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Results of the Acoustic Survey of Herring in the Southern Gulf of St. Lawrence and Sydney Bight, November 1985

by

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Abstract

Preliminary results of an acoustic survey of herring in the Gaspé - Baie de Chaleur area and Sydney Bight in November 1985 are presented. In the Baie de Chaleur area, most herring were encountered in the Chandler-Newport area with lesser amounts about Miscou Island. In Sydney Bight, a relatively large concentration of herring was found that extended along the coast from Neil Harbor to Wreck Point. Many smaller schools occurred in the inshore area of Glace Bay - New Waterford. A brief exploration at the end of the cruise also located herring schools at the entrance to Gabarus Bay.

The estimated total area scattering coefficient for the Baie de Chaleur area is 19 100 sr^{-1}. Using values of 0.2188 m^{-2} $sr^{-1}t^{-1}$ (Halldorson and Reynisson 1983) and 0.3049 m^{-2} $sr^{-1}t^{-1}$ (Edwards and Armstrong 1983) gives biomass estimates of 87 200 t and 62 600 t respectively. In Sydney Bight, the estimated total area scattering coefficient for the regions surveyed is 38 300 or 45 600 sr^{-1}, depending on assumptions regarding herring behavior. Using the same conversion coefficients, this gives biomass estimates of 174 300 t and 210 000 t (Halldorson and Reynesson) and 125 000 and 152 000 t (Edwards and Armstrong 1983) respectively. The best estimate is taken as 38 900 sr^{-1} (177 900 t).

A striking feature of the results of the 1985 survey was the similarity in the geographical distribution of herring schools to that observed in 1984. This indicates that acoustic surveys of these stocks during November could provide a good annual index of herring abundance.

Résumé

On présente les résultats préliminaires du relevé acoustique du hareng effectuée en novembre 1985 dans la région de Gaspé - Baie des Chaleurs et de Sydney Bight. Dans la région de la Baie des Chaleurs, on a constaté que la plus forte concentration de harengs se trouvait dans la région de Chandler - Newport et qu'elle était moindre aux alentours de l'île Miscou. Dans Sydney Bight, on a trouvé une concentration relativement importante de hareng le long de la côte, entre Neils Harbour et la pointe Wreck. Beaucoup de bancs de moindre concentration ont été repérés dans la région côtière de Glace Bay - New Waterford. Une brève exploration en fin du relevé a également permis de repérer des bancs de harengs à l'entrée de la baie Gabarus.

Le coefficient de diffusion estimé pour l'ensemble de la région de la Baie des Chaleurs est de 19 100 sr^{-1}. En utilisant des valeurs de 0.2188 $m^{-2}sr^{-1}t^{-1}$ (Halldorson et Reynisson 1983), et de 0.3049 $m^{-2}sr^{-1}t^{-1}$ (Edwards et Armstrong 1983), on obtient des estimations de biomasse de 87 200 t et de 62 600 t respectivement. Dans Sydney Bight, le coefficient de diffusion estimé pour l'ensemble des régions explorés est de 38 300 ou de 45 600 sr^{-1}, selon les hypothèses concernant le comportement du hareng. En utilisant les mêmes coefficients de conversion, on obtient des estimations de biomasse de 174 300 t et de 210 000 t (Halldorson et Reynisson) et de 125 000 t et 152 000 t (Edwards et Armstrong 1983) respectivement. La meilleure estimation est de 38 900 sr^{-1} (177 900 t).

Une caractéristique frappante des résultats du relevé de 1985 est la similarité de la distribution géographique des bancs de hareng avec celle de 1984. On en découle que le relevé acoustique de ces stocks en novembre pourrait donner un bon indice annuel de l'abondance de hareng.

1. Introduction

This report presents the results of the acoustic research cruise of the herring stocks in the NAFO areas 4T and 4Vn. The cruise had several objectives:

(1) To obtain an estimate of abundance of herring and determine their geographical distribution and relative abundance,

(2) To obtain information which would enable development of "optimal" sampling methods in the case of highly aggregated and mobile fish populations,

(3) Contribute to the understanding of the biology of herring in the survey area through increased knowledge of their spatial and temporal distribution.

This cruise (Needler #55), during November 1985, followed a similar cruise done in much the same area during the same period in 1984. Information on the distribution of herring encountered in 1984 was used in designing the cruise sample design in 1985. The principal differences in the cruise design were:

(1) The area adjacent to the N.W. coast of Cape Breton (Cheticamp to Cape North) was not surveyed in 1985 because of northwesterly gales during the time available. Herring were located in this area in 1984.

(2) The Souris - Cardigan Bay area adjacent to the eastern coast of Prince Edward Island was surveyed in 1985. No transects were undertaken in this area in 1984.

(3) Transects were run in the Cape Gabarus area in 1985. This area was not covered in 1984.

For the first part of this cruise - which covered the Gaspé - Baie de Chaleur area - continual problems were encountered with the magnetic tape drive. This occurred mainly while sampling in the strata L and M (Baie de Malbaie and Baie de Gaspé respectively). No schools were found (as indicated on the chart recorder) in stratum M. Schools were encountered in stratum L when the acoustic system was not working, but while the ship was steaming survey transects. When the transects were repeated, with the acoustic system operating normally, no schools were recorded. Thus while no herring are reported for Baie de Malbaie, some herring are known to have occurred in that stratum.

Two measures of herring abundance have been derived from the survey results. One is an acoustic measure, the area scattering coefficient ($s_{v/a}$), with units of sr^{-1}. The other, the biomass estimate (t) is derived from this using a coefficient whose value is subject to a number of assumptions, most of which cannot be tested, or which can be investigated only with great difficulty. This coefficient for herring, the backscattering cross section per tonne (σ_b /t), is given different values by different investigators. It will be affected by behavioral differences of the herring, their size and the (unknown) state of inflation of their swimbladders. Any change in the opinion as to the appropriate value of σ_b/t will result in an equivalent linear change in the estimated biomass.

2. *Survey Area*

Figure 1 shows the locations of the strata in the survey area. Figures 2-16 show the locations of the transects within the various strata. In strata where the existence of herring was believed to be minimal or unlikely, sampling was done along a continuous zig-zag transect. This was done in stratum P (north of North Point, western PEI, Figure 2), eastern PEI (strata CB,EP,BP, Figure 9) and Lorraine Head (stratum GA, Figure 16). In strata where herring had been found in relative abundance in 1984, replicated randomized transects were run. A minimum of two transects were completed in each stratum.

A different tactic was adopted during the night along the coast between Neil Harbor (Stratum NH) and Wreck Point (Sydney Bight)-Stratum WP); here herring occurred as a continuous band adjacent to the coast. In this area, in addition to randomized transects, a zig-zag track was adapted (Figures 13 and 15). The estimation of abundance derived from these data follows a method similar to that used by Buerkle (1985). Table 1 lists the areas of the sample strata.

3. *Sampling Methods*

3.1 *Acoustic System*

Acoustic data was collected using the ECOLOG system. During this survey a single beam transducer was used though data were recorded on the system's two channels. The relevant details of this system are described by Shotton and Randall (1982). The system was run with a pulse rate of 125/s, a pulse width of 0.4 ms, and an echo sample frequency of 10 kHz. The transducer has an equivalent beam angle of 0.00640 sr. Power transmitted is approximately 5 kw. Ship speed along transects was 8 knots. The transmitter and receiver that were used have been calibrated (May 1985) at the acoustic barge in Bedford Basin (Table 5).

3.2 *Sample Dates*

The dates that the areas were sampled are as follows:

	November
Gaspé - Western PEI	7 - 13
Eastern PEI	26 - 27
Sydney Bight	21 - 25
Lorraine Head (off Gabarus) (overnight)	28 - 29

More detailed information on sampling times is given in Table 2. The actual time spent sampling can be less than the difference between and starting and finishing time because in some transects, sampling was interrupted to fish or because of system failures. In some cases other strata were sampled between the first and last transects in a stratum, e.g., SY and HB, Figure 10.

3.3 *Calculation of the Area Backscattering Coefficient*

The area scattering coefficient ($s_{v/a}$) was calculated using the conventional acoustic integration model (Forbes and Nakken 1972).

$$s_v = \frac{I_r R^2 e^{2\beta R}}{I_0 (c\tau)/2 \int^{2\pi} b(\theta)^2 \, d\Omega} \qquad (1)$$

where s_v = volume backscattering coefficient

I_r = echo intensity at the transducer

R^2 = range of reverberation volume which returned the echo

β = coefficient of sound absorption in seawater

I_0 = intensity of sound transmitted from the transducer

c = speed of sound in seawater (1500 ms^{-1})

τ = pulse length

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

The area scattering coefficient, $s_{v/a}$, for the kth pulse was calculated by:

$$s_{v/a,k} = \sum_{j=1}^{J} 0.075\, s_{v,j}$$

where J = number of echo samples in the jth pulse.

The summed area scattering for the ith transect is:

$$s_{v/a,i} = \sum_{k=1}^{K} s_{v/a,k}$$

where K = number of pulses in the ith transect.

The total area scatter for a stratum is calculated by:

$$\Sigma\, s_{v/a} = \frac{area}{P} \sum_{i=1}^{I} s_{v/a,i}$$

where P = total number of pulses in the stratum.

I = number of transects in stratum.

3.4 *Estimation of Biomass*

The estimation of the herring biomass from the summed area backscattering coefficients, $\Sigma\, s_{v/a}$, requires use of an appropriate value for the backscattering cross section area per unit weight of herring. Determination of this value is difficult because it is hard to determine and because it is likely to change with the behavior of the herring, i.e., the daytime backscattering cross section per unit biomass may differ to that at night. The difficulties in selecting an appropriate value are discussed by Shotton (1985) and Buerkle (1985). Both authors tabulate values of backscattering cross sections per kilogram of herring cited in the literature. The value used by Buerkle (1985) was derived from the relation of Halldorson (1983),

$$\overline{TS}_{kg} = -14.7 \log L - 10.3 \log P - 10.9 \quad dB\, ref\, 1\, m^2,$$

where L = length in cm

P = pressure.

The value Buerkle (1985) used was $1.380 \times 10^{-4}\ m^{-2}\ sr^{-1}\ kg^{-1}$. Buerkle (pers. comm.) has since learnt that Halldorson and his collegue, Reynisson use their 1983 relation; apparently they believe it is better. This gives

$$\overline{TS}_{kg} = -10.9 \log L - 20.9 \quad dB,$$

or

$$\sigma_{b/kg} = 10^{-2.09} L^{-1.09} \qquad (2)$$

The relationship I have previously used (Shotton and Randall 1982) is that given by Edwards and Armstrong (1983),

$$TS_{kg} = -17.09 \log L - 10.6 \quad dB,$$

or

$$\sigma_{b/kg} = 10^{-1.06} L^{-1.709} \tag{3}$$

The results of Halldorson and Reynisson (1983) were obtained from *in situ* observations, which is why Buerkle prefers them. The results of Edwards and Armstrong (1983) were obtained from measurements on herring in cages.

For the distribution of herring lengths observed during this survey (Section 3.6), the result of Edwards and Armstrong (Equation 3) gives a value of 3.049 x 10^{-4} m^2 sr^{-1} kg^{-1}, that of Halldorson and Reynisson (Equation 2), 2.188 x 10^{-4} m^2 sr^{-1} kg^{-1}, i.e., this latter value will give biomass estimates 39% higher than that using the relation of Edwards and Armstrong. The relation of Halldorson and Reynisson has been used in the main part of the text. Any error (of which some must occur) in the value of the backscattering cross section per kilogram of herring used here, will result in a linearly proportional error in the herring biomass estimates.

3.5 *Estimation of Variance of Population Totals*

The estimates of the standard deviation of the population totals given in the results (Table 1) measure only the sampling variance, i.e., they do not include the contributions from the variances of the components of the acoustic integration model (Eq. 1).

In several strata, the survey consisted of a single continuous zig-zag transect, i.e. there was no replication of sampling. In these cases the variance has not been estimated. Where transects have been replicated within a stratum, the variance of the population total has been estimated as follows

$$Var(Y_{tot}) = \frac{1}{n-1} \frac{\Sigma P_i (Y_i - \overline{Y})^2}{\Sigma P_i} \tag{4}$$

where Y_{tot} = stratum total estimate (m^2 sr^{-1}).

n = number of transects in the stratum

P_i = number of samples (i.e., pulses) in the stratum

Y_i = stratum estimate derived from the ith transect

= $A\, s_{v/a}, i$

where A = area of stratum

$s_{v/a}$ = mean area scattering coefficient,

$$\overline{Y} = \frac{1}{n} \Sigma Y_i$$

This estimate of precision is conservative, i.e., it should give relatively large estimates of the variance. I prefer to use this (large) variance estimate in the absence of satisfactory understanding of the reliability of those variance estimators that use measures of the autocorrelation of successive observations obtained along transects, and which ignore trends in the observations. This topic remains to be further investigated.

3.6 *Herring Length Frequencies*

Table 3 lists the locations where midwater trawls were successful in catching herring. The herring length frequencies are shown in Figs 17 & 18. The mean length of herring caught in the Baie de Chaleur was 29.4 cm (s.d.= 1.84); mean length of herring caught in the Sydney Bight was 28.3 cm (s.d.= 4.33).

4. *Results*

4.1 *Introduction*

The cruise results are presented in terms of tonnes of herring, not because I am fully confident in the values of the conversion coefficient (the backscattering cross section per tonne) I use, but because tonnes biomass is a more comprehensible measure than the area scattering coefficient (sr^{-1}).

4.2 *Baie de Chaleur and Region*

The results for this area are as follows:

Region	Stratum	Biomass (t)	% of regional total
Cape Gaspé	N	0	0
Baie de Gaspé	M	0	0
Baie de Malbaie	L	0	0
Isle de Bonaventure	K	8260	14.8
Cap d'Espoir - Pte de Pespébiac (Chandler-Newport)	I/J	22 000	39.3
Western Miscou	G	36 400	9.3
Northern Miscou	H	0	0
Eastern Shippegan Is, - Miscou Bank	E	20 400	36.5
Northern North Point, Western PEI	P	71	0.1
		87 100	

While an estimate of zero is given for stratum L (Baie de Malbaie), herring were encountered in this area, but because of a failure of the acoustic system, they were not recorded by the system.

4.3 *Sydney Bight*

The results for this area are as follows:

Region	Stratum	Biomass (t)
Aspy Bay	AB	5590
Neil Harbour	NH	31 600
	NH (south)	27 300
Wreck Point	WP	59 200
Wreck Point	(Post Stratification & with extra sampling)	
north		34 700
centre coastal		56 000
centre wide		44 000
south		269
Haddock Bank	HB	9870
Sydney	SY	25 700
New Waterford	NW	39 800
Donkin	DON	6120

The Neil Harbor estimates refer to two separate continuous line transects in that area. During the second replication, the northern region was not surveyed because there appeared to be no herring in that part of the stratum.

In the Wreck Pt stratum, different parts of the stratum received different intensities of sampling effort. First a continuous zig-zag transect was run. This covered the southern, centre coastal, and northern substrata. This gave the first estimate in the preceeding list. Because it appeared that herring schools occurred beyond the offshore boundary of the stratum in the central section, an additional substratum was sampled that covered the central region, and extended further offshore. In returning to the this substratum an additional transect was run in the northern substratum. Thus three estimates are possible for the Wreck Pt stratum:

(1) From the single zig-zag transect covering the whole stratum (12 900 sr^{-1})

(2) From the post-stratified estimate for the southern substratum (59 sr^{-1}), plus the estimate from the mean of the two transects in the northern substratum (7600 sr^{-1}) plus the estimate from the single (post stratified) transect in the centre section (12 300 sr^{-1}).

(3) As for (2), but using the estimate from the centre 'wide' substratum rather than the single transect centre 'coastal' sample, 59 + 7600 + 9630 sr^{-1}. These three estimates are as follows:

(1) single continuous zig-zag:	59 200 t
(2) as for (1) but replicated transect in northern substratum	91 000 t
(3) as for (2) but with the estimate for the 'central' substratum from replicated transects in the 'wide' substratum:	79 000 t

If the relative bias of all the substratum estimates was the same, then the values from (1) and (2) should estimate the same population total. Estimate (3) should include the population that is estimated by (1) and by (2) plus that occurring in the marginal area surveyed.

Because the herring in the Wreck Pt stratum appeared to be relatively mobile, it is possible that the differences in the three estimates obtained arise, not from sampling variability, but from changes in the population being sampled. Thus the estimates from (1) is least likely biased while those from (2) and (3), because of the delay in time prior to sampling, could be. Thus no matter which estimate is chosen, some subjectively will be involved in the estimate.

There are at least two possible ways to estimate a regional total when two estimates of a population total have been obtained; if both estimates are unbiased, then a simple mean of the two estimates can be taken, or if one or other of the estimates is believed to be biased, one can be selected as being the least biased. In the Neil Harbor - Bentinck Point area, both in 1984 and 1985, the herring populations encountered appeared to be quite mobile. Thus, large differences in population estimates from two replications are more likely to arise from an actual change in the population size (due to school movement) within a stratum than from sampling variability. For example, there was a change from 57 to 1 in the number of schools encountered in the Neil Harbor region in samples separated in time by approximately 22 hours. In contrast replication of the sequences of transects in the central part of the Wreck Point stratum resulted in little difference in the population estimate, in this case only 21%; these transect replications were only 2.5 hours apart. Thus two population total estimates are possible for the western Sydney Bight stratum:

	low estimate (t)	high estimate (t)
North of Cape Smoky:		
Aspy Bay (AB)	5590	5590
Neil Harbor (NH)	27 300	31 600
South of Cape Smokey		
Wreck Pt (WP1)	59 200	91 000

This gives a range of 92 000 to 128 000 t. Because it appears that the low estimate for Neil Harbour was caused by a reduction in the size of the population over the period the area was surveyed, I judge the high estimate, here, to be best for this stratum. South of Cape Smokey (Wreck Pt), the delay between sampling successive substrata could give rise to'double counting', i.e., schools counted in one substratum moving to another and being counted a second time. Thus I judge the low estimate to be a conservative and appropriate estimate for this stratum, i.e., 59 200 t. Thus, based on these data, my preferred estimate for the western side of Sydney Bight is (5590 + 31 600 + 59 200) 96 400 t.Thus one estimate for all of Sydney Bight is:

North of Cape Smokey	37 200
South of Cape Smokey	59 200
	96 400 t
Southern coast of Bight	81 600
Total (t)	178 000t

Another estimate of the herring biomass occurring along the western edge of Sydney Bight can be obtained from the survey results from two successive nights when zig-zag transects covered a continuous aggregation of herring. (See Figures 13 and 15 for the survey path). On the first night (November 24-25) sampling started just north of Bentinck Point and continued northward finishing at Cape Smokey at daybreak. At this time, the aggregation could no longer be located, and subsequent survey effort indicated that it had formed discrete schools which had moved offshore. It is most likely that the entire aggregation was not sampled on this night. On the following night (November 25-26) sampling started at Cape Egmont and continued southward finishing south of Wreck Point at daybreak. No schools were located near the southern range of the survey area and only a few relatively dispersed schools near Cape Egmont. I am confident that the entire herring aggregation was surveyed on the second night. On both nights a continuous inshore zig-zag pattern was used.

The biomass estimates obtained are as follows:

Night 1:	
South of Wreck Point:	62 700 t
Night 2:	
Cape Egmont - Bentinck Point	119 600 t

Thus two additional estimates for the western side of the Sydney Bight are possible.

Using Nov. 24:	
North of Cape Smokey	37 200
South of Cape Smokey (Zig-Zag Design)	62 700
	99 900 t
Using Nov. 24-25:	
Aspy Bay (randomized transects)	5590
Cape Egmont South (Zig-Zag Design)	120 000
	126 000

The zig-zag design estimates compare with those from the randomized transects design of: 59 200 and 141 000 t respectively. The estimate for Night 1 (south of Wreck Point) was almost identical to that obtained from the randomized transects design, 106.0%, for the same area. The estimate from the zig-zag pattern for Night 2 was 29.9% greater than that given by the randomized transect design, but it was only 97.6% of the highest possible estimate obtained from the corresponding area, i.e., 128 000 t..

If the means of the corresponding estimates (littoral zig-zag and randomized transect design) one taken, the results are:

(1) With results from zig-zag design, Nov. 23-24:

Western Bight average,

(99 900 + 59 200) ÷ 2	79 500
Southern Bight (Haddock Bk, Sydney, New Waterford and Donkin):	81 600
	161 000

(2) With results from zig-zag design, Nov. 24-25:

Western Bight average,

(126 000 + 96 400) ÷ 2	111 200
Southern Bight (HB + SY + NW + DON)	81 600
	192 800

The similarity of these estimates strongly supports the view that the different survey designs, which were used in very different circumstances of herring distribution, did survey the same populations. The details relevant to the 'zig-zag' estimates are given inTable 4:

5. *The Distribution of Herring*

5.1 *Introduction*

Although acoustic surveys of the herring in the southern Gulf and Sydney Bight have been done for only two years, (1984 and 1985) the distribution of the herring encountered was surprisingly consistent. The main difference has been an apparent increase in abundance in 1985 relative to that of 1984.

In the Gaspé region scattered schools were encountered in both years, concentrated in the area from Pte St. Pierre to Grande Rivire. Relatively greater concentrations occurred between Chandler and Newport. During the night the herring in this region formed a near-continuous distribution along the coast, in some cases extending inshore further than was possible to go with the research vessel. Small schools were scattered throughout the waters of Miscou Bank, and in the area west and north of Miscou Island. A similar distribution of scattered schools occurred in depths from 10 to 40 m in the area east of Miscou Is. and Shippegan Island.

In 1985 several moderately large schools were observed while enroute along the northern coast of PEI in the area offshore from Monticello-Long Pt, (i.e. near the eastern end of the Island); no schools were encountered in this area in 1984. Inclement weather prevented completion of the transects planned for this area later during the 1985 cruise so the question of herring abundance in that area in 1985 remains unanswered. No herring were encountered along the eastern coast of the Island (Souris - Cardigan Bay) where the weather enabled survey transects to be completed.

In 1984 a few small schools were encountered along the north-western coast of Cape Breton Island (between White Cape and Cape St. Lawrence), but the same northwesterly gales which prevented sampling along the northern coast of PEI also prevented sampling in this area in 1985. In both 1984 and 1985, the largest concentration of herring encountered occurred in the area between Neil Harbor and Bentinck Point, on the west coast of Sydney Bight. In 1984 there appeared to be both an inshore-offshore movement in the band within 5 nm of the coast and an along-shore movement from north to south of Ingonish. No schools were encountered in Aspy Bay or in St. Ann's Bay in 1984. In 1985 scattered schools encountered in Aspy Bay and large schools in St. Ann's Bay about Ciboux Island.

The herring in the Aspy Bay - St. Ann's Bay area displayed a diel behavior similar to that observed in the Baie de Chaleur between Newport and Chandler. During the day the schools occurred as discrete entities and occurred upto (at least) 5 nm from the coast. At night the herring formed a continuous band-like distribution along the coast. On the first night this was sampled in detail, the distribution extended from about 1 km north of Black Rock to South Ingonish Bay (where sampling ceased), a distance of approximately 10 nm. The width of the band varied from about 200 m to about 1 km. This aggregation was encountered during the morning of November 24th; sampling continued from 0220 to 0600. The following night (November 24-25th) a more extensive aggregation was surveyed. It extended from Cape Egmont, in the north, to about a nautical mile south of Wreck Pt, a distance of 28 nautical miles. Again the width of the aggregation was variable, up to 1 km. The water depth ranged from 40 m to depths too shallow for the vessel to navigate. The vertical distribution of the herring aggregation was up to 30 m in extent. During both nights the sky was cloudless and a bright moon shone. Full moon was on November 27.

The nature of herring school distribution along the south coast of Sydney Bight was similar in 1984 and 1985; scattered schools were found along the coast but occurred most frequently in the region of Glace Bay - New Waterford. Sampling did not extend beyond about 5 nm from the coast, and about 50 m in depth as most schools occurred well inshore from this limit.

In 1985, while en route to Halifax, a number of transect legs were sampled between Main-A-Dieu Passage and Cape Gabarus. At the very end of the inshore leg of the last transect, herring were encountered, and a subsequent search resulted in the location of several schools inshore to where the previous transects had terminated. No estimation of abundance was made for this area. The existence of herring in this area raises several interesting possibilities. Herring distribution at the time of the survey may be continuous from Sydney Bight to much further south, perhaps to Chedabucto Bay and beyond. Future surveys may then ideally continue south along this section of the coast until the herring distribution ceases.

No survey effort was expended along the south-west coast of Newfoundland in 1985 because the survey effort in this area in 1984 found no trace of herring in that area. Consideration should be given to extending the survey to the Banquerau area in 1986 in view of the past herring fishery in that area.

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Table 1

Stratum Measurements

Stratum	Area (nm)^2	Sampling Time(min)	No. of schools	Mean $\Sigma s_{v/a}$ per school	Mean stratum $\bar{s}_{v/a}$	Total $s_{v/a}$ for Stratum	No. of Transects	Coeff. of Deviation %	Biomass (t) *
Western Gulf									
P	271	618	2	3.386×10^{-4}	8.768×10^{-9}	8.149		37	
E	560	1101	46	3.658×10^{-3}	1.223×10^{-6}	2348	3	33.7	10 730
N	136	799	0				2		
M	285	519	0				2		
L	88	624	0				3		
K	90	437	24	6.984×10^{-3}	3.072×10^{-6}	948.2	3	37.0	4 334
I&J	253	1019	47	7.887×10^{-3}	2.910×10^{-6}	2526	2	59.8	11 543
H	95	344	0				2		
G	105	617	82	1.091×10^{-2}	1.160×10^{-5}	4179	4	34.4	19 100
Prince Edward Island									
EP	155.0	544	0						
CB	221.8	829	0						
BP	177.6	483	0						

Stratum	Area (nm)^2	Sampling Time(min)	No. of schools	Mean $\Sigma s_{v/a}$ per school	Mean stratum $\bar{s}_{v/a}$	Total $s_{v/a}$ for Stratum	No. of Transects	Coeff. of Deviation %	Biomass (t) *
Cape Breton									
AB	47.62	256	32	3.924×10^{-3}	3.927×10^{-6}	641			2 932
NH	56.51	272	57	0.1118	1.873×10^{-5}	3630	1		16 590
WP(1)	72.53	821	177	0.01583	2.731×10^{-5}	6793			31 050
WP North	16.90	201	64	0.0296	6.882×10^{-5}	3989	2	50.8	18 230
WP Central/Coast	35.41	330	142	0.0154	5.296×10^{-5}	6432			29 400
CP Central/Wide	43.89	418	65	0.0270	3.356×10^{-5}	5053	4	30.6	23 090
WP South	20.36	127	6	6.296×10^{-4}	4.414×10^{-7}	31			141
HB	29.88	216	2	0.1493	1.106×10^{-5}	1133	5	38.0	5 178
SY	49.01	401	7	0.1259	1.758×10^{-5}	2956	4	38.4	13 510
NW	40.53	527	273	7.632×10^{-3}	3.289×10^{-5}	4572	6	21.3	20 900
DON	30.64	313	50	5.228×10^{-3}	6.690×10^{-6}	703.1	4	29.9	3 213

* Estimate derived from the relation of Halldorson and Reynisson (1983).

Table 2
Transect Sampling Times

Stratum/leg	Start	Finish	Actual Sampling Time*
P1	1630	1711	41
P2	1713	1840	87
P3	1842	2011	90
P4	2013	2145	92
P5	2146	2314	86
P6	2316	0046	90
P7	0046	0231	105
P8	0232	0257	25
1E	0522	1130	365
2E	1151	1820	349
3E	1857	2236	386
1N	1709	2120	251
2N	2120	0148	268
1M	0237	0658	261
2M	0717	1200	283
3M	1200	1615	255
1L	2049	0016	203
2L	0050	0402	57
3L	0415	0758	93
1K	0813	1056	197
2K	1132	1637	182
3K	1648	1824	96
1I	0900	1533	388
2I	1556	2220	382
3I	2229	0138	249
1H	0556	0844	167
2H	1939	2236	174
1G	0853	1130	155
2G	1146	1426	159
3G	1434	1727	172
4G	1727	1939	132
East Point			
2EP	0711	0822	71
3EP	0326	0438	71
4EP	0442	0618	96
5EP	0618	0733	75
6EP	0735	0900	85
7EP	0902	1022	80
8EP	1023	1129	66

Table 2 (Continued)

Stratum/leg	Start	Finish	Actual Sampling Time*
Cardigan Bay			
1CB	1210	1252	42
2CB	1256	1349	53
3CB	1352	1512	80
4CB	1514	1633	79
5CB	1638	1757	79
6CB	1759	1937	98
7CB	1938	2119	101
8CB	2120	2247	87
9CB	2249	0008	78
10CB	0012	0129	78
11CB	0132	0227	54
Beaton Point			
1BP	0914	0955	41
2BP	0957	1110	73
3BP	1110	1219	69
4BP	1223	1339	76
5BP	1340	1449	68
6BP	1454	1623	89
7BP	1623	1731	68
8BP	1737	1904	87
Wreck Point			
1WK1	2018	2043	26
1WK2	1952	2017	25
1WK3	1923	1952	29
1WK4	1856	1922	26
1WK5	1822	1855	33
1WK4	0523	0549	26
1WK5	0553	0619	25
1WK6	0619	0648	29
1WK7	0650	0731	42
1WK8	0732	0815	44
1WK9	0816	0850	34
1WK7 (repeat)	0850	0913	35
1WK9 (repeat)	0926	1005	39
1WK10	1005	1042	37
1WK11	1044	1149	30
1WK12	1151	1221	31
1WK13	1223	1252	29
1WK14	1253	1319	26
1WK15	1322	1344	22
2WK	1416	1609	100
3WK	1626	1816	103
4WK	1826	2011	103
5WK South	0658	1001	103

Table 2 (Continued)

Stratum/leg	Start	Finish	Actual Sampling Time*
5WK North	1001	1135	93
1HB	2113	2202	47
2HB	0119	0214	55
3HB	0223	0317	53
4HB'	0158	0408	55
4HB"	2047	2209	80
5HB	2222	0026	116
1SY	2204	2334	86
2SY	2340	0119	99
3SY	0327	0636	101
4SY	0026	0156	90
1NW	0639	0817	97
2NW	0829	0955	81
3NW	1002	1137	83
4NW	1740	1910	88
5NW	1917	2130	66
6NW	2146	2317	91
1Don	1140	1255	73
2Don	1304	1440	90
3Don	1443	1602	80
4Don	1612	1727	73
Z1	0034	0105	31
Z2	0106	0122	16
Z3	0124	0144	20
Z4	0145	0154	9
Z5	0157	0209	13
Z6	0211	0220	10
Z7	0221	0230	10
Z8	0231	0245	14
Z9	0246	0258	13
Z10	0300	0302	2
Z11	0303	0305	2
Z12	0307	0316	10
Z13	0317	0326	9
Z14	0327	0342	15
Z15	0342	0356	14
Z16	0357	0413	15
Z17	0413	0427	14
Z18	0427	0444	17
Z19	0445	0457	7
Z20	0457	0509	12
Z21	0509	0518	8
Z22	0519	0529	10
Z23	0529	0536	6

Table 2 (Continued)

Stratum/leg	Start	Finish	Actual Sampling Time*
Z24	0536	0546	10
Z25	0547	0559	13
Z26	0707	0720	13
Z27	0721	0744	21
Z28	0744	0810	26
Z29	0811	0836	25
Z30	0836	0847	11
Z31	0848	0854	6
1NH	0922	1409	272
2NH	1135	1707	306
1AB	1410	1941	226
Z49	1942	1951	9
Z48	1952	2002	10
Z47	2033	2041	8
Z46	2041	2049	8
Z45	4050	2055	5
Z44	2055	2100	5
Z43	2101	2107	10
Z42	2107	2113	7
Z41	2114	2120	6
Z40	2120	2127	7
Z39	2127	2134	7
Z38	2134	2138	4
Z37	2139	2145	6
Z36	2145	2149	4
Z35	2151	2158	6
Z34	2158	2206	7
Z33	2206	2213	7
Z32	2214	2219	6
Z31	2221	2229	7
Z30	2229	2239	10
Z29	2239	2254	15
Z28	2256	2309	13
Z27	2310	2324	14
Z26	2324	2339	15
Z25	0104	0108	4
Z24	0109	0120	11
Z23	0120	0121	1
Z22	0122	0127	5
Z21	0130	0132	2
Z20	0132	0143	10
Z19	0144	0148	4
Z18	0149	0159	10
Z17	0159	0206	8
Z16	0207	0214	8
Z15	0341	0351	10
Z14	0351	0406	15

Table 2 (Continued)

Stratum/leg	Start	Finish	Actual Sampling Time*
Z13	0409	0423	14
Z12	0423	0436	12
Z11	0437	0444	7
Z10	0449	0448	3
Z9	0449	0507	18
Z8	0507	1525	18
Z7	0527	0536	8
Z6	0537	0547	10
Z5	0548	0559	11
Z4	0600		
Z3		0630	30
Z2	0630	0646	16
GA	2001	0020	254

* N.B. Actual sampling time may be less than the time elapsed between start and finish because of time spent fishing, etc.

Table 3
Locations of Successful Midwater Trawl Sets

Set	Location	Latitude	Longitude	No. Measured	l(cm) (total length)	s.d.
1	Newport	48 14 60	64 43 00	206	29.9	1.84
2	Newport	48 15 80	64 43 20	206	28.9	1.84
2	New Waterford	46 17 89	60 04 98	5	30.7	3.27
3	New Waterford	46 19 15	60 05 00	83	25.6	4.46
6	Ciboux Shoal	46 24 68	60 21 77	207	31.5	2.42
7	Cape Smokey	46 37 23	60 20 15	216	29.4	4.48
8	Cape Smokey	46 38 60	60 20 27	209	26.4	3.92
9	Wreck Cove	46 35 20	60 21 75	215	28.7	4.13
10	Gobarus Bay	45 51 28	60 01 16	234	26.6	3.74

l for the Baie de Chaleur sets = 29.4 cm

l for the Sydney Bight sets = 28.3 cm

Table 4

Data pertaining to calculations for zig-zag survey. Western side of Sydney Bight, November 24-26.

	South of Wreck Pt. (Night 1)	Cape Egmont (Night 2)
Area Surveys (nm^2)	8.065	16.43
Sampling Time (mins)	211.3	351.0
No. of Transects Across Aggregation	23	45
Total Scatter (sr^{-1})	13700	26 200
Biomass (E)	62 600	119 600

Table 5

System and Calibration Data

	dB
First Part of Cruise	
Transmitter:	
Instruments Inc. SPG-4C # 102	126.8
Receiver	-78.3
Second Part of Cruise	
Transmitter:	
Instruments Inc. SPG-4C # 001	129.6
Same Receiver as first part of cruise	

Transducer used: AMETEK 50 kHz 187 LT-5., Δ narrow beam only

Calibration at Acoustic Barge, Bedford Basin, 21 May 1986 (Dowd, pers. comm.).

Figure 1

Areas Surveyed during November 1985

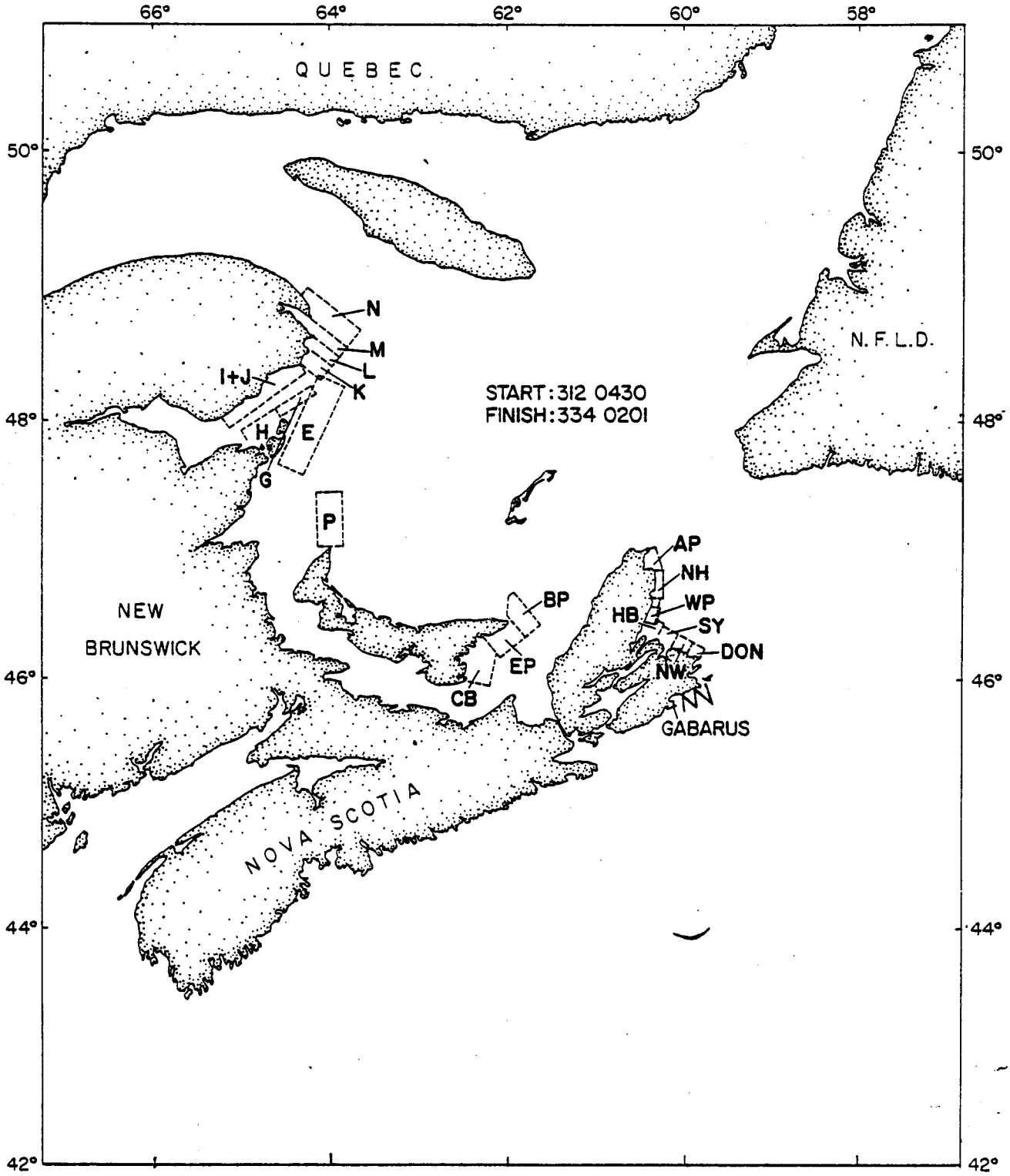

FIGURE 2

STRATUM P : 8 - 9 NOV. 1985

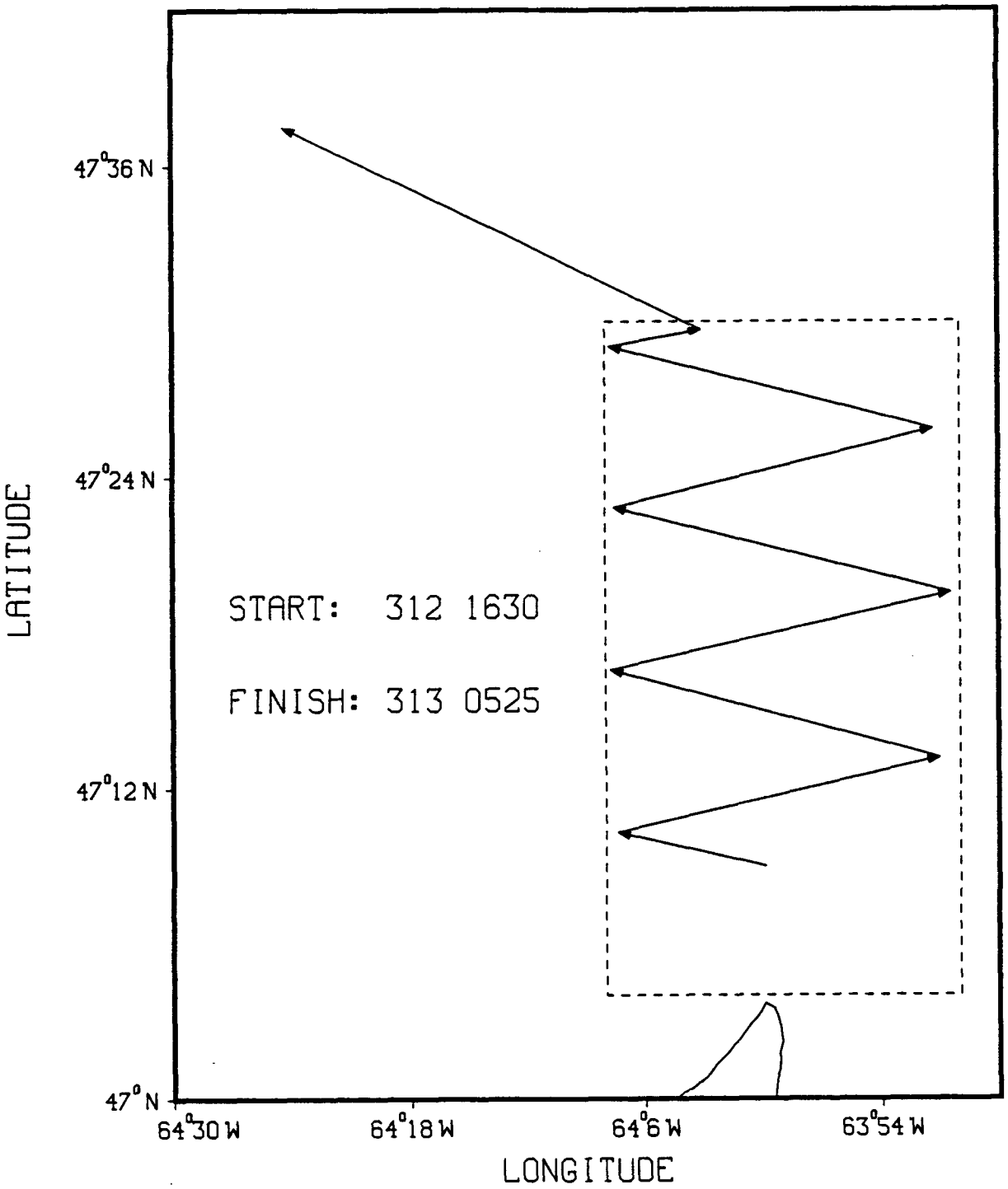

FIGURE 3

STRATUM E : 9 - 10 NOV. 1985

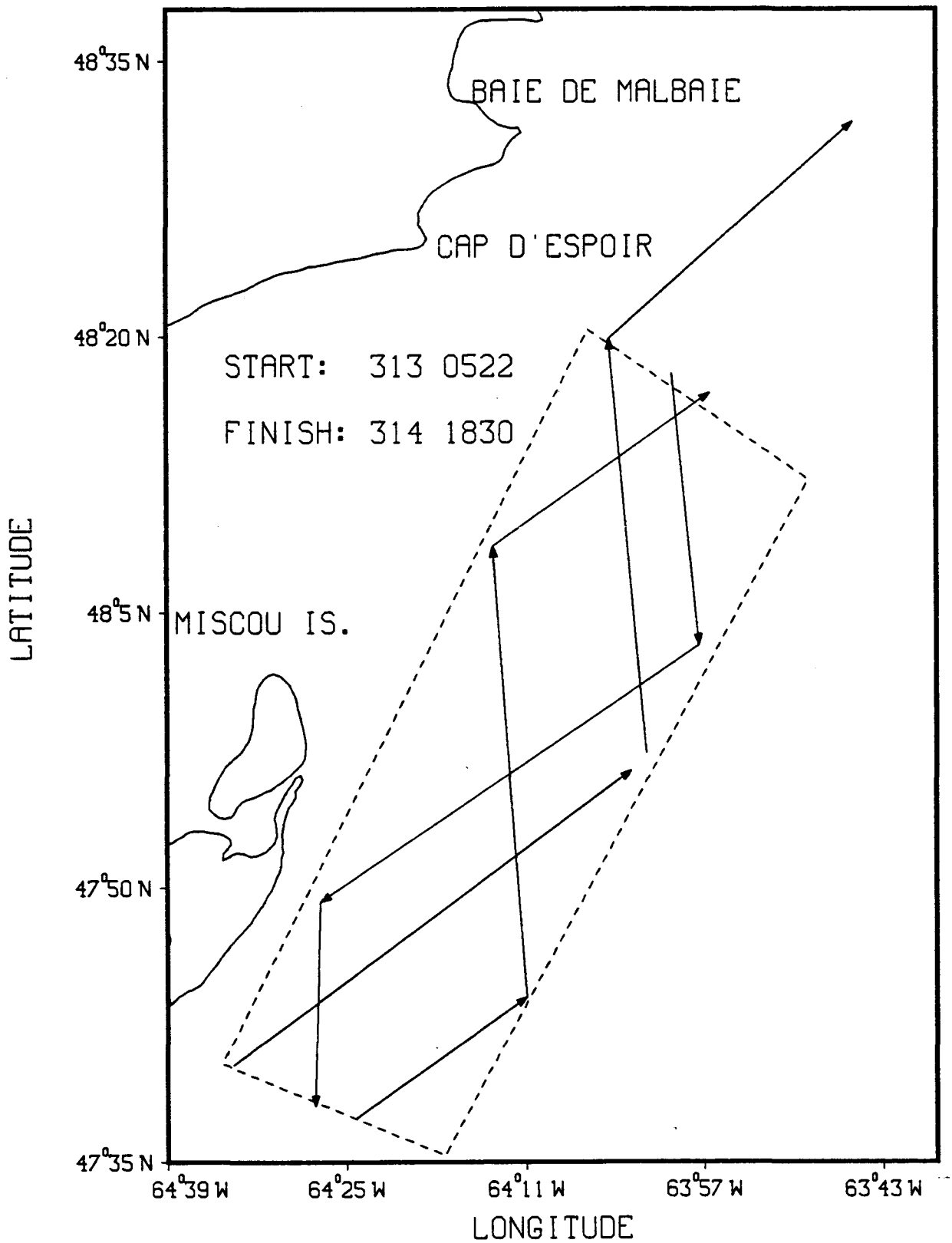

FIGURE 4

STRATUM N : 10 - 11 NOV. 1985

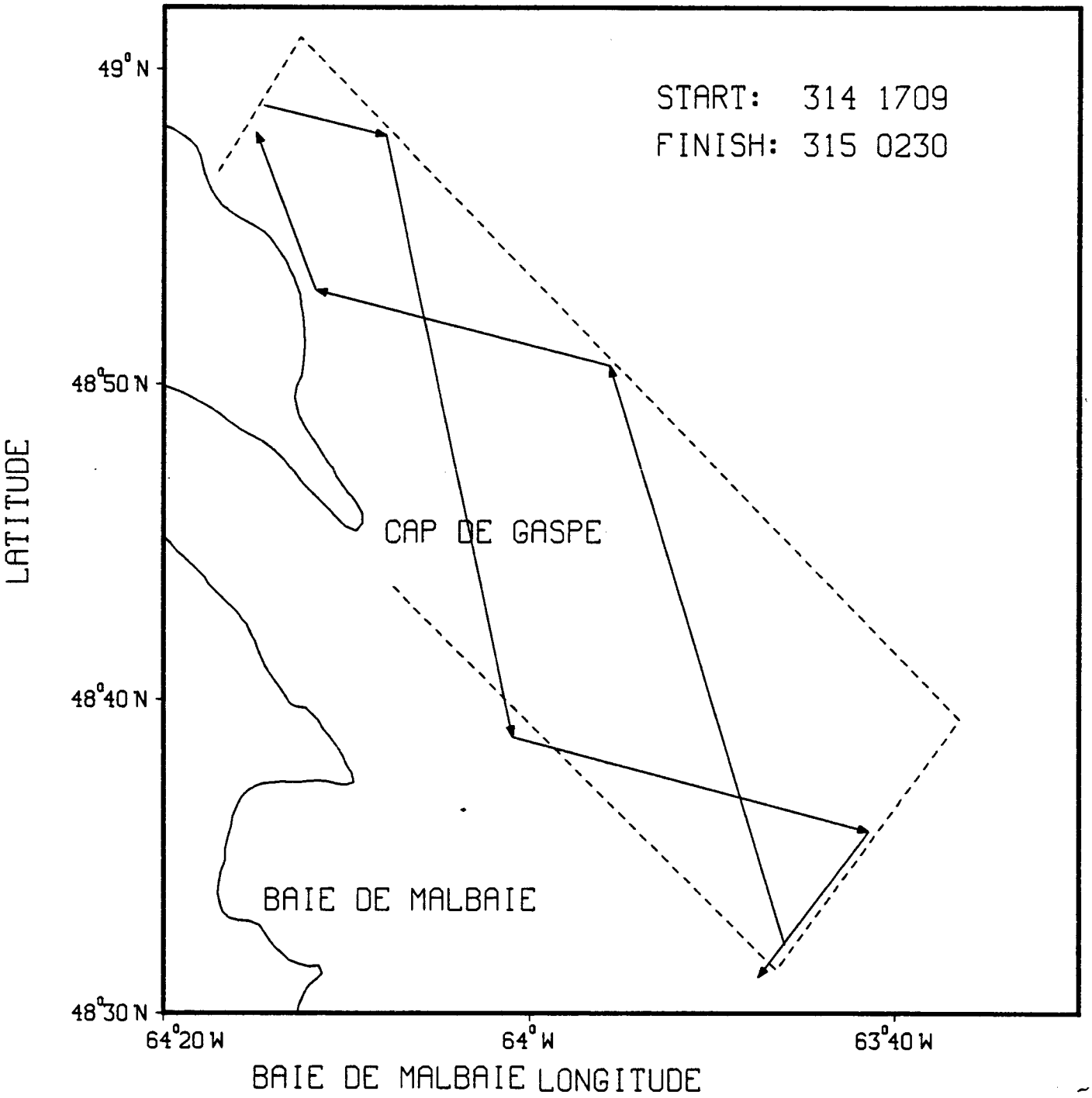

FIGURE 5

STRATUM M : 11 NOV. 1985

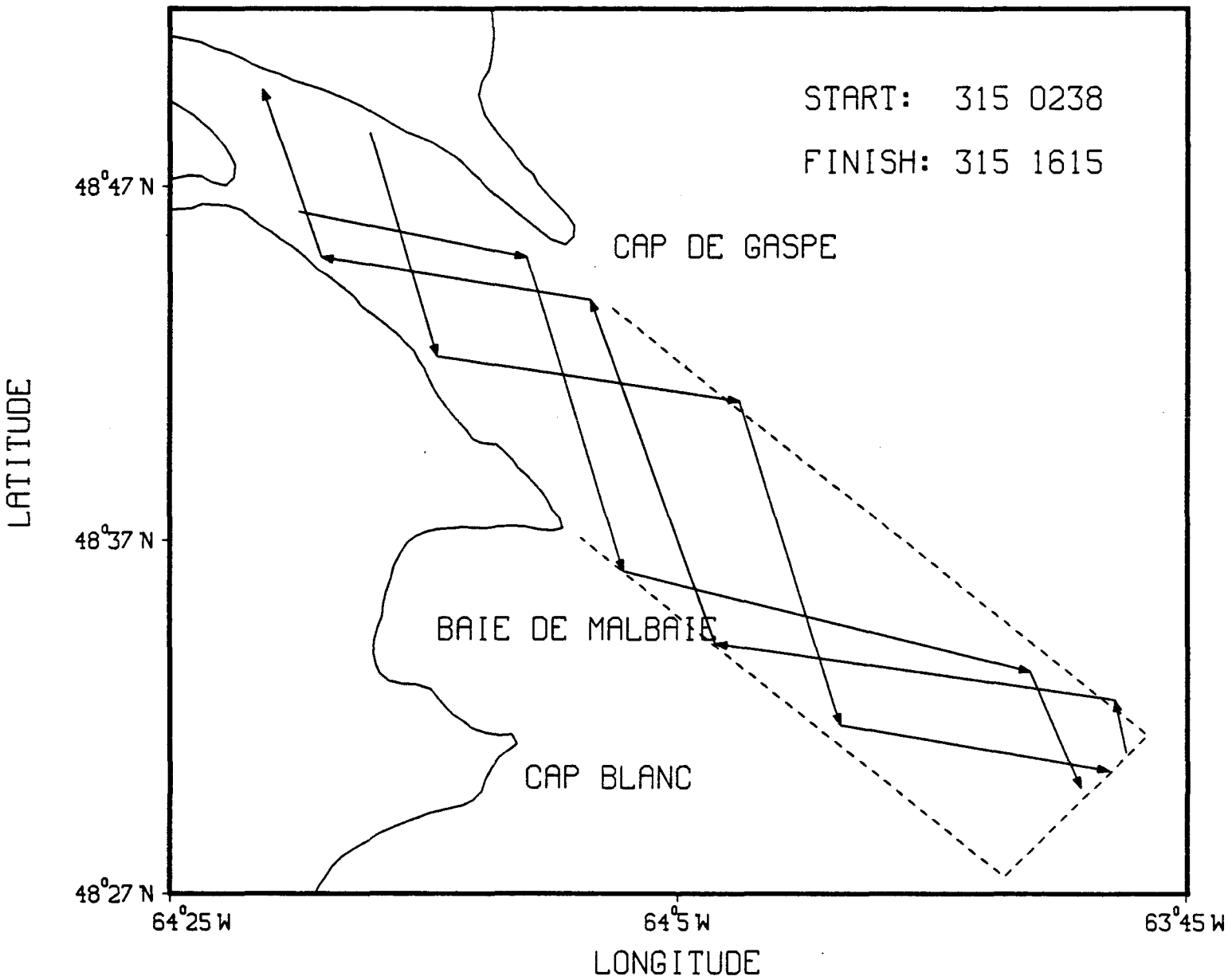

FIGURE 6
PTE ST-PIERRE - CAP D'ESPOIR
11 - 12 NOV. 1985

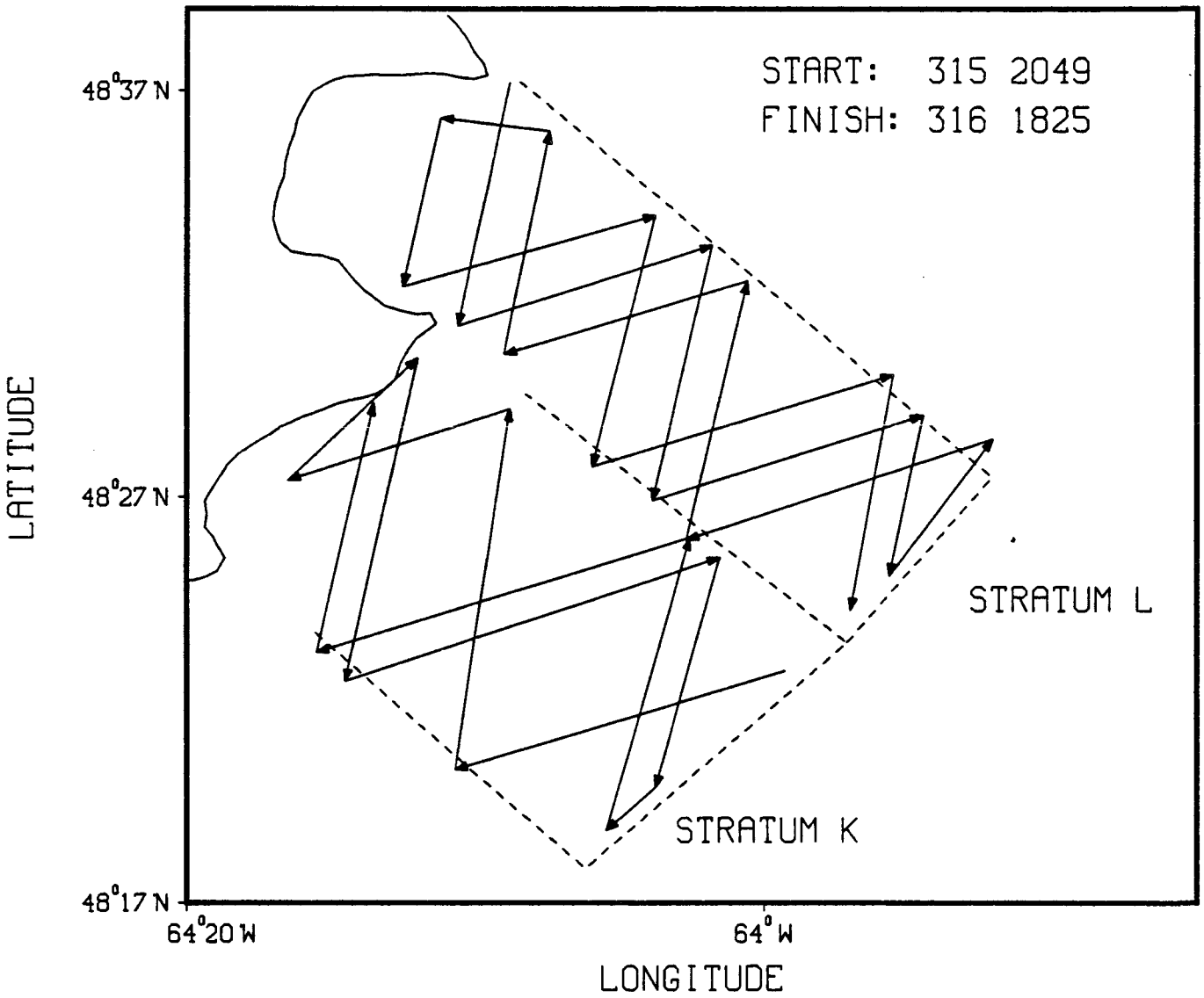

FIGURE 7

STRATUM I + J : 13 - 14 NOV. 1985

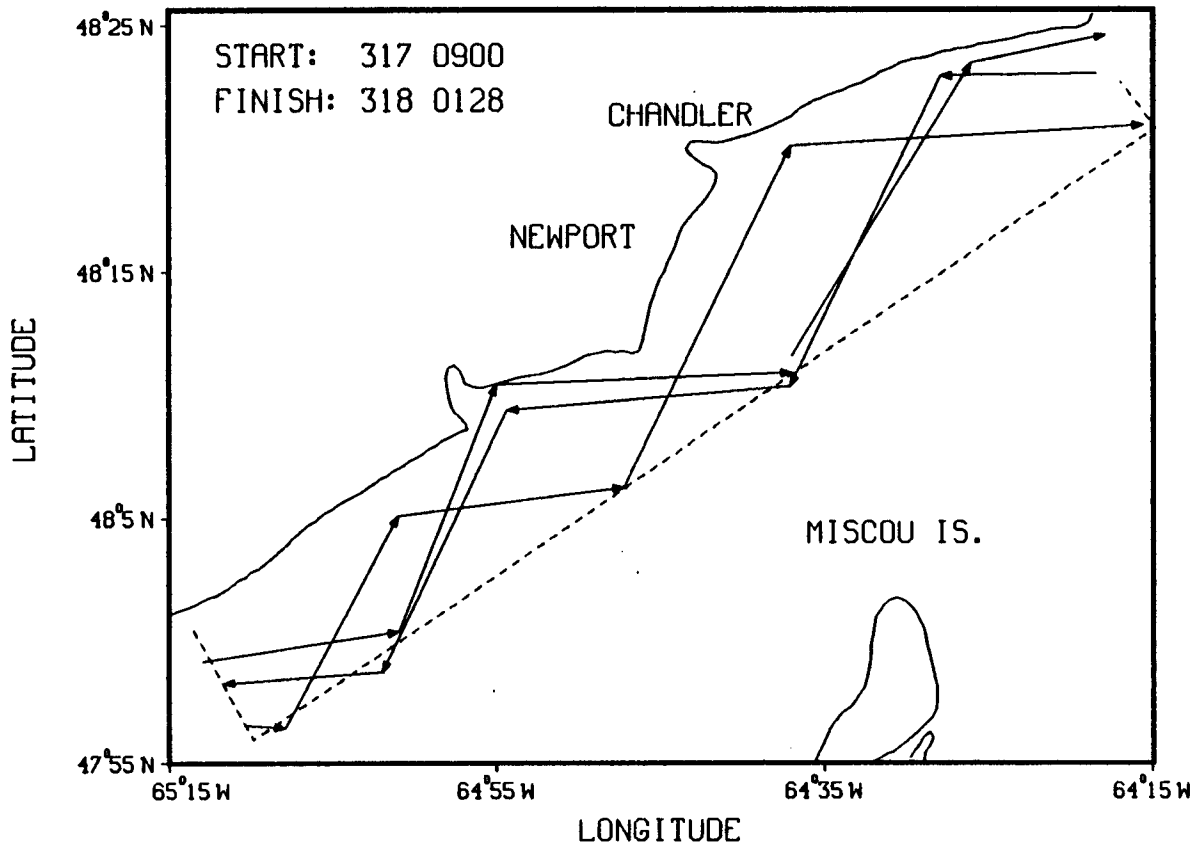

FIGURE 8

STRATUM G + H : 14 NOV. 1985

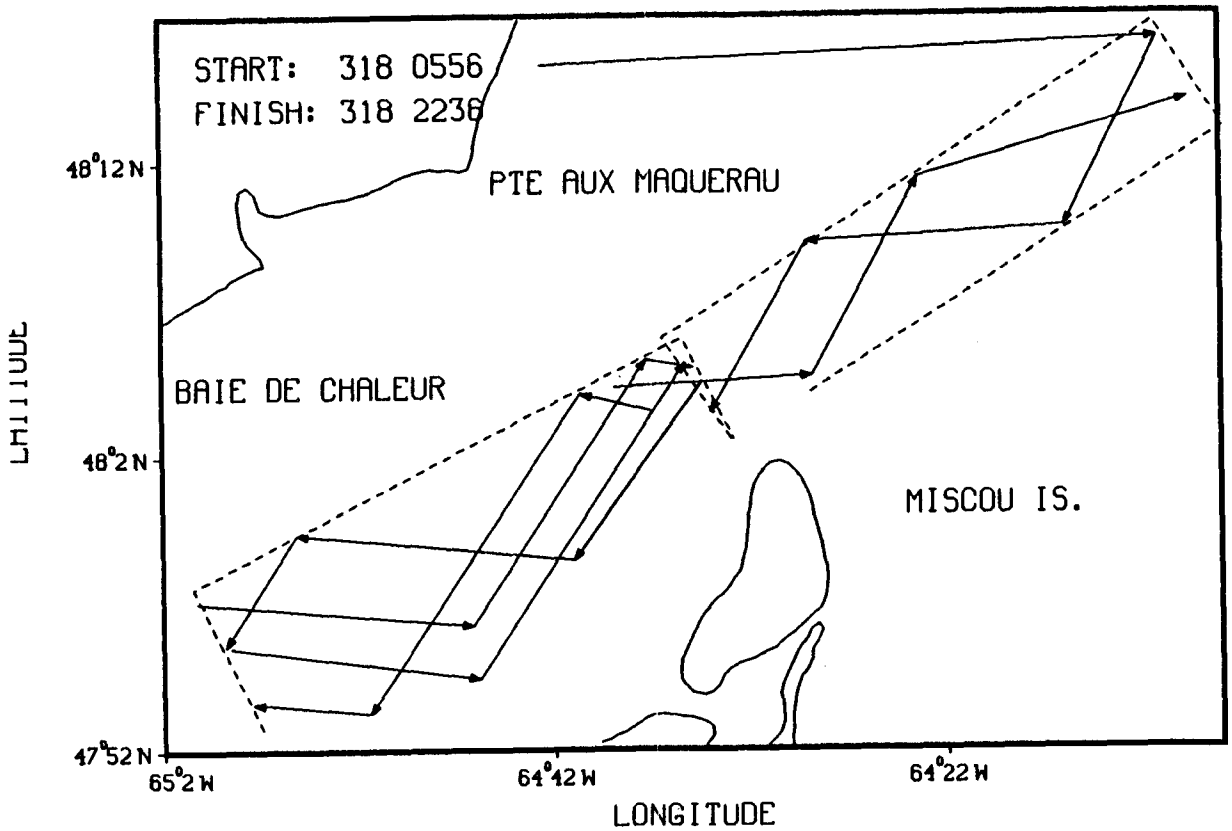

FIGURE 9

EASTERN PEI : 27 - 28 NOV. 1985

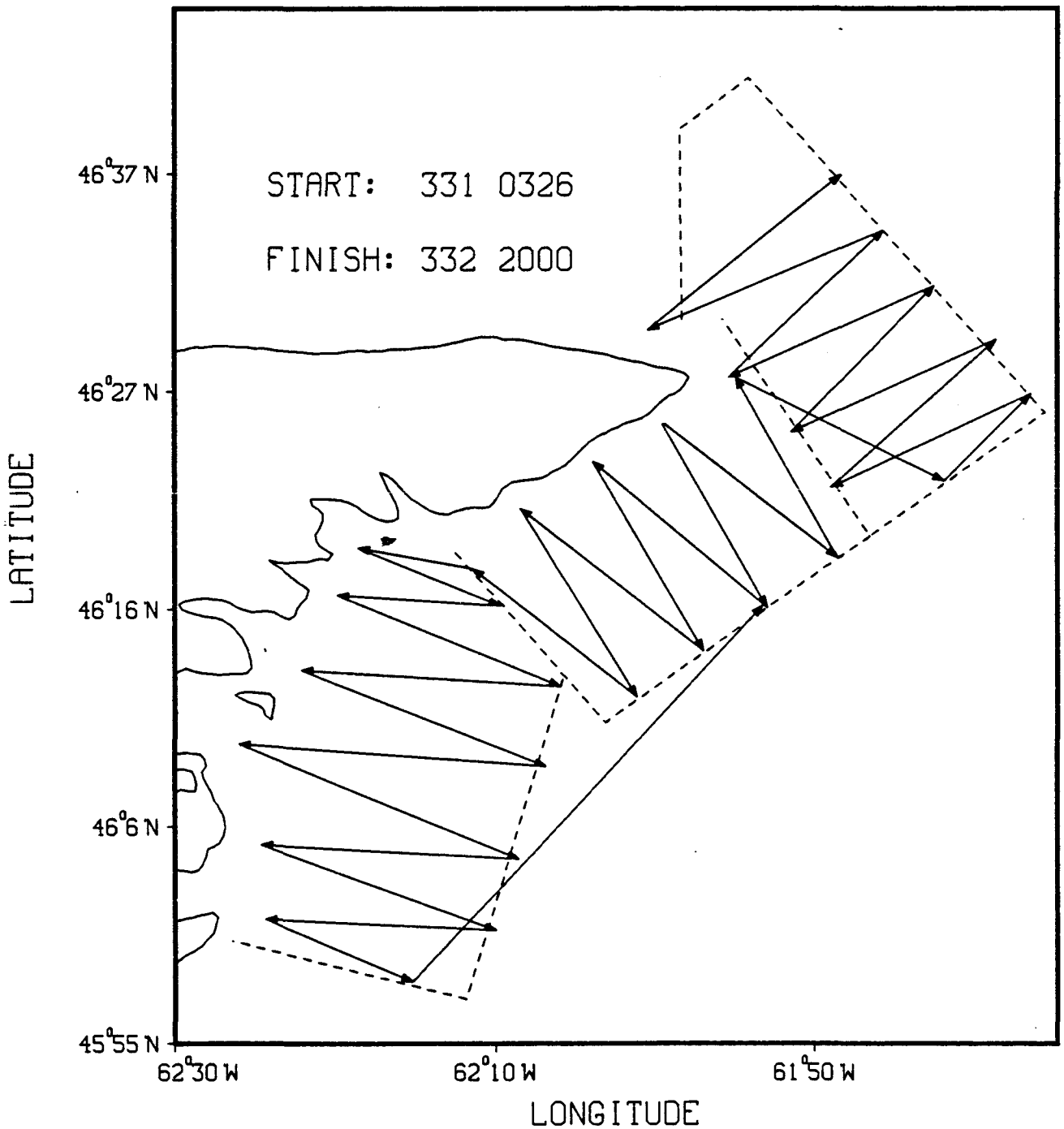

FIGURE 10

SYDNEY - HADDOCK BANK : 22 - 25 NOV.

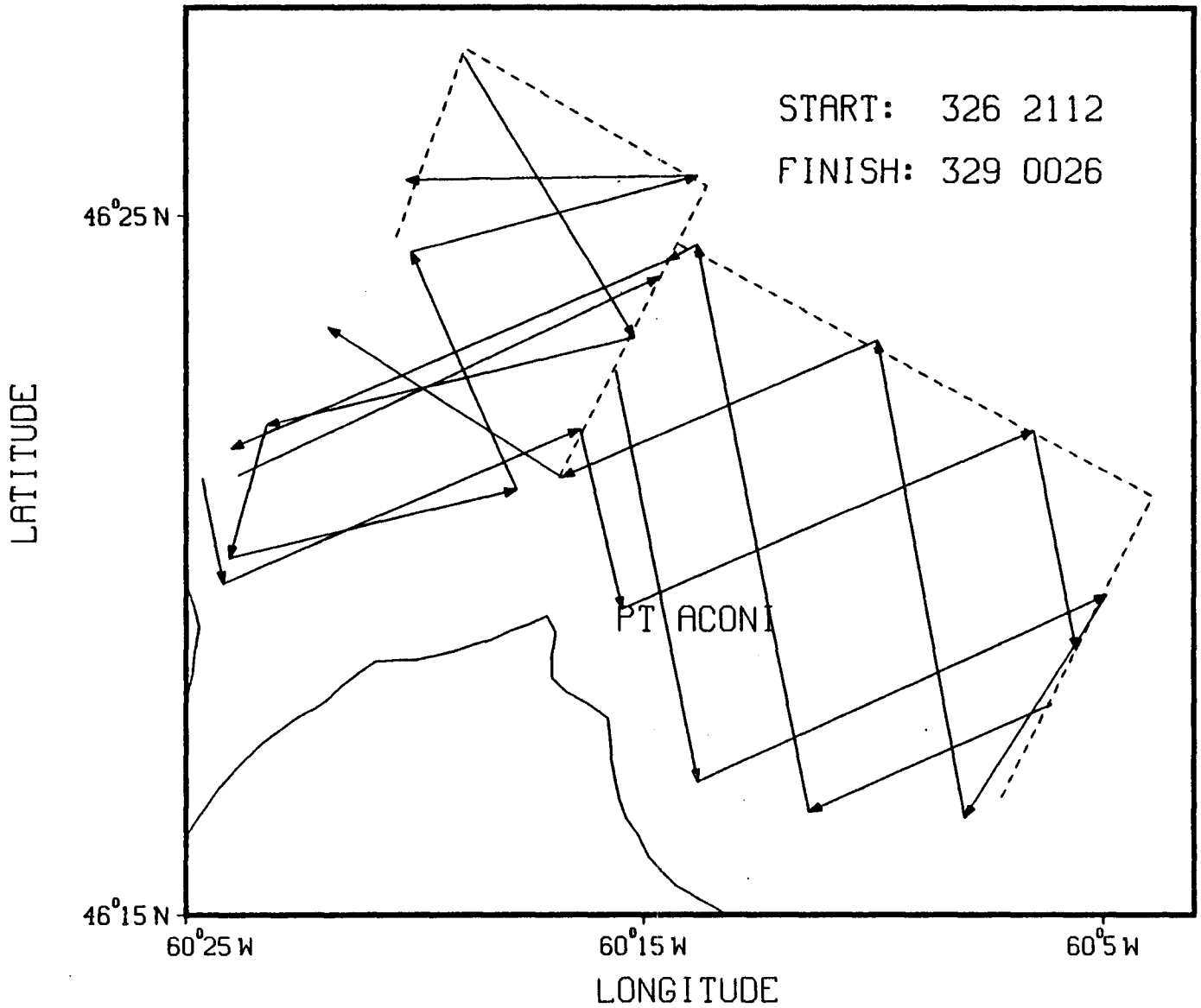

FIGURE 11

NEW WATERFORD - DONKIN : 23 NOV.

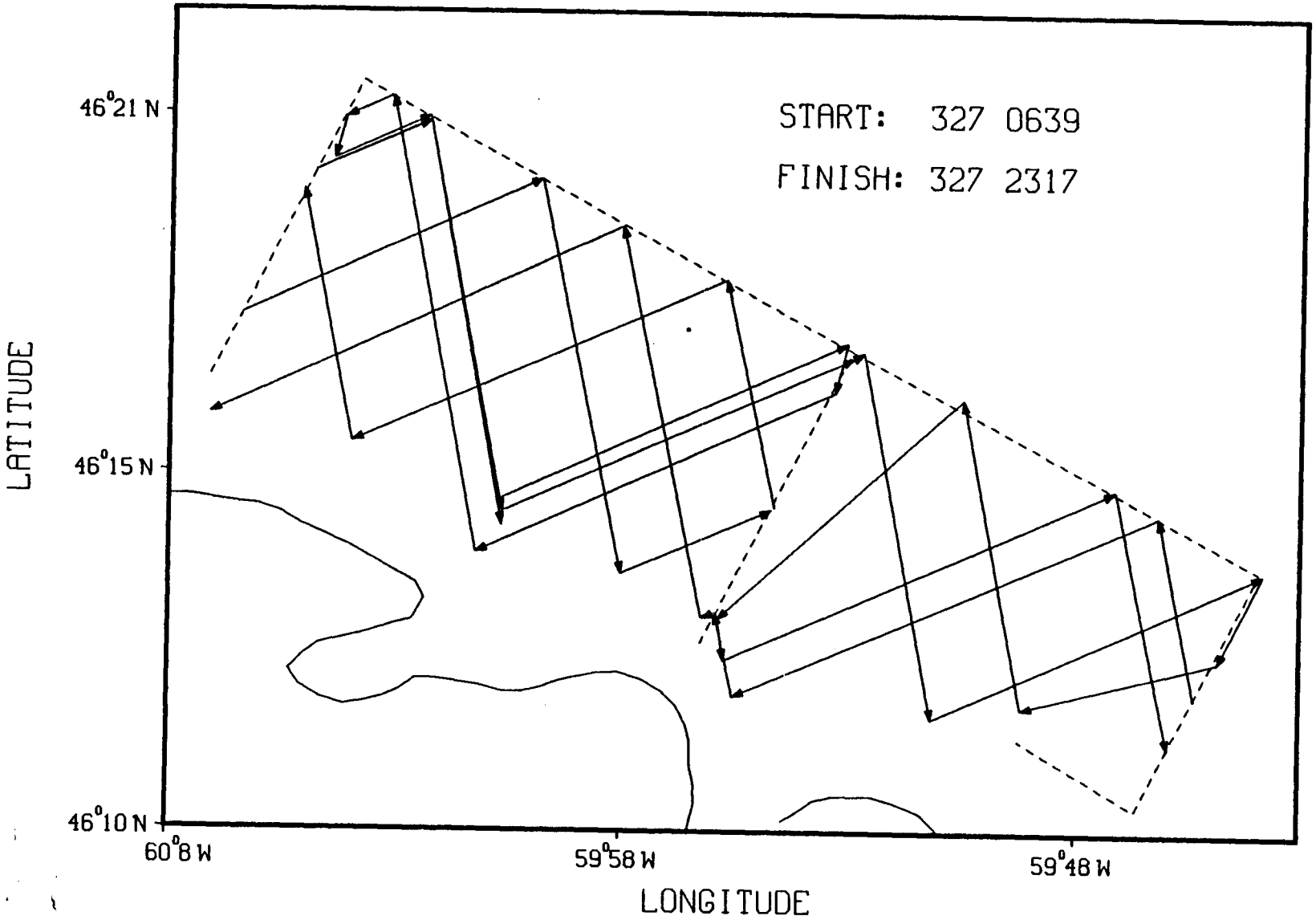

FIGURE 12

WRECK PT : 22 - 24 NOV.

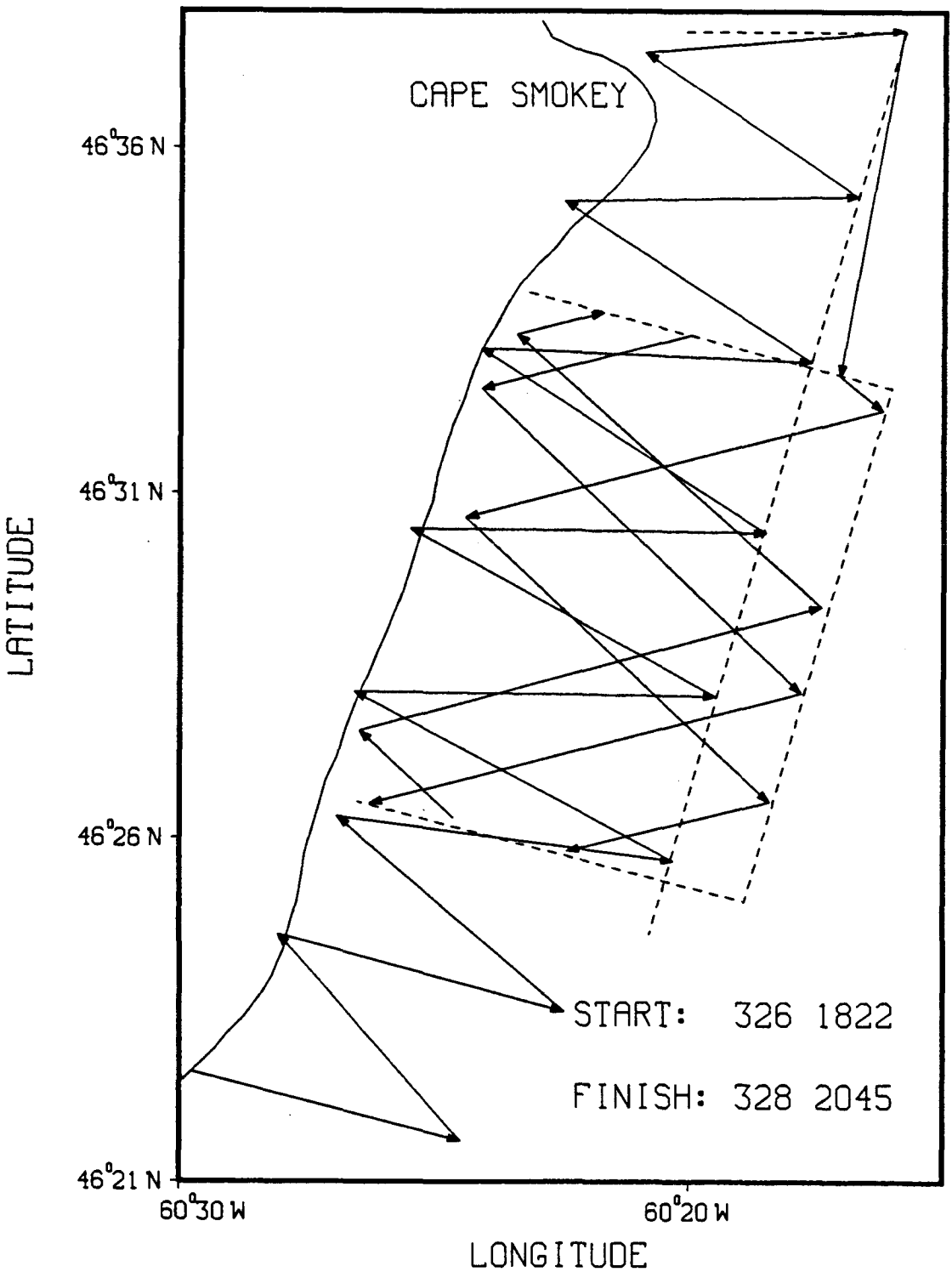

FIGURE 13

INSHORE ZIG-ZIG 25 NOV.

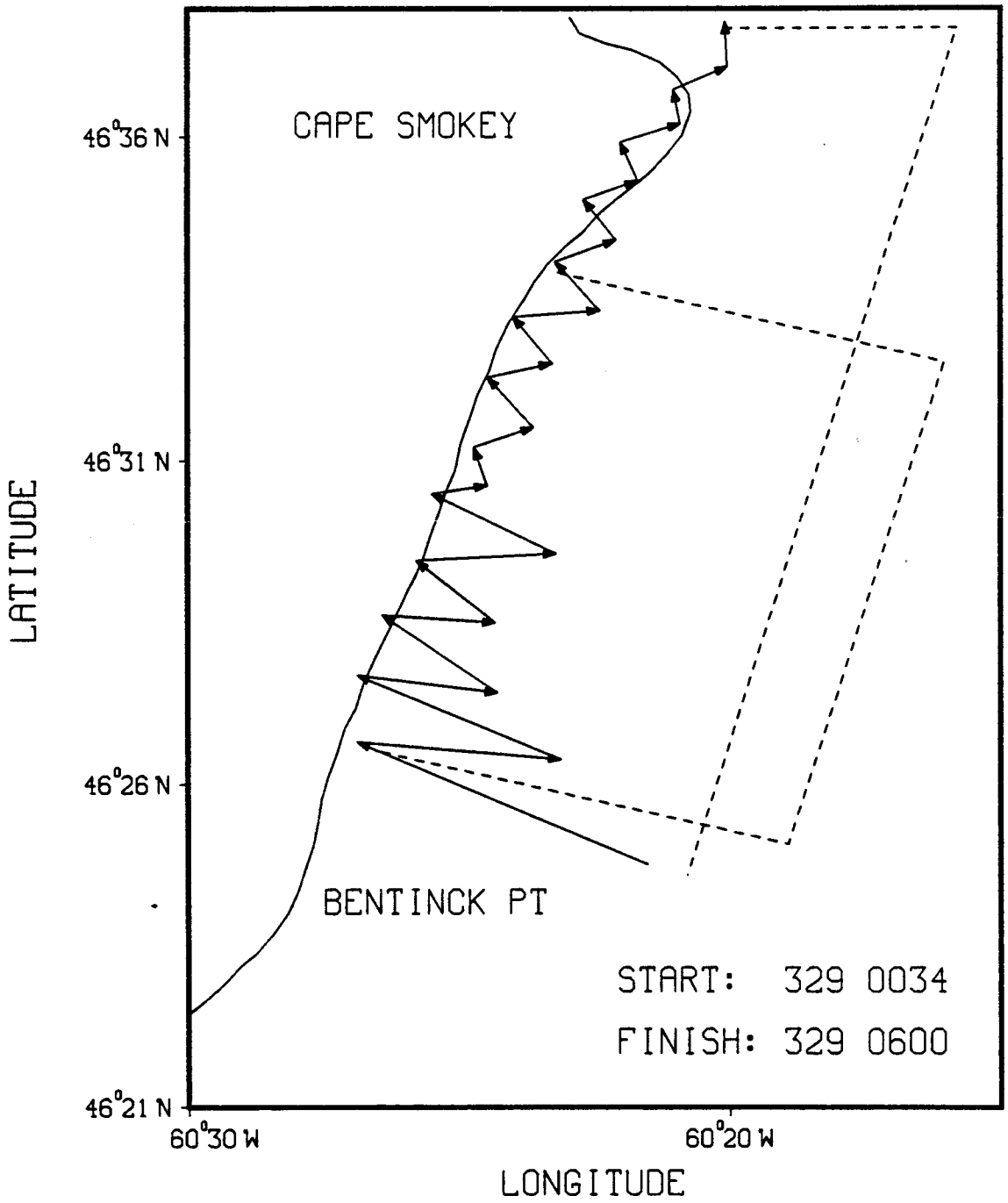

FIGURE 14

NEIL HARBOR 25-26 NOV.

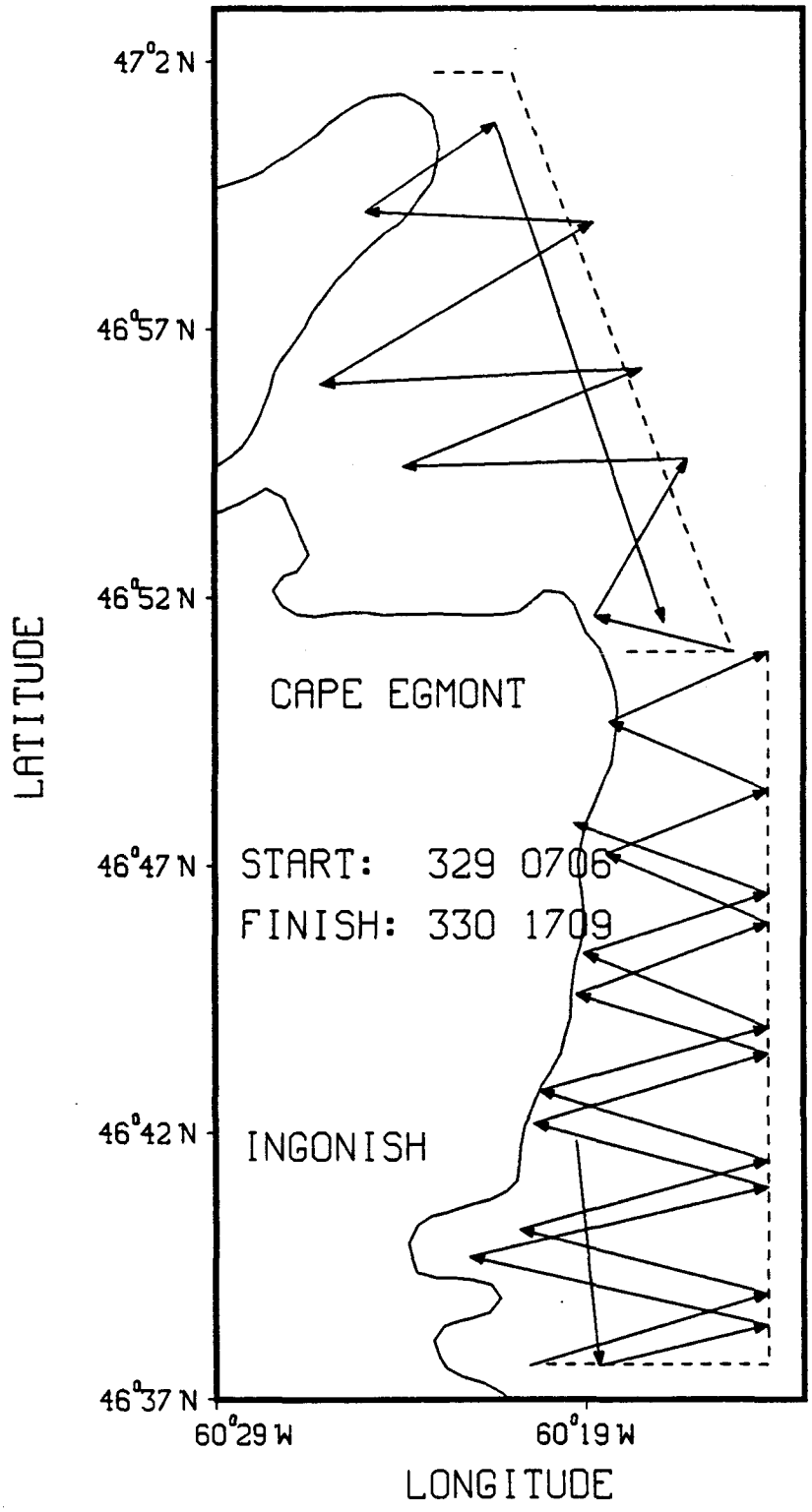

FIGURE 15

INSHORE ZIG-ZAG : 25 - 26 NOV.

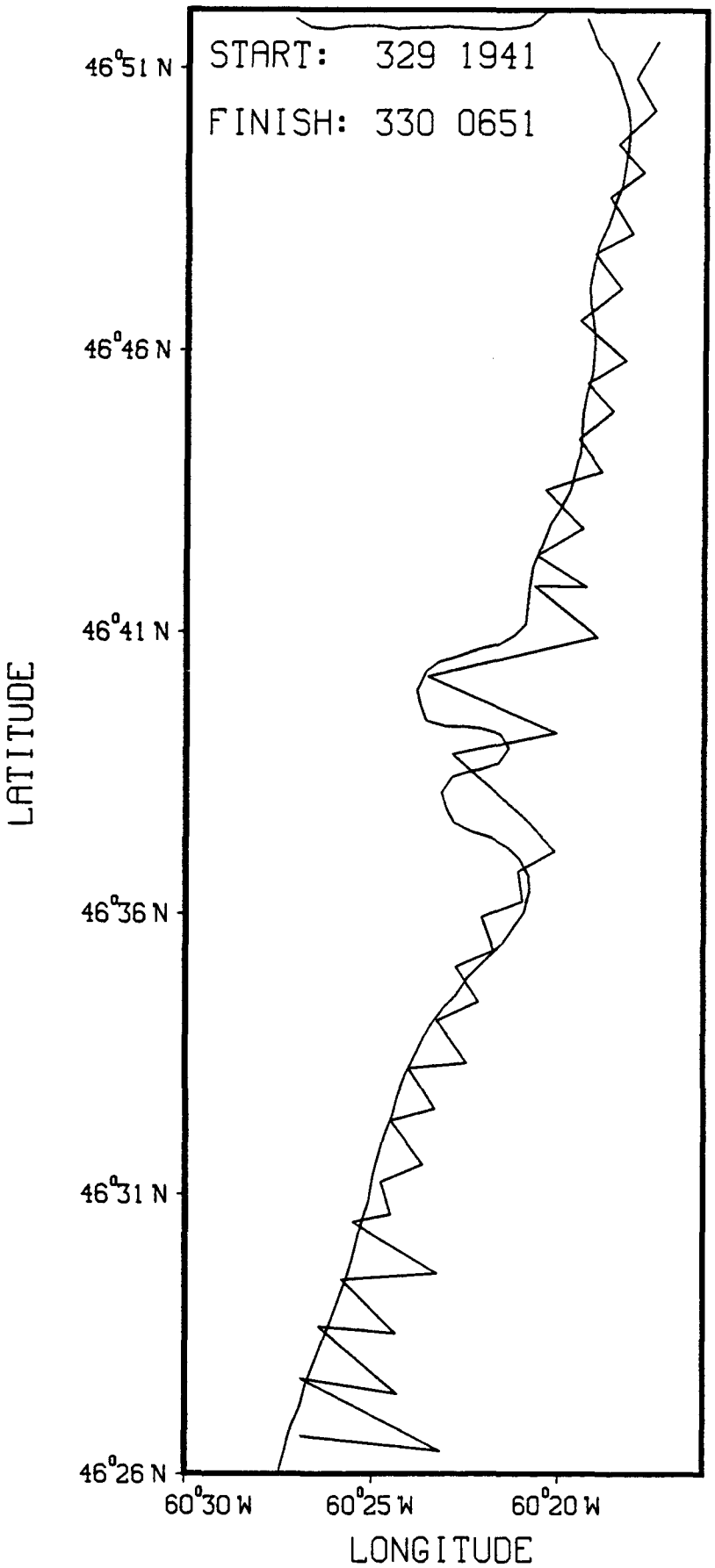

FIGURE 16

GABARUS BAY 28-29 NOV.

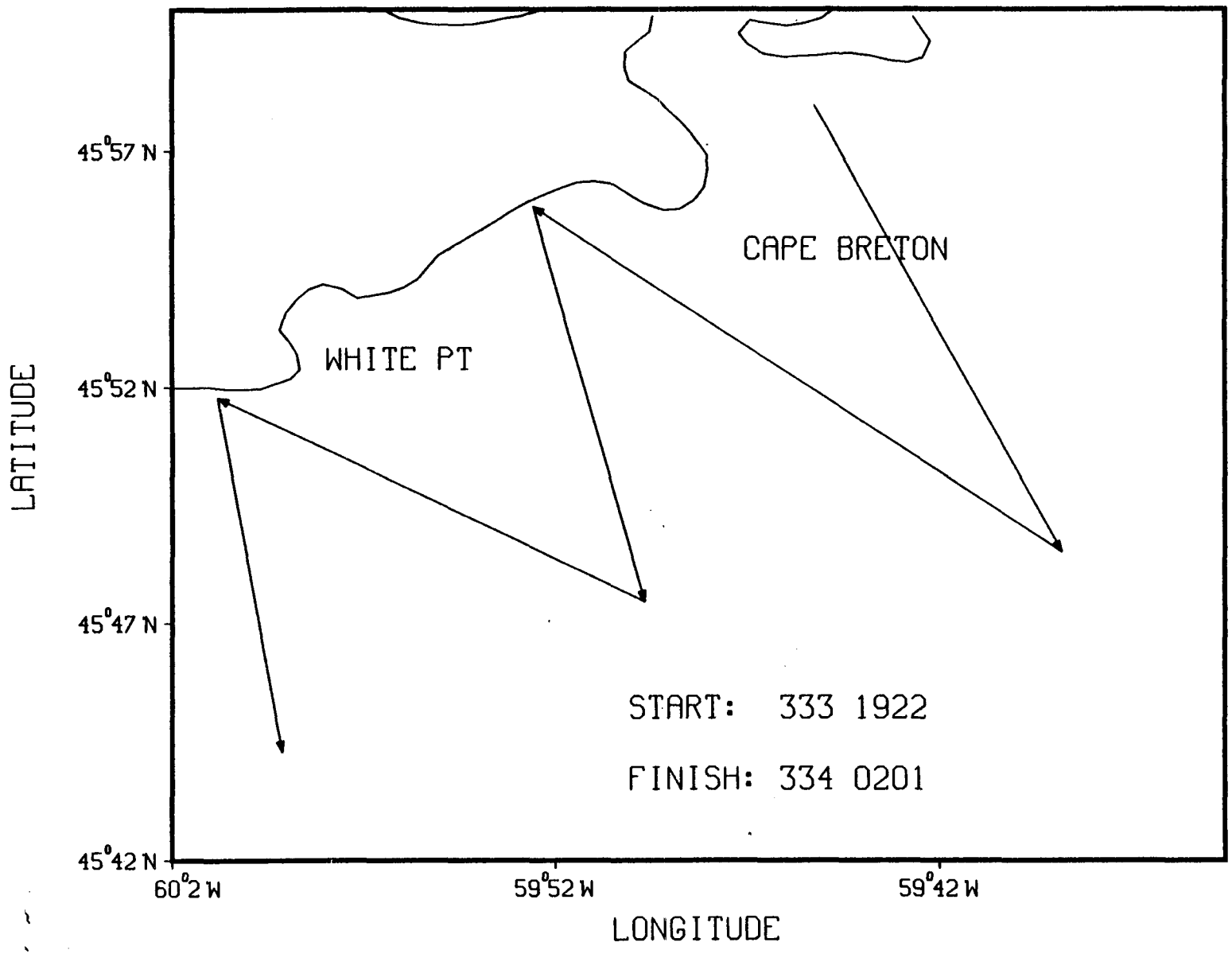

Figure 17

Herring Length Frequencies: Sets 1 and 1b are from the Baie de Chaleur, sets 9 and 10 from Sydney Bight

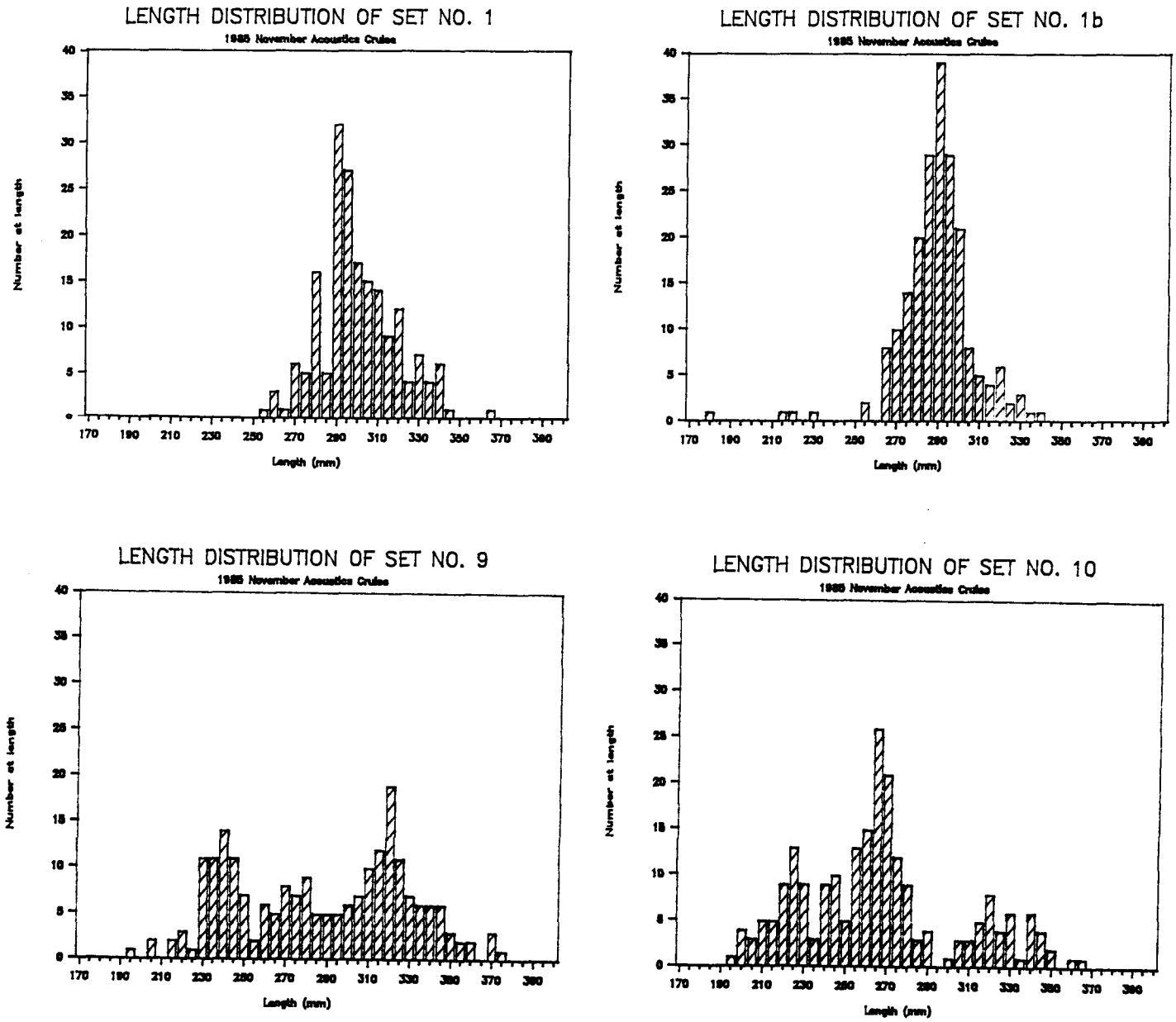

Figure 18

Herring Length Frequencies, Sydney Bight