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Results of the 1986 and 1987 Winter Acoustic Surveys of NAFO Div. 4WX Herring Stocks

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ABSTRACT

Results of the 1986 and 1987 winter acoustic surveys of herring are described and compared to results from the 1984 and 1985 surveys. The replicate surveys in 1986 and in 1987, were similar to those done in 1984 and 1985, and showed similar herring distributions. The herring were concentrated in varying numbers of fish patches in the southern portion and in the approaches to Chedabucto Bay, N.S. The fish patches changed shape and size with time and replicate surveys produced a wide range of estimates of acoustic abundance. The maxiumum acoustic estimate produced each year is taken as the best estimate of the quantity of fish present. The acoustic estimates are converted to herring biomass by a target strength estimate determined for in-situ herring in Denmark.

Herring abundance detected by the surveys has increased since 1984 by about 23% per year.

RÉSUMÉ

Les résultats de relevés acoustiques d'hiver de 1986 et 1987 pour le hareng sont décrits et comparés aux résultats de ces mêmes relevés effectués en 1984 et 1985. Les reprises de ces relevés en 1986 et en 1987 étaient analogues aux relevés effectués en 1984 et 1985 et ont indiqué des répartitions analogues du hareng. Les harengs étaient concentrés en nombres variables de bancs de poissons dans la partie méridionale et les approches de la baie de Chedabucto (N.-E.). Ces bancs de poissons changeaient de forme et de dimensions en fonction du temps et les reprises des relevés ont donné un large éventail d'estimations de l'abondance déterminée de manière acoustique. L'estimation acoustique maximale obtenue chaque année est retenue comme étant la meilleure estimation de la quantité de poissons présents. Les estimations acoustiques sont converties en biomasse de hareng au moyen d'une estimation de taille cible déterminée in situ pour le hareng au Danemark.

L'abondance du hareng, telle que déterminée par les relevés, a augmenté d'environ 23% par année depuis 1984.

INTRODUCTION

The 1986 and 1987 acoustic herring surveys were the fifth and sixth in the series begun in 1981. Until 1983 the surveys were done to cover the area of the historical winter purse seine fishery as estimated from catch reports since 1971. This area extends about 160 km along the shore of N.S. from Liscomb Island to Forchu Head and offhshore about 50 km.

The 1981 survey covered the area but found the herring concentrated in one small (30 km^2) area (Shotten and Randall 1982). The 1982 attempt failed completely, the boat was unable to survey because of windy weather. The 1983 survey used a more weather resistant survey track and again covered the area but found negligible quantities of fish. The fishery, however, was making good catches at night in an area where the survey found no fish during the day (Buerkle 1986). The 1981 and 1983 results led to the conclusion that herring are concentrated in small areas and are not reliably available for acoustic detection during the day.

In 1984 the emphasis was changed from surveying the whole area to replicate night time surveys in the areas of fish concentration as identified by the commercial fishing effort. The 1984 and 1985 surveys were successful in producing nightly replicate estimates of fish abundance in the areas of fish concentration. They also surveyed the larger area of the historical fishery but found no signficiant quantities of herring outside the areas of major concentration. This supported the conclusion that surveying the entire area is ineffective and that the surveying effort should be focused on the known areas of fish concentration.

The 1986 and 1987 surveys produced replicate estimates of herring abundance in the areas of commercial fishing in Chedabucto Bay and surrounding areas but did not survey the whole area of the historical winter fishery.

METHODS

The acoustic instrumentation, calibration, data editing and processing have been described (Buerkle 1984, 1985b, 1986, 1987). Except for surveying the whole area of the historical winter fishery, the method of survey in 1986 and 1987 was the same as that in 1984 and 1985. Areas of fish concentration were identified from information on the fishing effort and acoustic transects were run through the areas at night. The patterns of transects were guided by the presence or absence of fish and were intended to determine the shape and size of the major fish patches while recording digital acoustic data. This approach allows replicate estimates of fish abundance in a patch in relatively short time spans and facilitates representative biological sampling. Sampling was done by Engel 400 mesh midwater trawl.

RESULTS

Herring Distribution

In 1986 and 1987 the major areas of fish concentration were along the south shore of Chedabucto Bay in the same general area as in 1984 and 1985. Figures 1 and 2 show the cruise tracks for 1986 and 1987, respectively. The heaviest concentrations of cruise tracks indicate the areas and the degree of survey sampling of the major fish concentrations. No fish were found in the areas east of Isle Madame in 1986 or 1987. No fish were found in the area south of Chedabcuto Bay in 1986. Several small patches of fish were found south of Isle Madame in 1986. Fish were also found there in 1984 but not in 1985 or 1987. Large patches of fish were found in the areas east of Canso in 1986 and 1987. Similar patches were found there in 1985 but only small patches were found in 1984.

The locations and sizes of fish patches found in 1986 and 1987 are shown in Figures 3 and 4.

In 1986 the fish were located just north of Canso. There were, initially, several patches of fish (Fig. 3A, B), similar distributions were found in 1985. Most of the fish then aggregated in one big patch similar to that found in 1984 (Fig. 3C). The patch remained in the area for 3 days (Fig. 3D) and then moved eastward out of Chedabucto Bay (Fig. 3E, F). In the process, it split into more numerous smaller patches.

The areas of the various patches, together with the acoustic data are shown in Table 1. The highest total scattering 160135 m^2sr^{-1} was found during the night of Jan. 23-24. The patch area was about 24 km^2 and the average area scattering coefficient was 0.006966 sr^{-1}. The three replicate surveys of the patch during that night produced fairly consistent results, the total scattering varied by only 11%.

As in previous years, the total scattering varied widely from night to night. It seemed particularly low when the fish are distributed in more numerous smaller patches as on Jan. 20-21 and Jan. 29-30. An explanation for this would be that the survey is designed to delimit and quantify one or more known large patches of fish. Fish that are distributed in many small patches are not properly sampled and are underestimated. A systematic survey would correct this problem but would produce other errors because of the variable availability of the fish for acoustic detection (Buerkle 1985a, 1986).

In 1987 the fish were distributed in generally larger patches (Fig. 4, Table 2). On Jan. 10-11 there were two patches (Fig. 4A), the western one was surveyed twice, the eastern one formed a long narrow band to the east and out of the Bay. During the next four nights of survey (Fig. 4B, C, D, E), only single patches of fish were found and showed generally decreasing total scattering. The distribution in narrow bands along the south shore and to the mouth of the Bay indicate the possibility of fish movement out of the Bay. On Jan. 18-19 (Fig. 4F) the fish were divided into two patches, one inside the Bay and one outside, east of Canso. The total scattering of both patches was higher than during the preceding nights but was not as high as it had been on Jan. 10-11. Some fish were either not in the area surveyed, or were not available for acoustic detection.

On Jan. 20-21 (Fig. 4G) the fish again formed a single patch. This had the highest total scattering of the survey, 238329 m^2sr^{-1}. The area of the patch was 52.5 km^2 and the average area scattering coefficient was 0.0045396 sr^{-1}. This large quantity of fish probably indicates that the fish east of Canso on Jan. 18-19 moved back into the Bay and joined with other previously undetected fish. The remaining two nights surveys showed single patches (Fig. 4H, I) with somewhat lower total scattering. In general, the 1987 survey showed a smaller range of total scattering than the previous surveys. Acoustically determined herring abundance, however, is still variable, and reasonable estimates of the quantity of fish present depend on surveying in the right place at the right time.

Biological Sampling

Herring were caught in 10 midwater tows in 1986 and in 13 tows in 1987. Four samples of herring caught by purse seine were obtained in 1987. The mean fish lengths and their standard deviations and 95% confidence intervals are shown in Table 3. The positions of the midwater trawl samples in relation to the fish patches are shown in Fig. 3 and 4. Table 3 shows a significant range in herring sizes. In 1986 the larger fish in tows 3, 5, 6, 7 and 11 were caught in the north and eastern portions of the fish patches. The smaller fish were caught in the south and western portions of the patches. In 1987 tows 1, 4 and 8 produced very much smaller fish than any caught in 1986. Those fish also were caught in the western portion of the fish patches. The average length of fish from all samples in 1986 was 28.7 cm; the average length from all samples in 1987 was 27.7 cm.

Length weight relationships were calculated from length stratified samples of 520 fish in 1986 and 669 fish in 1987. The relationships were:

$$1986 \quad Wkg = 5.3522 \times 10^{-6}\ l^{3.0693}$$
$$1987 \quad Wkg = 5.4503 \times 10^{-6}\ l^{3.0587},$$

where Wkg is fish weight in kg and l is fish length in cm.

Biomass

The acoustic estimates of the 1984 and 1985 survey results were converted (Buerkle 1986) to biomass of herring using the target strength length relationship of Halldorson and Reynisson (1983).

$$TS = 21.7 \log l - 75.5,$$

where TS is the target strength of a herring of length l cm. The 1984 and 1985 herring length weight relationships were used to calculate the average target strength per kg for each year. The average target strength for 1984 was -36.2 dB/kg, for 1985 it was -36.3 dB/kg. The Halldorson and Reynisson (1983) relationship with the 1986 and 1987 length weight data gave average target strengths of -35.9 dB/kg and -35.7 dB/kg, respectively.

A more recent study of in situ target strengths of herring (Dengbol et al. 1985) reports the target strength relationship

$$TS = 20 \log l - 72.6.$$

This relationship results in target strengths that are about 0.4 dB higher than those based on the Halldorson and Reynisson (1983) relationship. The Dengbol et al. (1985) work used a least squares fitting technique to convert echo level distributions. It is less sensitive to sampling errors than the Craig and Forbes (1969) method used by Halldorson and Reynisson (1983).

The average lengths, weights and the target strengths calculated from the Dengbol et al. (1985) equation for the 4-yr's surveys are shown in Table 4. It also shows the maximum total nightly scattering for each year and the herring biomass calculated from that and the target strength. Biomass by year and an indication of the possible range of error due to uncertainty in transducer calibration is shown in Fig. 5. The range of error is the sum of the ±1 dB ranges for the receive sensitivity and for the transmit response.

Interpretation of these data, at this point, is speculative. If it is assumed that a constant proportion of the 4WX herring stock winters in the Chedabucto Bay area and that the surveys are successful in quantifying the herring present, the data should reflect changes in stock size. The second assumption, however, may be questioned for the year 1985. The low biomass found in that year may have been due to fish movements in response to anomalous environmental conditions. The fish were surveyed during five nights, then ice almost completely covered the Bay for 10 d. That is a phenomenon that has not happened, in local memory, for 50 yr. When survey was again possible, the fish had moved out of the Bay and were distributed in small patches over a wide area offshore. It is possible, that the fish had not formed their usual large aggregation before the ice disturbed the process, or that it formed under the ice and could not be surveyed. In either case, the 1985 results can be regarded as anomalous.

The other 3 years show an increasing trend in biomass from 424000 t in 1984 to 789000 t in 1987. The straight line increase from 1984 to 1987 passes well within the possible limits of error for 1986. The linear yearly increase for the 3-yr period can be calculated as 23%.

Other data on stock abundance from 1984 are available only for the years 1984 and 1995. Between those years the larval abundance index increased 53.9% and the mean population biomass calculated by SPA increased 16.9% (Stephenson et al. 1986). Considering the potential for error in all the estimates, the difference between the acoustic estimate and the mean population biomass estimate is probably not significant.

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Table 1. Summary of results of the 1986 winter acoustic herring survey.

Date	Fish patch	Transects	km^2	Average area scattering sr^{-1}	Standard error	Total scattering m^2sr^{-1}	Nightly total m^2sr^{-1}	Relative biomass
Jan. 19-Jan. 20	A	13	10.7	0.0060088	0.0001676	64294		
	B	4	11.6	0.0045279	0.0000988	52524		
	C	2	0.5	0.0056579	0.0000270	2829	119647	0.75
Jan. 20-Jan. 21	A	3	7.36	0.0045176	0.0000817	33249		
	B	6	4.63	0.0035527	0.0000759	16449		
	C	1	0.60	0.0033669	0.0000559	2020		
	D	1	0.24	0.0105574	0.0000963	2534		
	E	1	0.05	0.0089371	0.0001090	447		
	F	1	0.15	0.0106502	0.0000703	1598		
	G	2	0.60	0.0062230	0.0001715	3734		
	H	6	1.14	0.0049355	0.0002067	5627	65658	0.41
Jan. 21-Jan. 22		7	32.90	0.0032818	0.0000903	107970	107970	0.67
Jan. 23-Jan. 24	A	7	23.5	0.0060888	0.0001200	143087	143087	0.89
	B	5	23.6	0.0067854	0.0001440	160135	160135	1.00
	C	6	22.9	0.0069660	0.0001089	159521	159521	0.99
Jan. 25-Jan. 26	A	32	21.37	0.0033463	0.0001514	71510		
	B	7	0.35	0.0020769	0.0002379	727		
	C	4	1.15	0.0011842	0.0000939	1362	73599	0.46
Jan. 29-Jan. 30	A	11	11.63	0.0031889	0.0001158	37087	39328*	0.26
	B	6	8.99	0.0026161	0.0001204	23519	25769**	0.16
	C	1	0.40	0.0000005	0.0000002	0		
	D	2	0.40	0.0003302	0.0000278	132		
	E	1	0.11	0.0003586	0.0000507	39		
	F	3	0.74	0.0028096	0.0001963	2079		

*Total A+C+D+E+F
**Total B+C+D+E+F

Table 2. Summary of results of the 1987 winter acoustic herring survey.

Date	Fish patch	Transects	km^2	Average area scattering sr^{-1}	Standard error	Total scattering m^2sr^{-1}	Nightly total m^2sr^{-1}	Relative biomass
Jan. 10-Jan. 11	A	7	37.8	0.0052089	0.0000565	196896	236748*	0.99
	B	5	26.7	0.0039576	0.0000634	101710	141562**	0.59
	C	30	16.5	0.0024153	0.0001574	39852		
Jan. 13-Jan. 14		17	28.9	0.0048597	0.0000826	140445	140445	0.59
Jan. 14-Jan. 15		16	37.5	0.0046269	0.0001004	173509	173509	0.73
Jan. 15-Jan. 16		31	33.2	0.0038994	0.0001190	129460	129460	0.54
Jan. 16-Jan. 16		36	32.6	0.0027936	0.0000925	91071	91071	0.38
Jan. 18-Jan. 19	A	1	1.0	0.0029100	0.0000745	2910	176776	0.74
	B	11	21.8	0.0035502	0.0001042	77394		
	C	27	29.6	0.0032592	0.0000739	96472		
Jan. 20-Jan. 21		20	52.5	0.0045396	0.0000960	238329	238329	1.00
Jan. 21-Jan. 22	A	19	42.3	0.0047724	0.0000882	201873	201873	0.85
	B	17	49.4	0.0034338	0.0000675	169630	169630	0.71
Jan. 24-Jan. 25		23	55.7	0.0039285	0.0000722	218818	218818	0.92

*Total of A+C
**Total of B+C

Table 3. Herring length statistics from 10 midwater tows (T1-36 to T11-86 in 1986 and from 13 midwater tows (T1-87 to T13-87) and 4 seine samples (S1-87 to S4-87) in 1987.

Sample		N	Mean	S.D.	Individual 95% confidence interval for mean
T1	86	225	27.316	2.731	(-*)
T2	86	209	27.548	3.098	(-*)
T3	86	156	30.750	3.220	(-*-)
T4	86	193	27.285	4.041	(-*)
T5	86	165	30.558	2.865	(*-)
T6	86	196	29.819	2.970	(*-)
T7	86	222	28.797	2.689	(-*)
T8	86	194	27.436	2.756	(*-)
T9	86	219	28.064	2.712	(-*-)
T11	86	209	29.014	2.727	(-*-)
T1	87	216	25.144	2.779	(-*)
T2	87	274	28.617	1.985	(*-)
T3	87	225	29.464	2.834	(-*)
S1	87	208	28.442	2.579	(-*)
S2	87	226	28.482	2.467	(-*)
S3	87	146	29.240	2.753	(-*-)
S4	87	163	27.626	2.308	(-*-)
T4	87	277	24.666	4.205	(-*)
T5	87	185	29.732	3.005	(-*-)
T6	87	197	28.462	2.353	(-*)
T7	87	185	28.100	1.923	(-*-)
T8	87	234	22.953	3.522	(-*)
T9	87	226	28.381	2.421	(*-)
T10	87	199	27.417	2.444	(*-)
T11	87	221	28.172	2.886	(*-)
T12	87	180	28.694	2.640	(-*)
T12	87	280	29.545	2.646	(*)
					24.0 26.00 28.0 30.0

Table 4. Average herring length, weights and target strengths and maximum acoustic scattering and biomass estimated in four years surveys.

Year	Length (cm)	Weight (kg)	Target strength (db/kg)	Acoustic scattering (m^2sr^{-1})	Biomass (1000 t)
1984	28.9	.175	-35.8	111539	424
1985	29.5	.188	-35.9	52495	204
1986	28.7	.160	-35.5	160135	568
1987	27.7	.141	-35.2	238329	789

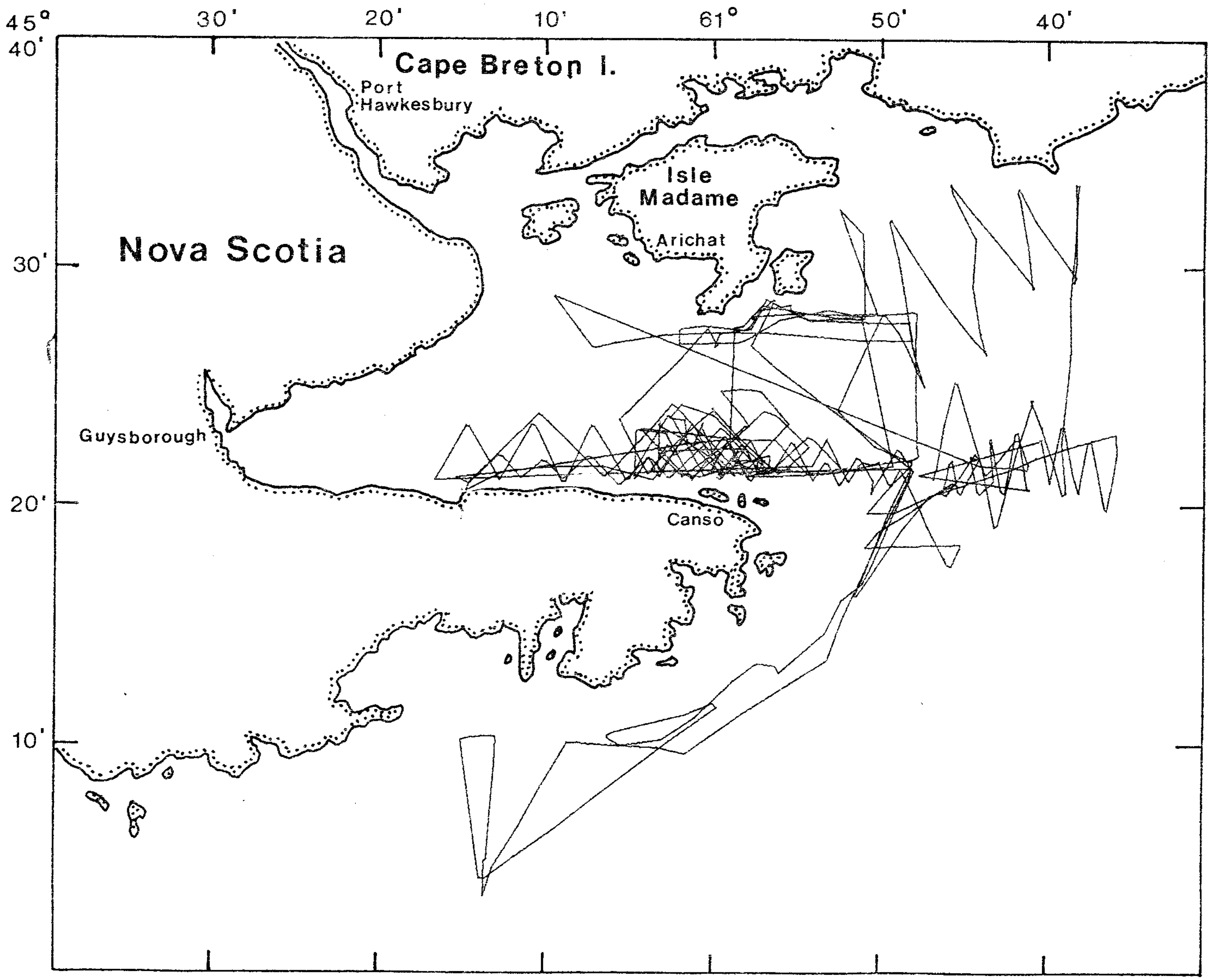


Fig. 1. Survey tracks for the 1986 winter acoustic herring survey.

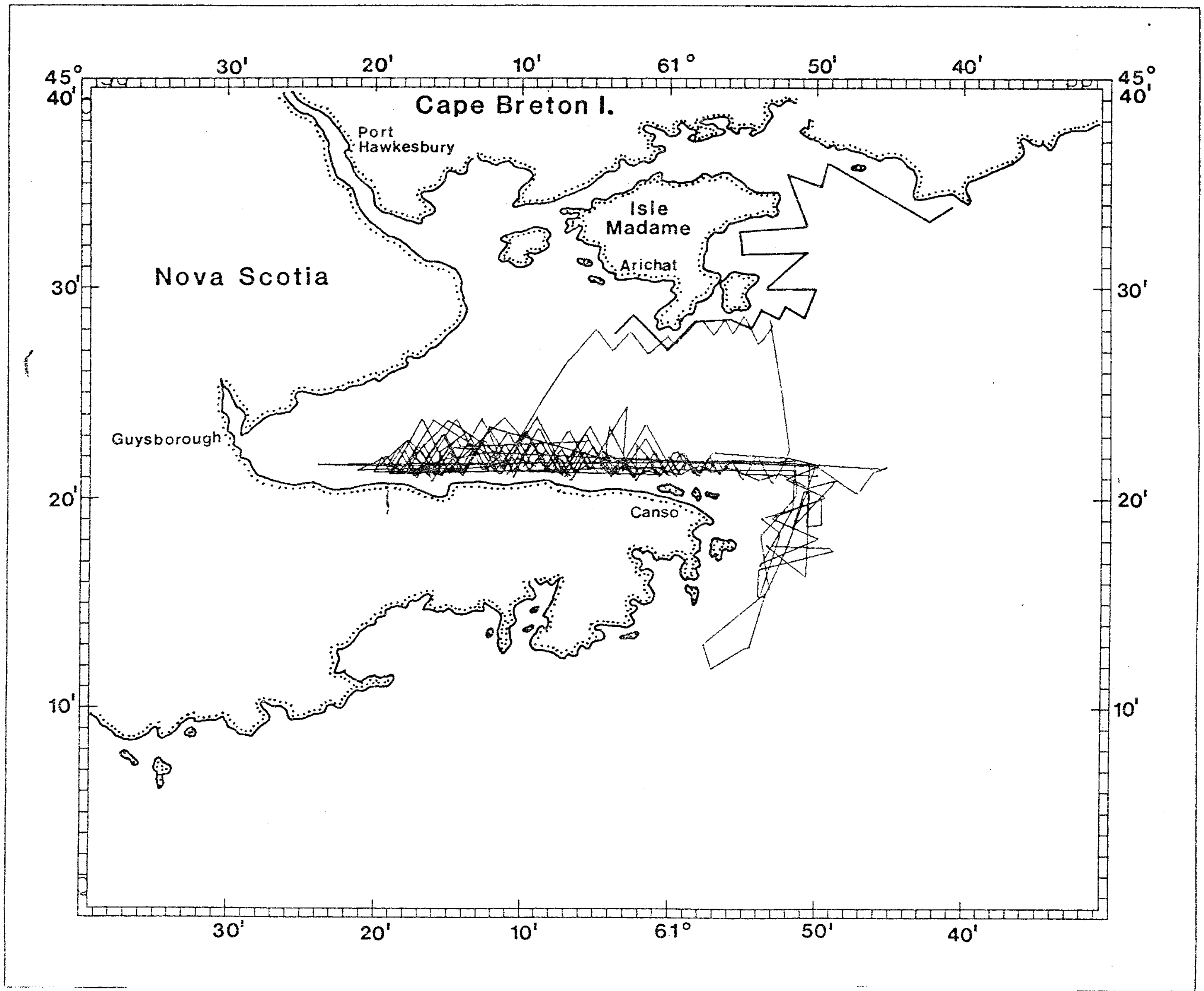


Fig. 2. Survey tracks for the 1987 winter acoustic herring survey.

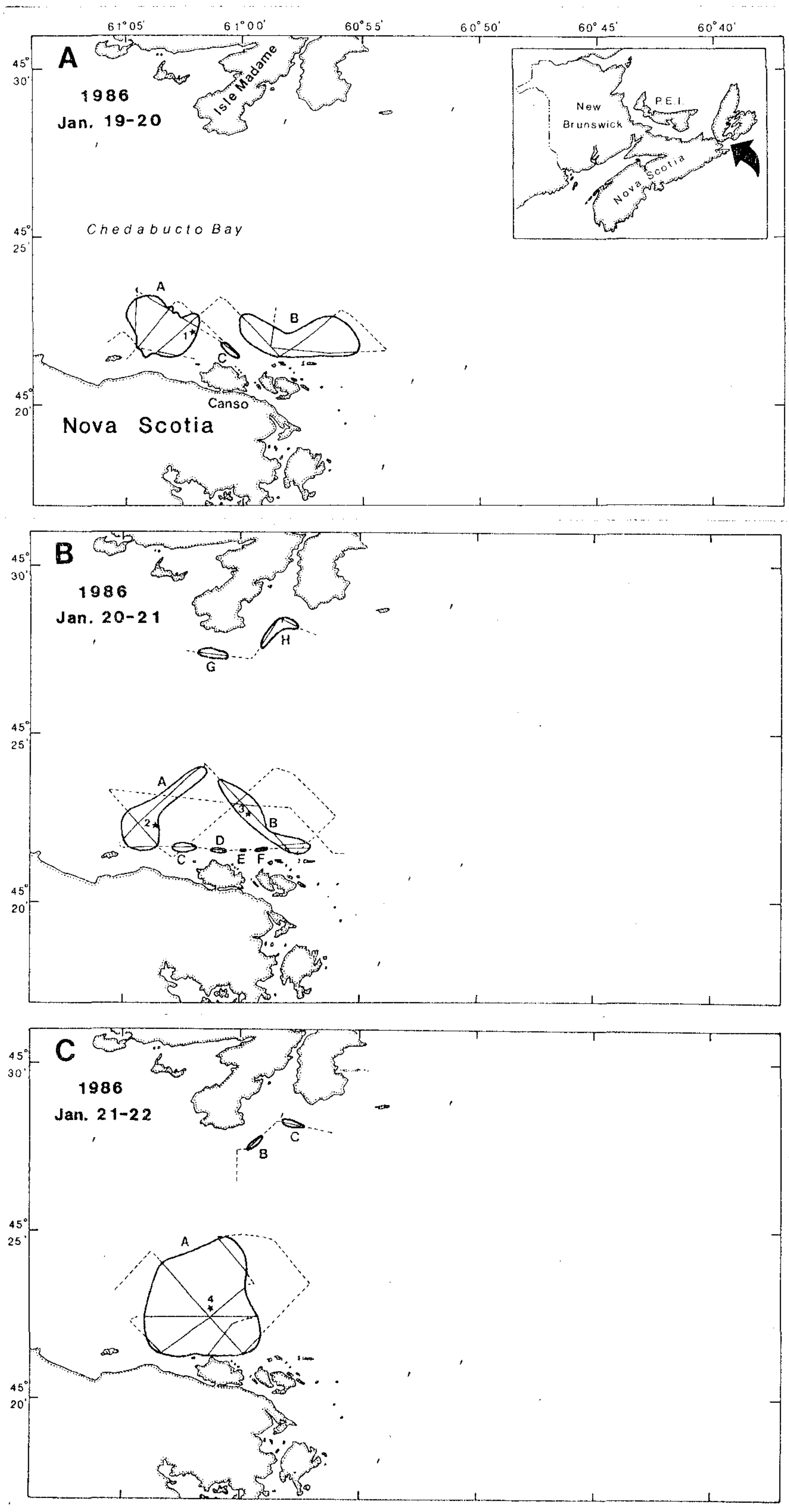
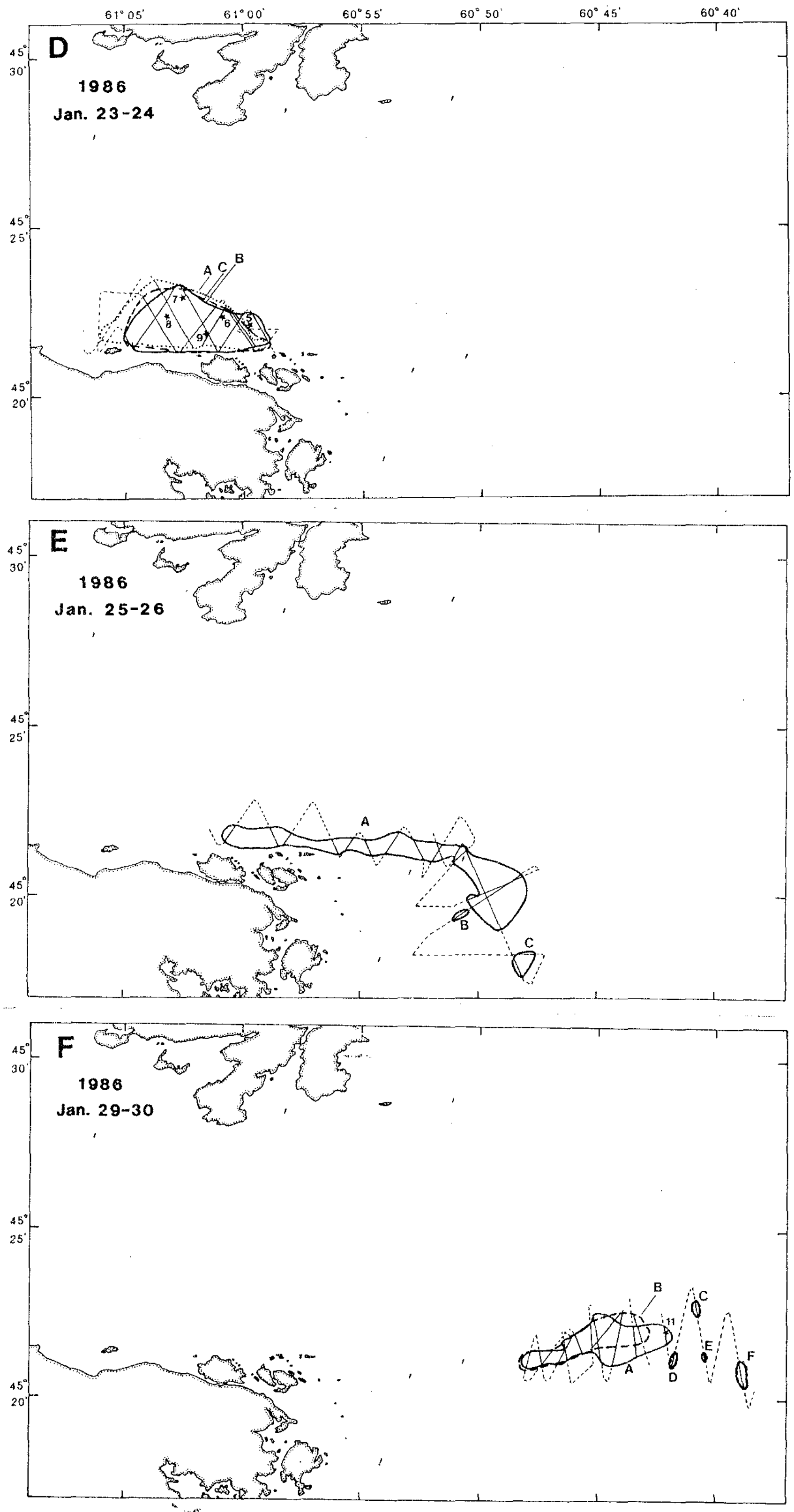


Fig. 3. Distribution and size of the patches of herring found in the 1986 survey.



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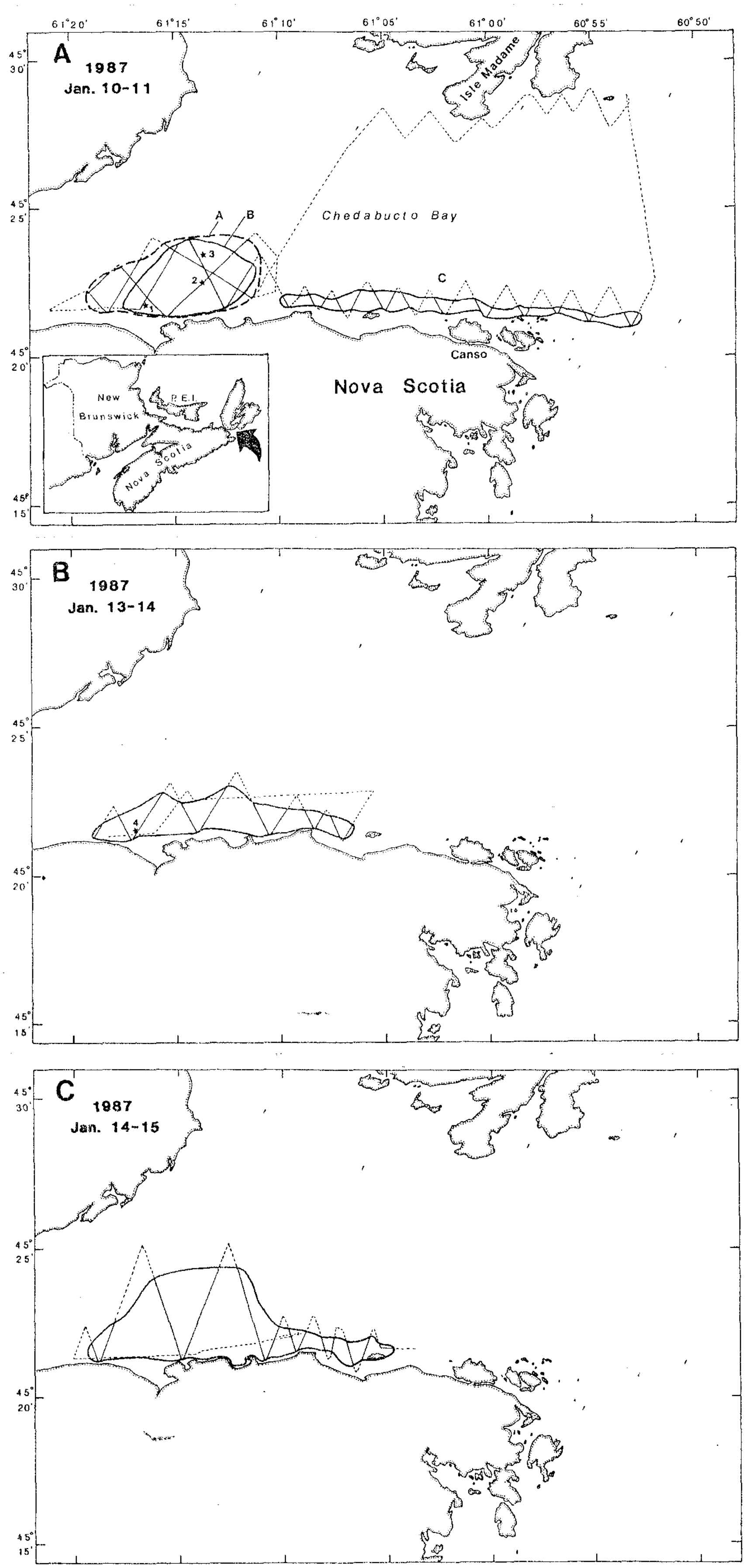
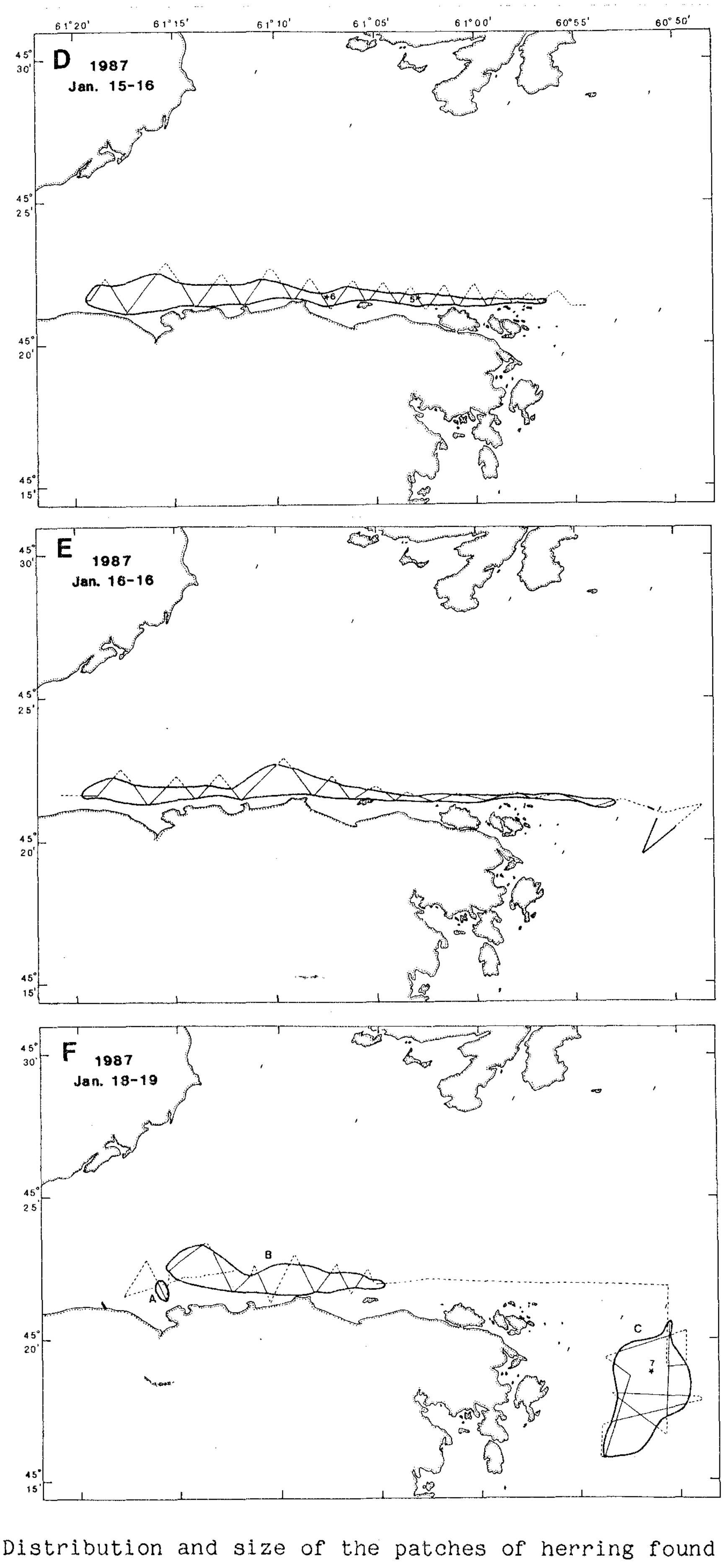


Fig. 4. Distribution and size of the patches of herring found in the 1987 survey.



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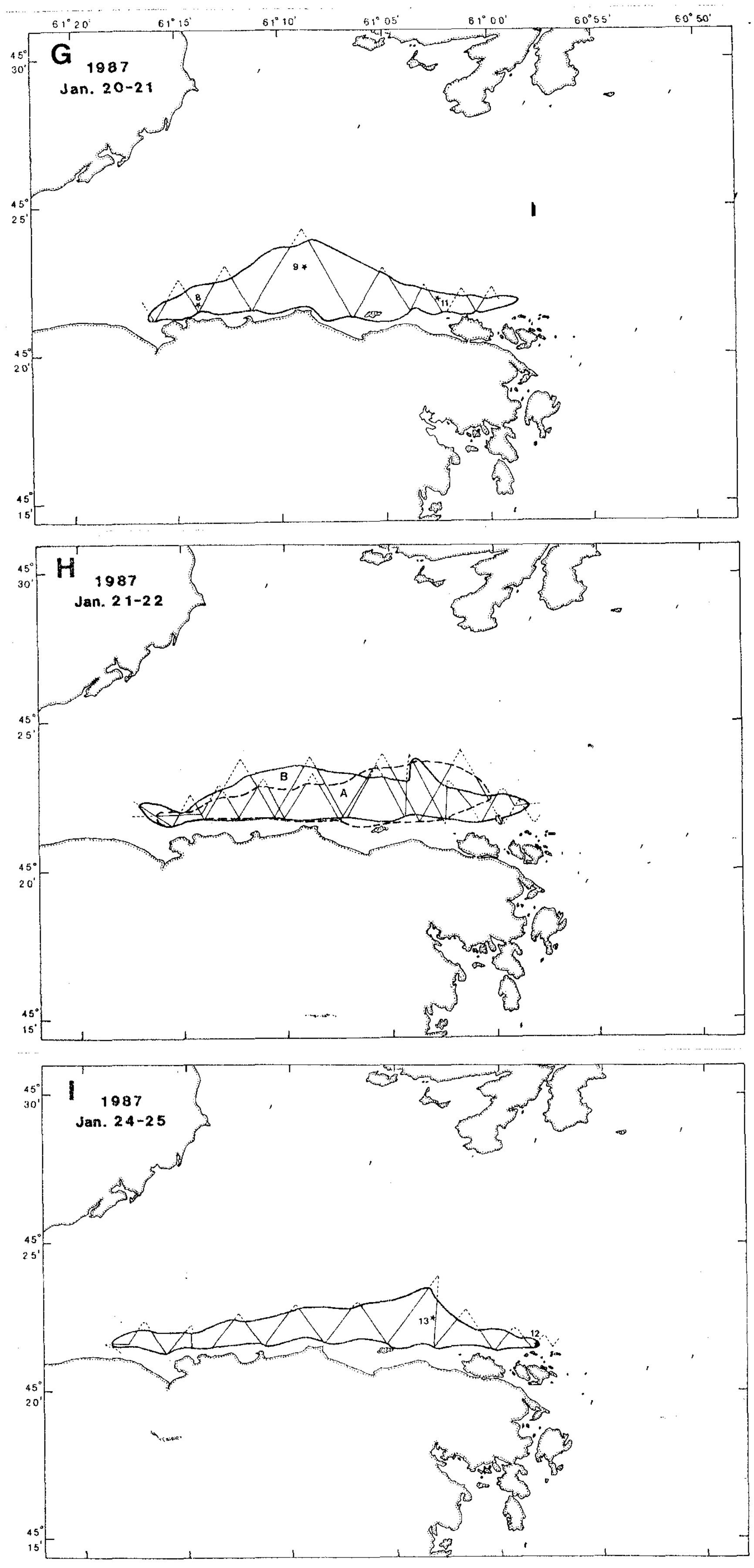

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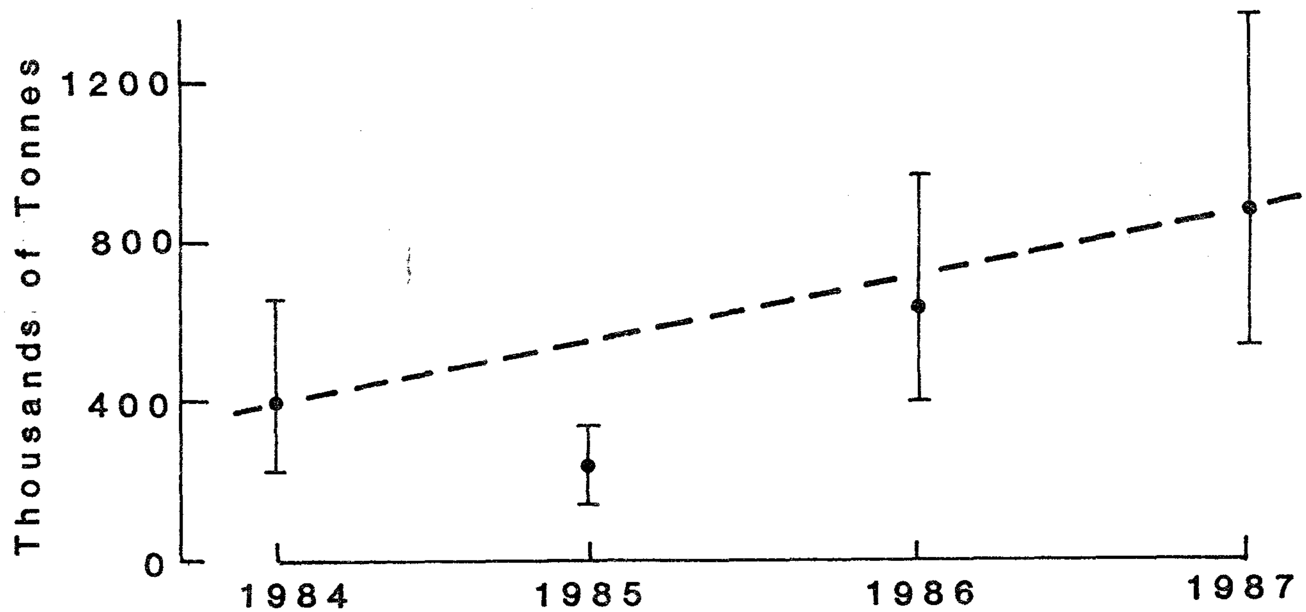

Fig. 5. Herring biomass estimated from acoustic surveys from 1984 to 1987 and the possible range of error due to transducer calibration.