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Acoustic Backscatter Estimates and School Behaviour of Herring in NAFO Divisions 4T and 4Vn, November 1987

by

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ABSTRACT

The fourth annual acoustic survey for herring in the southern Gulf of St. Lawrence and Sydney Bight was conducted in November 1987. Summed backscatter coefficients rose three to four-fold in both the Chaleur area and the Sydney Bight area, in comparison to 1986 estimates. A large concentration of herring in the West Miscou stratum accounted for the bulk of the backscatter in the Chaleur area. Most herring found on the north side of the Bay of Chaleur were spring spawners; those on the south side were mostly fall spawners. Herring were widely distributed in the Sydney Bight area. No herring were found in the Prince Edward Island area. In both the Chaleur and the Sydney Bight areas, herring sometimes aggregated in bands along the coast which persisted for several hours. In some strata limited evidence was found for diel behaviour cycles, with schools moving closer to the shore and becoming more detectable to acoustic equipment during the night.

RESUME

Le quatrième relevé acoustique du hareng a été mené dans le sud du Golfe Saint-Laurent et dans l'Anse de Sydney en novembre 1987. Les coefficients d'écho ont augmenté d'un facteur de trois ou quatre dans la région de la Baie des Chaleurs et dans l'Anse de Sydney, par rapport aux valeurs de 1986. Une forte concentration de hareng dans la strate de Ouest Miscou était la source de la majorité de la somme des échos mesurés dans la région de la Baie des Chaleurs. La plupart du hareng retrouvée du côté nord de la baie était des frayeurs de printemps; ceux du côté sud était principalement des frayeurs d'automne. Le hareng était présent sur l'ensemble de la région de l'Anse de Sydney. On n'a trouvé aucun hareng dans la région de l'île du Prince Edouard. Dans la région de la Baie des Chaleurs ainsi que l'Anse de Sydney, le hareng a parfois formé des bandes le long de la côte qui avaient une durée de vie de quelques heures. Dans certaines strates on a trouvé des indications que le comportement du hareng suit un cycle diurne, avec une migration vers la côte et une augmentation de leur detectabilité aux appareils acoustiques durant la nuit.

INTRODUCTION

Acoustic surveys are becoming increasingly important in the estimation of stock size of pelagic fishes. Herring (Clupea harengus) stocks of the southern Gulf of St. Lawrence (NAFO Division 4T) have been subject to acoustic surveys each November since 1984 (Shotton 1986, Shotton et al. 1987 a and b). Survey effort has concentrated in the Bay of Chaleur area, where 4T herring congregate in the late fall, and the Sydney Bight area of Cape Breton Island, which is the wintering ground for many, and possibly all, 4T herring (W.T. Stobo, unpubl.). Both of these areas are subject to important purse seine fisheries in November.

The long-term objective of these surveys is to obtain an independent relative 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 the Bay of Chaleur, Prince Edward Island, and Sydney Bight. We also present analyses of distribution patterns of herring encountered during the acoustic surveys. Specifically, we examined the location and distribution of fish concentrations (schools randomly occurring in space vs. single large aggregations), the frequency distribution of school size, and the patterns of herring distribution with respect to the day-night cycle, water depth, and distance from the coastline. Detailed knowledge of this sort is important in on-going efforts to improve survey design for eastern Canadian herring.

SURVEY AREA AND METHODS

Acoustic transects were run in 23 strata. Fourteen of these were in the Chaleur area, eight were in the Sydney Bight area, and one was in the Prince Edward Island area (Figs. 1-7). All strata surveyed in 1986 were also covered in 1987. Three strata in the Chaleur area (Gaspé Offshore, La Malbaie, L'Anse-à-Beaufils) were reduced in size on their seaward margins in 1987 because few fish were found along the seaward edges of these strata in previous surveys. Several new strata were initiated in the Chaleur area in 1987; these include American Bank, New Carlisle, and New Richmond (Figs. 3 and 4). In the Sydney Bight area coverage included the New Waterford and Donkin strata, which were surveyed in 1985 but not in 1986.

Within each stratum, the survey track followed predetermined transect lines. Transect lines were established by first randomly choosing a point along a straight margin of the stratum (usually the seaward boundary). For each stratum, an angle was chosen which allowed the transect line to traverse the stratum several times. For each transect, a new starting point was randomly chosen along the stratum boundary. The number of transects run per stratum varied from two to nine. This number was determined on the basis of the importance of the stratum for herring as indicated by previous surveys, and by available vessel time.

Surveys were conducted by the Alfred Needler (Cruises N-093 and N-094). Survey dates were 4 to 11 November (Chaleur area), 16-17 November (Prince Edward Island area), and 17-24 November (Sydney Bight area). Transects were run 24 hours a day at 10 knots, except in poor weather when speed was reduced to 8 knots. Weather conditions were generally favourable during the cruise, and little time was lost due to inclemencies.

An Ecolog system was used to acoustically estimate fish distribution and abundance. This system was operated and monitored by electronics personnel from the Bedford Institute of Oceanography. Equipment specifications and analytical procedures follow Shotton et al. (1987b).

A midwater trawl equipped with a headrope transducer was used to sample insonified schools in order to confirm species identification and obtain samples for length, age, and spawning group affinity. Two methods were used to compute backscatter per kg from length frequencies; those of Halldorson and Reynisson (1983) and Edwards and Armstrong (1983).

For analysis of diel cycles, dawn was taken as 0730 and dusk as 1730. Transects were considered to be daytime transects only if they were completed entirely between dawn and dusk. Similarly, nighttime transects were completed entirely between dusk and dawn. Analysis of preference with respect to water depth and distance from the coast was based on backscatter within 500 m and 1 km segments of the transect path, respectively. Water depth of each segment was mean depth within the segment, as visually estimated from depth contours on a nautical chart. Distance from the coast was measured from the midpoint of each segment.

RESULTS

BACKSCATTER ESTIMATES

Chaleur

Backscatter estimates for each transect are given in Tables 1 and 2, and mean estimates for each stratum are given in Table 3. In the Chaleur area, 92% of summed backscatter was found in the West, North, and East Miscou strata, on the south side of the bay. The largest single concentration of herring was located at the west end of the West Miscou stratum near sets NC7 and NC11 (Fig. 3). The large aggregation at this site comprised the bulk of the herring found in the West Miscou stratum. This stratum accounted for 76% of summed backscatter in the Chaleur area (Table 3).

The second area of concentration in the Chaleur area was the Grande Rivière, Newport and Shigawake strata on the north side. Herring in these strata accounted for 8% of the Chaleur summed backscatter. No herring were found in four strata (Cap Bon Ami, Gaspé Offshore, L'Anse-à-Beaufils, New Carlisle). Herring found in the Baie de Gaspé, American Bank, and La Malbaie strata accounted for only 0.1% of the regional total. In the New Richmond stratum, extensive, low-density schools of juvenile herring were encountered. The summed backscatter in this stratum comprised 0.14% of the Chaleur total.

Summed backscatter for the Chaleur area totaled 186,241 m^2 sr^{-1} (Table 3). This value is three times higher than the 1986 estimate, and more than six times higher than estimates for 1984 and 1985 (Table 3).

Samples taken on the north side of the bay indicated that most fish there were spring spawners, whereas fall spawners dominated on the south side (Table 4). Using the percentage of spawning groups found in each area, the total summed backscattering coefficient of spring spawners in the Chaleur area is estimated as 39,833 m^2 sr^{-1}, and that for fall spawners is estimated as 145,963 m^2 sr^{-1}.

Modal lengths of herring taken in sets in the Chaleur area ranged from 26 to 32 cm, with the exception of set NC6 where most fish were juveniles, probably two year olds, from 9 to 13 cm long (Fig. 8). Small numbers of juveniles were also taken in several other sets (Fig. 8). Both two and three year old fish were strongly represented among spring spawners, but two year olds were relatively infrequent among fall spawners (Fig. 9). In general fall spawners were larger than spring spawners, and had a much lower component of fish under 28 cm long.

Biomass estimates for the Chaleur area totaled 898,058 t (Halldorson and Reynisson's (1983) method) and 674,152 t (Edwards and Armstrong's (1983) method.

Sydney Bight

The major strata of herring concentration in the Sydney Bight area were Neil Harbour (43% of total) and New Waterford (34% of total) (Table 3). Herring were more widely distributed throughout strata than in Chaleur, and few transects and no strata were devoid of herring. Summed backscattering coefficients measured in 1987 were three to six times higher than 1984-1986 estimates (Table 4).

Tagging results (W.T. Stobo, unpubl.) indicate that herring in the northern part of Sydney Bight tend to belong to the 4T stock, whereas fish in the southern part of Sydney Bight tend to remain outside the Gulf. In the northern part of this area (Haddock Bank and north), samples contained 55% spring spawners and 45% fall spawners (Table 4). In the southern part (Sydney and east), spring spawners comprised 28% of samples and fall spawners 72% of samples. Using these percentages, we estimate that summed backscatter in the northern zone was 39,540 m^2 sr^{-1} for spring spawners and 32,351 m^2 sr^{-1} for fall spawners (Table 4). In the southern zone, estimates are 15,489 m^2 sr^{-1} for spring spawners and 39,829 m^2 sr^{-1} for fall spawners.

In the Sydney Bight area, seven of 14 sets showed distinctly bimodal length-frequencies, with the lower mode occurring at about 20 cm and the higher one at about 29 cm (Fig 10). The lower mode presumably represents two year old fish, and the higher one represents older fish.

Biomass estimates for the Sydney Bight area totaled 569,789 t (Halldorson and Reynisson's 1983 method) and 409,800 t (Edwards and Armstrong's 1983 method).

Other areas

The 1987 survey in the Prince Edward Island area revealed no herring, although small quantities were found there in the previous year (Table 3). The west coast of Cape Breton Island, which produced substantial herring backscatter in 1984, has not been surveyed since that year.

BEHAVIOUR OF HERRING SCHOOLS

Location and shape of aggregations

Figs. 11-18 map location and size of herring schools encountered in consecutive transects in six strata. In several transect series, the location of school encounters is consistent with the hypothesis that herring form continuous aggregations in a band-like fashion along the coastline, and that such aggregations remain together for periods of several hours. For example, the first four transects of the Grande Rivière series (Fig. 11) suggests that there was a band of herring close to the coast in the western part of the stratum, as herring were encountered in all near-shore passes. Later in the same night encounters with herring tended to occur further from shore and further east, suggesting that the aggregation was moving. Similarly, the pattern of school encounters in consecutive transects in the Neil Harbour stratum suggests that herring were distributed in a continuous band along the coast (Fig. 17).

In other cases, the pattern of school encounters did not offer a clear inference regarding the shape of herring aggregations. In the Shigawake stratum (Fig. 13), this was due to the shallow angle of the zigzags, which meant that encounters on successive transect legs were too far apart to judge whether herring were likely distributed continuously between them. In the two series available for the Aspy Bay stratum (Figs. 14 and 15), the pattern of school encounters suggests some aggregation at a local scale (e.g. concentration at south end of transect C, Fig. 14). However, herring distributions changed markedly between consecutive transects, suggesting that any aggregations that occurred were maintained for a shorter period than the duration of transects (ca. five hours).

Diel cycles of distribution and abundance

Figs. 19-21 show where herring were encountered during day and night in the Grande Rivière, Newport, and Shigawake transects. In Grande Rivière, herring tended to be close to shore at night, holding within 6 km of the coast, whereas daytime distributions were further offshore (Fig. 19). In the Newport and Shigawake strata, there was no consistent difference between day and night distributions (Figs. 20-21).

Figs. 22 and 23 compare the frequency distributions of area backscatter between day and night transects. In three of the six strata examined (Grande Rivière, Shigawake, Aspy Bay) nighttime frequency distributions appeared to be greater than daytime frequency distributions, and in the remaining strata there was no distinct difference in frequency distributions of day and night transects. The small number of transects run per stratum precluded more rigorous comparisons.

Distribution with respect to distance from the coast and water depth

The relation between herring backscatter and distance from the coast is plotted for the Grande Rivière, Newport, and Shigawake transects in Fig. 24. Backscatter was highest close to the coast, and peaked between 3 and 4 km offshore. Water depths in these strata fall away gradually with distance from the coast, so that it is not possible to distinguish between preference for a certain distance from the coast and preference for a certain water depth. Mean backscatter per 500 m of transect peaked in waters between 50 and 60 m in depth (Fig. 25). Mean backscatter was low in waters deeper than 60 m.

Frequency distribution of school size

Figs. 26 and 27 plot frequency distributions of school size in the Chaleur and Sydney Bight areas. In the Chaleur area, 59% of all backscatter was produced by two encounters with herring schools. These two encounters were with the same school, which was insonified on consecutive transects at the west end of the West Miscou stratum. Herring were also highly aggregated in the Sydney Bight area, where two encounters (both in the Neil Harbour stratum) produced 47% of all backscatter. Unlike the Chaleur area, small schools (beyond rank 20) in the Sydney Bight area accounted for a substantial (18%) portion of total backscatter.

DISCUSSION

The 1987 acoustic surveys in 4T-4Vn produced backscatter estimates much higher than those in previous years. Interpretation of these increased estimates must be tempered with the well-known limitations of acoustic technique (Shotton 1985). The time series of backscatter estimates must also be viewed in the context of changes in design of surveys since their initiation in 1984. The first survey did not use a stratified design, but instead attempted to cover broad areas in which herring were thought to possibly occur. This resulted in very light coverage of areas where they actually occurred. Since 1985, the survey has used a stratified design, but there have been numerous changes in stratum boundaries (Table 3). These changes have been brought about by the desire to concentrate efforts in important areas for herring, and to reduce or eliminate coverage in areas which herring do not use. The process of identifying important herring areas has not yet been completed, as was dramatically illustrated by the very large aggregation present in 1987 in the West Miscou stratum. This stratum was estimated to contain insignificant numbers of herring in previous surveys, and consequently received light survey coverage in 1987.

Another factor which influences coverage is weather. In most years many survey days are lost to inclement weather, but the 1987 survey was blessed with favourable conditions, which allowed many more transects to be conducted than in previous years (Table 3).

The analyses of school behaviour presented above point out several features of herring distribution in the Chaleur and Sydney Bight areas. Firstly, they show that herring have a tendency to aggregate, and that such aggregations may be in the form of continuous bands along a preferred depth contour or distance from the coast. In at least some cases the life-span of such aggregations is limited to several hours. Secondly, the distribution of herring appears to vary to some degree with the day-night cycle. The limited evidence presented above suggests that at least some of the time herring move toward shallower coastal water at night, and may be detectable by acoustic gear in greater numbers during that time. Finally, the analyses indicate that most of the herring in a given area may be concentrated in one or several very large schools, and that the success of the survey depends on finding these schools.

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Table 1. Time, number of schools, and area backscatter estimates for transects in strata in the 1987 acoustic survey in the Chaleur area.

Stratum	Transect	No. schools	Stratum area (km^2)	Time on transect (hours)	Total area backscatter ($m^2 sr^{-1}$)
Cap Bon Ami	A	0	109.8	0.867	0.0
	B	0	109.8	1.100	0.0
Baie de Gaspé	A	7	117.6	0.950	21.0
	B	0	117.8	0.900	0.0
Gaspé Offshore	A	0	150.0	1.683	0.0
	B	0	150.0	1.583	0.0
	C	0	150.0	1.767	0.0
American Bank	A	372	187.4	1.933	343.5
	B	0	187.4	1.900	0.0
	C	0	187.4	1.883	0.0
La Malbaie	A	52	191.2	1.867	21.4
	B	45	191.2	1.817	161.6
	C	0	191.2	2.000	0.0
Anse-à-Beaufils	A	0	191.9	1.283	0.0
	B	0	191.9	1.333	0.0
	C	0	191.9	1.450	0.0
	D	0	191.9	0.833	0.0
Grande Rivière	F	7	173.8	1.783	714.6
	C	13	173.8	1.700	1828.3
	E	11	173.8	1.833	7248.7
	B	31	173.8	1.667	7523.2
	G	80	173.8	1.717	611.1
	A	20	173.8	1.700	1362.0
	D	90	173.8	1.633	452.5
	I	6	173.8	1.717	1227.7
	J	181	173.8	2.033	12031.5
Newport	C	3	187.0	1.300	173.4
	A	12	187.0	1.417	79.6
	B	4	187.0	1.550	10046.6
	D	1	187.0	1.283	24.8
	F	1	187.0	1.333	5591.3
	I	2	187.0	1.400	3856.6
	J	9	187.0	1.567	1932.1
	E	0	187.0	1.567	0.0
Shigawake	A	8	323.3	2.217	9426.6
	D	65	323.3	2.450	30033.7
	C	246	323.3	2.167	7998.0
	E	115	323.3	3.267	3225.1
	B	80	323.3	3.383	7524.1
	I	5	323.3	2.550	5420.9
	G	5	323.3	2.800	20.8
	H	1	323.3	2.750	1483.2
New Carlisle	A	0	167.0	2.050	0.0
	B	0	167.0	2.233	0.0
	C	0	167.0	1.850	0.0
New Richmond	B	4	253.6	2.800	773.9
	A	0	253.6	1.350	0.0
	D	0	253.6	1.467	0.0
West Miscou	A	20	378.0	2.233	7458.8
	B	47	378.0	1.933	250918.5
	C	7	378.0	2.067	167276.3
North Miscou	A	19	417.8	2.050	616.0
	C	73	417.8	2.367	3552.4
	A	0	417.8	1.367	0.0
East Miscou	A	164	2093.5	4.917	2479.5
	B	7	2093.5	5.233	53521.4

Table 2. Time, number of schools, and area backscatter estimates for transects in strata in the 1987 acoustic survey in the Prince Edward Island and Sydney Bight areas.

Stratum	Transect	No. schools	Stratum area (km^2)	Time on transect (hours)	Total area backscatter (m^2 sr^{-1})
Northeast P.E.I.	A	0	1989.9	5.983	0.0
	B	0	1989.9	5.950	0.0
Aspy Bay	A	41	168.3	4.467	6511.0
	B	188	168.3	4.550	8916.8
	C	269	168.3	4.117	3956.4
	E	104	168.3	3.800	1932.9
	G	146	168.3	3.783	1035.2
	F	101	168.3	3.983	1166.2
	H	48	168.3	3.817	869.2
Neil Harbour	A	75	259.5	2.733	12637.4
	J	48	259.5	2.367	22905.1
	F	92	259.5	2.300	157261.5
	C	40	259.5	2.167	80269.0
	K	23	259.5	1.917	64305.1
	A	0	259.5	2.733	0.0
	E	0	259.5	2.317	0.0
	G	0	259.5	2.467	0.0
Wreck Cove	D	1	109.7	1.367	0.0
	B1	41	109.7	2.050	433.7
	F	18	109.7	1.100	27629.8
	B2	7	109.7	1.033	14242.2
	J	8	109.7	1.000	9564.4
	C	23	109.7	0.850	22696.0
	M	14	109.7	1.017	16024.5
	G	1	109.7	1.000	0.0
	A	0	109.7	1.133	0.0
St. Ann's Bay	A	9	159.0	1.533	182.3
	E	14	159.0	1.417	442.0
	C	15	159.0	1.283	94.9
	B	29	159.0	1.350	678.1
	F	72	159.0	1.283	16222.3
	H	31	159.0	1.533	4902.4
	D	1	159.0	1.183	280.3
Haddock Bank	A	9	94.9	0 767	1455.7
	H	10	94.9	1.033	48.5
	D	24	94.9	0.633	1378.2
	E	0	94.9	0.683	0.0
	G	0	94.9	0.883	0.0
	I	0	94.9	0.850	0.0
	J	0	94.9	1.100	0.0
Sydney	B	42	168.6	3.333	1921.6
	D	116	168.6	3.217	1062.7
	E	201	168.6	3.133	2620.2
	A	11	168.6	3.067	188.9
	C	67	168.6	2.867	1098.1
	G	45	168.6	2.983	20895.5
	F	0	168.6	3.433	0.0
New Waterford	A	116	141.3	1.367	61741.8
	E	106	141.3	1.467	94738.7
	H	165	141.3	1.417	78312.7
	B	31	141.3	2.233	1374.7
	C	21	141.3	0.967	36663.0
	F	37	141.3	1.117	2001.2
	D	31	141.3	1.133	1351.0
	G	26	141.3	0.767	69958.5
Donkin	A	21	109.2	1.033	3924.2
	I	46	109.2	0.917	2286.3
	F	90	109.2	1.000	3488.5
	B	53	109.2	0.917	508.0
	E	3	109.2	0.650	502.3
	H	91	109.2	0.867	314.8
	C	29	109.2	0.900	45538.2

Table 3. Summed backscattering coefficients of herring surveyed in 4T and 4Vn, 1984-1987. N means number of transects run. A dash (-) indicates that the stratum was not surveyed.

Stratum	Summed backscattering coefficient ($m^2 sr^{-1}$)									
	1984	1985			1986			1987		
	mean	mean	SD	N	mean	SD	N	mean	SD	N
Chaleur										
Cap Bon Ami		0@		2	0*		3	0*		2
Baie de Gaspé		|--- 0@		2	23*	19	3	11*	15	2
Gaspé Offshore		|			0#		4	0*		3
American Bank		-			-			115*	198	3
La Malbaie		0@		3	0#		4	61*	88	3
Anse-à-Beaufils		1807@	1035	3	535#	500	7	0*		4
Grande Rivière		|			25731*	17976	7	3667*	4194	9
Newport		|-4814	4455	2	16275*	12775	3	2713*	3624	8
Shigawake		|			18600*	8123	3	8142*	9435	8
New Carlisle		-			-			0		3
New Richmond		-			-			258	447	3
West Miscou		7964*	4220	2	59*	82	3	141885*	123700	3
North Miscou		0@		3	0*		3	1389*	1898	3
East Miscou		4464*	2864	4	20*	727	4	28000*	36092	2
Total Chaleur	28700	19048		21	61243		44	186241		56
Prince Edward Island										
North Point	-	16		1	-			-		
Northeast P.E.I.	-	-			2346*	1233	3	0*		2
Beyond East Point (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*	164	2	3484*	3149	7
Neil Harbour		3630@		1	16310*		1	54672*	73810	8
Wreck Cove		17246@		9	16755#	11425	3	10066*	10712	9
St. Ann's Bay		-			-			3257	5968	7
Haddock Bank		1133@		5	12*	25	4	412*	687	7
Sydney		2956*		4	0*		3	3970*	7519	7
New Waterford		4572*		6	-			43268*	38153	8
Donkin		703*		4	-			8080*	16584	7
Total Sydney Bight	22318	30882		30	33251		13	127209		60
Total all areas	61805	49946		55	96840		60	313450		118

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

Table 4. Summed backscattering coefficients (m^2 sr^{-1}) of spring and fall spawning herring in the Chaleur and Sydney Bight areas, as estimated from acoustic surveys in November 1987. Estimates for the north side of Chaleur Bay are from the Grande Rivière, Newport and Shigawake strata. Estimates for the south side of Chaleur Bay are from the West, North, and East Miscou strata. Estimates for Sydney Bight North are for the Aspy Bay, Neil Harbour, Wreck Cove, St. Ann's Bay, and Haddock Bank strata. Estimates for Sydney Bight South are for the Sydney, New Waterford, and Donkin strata.

Area	Spawning affinity			Summed backscattering coefficient		
	% spring	% fall	N	Spring spawners	Fall spawners	Total
Chaleur						
North Side	62	38	224[a]	9004	5518	14522
South Side	18	82	104[b]	30829	140445	171274
Total				39833	145963	185796
Percent of Chaleur total				21	79	100
Sydney Bight						
North	55	45	471[c]	39540	32351	71891
South	28	72	155[d]	15489	39829	55318
Total				55029	72180	127209
Percent of Sydney Bight total				43	57	100

[a]From sets NC2, NC3, NC4, NC5, NC15, and NC16.
[b]From sets NC10 and NC11.
[c]From sets NS2, NS4, NS5, NS6, NS7, NS12, NS13, and NS15.
[d]From sets NS8, NS9, NS10, and NS14.

Table 5. Comparison of herring biomass estimates in tonnes for four areas in 4T and 4Vn, November 1984-1987.

Year	Chaleur		P.E.I.		W. Cape Breton		Sydney Bight	
	H&R[a]	E&A[b]	H&R[a]	E&A[b]	H&R[a]	E&A[b]	H&R[a]	E&A[b]
1984	131500	95000	-	-	49300	35300	102000	73100
1985	87060	63000	71	51	-	-	174000	125000
1986	280000	201000	-	-	-	-	152000	109000
1987	898058	674152	0	0	-	-	569789	409800

[a]Based on scatter kg^{-1} factor from Halldorson and Reynisson (1983).
[b]Based on scatter kg^{-1} factor from Edwards and Armstrong (1983).

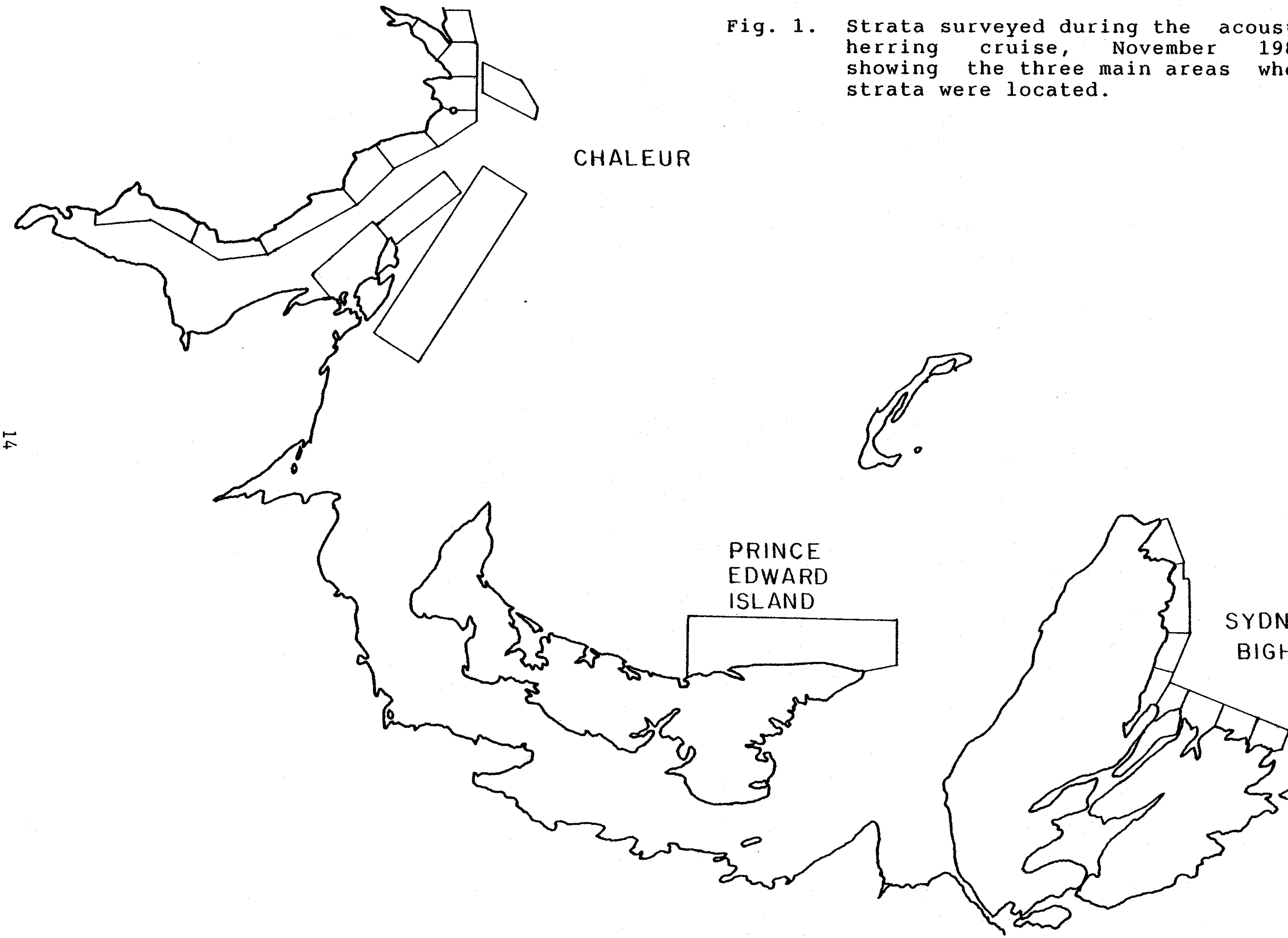


Fig. 1. Strata surveyed during the acoustic herring cruise, November 1987, showing the three main areas where strata were located.

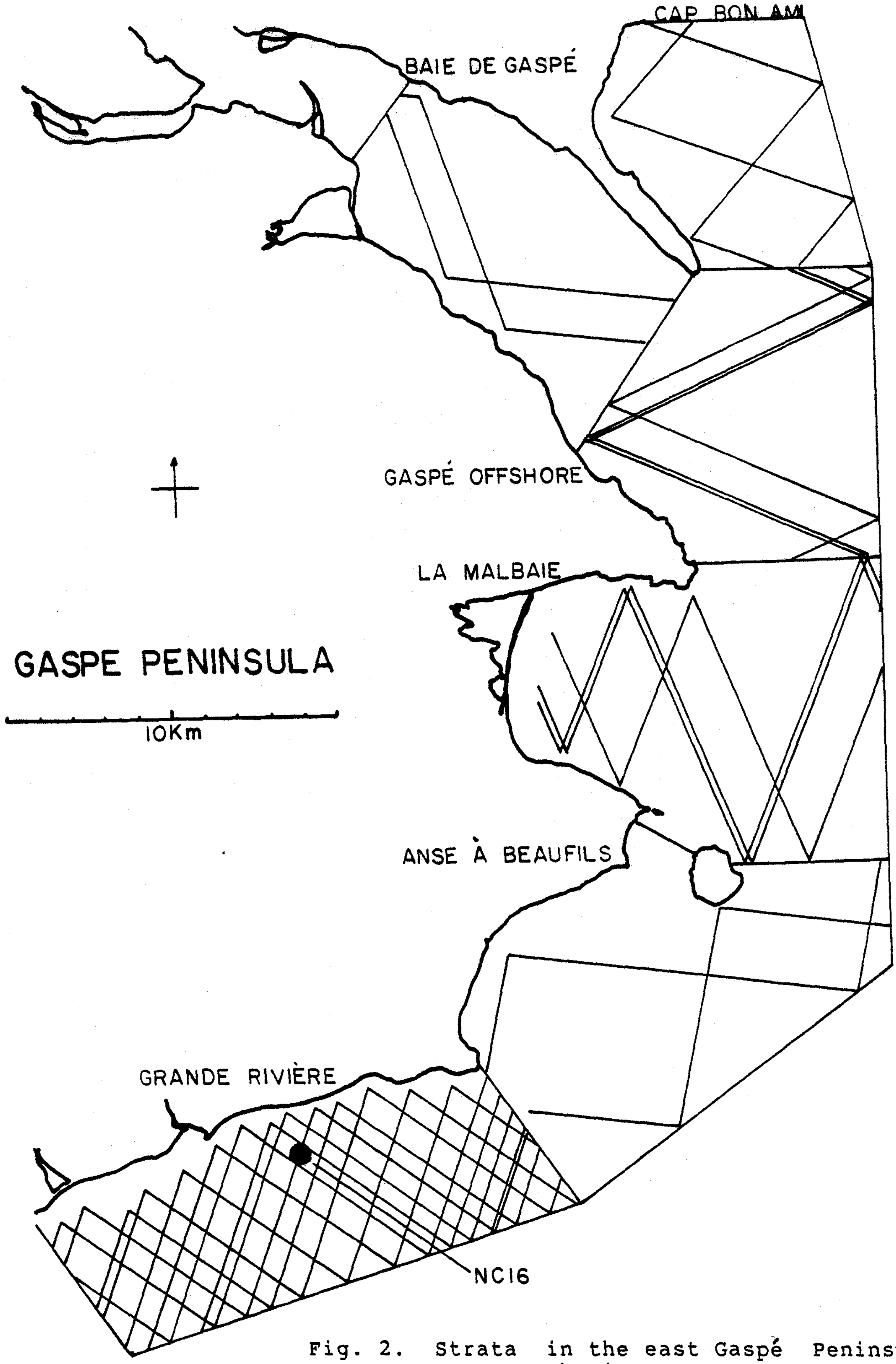


Fig. 2. Strata in the east Gaspé Peninsula area, showing survey transects. Solid dots indicate location of sets.

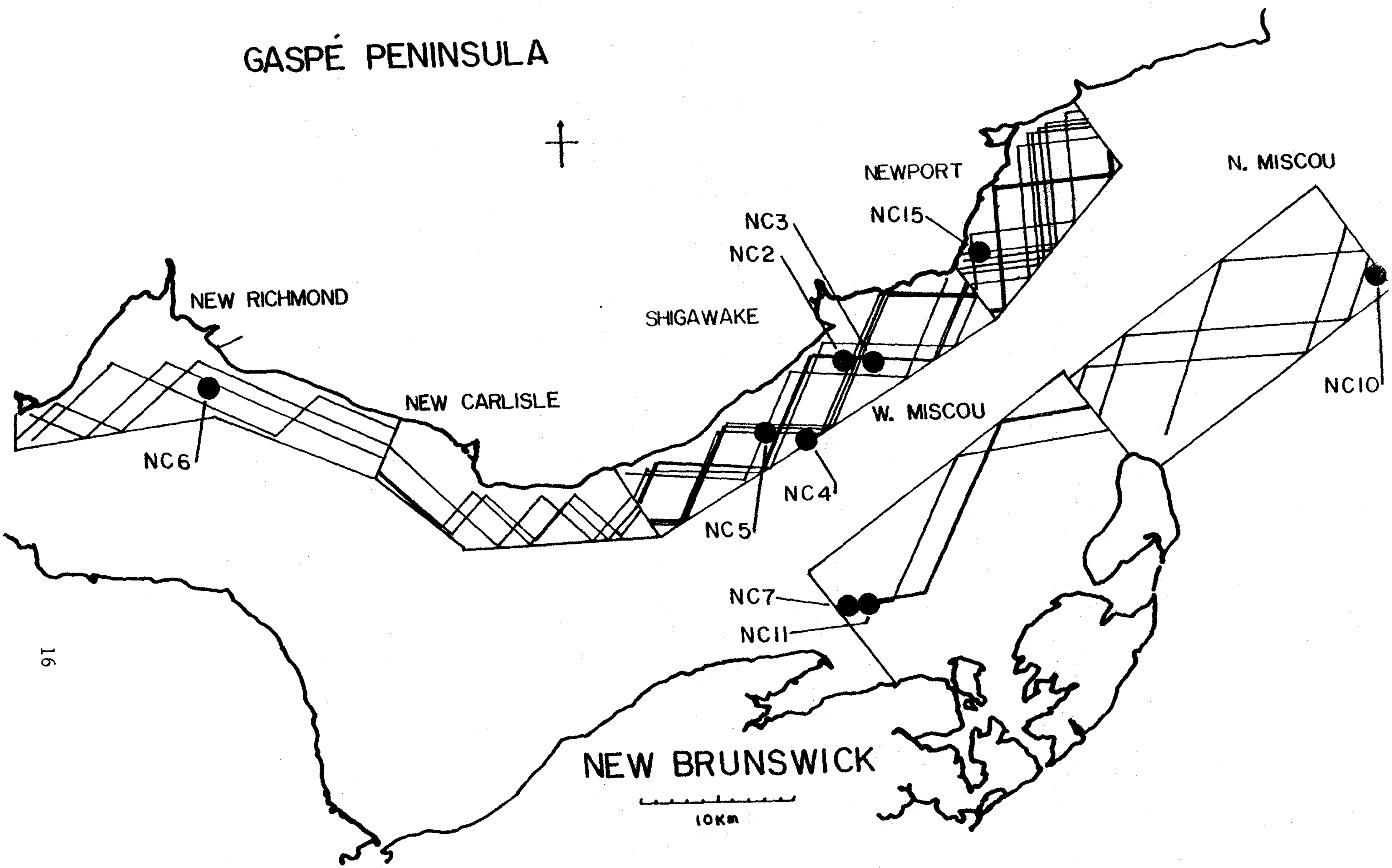


Fig. 3. Strata in the Bay of Chaleur area, showing survey transects. Solid dots indicate location of sets.

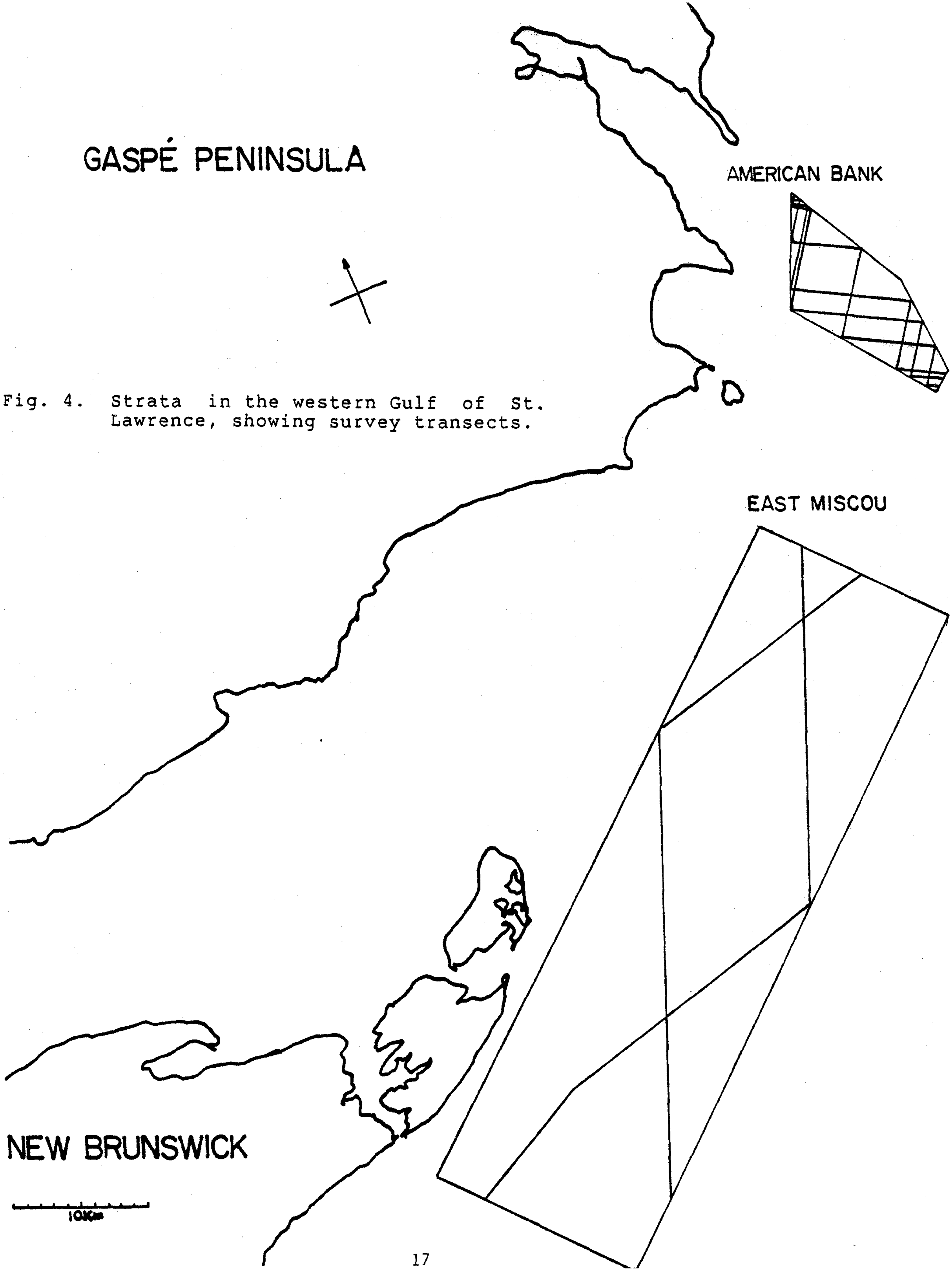


Fig. 4. Strata in the western Gulf of St. Lawrence, showing survey transects.

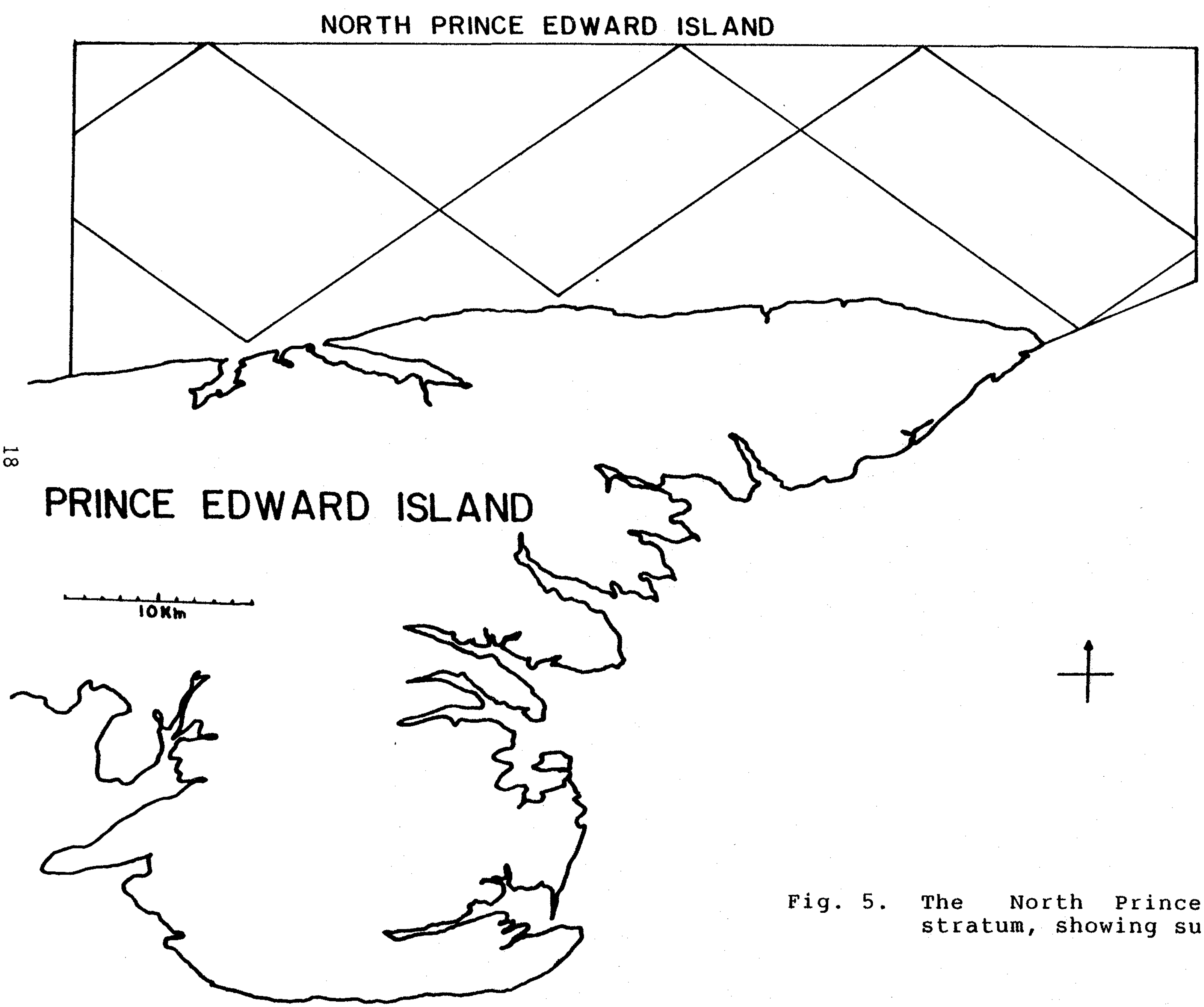
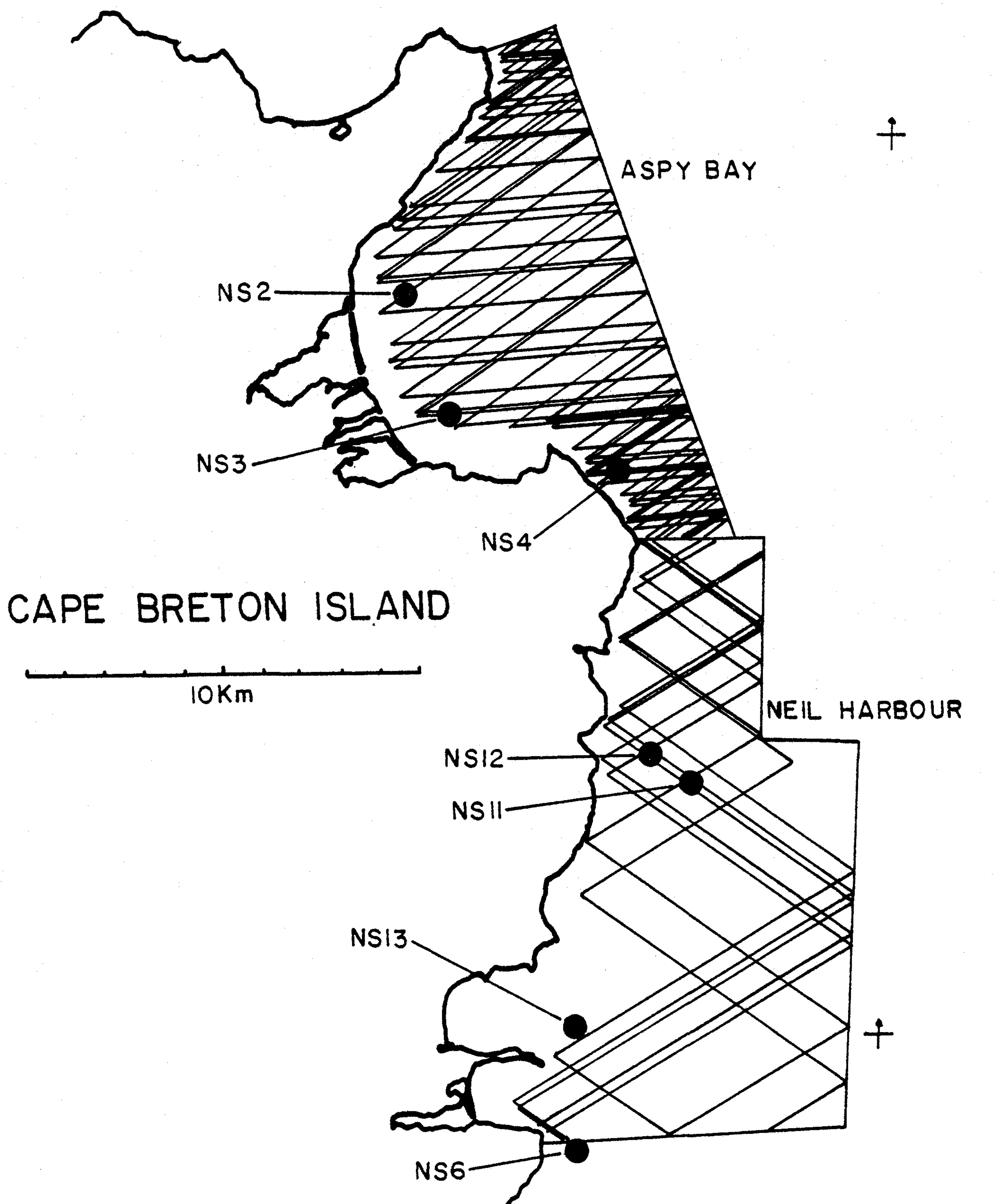


Fig. 5. The North Prince Edward Island stratum, showing survey transects.

Fig. 6. Strata in the northern Sydney Bight area, showing survey transects. Solid dots indicate location of sets.



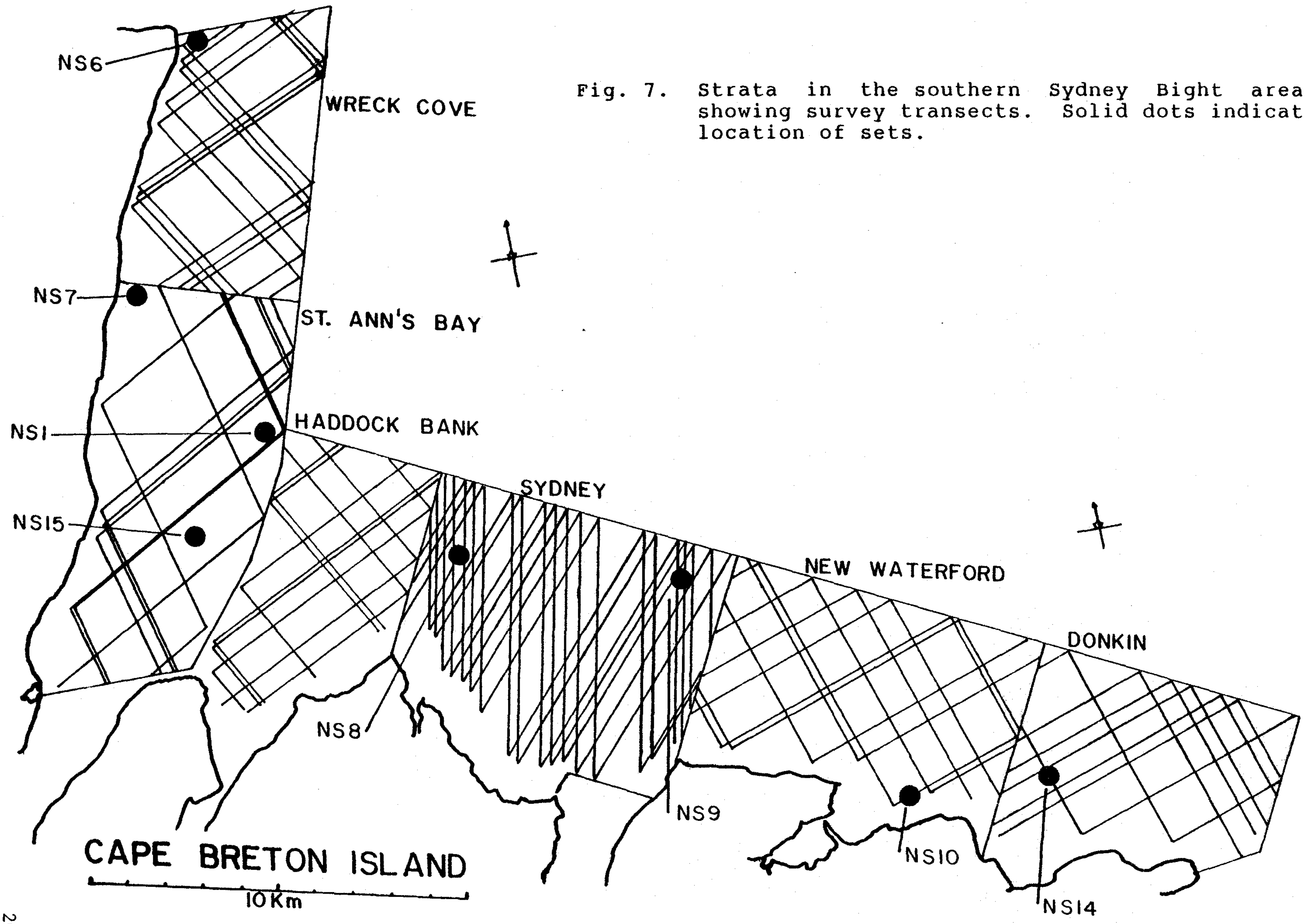


Fig. 7. Strata in the southern Sydney Bight area, showing survey transects. Solid dots indicate location of sets.

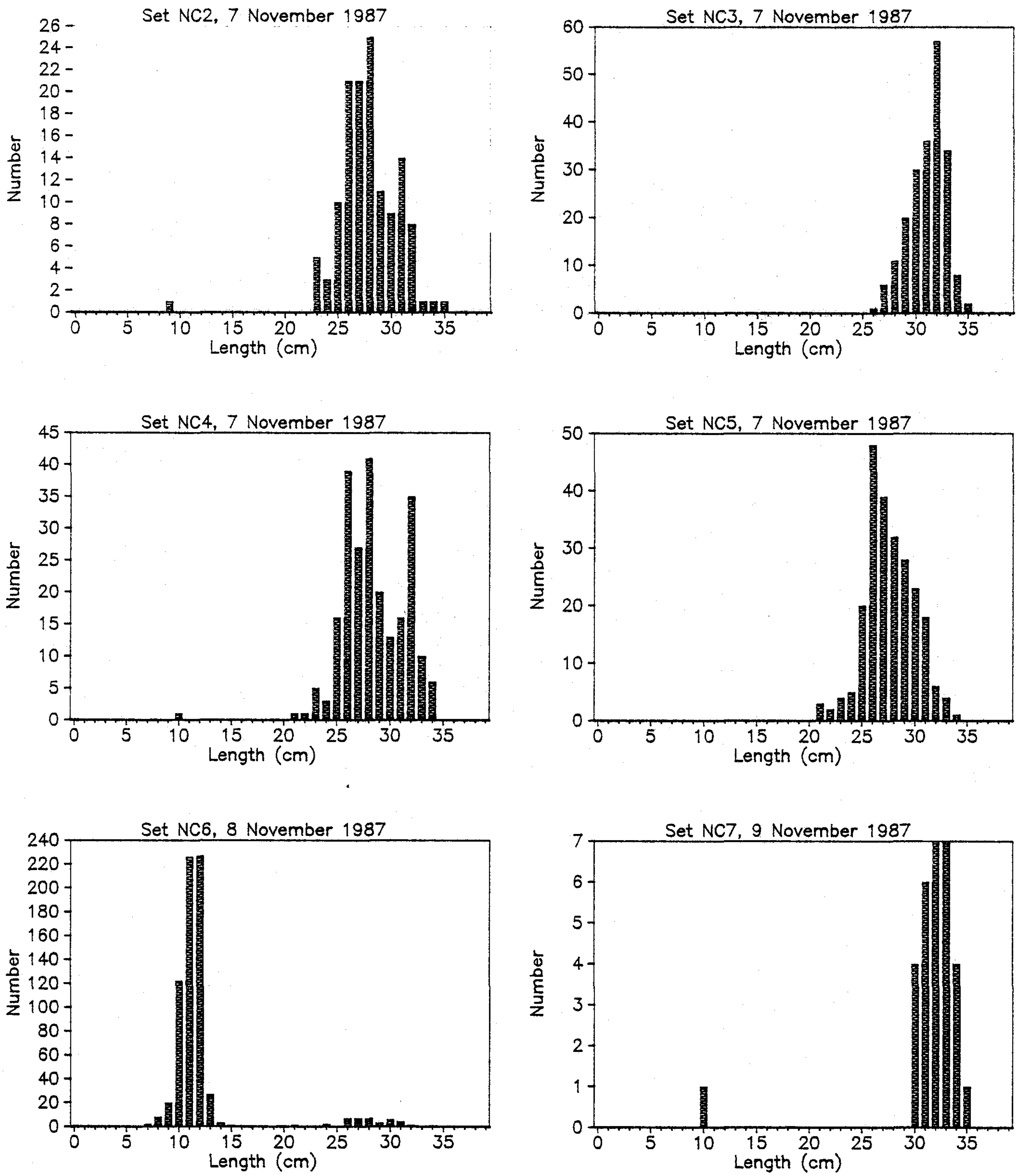


Fig. 8. Length—frequencies of herring taken in sets by the Alfred Needler in the Bay of Chaleur

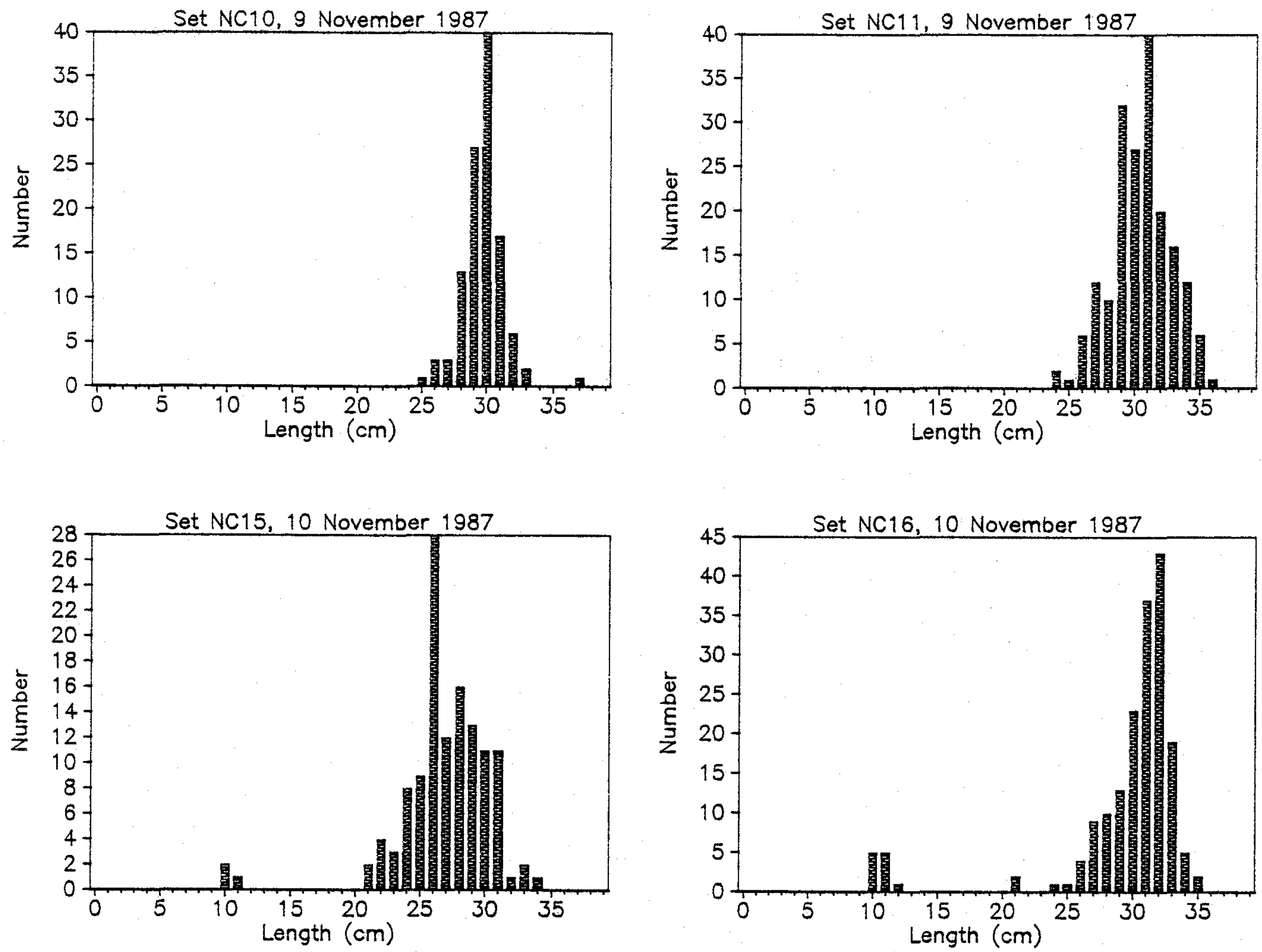


Fig. 8. (Continued). Length–frequencies of herring taken in sets by the Alfred Needler in the Bay of Chaleur.

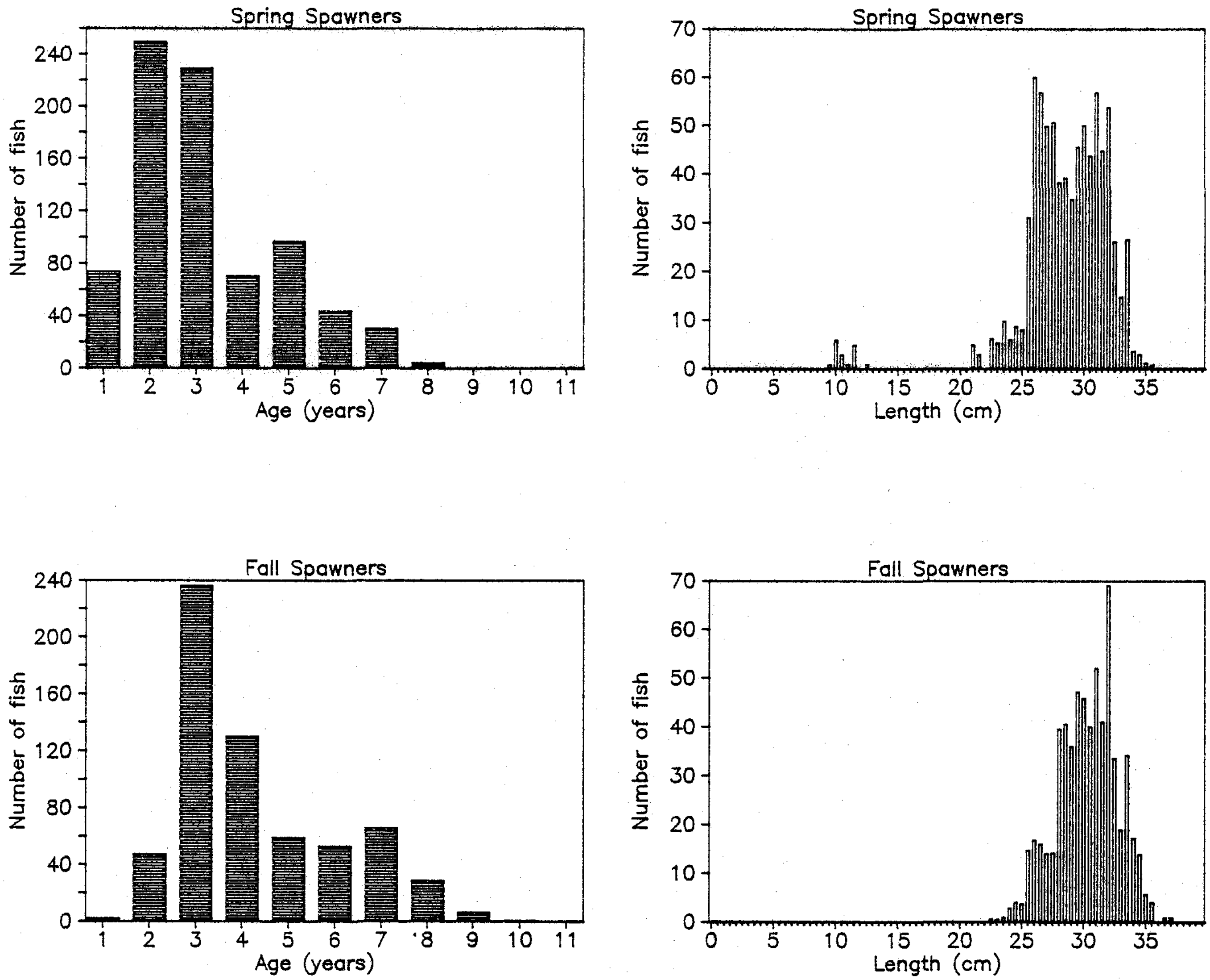


Fig. 9. Age and length frequencies of spring and fall spawning herring taken in sets by the Alfred Needler in the Bay of Chaleur, November 1987. Excludes fish from Set NC6.

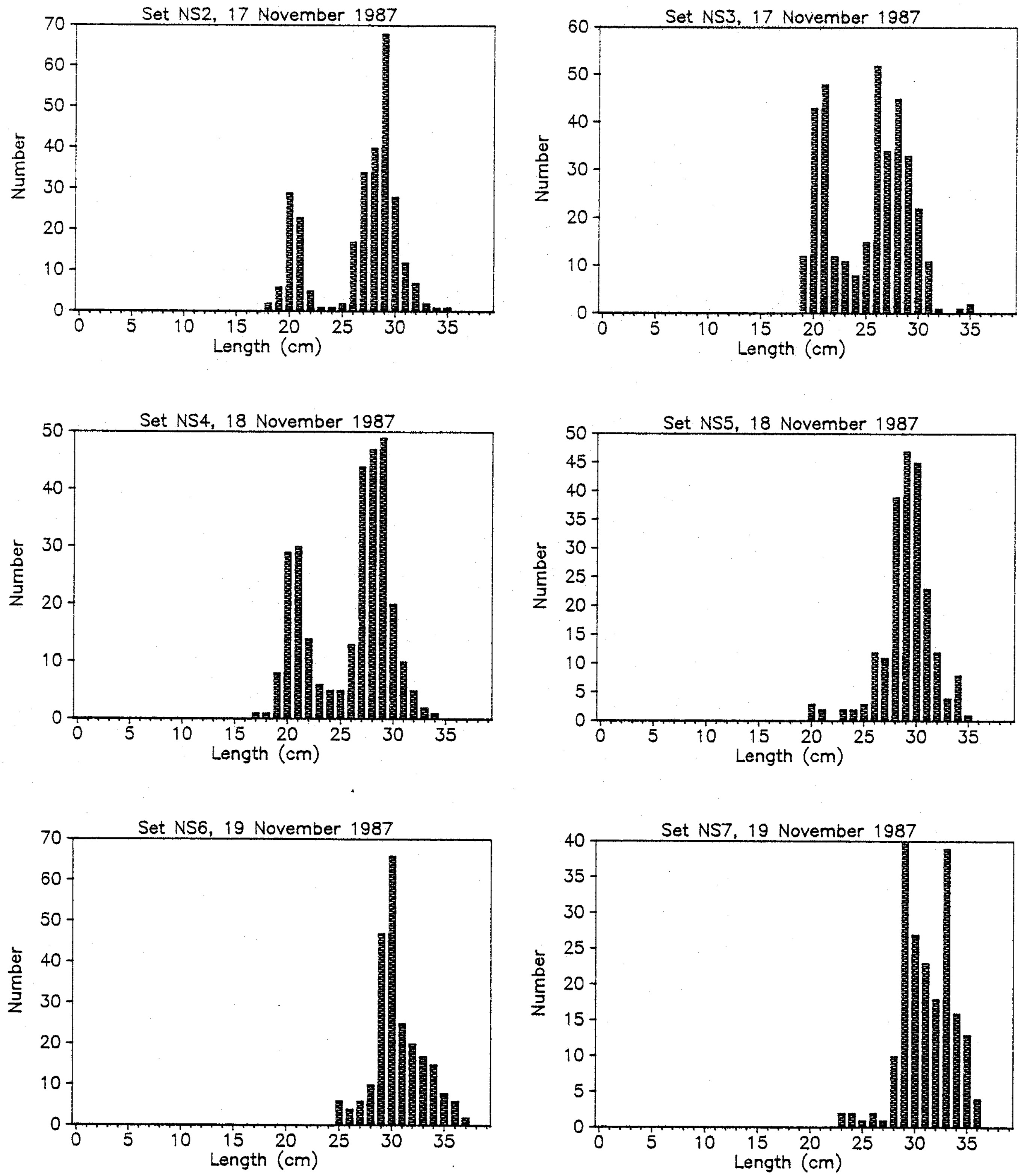


Fig. 10. Length–frequencies of herring taken in sets by the Alfred Needler in Sydney Bight.

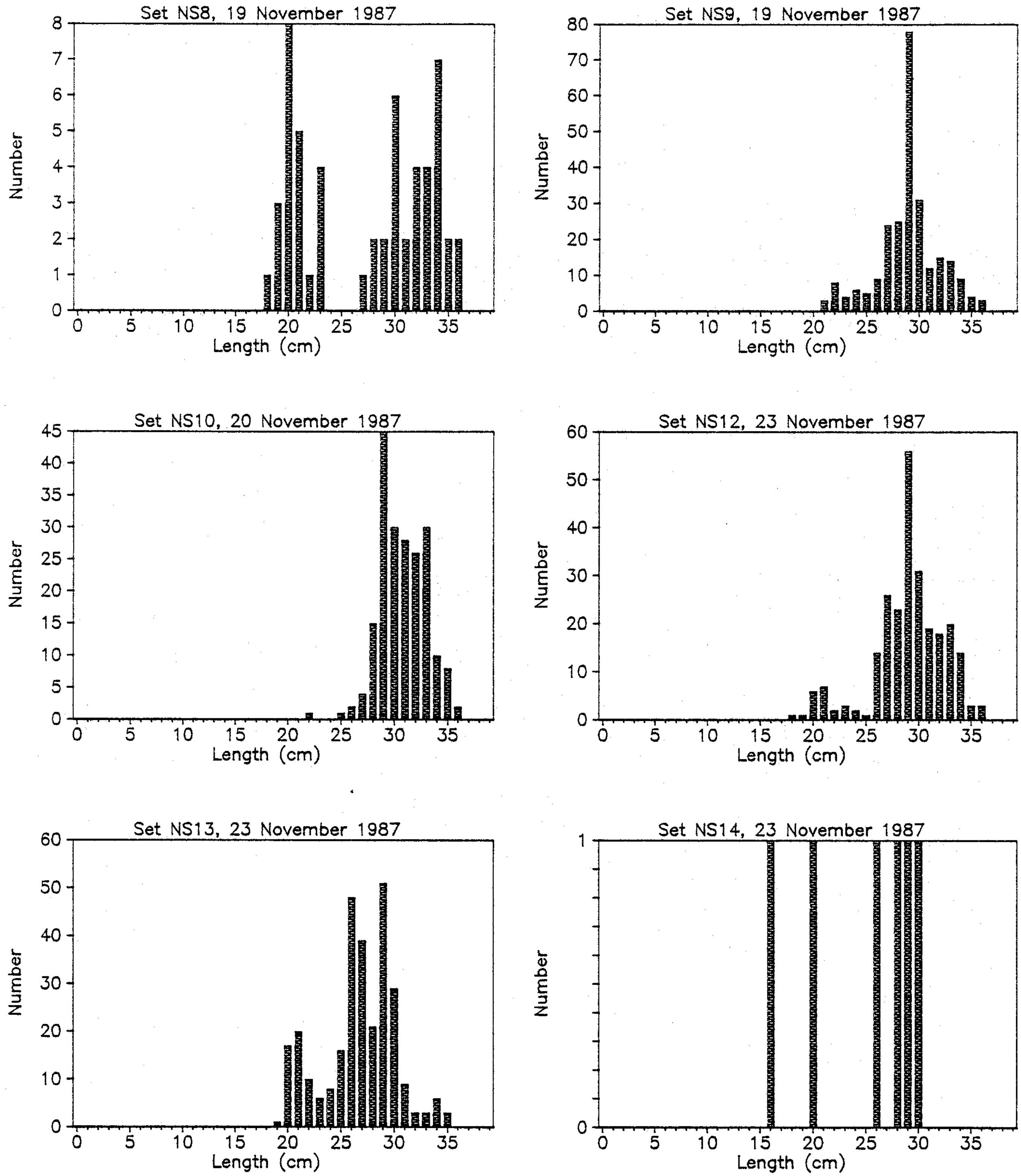
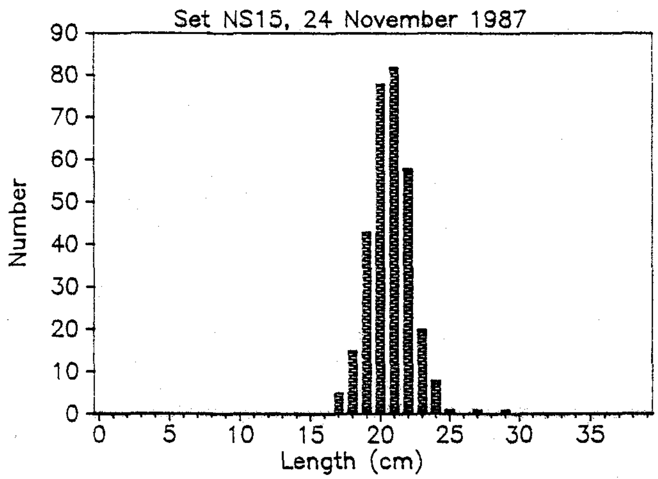


Fig. 10. (Continued) Length–frequencies of herring taken in sets by the Alfred Needler in Sydney Bight.



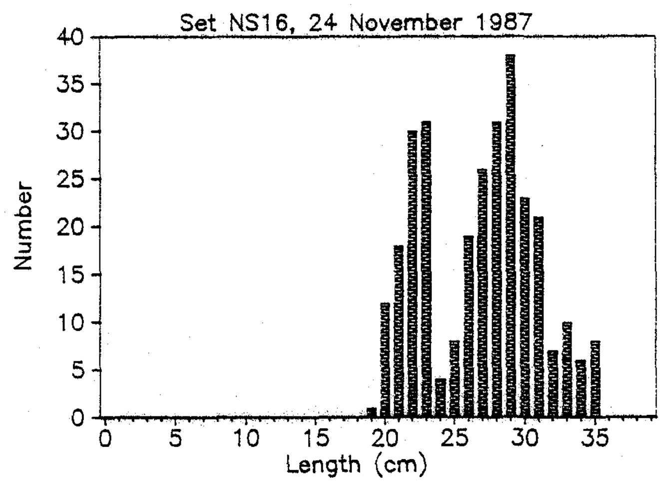


Fig. 10. (Continued) Length–frequencies of herring taken in sets by the Alfred Needler in Sydney Bight.

Fig. 11. Size and location of herring schools encountered in the Grande Rivière stratum during transects on 5-6 November 1987. School size categories are given as the exponent of total area backscatter (m^2 sr^{-1}).

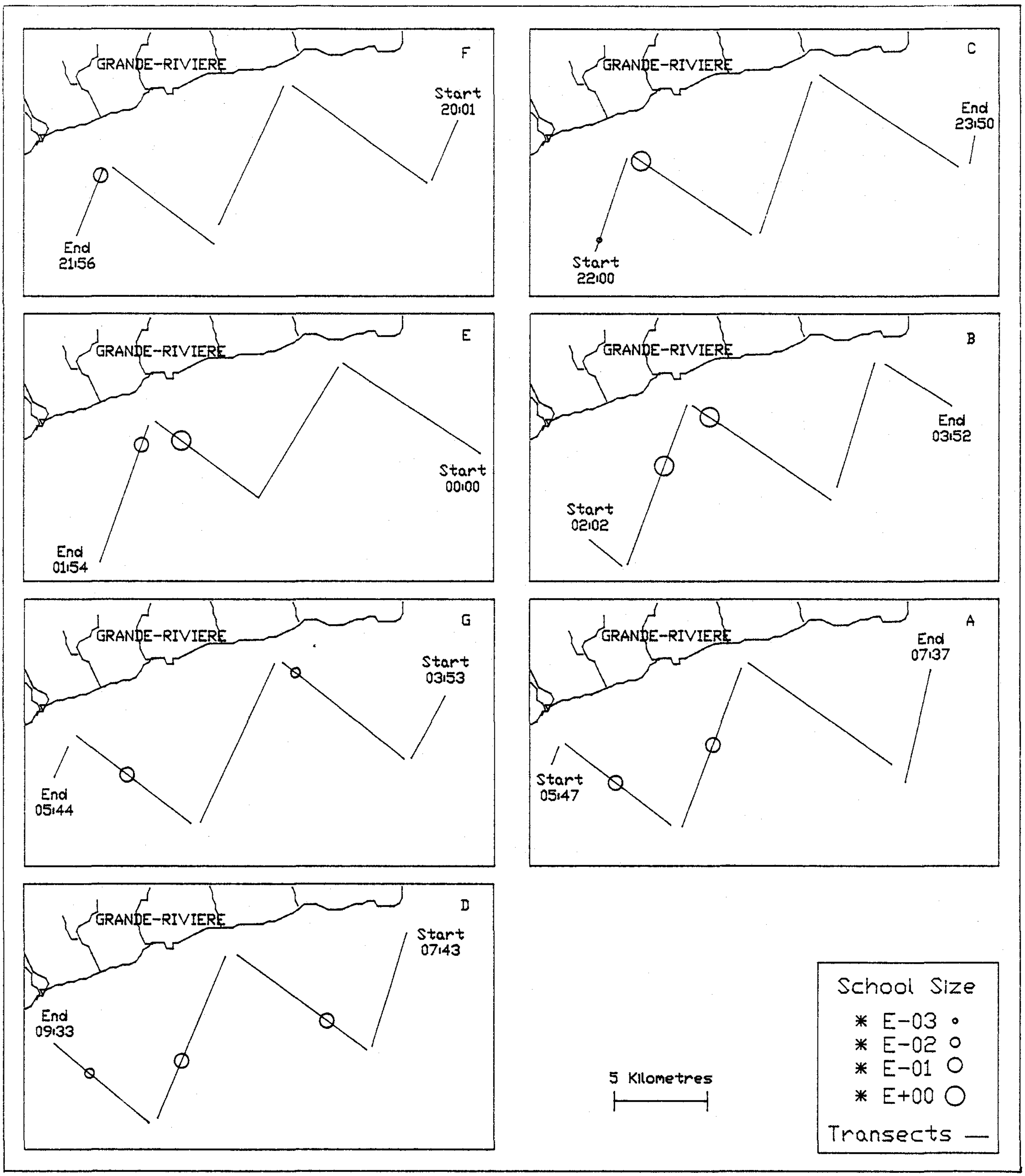


Fig. 12. Size and location of herring schools encountered in the Newport stratum during transects on 6 November 1987. School size categories are given as the exponent of total area backscatter (m^2 sr^{-1}).

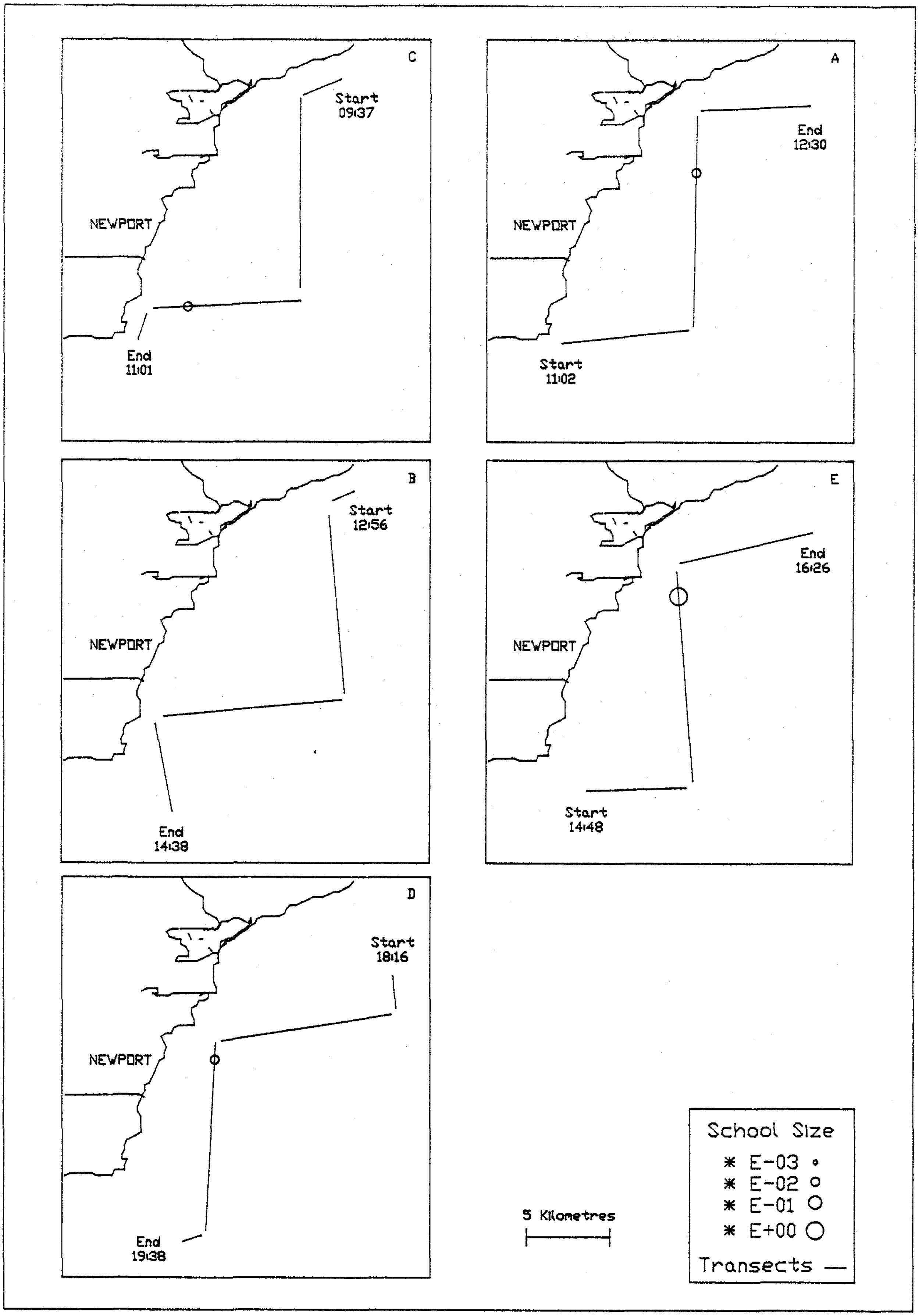


Fig. 13. Size and location of herring schools encountered in the Shigawake stratum during transects on 6-7 November 1987. School size categories are given as the exponent of total area backscatter (m^2 sr^{-1}).

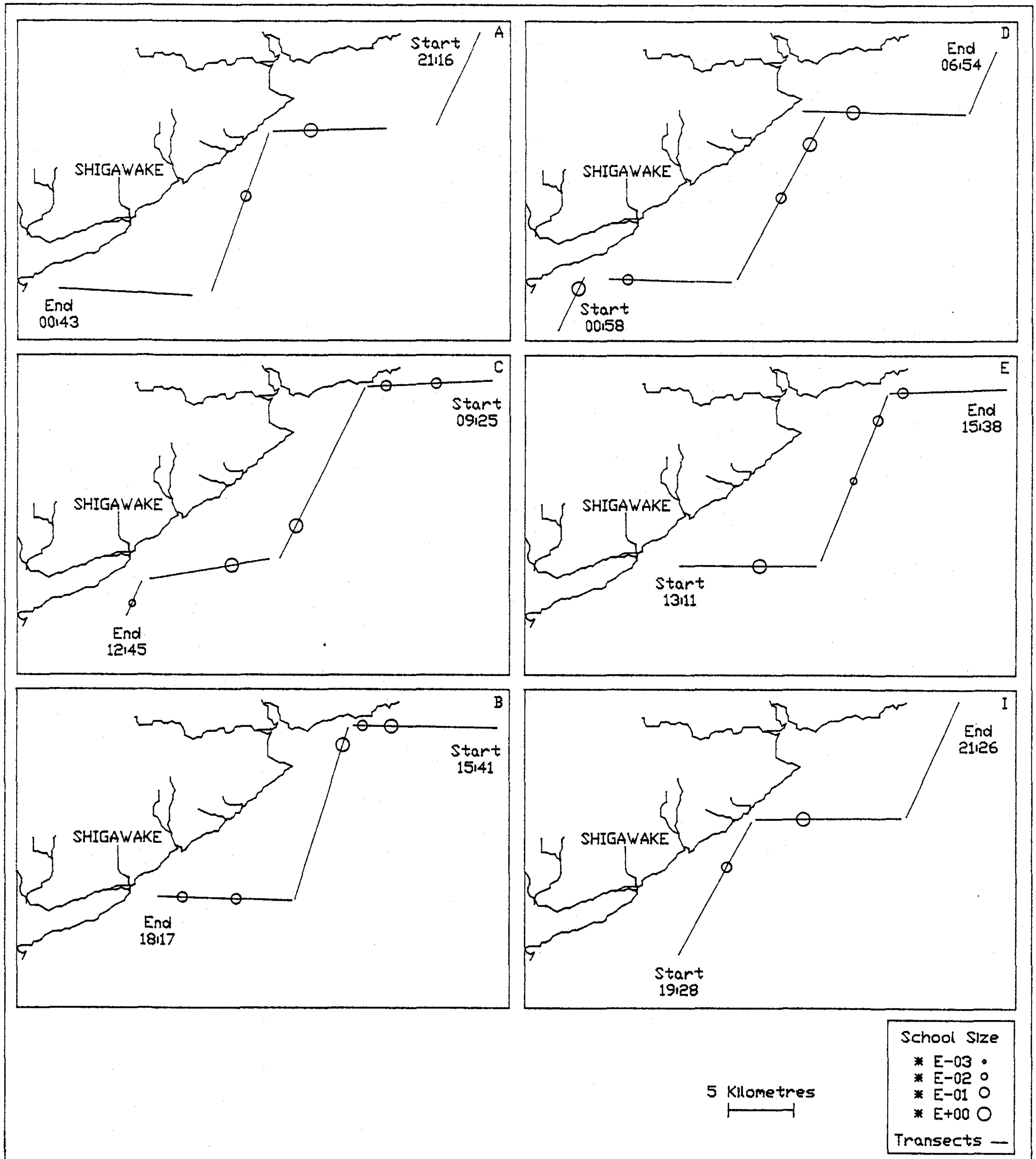


Fig. 14. Size and location of herring schools encountered in the Aspy Bay stratum during transects on 17-18 November 1987. School size categories are given as the exponent of total area backscatter ($m^2\ sr^{-1}$).

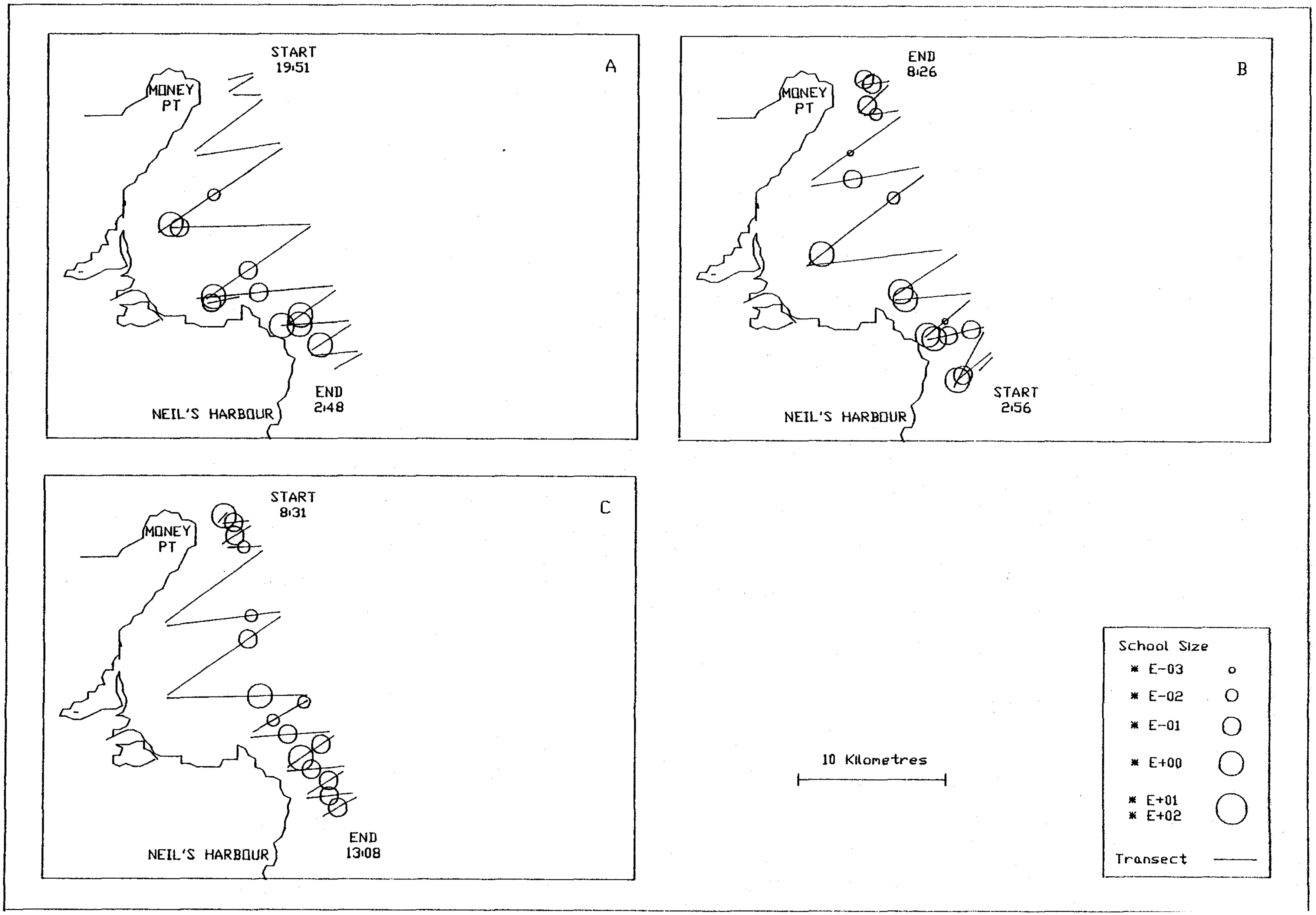


Fig. 15. Size and location of herring schools encountered in the Aspy Bay stratum during transects on 21-23 November 1987. School size categories are given as the exponent of total area backscatter ($m^2\ sr^{-1}$).

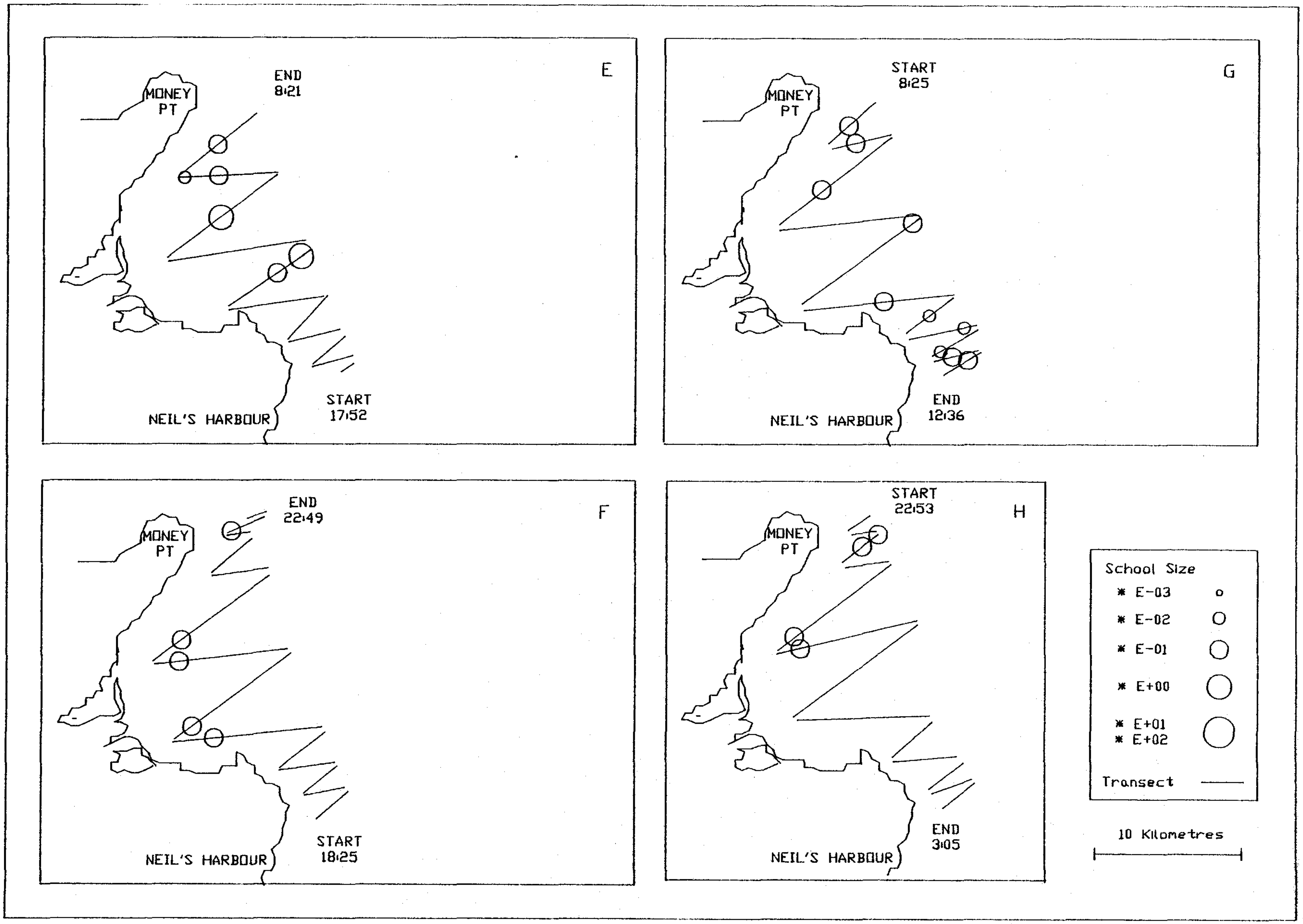


Fig. 16. Size and location of herring schools encountered in the Neil Harbour stratum during transects on 18 November 1987. School size categories are given as the exponent of total area backscatter ($m^2 sr^{-1}$).

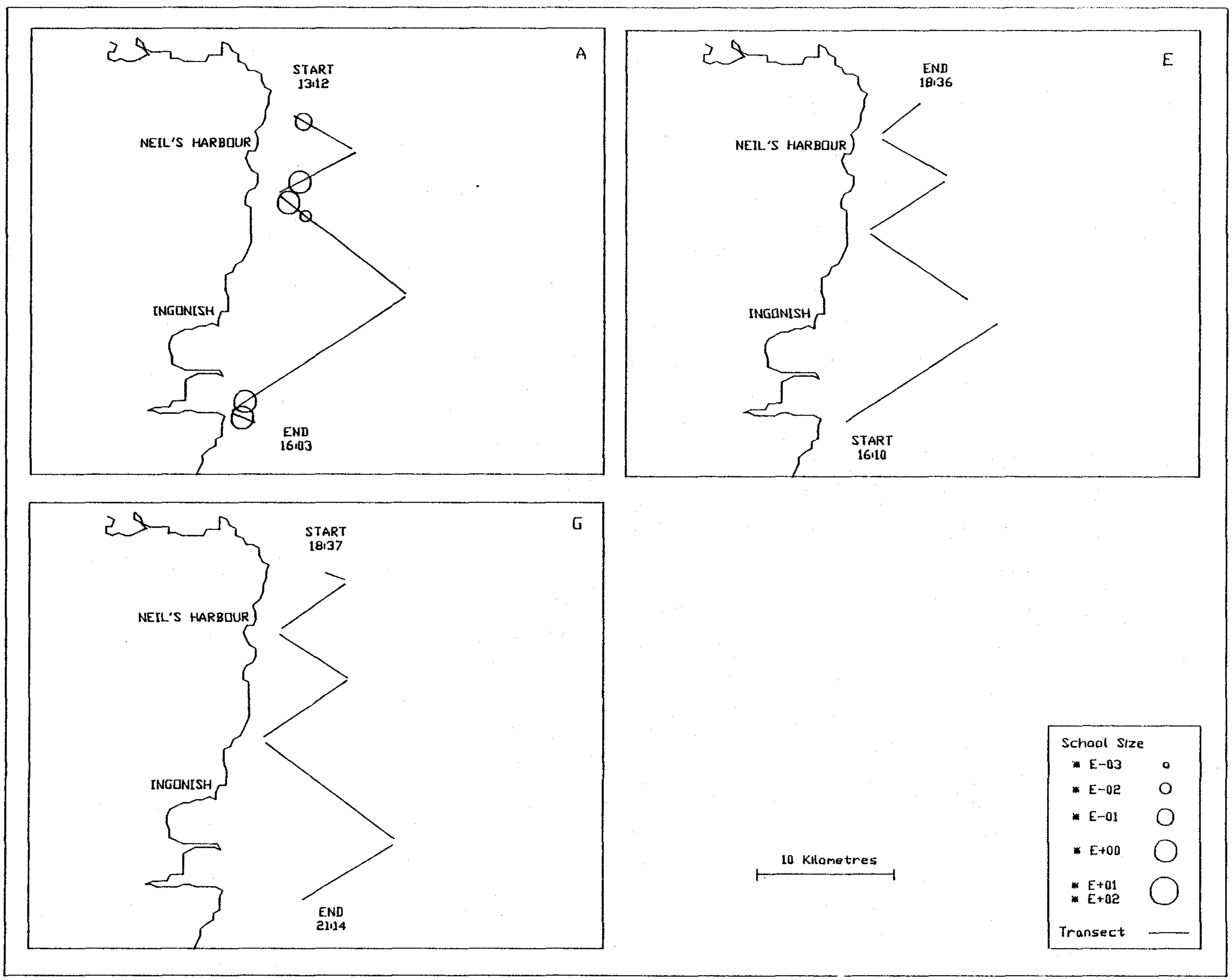


Fig. 17. Size and location of herring schools encountered in the Neil Harbour stratum during transects on 22 November 1987. School size categories are given as the exponent of total area backscatter ($m^2\ sr^{-1}$).

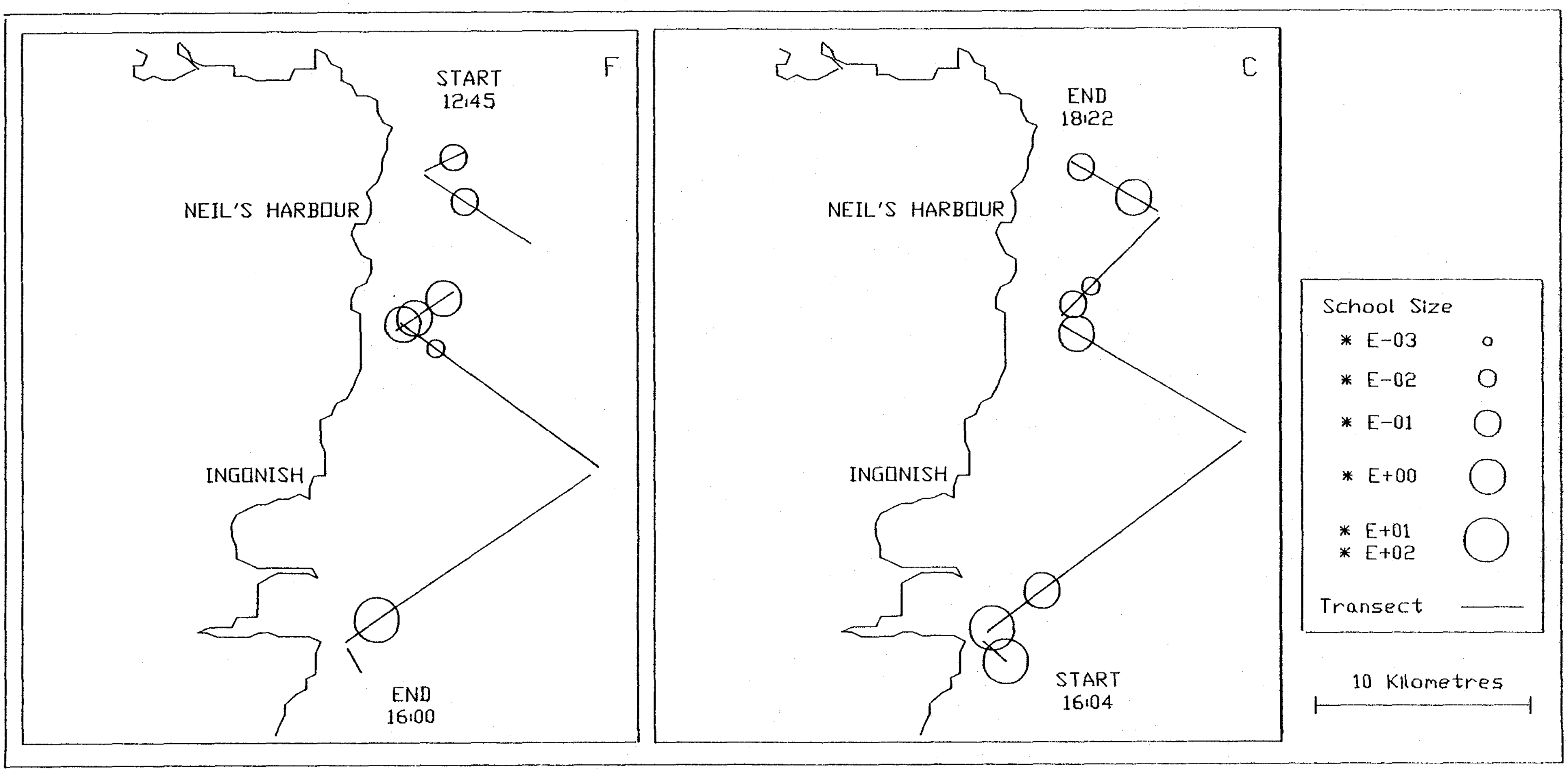


Fig. 18. Size and location of herring schools encountered in the Wreck Cove stratum during transects on 24 November 1987. School size categories are given as the exponent of total area backscatter ($m^2\ sr^{-1}$).

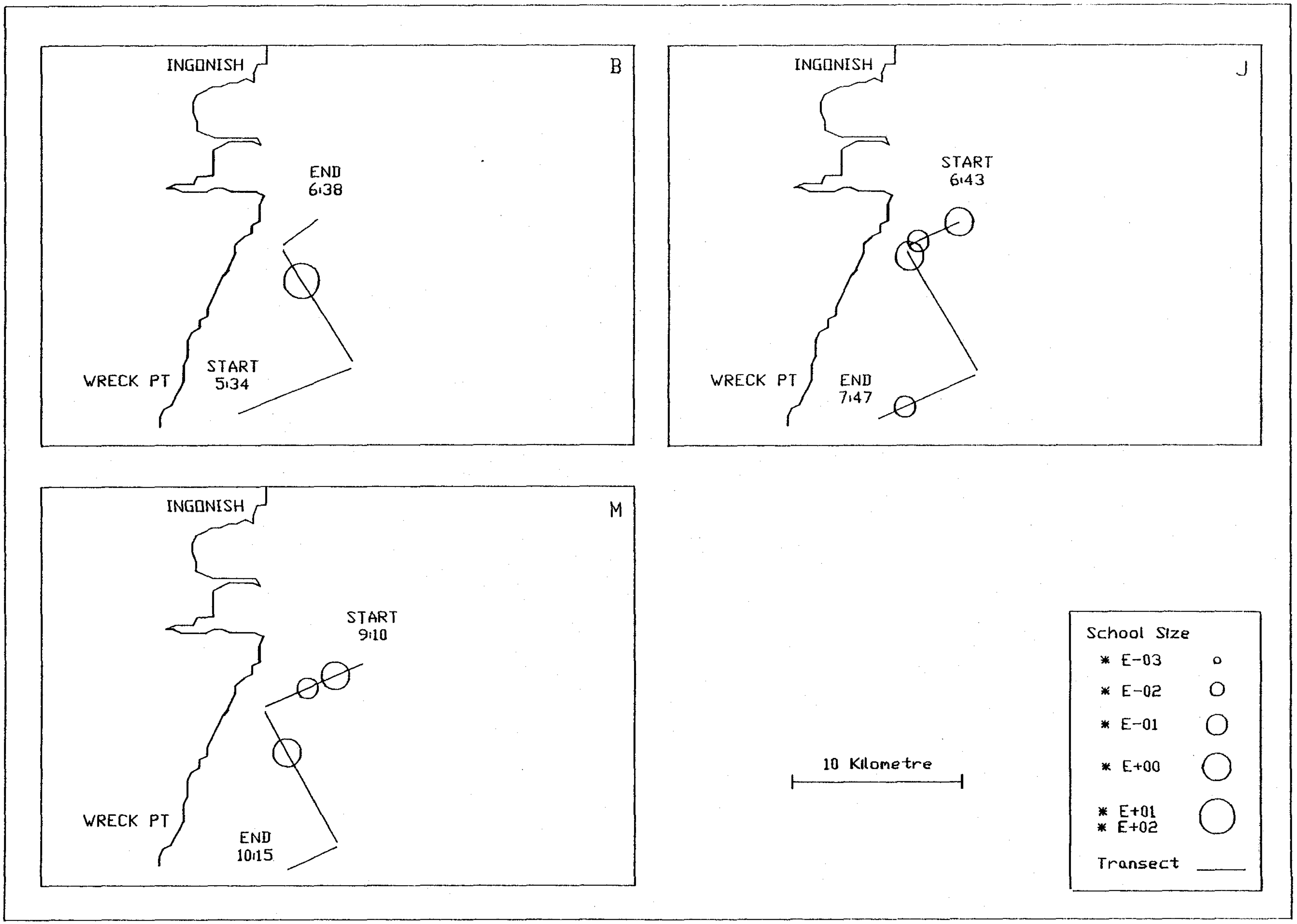


Fig. 19. Location of herring along transect lines in the Grande Rivière stratum, November 1987.

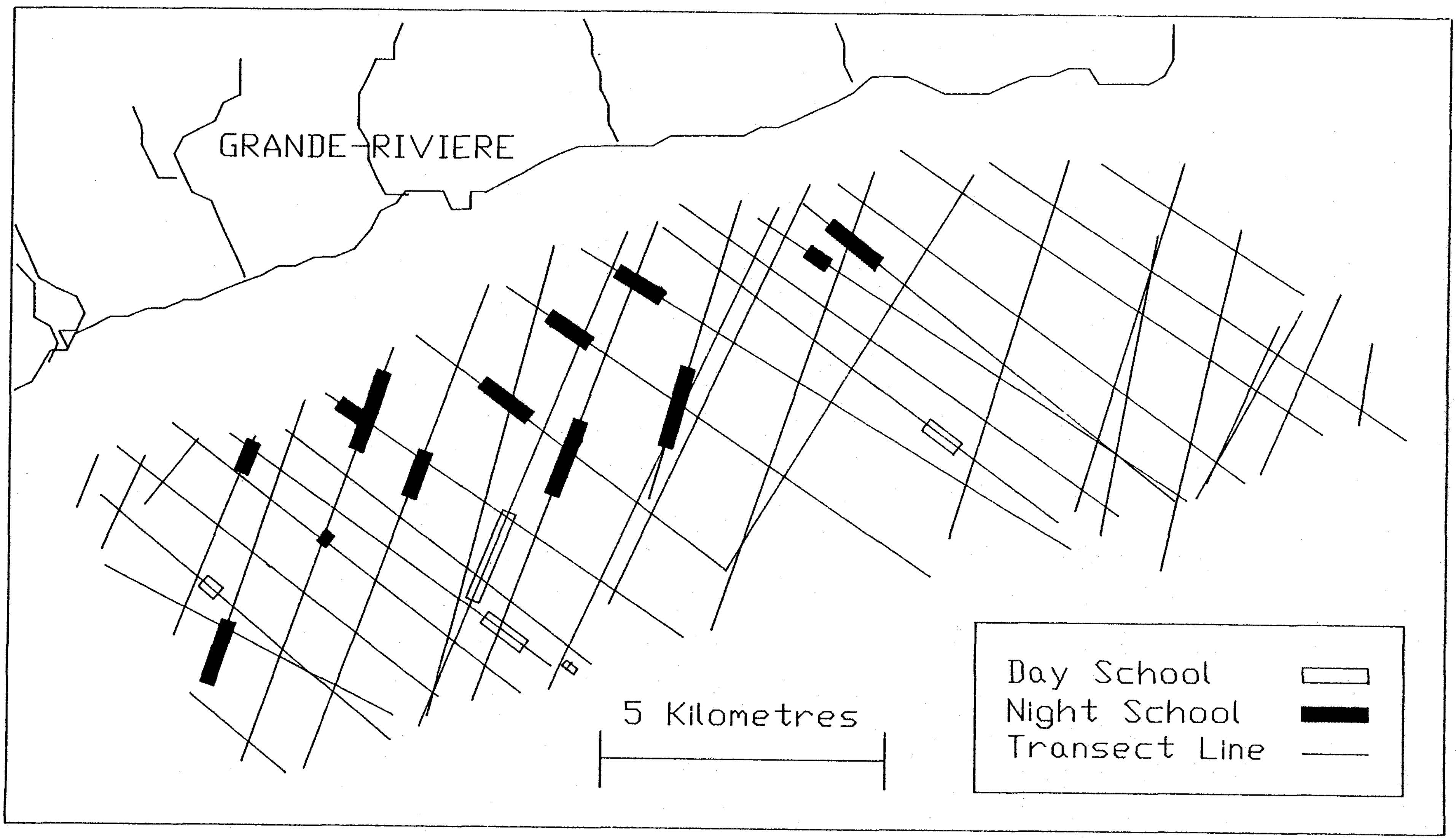


Fig. 20. Location of herring along transect lines in the Newport stratum, November 1987.

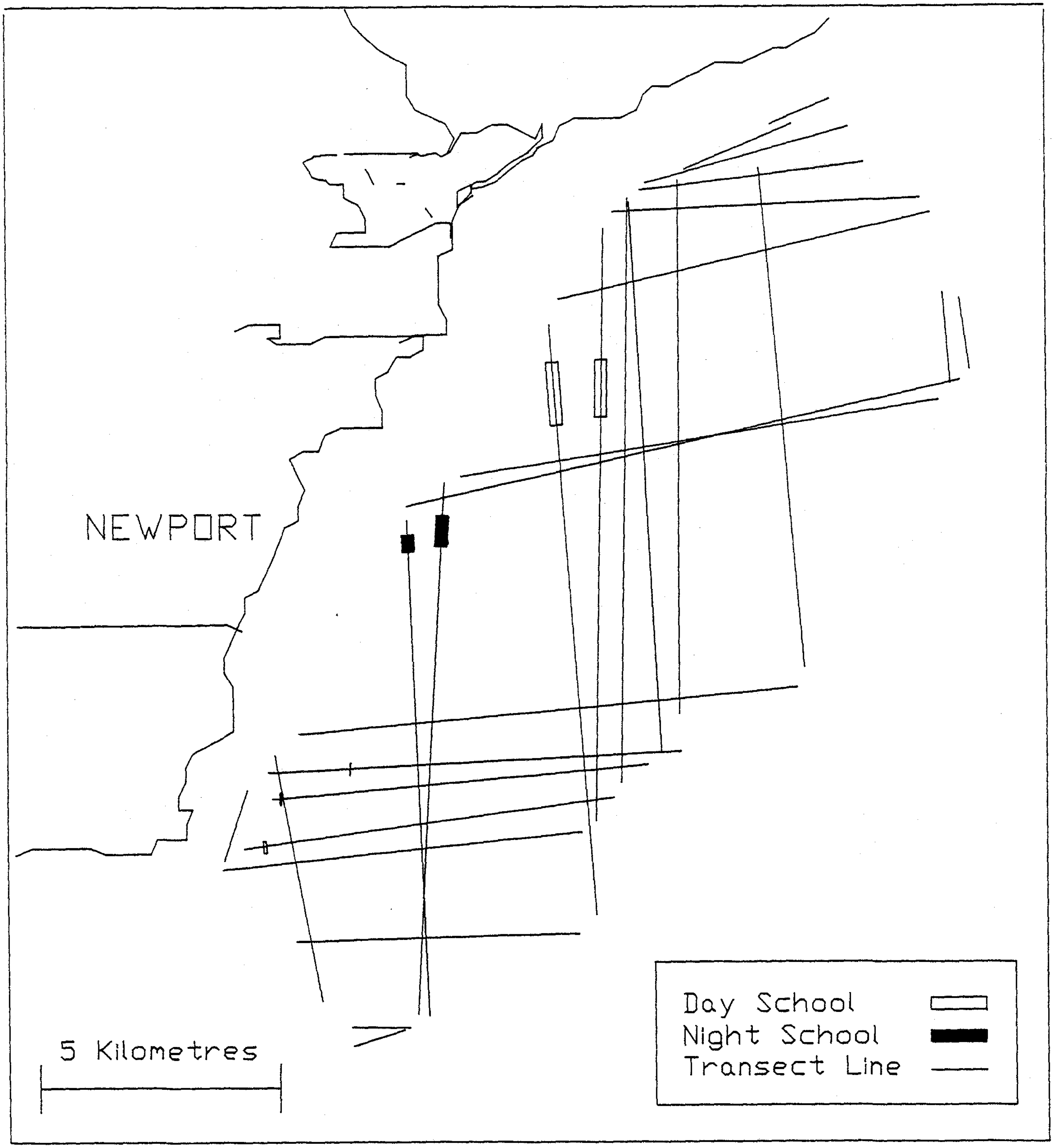
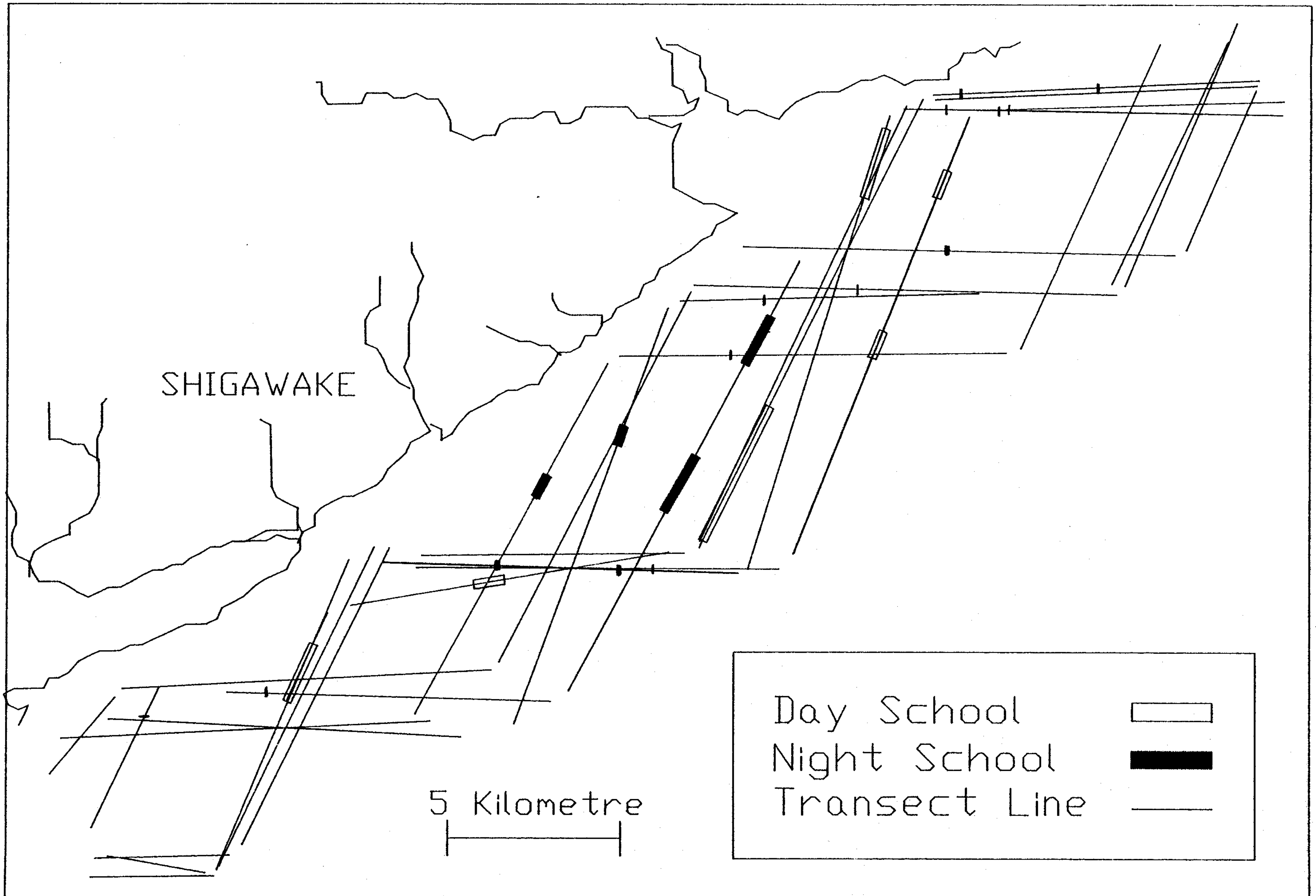


Fig. 21. Location of herring along transect lines in the Shigawake stratum, November 1987.



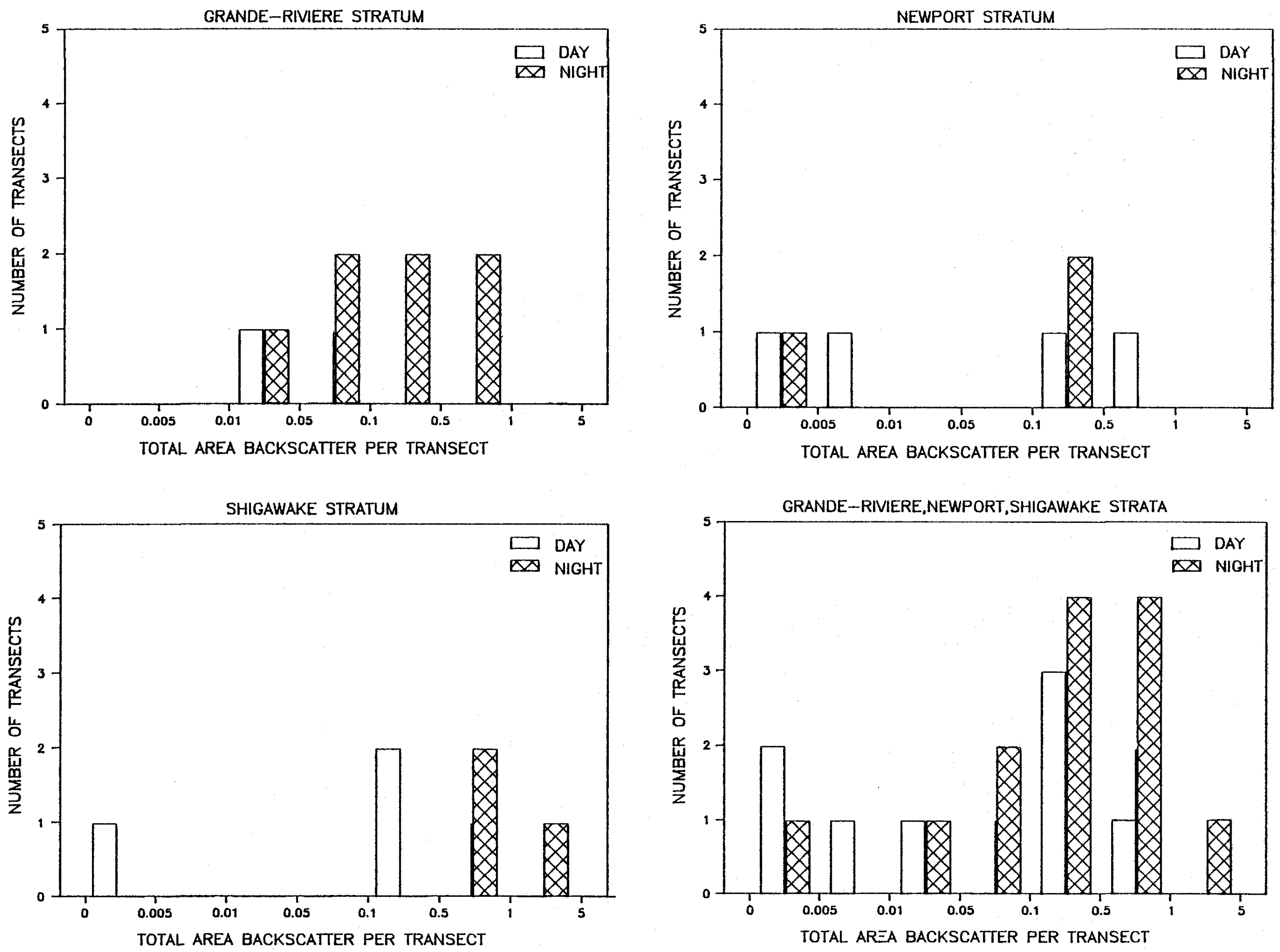


Fig. 22. Frequency distribution of total area backscatter (in m^2 sr^{-1}) per transect in daytime and nighttime transects, for three strata on the north side of the Bay of Chaleur. Note non-linear abscissal scale.

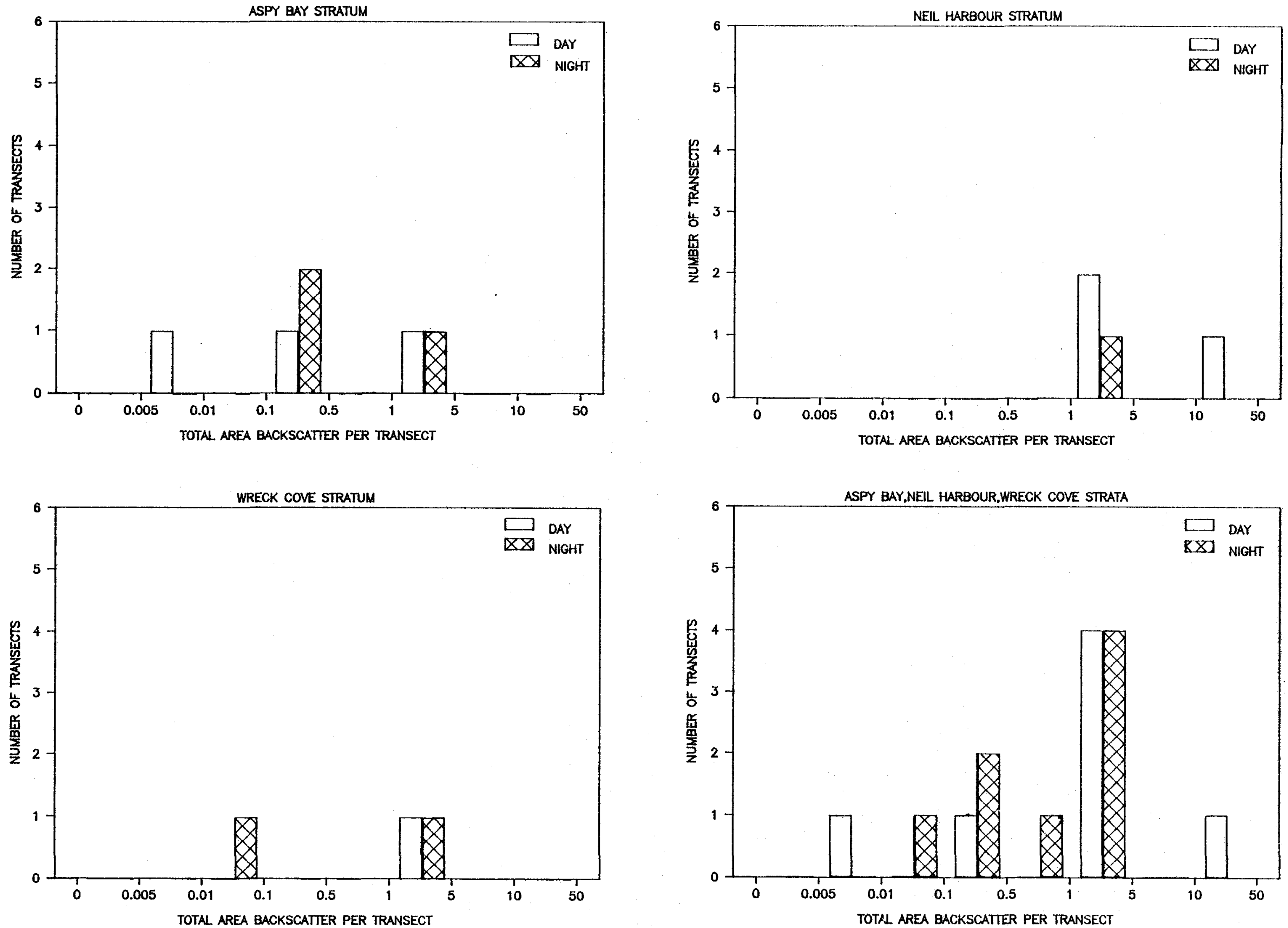


Fig. 23. Frequency distribution of total area backscatter (in m^2 sr^{-1}) per transect in daytime and nighttime transects, for three strata in the Sydney bight area. Note non-linear abscissal scale.

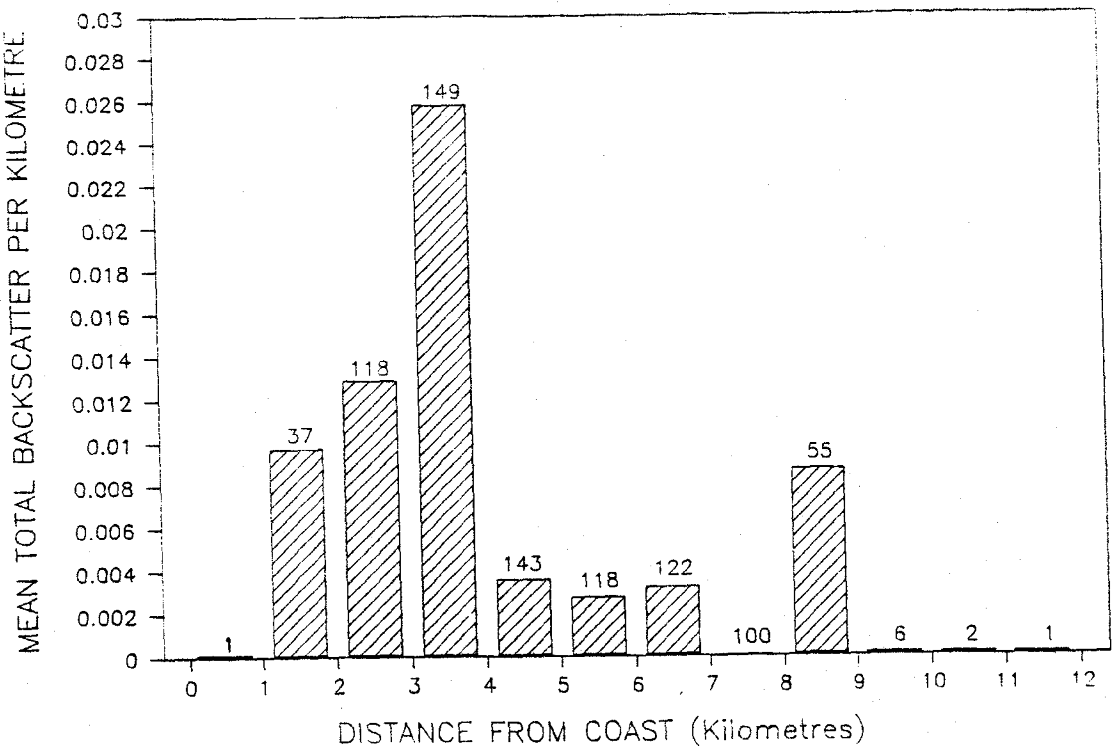


Fig. 24. Mean total backscatter ($m^2\ sr^{-1}$) per kilometre of transect with respect to distance from the coast in the Grande Rivière, Newport, and Shigawake strata. The numbers above the transects are the number of kilometres run in each distance category.

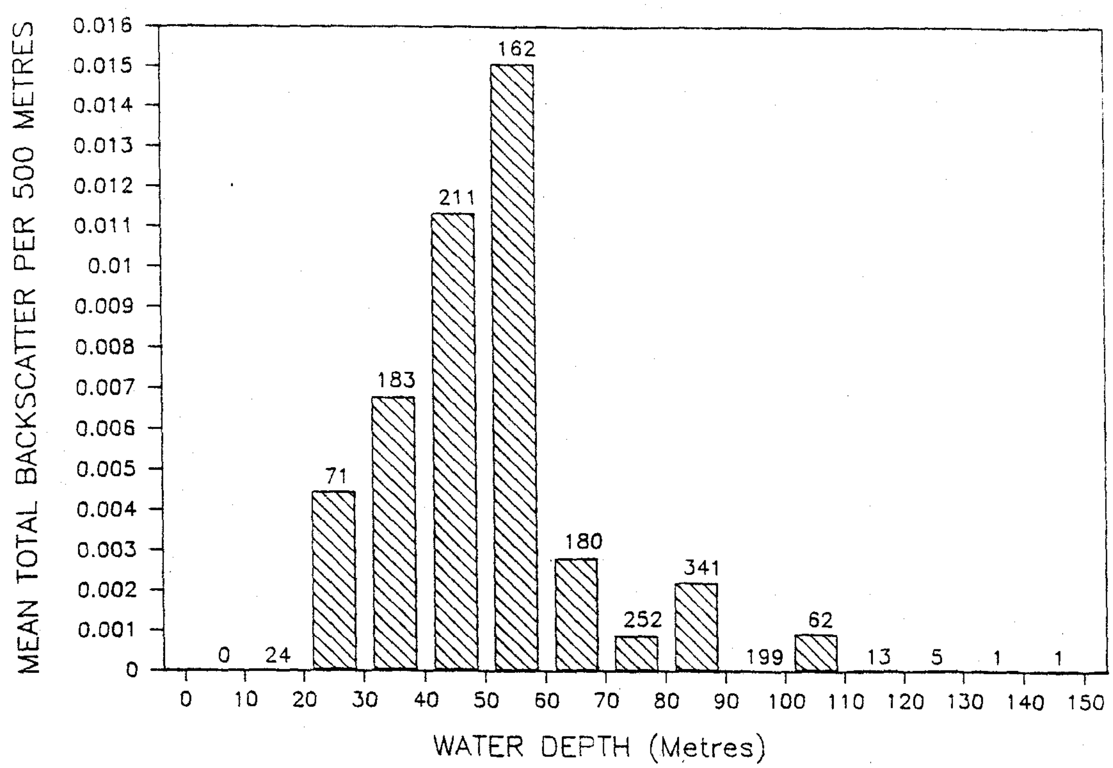


Fig. 25. Mean total backscatter ($m^2\ sr^{-1}$) per 500 m of transect with respect to water depth in the Grande Rivière, Newport, and Shigawake strata. The numbers above the transects are the number of 500 m segments run in each depth category.

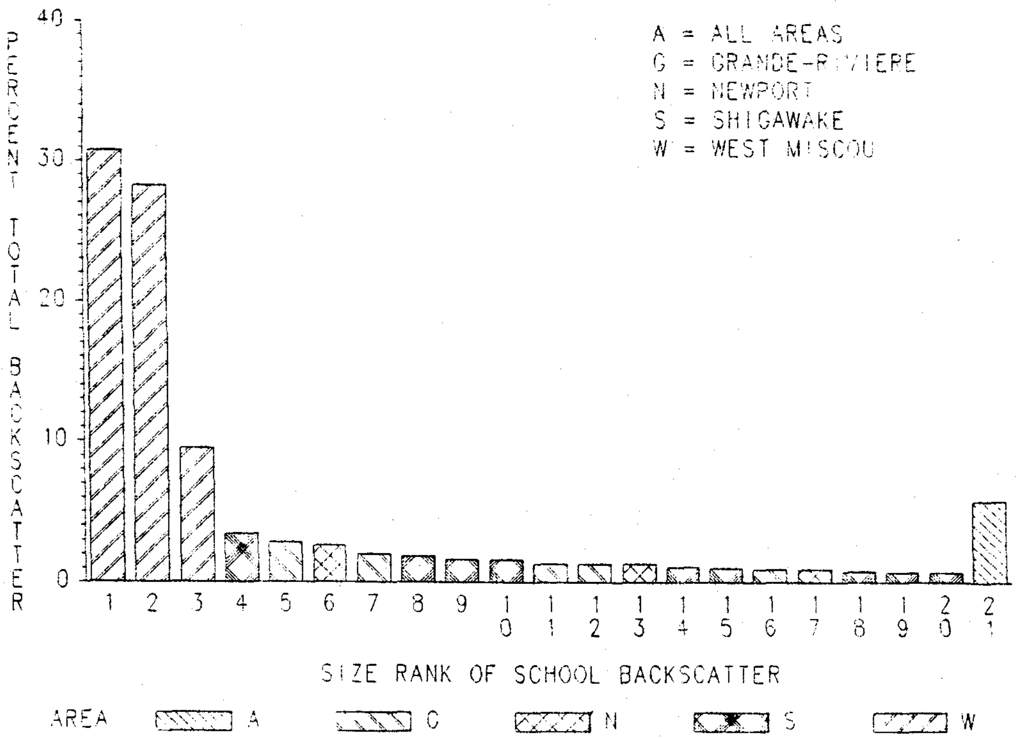


Fig. 26. Sizes of herring schools encountered in the Chaleur area. Sizes are given in $m^2\ sr^{-1}$. Sizes of the 20 largest schools are shown; the summed size of schools above rank 20 is given at position 21.

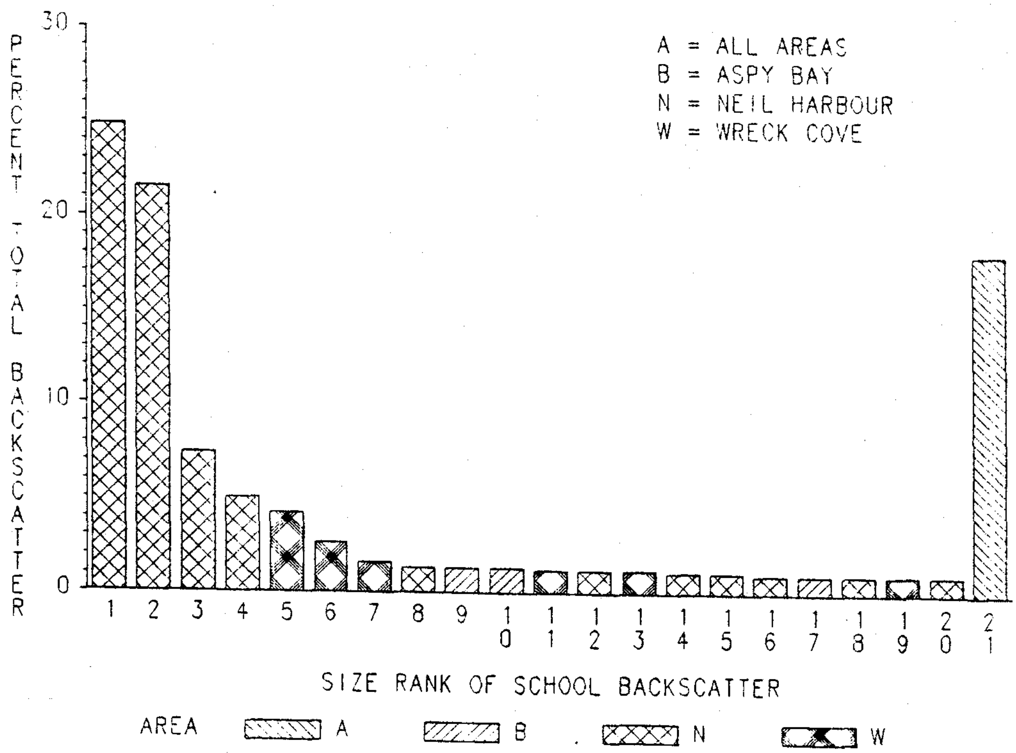


Fig. 27. Sizes of herring schools encountered in the Sydney Bight area. Sizes are given in $m^2\ sr^{-1}$. Sizes of the 20 largest schools are shown; the summed size of schools above rank 20 is given at position 21.