Canadian Atlantic Fisheries
Scientific Advisory Committee

Comité scientifique consultatif des
pêches canadiennes dans l'Atlantique

CAFSAC Research Document 90/14

CSCPCA Document de recherche 90/14

A review of the Banquereau Bank fishery for *Mactromeris polynyma* for the 1986 to 1989 period

by

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ABSTRACT

A series of fisheries development surveys for underutilized clam species was initiated in 1980. The surveys identified commercial concentrations of Arctic surfclams (*Mactromeris polynyma*) on Banquereau Bank, and in 1986, a commercially exploitable biomass of 561,000 t and an MSY of 16,821 t were estimated for the stock.

After a three month test fishery, the estimated MSY was increased to 24,000 t, and a three year offshore fishery program was initiated in 1987. A total allowable catch (TAC) for Banquereau Bank was set at 30,000 t , divided between two enterprise allocations (EAs). A TAC of 15,000 t was set for the rest of the Scotian Shelf, divided between three EAs. Both the TACs and the EAs were set for each of the three years of the development plan.

As this program has come to an end, the data was reviewed to see how our knowledge of this stock and advice on its exploitation has progressed.

Catch rates have remained stable during this period with little change in fishing locations. It is concluded that present market demands rather than resource supply is constraining the fishery. Our present knowledge of the biology of this species, while increasing, is still insufficient to recommend any changes to the TACs. However, it is suggested that the original 1986 biomass estimates may have been too high. Overfishing of the stock would result in a recovery period of at least ten years due to the slow growth rate of this species.

RÉSUMÉ

Une série de relevés exploratoires a commencé en 1980, en vue de développer une pêcherie d'espèces bivalves sous-exploitées. Une concentration d'envergure commerciale de la Mactre arctique (*Macromeris polynyma*) fut identifiée sur le Banc Banquerau en 1986. Une biomasse exploitable et un rendement maximum soutenu (RMS) furent estimés à 561,000 t et 16,821 t respectivement pour ce stock.

Après une pêcherie d'essai de 3 mois, le RMS fut élevé à 24,000 t et un programme de pêche hauturière de 3 ans fut établi en 1987. Le taux de prise admissible (TPA) pour le Banc Banquerau fut fixé à 30,000 t, divisé en 2 contingents d'entreprise; de plus un TPA de 15,000 t fut établi pour le reste du plateau néo-écossais et divisé en 3 contingents. Des TPAs et contingents d'entreprise furent fixés pour chacune des trois années du plan de développement.

Ce programme est maintenant terminé et les données recueillies sont examinées pour évaluer les connaissances acquises et les recommendations par rapport à l'exploitation de ce stock.

Les taux de prise sont demeurés stables au cours de cette période avec peu de changements des lieux de pêche. On conclu que c'est la demande du marché actuel plutôt que l'approvisionnement qui contraint cette pêcherie. Nos connaissances de la biologie de cette espèce s'accumulent mais sont encore insuffisantes pour recommender un changement au TPA. Toutefois, on suggère que l'estimé initial puisse être trop élevé. Etant donné le taux de croissance de cette espèce, une période d'au moins 10 ans serait nécessaire pour rétablir le stock dans l'éventualité d'une surexploitation.

HISTORY OF THE FISHERY

A fisheries development plan to determine the resource potential of the Ocean quahog (*Artica islandica*) and other underutilized clam species in the Scotia-Fundy region was initiated in 1980. During these surveys, which took place from 1980 to 1983, commercial quantities of Arctic surfclams, *Mactromeris polynyma*[1], were found on Banquereau Bank (Rowell and Chaisson, 1983; Chaisson and Rowell, 1985). Due to the exploratory nature of the surveys, other areas of the Scotian Shelf could not be precluded from containing commercial quantities of Arctic surfclams, although these were not found. There has as yet been no commercial interest in *Artica islandica*, due to the lack of a market.

In 1986 it was estimated that Banquereau Bank had a commercially exploitable biomass of 561,000 t and an MSY of 16,821 t (Rowell and Amaratunga, 1986). A three month test fishery took place with three companies taking part. Each company used a chartered U.S. vessel equipped with a single hydraulic clam dredge.

The results from the test fishery revised the previous estimates to give an MSY of 24,000 t (Amaratunga and Rowell, 1986). The MSY estimates were based on the model $MSY=0.5MB_o$, (B_o = virgin biomass, M estimated by $M=3/T_{max}$). It was recognized that this approach makes some assumptions that compromise the use of the model, especially that of equilibrium conditions within the population, and that it was based on limited data. Another approach used by Amaratunga and Rowell (1986) was to look at biomass as a finite resource, and not make any assumptions about natural mortality, growth or recruitment. In this way an annual level of exploitation is established that would, over a defined period of time, remove the existing biomass. For this analysis, assuming an initial biomass of 600,000 t, the level of removals required to have the resource last 10, 20 or 25 years were 60,000 t, 30,000 t and 24,000 t respectively.

In 1987 a three year offshore fishery program was developed with industry concensus. TACs and EAs were set for each of the three years of the program, and were based on biological information provided by the surveys and test fishery, and an economic break-even analysis on the required resource to make a vessel and processor viable. The TACs were set at 30,000 t for Banquereau Bank and 15,000 t for the rest of the Scotian Shelf. The TACs were divided into EAs between three companies, two having access to Banquereau Bank, and all three to the rest of the Scotian Shelf. The program was to be reviewed at the end of the three year development period 1987-1989.

In 1987 two companies took part in the fishery, landing 883 t. One company worked on Banquereau Bank where there were commercial quantities. The other company, not having access to Banquereau Bank, did exploratory fishing on the remainder of the Scotian Shelf; it also tried experimentally in NAFO area 3LNO. It did not find sufficient quantities on the Scotian Shelf to continue fishing after 1987. Each company used a chartered U.S. vessel. The third concentrated on marketing, while exchanging information with, and buying clams from, one of the others. Marketing efforts were concentrated on Japan where the sweet taste and red coloration of the foot was an asset in entering the lucrative surimi and sushi markets.

In 1988 the two companies that had access to Banquereau Bank fished there, initially with a chartered U.S. vessel. Canadianization of the fleet by October 1988 was a requirement, and three

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[1] The scientific name of this species was changed from *Spisula (Mactromeris) polynyma* to *Mactromeris polynyma* by F.T. Bernard (1983). The American Fisheries Society: Common and scientific names of aquatic invertebrates from the United States and Canada: Mollusks (Turgeon *et al.* 1988), has accepted this interpretation and suggests the uniform nomenclature for this species as *Mactromeris polynyma*, Arctic surfclam. Although the authors will use this standard nomenclature, the common name usually used for this species in eastern Canada is Stimpson's surf clam.

Canadian vessels started fishing, one in July and the other two in November. All three were converted oil rig supply ships, 53-61 meters in length, equipped with two, stern mounted, hydraulic dredges. As is usual with a new fishery and new vessels, there was a period of working out problems with the vessels, and learning how to handle the gear so that it fished efficiently. Thus in 1988, the second year of the plan, only 2,860 t were landed.

In February 1989, Arctic surfclams officially became a regulated species under the Atlantic Fishery regulations. During this year the two companies involved in Banquereau Bank landed 7,773 t. One of these companies, which had one Canadian vessel, brought a chartered U.S. vessel back for seven months, with ministerial approval. The other company found it could catch more than it could market and tied one of its two vessels up in March. The third company was not fishing, but was purchasing clams from some inshore fishermen and concentrating its efforts on processing and marketing. Two exploratory licences and two exploratory permits were issued for 3LNO. These were issued to the three current participants plus a fourth, Newfoundland based company, and the TAC for the Scotian Shelf outside of Banquereau Bank was increased to 20,000 t, with access to this area expanded to include the new company. This company has been fishing in 3LNO since July.

As the fishery has completed the three year program, it was felt that the information obtained from the commercial fishery should be examined to assess the present status of this stock and to see what if any changes should be made to the biological advice. As the only activity on the Scotian Shelf at present is on Banquereau Bank the analysis is restricted to this stock.

METHODS

The data used in the analyses come from many sources: 1) logbooks and sales slips filled out from both test and commercial fisheries, 2) the international observer program, 3) samples of the catch, collected either at sea or on shore, 4) data from benthic surveys done by the Habitat Ecology Division, and 5) the original 1981 and 1982 Delaware II developmental survey data from Banquereau Bank.

Logbook analysis:

Logbook coverage is excellent in this fishery with 100% coverage and good co-operation from the owners and captains. The only deficiency in the data is the lack of accurate discard information. Log data is recorded on a watch basis and log catches are prorated to sales slip information. For the processing vessels this has little effect as the product is being weighed as it is processed on the vessel so the captain has the actual information at hand. For the vessels landing live clams, the logged landings are the officers' estimates, as the catch is not weighed until it is landed. These estimates are facilitated in that the catch is put into 'cages' as it comes aboard. With a good idea of the weight of a cage the estimates are usually accurate, however on some trips the log estimates have been off by up to 25%.

Catch and effort data from the commercial logs were aggregated by one minute squares of latitude and longitude to examine the distribution of catch and effort on the bank.

Data on the percentage area of the bottom dredged in each one minute square were calculated from commercial log data. Area dredged was calculated from tow time, vessel speed (over bottom) and width of the gear. This was then aggregated over one minute squares, and the total plotted as a fraction of the bottom area of the one minute square. This was done to show the cumulative effect of the dredging and to give an indication of how much more effort different areas of the bank could sustain in the short term.

The six one minute squares that had received enough effort to drag more than 100% of the bottom were separated out, and CPUE by month for each of these was plotted to show trends.

CPUE was aggregated by month over the last two years and plotted to show trends over time. It was also averaged over one minute squares for 1988-89 to show distribution of high CPUE areas.

International Observer Program:

Coverage targets for this program are 100% for foreign vessels and 50% for domestic vessels. The observers collect data on length frequencies, species composition, and the percentage of broken clams in the catch. There are two vessels licensed for Banquereau which are landing processed products, processing and freezing on board the vessels. The product being landed is individually frozen and glazed foot portions, referred to as tongues, and frozen blocks of body meat. These weights have to be converted back to round weights, and so sampling is carried out to determine conversion factors for these vessels. As this requires the shutting down of the processing line the observers are asked to do only four samples during each of the approximately one month trips, and to take advantage of any shutdown periods that are available to run their samples. Samples of several bushels are weighed before being run through the line, and weight of processed foot and body portions obtained are recorded. In addition to final product weights the weight of glaze and percent by weight of foot pieces in the body meat are taken. Initially attempts were made to obtain intermediate weights at each stage of processing that could result in a change of weight, but due to the cramped and automated setup of the line, this required frequent shutdowns during the run, resulting in the sample spending more time than normal in various processing stages, possibly creating biases in the estimates.

During the time on the vessel the observer also records data on individual tows, discards, bycatch and catch data, and on dimensions of, and settings on, the dredges. The observers also compare their estimates with the logbook records. Samples are collected as required for growth, ageing and allometric studies.

Mean shell length of the catch from the length frequency data over 2.5 minute square grid areas was calculated to examine differences is size distribution over the bank.

Sample processing:

Samples from the fishery are examined and individual weights are recorded for total weight, shell and body weights, foot weight, and sand and other debris weight. The shell dimensions are measured, and the gonads are subjectively partitioned into the classification scheme described in Ropes (1968). This classification was originally set up for histological preparations but in this study the assignment was done subjectively by visual examination. The shells are aged by the method of Ropes and Sheperd (1988). This consists of taking thin sections through the chondrophore, mounting these on glass slides, and polishing them. Rings in the chondrophore are counted with the aid of a microscope. An extension to this methodology is that the slide can also be examined using an image analysis system, or photographed and projected on a digitizing screen, to measure the distance to each ring for back calculating size at age. This is done by using a regression of shell length on chondrophore length to calculate a shell size for each chondrophore ring. The aged samples from the high effort areas on Banquereau Bank were used in fitting von Bertalanffy curves to both the original and the back calculated size at age data. These were compared to a published curve for an Alaskan population of the same species (Hughes and Bourne 1981) .

Habitat Ecology Division benthic surveys:

Data from 1987 to 1989 benthic surveys, using 0.5 meter square, van Veen bottom grabs on Banquereau Bank, were examined for evidence of pre-recruit surf clams (<100 mm). The catches were plotted to show abundance and distribution. Length frequencies were examined and compared to those from the 1981 and 1982 Delaware II research surveys and those from commercial catches. The age frequency distribution of the 1987 samples was examined as well.

Review of the original survey data and analyses:

The 1981 and 1982 research survey data were edited and re-examined. Three techniques were used: 1) the subjective post-stratification method applied in Rowell and Amaratunga (1986), 2) a contouring package (ACON: developed by G. Black, DFO Halifax) based on Delaunay triangles and the inverse distance weighted interpolation as given in Watson and Philip (1985), and 3) the GULF KRIG kriging package (developed by G. Conan , DFO Moncton).

There have been no studies to date on the environmental effects of this fishery on the bank. A survey of the literature was done to see what impact from dredging might be expected.

RESULTS

Catches, from sales slips and other sources, for NAFO areas 4Vn, 4Vs, 4W, 4X and 5Ze over the 1986-1989 period, are given in Table 1. Catch (kg) in NAFO area 4Vs increased exponentially over the four year period.

The analysis of the logbook data showed how the fishery has developed, first doing some exploratory fishing and then concentrating effort in a small area of the bank where catch rates were good. In the latter part of 1989, although catch rates have remained high in the main areas, there was some exploratory fishing once again. Some of this was due to ice conditions on the bank making the preferred areas inaccessible. Since logbook data is confidential commercial data and only a few vessels are presently involved in this fishery, details on actual fishing locations and catch rates are not presented in this paper.

This concentration of effort means that a small area of the bank has been dredged very often. The one minute square that has received the most effort has had a total area equal to 152% of the bottom dredged. The introduction of three new vessels during 1988, which are all equipped with double dredges and able to fish in worse weather than any of the previous vessels used, greatly increased the fishing capabilities of the fleet (although the tying up of one vessel has at least temporarily reduced this). In 1986 Banquereau Bank had a total area of 0.4 km^2 dredged. This increased exponentially to 8.9 km^2 in 1987, 32.0 km^2 in 1988 and to 86.8 km^2 in 1989.

The plots of CPUE by month for 1988 and 1989 (Figure 1) do not show any strong trends indicative of changes in available biomass, fishing efficiency, or discovery of new areas. The catch rate has remained relatively constant.

The CPUE by month for the six one minute squares that have received a concentrated fishing effort (covering more than 100% of the bottom) are shown in figure 2. These areas show a fairly constant catch rate. The high initial value seen in April 1987 for the square receiving enough effort to cover 111 percent of the bottom is based on only two tows, with a total towing time of 29 minutes.

The shell length frequencies of *Mactromeris* from the original 1981 and 1982 surveys and the International Observer Program (IOP) samples of the fishery from 1986-1989, can be seen in figures 3 and 4. Figure 4 compares the unsorted catch to the landed catch for the years 1987-1989.

Mean shell length of the unsorted catch for different areas of the bank obtained from the IOP length frequency data showed that this varies over the whole bank, ranging from 32 mm to 134 mm.

Catch composition is given in Tables 2a and b. Arctic surfclams compose the largest fraction of the catch, however shell debris contributes an equally large portion. Northern propellerclams (*Cyrtodaria siliqua*) are the most abundant species after *M. polynyma.*

Sampling for shell breakage of live clams showed a high percentage of clams with broken shells. Twenty four samples of two bushels from the hoppers, before any on board sorting or discarding, had a range of 13.9% to 46.2% of the clams broken, with an average value of 27.6%. The small percentage of discards (1.23 - 2.45% by weight from observer estimates) contained mostly broken shells (53.4 - 93.4%, average 76.2%). The reason for the high percentage in the discards is that the broken clams fit through the spaces in the sorter systems.

The results from the study to calculate conversion factors for the vessels processing at sea are variable. The vessels involved have made few trips since the study was initiated, and the processing of the product has changed during this time. Attempts to get factors at each stage of processing for conversions of older data were unsuccessful, and emphasis was switched to concentrate on overall conversion factors. This was done both with the actual processing line and with hand shucked samples. On the processing line samples of several bushels (~60 kg) were weighed and sent through the line and the weight of the products produced was taken. This resulted in a range of conversion factor values from 6.09 to 8.08 with an average of 7.27 and a standard deviation of 1.00. For the hand shucking, samples were weighed and the weight of the foot portions recorded. Processing line conversions were estimated by using factors of a 13.74% weight loss from blanching, and a 6% weight gain for the glaze. The first factor was derived from the processing line samples and may be overestimated due to having to stop the machinery and extract the samples to weigh them. The second is the target for the processing line and was verified by the observers. This gave an average conversion factor of 7.2 with a standard deviation of 0.06. In addition, the output going into blocks of body meat had a percent by weight of foot pieces ranging from 4 to 19% with an average of 12%. Company efforts to reduce this percentage are ongoing and have been successful, they estimate that presently, conversion factors for converting from processed foot weight back to round weight are in the order of 6.0 to 6.5.

Regressions of shell length on shell width, (n=396) and foot weight versus shell length (n=313) are shown in figures 5 and 6. Sand and other debris amounted to 3.36 percent by weight overall, but had considerable variation both within and between samples.

A von Bertalanffy growth curve fit to 200 aged shells is shown in figure 7. Chondrophore size was plotted against shell length (Figure 8). This relationship was nonlinear and so a second degree polynomial was fit to the data. The regression equation was then applied to the measurements of chondrophore rings, to back calculate shell length at each age. The back calculated data was also fit with a von Bertalanffy curve (Figure 9). For comparison, a curve from an Alaskan population of the same species (Hughes and Bourne, 1981) is also shown on the graph.

The plot of percent of gonads subjectively assigned to the maturity stages defined by Ropes (1968) is shown in figure 10. As the study was done in addition to other sampling to have a first look at the reproductive cycle, the time series was not as complete as it could be with directed sampling. It does however indicate that spawning takes place in July-August, and is fairly protracted.

The data from the 1987-1989 Habitat Ecology Division benthic survey samples (taken with a 0.5 m^2 van Veen bottom grab) are shown in figure 11, along with the length frequencies, and the 1987 age frequency histograms. In 1989 it was decided to concentrate the grab samples in a small area near a known adult population. In seventy grabs only four *Mactromeris polynyma* were caught, one was unmeasurable and the other three were 58, 61, and 63 mm in length.

The editing and re-analysis of the 1981 and 1982 research survey data using the original post-stratification resulted in a decrease of less than 5% in the overall estimate of the biomass on Banquereau Bank, and less than 1% in the estimate for the two areas originally defined as having commercial potential (Table 3). The ACON contouring package produced similar results (Figure 12). This package restricts its contouring to the boundaries of the data points used, and thus the total biomass estimate is for the smaller area of 7,001 km^2 rather than the 9,182 km^2 enclosed by the 100 m isobath, as is used in Rowell and Amaratunga (1986). This contouring estimates a total biomass of 681,147 t which is 86% of the original estimate, based on an area 76% of the original. The estimates of the area of commercial densities, defined as >100g/m^2 from data from the U.S. surf clam fishery, are 4% smaller, 2,208 km^2 from the ACON analysis compared to 2,298 km^2 in the original estimate (Rowell and Amaratunga, 1986).

The kriging analysis did not improve the biomass estimates (Figure 13). The variogram (Figure 14), showed that, with the exception of one pair of stations, the distance between stations was at the limits of the "range of influence" of the stations. Because of this the method did not offer the improvement that could be expected for a survey with a closer grid spacing or greater spatial autocorrelation of the data.

DISCUSSION

The analysis of the logbook data shows how the fishery had concentrated on one area of the bank by 1988. This concentration continued for most of 1989, but during the last quarter some exploratory fishing took place. The lack of interest in exploration may be due to the fact that the marketing side is, at present, not able to handle what the fishery is capable of producing. The vessels are sent out to load up quickly, and go to where they know they can do this.

The cumulative effect of dredging in a small area would give reason for concern over the long term future of this fishery, if they were accompanied by drops in the CPUE. The areas that have attracted the most interest from the fleet have been extensively dredged. Hydraulic dredges as a whole are reported to be very efficient, often approaching 100% (Caddy *et al.* 1974). Yet areas that have received enough effort to dredge more than 100% of the bottom are still supporting good catch rates. Neither the CPUE of the fleet overall, or just in the areas that have received the most effort, showed a decrease (Figures 1 and 2). This could be partially explained by decreases in available biomass being hidden by a learning curve as the captains and crew worked out the best way to set up and use the gear. However, with the amount of effort expended in a small area, and the time involved, a decrease in CPUE would be expected to show by now. One explanation is that the dredges are not as efficient as first thought.

The analysis of CPUE by one minute squares indicates that there are other areas of Banquereau Bank that can support good catch rates.

The International Observer Program was successful last year in covering 100% of trips by the one foreign chartered vessel, but only covered 12.5% of trips by domestic vessels, instead of the 50% targeted. In light of our lack of ability to conduct research surveys on this stock, good coverage and data from the commercial vessels are essential.

The length frequencies from the observer program (Figures 3 and 4) do not provide much information about recruitment . The gear should be of a size for nearly 100% retention at 32 mm shell width. The shell length-width regression (Figure 5), indicates that this corresponds to a shell length of 86 mm. The modal length of the catch, however is 120 mm, indicating a high abundance of older animals. This suggests that the stock is not having constant recruitment. There are no definite age modes, although this is not unexpected in a slow growing species due to the large overlap in size of successive age classes. The van Veen bottom grabs used during 1987 and 1988 cruises did catch some clams less than 80 mm, but only in low numbers and in restricted areas of the Bank (Figure 11). This makes the small clams showing up in the 1989 length frequency data at 35 mm encouraging. The analysis of mean shell length of the catch from the observer program shows that this varies over the bank. This is an indication that the population does not have a stable age distribution and that recruitment is patchy. Our knowledge of the recruitment process for this species is limited. There is a large mode of older animals over much of the bank, but it is not known if their removal through fishing will effect future recruitment.

The areas that appear to have the largest numbers of small clams in the benthic surveys are in or near areas of high adult biomass. This may indicate a limited area of suitable habitat, and raises concerns about the incidental effects of dredging on pre-recruit clams. The effects of direct incidental mortality on small *Mactromeris polynyma* are not known for this area, but have been shown to be low in other clam fisheries using hydraulic dredges (Kauwling and Bakus, 1979). This may, however, be greatly exceeded by the indirect effect of predation on small clams exposed on the surface (Kauwling and Bakus, 1979; Medcof and Caddy, 1974).

The results of the study on conversion factors are insufficient and must be continued; variation is large and the processing lines are still undergoing changes. The conversion factor presently used for the logbook analysis is 7.4179 applied to the weight of the foot meat. This is done because the foot portions are what the fishery is after and if something is going wrong in the processing, the body meat is sacrificed before the foot meats. Some of the comments in the logs show that at times all of the body meat has been discarded. Statistics Branch uses a factor of 6 applied to the sum of the foot and body meat. Results to date indicate that the 7.4179 applied to the foot portions is fairly accurate as it is not significantly different from the results obtained running samples through the processing line. Current changes in the processing line mean that this factor will decrease slightly in the short term, before stabilizing as the processing setup is optimized. The lower conversion factors obtained from the handshucked samples is expected, since during regular processing a percentage of foot meat ends up in the body meat. These factors do not take into account the sand content in the clams. This should be taken into account for removals, but if it is done for the official landings it would have to be taken into account for the companies landing live as well. As neither company is coming anywhere close to its TAC at this time, the conversions do not have an influence on the EA program, but for biological assessments good estimates of removals are important.

The extent of shell breakage is very high. It does not present a problem for survival at this time due to the low discard rate. However, it does raise a concern over incidental mortality, especially in light of the possibility that the dredges are operating with lower than expected efficiency . There are no estimates of incidental mortality on the bottom, and with the gear and depths involved they will be difficult to obtain.

With the exception of other species of clams, the by-catches in this fishery are low and do not appear to be an area of concern. The comparison of Table 2, parts a and b, indicates that the visual estimates by the observers of percentage composition of the major components are accurate.

The results from the subjective study of the reproductive cycle, indicating a protracted late summer spawning, correspond to a study done on an Alaskan population of the same species (Hughes and Bourne, 1981). That study reported that clams collected during July and August of 1977 and 1978 were ripe, spawning or recently spent.

The age data obtained to date verifies the slow growth rate of this species. The curve from the Alaskan population is interesting in that it appears to closely follow a mode of faster growing clams. If this mode comprises a sizable fraction of the population it would mean that the population could withstand higher exploitation rates than calculated from the mean growth curve. The ability to use all chondrophore rings to obtain back calculated sizes at age greatly increases the amount of data obtained from each shell, and reduces the standard errors of the estimated growth parameters by more than 80%. Since the population that is being fished is still a virgin population, the back calculated ages can be used without the problems incurred when this method is applied to a population that has grown up under the influence of a size selective fishery (Roddick and Mohn, 1985). The slow growth rate means that correspondingly low exploitation rates are needed. Combined with the length frequency data, it indicates that replacement of the stock by growth of pre-recruits will not take place over the short term. With a greater number of aged clams, we may be able to say more about the age structure of the population and obtain better estimates of recruitment variability and mortality rates.

The editing and re-examination of the original survey data did not result in any great changes. The contouring packages used also gave similar results. ACON uses contours based on inverse distance weighting and GULF KRIG performs a distance weighting based on the spatial autocorrelation in the data. In this case, the distance between stations was at the limits of the 'range of influence', and thus offered no improvement in the estimates. A comparison of the station locations in figure 12 with the CPUE data from the commercial fishery shows that the high biomass appears to be concentrated in a narrow band, and that most of the survey stations missed it. The large area assumed to have a high biomass according to the survey data also appears to be overestimated when compared to the commercial data. If this is the case the TAC set for Banquereau Bank is likely too high and it may be fortunate that the exploitation rates are still low.

The environmental effects of dredging on Banquereau Bank have not been studied to date, and the depths involved and distance from shore will make such studies difficult and expensive to carry out. There are, however, studies on the effects of hydraulic clam dredges in other areas. Meyer et al. (1981) looked at the short-term effects of dredging for *Spisula solidissima* off Long Island, N.Y. in 10-15 m depth. They noted that the dredge track was at first well-defined, but by 24 h was visible only as a series of small depressions. Predators increased both in the number of species and in abundance for the first two hours after dredging but, with the exception of moon snails, returned to pre-dredging levels within 24 h.

MacKenzie (1982) compared the effects of dredging between three areas off New Jersey at a depth of 37 m and within 20 km of each other. The test areas included one area which was being actively dredged for Ocean quahogs, one which had been fished for a year but had not been fished for the last 4-5 months, and another area which supported a population of ocean quahogs but had not been fished. Invertebrate abundance and species composition were determined for each site using a 0.1m^2 Smith-McIntyre grab. He concluded that hydraulic dredging for Ocean quahogs does not alter the abundance and species composition of benthic macro-invertebrates.

The largest study on this subject (Kauwling and Bakus, 1979) was carried out in an area proposed for a *Mactromeris polynyma* fishery at 15 to 37 m depth, in Bristol Bay, Alaska. The study examined sediment composition and predator species number and abundance from pre-harvest up to 3 weeks after dredging, at inshore and offshore sites. There were concerns that dredging might result in a change in sediment structure, due to the finer material being resuspended and carried away by the currents. It was found that dredging produced no effect on sediment composition. This was attributed to the lack of fine material in the undisturbed sediment. *Mactromeris polynyma* appears to inhabit medium to coarse sand, and thus there is very little fine material to be lost.

There was an increase in the abundance of predators in the area for 2 days following dredging. The number of species and the abundance per core were periodically sampled from pre-harvest to 3 weeks after dredging. For the offshore stations there was a marked decline 1-2 weeks post-dredging, but returning to pre-harvest levels within 3 weeks. However, the inshore stations showed a steady increase from pre-harvest levels to 3 weeks following dredging. This unexpected response was difficult to explain, however, a patchy distribution of the infauna, and the difficulty of sampling in the dredge tracks may have confounded the results.

These studies all indicate that dredging has little or no long-term effect on species composition of the benthos. The invertebrate community as a whole appears to easily withstand dredging. The effect on the *Mactromeris* population per se is unknown. It is possible that the disturbance of the sediment and removal of large filter feeders may be beneficial to the population. They do show that clams disturbed by the dredge but not captured have an increased vulnerability to predation.

Possible effects on fish stocks on Banquereau Bank are few. There is little bycatch of finfish (Table 2a and b) and the effects on spawning behavior or egg survival would be limited. Banquereau Bank is an identified cod spawning area but, as cod eggs are pelagic, dredging would not affect their survival. There is indirect evidence (the occurrence of ripe adults) that there may be haddock spawning on the bank, however, the eggs of this species are epibenthic and so again there would be little effect on them. Similarly there is some evidence that herring spawn on Banquereau Bank. Although herring eggs are attached to the bottom they are found in areas of hard bottom, not moving sand, and thus would not be in areas supporting populations of surf clams. The only problems for these species would be possible disruptions of spawning behavior. There are no studies showing if fishing gear has any detrimental effects of this type, and it would likely be a lot less for the slow moving dredges than for the larger, faster trawls used in the area.

SUMMARY

In summary, the long term future of the fishery is still not clear. The high concentration of effort apparently has had surprisingly little effect on catch rates. There also appears to be relatively unfished areas of the bank capable of supporting good catch rates. At the moment the market for these clams is in Japan, but the fishery is capable of producing a much greater volume of clams than this market has ever absorbed in the past. Landings have more than doubled each year from 1987 to 1989. Landings could have increased much more this year, but the companies made the decision not to fish as they did not have the markets. The market rather than the supply of the resource is the constraint for the fishery at this time.

There is, at present, no solid biological foundation from which to recommend any changes to the TACs. The biological data available for this species for such basic determinations as growth rates, recruitment and natural mortality are preliminary. We also lack the capability of doing research surveys. It is hoped that an increase in the data available through research and sampling programs will help to fill in the gaps and provide for better estimates of important parameters. It is unlikely that our knowledge will increase enough during the year to be able to provide sound biological advice on TACs in the short term without better estimates of the standing stock biomass.

The data from the commercial fishery does not suggest a decline in the available biomass, however, the data does suggest that the original biomass estimates may have been too high. If this is true, the present TAC level could result in overfishing of the stock. In the event of original biomass overestimates and a considerable rise in market demand, the quickest the stock could be expected to recover from an overfished state is on the order of a decade.

ACKNOWLEDGEMENTS

We would like to thank Terry Rowell and Tissa Amaratunga for the use of the early data collected during their tenure as biologists responsible for the surf clam fishery. Terry Rowell for the use of the Habitat Ecology Division data from the benthic survey grab samples. Gerry Black for his help with, and revisions to, the ACON package; and G. Conan for performing the kriging analysis of the survey data.

REFERENCES

Amaratunga, T. and T.W. Rowell. 1986. New estimates of commercially harvestable biomass of Stimpson's Surf Clam, *Spisula polynyma*, on the Scotian Shelf based on the January through April 1986 test fishery and new age data. Can. Atl. Fish. Adv. Comm. Res. Doc. 86/112: 24 p.

Bernard, F.R. 1983. Catalogue of the living Bivalvia of the eastern Pacific Ocean: Bering Strait to Cape Horn. Can. Spec. Publ. Fish. Aquat. Sci. 61:102p.

Caddy, J.F., R.A. Chandler and D.G. Wilder. 1974. Biology and commercial potential of several underexploited molluscs and crustacea on the Atlantic Coast of Canada. *In*: Fish. Mar. Serv. Proceedings, government-industry meeting on the utilization of Atlantic marine resources. Queen Elizabeth Hotel Montreal, P.Q. February 5-7, 1974: 57-106.

Chaisson, D.R. and T.W. Rowell. 1985. Distribution, abundance, population structure, and meat yield of the ocean quahaug (*Artica islandica*) and the Stimpson's surf clam (*Spisula polynyma*) on the Scotian Shelf and Georges Bank. Can. Ind. Rep. Fish. Aquat. Sci. 155: ix + 125 p.

Hughes, S.E., and N. Bourne. 1981. Stock assessment and life history of a newly discovered Alaska surf clam (*Spisula polynyma*) resource in the Southeastern Bering Sea. Can. J. Fish. Aquat. Sci. 38: 1173-1181.

Kauwling, T,J. and G.J. Bakus. 1979. Effects of hydraulic clam harvesting in the Bering Sea. Tetra Tech Report TC 3324. Prepared for: North Pacific Fishery Management Council: 183p.

MacKenzie, C.L. Jr. 1982. Compatibility of invertebrate populations and commercial fishing for ocean quahogs. N. Amer. J. Fish. Management. 2: 270-275.

Medcof, J.C. and J.F. Caddy. 1974. Underwater observations on performance of clam dredges of three types. Fish. Res. Board Can. Ms. Rept. 1313: 9p.

Meyer, T.L., R.A. Cooper and K.J. Pecci. 1981. The performance and environmental effects of a hydraulic clam dredge. Mar. Fish Review. 43(9): 14-22.

Roddick, D.L. and R.K. Mohn. 1985. Use of age-length information in scallop assessments. Can. Sci. Adv. Comm. Res. Doc. 85/37 16p.

Ropes, J.W. 1968. Reproductive cycle of the surf clam, *Spisula solidissima.* in offshore New Jersey. Biol. Bull. 135: 349-365.

Ropes, W. and G.R. Sheperd. 1988. Surf clam *Spisula solidissima. In* J. Pentila and L.M. Dery (eds.), Age determination methods for Northwest Atlantic species. NOAA Tech. Rept. NMFS 72: 125-128.

Rowell, T.W. and D.R. Chaisson. 1983. Distribution and abundance of the ocean quahaug (*Artica islandica*) and Stimpson's surf clam (*Spisula polynyma*) resource on the Scotian Shelf. Can. Ind. Rep. Fish. Aquat. Sci. 142: v + 75 p.

Rowell, T.W. and T. Amaratunga. 1986. Distribution, abundance, and preliminary estimates of production potential for the Ocean Quahaug (*Artica islandica*) and Stimpson's Surf Clam (*Spisula polynyma*) on the Scotian Shelf. Can. Atl. Fish. Adv. Comm. Res. Doc. 86/56: 21 p.

Turgeon, D.D., A.E. Bogan, E.V. Coan, W.K. Emerson, W.G. Lyons, W.L. Pratt, C.F.E. Roper, A. Scheltema, F.G. Thompson, and J.D. Williams. 1988. Common and scientific names of aquatic invertebrates from the United States and Canada: mollusks. American Fisheries Society Special Publication 16: 227p., 12 pls.

Watson, D.F. and G.M. Philip. 1985. A refinement of inverse distance weighted interpolation. Geo-Processing 2: 315-327.

Table 1. - Catches (kg) of Arctic surfclams 1986-1988.

NAFO Area	1986[1]	1987[2]	1988[3]	1989[4]
4Vn	-[5]	0	-	-
4Vs	28,669	1,221,720	2,859,740	7,772,621
4W	2,075	6,180	2,919	-
4X	-	0	-	-
5Ze	-	360	-	-
Total	30,744	1,228,950	2,862,659	7,772,621
[6] Official Statistics 4Vs Landings		883,000	2,929,000	8,505,000
Official Statistics 4Vs Value $		171,000	2,724,000	5,972,000

1 - From International Observer data, 100 percent coverage in test fishery.

2 - From logbooks, most of catch from exploratory fishing was discarded, catch recorded in bushels and converted to kilograms as 30 kg/bushel.

3 - 4Vs data from sales slips, processed weights converted to round weights by using a factor of 7.4179 applied to processed foot weights; exploratory fishing from International Observer Program and may be incomplete.

4 - Data from sales slips.

5 - A '-' indicates no fishing, '0' indicates fishing but no catches.

6 - Statistics Branch converts processed weights to round weights by using a factor of 6 applied to the sum of processed foot and body meat weights.

Table 2a. - Catch composition for the Banquereau Bank *Mactromeris polynyma* fishery from sorted and weighed two bushel samples from the hoppers.

Fraction %	Artic surfclams	Shell	Northern propellerclams	Ocean quahogs	Other*
High	74.50	63.20	33.61	13.50	15.30
Low	28.79	9.20	3.10	0.00	0.00
Average	48.93	37.33	12.73	0.05	0.78

* Other includes rocks and various invertebrate and fish species, see next table.

Table 2b. - Catch and species composition for the Banquereau Bank *Mactromeris polynyma* fishery from International Observer Program visual estimates made during 1989.

Common name	Scientific Name	Weight caught (kg)	% of total
Arctic surfclam	*Mactromeris polynyma*	1,697,402	46.1818
Shell debris	-	1,387,449	37.7488
Northern propellerclam	*Cyrtodaria siliqua*	352,102	9.5798
Ocean quahog	*Arctica islandica*	207,841	5.6548
Rocks/stones	-	22,069	0.6004
Sand dollars	*Echinarachnius parma*	3,110	0.0846
Skates	*Rajidae ssp.*	3,009	0.0819
Tellins	*Tellina ssp.*	880	0.0239
Gould pandora	*Pandora gouldiana*	400	0.0109
Sea cucumber	*Holothuroidea ssp.*	246	0.0067
American plaice	*Hippoglossoides platessoides*	167	0.0045
Greenland cockle	*Serripes groenlandicus*	160	0.0044
False quahog	*Pitar morrhuanus*	148	0.0040
Yellowtail flounder	*Limanda ferruginea*	121	0.0033
Starfish	*Asteroidea ssp.*	93	0.0025
Sculpins	*Cottidae ssp.*	88	0.0024
Goosefish	*Lophius americanus*	73	0.0020
Atlantic razor	*Siliqua costata*	60	0.0016
Blue mussel	*Mytilus edulis*	20	0.0005
Witch flounder	*Glyptocephalus cynoglossus*	19	0.0005
Sea scallop	*Placopecten magellanicus*	8	0.0002
Atlantic halibut	*Hippoglossus hippoglossus*	5	0.0001
American lobster	*Homarus americanus*	3	0.0001
Atlantic cod	*Gadus morhua*	2	0.0001
Sea urchins	*Strongylocentrotus droebachiensis*	1	0.0000
Argis	-	1	0.0000
Longhorned sculpin	*Myoxocephalus octodecemspinosus*	1	0.0000
Silver hake	*Merluccius bilinearis*	1	0.0000
	Sums	3,675,479	99.9998

Table 3. - Banquereau Bank biomass estimates based on 1981 and 1982 Delaware II surveys.

A - From Rowell *et al.* (1886), using length weight regression from entire Scotian Shelf data.

Area	km^2	n	Mean Density (g/m^2)	Biomass (t)
1	1,589	14	248	394,072
2	709	4	230	163,070
Remainder	6,884	52	34	234,056
Mean for Areas 1&2	2,298	18	244	560,712
Sum of Areas 1&2	2,298	18	-	557,142
Sum for Bank	9,182	70	-	791,198
Mean for Bank	9,182	70	88	808,016

B - Reanalysis based on edited data and using length weight regression from Banquereau Bank data only ($n = 1364$, $r = 0.98$).

Area	km^2	n	Mean Density (g/m^2)	Biomass (t)
1	1,589	14	246	389,250
2	709	4	229	162,613
Remainder	6,884	50	29	199,535
Mean for Areas 1&2	2,298	18	242	556,831
Sum of Areas 1&2	2,298	18	-	551,863
Sum for Bank	9,182	68	-	751,398
Mean for Bank	9,182	68	86	784,707

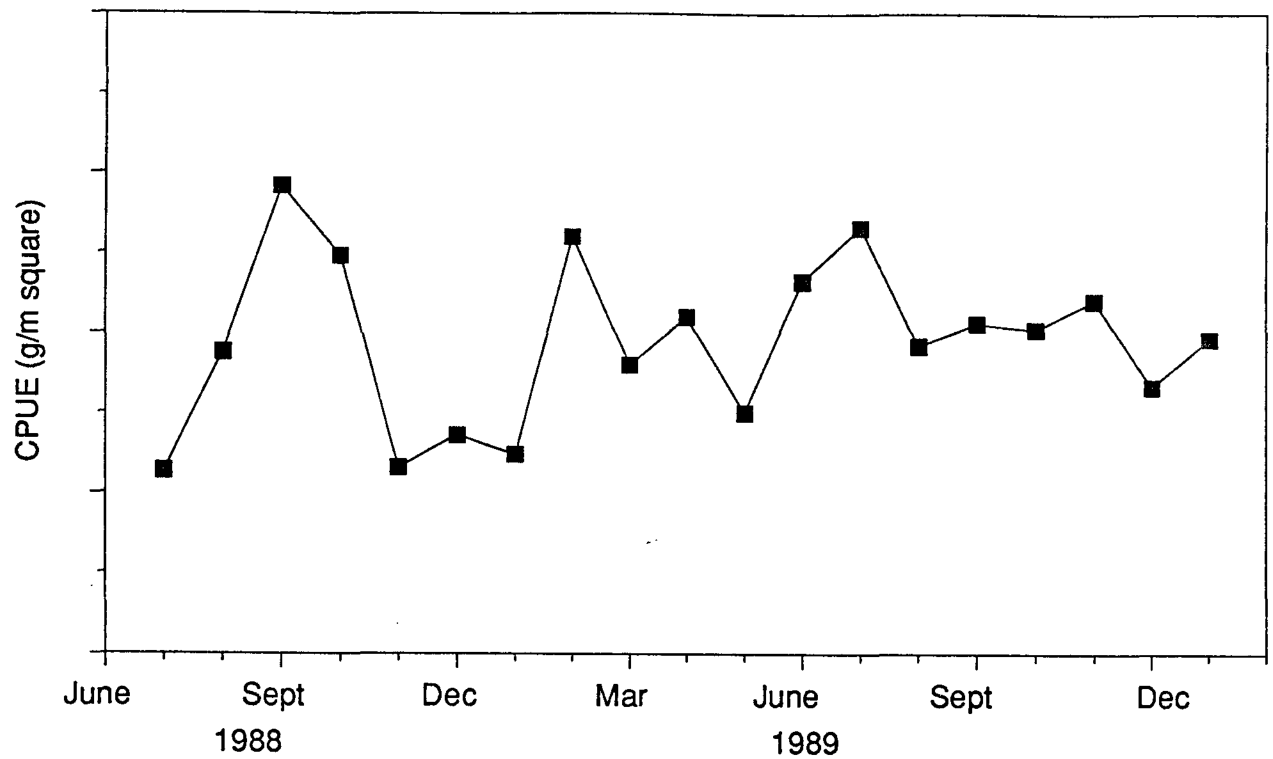

Figure 1. - CPUE (g/meter square) on Banquereau Bank, for all vessels combined. Y axis scale removed, as data is confidential commercial logbook data.

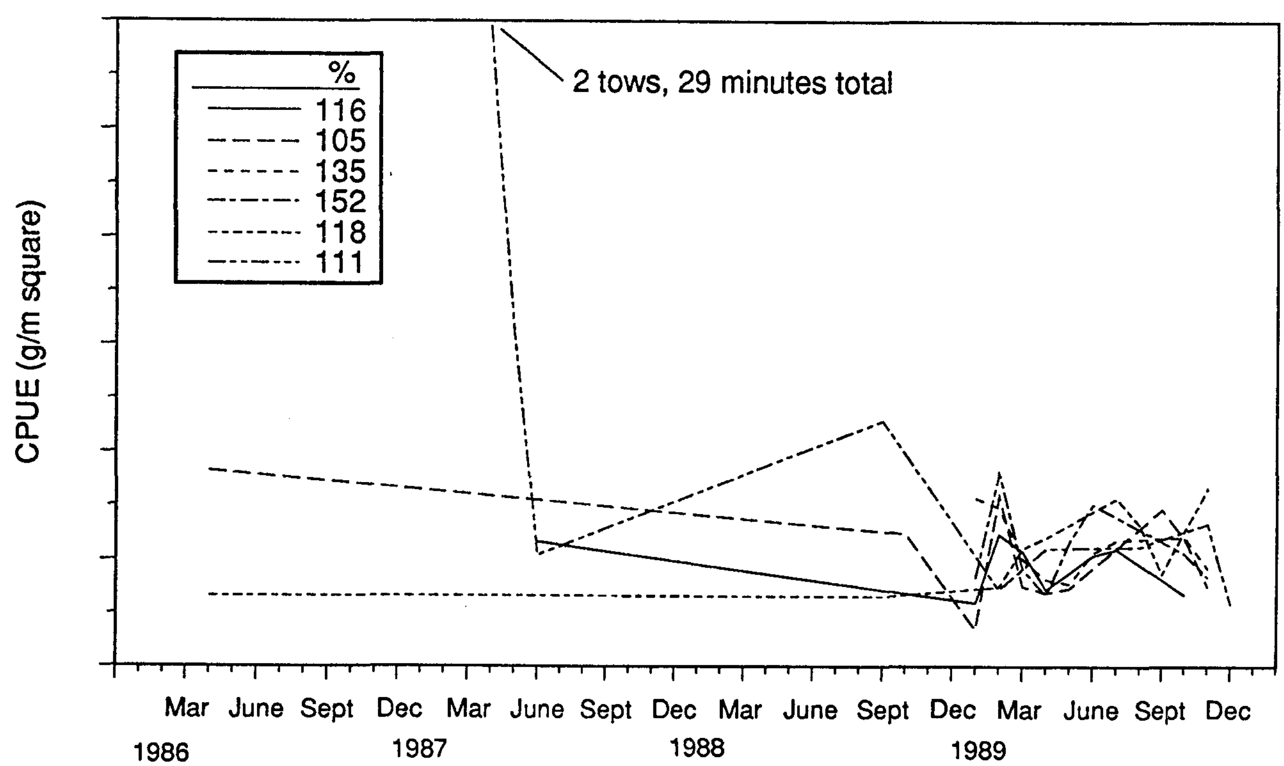

Figure 2. - Monthly mean CPUE in the six one minute squares receiving enough effort to dredge more than 100% of the bottom. Y axis scale removed, as data is confidential commercial logbook data.

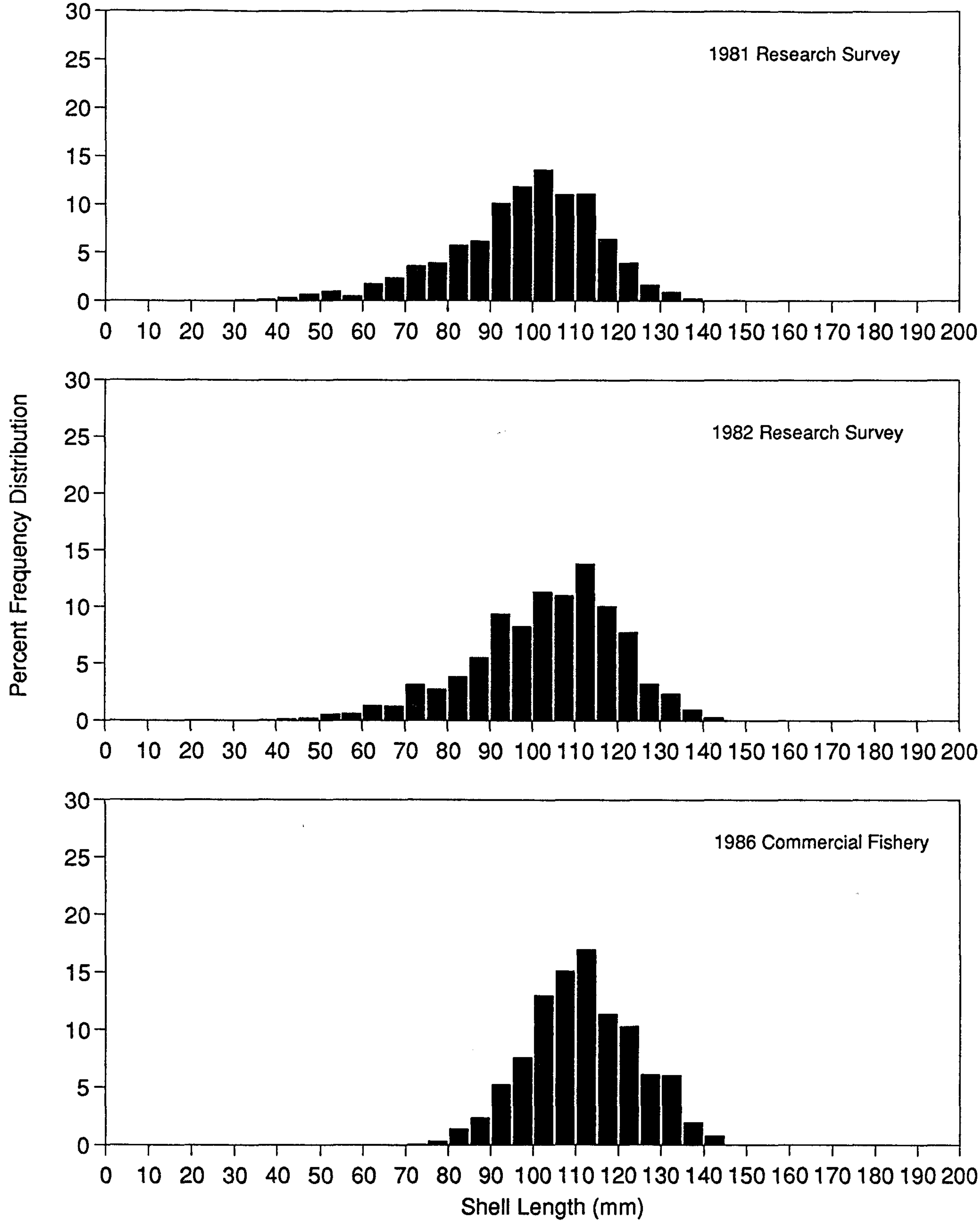

Figure 3. - Shell length frequencies from 1981 and 1982 research surveys, and the 1986 commercial fishery.

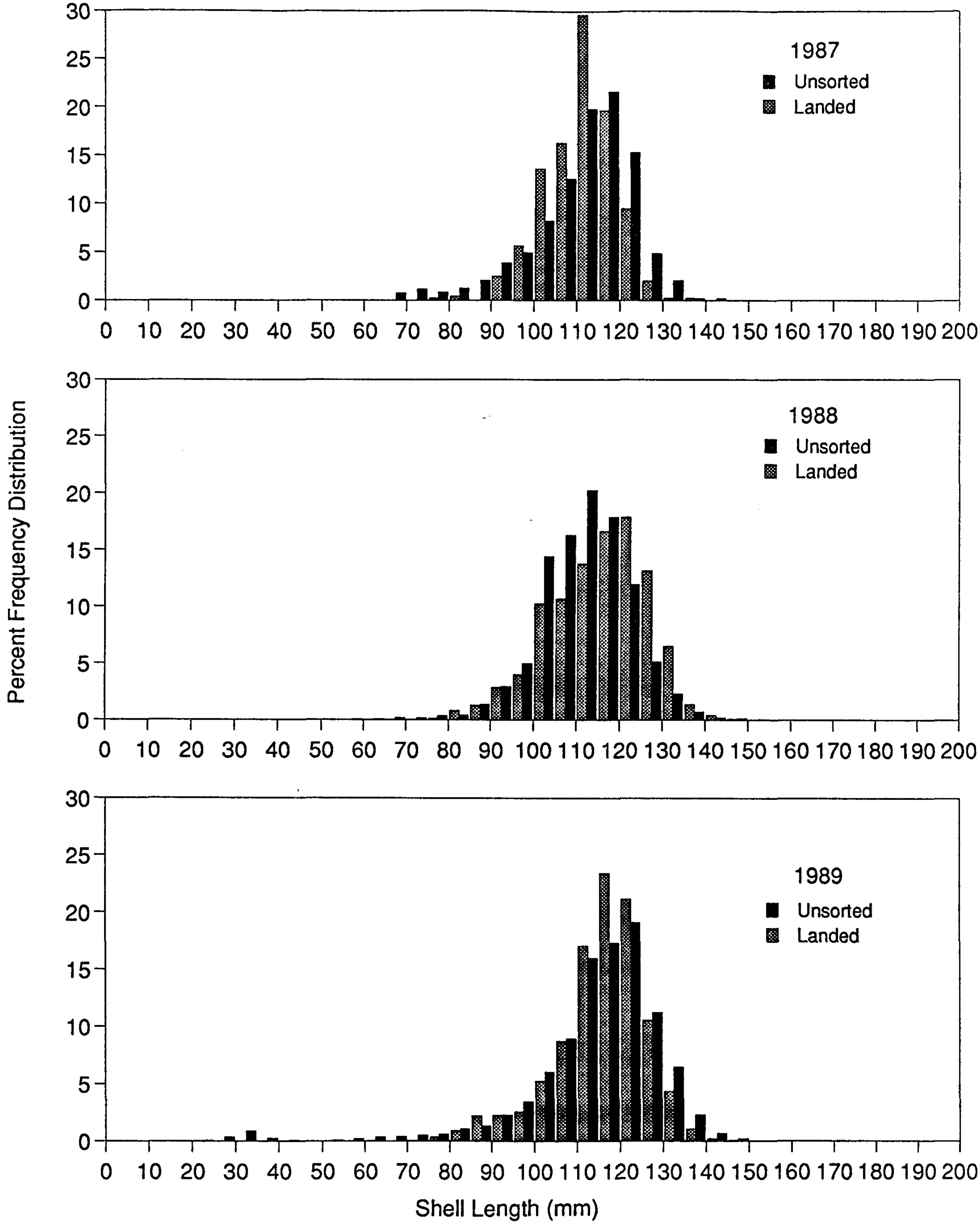

Figure 4. - Shell length frequencies for 1987-1989 for international observer program samples from the commercial fishery.

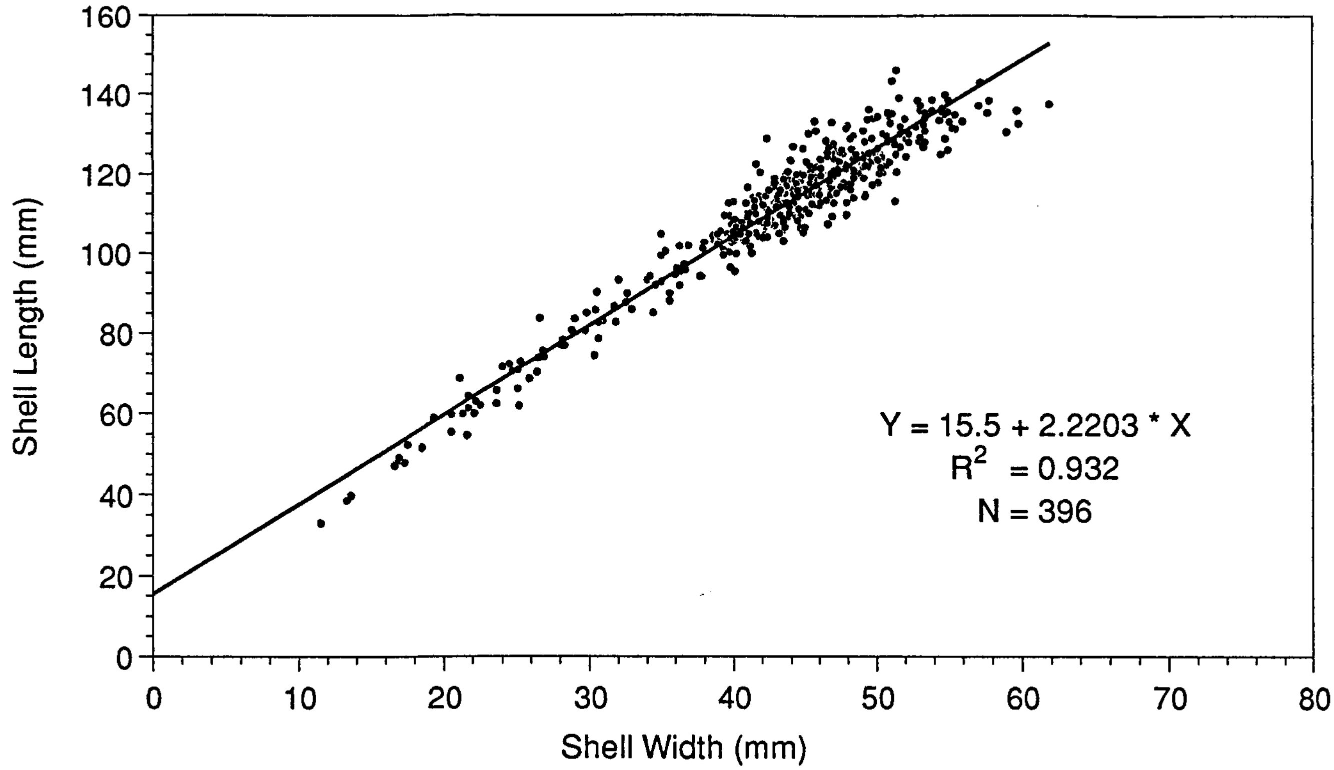

Figure 5. - Regression of shell length against shell width.

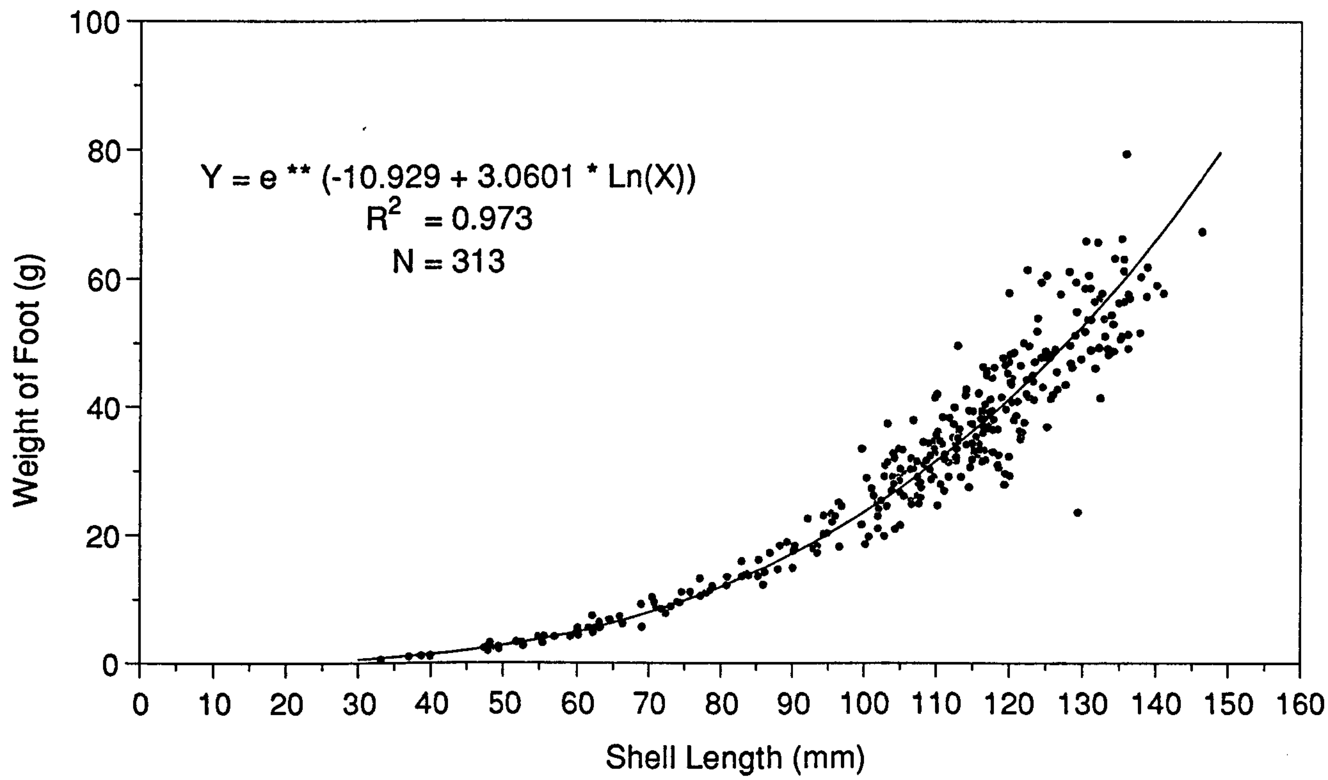

Figure 6. - Regression of foot weight against shell length.

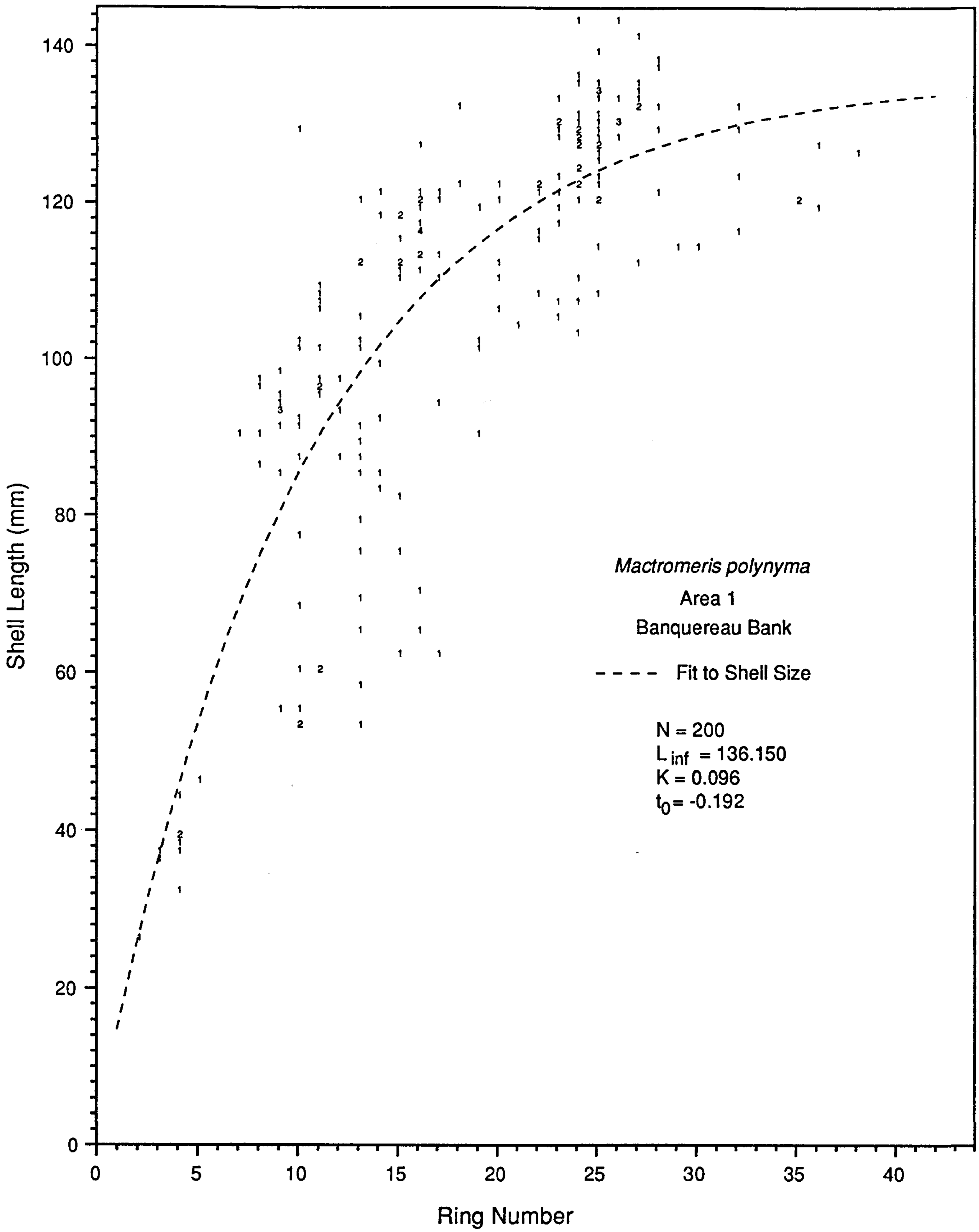

Figure 7. - Von Bertalanffy growth curve fit to actual shell length.

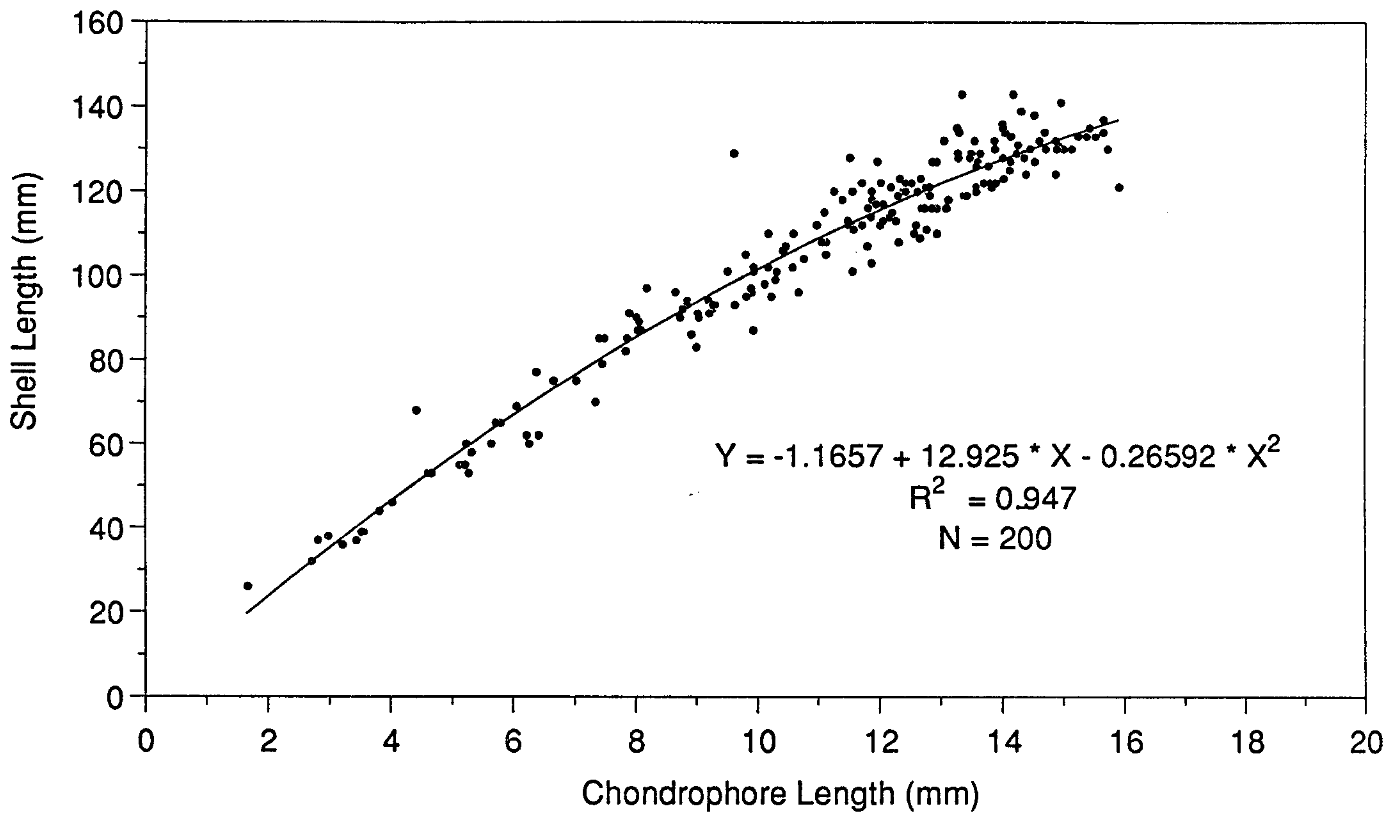

Figure 8. - Regression of shell length against chondrophore length.

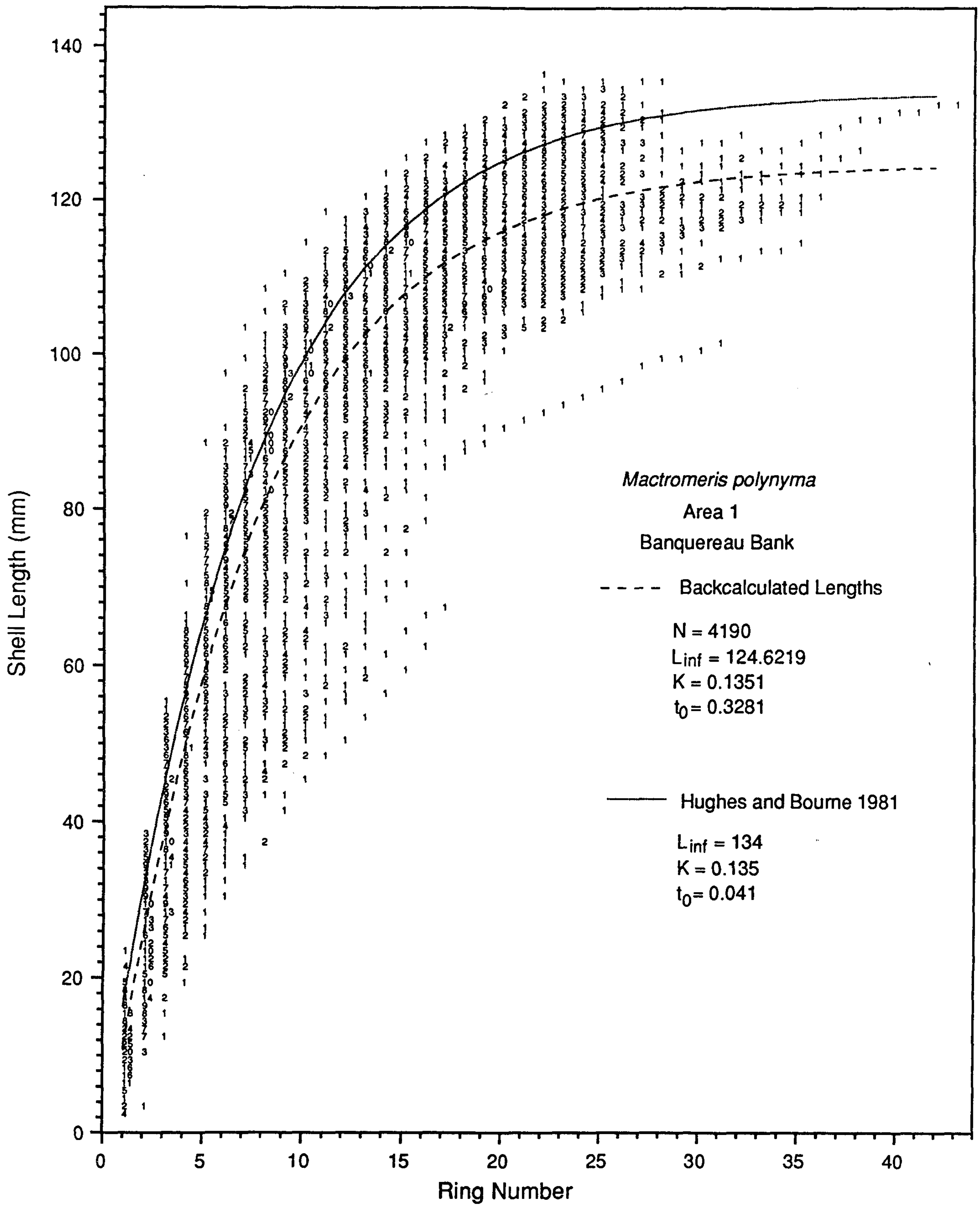

Figure 9. - Von Bertalanffy growth curve fit to shell lengths backcalculated from chondrophore rings. Also shown is a growth curve from an Alaskan population (Hughes and Bourne 1981).

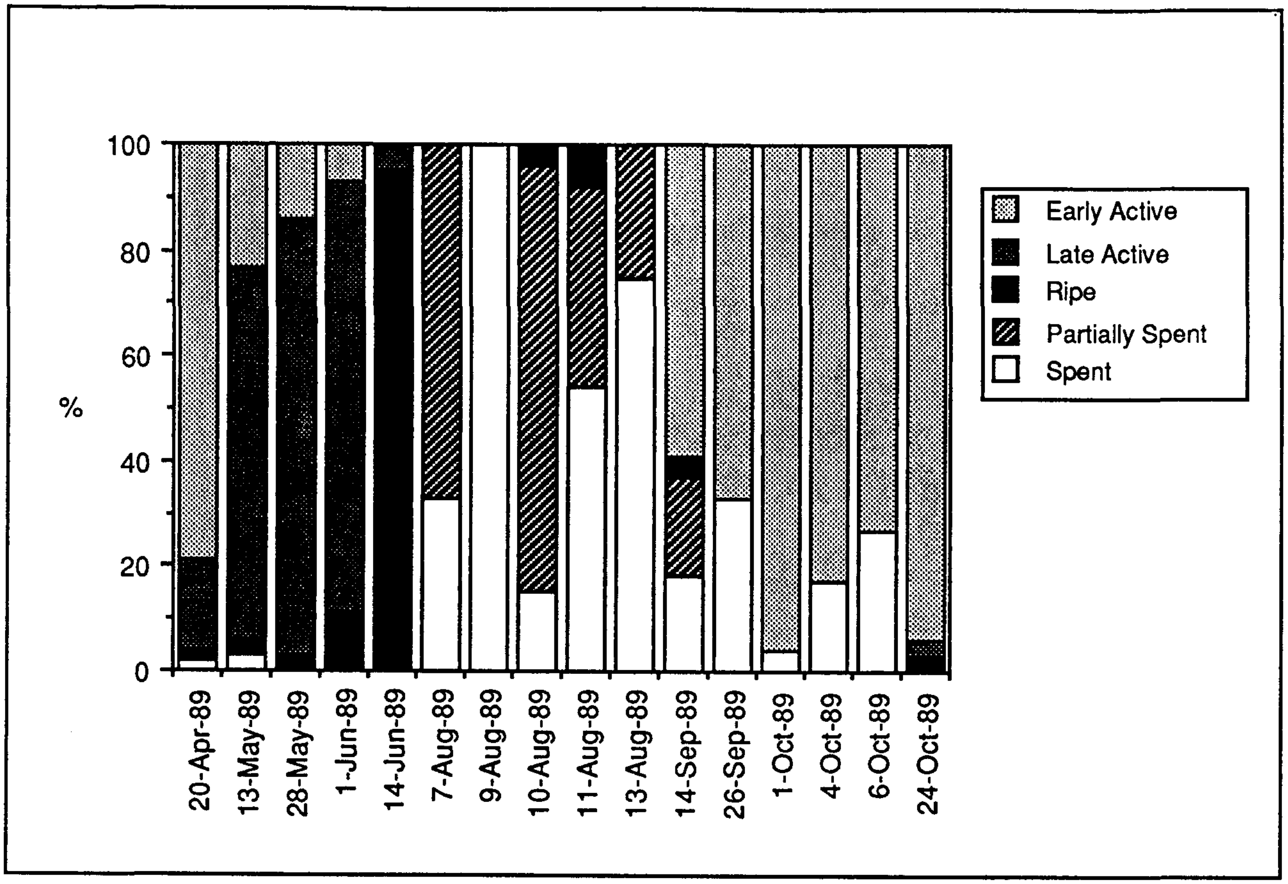

Figure 10. - Maturity stages of *Mactromeris polynyma* from Banquereau Bank samples, subjectively assigned to the stages of Ropes (1968).

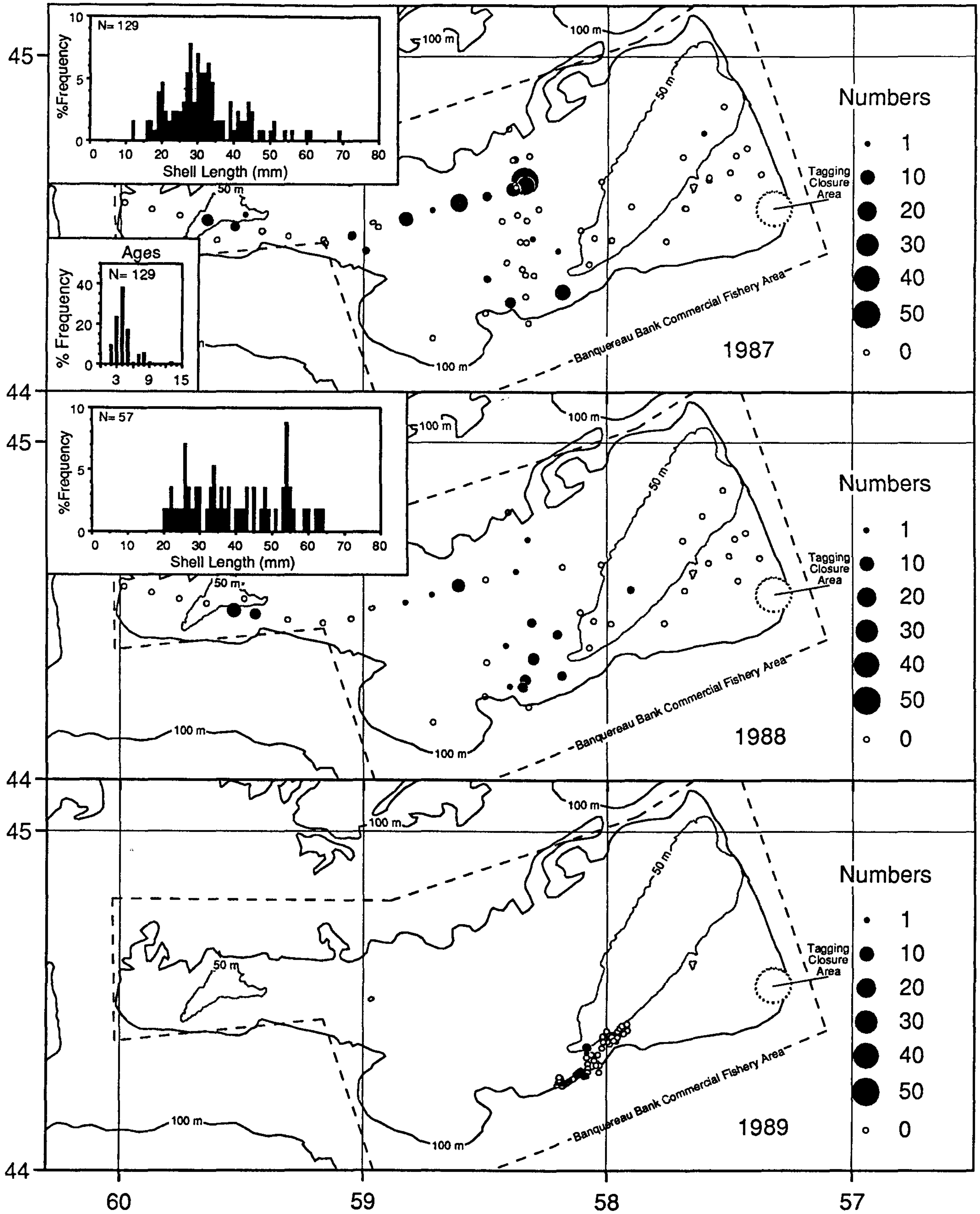

Figure 11. - Numbers of small (<100 mm) Arctic surfclams caught with a $0.5m^2$ van Veen bottom grab during 1987 to 1989 benthic surveys.

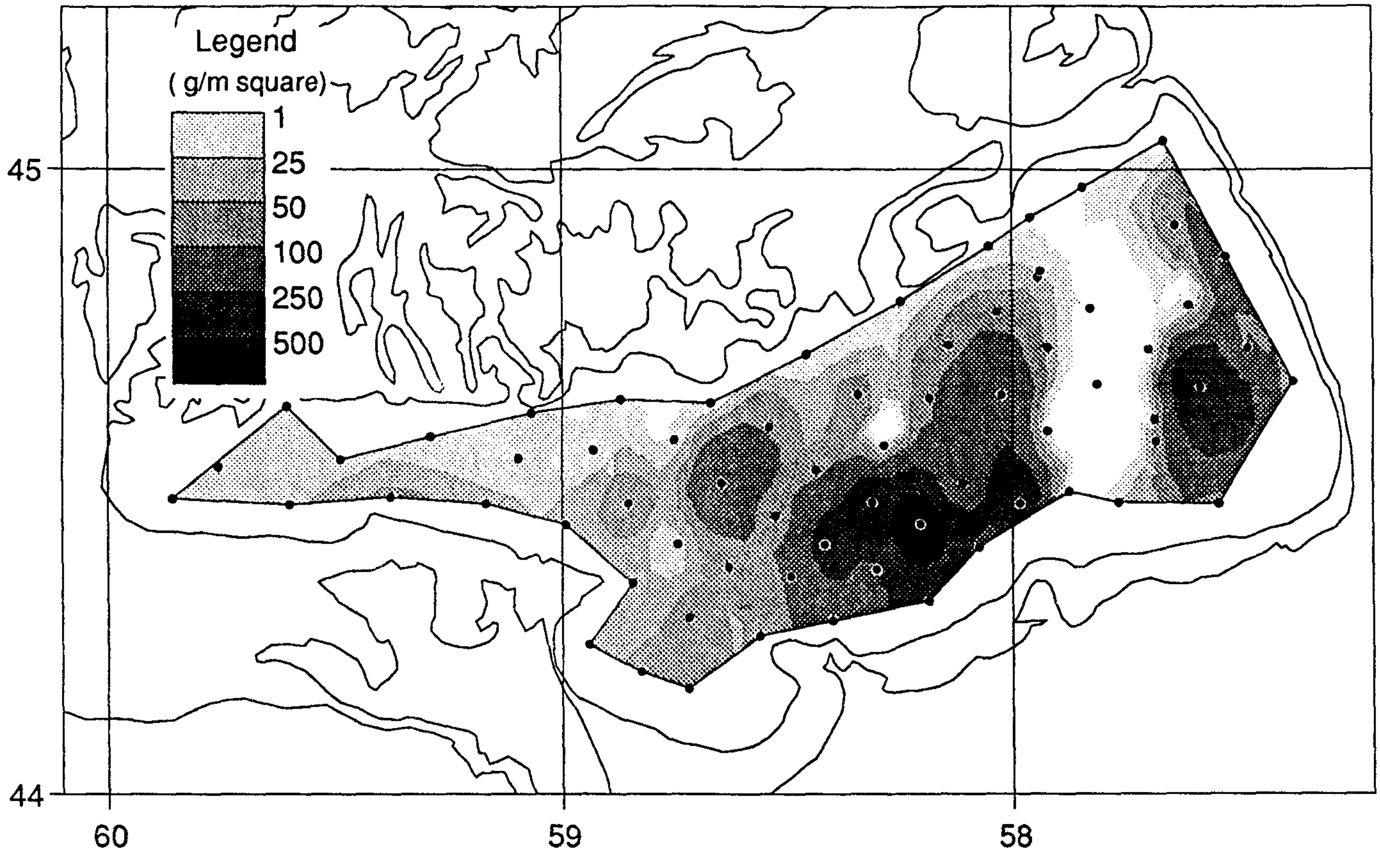

Figure 12. - ACON contouring of 1981 and 1982 survey data.

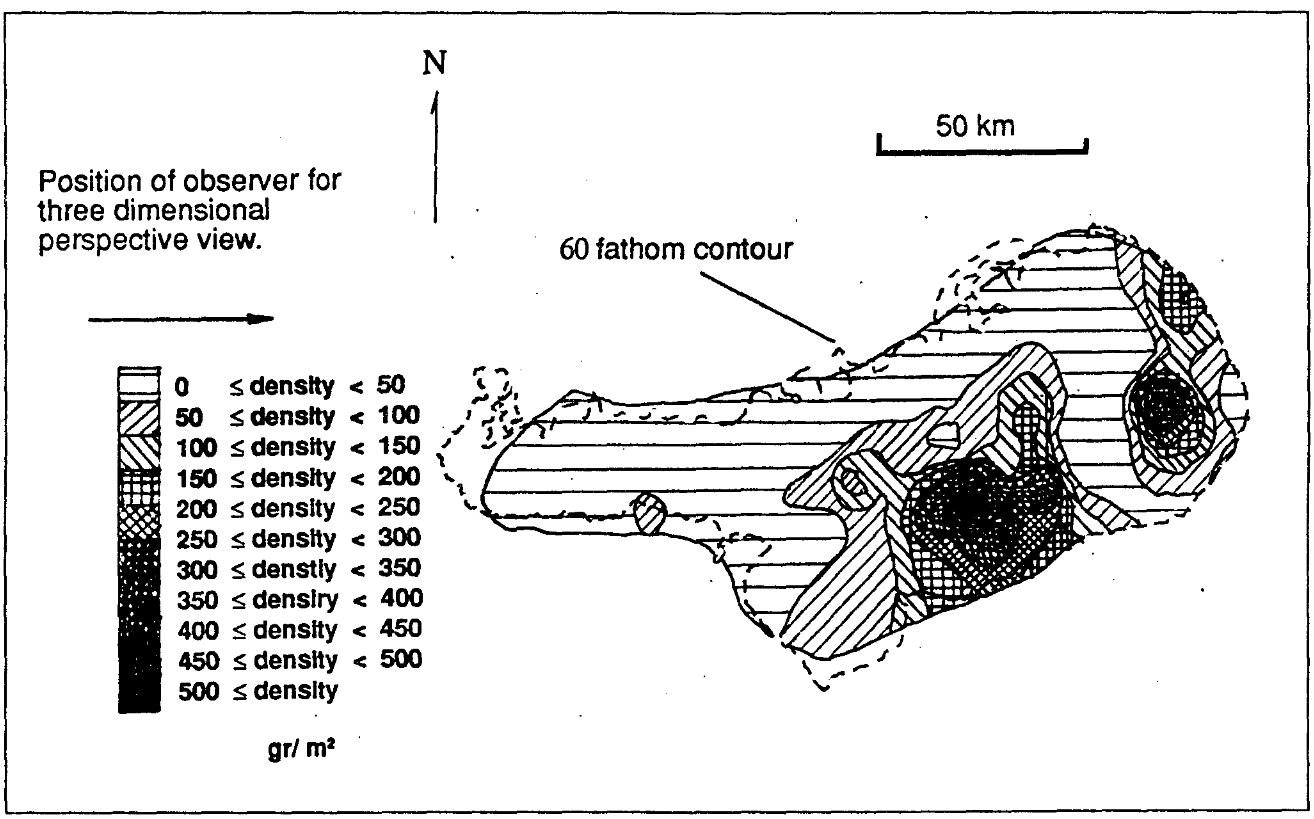

Figure 13. - Contouring of results of kriging 1981 and 1982 survey data.

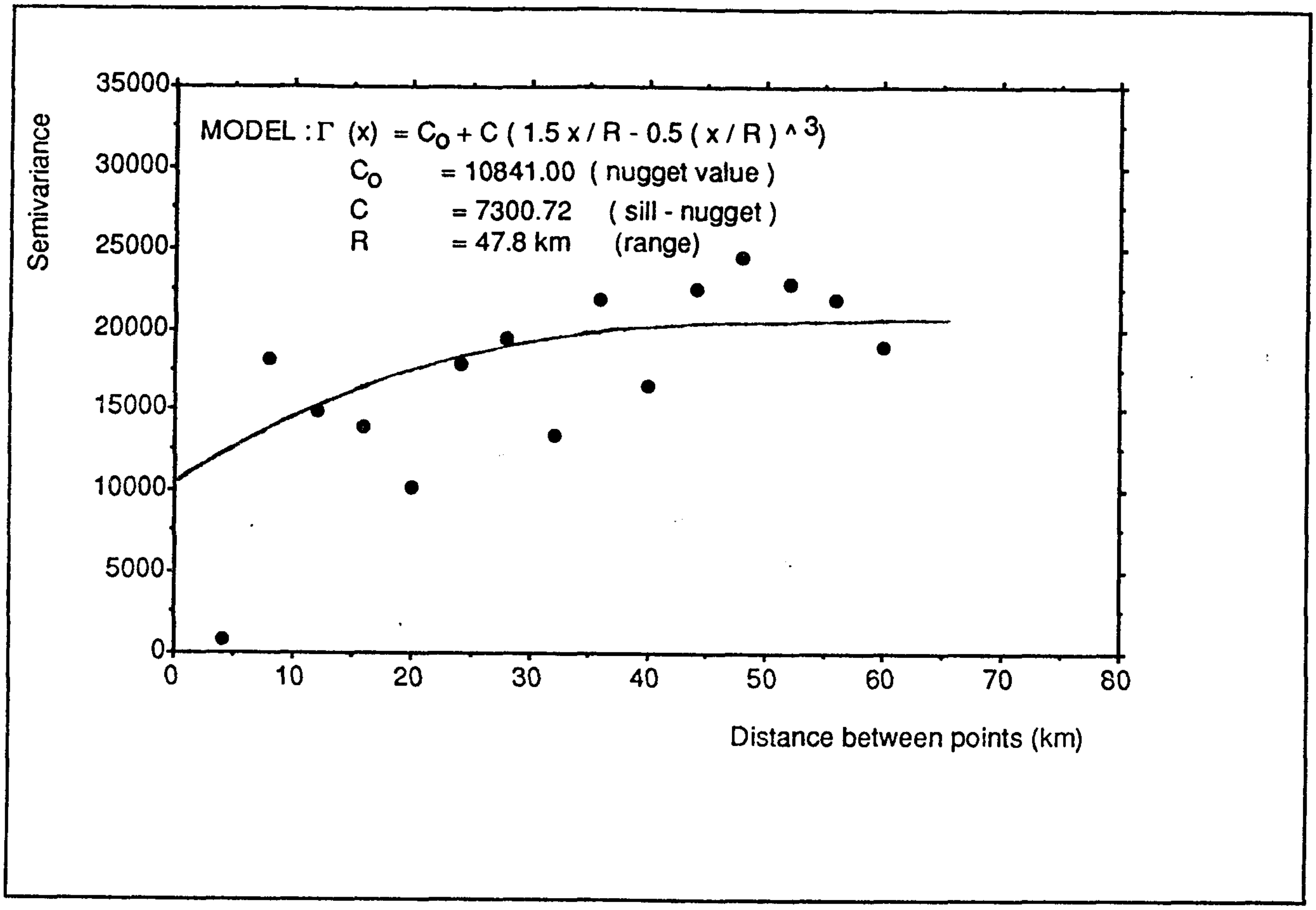

Figure 14. - Variogram for 1981 and 1982 survey data used in kriging contouring.