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Results of the 1989 Winter Acoustic Surveys of NAFO Div. 4WX Herring Stocks

by

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ABSTRACT

Results of the 1989 acoustic winter herring surveys are presented. In Chedabucto Bay, five day and nine night surveys were done in an area that has contained almost all the herring found in the five annual surveys done since 1984. Each 1989 survey consisted of equally spaced parallel transects located randomly in the area. Each survey was taken as a single sample to calculate mean abundance and variance. Results from the 1984, 1986 and 1987 nighttime surveys have been reprocessed to estimate mean abundance and variance in the same survey area. Mean nighttime herring abundance has increased from 208,000 t in 1984 to 491,000 t in 1987 and has decreased to 450,000 t in 1989. A single randomized parallel transect survey estimated 323,000 t ± 95% CI of 288,000 t in a 770 km² area southeast of Canso. An exploratory survey along the Cape Breton coast and in Sydney Bight found no herring.

RESUME

On présente les résultats de relevés acoustiques du hareng réalisés durant cinq jours et neuf nuits, au cours de l'hiver 1989, dans un secteur de la baie de Chedabucto d'où provenait la quasitotalité des harengs présents dans les cinq relevés annuels effectués depuis 1984. Chacun des relevés de recherche réalisés en 1989 portait sur des transects parallèles également espacés et choisis au hasard dans la zone, et servait d'échantillon unique pour calculer l'abondance et la variance moyennes. Les résultats des relevés de nuit de 1984, 1986 et 1987 ont été réutilisés pour estimer l'abondance et la variance moyennes dans la même zone. L'abondance moyenne du hareng durant la nuit est passée de 208 000 t en 1984 à 491 000 t en 1987, puis est tombée à 450 000 t en 1989. Un relevé portant sur un seul transect parallèle sélectionné au hasard donne une estimation de 323 000 t ± 95 % IC de 288 000 t dans un secteur de 770 km² au sud-est de Canso. On n'a pas trouvé de hareng lors d'un relevé exploratoire le long de la côte du Cap-Breton et de la baie de Sydney.

INTRODUCTION

The 1989 survey extends the time series of acoustic herring surveys in Chedabucto Bay by another year, and makes 4 yr (1984, 1986, 1987, 1989) of data available for input to the herring stock assessment process.

The meeting of the CAFSAC pelagic subcommittee on the design and operation of pelagic acoustic surveys (Aug. 1988, Moncton) recommended that future surveys use parallel random transects and that the survey area be extended towards Sydney Bight and to other overwintering aggregations of herring. This 1989 survey complies with these recommendations.

A survey strategy that takes into account the mobile nature of herring schools and the day-night difference in availability was developed. The results present separate mean herring abundance and variance estimates during days and during nights. The results of the 1984, 1986 and 1987 mapping surveys were also reprocessed to estimate mean abundance and variance to establish a time series of comparable data.

An exploratory survey was run along the coast of Cape Breton north to Ingonish. The ship sounder was operated on the return trip to Halifax and in the Herring Cove area where herring had been reported in previous winters.

Acoustic data processing on the new equipment this year revealed inaccuracies in the bottom echo rejection method used in previous years. A more simple and more reliable method was used this year, and in reprocessing the 1984, 1986 and 1987 data.

Midwater trawl sampling during days and during nights, for the first time this year, showed a difference in herring lengths that may indicate a deficiency in nighttime trawl sampling that needs to be addressed.

SURVEY DESIGN

A fundamental prerequisite for survey design is that the area of the survey cover the distribution range of the fish. Since 1984, the 4WX winter herring have been found in and around Chedabucto Bay in areas totaling about 350 km^2. The distribution of the herring in these areas is patchy with patches ranging in size from a few hundred meters to tens of kilometers. There are also day-night differences in the behavior of the herring. The patches move continually and change shape and size. The movements are often rapid so that a fish patch that is in one area during the night may break up and partially disappear during the following day and then reappear as a different patch somewhere else the following night. At other times, patches, particularly larger ones, remain more or less stable for several days.

With such fish behavior, the usual type of parallel transect surveys that progress across an area over a period of several days overestimates fish that move with the survey and underestimates fish that move against the direction of the survey. Surveying the whole area in short time spans would minimize these effects. The shortest practical time spans are 12 h for nighttime surveys and 12 h for daytime surveys. These time periods must include about 2 h for sample trawling, that leaves 10 h for survey. Usual survey speed is 8 knots; that means about 150 km of survey track including the 75 km of traverses between the actual sample transects. The total distance for sample transects in the 350-km^2 area is 75 km and the average distance between transects if 4.7 km. Randomization of the transects can result in transect spacing that is several times that distance and the entire fish population could fit between such spacing.

To minimize this danger, we decided to select a smaller index area for the survey. This is an area about 7 km by about 44 km along the south shore of Chedabucto Bay that has contained almost all of the herring every year since 1984. The area is shown as the shaded rectangle in Fig. 1. The original plan was to have 10 transects in the area, and to avoid large spacing between transects due to the randomization, the individual transects were spaced equidistant but the set of transects was located randomly in the survey area by choosing a random starting point for the first transect. The whole set of transects is one sample. A new set of transects is chosen for each night's survey; the same set of transects was used for the following day's survey.

Experience showed that survey speed could be increased up to 10 knots and that sample trawling did not require the full time allocated. That made it possible to increase the number of transects to 16 per set. Figure 2 shows 16 night transects and 16 day transects and the 44-km baseline for the index area.

ACOUSTIC DATA RECORDING

The echo sounder was the Simrad EK50 used in previous surveys. The receiver was calibrated for fixed and time-varied gain by the method described by Buerkle (1984) except that continuous input was used instead of a pulse train. The sounder was operated at 50 pings per minute and at a pulse length of 0.3 ms. The transducer was the 10 degree half power angle Amatek Straza 302 LT-1. It was calibrated with the sounder transmitter for source level, beam pattern and receive sensitivity at the Defence Research Establishment barge in Bedford Basin.

Echograms were recorded on the Simrad 11000 recorder. Echo voltages from the receiver were detected and digitized by the Simrad 525 QX preprocessor. The threshold of the preprocessor was set at 0.15 mv. Digitized voltages were formatted for storage on Bernoulli disks by the Femto direct memory access card in the Sanyo MBC 890 personal computer with an 8087 math coprocessor. For each ping, the Femto system records one data record that contains the time of the ping and digitized echo voltages and depths for echos above threshold at 0.05-m intervals in the water column. At 20-sec intervals it records navigation records that contain the boat position latitude and longitude obtained from a North Star 800 Loran C through the Com 1 port of the PC. The system was operated to record one data file for each sample transect.

DATA EDITING

The first step in acoustic data processing is editing the echograms. Echograms were examined to identify the sections that contain herring echos. Integrating only the echos in these sections avoids the possibility of including weak noise echos and occasional bottom echos from the large segments of data that contain no herring echos. For processing the survey data from 1984-89, the echograms were also used to separate herring echos from bottom echos. Closer examination of this procedure showed that inaccuracies of bottom location on the echograms can lead to errors, particularly on sloped bottoms. A point located at the apparent bottom on the echogram can be several meters above or below the actual bottom at that instant in time. When the apparent bottom is below the actual bottom, integration is normally stopped by the bottom pulse generated by the echo sounder and no error occurs. When the bottom pulse is not generated, however, bottom echos will be integrated with fish echos. When the apparent bottom is above the actual bottom, fish echos between them are not integrated.

The data from the 1984, 1986 and 1987 surveys are being reprocessed to examine average volume scattering in relation to depth near bottom. Preliminary results show that, in general, average volume scattering increases with proximity to bottom. The effect is most pronounced in the last 0.5 m above the bottom. This could mean that there is a dramatic increase of fish aggregation density in the last half meter above bottom, but it is more likely that the increased scattering is due to bottom effects. When the bottom is not smooth and flat, areas of bottom protruding into parts of the acoustic beam will be detected as weak echos above the main bottom echo. In anything but a flat calm sea, the towed body pitches and rolls and that can make the problem worse. If weather conditions are bad enough, transducer instability can cause similar problems even on smooth flat bottom. To be reasonably sure of not integrating bottom echos with fish echos, all echos that were less than 0.5 m above the last echo in each ping were excluded from integration. The top 5 m of the water column often include noise, especially in poor weather conditions. The top 5 m were also excluded from integrations.

DATA PROCESSING

The aim of data processing is to integrate herring echos in the manner of Forbes and Nakken (1972) and Craig (1981). The Simrad receiver, however, applies an analog $20 \log R + 2 \alpha R$ function that has been shown to be in error (Buerkle 1984). Processing acoustic data therefore begins by calculating a TVG (time varied gain) correction from the receiver calibration parameters so that sample voltages can be adjusted to an accurate $20 \log R + 2 \alpha R$ gain with α at 0.0122 dB. The correction factors are stored in an array indexed by sample depth intervals and are referenced by the depth associated with each sample voltage.

The echos in each ping have a different vertical distribution that is uncorrelated with bottom echos. In order to integrate only the echos that are precisely 0.5 m or more above the bottom, echo sample processing in each ping must be done from the bottom sample up.

Outputs of the processing program are:

1. For each section of echogram with herring:
   - time of the start and the end of the herring;
   - average volume scattering coefficient;
   - average area scattering coefficient;
   - latitude and longitude of the beginning and end of the herring.

2. For each whole sample transect:
   - time of the start and the end of the transect;
   - length of the transect;
   - average area scattering; this is the sum of (the area scattering in the fish sections x length of sections)/length of the sample transect;
   - latitude and longitude of the start and the end of the transect.

Total scattering in the survey area is the product of average area scattering per transect weighted by transect length and the total area. Sample transects vary in length (Fig. 2) because the inshore boundary of the survey area is the shoreline which is not a straight line. The survey area is the area baseline (east/west line in Fig. 2) multiplied by the average transect length.

RESULTS

The survey areas and tracks are shown in Fig. 1. The ship sounder was also run along the shore on the return trip from Canso to Halifax and in the Herring Cove area. No herring were detected in either place.

The zig-zag track from Chedabucto Bay towards Sydney Bight crossed no herring. The two sets of random parallel lines in Sydney Bight also found no herring. The shaded rectangle in Chedabucto Bay is the area selected as the abundance index area that was surveyed repeatedly. The offshore survey southeast of Canso is a survey of random transects done once; the thick lines show location of fish.

A summary of results is shown in Table 1. In Chedabucto Bay, 11 nighttime and 7 daytime surveys were done. All of these surveys showed herring distributed in a very narrow band very close to the south shore of the bay. Nine of the nighttime surveys and 5 of the daytime surveys used equidistant transects located randomly along the area baseline. The surveys on Jan. 10, 11 and 12 daytime were not randomized surveys. They were systematic in that the equally spaced transects were not randomly located in the survey area. They were done as an attempt to overcome the problem of getting consistently close to shore where the herring were. Randomized transects intersect the shore at a different place every time; the shoreline may be shallow or steep and the boat cannot get equally close every time. With transects in the same place, it was thought the boat could approach shore to a more consistent minimum distance. That proved to be wrong; the minimum distance from shore depends more on the judgment of the person in charge of the boat and on weather than on the shoreline. Sometimes they will go in close; other times they will not. The non-random surveys were not used in calculating total scattering.

The night survey on Jan. 23 was a mapping survey as done in previous years. The map (Fig. 3) suggests a continuous band of fish close to shore and close to the rocks towards Grimes Shoal in the east.

Total scattering for the parallel transect surveys in Chedabucto Bay is shown in Fig. 4. It shows large variation from day to day and from night to night, but nighttime variation is less than that during day. Except for one large daytime value on Jan. 9, daytime scattering for the randomized surveys is lower than nighttime scattering. There appears to be a trend towards lower scattering towards the end of the month. The slope of the decrease in nighttime scattering is

8886 m^2 sr^{-1} per night and is significant at the 12% level. That might indicate that herring were moving out and that the survey had missed the period of peak abundance in the bay.

TRAWL SAMPLING

Twenty-one midwater trawl tows were made in Chedabucto Bay (Fig. 5). Eight were made during days and 13 were made during nights. Table 2 indicates that larger fish were caught in daytime. The mean length of fish caught during day was 29.2 cm, the mean length of fish caught at night was 26.6 cm. The difference is significant at the 5% level, and most likely indicates a sampling problem. During daytime, the herring are squeezed closer together near the bottom and the trawl must go close to bottom to catch them. At nighttime, the herring are spread out more vertically and samples are taken near the top of the distribution rather than risk damage to the trawl near the bottom. Catching herring in weirs and seines for tagging has shown that smaller fish are found near the surface; to get larger fish requires longer handled dipnets (Clayton Dickson, pers. comm.). Such stratification could explain the day-night difference and more care must be taken in sampling in the future. The overall length of the herring from the midwater tows in Chedabucto Bay was 27.7 cm. Tow #15 was a bottom trawl tow in an area where the sounder showed light fish traces near the bottom. These traces were juvenile herring. Tow #26 was made in the offshore area southeast of Canso and caught herring that were larger than the average in the bay, but not the largest caught.

The length/weight relationship calculated from all samples was:

$$W_{kg} = 6.674\ l_{cm}^{2.996} \times 10^{-6}$$

BIOMASS

Conversion from acoustic scattering to biomass was done with the target strength length relation of Foote (1987):

$$TS = 20 \log l_{cm} - 71.9$$

With the length/weight relationshp for the fish in this survey, the target strength per kg is:

$$TS_{kg} = -9.96 \log l_{cm} - 20.1$$

The average length of fish in Chedabucto Bay was 27.7 cm, their target strength was -34.5 dB. The average length of the fish in the southeast Canso area was 30.6 cm, their target strength was -34.9 dB.

Table 3 shows the results of the Chedabucto Bay random surveys. The nighttime biomass of 450,000 tonnes (t) is lower than the 568,000 and 789,000 t estimated in 1986 and 1987, but those estimates were the maximum estimated during the surveys, not the mean over a period of time as in this case. Previous years' survey data are being reprocessed to make better comparisons. The standard error estimated for the nighttime surveys is 71,000 t, that leads to a 95% confidence interval of $\pm$36% for the biomass. The average daytime biomass is lower than the nighttime estimate and the standard error is made larger. It leads to a 95% confidence interval of ±142%.

The mapping survey in Chedabucto Bay (Table 4) shows a biomass of 760,000 t. That is larger than the estimate from the nighttime random surveys and could indicate a problem with the mapping procedure, but more likely indicates that random parallel transects do not pass over fish near shore as well as zig-zag transects. It is safer to approach a shore at a 45° angle than at 90° and the boat probably gets closer to shore with zig-zag transects than with parallel ones.

Results of the offshore survey southeast of Canso are shown in Table 5. The transects for this survey were randomized because it was to be done only once. As expected, most transects showed no herring. Transects 362, 366 and 367 showed the most fish and are segments of a single transect which was interrupted for trawl sampling. The variance in this type of survey is large; it leads to a 95% confidence interval of ±89%. Single surveys in patchy fish do not give good information on the quantity of fish present.

BAY OF FUNDY SURVEY

During the last few winters, seiners have reported increasing numbers of herring in the Grand Manan, Wolves Islands area. An acoustic survey to investigate these fish was done in 1989 during the nights of Feb. 27-28 and Feb. 28-Mar. 1. Three areas totaling about 370 km^2 were surveyed by random parallel transects (Fig. 6). Few fish were found off Grand Manan, more were located southeast of the Wolves and most were found between the Wolves and Beaver Harbour. No trawl sampling could be done during the survey but commercial catch samples indicate that the fish between Grand Manan and the Wolves were larger (mean length 22.9 cm) than the fish between the Wolves and Beaver Harbour (mean length 13.9 cm). The length/weight relationship from commercial catches was:

$$W_{kg} = 3.313\ l_{cm}^{3.21} \times 10^{-6}$$

The target strength for the Beaver Harbour fish worked out to be -30.9 dB, the target strength for Grand Manan and the Wolves was -33.6 dB.

Total scattering and biomass estimates in the three areas are shown in Table 6. Variance estimates for these surveys are large. In the Grand Manan area, fish were seen only on one out of the seven transects and the 95% confidence interval was ±244%. In the area southeast of the Wolves, fish were found on three out of six transects and the 95% confidence interval decreased to ±134%. In the Beaver Harbour area, the fish were most equally distributed and the confidence interval is ±62%.

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Table 1. Acoustic scattering in Chedabucto Bay and southeast Canso surveys.

Date Jan.	Time	Transects	Area km^2	Average scattering sr^{-1}	Total scattering $m^2\ sr^{-1}$	Standard[a] error $m^2\ sr^{-1}$
7	Night	9	264.31	.000883	233,450	116,551
8	Day	9	229.35	.000693	158,956	93,762
8	Night	10	265.01	.000785	208,002	125,396
9	Day	12	263.64	.001279	337,225	203,892
9	Night	12	280.58	.000952	267,097	133,725
10[b]	Night	16	290.19	.000517	150,086	72,074
11[b]	Day	16	297.04	.000276	82,060	45,757
12[b]	Day	16	287.06	.000330	94,668	53,409
12	Night	15	258.51	.000143	36,839	22,819
14	Night	16	268.92	.000619	166,474	67,596
15	Day	14	272.72	.000156	42,571	25,742
15	Night	14	291.88	.000330	96,391	53,572
16	Night	15	259.98	.000562	146,031	59,628
17	Day	14	292.25	.000170	49,750	28,410
17	Night	15	277.63	.000715	198,631	100,175
22	Night	14	285.50	.000297	84,757	50,541
23	Day	15	259.61	.000048	12,533	12,533
23[c]	Night	13	25.40	.009000	229,551	
24[d]	Day	17	768.86	.000136	104,501	43,929

[a]Standard error is calculated as if samples were randomly selected.
[b]Systematic sample patterns.
[c]Zig-zag transect mapping of fish in Chedabucto Bay.
[d]Random samples southeast of Canso.

Table 2. Herring lengths in 22 midwater tows and 1 bottom tow.

Tow #	Date Jan.	Time	No. fish sampled	Mean length	Standard deviation
1	7	Night	137	23.4	2.6
2	8	Night	250	26.8	4.4
3	8	Day	203	31.7	3.8
4	8	Day	203	29.2	2.6
5	9	Night	261	23.6	3.8
6	9	Night	199	27.0	4.0
7	9	Day	200	30.7	2.5
8	9	Day	210	30.7	3.1
9	10	Night	269	26.0	3.7
10	10	Night	200	28.7	5.2
11	11	Day	202	29.5	2.1
12	12	Day	209	30.0	2.5
13	13	Night	201	29.3	3.2
14	15	Day	205	28.5	2.4
15*	16	Day	200	13.5	1.3
17	17	Night	269	26.4	3.5
20	21	Night	199	28.4	2.7
21	22	Night	228	29.7	2.2
22	23	Day	338	23.0	2.4
23	24	Night	250	27.4	3.5
24	24	Night	267	24.9	3.7
25	24	Night	256	24.7	3.6
26	24	Night	220	30.6	2.3

*Bottom trawl tow.

Table 3. Summary of Chedabucto Bay random survey results.

Date (Jan.)	Total scattering ($m^2\ sr^{-1}$) Day	Night
7		233,450
8	158,956	208,002
9	337,225	267,097
12		36,839
14		166,474
15	42,571	96,391
16		146,031
17	49,750	198,631
22		84,757
23	12,533	
Mean total scattering	120,207	159,741
Standard error	59,659	25,214
+95% CI	806	614
Biomass (1000 tonnes)	339	450
-95% CI	-138	286

Table 4. Summary of Chedabucto Bay mapping survey Jan. 23.

Transect no.	Length in fish (m)	Average scattering (sr^{-1})
331	1502	.00639
332	2399	.01644
333	931	.01329
334	598	.00479
335	596	.00771
336	233	.00287
338	246	.00309
339	228	.01283
340	213	.00476
341	105	.00581
341	37	.01208
341	337	.00552
342	223	.00274
342	64	.00063
342	158	.00365
342	1095	.00760
344	887	.00672
344	1223	.01105
345	214	.00360
345	602	.00272
345	142	.00138

Sum (length x avg. scatt.)	= 108.75
Sum length	= 12,033
Average area scattering	= .0090
Area of fish (km^2)	= 25.4
Total scattering (m^2 sr^{-1})	= 229,551
Biomass (1000 tonnes)	= 760

Table 5. Summary of southeast Canso randomized survey, Jan. 24.

Transect no.	Length (m)	Average scattering (sr^{-1})
355	13,955	.0
356	12,998	.0
357	12,804	.0
358	13,645	.0
359	13,682	.0
360	13,835	.0
361	17,866	.000030
362	7,609	.000892
366	1,061	.004745
367	7,535	.001141
368	16,609	.000441
369	16,475	.000102
370	16,705	.0
371	17,628	.0
372	9,812	.0
373	15,561	.0
374	13,651	.0

Sum (length x avg. scatt.)	= 29.96
Sum (length)	= 221431
Average scattering (sr^{-1})	= .000136
Total scattering	= 104,501
Standard error	= 43,929
+95% CI	= 611
Biomass (1000 tonnes)	= 323
-95% CI	= 35

Table 6. Summary of Bay of Fundy survey.

Area		Beaver Harbour	Wolves	Grand Manan
Transects		7	6	7
Tot. scatt. $m^2\ sr^{-1}$		46767	15440	3896
Std. error		12072	7324	3896
	+95% CI	94	82	31
Biomass (1000 tonnes)		58	35	9
	-95% CI	21	-11	-13

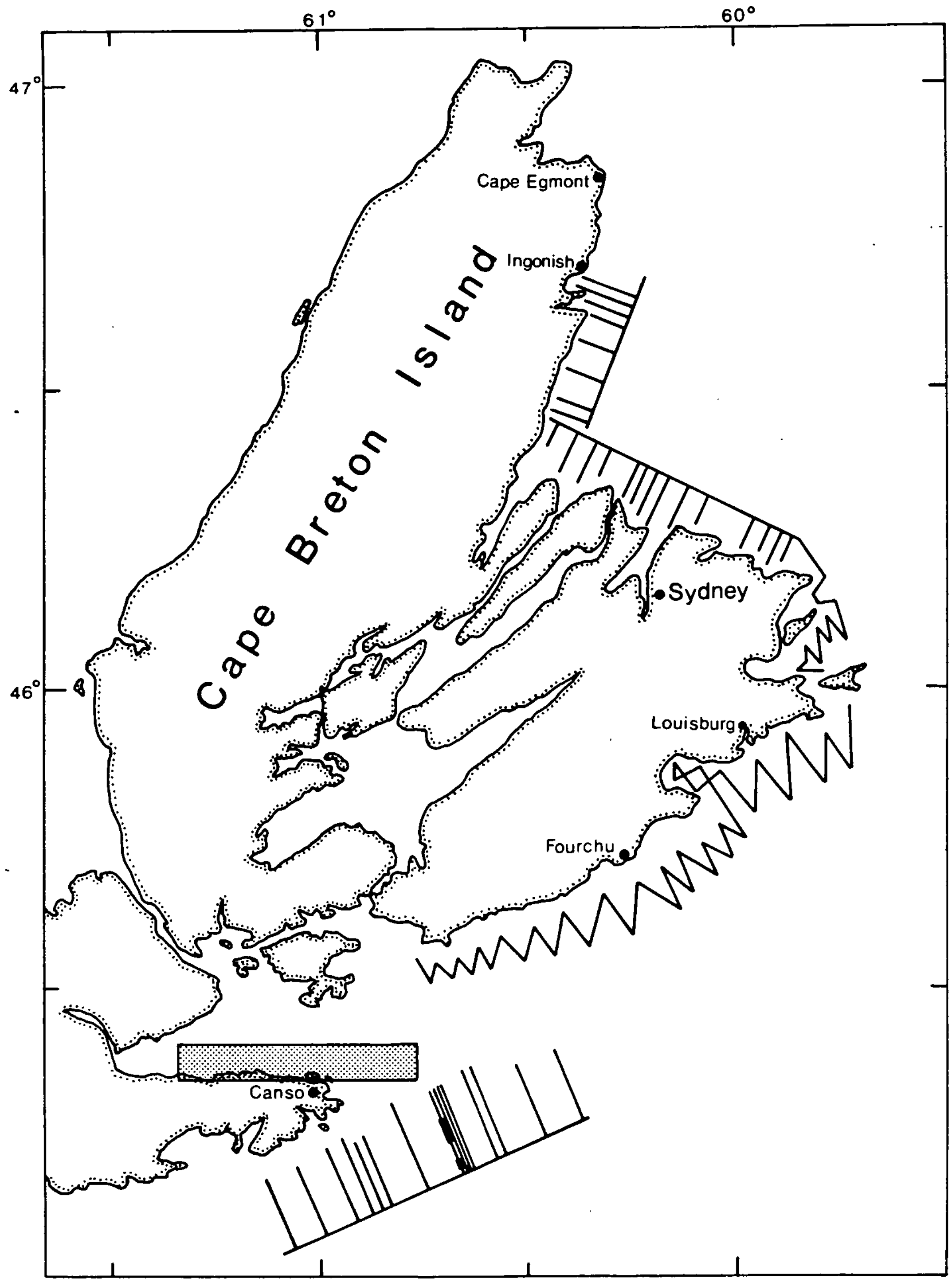

Fig. 1. Chedabucto Bay survey area (shaded) and survey tracks for other areas covered in the 1989 winter herring survey.

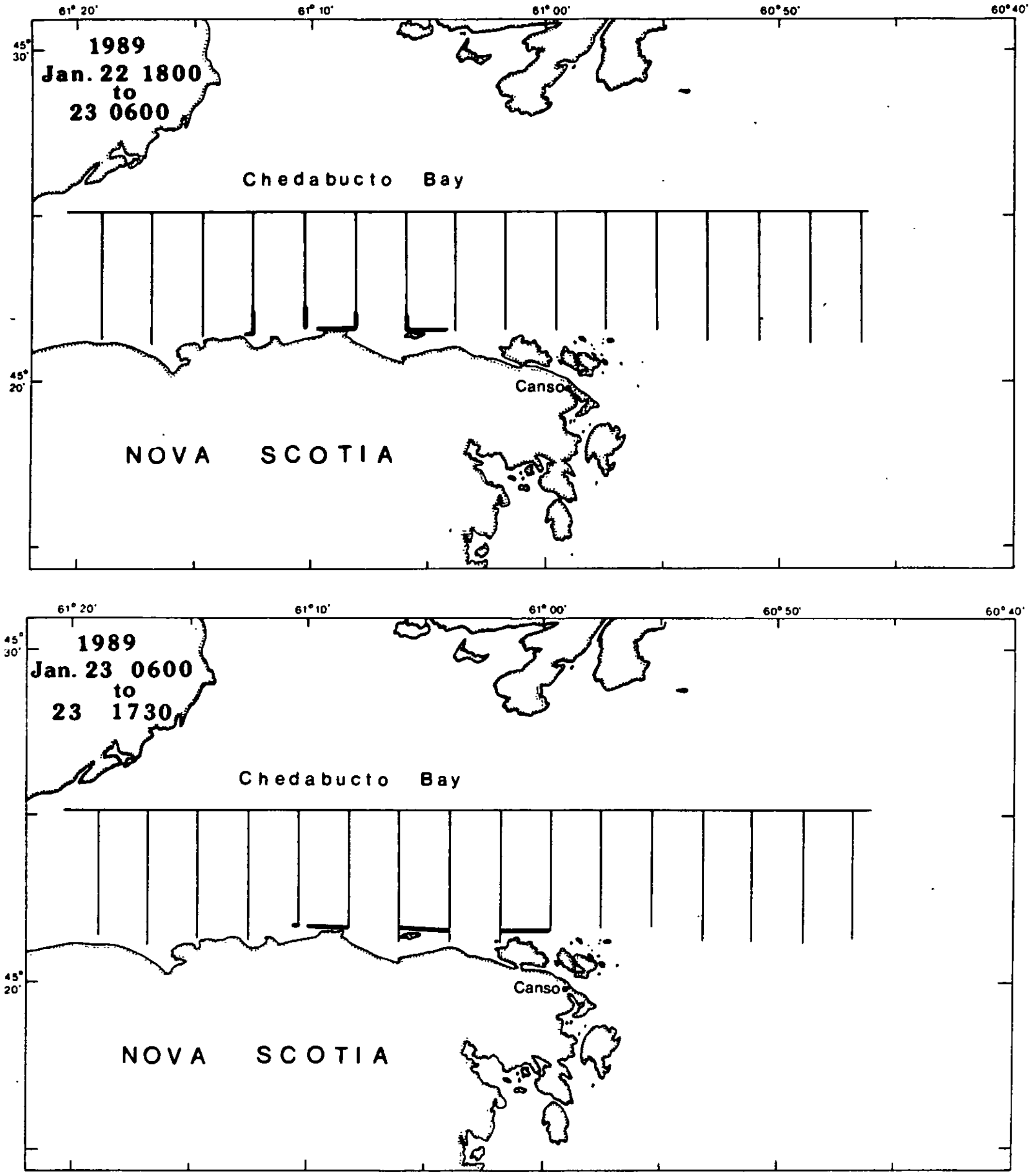

Fig. 2. Sample of transects in Chedabucto Bay survey area for one night and one day sample. Heavy lines show location of fish.

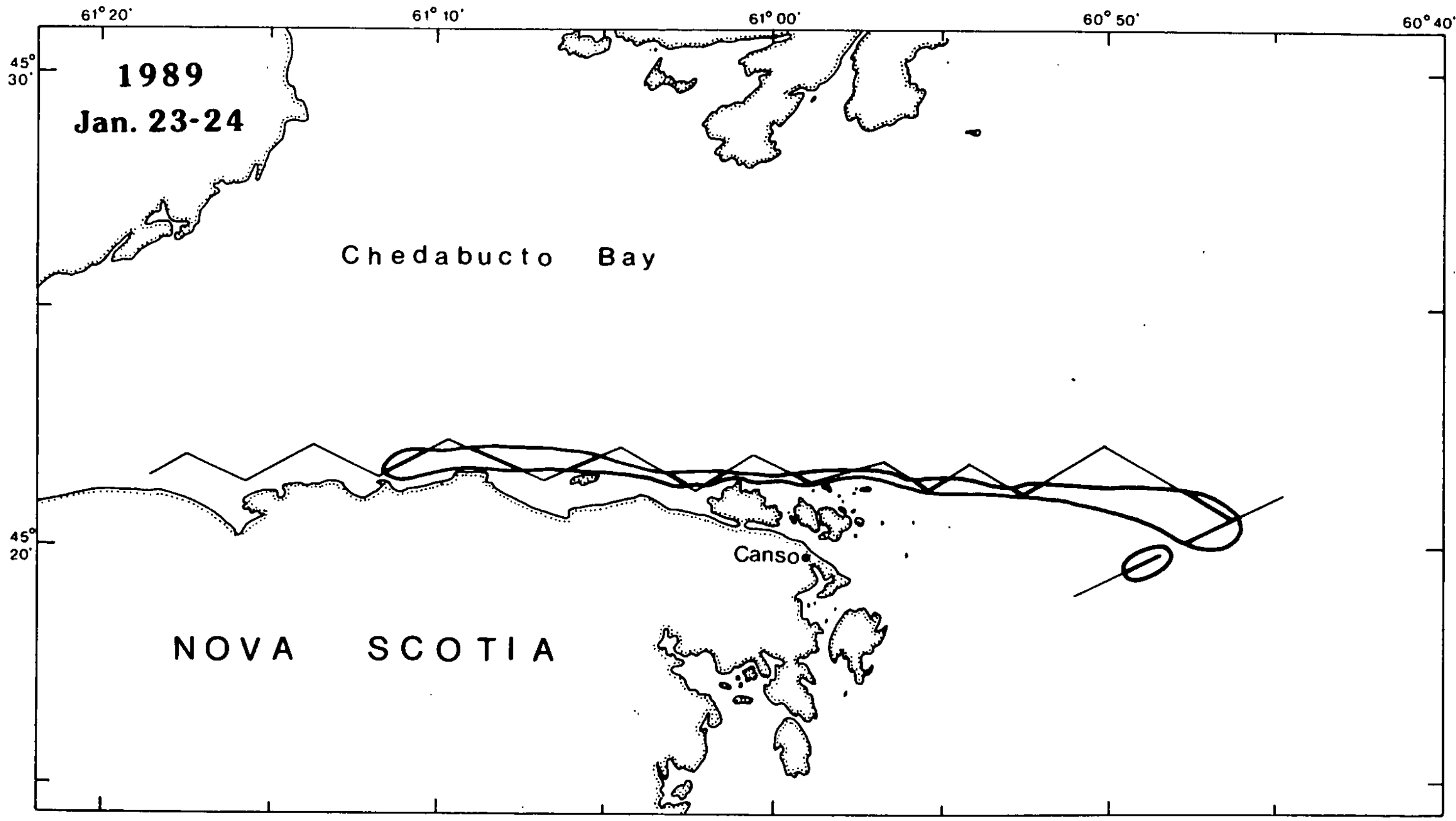

Fig. 3. Zig-zag mapping survey Jan. 23.

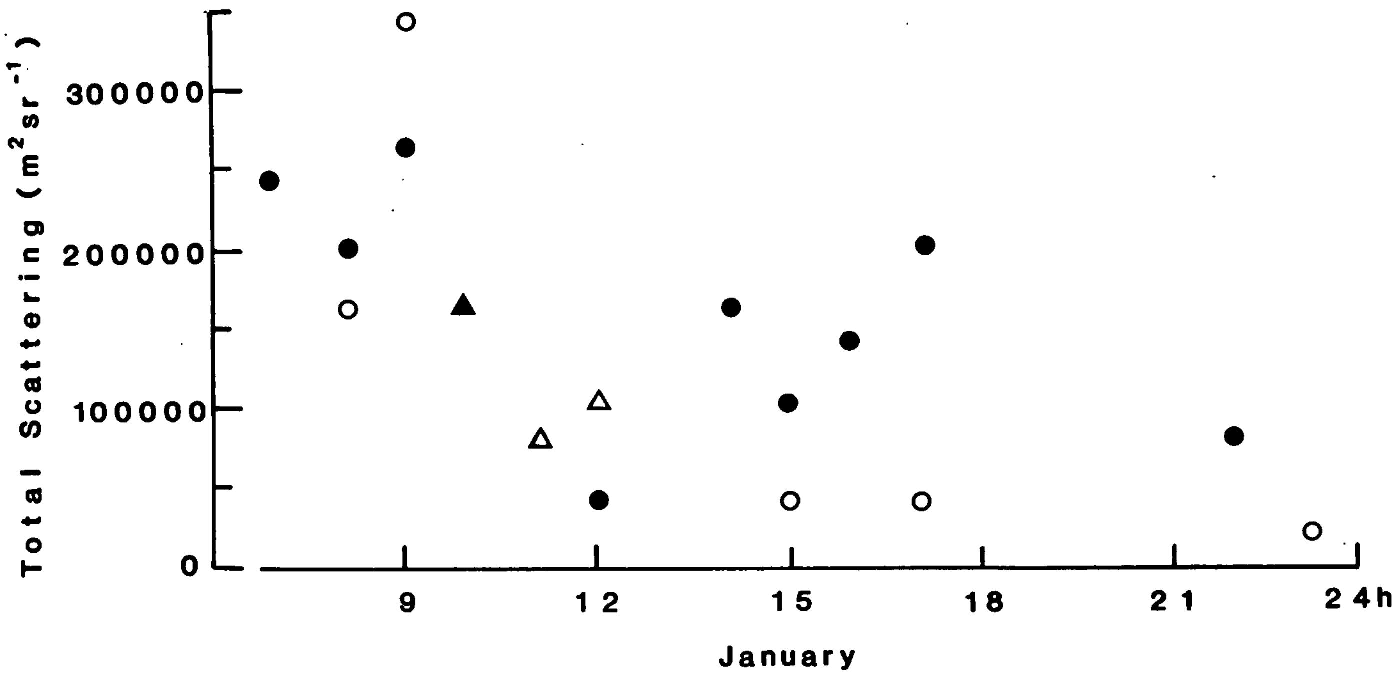

Fig. 4. Total scattering in Chedabucto Bay. Circles are randomized surveys, triangles are systematic surveys. Day surveys (○,△); night surveys (●,▲).

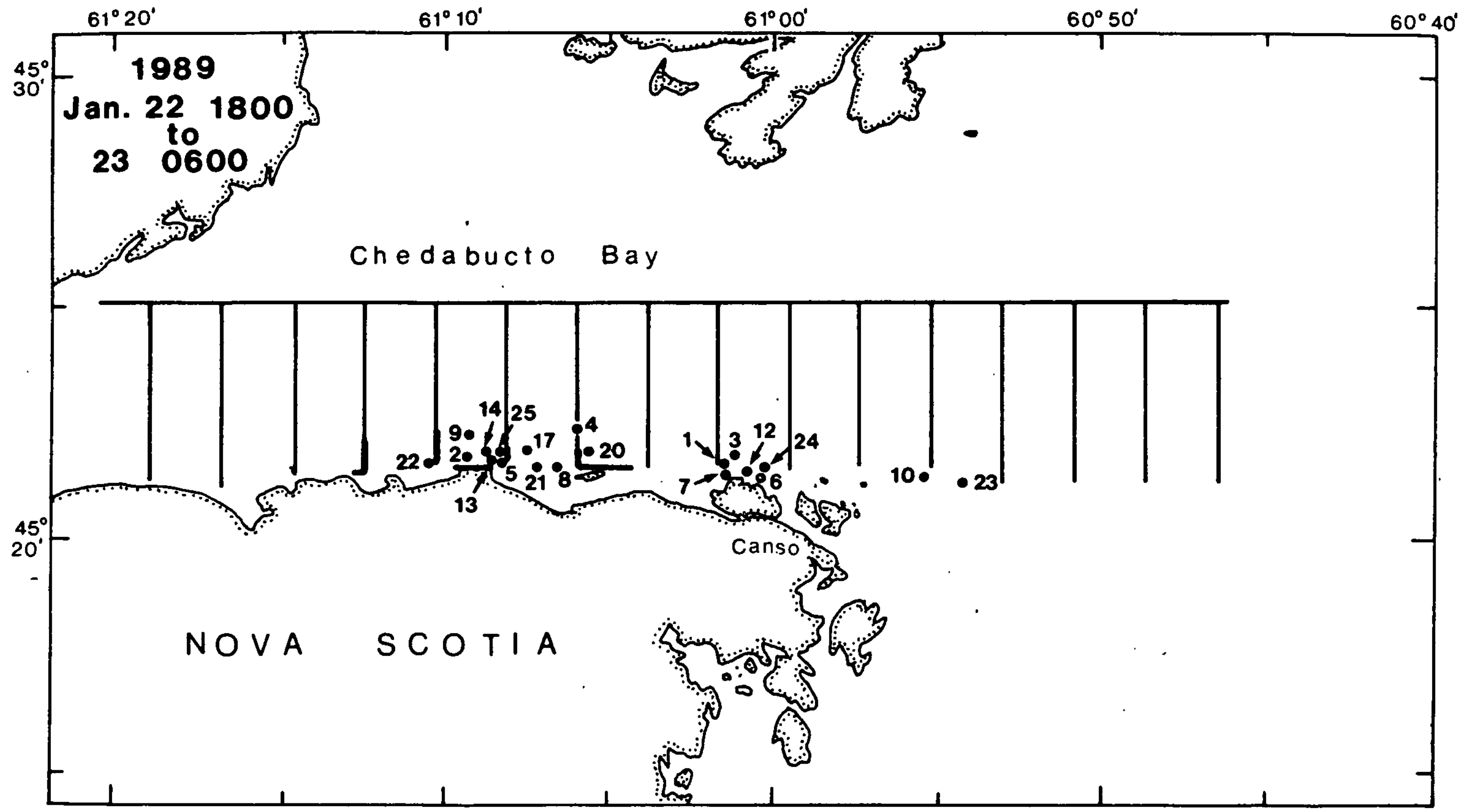

Fig. 5. Location of midwater tows in Chedabucto Bay.

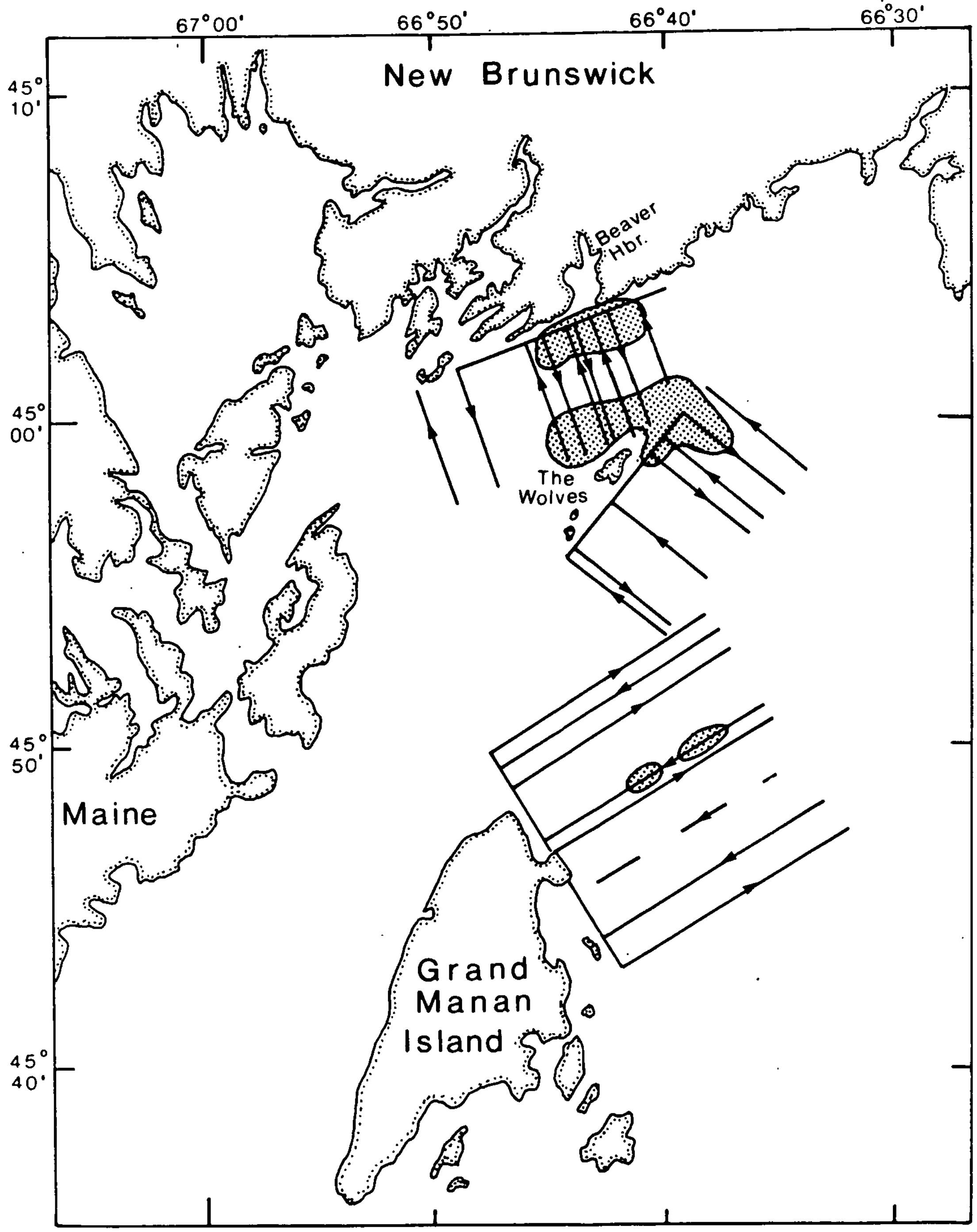

Fig. 6. Bay of Fundy survey areas.

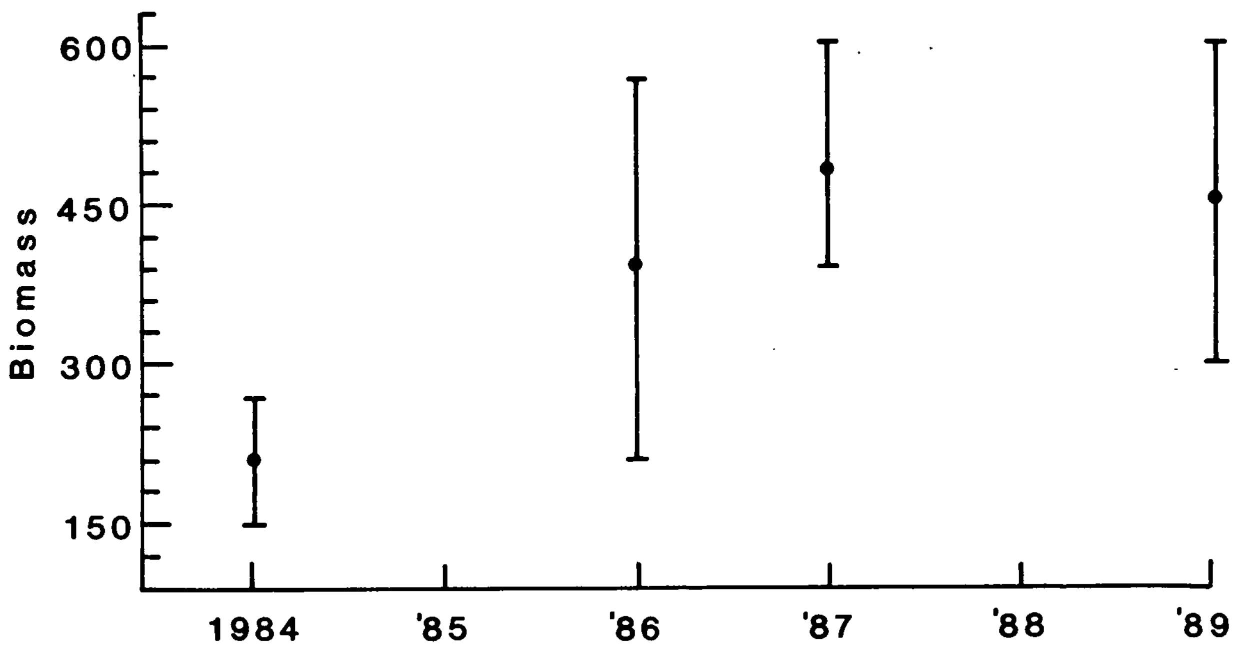

Fig. 7. Herring biomass (1000 tonnes ± 95% C.I.) in Chedabucto Bay, 1984-89.