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Results of acoustic surveys of the Southwest Nova Scotia (NAFO Division 4WX) herring stock during February and July, 1981

by

R. Shotton
Marine Ecology Laboratory
Bedford Institute of Oceanography
Dartmouth, N.S.
B2Y 4A2

and

R.G. Randall
Marine Fish Division
Department of Fisheries and Oceans
St. Andrews, N.B.
E0G 2X0

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Abstract

Acoustic surveys of the 4WX herring stocks during winter and summer, 1981, obtained stock size estimates of 408 000 t and 201 000 t, respectively. Sampling error and unavailability of the stock to survey during the summer period meant that there is a large amount of uncertainty in these estimates. Despite this, many of the problems associated with these surveys appear tractable and the continuation of these surveys should provide cost-effective estimates of the abundance of this herring stock.

Résumé

Des relevés acoustiques des stocks de harengs faits dans la division 4WX à l'hiver et à l'été de 1981 ont permis d'estimer les populations respectives à 408 000 t et 201 000 t. L'erreur d'échantillonnage et le déclin de la population pendant l'été peuvent entacher les estimations d'une bonne part d'incertitude. Malgré cela, il semble que bien des problèmes inhérents à de tels relevés soient surmontables et la poursuite des relevés devrait donner des estimations économiques de la taille de cette population de harengs.

INTRODUCTION

The southwest Nova Scotia herring population (NAFO Division 4WX) is a large stock that feeds and spawns off southwest Nova Scotia and migrates to and over-winters in the Chedabucto Bay area each year. 4WX herring are exploited by a large purse seine fleet during periods both in summer and winter. Landings over the past ten years (1972 to 1981) have ranged between 58 000 and 153 000 t.

The 4WX herring stock was surveyed using an acoustic system during winter (February) and summer (July) in 1981. These surveys were conducted jointly between the Marine Fish Division and the Marine Ecology Laboratory. The main objectives were to: (i) determine the geographic distribution of the herring during winter and summer and (ii) obtain acoustic data on the volume scattering characteristics of the herring schools. Some trawling was done during the winter survey to identify acoustic targets and obtain samples for biological measurements. This report describes the results of both surveys. Data from these surveys provide the first acoustic assessment of a herring stock in the Maritimes Region.

SURVEY DESIGN AND METHODOLOGY

Winter Survey, Chedabucto Bay, February 1981

The expected range of herring distribution during February was based on records of past purse seine catch locations. These had occurred in Chedabucto Bay and the coastal region from Lockwood Rock north to Cape Gabarus as far as 20 miles seaward (Figure 1).

This survey, using the research vessel E.E. Prince, commenced at 2000 February 17, 1981 and ended at 1600 February 22, 1982. The cruise was blessed with uninterrupted good weather. 75% of the survey time was spent steaming transects. The remaining time included some unscheduled steaming and fishing time. Although a vessel speed of 8 knots was maintained over the ground, speeds varied as a result of tide and current movements. During calm weather such water movements are not be expected to exceed 0.5 km hr^{-1} (K. Drinkwater, pers. comm.)

Six days were allocated to steaming transects. The survey area was divided into seven strata in order to facilitate positioning of transects and to permit allocation of further transects to strata which showed high abundance or variability. Each stratum contained two transects, randomized in position, whose combined lengths were approximately proportional to the strata areas. Because the ends of the inshore legs of transects sometimes varied from that which was intended, further variability occurred in the sampling ratio between strata. Strata areas were delimited on the inshore boundary by the 36.6 m (20 fathom) isobath (Table 1) Offshore position was determined by the extent of locations of past catches. At the end of the survey period, a further 3 days were spent obtaining additional data on the acoustical characteristics of herring schools.

Some trawling was carried out using two types of gear: a Yankee 36 Otter trawl and an Engel mid-water trawl. Although the survey was originally scheduled for a total period of 24 d, the first half of the cruise was cancelled because of vessel refit delays. Trawling during the actual survey period was therefore kept to a minimum because of time constraints.

Detailed log records were kept throughout the survey, and the echo-sounder paper was marked with the time at 15-min intervals.

Summer Survey, Southwest Nova Scotia, July 1981

This survey was executed during the period 1300, July 13 to 0100, July 21. Subsequent to this, until 1400, July 23, acoustic data were obtained between Bongo stations in the inshore area south of Yarmouth. This latter part of the cruise undertaken by Dr. A. Koslow of Dalhousie University, was directed to studies of the plankton - herring distribution.

As with the winter survey, the range of the summer survey area was based on records of past catch successes during the time of the survey. The general movement behaviour of the herring involves a period when they are offshore from the S.W. Nova Scotian coast, in sea depths of approximately 40 - 200 m, and distances of up to 40 miles during late June and July. After this the herring move close inshore to spawn, in depths of less than 40 m. During this time it is not possible to survey the herring because of the shallowness of the area where they occur. A major requirement of the summer survey is to time the cruise so that the survey can be completed before the herring start their inshore movement, but not so early as to be completed before all the herring have arrived in the offshore area. There is still some uncertainty as to the identity of the herring in the area off Southwest Nova Scotia. Sinclair and Iles (1981) note that other stocks from NAFO areas 5 and 6 may occur in the area, and it is possible that the herring surveyed in winter, do not all move to the Southwest Nova Scotia area in the summer.

Catch records from previous years indicate that herring have been caught in an area bounded by the 43° 10' parallel in the south, the 66° 50' meridian in the west end and the 44° 40' parallel to the north. A disjunct herring fishery also occurrs during the latter part of July and early August, in the northeastern corner of the Bay of Fundy (Scots Bay) but this area was not included in the survey.

The area surveyed is shown in Figure 2. The time allocated to steaming transects was allocated on a simple proportional basis, though the inshore termination of the different transects often varied from what had been planned depending on local conditions. Survey statistics of the strata are listed in Table 2. Transects were randomized in position and ran along parallels. Because of the strong tides that occur in this area, steaming times along transects were not always proportional to their length. Few herring were caught during the summer survey.

Acoustic Assessment Techniques

The basis of acoustic echo integrating theory is that the echo intensity from fish bears a known and linear relation to the biomass of the sonified fish. If this relation is known, then the echo intensity can be accurately measured from knowledge of system characteristics, such as the transmitted sound (source) level, receiver sensitivity and system gains.

The echo intensity at the transducer face is determined by:

$$I = I_o \frac{\frac{\rho\sigma}{4\pi} \quad \frac{c\tau}{2} \quad \int b(\theta)^2 d\,\Omega}{R^2 \; e^{2\beta R}} \qquad (1)$$

where;

I_o = source level intensity

σ = scattering cross-section of the fish in the reverberation volume.

ρ = density of fish in the reverberation volume

$c\tau$ = pulse width

β = attenuation coefficient of sound in seawater

R = range of pulse volume with respect to the transducer

$b(\theta)$ = directivity function of the transducer

then,

$$\rho = \frac{I R^2 e^{2\beta R}}{\sigma/4\pi \quad c\tau/2 \quad \int b(\theta)^2 \, d\Omega} \qquad (2)$$

The terms $R^2e^{2\beta R}$, which account for attenuation of sound by spreading or absorption are compensated for by hardware (TVG) in the acoustic system. The equivalent beam angle, $\int b(\theta)^2 d\Omega$ is calculated directly from directivity plots of the transducer. The pulse width $C\tau$ can be measured very accurately; it depends on the speed of sound in water, and the pulse period τ. The scattering coefficient is the term in which most error is likely to exist. The value used herein, -32.5 dB/kg. per steradian, equivalent to a backscattering area of $0.00707M^2$/kg. was suggested as most appropriate by I. Edwards (pers. comm.) of The Marine Ecology Laboratory, Aberdeen. This is considered by Edwards as a "best-judgement" value. In experimental studies, on herring, Edwards (1980) reported these results:

Target Strength/kg	Mean Fish Length (cm)
-31.2	22.2
-30.2	21.8
-32.5	24.8
-31.2	24.1
-31.9	23.8

Edwards gives an overall result of -31.5 dB/kg. The mean length of herring caught in trawls made by the E.E. Prince was in the range 25–30 cm. Herring taken by the commercial fishery were slightly larger. Previous acoustic surveys of herring in European waters have used an assumed target strength of -34 dB/kg (Bailey *et al.* 1980; Anon 1980 and others). The target strength values given by Edwards are believed to be unreliable because of deficiencies in the calibration methods that were used (pers. comm. Buerkle). An increase in the target strength value of herring to -31.5 dB would result in a 20.6% decrease in the herring biomass estimate by 25.9%.

The power output from the system is:

$I_m = I \, k \, g$

where

I = intensity of received sound
k = is the receiver sensitivity
g = system gains

As k and g are readily measured, then if σ is assumed, ρ can be estimated from (2).

For each pulse within a transect, the intensities and times of successive echoes are measured and recorded on magnetic tapes. From these successive estimates of backscattering area and hence herring biomass/m^3 can be obtained. By summing these, for each pulse an estimate of biomass/m^2 is determined. It is a simple application of sampling theory to obtain the total population estimate for a stratum of known area.

Acoustic data were collected at sea in a 16 bit word, reverse bit, reverse byte and complemented format were converted on computer to a CDC compatible form. Echoes from herring schools were extracted from the data record for processing to ensure that false bottom echoes were removed. A simple correction for lost bottom conditions in schools was implemented by interpolating data from the adjacent "good" pulses. This would be expected to cause an underestimate of the total scattering cross-section. "False" bottom conditions occur when the fish density is very high causing "sea bottom echo condition" to be detected in the system. "Lost" bottoms occur when the bottom echo is so attenuated due to a steeply sloping bottom or when dense schools considerably attenuate the pulse intensity such that the bottom echo intensity is subthreshold, and sampling continues after the bottom echo return. Few of the pulse data ($<1\%$) needed so adjusting.

RESULTS

Winter Survey, Chedabucto Bay Area

Echo-sounder traces of fish thought to be herring schools were found in most of the survey area (Fig. 3). Herring traces were scarce and absent in strata 1 and 4, respectively, but the frequency of sightings was reasonably uniform in the other strata. A total of 28 schools was located.

Water depth, the location of schools within the water column, and the relative size of schools (as transected by the vessel) are given in Table 3. Most sightings were made in a fairly restricted depth range (80-160 m; Fig. 4), and most schools were located on, or close to, the bottom. Approximately equal numbers of sightings were made during light and dark hours, and there were no diel differences in the locations of schools within the water column (Table 4). The detailed survey conducted in stratum 2, where the same school(s) was observed frequently over a 3 day period, also showed no differences in diel distribution of the herring within the water column.

School sizes determined by measuring transects across schools from the sounder paper give no indication of absolute school size because schools are crossed by the research vessel on only one axis. Most of the sounder traces indicated school widths ranging between 10 and 70 m and depths ranging between 3 and 20 m, but one larger tracing (indicating a school size of 1.5 x 0.05 km) was recorded in stratum 2 (school number 6, Table 3). The acoustic assessment indicated that 93% of the total herring biomass estimated in the survey area (408 000 t) occurred in stratum 2.

Ten mid-water and three bottom-trawl sets were made during the survey (Fig. 5). Although most fish traces were on the bottom, the bottom trawl proved ineffective because the topography of the substrate was too rough to trawl in many areas. It was interesting to note that of the three bottom tows at random locations, two caught herring, although in small numbers (Table 5).

Most of the mid-water trawling was conducted where herring traces were recorded; seven of the ten sets caught herring but all catches were small (Table 5). Length frequencies and ages of captured herring are given for each tow in Figure 6. Most of the herring captured were 4-5 yr old and averaged 25-30 cm in length. One exception was the small sample from one bottom tow from stratum 7 (BT 5; Fig. 6) which was predominantly 2-yr herring averaging 13 cm in length.

Length-frequency and catch-at-age information for all research vessel catches combined were compared (Fig. 7) to samples from purse-seine landings from January and February 1981. The strong 1976 and 1977 year-classes (ages 4 and 5) were predominant in both research vessel and commercial fisheries catches, and mean lengths were similar. These results are encouraging in suggesting that the large school(s) surveyed by acoustic means in stratum 2 was the same school(s) exploited by the commercial purse seines, and that trawl catches during the survey, although consistently small, provided representative samples of herring.

Table 6 lists the estimated biomass for each strata surveyed. Biomass is estimated by

$$b_h = \frac{\bar{\gamma}_h \quad a_h}{\sigma/4\pi} \qquad (3)$$

where

b_h = biomass for the h^{th} stratum (Table 6)

a_h = area of h^{th} stratum (Table 1)

σ = scattering cross section/kilo

$\bar{\gamma}_h$ = mean area scattering coefficient for h^{th} stratum

$$= \frac{1}{P_h} \sum_{i=1}^{n_h} \sum_{j=1}^{n_i} \gamma_{jik}$$

where P_h = number of pulses in the h^{th} stratum

n_i = number of pulses in the i^{th} transect

n_h = number of transects in the h^{th} stratum

$$\gamma_{hij} = \sum_{k=1}^{n_{ij}} \gamma_k$$

and n_{ij} = number of echo samples or "interrupts" from the j^{th} transmission, i^{th} transect, h^{th} stratum.

Total biomass is given by

$$B = \sum^{7} b_h .$$

The relative variance estimate of the total biomass has been calculated by

$$\mathrm{Var}(B) = \sum^{7} a_h^2 \ \mathrm{Var} \ (w_h)$$

where

a_h = area of h^{th} stratum

w_h = mean biomass/m^2 of herring for the h^{th} stratum.

This is an interim measure. An appropriate measure of the sonified volume during a survey transect and hence the sampling fraction has not yet been determined. The sampling volume is a function of depth, backscattering cross-section values encountered, and threshold detection levels used within the system. These variance estimates must therefore be considered only as relative estimates.

The contribution to the variance estimate from the error in the estimate of the backscattering area per km has also been ignored. This would further increase the actual variance. These considerations are discussed by Shotton (1981).

Because the transects within each stratum were not of equal size, sample variance was estimated by:

$$\mathrm{Var}\ (w_h) = \frac{1}{N-1} \sum_{i=1}^{N} \frac{P_{hi}}{P_h} (w_{hi} - \bar{w}_h)^2$$

$$w_{hi} = \frac{4\pi}{\sigma} \sum_{j=1}^{n_j} \gamma_{hij}$$

$$\gamma_{hij} = \sum_{k}^{n_j} \gamma_{hijk}$$

n_j = number of echo samples from the j^{th} transmission, i^{th} transect, h^{th} stratum.

$$\bar{w}_h = \sum \frac{P_{hi}}{P_h} w_{hi}$$

where

N = number of transect = 2

P_{hi} = number of observations in the i^{th} transect of h^{th} stratum.

The total estimated biomass for the survey area was 401 000 t. The 50% confidence interval, assuming central limit theorem and the caveats discussed earlier, is ± 199 200 t, i.e. the result obtained has a very large variance.

Summer Survey, S.W. Nova Scotia

The July survey results are tabulated in Table 7. Because discriminator settings were incorrectly set for the first part of the first transect, several large schools encountered during this period were not completely recorded. To obtain a biomass estimate for this transect, the areas of correctly recorded schools was determined and their total backsetting coefficient determined. Based on this and the relative areas of the schools on the echo sounder paper, an estimate of the backscatter of the schools encountered in the first transect was made. A value of -32.5dB/kg was used to convert backscattering cros-sectional areas to biomass of herring. The estimate of herring biomass for the area was 201 000 t (Table 8).

DISCUSSION

There appear to be several advantages to surveying 4WX herring during their overwintering phase in the Chedabucto Bay area. The majority of the herring biomass was relatively localized in distribution and, if this characteristic is repeated in other years, it could greatly enhance the efficiency by which the herring schools can be surveyed each year. The entire survey area can first be systematically searched as quickly as possible to locate the major concentration(s) of herring, and after this, the remaining survey time can be spent conducting a detailed and replicated survey in the area where the herring concentrations are located. Replicated sampling would increase the precision of the acoustic abundance estimates. The herring schools seemed to be relatively stable in winter and there appeared to be no migrations of the schools within the water column during light and dark periods. This makes it feasible to survey the herring during both day and night without concern for possible day-night differences in schooling behaviour.

The estimate of 408 000 t obtained from the Chedabucto Bay survey is remarkably close to a recent estimate of the 4WX herring biomass of 350 000 t calculated by Sinclair and Iles (1981) by using cohort analysis. However, until more research is done on target strength and volume-scattering characteristics of herring schools, acoustic estimates of stock size should be considered more appropriate as relative than absolute indications of abundance.

The July estimate was approximately half that obtained during the February survey (201 000 t). When an appropriate variance estimator has been determined, it may be that the two results can be considered significantly different only with a low level of confidence. Notwithstanding this, there are two possible causes that might have caused the low estimate, obtained in July. Firstly, part of the stock may have been outside the survey area. This seems quite likely as in stratum 2, all of the herring schools that were encountered were along the inshore margin of the stratum (defined by the 20 fathom contour). It seems reasonable to assume that the inshore movement of the herring stocks had already progressed to the extent that part of the stock was unavailable to the Prince for acoustical surveying. During work subsequent to completion of the survey, extensive herring traces were recorded in the inshore region south of Yarmouth, indicated by the transects marked in Figure 2 that run parallel to the coast.

An interesting observation was made during an earlier cruise by Dr. A. Koslow on the R.V. Dawson. "Herring-like" traces (Figure 8) were obtained from a position near the shelf break of Browns Bank, approximate latitude and longitude 42°35'N, 66°11'W. If these traces are from herring, then part of the stock may still have been enroute to the surveyed area, though they could be part of another stock. In addition, the question of the status of the Scots Bay herring remains; is it part of the 4WX stock?

The second possible cause that could contribute to an underestimate of herring abundance would be use of inappropriate target strength values. One value, -32.5dB/kg has been used for all the date collected. Unlike the winter survey, the herring schools in summer had different structures during the day and night. Also, herring at night has been found to show a wide range of orientations. (See Shotton 1981). At night a different (and at present unknown) target strength value should be used in estimating abundance. Figures 9 and 10 show echo traces obtained from herring during the night and day respectively. The echo data obtained is being further analyzed to quantify diel variation in school volume scattering levels.

AN EVALUATION OF THE ACOUSTIC METHODOLOGY, AND FUTURE SURVEY REQUIREMENTS

Primary Editing

Primary editing is undertaken for two reasons:

(1) to reduce the amount of data (which is enormous) that must be processed, and

(2) to reduce the opportunity for error in processing algorithms which determine if data is spurious, i.e. noise records, bottom samples, echos from fish other than herring, or samples taken when the bottom does not trigger the threshold detection level. Even with such processing, further editing is necessary to delete bottom echoes and to detect situations where a false bottom has been triggered due to dense herring schools, or inappropriate bottom discrimination levels.

In deeper water noise due to amplification of ship generated noise requires operation of the system (see Figures 11 and 12) at higher threshold levels. This means that low densities of fish will not be recorded. Figure 13 shows "deep water" noise. Our subjective estimate is that the total bias from these two causes is unlikely to exceed 10%. In future cruises, this potential source of bias will be reduced by more appropriate gain settings on the acoustic system.

Target Strength Estimates

With the exception of σ, all of the variables in equation (2) are known quite accurately, to within $\pm$ 1 dB. The scattering characteristics of fish depend on a variety of factors, mainly their size; and their aspect, or orientation, in the sea, and hence on any of the behaviour characteristics affecting the latter. For example, the orientations in space at night observed by Ryzhenko *et al.* 1963 and Beltestad (1973) cited in Nakken & Olsen 1977 and others, would result in the same amount of herring having a lower backscattering value than if they were oriented in a horizontal mode. To avoid underestimating abundance, appropriate scattering values should be used for day and night observations. No information exists on herring aspect during their winter phase. Investigation of this would enable more appropriate backscattering values to be used, and this should be a research priority.

Future Surveys

The 1981 Chedabucto Bay cruise was lucky in having continuous good weather. The preceding and following two weeks were characterized by almost continuous gales. For this reason, a month may be needed to provide sufficient time for completion of the survey. A further consideration for January-February scheduled cruises is the frequent delay in completion of the year-end refit to the *E.E. Prince*.

The cruise had the mixed blessing that no commercial fishery was operating at the time of the cruise. While no-real time information on herring distribution was available, no fishing vessels interferred with the survey work. Evidence seems to indicate that the position of the major concentration of herring located off White Head is extremely stable from year to year. Brodie (pers. comm.) notes that whales have been reported in this area for many years at the time of the year the survey was conducted. When whales were sighted during the survey, herring were inevitably located by the echo sounder. For this reason, an optimum allocation of sampling effort would make sense.

Future February cruises could follow a similar design as that for 1981 for the first 6 days with three additional days available for allocation to strata showing high abundance and/or variability. This effort could be focussed on the area of high concentration discussed previously. Additional transects need not equal in length.

A schedule might be as follows:

Weekend	Gear Preparation
Day 1	Steaming to grounds
2-7	Equal probability coverage
8-10	Allocated sampling
11-20	Down Time Allowance
21-26	Photographic Studies
26-27	Return to Halifax
(4 weeks in total)	

It would be advantageous to commence the S.W. Nova Scotia cruise even earlier in July than was done in 1981, possibly by one to two weeks. Reports from fishermen in the area indicate that the inshore movement of the herring had begun before the start of the survey on July 13th.

As most fish were encountered in stratas 1 and 2, same cruise time should in future be kept aside for real-time allocation to those strata showing most abundance.

Determination of the appropriate target strength value for herring sonified at at night is necessary if any confidence is to be placed in results derived from acoustic data collected at night. To do this will require a combination of photographic and acoustic studies both in natural and controlled situations.

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TABLE 1 - SAMPLING EFFORT STATISTICS FOR THE CHEDABUCTO BAY WINTER SURVEY

Stratum	Transect	Area Nautical Sq. Miles	Total Transect Length n.m.	Sampling Time		Normalized Sampling Ratio Density Length	Time
1	1	372.2		6h 25m			
	2		108.5	7h 3m	13h 28m	1.000	1.000
2	1	390.3	91.1	7h 17m			
	2			6h 54m	14h 1m	0.801	1.004
3	1	466.1		9h 1m			
	2		116.7	6h 14m	15h 15m	0.859	0.904
4	1	167.4		5h 57m			
	2		71.1	6h 43m	5h 43m	1.457	0.944
5	1	318.9		5h 57m			
	2		84.5	6h 43m	12h 40m	0.938	1.098
6	1	117.2		2h 54m			
	2		41.1	2h 24m	5h 18m	1.203	1.250
7	1	244.5		4h 0m			
	2		65.0	4h 29m	8h 29m	0.912	0.959

TABLE 2 - SAMPLING EFFORT STATISTICS FOR THE S.W. NOVA SCOTIA SUMMER SURVEY

Stratum	No. of Transects	Area nm^2	Total Sampling Time (h)	Normalized Sampling Density
1	4	705.3	21.88	1.00
2	8	595.1	30.23	1.64
3	11	643.7	19.79	0.99
4	4	485.3	15.35	1.02

TABLE 3 - HERRING SCHOOL CHARACTERISTICS DURING THE WINTER SURVEY

School No.	Date in February	Time (nearest ½ h)	Depth[a] (m)	School dimensions (m) Depth	Width[b]	Distance of School off bottom (m)
1	18	0930	74.0	3.3	54.9	0.0
2	18	2230	159.0	-	-	0.0
3	18	2330	128.0	7.4	63.3	15.7
4	19	0000	91.0	13.8	38.3	2.8
5	19	0000	88.0	7.0	67.9	2.5
6	19	0230	119.0	57.4	1456.0	0.0
7	19	1000-1030	146.0	-	-	0.0
8	19	1300	123.0	25.0	64.0	24.2
9	19	1700	128.0	14.8	24.3	0.0
10	19	2200	132.0	13.8	0	0.0
11	19	2200	127.0	21.3	14.7	15.0
12	19	2200	129.0	9.3	4.5	3.7
13	19	2200	127.0	7.5	121.8	4.6
14	20	1330	97.0	8.3	8.4	0.0
15	20	1330	112.0	2.7	6.7	0.0
16	20	1400	117.0	13.9	35.4	3.7
17	20	1530	97.0	4.7	37.7	0.0
18	20	1530	73.0	3.7	20.9	0.0
19	20	1900	154.0	2.8	31.2	0.0
20	20	1930	146.0	13.9	51.5	12.0
21	20	2000	172.0	5.6	9.6	0.0
22	20	2030	135.0	11.1	62.5	0.0
23	20	2100	183.0	5.6	18.1	0.0
24	21	2200	119.0	5.6	15.6	0.0
25	21	2200	128.0	1.8	24.3	0.0
26	22	1100	128.0	27.9	53.5	0.0
27	22	1100	163.0	25.0	59.3	0.0
28	22	1300	146.0	20.3	158.6	0.0

[a] Depth to nearest m $\pm$ 2 m.

[b] Width of school transected by vessel after correcting for transducer beam angle.

TABLE 4 - DAY AND NIGHT COMPARISONS OF SCHOOL SIGHTINGS

	Daytime	Nighttime	Total
Number of schools sighted	12	16	28
Mean depth of bottom (m)	115.8	134.4	123.2
Mean depth of schools (m)	13.6	12.3	12.8
Mean width of schools (m)	60.6	156.4	114.3
Mean distance of school off bottom (m)	2.3	3.5	3.0

TABLE 5 - NUMBERS OF HERRING CAPTURED BY TRAWLING DURING THE CHEDABUCTO SURVEY, FEBRUARY 1981.

Date	Time	Tow number	Number herring captured	Number herring sampled
18	1102-1132	MWT 1	0	-
18	1601-1631	MWT 2	Larvae in mesh	-
19	0425-0455	MWT 3	1	-
19	0556-0615	BT 4	0	-
20	1210-1240	BT 5	28	28
20	1650-1717	BT 6	10	10
21	1227-1257	MWT 7	0	-
22	2216-2241	MWT 8	49	49
23	0417-0514	MWT 9	11	11
23	1050-1123	MWT 10	163	100
23	1613-1641	MWT 11	518	100
23	2305-2325	MWT 12	162	100
24	0425-0517	MWT 13	428	100

TABLE 6 - ESTIMATED BIOMASS OF HERRING IN EACH STRATA DURING THE CHEDABUCTO BAY SURVEY

Stratum	Mean Volume Scattering Coeff/Area	Mean Biomass Estimate (tonnes)	Standard Deviation	50% Confidence Interval
1	0.0000182	3304	3150	2123
2	0.0020076	380733	295410	199,106
3	0.0000520	11769	3971	2676
4	0.0	0	-	-
5	0.0000198	3079	3269	2203
6	0.0000208	1184	1300	876
7	0.0000671	7974	7533	5077
TOTAL		408,042	295,570	199,214

TABLE 7 - ACOUSTIC STATISTICS FOR EACH TRANSECT SEARCHED DURING THE S.W. NOVA SCOTIA SURVEY

Transect	No. of Pulses	No. of Interrupts	Mean Vol. Scattering Level dB	Total Scattering Cross Section (M^2)	Biomass t/nm^2
1-1	31968	-	-	-	687.4
1-2	30240	252	-34.5	1.133	9.1
1-3	32352	0	0.0	0.0	0.0
1-4	31488	1642	-40.4	1.877	14.5
2-1	31872	240	-40.4	0.276	2.1
2-2	30144	4198	-30.1	51.237	413.0
2-3	22464	3529	-38.6	6.156	66.6
2-4	21216	2279	-30.1	28.245	323.0
2-5	22560	279	-34.2	1.324	14.2
2-6	21216	0	0.0	0.0	0.0
2-7	21408	0	0.0	0.0	0.0
2-8	19776	1998	-35.1	7.752	95.2
3-1	11712	0	0.0	0.0	0.0
3-2	14592	842	-41.3	0.782	13.0
3-3	16416	0	0.0	0.0	0.0
3-4	7008	0	0.0	0.0	0.0
3-5	12192	0	0.0	0.0	0.0
3-6	9504	0	0.0	0.0	0.0
3-7	11520	0	0.0	0.0	0.0
3-8	8544	0	0.0	0.0	0.0
3-9	7680	0	0.0	0.0	0.0
3-10	8544	0	0.0	0.0	0.0
3-11	6240	0	0.0	0.0	0.0
4-1	19776	1010	-42.8	0.665	6.7
4-2	24000	0	0.0	0.0	0.0
4-3	22752	0	0.0	0.0	0.0
4-4	21888	480	-43.0	0.299	3.2

TABLE 8 - ESTIMATED BIOMASS OF HERRING IN EACH STRATUM DURING THE S.W. NOVA SCOTIA SURVEY

Stratum	Average Biomass $/nm^2$		Total (t)
1	180.1		127024
2	121.0		72007
3	1.7		1095
4	2.3		1116
		TOTAL	201242

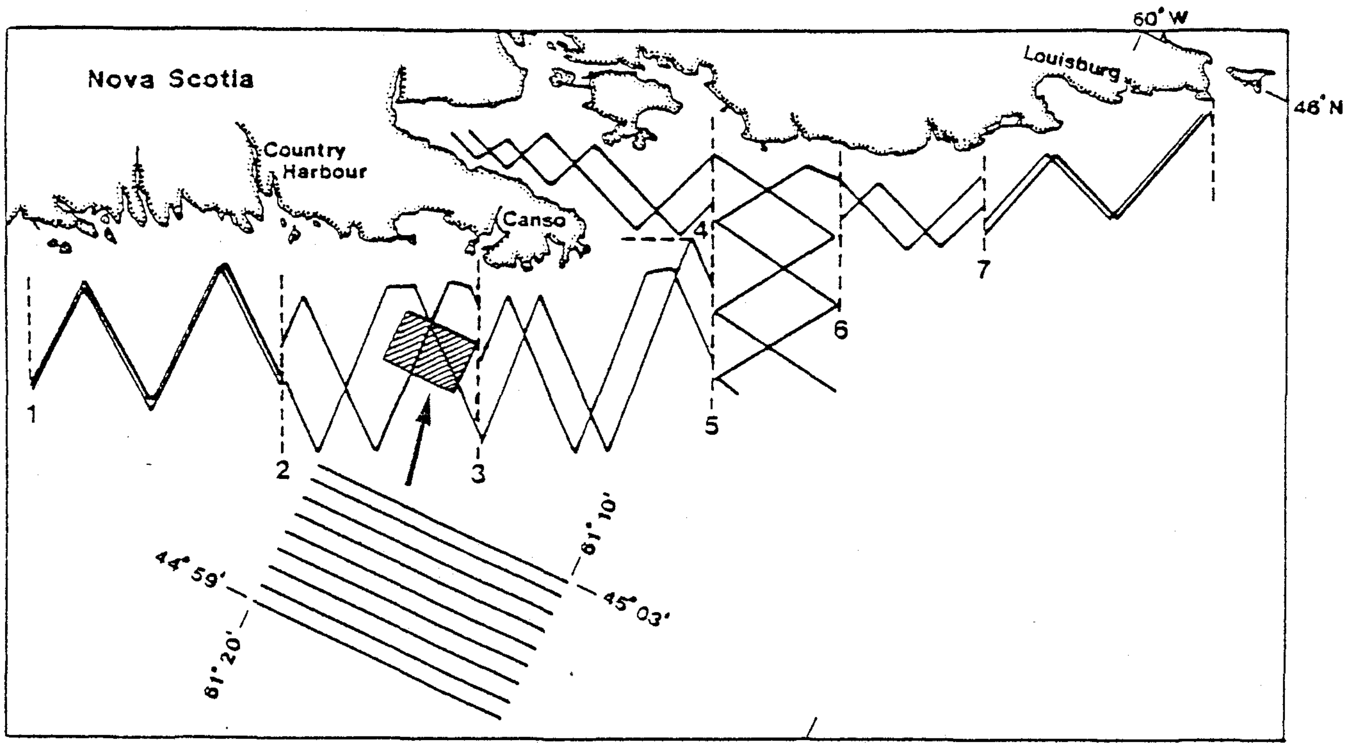

Figure 1. Map of northeast Nova Scotia showing the location of the seven strata and the survey track in the Chedabucto Bay area. Inset shows the area in stratum 2 where a more detailed survey track was searched.

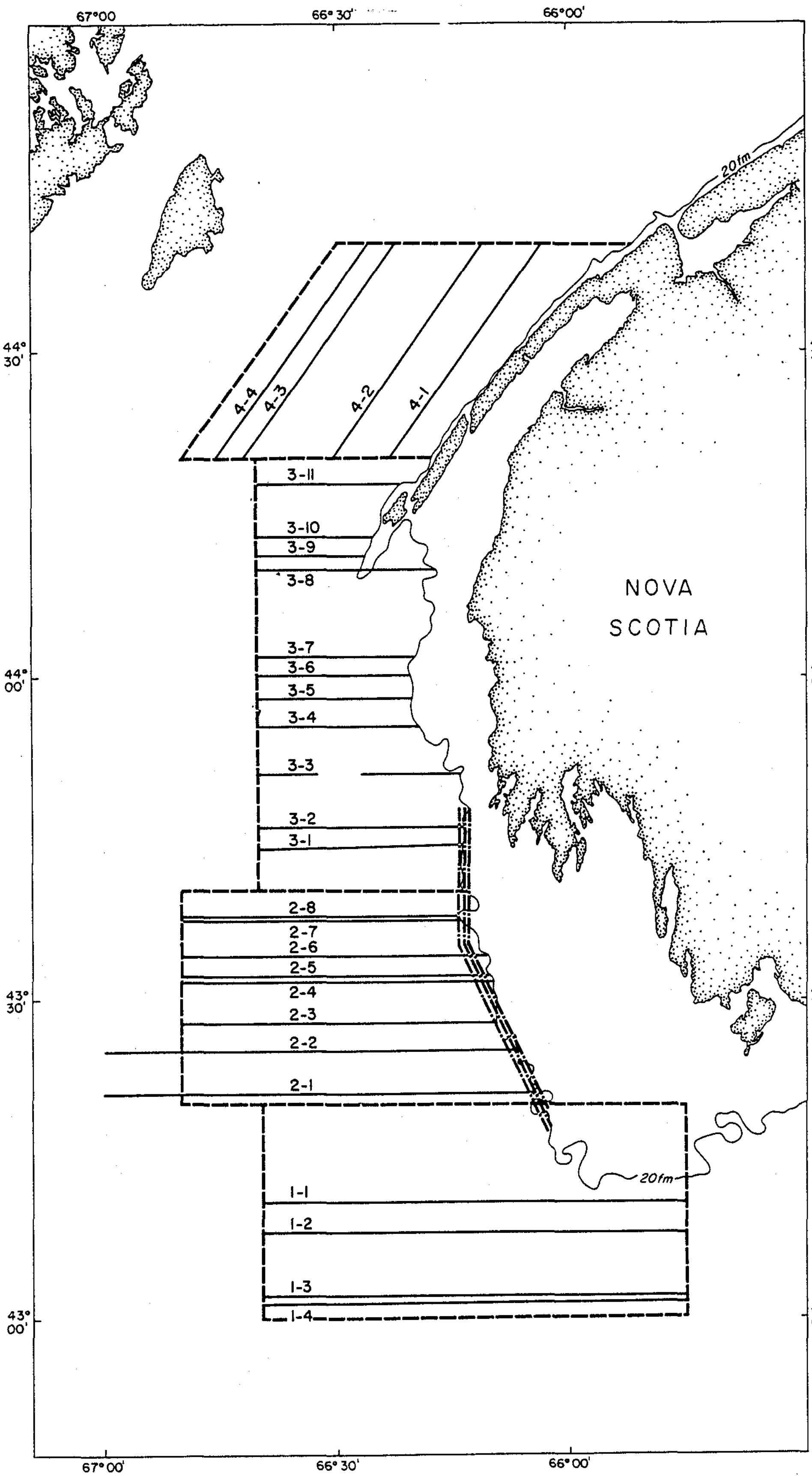

Figure 2. Map showing the survey track off southeast Nova Scotia.

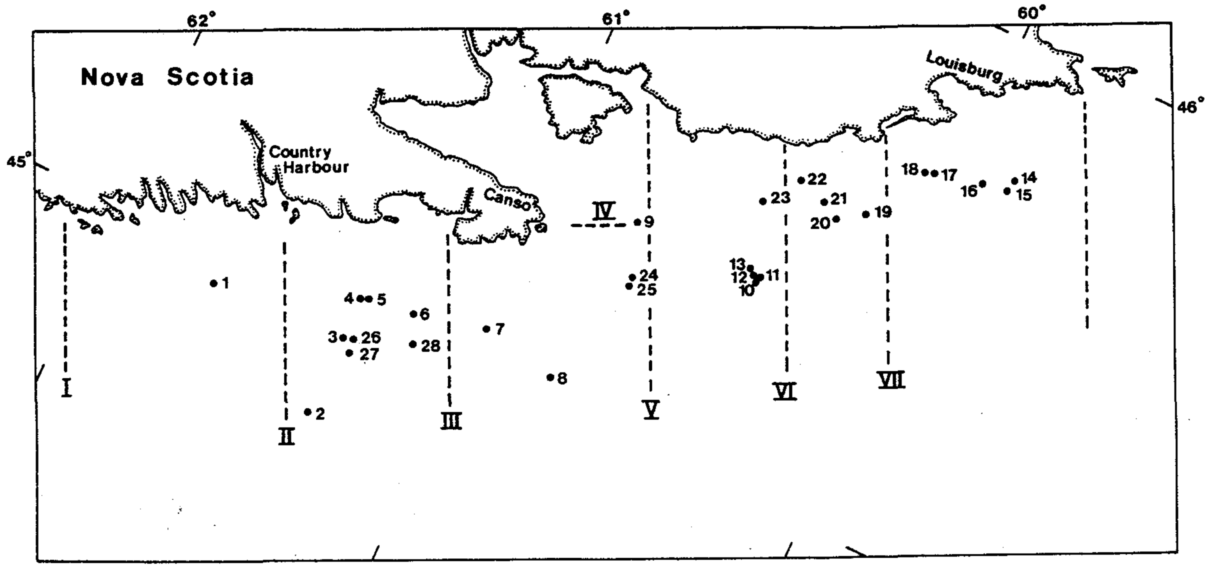

Figure 3. Geographic distribution of herring schools sighted in the Chedabucto survey area. Total number of schools sighted was 28.

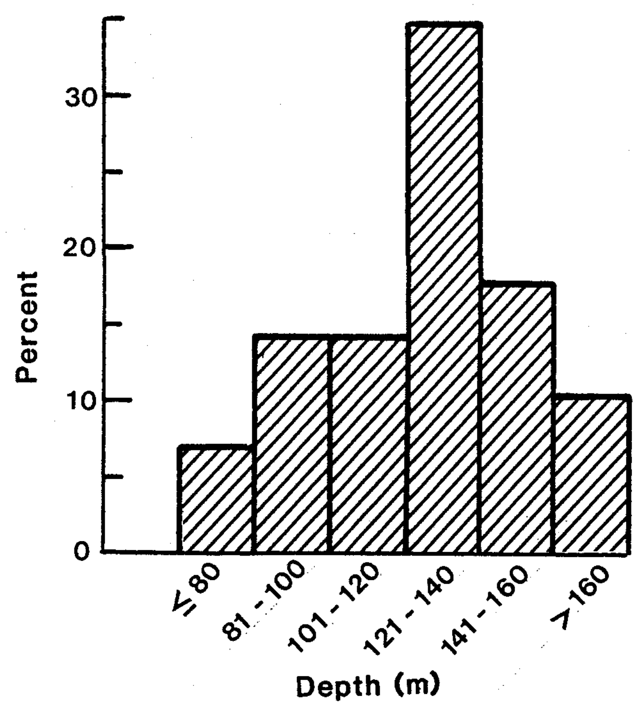

Figure 4. Depth-frequency distribution of herring schools.

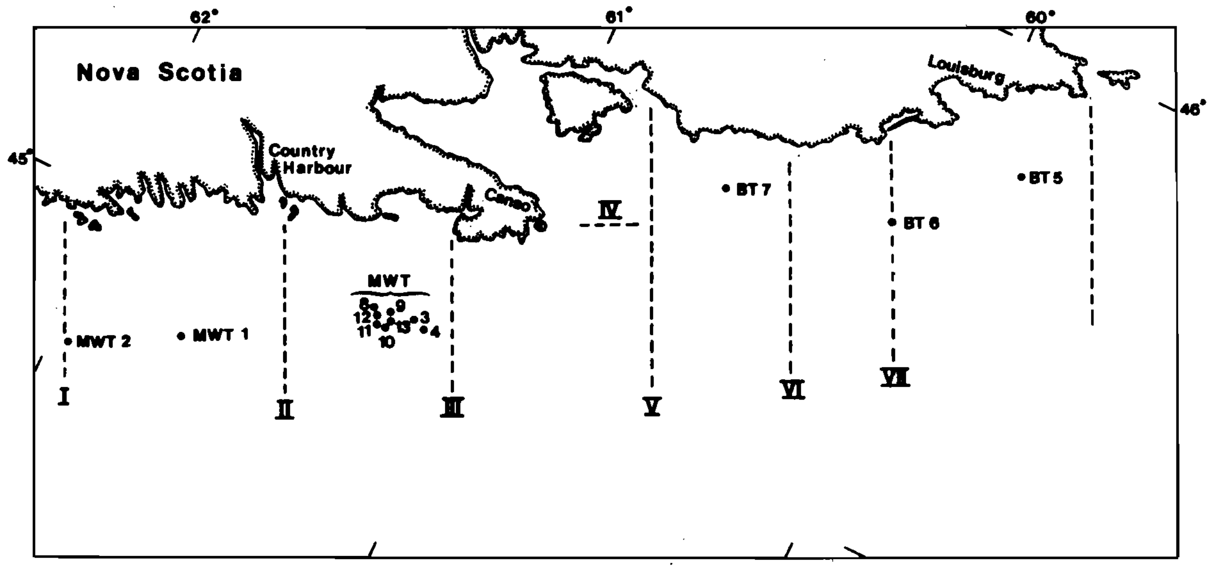

Figure 5. Location of bottom tows (BT) and mid-water tows (MWT) during the Chedabucto survey.

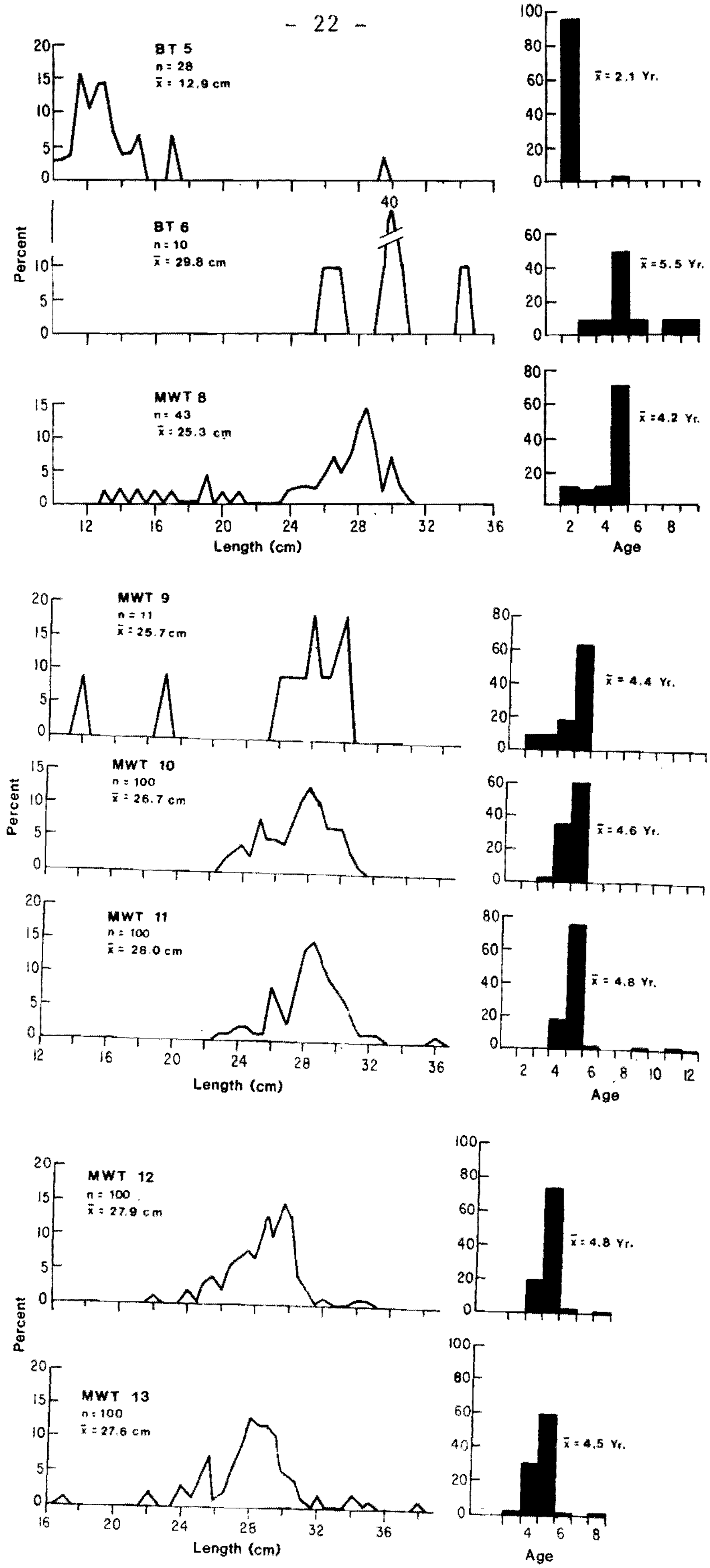

Figure 6. Length-frequencies and age-composition of various bottom trawl (BT) and midwater trawl (MWT) catches.

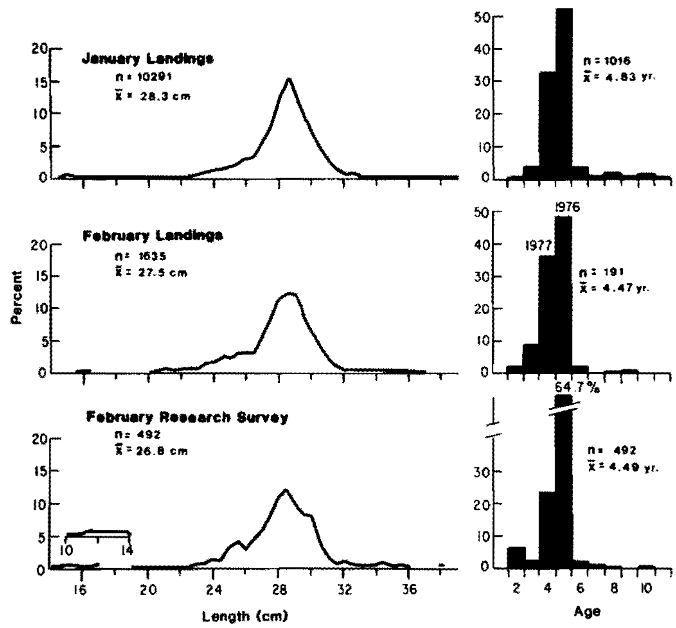

Figure 7. Length-frequencies and age-composition of purse seine landings from 4Wa in January and February 1981, and of the research vessel samples.

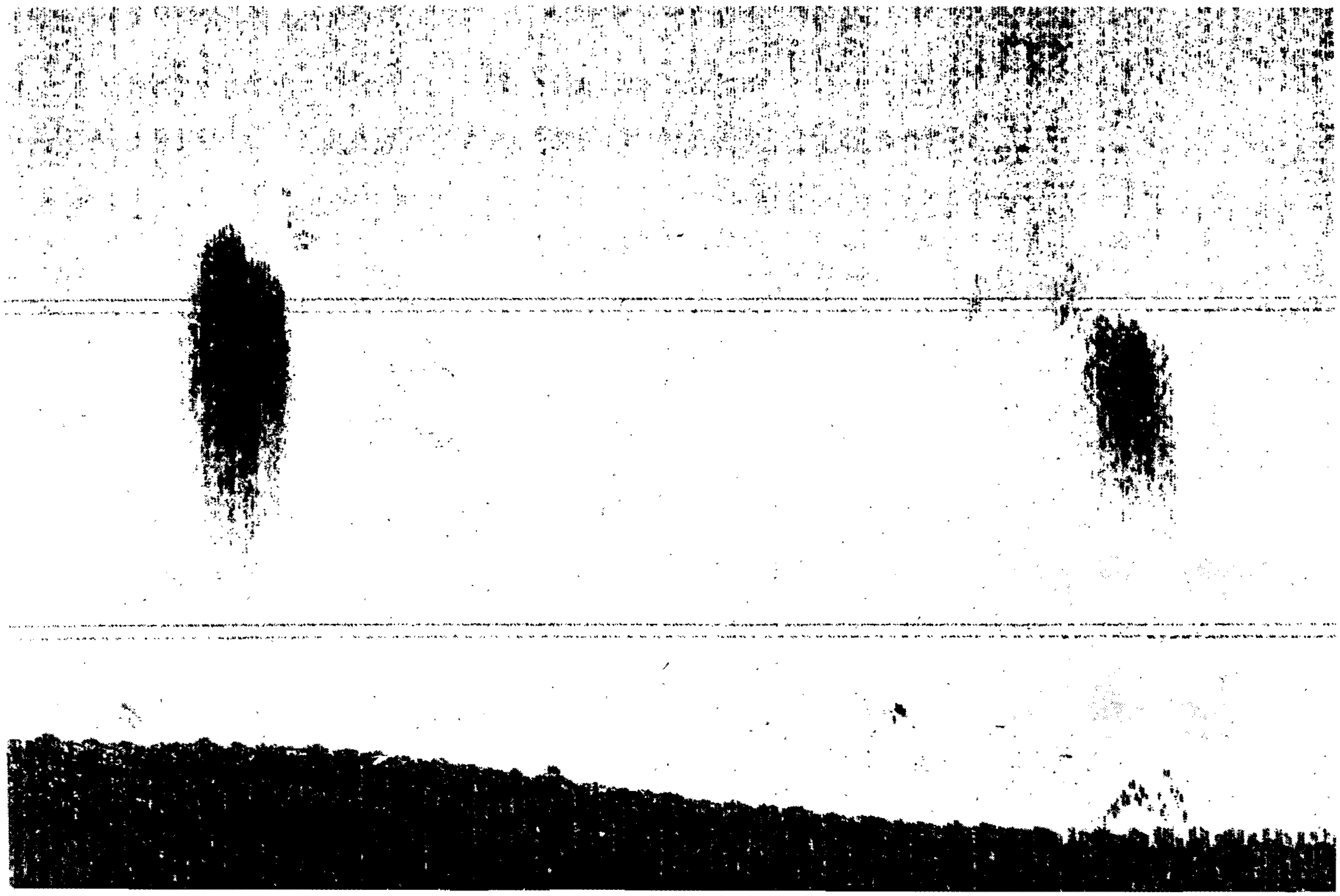

Figure 8. "Herring school-like" traces recorded near the shelf break of Browns Bank (42°35N, 66°11'W). Herring have not been located in this area before.

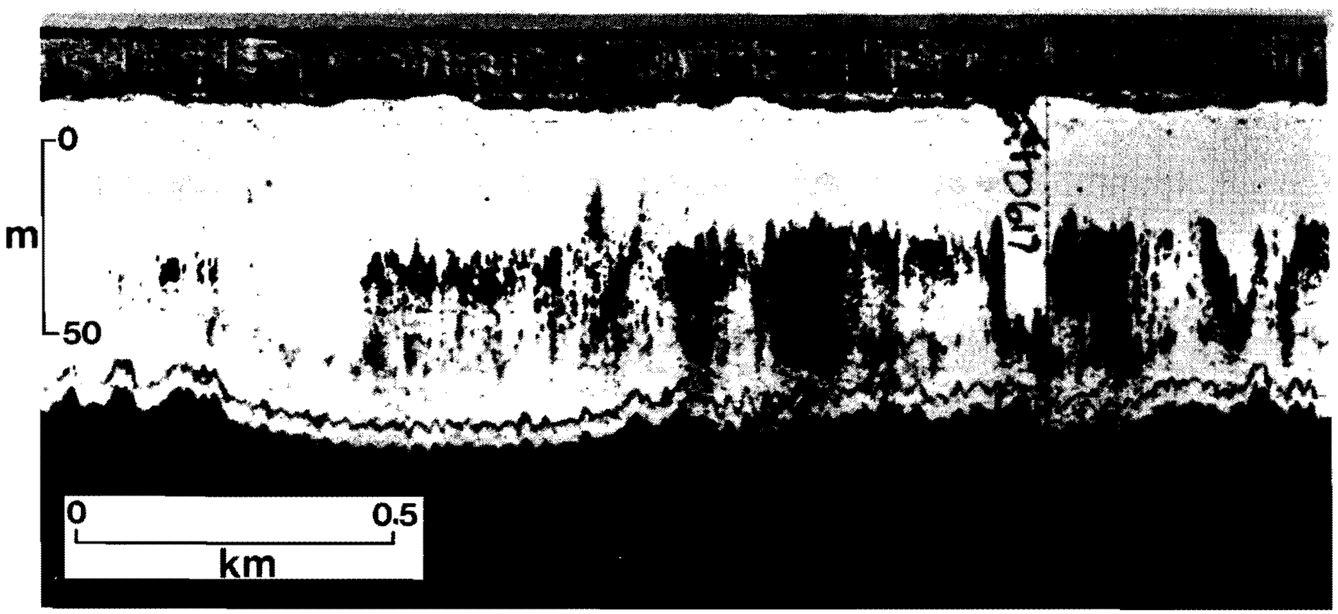

Figure 9. Echogram showing herring traces typical of the nighttime dispersed condition.

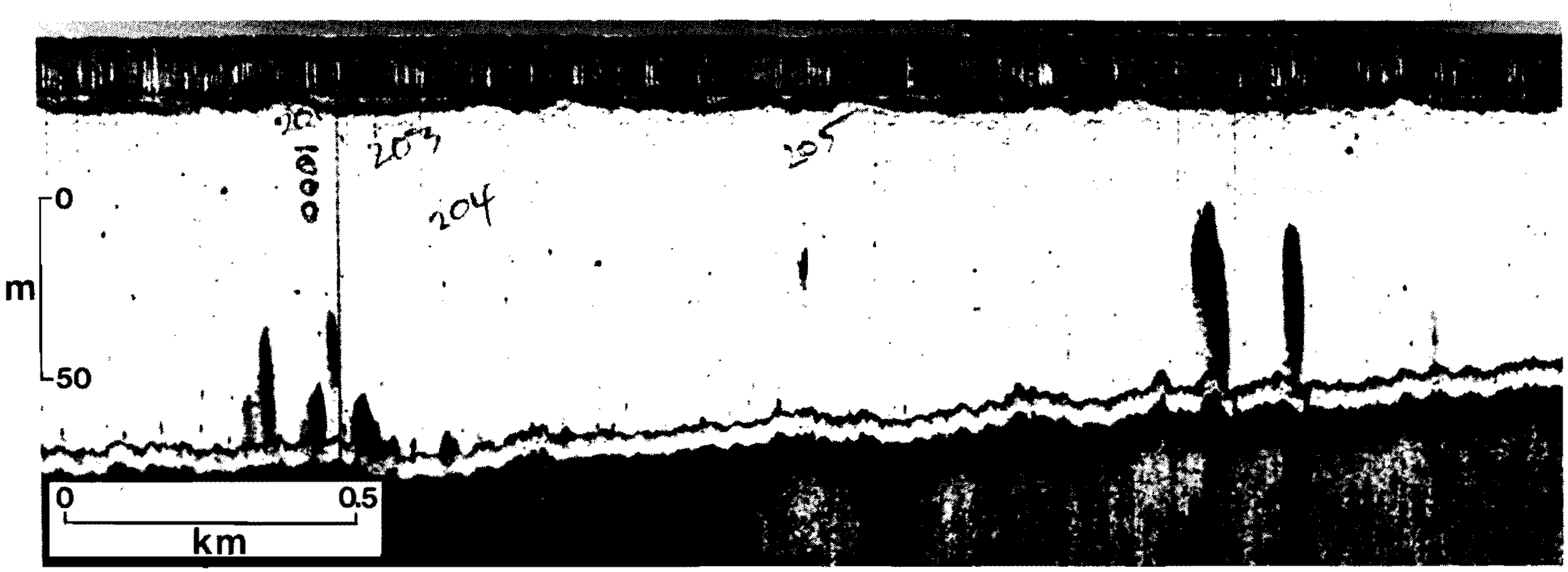

Figure 10. Typical echo traces of herring in daytime "discrete" school condition.

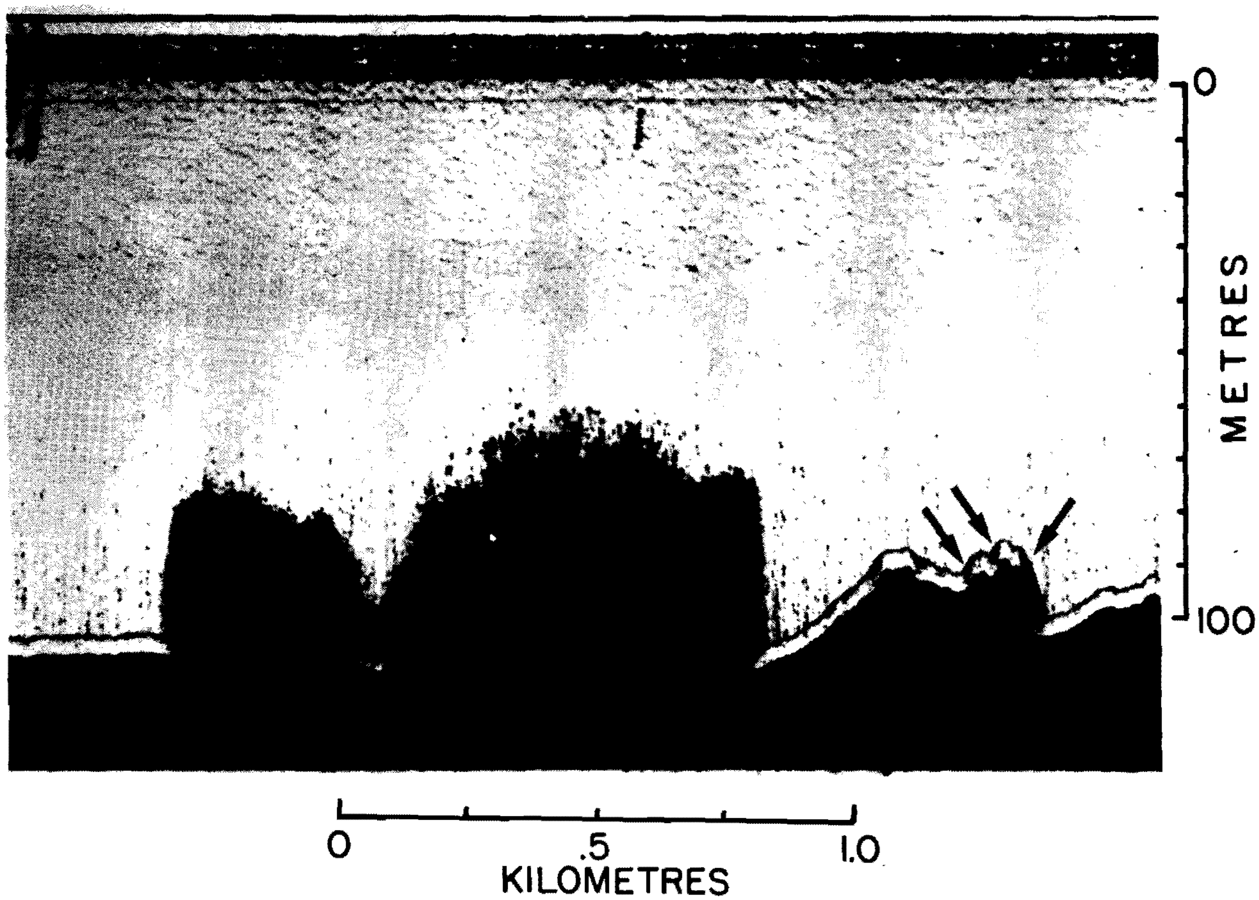

Figure 11. The arrows indicate sections of the bottom, where because of the steep slope, bottom triggering in the system has been delayed, resulting in bottom echoes being stored as part of the acoustic record.

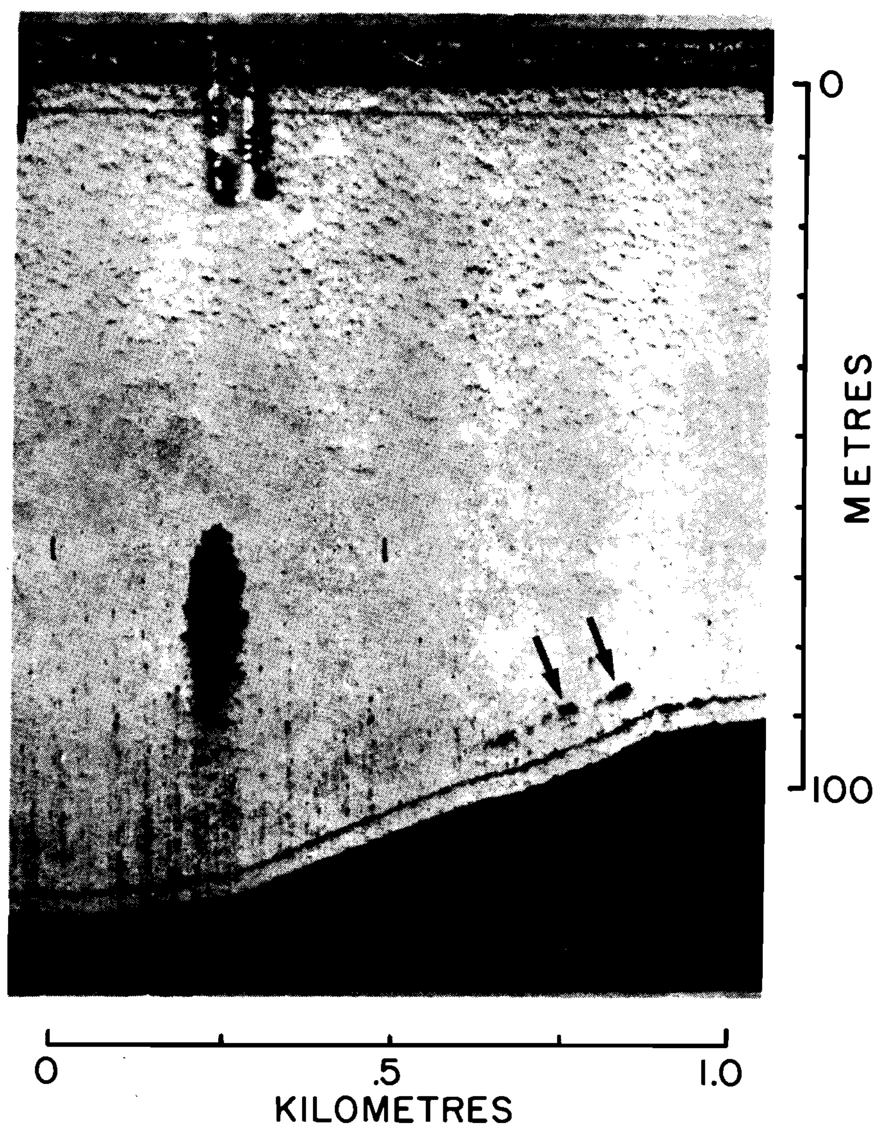

Figure 12. Echo traces of fish unlikely to be herring are evident to the right (see arrows). Reverberation within the herring school is shown by the "shadow" beneath the herring school. Ship's noise is evident as intermittent verticle streaks, and is vessel equipment.

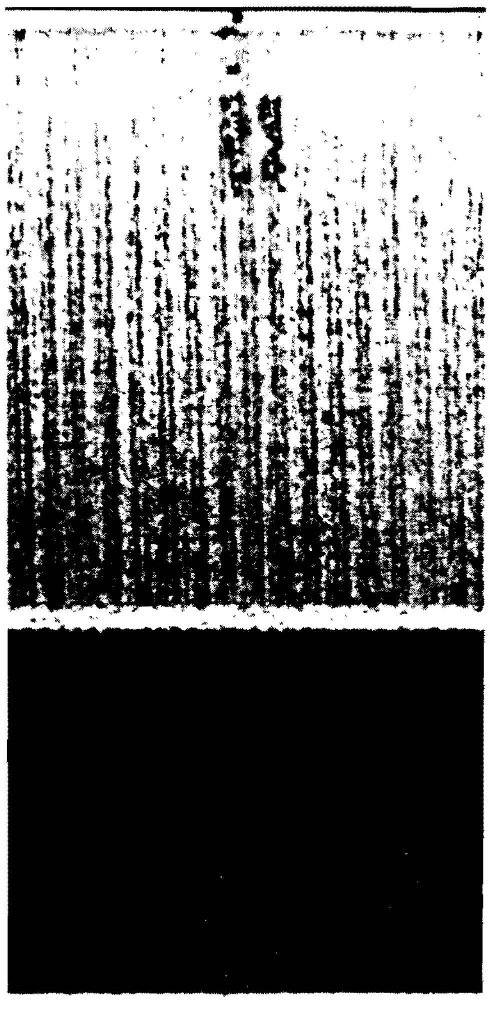

Figure 13. "Deep Water" ship's noise. Sea depth is 160 m. The occurrence of this source of noise stems from the last Prince refit. It is likely caused by propeller or shaft inalignment. These sources of noise are difficult to eradicate.