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Estimates of Snow Crab (Chionoecetes opilio) Abundance by Underwater Television

by

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SPECIAL SESSION ON BIOLOGICAL SURVEYS

Summary

An underwater TV camera towed on a sledge allows to estimate the densities of snow crabs Chionoecetes opilio on the fishing grounds. The camera is mounted in front of a rake which digs into the sediment. Semi-buried animals flounce over the transversal bar of the rake. They can then be counted either immediately while watching a T.V. monitor on deck, or later on, from video recordings. The distribution of crabs on the sea floor is slightly patchy ($\bar{x}$ = 13 . $10^3 \pm 2 . 10^3$ individuals/Km^2; the dispersion index $I = S^2/\bar{x}$ = 1.41 is significantly > 1 at the 5% level). This spacial distribution is bimodal and is not satisfactorily modelled by a negative binomial. No rhythm or auto-correlation is detected within the spacial series of observations. About 40% of crabs are semi-buried. The percentage of semi-buried individuals appears inversely correlated with size, 78% of semi-buried individuals have a carapace width smaller than 10 cm.

Résumé

Une caméra de télévision sous-marine remorquée sur un traineau permet d'évaluer les densités de crabes des neiges, Chionoecetes opilio sur les fonds de pêche. La caméra est montée en avant d'un râteau qui racle le sédiment. La faune semi endogée passe au dessus de la barre du râteau. Les comptages de crabes s'effectuent soit en temps réel sur un moniteur de télévision situé à la passerelle, soit en temps différé à partir d'enregistrements vidéo. La distribution des crabes sur le fond est de type agroupé ($\overline{x}$ = 13 . 10^3 $\pm$ 2 . 10^3 individus/Km2; l'indice de dispersion I = $S^2/\overline{x}$ = 1.41 est significativement > 1 au seuil de 5%). Cette distribution est bimodale et s'ajuste mal à la binomiale négative. Il n'a pas été décelé de composante cyclique ou auto-correlation dans la série spatiale des échantillons. Près de 40% des crabes paraissent semi endogés. Le pourcentage d'individus endogés varie en fonction inverse de leur taille, 78% des individus endogés avaient une largeur de carapace inférieure à 10 cm.

Introduction

The snow crab Chionoecetes opilio is widely harvested in the Gulf of St. Lawrence, little is known however about its growth, its density on the fishing grounds and its geographic distribution. The fishery operates only by trapping and great fluctuations of catchability as a function of seasons, sex, age and size are to be expected. Female snow crabs, for instance, are not usually caught in the traps in the same place as the males, a fact which is also known for other species of crabs such as Geryon quinquedens.

The primary concern for regulating the fishery has so far been to assess how many crabs were taken over the fishing season, and to tentatively evaluate from there on whether the stocks were in a stable condition or were declining as the fishery progressively developed its fishing power and expanded over wider grounds.

This approach is particularly difficult since the information on basic biological parameters such as growth and natural mortality is still insufficient. A standard virtual population analysis approach is not possible because the age classes cannot so far be distinguished in the catch. Jones (1983 variation of cohort analysis based on sizes is not possible because growth is not sufficiently known. If a terminal molt were shown to exist and if most of the size range in the catch pertained to the group of individuals in terminal molt, Jones approach would not apply. All virtual population types of approach require: 1) that the abundance on the grounds and the natural mortality be known in order to estimate the fishing mortalities, or 2) that the mortalities be known to estimate the abundance, or 3) that some simple minded assumption be made about mortalities such as natural mortalities and fishing mortalities independent from age. Otherwise an infinite number of solutions exists since there are more unknown parameters than observations.

"Leslie's method" (Ricker, 1975) has been used for assessing abundance of snow crabs, it is somehow a simplification of virtual population analysis, in which the underlying assumptions are that there is no natural mortality, growth or recruitment to the fishery over a discrete fishing season, and that the fishery is not expanding its fishing grounds or becoming more efficient through this discrete fishing season. All these assumptions may turn out to be doubtful because: 1) the summer fishing season is also the season of maximum biological activity in the Gulf of St. Lawrence, the period at which most species grow, reproduce and die as summer surface water temperatures raise and food chains work with high turnover rates; 2) fishermen are likely to move their traps when they do not fish well therefore expanding fishing grounds and eventually increasing their efficiency.

Direct estimates of abundance analogous to those obtained on pelagic fish by echosounding would possibly be the most reliable tool. Traps cannot be used easily for estimating densities because their efficiency varies greatly as a function of the physiological state of the individuals. Trawling is fairly destructive. Further, snow crabs are frequently caught on pockets of soft mud among hard (rocky) bottoms where heavily chained trawls required for catching benthic semi-buried animals are difficult to operate with full efficiency. Attempts have been made to count crabs on the bottom using underwater photographic cameras set on a towed unmanned submersible, the "BRUTIV" operated by the Department of Fisheries and Oceans Canada, St. Andrews laboratory (Elner, 1982, personal communication). The reported densities were quite low.

We attempted to develop a slightly different approach in which the towed vehicle is a rake which carries an underwater television with continuous recording of the sea floor activity along the area covered. We report hereon the results of our trials.

Material and Methods

Technology:

A black and white CM8 television camera manufactured by Subsea Systems is mounted on a modified sea scallop 2 m wide rake dredge (Fig. 1) of the type used in northern Brittany (France). The camera faces backwards at the rake. All benthic animals and rocks, including those buried in the sediment to a depth of 10 cm tumble over or swim over the toothed drag bar. They are counted, identified and frequently measured by reference to a black and white scale painted on the bar. The T.V. system is operated from the surface through a television cable. The 120 volts power required by the TV and the light is provided either by the towing ship's electric power or by a portable generator. The TV signal is recorded on a video system in which it is possible to manually superimpose information such as geographic position of the ship and depth. An internal clock displays time on the screen at recording. It is possible to play back the video recording in a slow motion and to make stops on an image for better interpretation of the data displayed.

This set up is very similar to the one used for estimating abundance of sea scallops on fishing grounds in Brittany. It was first designed by Albert Merrien (1980). It had previously been shown to be efficient for counting the Majid crab *Maia squinado*. *Chionoecetes opilio* is also thought to pertain to the majid family.

In our experiment the camera rake was towed by the 76 foot "Shamook", a research vessel from St. John's, Newfoundland. It can be operated, however, from a much smaller ship (42 ft) should the surveys be more coastal for species such as scallops.

Data Acquisition

The experiment took place in "Baie des Chaleurs" during the month of October 1983. The location (Fig. 2) is not known as a commercial fishing ground for snow crabs and is rather marginal to the true fishery (densities are likely to be lower than on a true fishing ground). However, the location was selected for its accessibility and shallow depth which would have allowed a salvage operation of the camera rake in case of wrecking.

The rake was towed for 4 hours 25 minutes over a distance of 9.65 nautical miles. The track included two sharp turns in order to check for stability of the device (Fig. 2).

The video recordings were reviewed at the lab and counts were made at the lab over 0.25 km units of towing estimated by interpolation from time and geographic positions displayed on the video screen. The width of the viewing area along the toothed drag bar was 1.3 m. The crabs and rocks were counted, the presence/absence of brittle stars was also recorded.

Data Processing

A principal components analysis was run on the data sets using as variables the presence/absence of brittle stars, the number of rocks, the number of crabs, the sample number along the track and the speed. This analysis was used for obtaining information on the correlations between these variables and on possible sources of bias in the abundance estimates. We used a graphic representation of the PCA described in Lebart, Morineau and Fenelon (1979) which allows to represent simultaneously observations and variables on a two dimensional plot of principal components taken two at a time.

The distribution of counts per sample was tested for its dispersion characteristics, using a variance to mean ratio. The departure of this ratio from 1 (random non patchy or Poisson type distribution) was tested by chisquare. A negative binomial function was fitted by maximum likelihood procedure to the observed distribution, Rogers (1974). The mean density and variance estimates for counts per sample were converted to estimates per standard square kilometer using mathematical expectation: $E(ax) = a\ E(x)$ and $\sigma^2 ax = a^2 \sigma x^2$. Confidence limits were calculated for the estimate of the mean using the central limit theorem approximation since the number of samples was greater than 30.

A periodogramme (Enright, 1965) was used for detecting possible periodicities in the counts along the tracks (such periodicities or an autocorrelation in the counts may cause bias in estimating the abundance along transects). In this procedure, the counts are sorted out along the track by steps (periods), P, increasing from 2 to N-2, where N is the number of counts. A statistic "A ", the amplitude, is calculated for each step, P. If X(k) is the count at the k th interval, and Y(P,i) is the mean of the m counts starting at the i th interval and separated along the track by a period P so that:

$$Y(P,i) = (1/m) \sum_{j=1}^{m} x[i + (j - 1)P]$$

and Y(P) is the overall mean defined as:

$$\overline{Y}(P) = (1/P) \sum_{i=1}^{P} Y(P,i)$$

$$A(P) = (1/P) \sum_{i=1}^{P} [Y(P,i) - Y(P)]$$

At each step size coinciding with a consistent period or its multiple, a peak value may be expected in the diagram of the statistic "A(P)" plotted v.s. step size. Troughs reveal half periods or multiples of half periods.

Since it is difficult to objectively decide what is a peak or a trough departing from random variability, a stochastic mean and 95% confidence limits were calculated by simulation for each value A(P) at P. In the simulation process three hundred random periodograms were generated from 300 series of N counts drawn randomly from a negative binomial distribution fitted to the actual data. No autocorrelation was assumed to exist between successive counts.

All computations and graphs were made on the HP 9845B computer of the "Marine Biology Research Centre" connected to an HP 9872C plotter and a 9895A dual flexible disc drive. All programs used were custom made.

Results

The position of the samples along the track, the data on tow number, crab counts, presence/absence of brittle stars are presented in Figure 2.

The graphics output of the principal components analysis is provided in Figure 3. Principal component 1 and 2 explain 39.50% and 28.59% of the variance, respectively. A plot of the observations and variables in the space defined by these two components was considered sufficient for the present analysis. There is no strong correlation between number of rocks and number of crabs. The correlation between speed and number of crabs is positive and very weak, showing that within the present range speed is not a major source of bias. There is a strong inverse correlation between speed and number of brittle stars, brittle stars being small are possibly less readily seen at high speeds. There is an inverse correlation between speed and number of rocks possibly showing that the rake skips over the rocks at higher speeds.

The mean number of counts per sample is 4.18 with a variance of counts of 5.93. The dispersion index is 1.41, it is significantly greater than 1 ($.01 < p < .025$ for chi2 = 75.06 and 53 degrees of freedom). Within this sample scale, the distribution of crabs is therefore moderately but significantly patchy.

The binomial distribution for our data on crab counts could be acceptable since the dispersion index is significantly larger than 1. A special procedure would then be required for setting asymetric confidence limits on the mean for any set of samples smaller than 30 (Conan et al. (1980). However, the parameter of the binomial distribution fitted by maximum likelihood K = 10.74 and the arithmetic mean x = 4.18 do not provide a good fit of the calculated to the observed distribution (Fig. 4). A significant departure from goodness of fit is detected by chi 2 (Chi 2 = 10.20, with 4 degrees of freedom, $0,025 < P < 0.05$). The actual distribution of counts in Figure 4 appears to be bimodal.

The graphic representation of Figure 5 does not allow to detect any well defined periodicity within our data of crab counts along the track. The peaks and troughs remain well within the 95% confidence limits generated by simulation for sets of counts drawn from the negative binomial fitted to the data and assuming no autocorrelation.

The mean density estimate for 250 x 1.3 = 325 m^2 is 4.18 and the variance of the mean is $S^2(\bar{x}) = 5.93/54 = 0.11$. For 10^6m the estimate of the mean $\bar{x}'$ = 12 860 and the estimate of the variance of the mean $S^2(\bar{x}') = 0.11(10^6/325)^2 = 1.04\ 10^6$.

Since the number of samples N = 54 is greater than 30 we can use the central limit theorem and set symmetric confidence limits for the mean based on a normal distribution around the observed mean with variance $S^2(\bar{x}) = S^2/N$. Therefore per square kilometer the average number of counts is expected to be:

$$\bar{x}' = 12\ 860 \pm (10^3\ \ 1.04)\ 1.96 = 2\ 10^3$$

In Table 1, estimates are provided for number of crabs appearing to be walking above the sediment (mud) and buried in the sediment. Thirty seven percent of the crabs appear to have been buried in the mud. Most of these were small crabs, possibly mostly females or juveniles: 79% of crabs buried in the mud were smaller than 10 cm width.

Discussion

The method here described for direct estimation of snow crabs appears to be quite promising. The use of a rake and underwater TV rather than still photographic frames and a vehicle towed above the grounds allowed to show that a substantial amount of crabs may be buried in the sediment. This burying behavior is likely to vary as a function of hour of day and season, it may be related to rhythms of activity and catchability in traps.

This distribution of crabs appears to be slighty patchy at the scale studied. However, the variance of counts remains relatively small and allows quite precise estimates even with a rather small number of samples. The observed bimodal distribution of counts may possibly be explained by the fact that the track crossed two different areas with modal densities at 3 and 6 per unit respectively, or that the population of individuals sampled was heterogeneous (possibly males and females appearing with uncorrelated densities).

Further technical improvements will allow us to automatically record physical parameters such as temperature and salinity along the track and to measure more accurately the individuals as well as sex them. Further research is now conducted on rhythms of activity, on geographic location of males, females, small individuals and berried females, and on characteristics of patchiness of the distribution at different sample scales.

Acknowledgements

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Table 1 - Burying behavior as a function of size.

	Carapace Width	Count	% Among total number of individuals measured	% Within buried or non buried groups
Not buried	10 cm	28	35.4%	54.9%
	10 cm	23	29.1%	45.1%
Buried	10 cm	6	7.6%	21.4%
	10 cm	22	27.9%	78.6%

Overall % of buried individuals: 36%

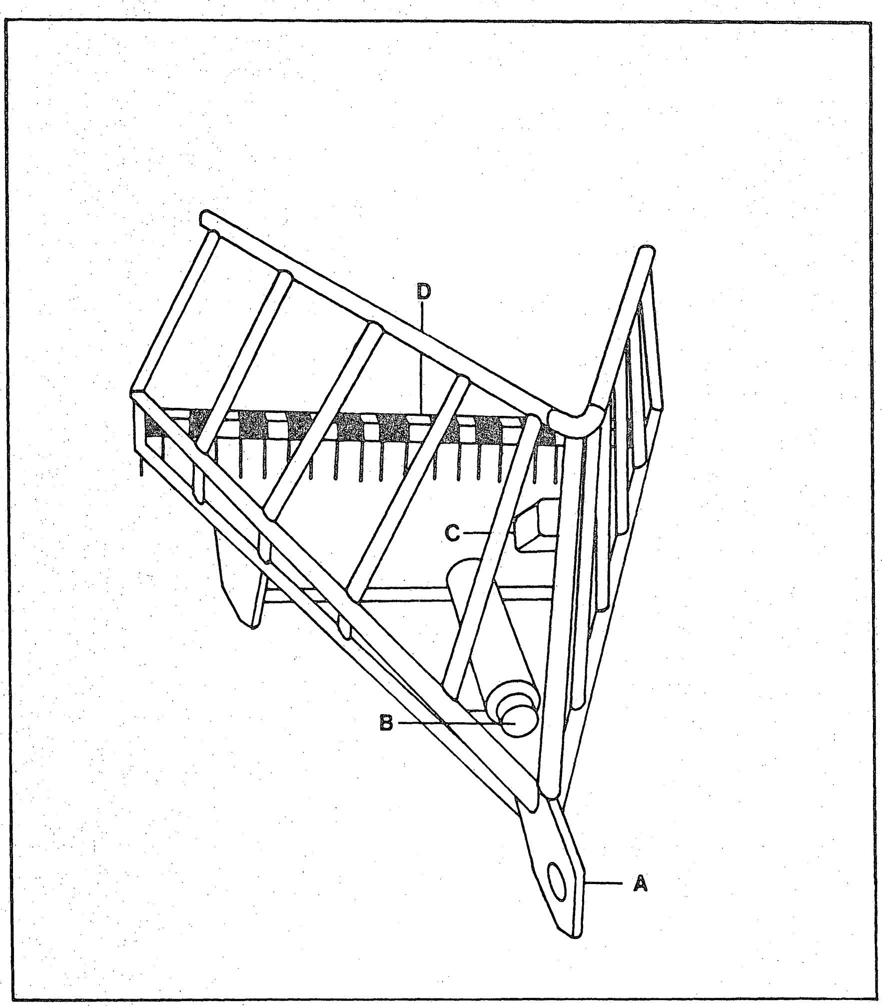

Figure 1 - Camera rake. The television camera is aimed backwards at the toothed drag bar. The objects digged out of the sediment can be counted while tumbling over the toothed bar.

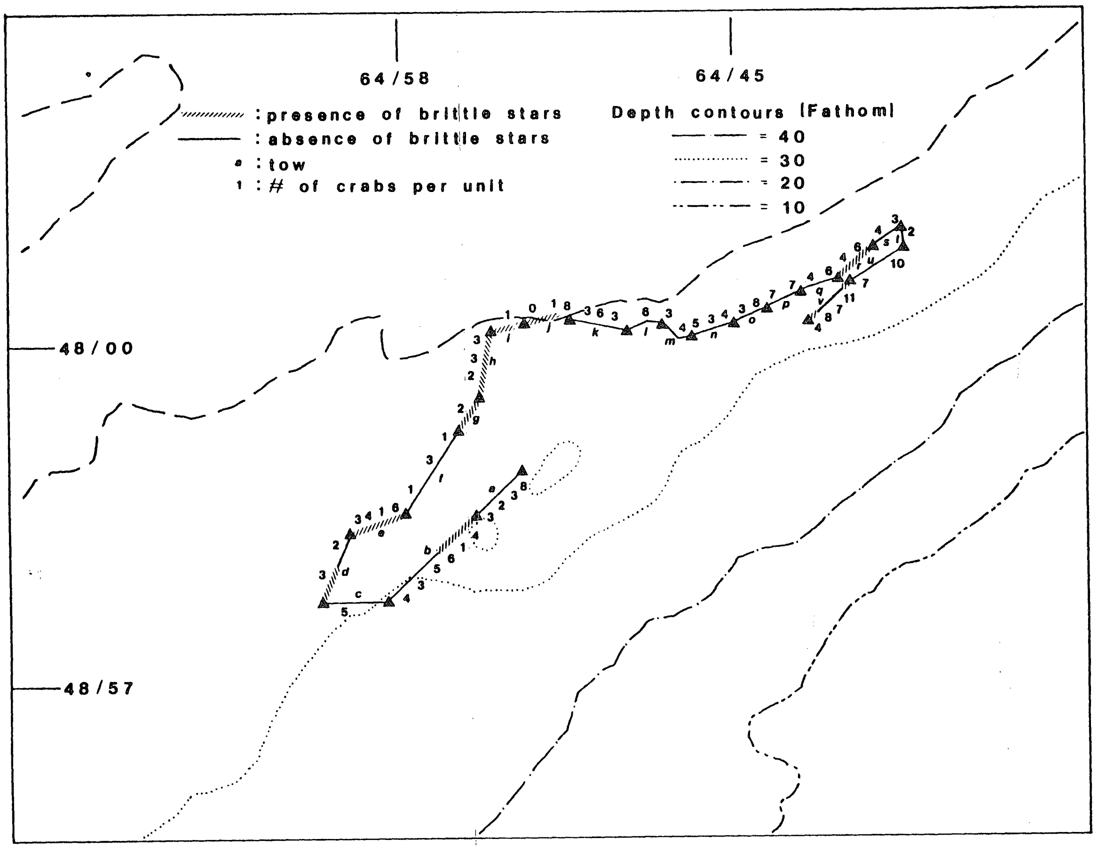

Figure 2 - Tow track followed by the camera rake. The data recorded on video tape are represented by numbers and symbols along the track. Crab counts are made over .25 km tow units.

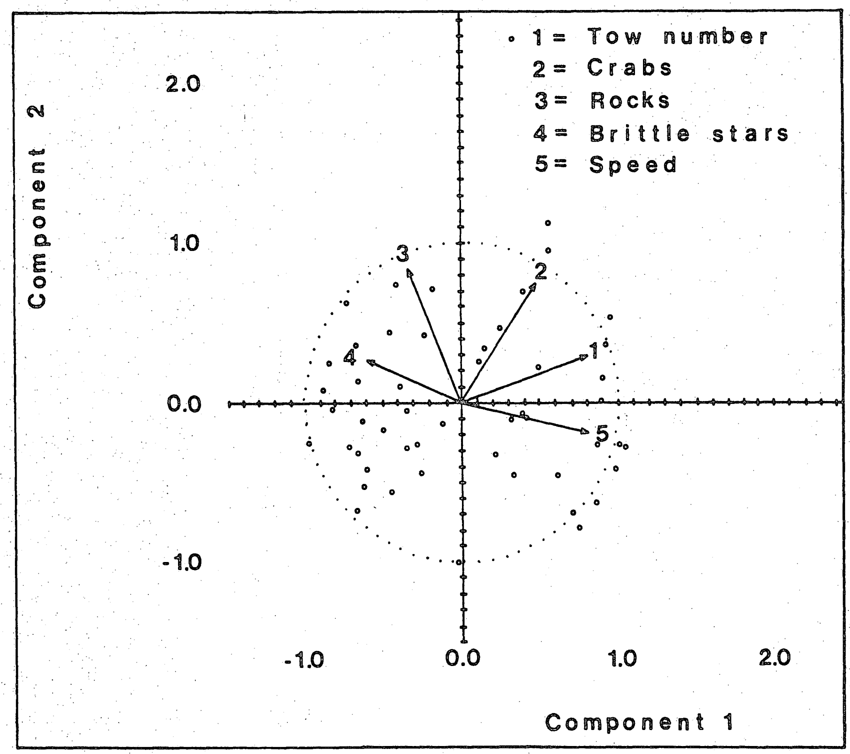

Figure 3 - Graphical representation of a principal components analysis of the data. The variable (vectors) and observations (dots) are projected on the plane defined by the two first principal components. The data were centered and reduced for each variable, i.e. new coordinates were calculated after the transformation: X' = (X - M) /S where M is the mean and S the standard deviation. There are no clusters among the observations which would indicate an heterogeneity in the data. The first and second principal components explain most of the variability: all vectors of module 1 almost reach the perimeter of the circle of radius length 1.

The abundance of crabs (variable 2) is independent (perpendicular) to speed (5) and presence of brittle stars (4), it is weakly correlated (acute angle) with presence of rocks and tow number. It is concluded that within the range used the crab counts were not biased by changes of speed. The crab density may have slightly varied along the track (tow number).

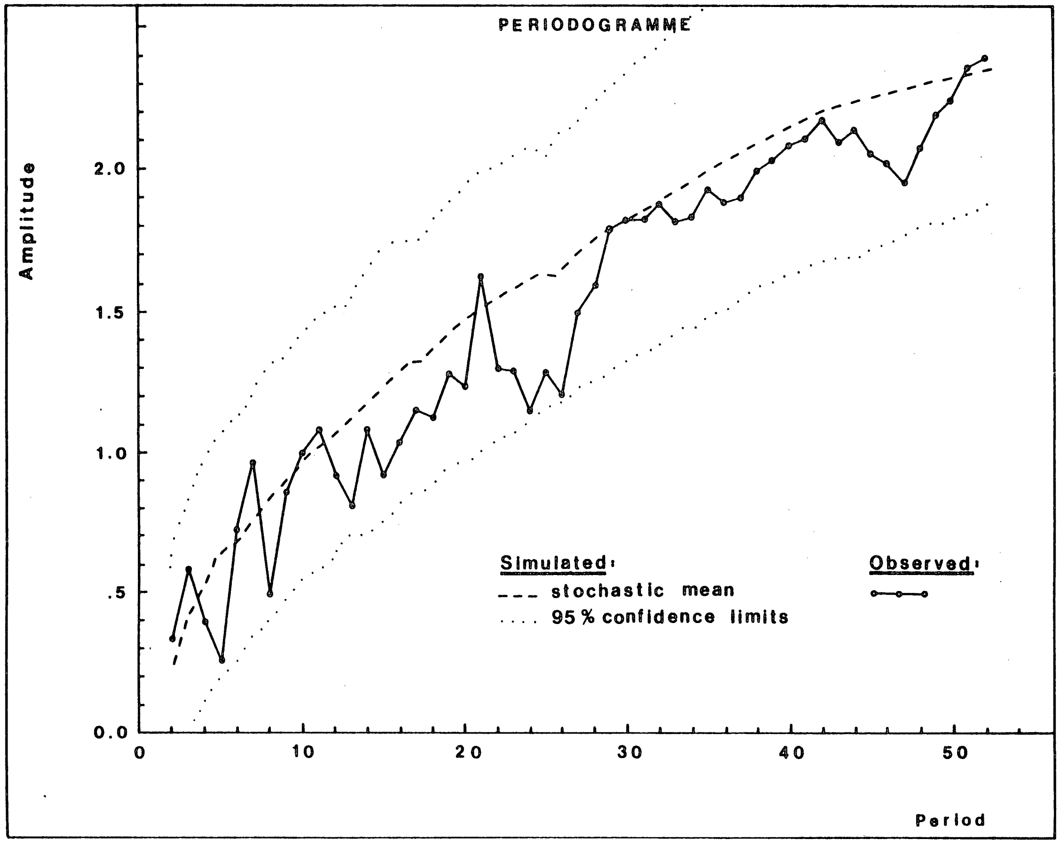

Figure 5 - Periodogramme of crab counts along the track. The amplitude statistic "A" is plotted against the period (step size by which counts are regrouped). Peaks reveal a periodic component in the data or one of its multiples. Troughs reveal half periods or multiples of half periods. The stochastic mean and 95% confidence limits were set after simulating 300 random walks assuming a negative binomial distribution of counts with parameters fitted to actual data and no autocorrelation. No well marked periodicity is detected in the data.