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Why Skippers Skip Grounds:

A Probabilistic Decision Model for Whether a Skipper Continues Fishing on the Same or Change to Some Other Ground, Based on Data From the West Greenland Shrimp Fishery.

by

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Abstract

This paper presents a probabilistic decision model of whether a skipper makes his next haul on the same ground or change to some other ground provided he does not return to port. The decision model is based on catch rate information only. The probabilities for three different levels of catch rates of whether to remain on the same ground or not, are estimated for five shrimp trawlers fishing during the fourth quarter in NAFO Division 1B off West Greenland. These estimates show an increased tendency on the part of the skipper to change ground, if the catch rate is low, but also that the probabilities for remaining are for all three levels of catch rates above 80 %.

Gear Selectivity/Technical Interactions Symposium

Introduction

Closing areas to fishing, possibly only for some limited period of the year, is one of several measures applied in fisheries management. Predicting the effect of such boxes, requires a model of how the fisheries will react to a box restriction imposed upon them. Therefore insight into the decision process of how skippers choose their fishing grounds must be available. This present paper investigates a simple model of this decision process based on information of catch rates.

A skipper may decide to skip or remain on the same ground based upon

- the result of the latest haul(s)
- information provided from outside e.g. over the radio on catch performance of other vessels, weather forecast, water supply, freezer storage limitations
- factors outside the catch rates e.g. prices reported over radio from the landing auctions

Both under the first and the second assumption low catch rates cause a change of fishing ground, while good catch rates induce the skipper to remain on the same ground. The second assumption is difficult to investigate since little is known about the communication between vessels.

However factors other than catch rates e.g. prices, would probably mainly affect a decision whether to land the catch or to continue fishing. Therefore, this analysis excludes data for the last ground before returning to port. As long as the vessel is at sea, it will probably attempt to optimize its revenue from fishing.

The paper investigates whether the catch rate affect the skippers decision on where to make the next haul provided he continues to fish.

The data analysed in this paper are from a particular simple example, the shrimp fishery off West Greenland. This fishery has no commercially important by-catch and the vessels are specialized shrimp trawlers with no alternative options. The vessels operate approximately 30 days at sea with 4-5 hauls per day, each haul with a duration of about four hours at 2 - 2.5 knots.

The study is further simplified as only data from five trawlers owned by the same company are included in the analysis. These five trawlers all operated in the same general area during the fourth quarter of 1990.

Material and Methods

All Greenlandic fishing vessels above 50 GT are under legal obligation to keep a fishing logbook on board and in this register each haul giving date, time, position, depth, duration and catch in weight by species. These logbooks are submitted to the Greenlandic fishing authorities and to the Greenland Fisheries Research Institute.

The data used for the present investigation refer to the operations in the fourth quarter of 1990 of five trawlers all belonging to the same trawler company. During this period these trawlers were fishing the same area on West Greenland in Division 1B, where they made thirteen fishing trips or 1491 hauls. Fig 1a - 1e shows the position of each haul by vessel. These trawlers at that time all had sufficient overall shrimp quota. However, West Greenland waters are managed in two areas each having its own quota and the quota for the southern area was rather short, this could affect the geographical distribution of the catches, but this is not expected to have had any major influence on their fishing behaviour.

The aim of this paper is to investigate <u>why skippers skip fishing grounds</u>, and we had to define a 'fishing ground'. Changing a fishing ground involve steaming and a vessel was said to fish the same ground as long as no major steaming took place. The average duration of a haul is approximately 4 hours at 2 - 2.5 knots making the average distance between the start of two haul less than 10 nautical miles. Therefore, somewhat arbitrary, a fishing ground was defined by specifying that a new ground was entered, if the start of the next haul was more than 15 nautical miles away from the start of the previous haul. Fig. 2 shows the frequency distribution of the distance between the start position of a haul and the start position of the next haul. This distribution levels off quite fast between 10 to 15 nm.

The five trawlers mainly fished seven different grounds during this period, see fig. 1, and all vessels changed grounds several times during each trip, in total about 140 shifts between grounds took place. Most trips lasted for about 30 days and the decision to return to port could be caused by lack of water, full storage, prices obtained at landing or otherwise. As such a decision is made on other considerations than catch rates, data from the last ground fished before returning to port are excluded from the analysis.

The catch rates (kg per haul ignoring differences between haul duration) were classified into three groups A: bad, B: average and C: good. The size of the five vessels differs and so do their average catch rates. Average catch rate and its standard deviation were calculated for each vessel for the entire fourth quarter of 1990, see table 1. Based upon this, an A haul was defined as the catch rate being below half a standard deviation below the average catch rate for that vessel. B hauls are between half a standard deviation below and half a standard deviation above the average catch rate. C hauls are larger.

Excluding the hauls from the last ground fished before returning to port left 1423 hauls. Table 2 shows the distribution of the classification of these 1423 hauls together with the haul category of the last haul made on the ground before switching. Each set of hauls made on the same ground is called a sequence in the following sections.

Theory

The decision model developed is restricted to the situation when the vessel remains at sea and do not call on port.

If the decision to remain on the same ground or not is based on the vessel catch performance only, then the skipper should tend to remain on the same ground more often if the catch is an C than if the catch is a B. And again more often than if the catch is an A.

A mathematical formulation of this idea, described below, is based on the following assumptions

- The skipper makes his decision alone on information of catch rate of his own vessel
- The skipper makes his decision after he is informed of the catch success of a haul and before the next haul is set
- The skipper makes his decision based on the catch success of the latest haul independent of the result of any previous hauls
- The decision is independent of the number of hauls already made on the ground.

Let now O(A), O(B) and O(C) be the probabilities that the next haul is made on the same grounds provided the outcome of the previous haul was A, B or C respectively. The estimators for O(A), O(B) and O(C) are derived in the appendix and are

$$O(A) = 1 - T(A)/n(A)$$

where

T(A) is the total number of sequences, which are terminated by an A haul

n(A) is the total number of A hauls (summmed over all sequences independent of the terminating haul).

The estimators for O(B) and O(C) are similar to that given above for O(A).

Results

If the skipper leaves the ground when catch rates are low then the average catch rate of the last haul made on a fishing ground averaged over all sequences should be considerably below the overall average catch rate. Table 1 shows for each of the five vessels both their overall mean catch rate and the mean catch rate for the last haul made before the skipper decided to change fishing ground. It is apparent from this table that on average the skipper changes grounds, when the catch rate is low.

The decision model requires that the catch rate of the latest haul has some predictive power for catch rates in subsequent hauls. This hypotese is investigated by pairing each haul with the next in the sequence, table 3. A chi-square test (Lehmann 1986) whether the previous haul has no predictive power i.e. that the outcome of a haul is independent of the catch rate in the previous haul gives X

= 250.0 with df = 4 or P < 0.001. This demonstrates that the outcome is not just random, there are good and bad grounds. Further there is a tendency that low catch rates follow one another. The overall proportion of A hauls are 35 %, table 2. However pairing the hauls for the analysis presented in table 3 only include the first and last haul in each sequence in one pair while the others hauls are included in two pairs. Therfore table 3 shows a smaller proportion of a hauls (32 %) because the skipper tends to change ground, if his haul has low catch.

Table 2 shows the number of trips and the number of sequences and hauls by category. Table 4 gives the estimates of O(A), O(B) and O(C) for each vessel. Table 4 indicates that the probabilities of changing ground are rather constant between vessels. The pooled estimates were

O(A)	O(B)	O(C)
0.82	0.94	0.96

As seen from the text table above the probability to remain on the ground increases with increased catch performance. Analysis of similar models, where the decision is based on the catch of an entire day or on the catch of the two latest hauls did not change this conclusion. Also apparently, the tendency to remain on the same ground is independent of whether the haul was in category B or category C.

The hypothesis that all three probabilities on the ground are identical i.e. that the decision is independent of catch rates, is rejected, a likelihood ratio chi-square test (Lehmann, 1986) gives X = 58.7, df = 2 or P < 0.001.

This analysis indicate that a low catch rate induces the skipper to change fishing ground while an average or a good catch rate, measured relative to average catch performance of that vessel, will not do so. However the estimates also indicate a general unwillingness on the part of the skipper to change ground. This is a rational behaviour if steaming costs of the vessel, both in terms of lost fishing time and actual costs of steaming, are included in the analysis. A simple analysis indicate that this is the case. Assuming that the main cost in changing ground is the time lost, when fishing could have been done and assuming that there is no difference in value of the catch on the two grounds, the decision model is

Catch(old ground) * H ¾ Catch(new ground) * (H - L)

where the H is the number of hauls considered by the skipper in his decision and L is the number of hauls lost while steaming. Catch is the yield in weight per haul. The average number of hauls made on a ground is about 10, table 2, and the ratio between the average catch and that in the last haul is about 1.4, table 1. From this it follows

H / (H - L) ¾ Catch(new) / Catch (old)

or

10 /(10 - L) ¾ 1.4

which gives

L ¾ 3

This means that the skipper can only allow himself about the time corresponding to three hauls for steaming and that longer steaming would require an expected significant improvement of the catch per haul.

Discussion

Hilborn and xxxx (1985) studied fishermen choice of fishing ground in the Canadian pacific salmon fishery. They found that the selection of fishing ground is a function of catch expectations and distance from the home port.

However the estimated probabilities are very high indeed, which probably indicates that other factors are important. Such factor could be the sharing of information between vessels, cost in changing fishing grounds and the loss of fishing opportunities under steaming.

The analysis is made on the total catch kept on board ignoring the size composition of the catch. This may modify the analysis significantly as the value of shrimp is very much dependent on size, about 1:10 between the smallest and the largest commercial sizes. The data chosen for this study however were from the same general fishing area and from the same quarter, thereby hoping that factors such as differences between prices, length composition are kept constant.

The decision on whether to change ground or no is probably a mixture of several factors of which catch rates are one. Other factors may be the weather conditions under which the vessel is idle and a change of ground under such conditions would therefore not include loss of fishing opportunities.

If there is full sharing of information and the skipper takes this information into account, then the next ground should be the the one showing the best catch rates and this might be pursued within these data. If there is no information exchange or if this is ignored, then the next ground is likely to be either randomly chosen or be the nearest ground to the one just fished. This analysis has not been conducted.

Finally the analytical approach to this analysis is one of rational decisions with the aim of optimizing catch rates. The decision process may well be of a more caotic nature including elements of catch expectations.

Acknowledgement

This work was done while both authors were employed by the Greenland Fisheries Research Institute. We would like to thank all members of the staff which are collecting, vetting and storing these logbook data on computer media, and for their help and guiding through these files.

References

Hilborn and (1985).

Lehmann E. L. (1986) Testing Statistical Hypotheses
J. Wiley 2nd ed.

Table 1. Mean and standard deviation of catch rates of shrimp (Pandalus borealis) by vessel. Further, mean catch rate for the last haul in each sequence. The sequences are defined based on the distance between start position of a haul and that of the next haul.

Vessel	No of hauls	Mean catch kg/hr	Std. dev. catch kg/hr	Mean catch kg/hr last haul
V1	53	964	652	618.0
V2	392	1210	904	794.5
V3	425	2072	1432	1622.1
V4	229	1302	1004	633.8
V5	392	1955	1362	985.0

Table 2 Number of hauls by type and number of sequences by termination haul type for each vessel

	Haul category				Sequences			
Vessel	a	b	c	total	Total	a	b	c
V1	15	28	7	50	5	3	2	0
V2	144	135	91	370	39	21	15	3
V3	152	144	107	403	30	20	5	5
V4	65	101	50	216	26	17	7	2
V5	128	157	99	384	40	30	5	5
Total	504	565	354	1423	140	91	34	15

Table 3. Number of haul pairs by catch rate category.

		1. HAUL			
		A	B	C	Total
2. HAUL	A	234	165	51	450
	col %	55.1	29.7	14.0	
	B	142	277	128	547
	col%	33.4	49.8	35.2	
	C	49	144	185	348
	col %	11.5	20.5	50.8	
	Total	425	556	364	1345
	row %	31.6	41.3	27.1	
	All Hauls	516	593	382	1491
	%	34.6	39.8	25.6	

Table 4. Estimates of the probability of remaining on the same fishing ground dependent on the observed catch rate in the previous haul. The O(A) is the probability that the skipper makes his next haul on the same ground given that the previous haul had a catch rate of category A, i.e. half a standard deviation below the mean, see table 1. The estimates are based on the data given in table 2.

Vessel	O(A)	O(B)	O(C)
V1	0.80	0.93	1.0
V2	0.85	0.89	0.97
V3	0.87	0.97	0.95
V4	0.74	0.93	0.96
V5	0.77	0.97	0.95
Combined	0.82	0.94	0.96

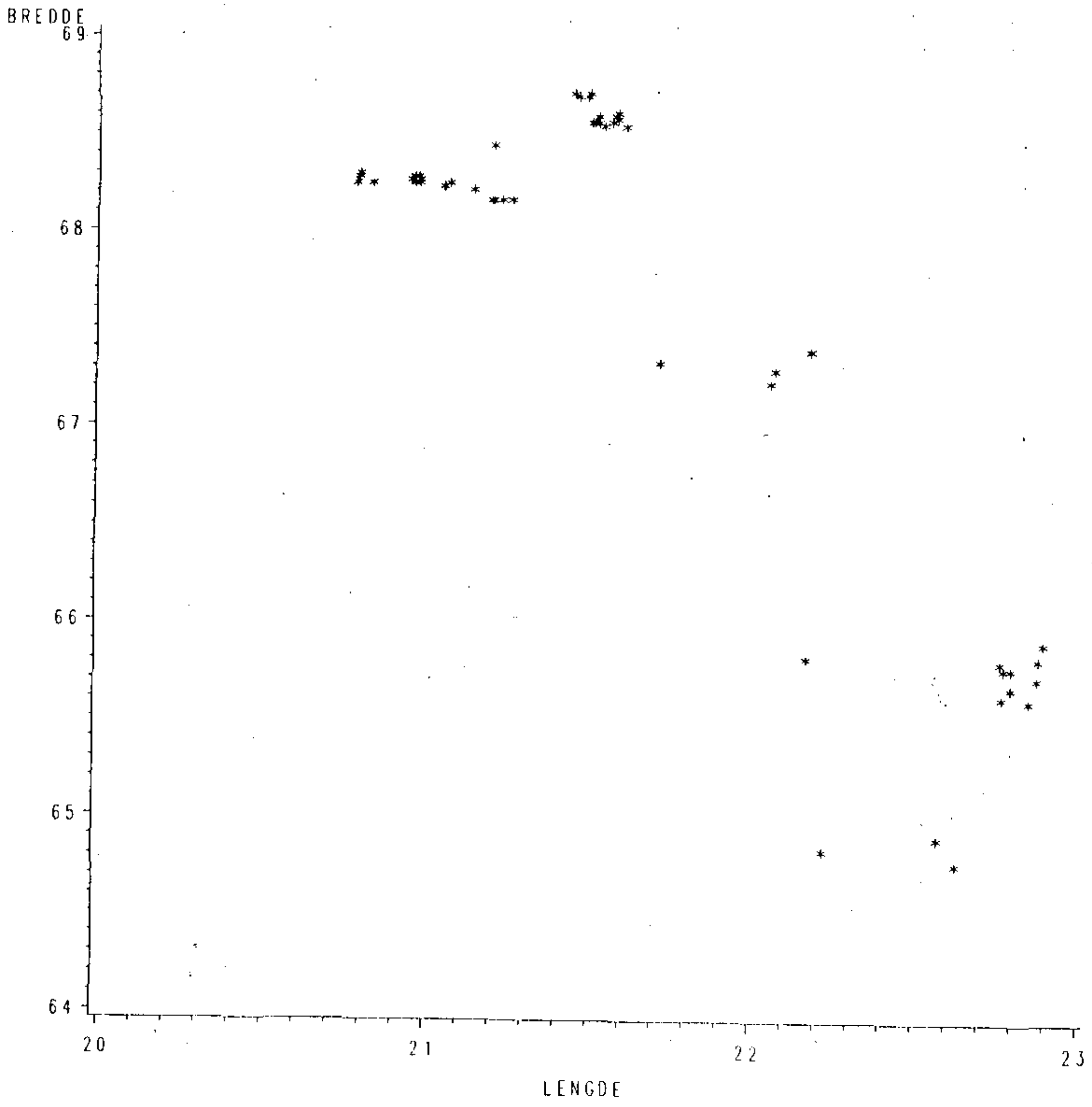
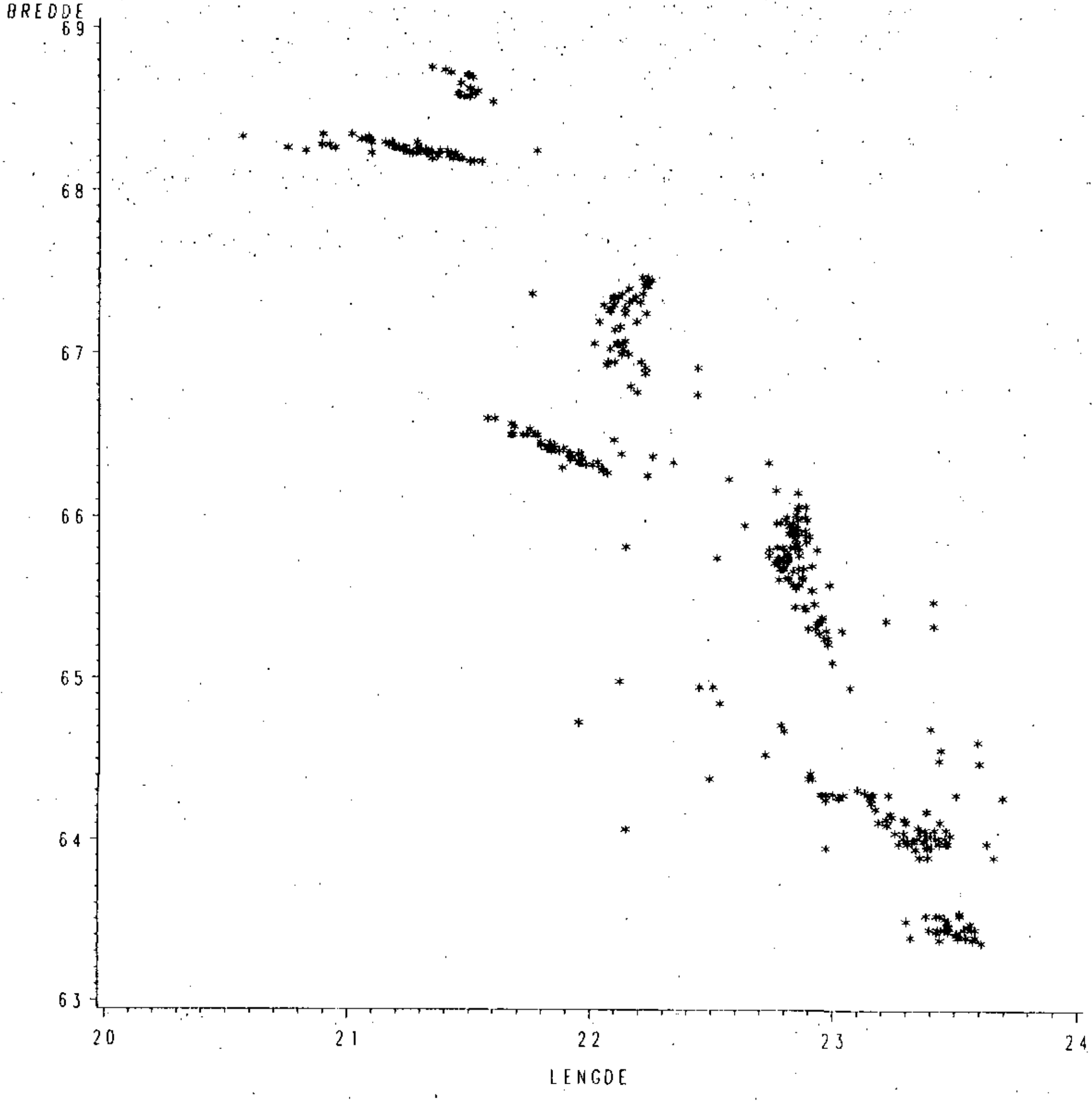


Fig. 1 Fishing positions by vessel. All trips are included and also all hauls. The projection is equidistant, 1 unit = 1 nautical mile both on the latitude as well as on the longitude axis.



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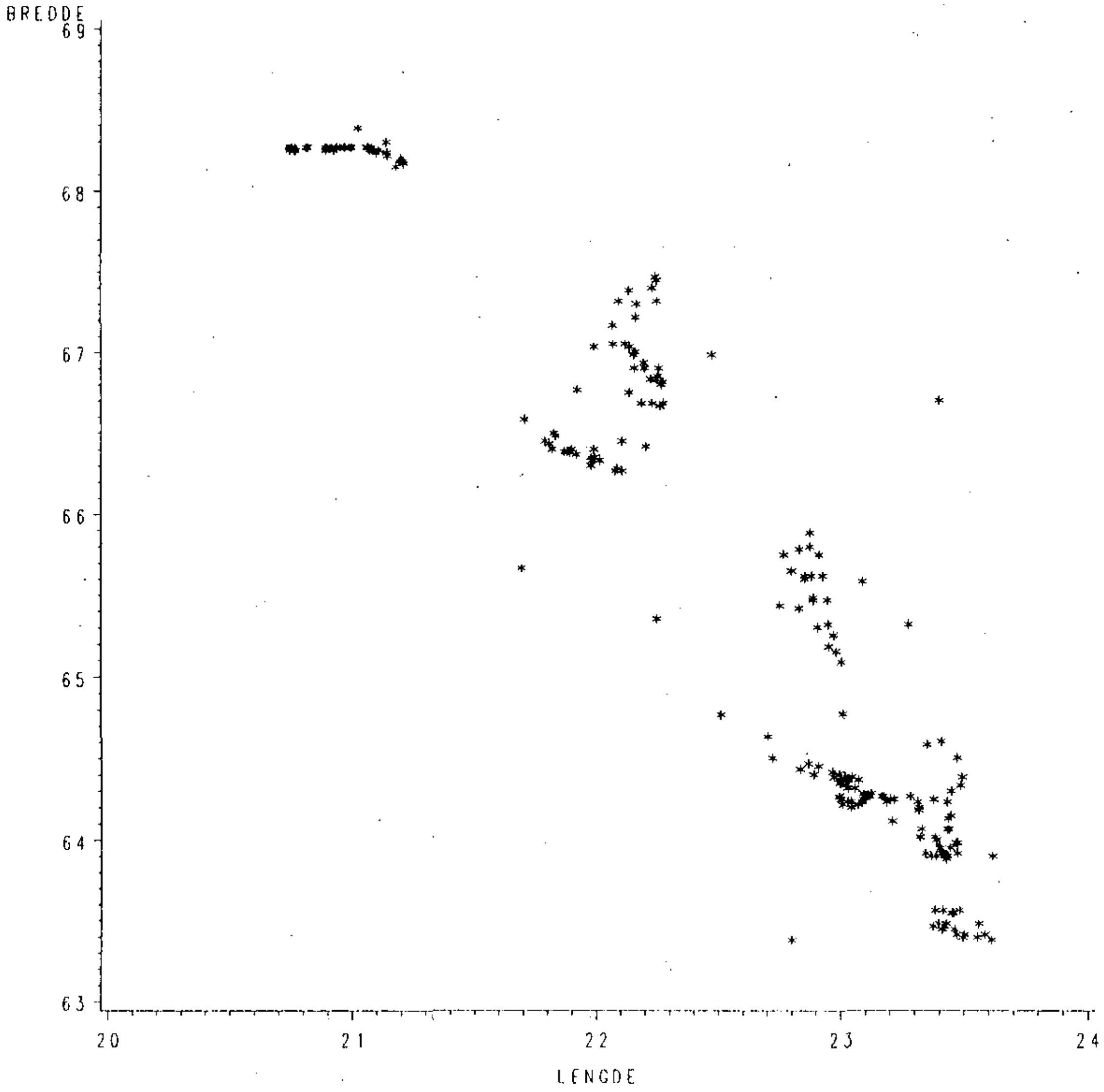

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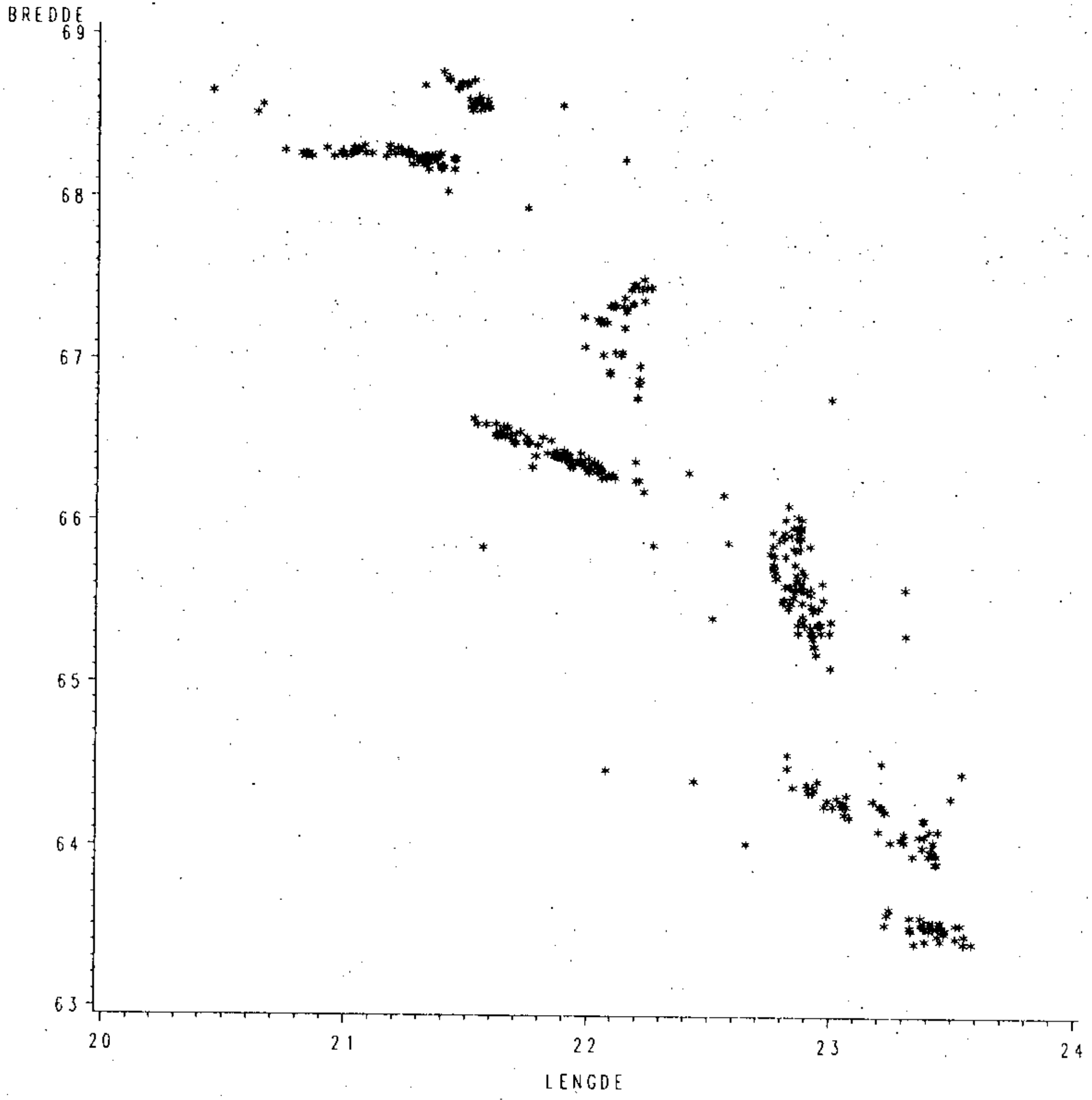

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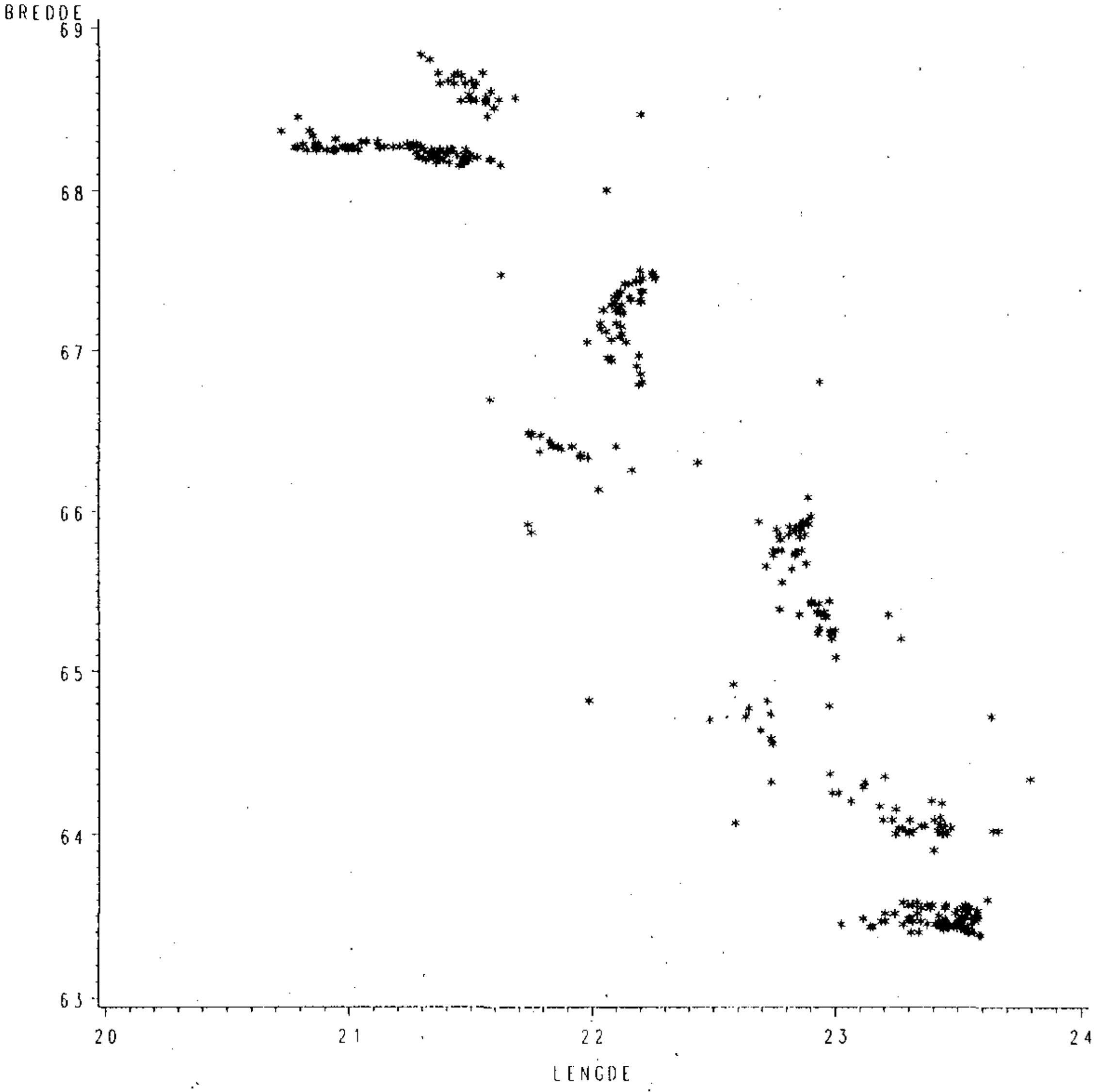

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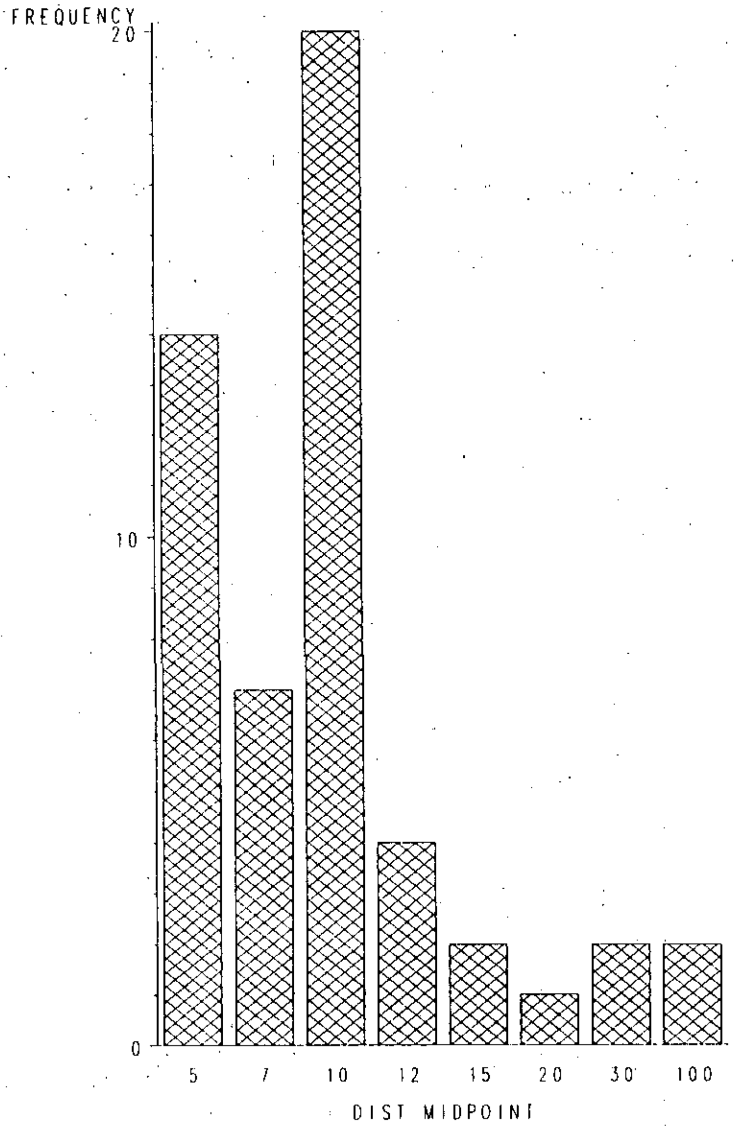
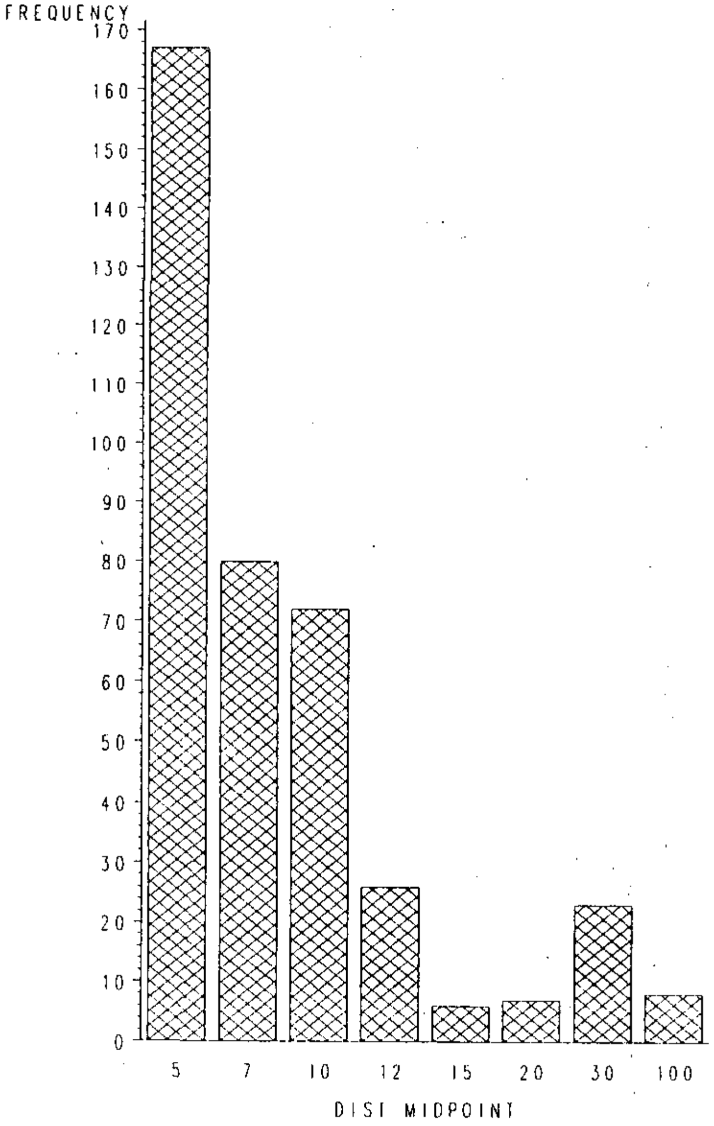


Fig. 2 Frequency distribution of the distance (nm) between the start position of a haul and the next for each of the fivce trawlers.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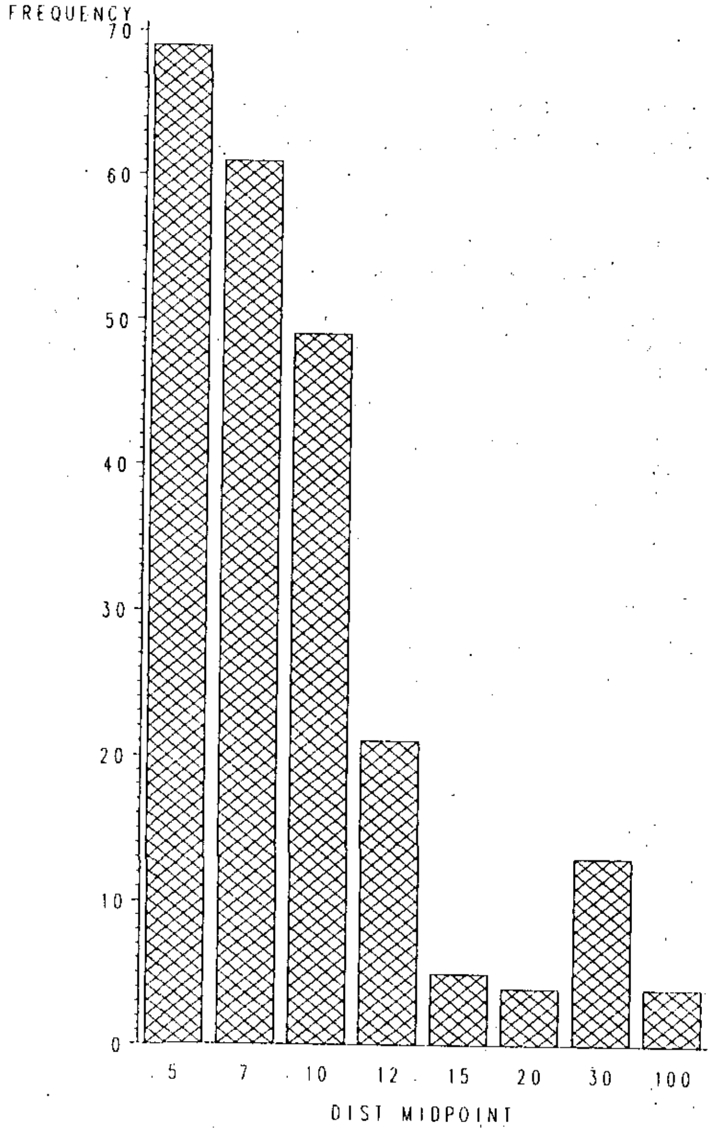
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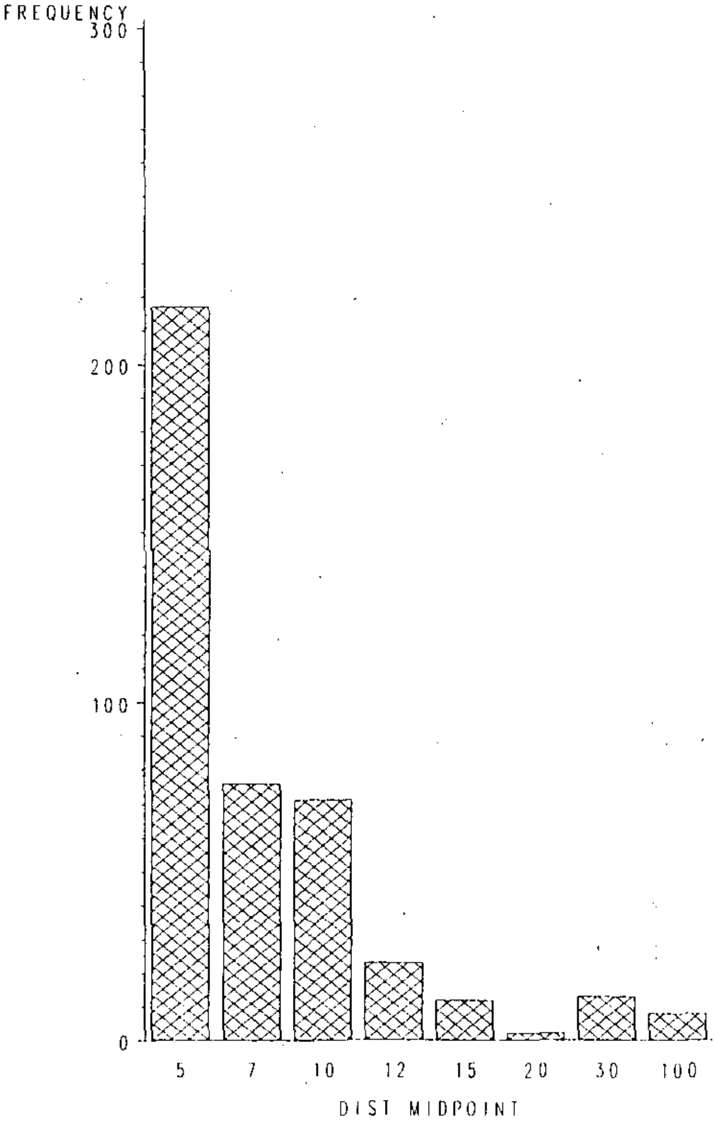

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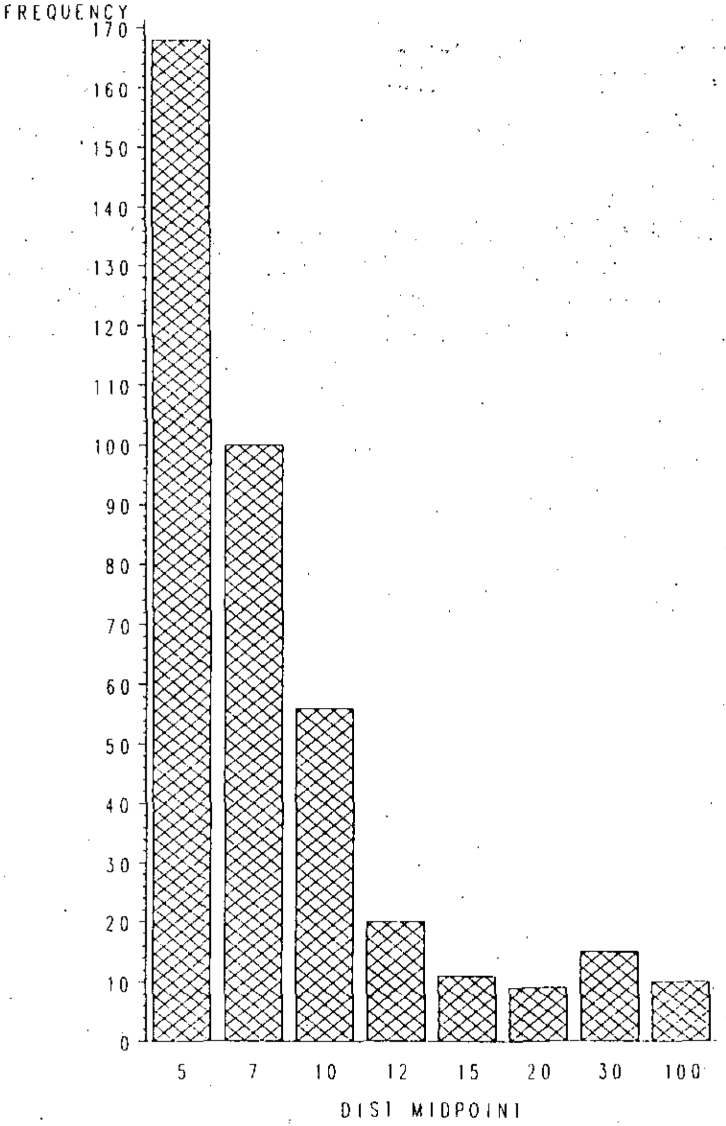
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Fig 2 (cont'd)

Appendix

Estimation of Probability for Remaining on the same Fishing Ground dependent on the outcome of a haul.

The likelihood estimator Lehmann (1983) is sought.

The observation unit considered is a sequence of hauls terminated by the skipper decision to change grounds. It is assumed that this decision is made for each haul independently.

The probability for observing a particular sequence terminated by an A haul is

$$[1 - O(A)] * O(A) \quad * O(B) \quad * O(C)$$

where n is the number of A hauls in sequence i.

Now calling the number of sequences terminated by an A haul T(A) and defining T(B) and T(C) similarly, the corresponding log-likelihood function for a series of data sequences is

$$\begin{aligned} \log L = {} & T(A)*\log[1 - O(A)] + [n(A) - T(A)]*\log[O(A)] \\ & + T(B)*\log[1 - O(B)] + [n(B) - T(B)]*\log[O(B)] \\ & + T(C)*\log[1 - O(C)] + [n(C) - T(C)]*\log[O(C)] \end{aligned}$$

Differencing the log L function with respect to O(A), O(B) and O(C) provides the estimation equations

$$O(A) = 1 - T(A)/n(A)$$

$$O(B) = 1 - T(B)/n(B)$$

$$O(C) = 1 - T(C)/n(C)$$