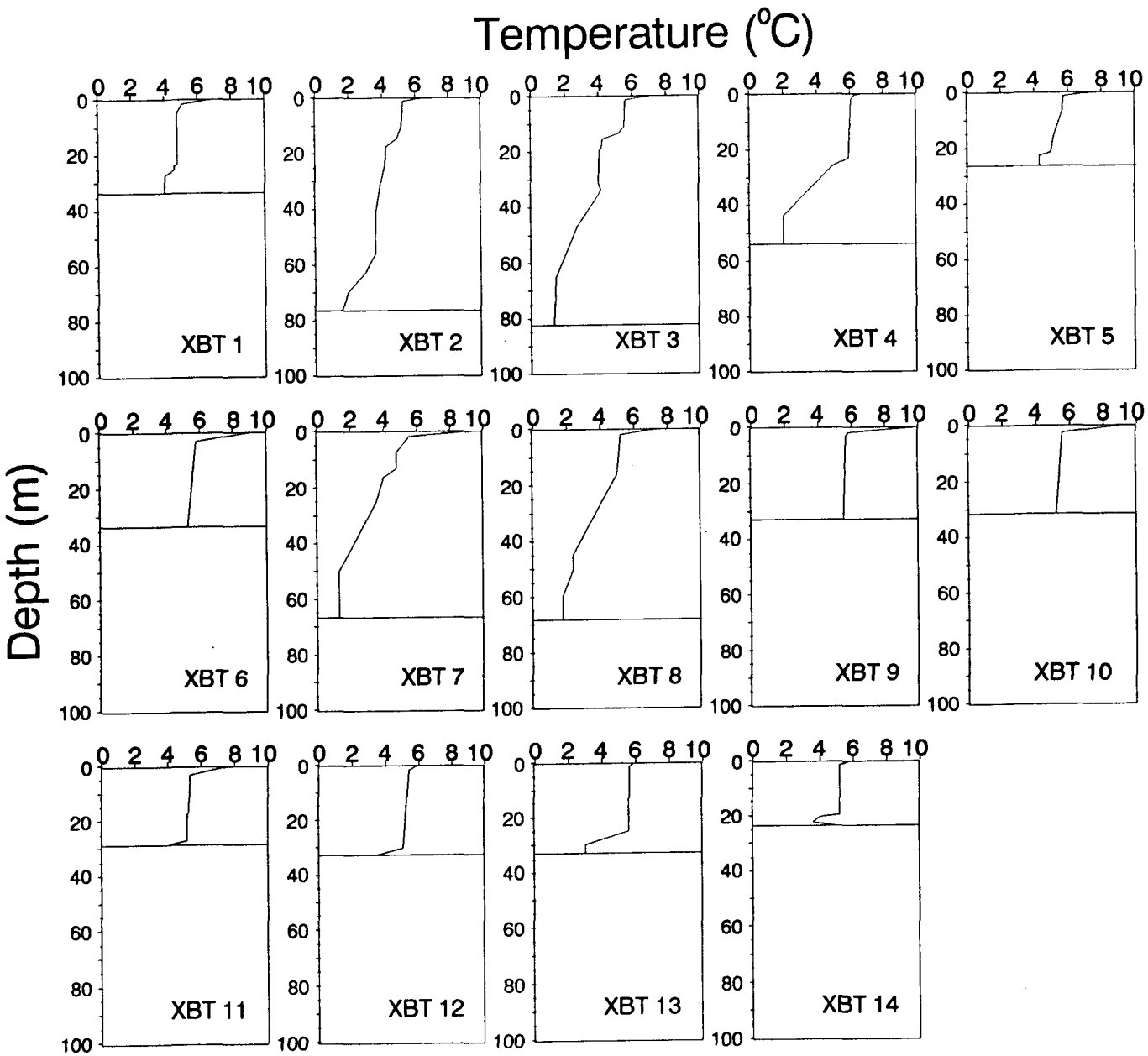


Fig. 6. Temperature profiles at 14 locations in the Bay of Chaleur, 9-10 November 1989. Cast locations are given in Fig. 2.

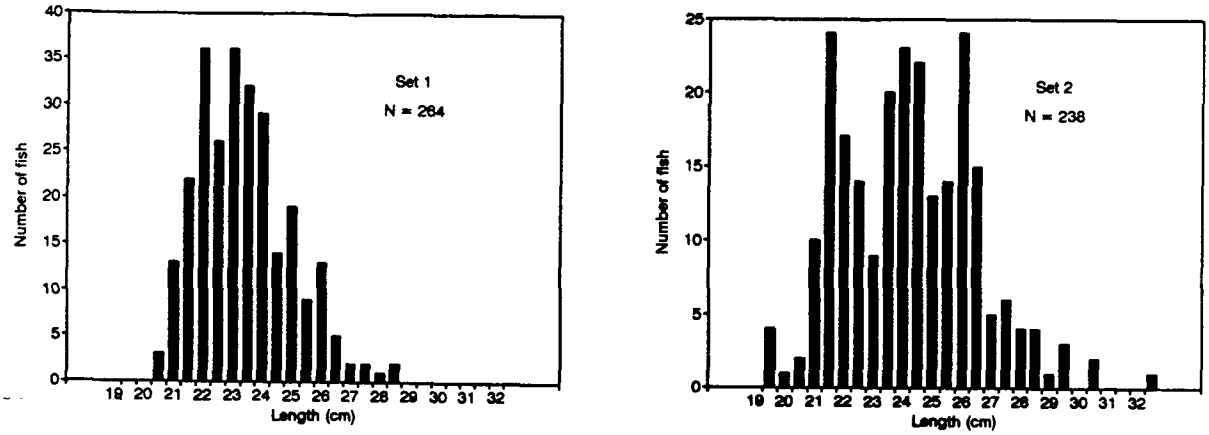


Fig. 7. Length frequency of herring taken in sets in the Bay of Chaleur, 9-10 November 1989. See Fig. 2 for set locations.

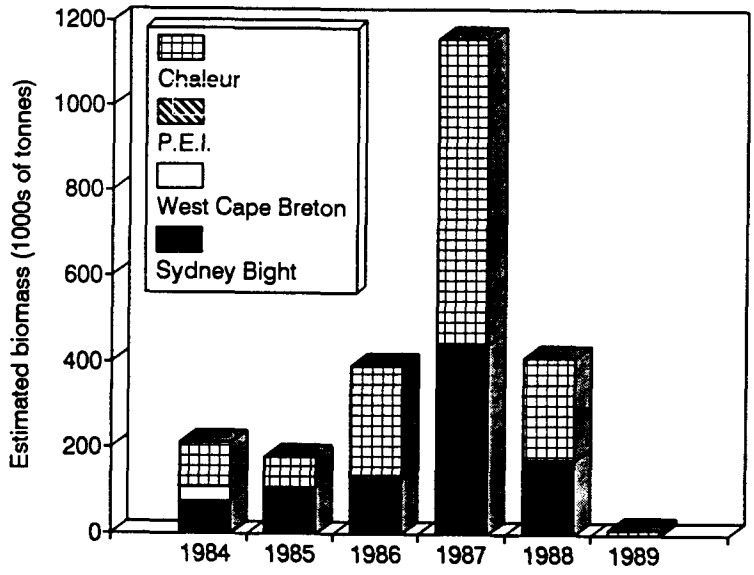


Fig. 8. Herring biomass estimates for the southern Gulf of St. Lawrence and Sydney Bight, from acoustic surveys. Note that P.E.I. was not surveyed in 1984 and 1988-1989, West Cape Breton was not surveyed in 1985-1989, and Sydney Bight was not surveyed in 1989.