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An assessment of shrimp stocks off southeast Cape Breton, south Esquiman and north Anticosti

by

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ABSTRACT

The status of three underexploited shrimp stocks, off southeast Cape Breton, north of Anticosti Island and south of Esquiman channel, is assessed. Several biological parameters such as growth, mortality, age and size at recruitment, average age and size in the fishery, age at first spawning, were determined for P. borealis in each area. Values of the different parameters were fairly similar for the three areas, in particular natural mortality which ranged from 0.53 to 0.76. Using logbooks for 1977-79 and six research surveys (1978-79 SE Cape Breton, 1975-76 in the south Esquiman area and 1976-77 north of Anticosti) average biomasses were calculated. TACs were estimated by three different methods, all involving virgin biomass. Option 1 is based on an approximation (MSY = $0.5MB_0$) and gives the highest estimates. Option 2 is based on a reduction of 50% in the virgin spawning stock size and gives the lowest estimates. Option 3, which is based on empirical evidence in the Sept-Iles shrimp fishery, always is close to the average for the two first options (within 5%) and appears the most reliable one.

RESUME

On a évalué l'état de trois stocks sous-exploités de crevettes; au sud-est du Cap Breton, au nord d'Anticosti et dans la partie sud du chenal d'Esquiman. Dans chaque région, nous avons déterminé plusieurs paramètres biologiques de _P. borealis_, tels que: la croissance, la mortalité, l'âge et la taille au recrutement, l'âge et la taille moyens dans les captures, ainsi que l'âge à la première ponte. Les valeurs obtenues pour les différents paramètres se ressemblent passablement pour les trois régions, en particulier la mortalité naturelle qui s'étend de 0.53 à 0.76. Nous avons calculé la biomasse moyenne de crevettes dans chaque région au moyen des données commerciales tirées des livres de bord entre 1977 et 1979, ainsi qu'à l'aide de six croisières de recherche effectuées en 1978-79 au sud-est du Cap Breton, en 1975-76 dans le sud du chenal d'Esquiman et en 1976-77 au nord d'Anticosti. Des PTA ont été estimés selon trois méthodes différentes qui, toutes nécessitaient une estimation de la biomasse vierge. La première option repose sur une approximation (RMS=0.5MB_0) et donne les estimations les plus élevées. La deuxième option consiste en une réduction de 50% du stock vierge des géniteurs (spawning) et donne les estimations les plus basses. La troisième option est basée sur des évidences empiriques de la pêcherie de crevettes de la région de Sept-Iles. Les valeurs de PTA obtenues sont toujours la moyenne (à 5% près) des deux premières options et semblent les plus fiables.

INTRODUCTION

The shrimp (Pandalus borealis) fishery in the Gulf of St.Lawrence and SE Cape Breton (Fig. 1) is still at a very low level of exploitation, except in the Sept-Iles area and in the northern part of Esquiman Channel (north of 50°N). Shrimp stocks North of Anticosti Island, South of Esquiman Channel (south of 50°N) and Southeast of Cape Breton could be considered as practically virgin.

Considering that these last three areas may represent a considerable potential fishery, we used available, relavant information to estimate the potential yield of shrimp for these three areas.

1. Fishing patterns and catch per-unit-effort

From 1977 to 1979, 14-15 vessels from New Brunswick and 4-5 vessels from Quebec fished the three areas - S.E. Cape Breton, S. Esquiman and N. Anticosti. Quebec boats fished in the western part of N. Anticosti area during 1977, 1978 and 1979. Most of the Maritime boats were fishing the eastern part of N. Anticosti area in 1977 and 1978, and only two vessels were fishing in the Cape Breton area during these two years. In 1979, the New Brunswick vessels increased their efforts in the Esquiman and S.E. Cape Breton areas (Fig. 1).

1.1 Southeast Cape Breton

Only two vessels fished this area during 1977 and 1978, and they landed around 300 MT. However, in 1979, catches almost tripled with the arrival of a few other boats (Table 1). The mean annual CPUE increased from approximately 125 kg/hr in 1977-78 to 180 kg/hr in 1979. However, in looking at monthly catch rates, we have found a significant difference of CPUE for the three different types of trawl used in the shrimp fishery: the Yankee 36 being the least powerful, the Yankee 41 being 1.30 times more powerful than the Yankee 36, and the Western 2A being 1.50 times more powerful than the Yankee 36. Since a Yankee 36 trawl is used for our shrimp surveys, we considered one hour of fishing with that trawl as the standard unit of effort. Figure 2 shows the monthly CPUE (original or non-standardized and standardized) from 1977 to 1979. Once standardized, CPUE for the three years follows the same trend as the original CPUE. However, the differences between 1977, 1978 and 1979 are much smaller.

1.2 South Esquiman

Prior to 1979, vessels from the Maritimes were only fishing occasionally in the southern part of Esquiman Channel. Landings reported from that area were under 100 MT, (Table 1), both in 1977 and 1978. In 1979, at least 437 MT have been landed from that area and monthly CPUE are available (Fig. 3). The mean annual standardized CPUE was 90 kg/hr in 1979, higher than in 1977 and 1978.

1.3 North Anticosti

Results presented here do not include Quebec vessels (4-5) fishing in the western part of the area. From 1977 to 1979, the annual CPUE remained constant even if the total catches were different (Table 1). In 1977 and 1979, monthly CPUE shows a steady decline from June to October (Fig. 4). In 1978, there is no such trend. Considering that bad weather conditions occur often in September and October (which may decrease fishing efficiency) and that most of the catches are taken before September, there is little variation of the CPUE during the season.

1.4 General

There are some very noticeable differences between CPUE for the three areas. The best catch rate is obtained in Cape Breton area, followed by south Esquiman and North Anticosti areas, and this for 1977, 1978 and 1979.

The difference between the original and standardized CPUE increased from 1977 to 1979. This is due to the fact that more fishermen outfitted their boats with a new, more powerful trawl, the Western 2A. The horizontal opening of that trawl is the same as the Yankee 36 trawl, but the vertical opening is twice as high: 2.5 m for the Yankee 36 vs 4.5 m for the Western 2A (P.J.G. Carrothers, pers. comm.)[1].

2. Biomass estimates

2.1 Southeast Cape Breton

2.1.1 Direct estimates from surveys

2.1.1.1 1979 survey

The survey was carried out on board a commercial side trawler, the Jean Collette, from October 19 to October 27, 1979. The

[1] - P.J.G. Carrothers, engineer. Dept. Fisheries and Oceans, Biological stations, St-Andrews, N.B.

stratification of the area and the sampling procedure have been described by Labonté, 1979a (1978 survey). Fifty-two stations were sampled during the 1979 survey (Fig. 5).

The gear used was a Yankee 36 shrimp bottom trawl with 38 mm mesh size (stretched). We trawled only during daylight hours to avoid bias introduced by the diurnal migration of shrimp (Barr, 1970; Carlsson et al., 1978) in estimating the shrimp biomass.

Biomass estimates for shrimp were calculated for all strata by the swept area method. The minimum trawlable biomass per strata is given by:

$$B_i = A_i \frac{\Sigma(Y_{ij}/b_{ij})}{n_i}$$

where: B_i = biomass in stratum i,
A_i = surface area (square naut. mile) in stratum i,
Y_{ij} = catch per tow j in stratum i,
b_{ij} = area swept (square naut. mile) per tow j in stratum i,
n_i = number of tows in stratum i.

Standard error ($S_{\bar{x}}$) were calculated using Mackett's method (1973).

Catches of shrimp per 30 min. tow are illustrated in Fig. 6. The minimum trawlable biomass for the whole area (1240 naut. miles^2) in October 1979 was estimated at 12,293 MT (Table 2). This figure represents the biomass for the first 2.5 m above the bottom. Considering the difference of the commercial CPUE obtained by a Western 2A and a Yankee 36 trawl (W2A/Y36 = 1.5), and knowing that there is no difference in the horizontal opening of these two trawls but only in their vertical opening, we increased the original biomass obtained by a factor of 1.5. After adjustment, the total biomass for the whole area is estimated at 18,438 MT (Table 3).

2.1.1.2 1978 survey

From September 21 to October 3, 1978 the survey was also carried out on board a commercial side trawler, the Michel Pierre, geared with a Yankee 36 shrimp bottom trawl with 38 mm mesh size (stretched).

Due to lack of time and bad weather conditions, the survey was not completed. The minimum trawlable biomass for the area surveyed (845 naut. miles^2) was estimated at 8,082 MT (Table 2). Once adjusted by the 1.5 availability factor, the total biomass in Sept./Oct. 1978 is estimated at 12,123 MT for that area (845 naut. miles^2) (Table 3).

2.1.1.3 Combined 1978 and 1979 surveys

Since the 1978 survey was not completed and the fishing effort is still at a very low level off southeast Cape Breton, we have combined results of the 1978 and 1979 surveys to get a more reliable estimate of the shrimp biomass in this area.

The procedure was the following:

a) If fishing activities occurred during 1979 in a particular region, like Canso hole (e.g. strata: Col, Co2, Co3), the mean biomass for this region was calculated by taking the average between the adjusted biomass of 1978 and the adjusted biomass of 1979 plus the commercial catch taken in this region in 1979 (Table 3).

b) If no fishing activities occurred in a particular region in 1979, (e.g. strata Co4 + Co5), the mean biomass was calculated by taking the average between the adjusted biomass of 1978 and 1979.

c) If a region was not sampled in 1978, (e.g. stratum Mo5), the mean biomass for this region was the adjusted one estimated in 1979.

The mean adjusted biomass for the whole Cape Breton area is estimated to 20,169.5 MT (Table 3). For comparison and management purposes, since we do not know to what extent shrimp migrate between strata (Fig. 5), we subdivided the area into three regions: 4VA + 4VB (strata Lo1 to Lo5 and Ao1 to Ao4), 4VC (strata Mo1 to Mo6) and 4WD + 4WE (strata Co1 to Co5). Adjusted biomass figures for those three regions are presented in Table 4.

2.1.2 Estimates from CPUE by areal expansion

Since the fishing effort was very low, it was impossible to use Delury or Leslie methods to estimate the population. However, if we know:

1) Annual CPUE (standardized for a Yankee 36)

2) Surface swept by a Yankee 36 trawl at the average trawling speed of a commercial boat (3 knots)

3) Surface of the area

we can roughly estimate the biomass of an area in assuming homogeneity and constant availability of the shrimp stock.

$$\text{Thus: Biomass} = \frac{\text{Surface of the area}}{\text{Surface swept in 1 hr of fishing}} \times \text{CPUE (kg/hr)}$$

For comparison I present (Table 5) original and adjusted biomass thus calculated vs original and adjusted biomass estimates from 1978 and 1979 surveys. Since fishing occurred only in Louisbourg and Canso holes in 1979, biomass estimates by mean CPUE is possible only for those two zones.

2.2 South Esquiman

2.2.1 Direct estimates from survey

Two biomass estimates for the southern part of Esquiman Channel are available for 1975 and 1976 (Sandeman, 1978). Those two estimates have been adjusted by the 1.5 availability factor (Table 5).

2.2.2 Estimates from CPUE by areal expansion

Calculations were impossible for 1977 and 1978, fishing being practically absent for both years. In 1979, the adjusted shrimp biomass calculated from CPUE is 17,098 MT (Table 5).

2.3 North Anticosti

2.3.1 Direct estimates from surveys

One estimate of 16,018 MT is available from two combined surveys carried out by Quebec and Newfoundland in 1976 and 1977 (Sandeman, 1978) and Fréchette (pers. comm.).

2.3.2 Estimates from CPUE by areal expansion

Biomass estimates were calculated from CPUE for 1977, 1978 and 1979 (Table 5). All three estimates are very close, since the annual CPUE for the three years were very similar.

2.4 General

For the purpose of the assessment, we considered that all biomass estimates obtained were virgin, since fishing is at a very low level in each area. In the SE Cape Breton area, we retained only the estimates obtained during the 1978 and 1979 surveys, fishing being located in very specific zones. In South Esquiman and North Anticosti areas, we calculated a mean biomass based on all estimates available in each area.

3. Parameters needed for the assessment

3.1 Growth + size composition

The constants (K, L_{00} and t_0) of the von Bertalanffy (1938) growth equation (Table 6) were obtained by analysis of size composition data. Polymodal size frequency distributions were analysed by Normsep technique (Abramson, 1971) to identify the modes which were assumed to be year classes; the differences in length between modes being the annual growth rate.

In the Cape Breton area, 3 modal groups of immatures and males: 0, 1 and 2 years old, and 2 discernable groups of females: 3 and 4+ are present in the regions 4VA + 4VB and 4C (Figs 7, 8). In the 4WD + 4WE regions, 4 modal groups of immatures and males: 0, 1, 2 and 3 years old and 1 group of females 4+ form the population (Fig. 9).

In the South Esquiman and North Anticosti areas, commercial data reveal 2 groups of immatures and males (1 and 2 years old) and up to 3 groups of females (probably 3, 4 and 5+ years old) (Figs 10, 11).

There were some differences between the growth constants for the three stocks considered. The growth coefficient (K) in the North Anticosti area was much higher than those from South Esquiman and Cape Breton areas. However, L_{00} were very similar for the three areas. The last discernible age group was IV+ in the three areas. However, according to the growth curves obtained (Fig. 12), the maximum age would be 5 years in North Anticosti and South Esquiman areas and approximately 6 years in the Cape Breton area.

3.2 Length (L_c) and age (t_c) at recruitment in the fishery

In the Maritimes, the mesh size in use in the shrimp fishery is 38 mm (stretched). The mean selection size (L_c) (carapace length) correspond to 16.6 mm or 18.6 mm depending if we use the value calculated by the ICES Working Group (1977) or by Labonté and Fréchette (1978).

The mean age at recruitment in the fishery was calculated for the three areas considered (Table 7) by using a logarithmic transformation of the von Bertalanffy growth equation:

$$t_c = t_0 - \frac{1}{K} \ln \frac{(L_{00} - L_c)}{L_{00}}$$

where: L_c = mean selection size

L_{00} = asymptotic length in Brody-Bertalanffy growth equation

K = Brody growth coefficient

t_0 = theoretical age where the length = 0

t_c = mean age at recruitment in the fishery

The mean age at recruitment (t_c) in South Esquiman area was half a year less than in North Anticosti and Cape Breton areas.

3.3 Age (t_s) at first spawning

In the three areas, shrimp spawn for the first time at three years old, except in Canso Hole, were first spawn as four-year-old (Table 7).

In the Cape Breton area, spawning starts at the beginning of August. In the North Anticosti and South Esquiman areas, shrimp begin to spawn in early October.

3.4 Average length ($\bar{L}$) and age ($\bar{t}$) of fully recruited shrimp in the commercial catches

The age (t_c) at recruitment depends on the mean selection size (L_c) used. $\bar{L}$ corresponds to the average length computed for L_c upwards, and $\bar{t}$ was calculated the same way as t_c, using $\bar{L}$ instead of L_c (Table 8).

Average length of fully recruited shrimp in commercial catches was very similar for the three areas, but $\bar{t}$ in North Anticosti and in South Esquiman was lower than for the Cape Breton stock.

3.5 Mortality

3.5.1 Mortality for females in Canso Hole

Since total biomass in Canso Hole in fall 1978 was very similar to biomass in fall 1979 + the catches taken there during the 1979 fishing season, we have calculated mortality for the fully recruited group of females in that region. Knowing the percentage (in weight) of females caught during the 1978 and 1979 surveys, it is possible to estimate the biomass of females as 1,161.9 MT in Sept./Oct. 1978 and 1,192.6 MT in Oct. 1979. Once adjusted by the availability factor of 1.5, the biomass became 1,742.9 MT for 1978 and 1,788.9 MT for 1979. The mean weight for a female shrimp was 10.65 g ($\sigma = 0.38$) during the 1978 survey and 12.38 g ($\sigma = 0.82$) during the 1979 survey. Consequently, the total number of females was estimated to be 163.7×10^6 in Sept./Oct. 1978 and 144.5×10^6 in October 1979. Among females present in Canso Hole during the October 1979 survey, only a fraction belonged to the total group of females present in Sept./Oct. 1978. That fraction of females had spawned at least twice.

Before the spawning period (August), it is possible to differentiate females which have never spawned from those which have spawned at least once. Females which have never spawned possess a series of sternal spines (like males) until the first molt into breeding dress (McCrary, 1971).

During the 1979 fishing season, prior to spawning, we examined several females caught in the Canso Hole. The proportion of females having sternal spines was 48.0% in May, 47.6% in July and 48.3% in August. After August, all females were ovigerous. Furthermore, we did not observe any new females until the October survey, which means that no sex inversion occurred from May to October 1979. All females being fully recruited to the fishery, they should be equally vulnerable to the fishing gear. They should also be affected by the same causes of natural mortality. Consequently, the proportion of females which spawned at least twice in October 1979 should be the same than as the proportion of females which spawned at least once before August 1979 (approx. 50%). So, from the 144.5 x 10^6 females present in Canso Hole in October 1979, about 72.3 x 10^6 should have spawned at least twice.

Knowing that $Z_{t-t_o} = \ln N_t / N_0$

where: Z = inst. rate total mortality

N_0 = No. of shrimp at t_0

N_t = No. of shrimp at t

Thus: $$Z^1_{13\text{ months}} = -\ln \frac{(\text{No. females which spawned at least twice in Oct. 1979})}{(\text{Total No. of females in Sept./Oct. 1978})}$$

$Z^1_{13\text{ months}} = 0.818$ and $Z_{1\text{ year}} = 0.755$

During the 1979 fishing season, shrimp samples were collected each month. From the 513.8 MT of shrimp caught in Canso Hole during the 1979 fishing season (May-Sept.), we were able to estimate the monthly catch of females (Table 9). Knowing the mean weight of a female during each of those months, we calculated the total number of females caught in the Canso Hole in 1979 (Table 9). From those 19.6 x 10^6 females, half of them (9.8 x 10^6) should have spawned at least once.

So knowing that:

$$F = \frac{C\ Z}{N_0\ A}$$

where: F = inst. rate fishing mortality
C = no. of shrimp caught between Oct. 1978 and 1979
A = annual mortality rate associated with Z

$$F_{1\ year} = 0.087$$

and the instantaneous rate of natural mortality is estimated to be Z - F = M = 0.668

3.5.2 Mortality for the recruited group to the fishery

Mortality rates were also calculated for the recruited group of shrimp in the fishery by using the following equation (Beverton and Holt, 1956):

$$Z = \frac{K\ (L_{00} - \overline{L})}{\overline{L} - L_c}$$

where: K = Brody growth coefficient

L_{00} = asymptotic length in Brody-Bertalanffy growth equation

$\bar{L}$ = average length computed for L upwards

L_c = mean selection size

For our calculations, we used two different values of L_c: L_c = 16.6 mm (ICES, 1977) and L_c = 18.6 mm (Labonté et Fréchette, 1978). Mortality rates for the three areas are presented in Table 10.

4. Estimation of TAC

Since the fishing effort was very low in the three areas considered for the assessment, the estimates of biomass obtained in each area were assumed to represent virgin stocks (B_0).

TAC were calculated from three different options:

1- $TAC = Y = 0.5\ MB_0$

2- $TAC = C = \dfrac{B_0\ F}{Z}\ (1 - e^{-Z})$

This option consists in a reduction of 50% of the virgin spawning stock. Considering the range of natural mortality rates obtained, we constructed a table giving the ratio of spawning stock size (S) to virgin spawning stock size (S_0) for a range of fishing mortality and three values of time ($t_s - t_c$) between recruitment and first spawning. The following equation was used (Ulltang, 1978) to build Table 11:

$$S/So = \frac{e^{-F(t_s - t_c)}(1 - e^{-M})}{1 - e^{-(F+M)}}$$

3- $TAC = Y = 25\% B_0$

Fréchette (pers. comm.)[1] notes that a yield equivalent to 40% of the present available biomass is proved sustainable in the Sept-Iles fishery. This 40% corresponds to 25% of the initial virgin biomass.

The following parameter values were used for the three options.

Cape Breton

1- 4VA + 4VB : B_0 = 6127 MT, M = 0.63, F^2= 0.30, $t_s - t_c = 1.5$
2- 4VC : B_0 = 9399 MT, M = 0.63, F^2= 0.30, $t_s - t_c = 1.5$
3- 4WC + 4WE : B_0 = 4647 MT, M = 0.63, F^2= 0.20, $t_s - t_c = 2.5$

South Esquiman

B_0 = 19992 MT, M = 0.63, F^2= 0.25, $t_s - t_c = 2.5$

North Anticosti

B_0 = 15230 MT, M = 0.69, F^2= 0.30, $t_s - t_c = 1.5$

TAC's obtained by the different options are presented in Table 12.

1 - J. Fréchette, Biologiste, Direction générale des pêches maritimes, ministère de l'Agriculture, des pêcheries et de l'Alimentation, 2700 Einstein, Sainte-Foy, Québec.

2 - These F values are used only in option 2 and are obtained from Table 11.

5. Bycatch in the SE Cape Breton area

The small mesh used in shrimp fisheries is known to result in bycatches of various finfish species, small ones in particular. Since the shrimp fishery is quite recent in the southeast Cape Breton area, we present bycatch information obtained during the 1979 fall survey in that area.

The main bycatch species are different for each area. In the Louisbourg Hole region, redfish and cod are the two main bycatch species (Fig. 13). By contrast, cod and redfish are practically absent in the Canso Hole area and silver hake is by far the most important bycatch (Fig. 13).

Most redfish caught during the survey were of commercial size (⩾ 14.5 cm) (Fig. 14). Figure 14 also shows size frequency distribution for cod and silver hake caught in October 1979.

Most concerns are generally raised when large quantities of non-commercial fish are caught. Our present observations do not show any large amount of small fish caught by shrimp trawls in the area surveyed.

6. Discussion

Shrimp biomass were estimated from research surveys by the "swept area" method and from commercial CPUE by the "areal expansion" method. There is good agreement between estimates obtained from both methods. The average biomass figures were: 19,992 MT (range 17,098 to 21,971) in the South Esquiman area during 1975-79; 15,230 MT (range 13,962 to 16,018) in the North Anticosti area during 1976-79; and 20,170 MT in the Southeast Cape Breton area for 1978 and 1979. These low variations in biomass may suggest a level of recruitment quite constant in the last few years, at least for the North Anticosti area. However, even with high biomass, exploitation rates of these three shrimp stocks are still at a low level. In fact, the areas of South Esquiman channel and Southeast Cape Breton were fished for the first time on a regular basis in 1979. Consequently, the average biomasses estimates obtained in each area were assumed to represent, virgin stocks, even if these present biomass are probably slightly less than the virgin ones.

TAC estimates were made based on three options, all involving estimation of virgin biomass. In option 1, we considered that TAC could be set at MSY level. To estimate MSY, we assume that a shrimp population at equilibrium will fit a Schaefer surplus production model. Following this hypothesis, it is obvious that MSY estimates ($MSY = 0.5\ MB_0$) are very dependent on the natural mortality. M values range from 0.53 to 0.76 for the three areas investigated. Moreover these values match the M's obtained for shrimp in the northwest Gulf of St.Lawrence (Sept-Iles area, M = 0.48 - 0.80) (Labonté, 1979b). Considering the similarity of biological parameters (such as growth, age at recruitment, longevity) inside the Gulf, it seems reasonable to expect similar natural mortality rates.Having a good confidence in our M values, MSY estimates are probably conservative, virgin biomass being slightly underestimated. However, set TAC to MSY level may be questionable, as proven by several fisheries.

Option 2 gives a safer position to set TAC. Catch level is determined by maintaining the spawning stock level at about 50% of the virgin spawning stock size. The rationale of this method is to assure that an adequate spawning stock is left at the end of the season. The females are larger, and may be presumed to be fully retained by the gears and hence are most vulnerable to exploitation. They may be expected to be overrepresented relative to males in the catch, unless (as yet undiscovered) behavioural factors intervene. The method for calculating by how much the fishery will reduce the spawning stock biomass is described by Ulltang (1978). Option 2 gives TAC approximately 45% lower than option 1 which is probably very conservative.

Option 3 is based on empirical evidence in the Sept-Iles shrimp fishery, where yields have been found to be sustainable at approximately 40% of the available biomass (equivalent to 25% of B_0). Since biological parameters, (such as growth and natural mortality (Labonté, 1979b)) of P. borealis in Sept-Iles area are similar to these of shrimp in North Anticosti, South Esquiman and Southeast Cape Breton areas, it is quite probable that these last three stocks could also sustain a yield equivalent to 25% of B_0.

It is interesting to note that option 3 is always near the average of the two first options (near 5%). For all these reasons, TAC's based on option 3 would be probably the most reliable ones.

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Table 1: Yearly catch + effort by Maritimes boats - 1977 to 1979

Area	Year	Catch (MT)	Effort (hr. fish.)	Effort std. (hr. fish.)	CPUE (kg/hr)	CPUE std. (kg/hr)
Cape Breton	1977	269.0[1]	2093	2575	128.5	104.5
South Esquiman		50.0[1]	535	661	93.5	75.6
North Anticosti		633.5[1]	9709	11219	65.2	56.5
TOTAL		(952.5[1]) (1090 [2])				
Cape Breton	1978	306.4[1]	2513	3149	121.9	97.3
South Esquiman		83.6[1]	768	1106	108.9	75.6
North Anticosti		843.1[1]	11519	13298	73.2	63.4
TOTAL		(1233.1[1]) (1440 [2])				
Cape Breton	1979	776.7[1]	4301	5804	180.6	133.8
South Esquiman		437.1[1]	3724	4862	117.4	89.9
North Anticosti		501.4[1]	7077	8119	70.9	61.8
TOTAL		(1715.2[1]) (-)				

[1] = From Logbook.
[2] = From Stat.

Table 2: Minimum trawlable biomass for shrimp in Cape Breton area, Sept./Oct. 1978 and Oct. 1979.

Strata	Area (n. miles)	# sets 1978	Mean biomass (MT) per n. miles^2 (1978) $\bar{X}$	$S_{\bar{X}}$	Total biomass (MT)	# sets 1979	Mean biomass (MT) per n. miles^2 (1979) $\bar{X}$	$S_{\bar{X}}$	Total biomass (MT)
Col	154.4	5	11.52	0.88	1778.5	5	8.56	2.98	1321.8
Co2	19.7	2	11.28	4.93	223.3	2	0.65	0.55	12.7
Co3	49.3	2	12.28	3.89	605.6	2	12.34	1.26	608.3
Co4 + Co5	92.0	4	7.85	1.30	722.2	3	6.31	2.09	580.1
Lol	50.5	3	8.47	6.58	427.9	3	2.44	1.53	123.1
Lo2	84.2	4	10.83	3.04	911.6	4	10.78	3.46	907.5
Lo3	45.7	2	3.68	2.32	168.1	2	3.38	0.30	154.4
Lo4	137.2	6	15.28	1.46	2096.1	7	11.86	2.39	1627.5
Lo5	28.9	2	3.54	1.25	102.3	2	1.12	1.08	32.3
Aol + Ao2	62.6	4	9.93	1.64	621.4	3	3.15	2.14	197.4
Ao3 + Ao4	72.2	N.S.[1]	-	-	-	3	4.30	2.29	310.4
Mol + Mo2	69.8	N.S.	-	-	-	3	11.49	3.30	801.8
Mo3	129.9	N.S.	-	-	-	4	33.36	11.17	4333.6
Mo4	79.4	N.S.	-	-	-	3	4.14	2.55	328.3
Mo5	65.0	N.S.	-	-	-	2	3.48	0.44	226.4
Mo6	98.7	4	4.31	0.86	425.0	4	7.36	5.46	726.4
TOTAL	1239.4	38	9.82[2]	0.70[2]	8082.0[2]	52	9.92	1.40	12292.0
Canso Hole (Col, Co2, Co3)	223.4	9	11.67	1.14	2607.4	9	8.70	2.08	1942.8
Louisbourg Hole (Lol to Lo5)	346.5	17	10.70	1.41	3706.0	18	8.21	1.29	2844.8

1 = Stratum not sampled.
2 = Estimate for 845 naut. miles^2

Table 3. Adjusted biomass in the southeast Cape Breton area. (adjusted to biomass available to Western 2 trawl).

Strata	1978 Adj. biomass (MT)	1979 Adj. biomass (MT)	1979 Comm. catch (MT)	1978 - 1979 Mean Adj. biomass
Co1	2667.8	1982.7		
Co2	335.0	19.1	513.8	3669.6
Co3	908.4	912.5		
Co4 + Co5	1083.3	870.2	0	976.8
Lo1	641.9	184.7		
Lo2	1367.4	1361.3		
Lo3	252.2	231.6	262.9	5044.6
Lo4	3144.2	2441.3		
Lo5	153.5	48.5		
Ao1 + Ao2	932.1	296.1	0	614.1
Ao3 + Ao4	N.S.[1]	465.6	0	465.6
Mo1 + Mo2	N.S.	1202.7	0	1202.7
Mo3	N.S.	6500.4	0	6500.4
Mo4	N.S.	492.5	0	492.5
Mo5	N.S.	339.6	0	339.6
Mo6	637.5	1089.6	0	863.6
TOTAL	12,123.3[2]	18,438.4[3]		20,169.5[3]

[1] = Stratum not sampled.
[2] = Estimate for 845 naut. miles^2.
[3] = Estimate for the whole Cape Breton area.

Table 4. Shrimp biomass by region in the Cape Breton area.

Region	Strata	Surface (n. miles^2)	1978-79 mean adj. biomass (MT)
Louisbourg Hole	Lo1 to Lo5	346.5	5045
	Ao1 to Ao4	134.8	1082
4VA + 4VB		481.3	6127
4VC	Mo1 to Mo6	442.8	9399
Canso Hole	Co1 to Co3	223.4	3670
	Co4 and Co5	92.0	977
4WD + 4WE		315.4	4647

Table 5. Shrimp biomass estimates from different sources.

Area	Year	Source of estimation	Non-adjusted biomass (MT)	Adjusted (x 1.5)
Canso Hole	1978	survey (Marit.)	2607	3911
	1979	survey (Marit.)	1943	2915
	1979	CPUE (N.B.)	1883	2825
Louisbourg Hole	1978	survey (Marit.)	3706	5559
	1979	survey (Marit.)	2845	4269
	1979	CPUE (N.B.)	2715	4073
South Esquiman	1975	survey (Nfld)	13797	20696
	1976	survey (Nfld)	14647	21971
	1979	CPUE (N.B.)	11399	17098
	mean		13281	19992
North Anticosti	1976-77	survey (Qué.+Nfld)	10679	16018
	1977	CPUE (N.B.)	9308	13962
	1978	CPUE (N.B.)	10444	15666
	1979	CPUE (N.B.)	10181	15272
	mean		10153	15230

Marti. = Resource Branch (Maritimes) survey.
Nfld = Resource Branch (Newfoundland) survey.
Qué. = Direction gén. Pêches maritimes (Québec) survey.
N.B. = Logbook from New Brunswick fishing boats.

Table 6. Values of L_{00}, K and t_0 for the von Bertalanffy equation.

Region	L_{00}	95% I	K	95% I	t_0	95% I
Cape Breton	34.66	6.88	0.206	0.090	-1.644	0.550
South Esquiman	34.50	2.95	0.223	0.062	-1.876	0.560
North Anticosti	32.17	3.03	0.347	0.115	-0.472	0.495

Table 7. Age at recruitment (t_c), at first spawning (t_s) and time interval between t_c and t_s (year).

Region	t_c (L_c = 16.6 mm)	t_c (L_c = 18.6 mm)	t_s	$t_s - t_c$
Cape Breton (4VA, 4VB, 4VC)	1.52	2.09	≃ 3.3	≃ 1.5
Cape Breton (4WD, 4WE)	1.52	2.09	≃ 4.3	≃ 2.5
South Esquiman	1.07	1.60	≃ 3.4	≃ 2.0
North Anticosti	1.62	2.02	≃ 3.4	≃ 1.5

Table 8. Mean length ($\bar{L}$) and age ($\bar{t}$) of fully recruited shrimp in commercial catches.

Region	L_c = 16.6 mm		L_c = 18.6 mm	
	$\bar{L}$ (mm)	$\bar{t}$ (year)	$\bar{L}$ (mm)	$\bar{t}$ (year)
Cape Breton	21.1	2.91	22.0	3.25
South Esquiman	21.2	2.40	22.4	2.82
North Anticosti	21.7	2.76	22.5	2.99

Table 9. Monthly catches of female in Canso Hole in 1979.

Month	Catch (MT)	Av. weight of one female (g)	No. of females (x 10^6)
May	72.60	11.25	6.45
June	14.68	11.20	1.31
July	40.19	10.95	3.67
Aug.	87.06	10.95	7.95
Sept.	2.22	11.35	0.20
TOTAL	216.75		19.58

Table 10. Instantaneous mortality rates.

Area	Z	F	M
Canso Hole	0.76 [1] 0.62 - 0.77 [2]	0.09	0.67 0.53 - 0.68
South Esquiman	0.65 - 0.71 [2]	≃ 0.05 [3]	0.60 - 0.66
North Anticosti	0.71 - 0.86 [2]	≃ 0.10 [3]	0.61 - 0.76

[1] = Direct estimate for the females group.
[2] = Estimate for the recruited group in the fishery (Beverton + Holt, 1956).
[3] = Approximation.

Table 11. Ratio of spawning stock size to virgin spawning stock size (S/S_0) for various values of fishing mortality (F), natural mortality (M) and time ($t_s - t_c$) between recruitment to the fishery and first spawning.

F	$t_s - t_c = 1.5$				$t_s - t_c = 2.0$				$t_s - t_c = 2.5$			
	M = 0.5	M = 0.6	M = 0.7	M = 0.8	M = 0.5	M = 0.6	M = 0.7	M = 0.8	M = 0.5	M = 0.6	M = 0.7	M = 0.8
0.10	0.75	0.77	0.79	0.80	0.71	0.73	0.75	0.76	0.68	0.70	0.71	0.72
0.15	0.66	0.68	0.70	0.72	0.61	0.63	0.65	0.67	0.57	0.59	0.60	0.62
0.20	0.58	0.61	0.63	0.65	0.52	0.55	0.57	0.58	0.47	0.50	0.51	0.53
0.25	0.51	0.54	0.56	0.58	0.45	0.48	0.50	0.51	0.40	0.42	0.44	0.45
0.30	0.46	0.48	0.51	0.53	0.39	0.42	0.44	0.45	0.34	0.36	0.38	0.39
0.35	0.41	0.44	0.46	0.48	0.34	0.37	0.38	0.40	0.29	0.31	0.32	0.34
0.40	0.36	0.39	0.41	0.43	0.30	0.32	0.34	0.35	0.24	0.26	0.28	0.29
0.45	0.33	0.35	0.38	0.39	0.26	0.28	0.30	0.31	0.21	0.23	0.24	0.25
0.50	0.29	0.32	0.34	0.36	0.23	0.25	0.27	0.28	0.18	0.19	0.21	0.22
0.55	0.27	0.29	0.31	0.33	0.20	0.22	0.23	0.25	0.15	0.17	0.18	0.19

Table 12. TAC estimates (MT).

Area	Option 1 $Y = 0.5\ MB_0$	Option 2 $C = \frac{B_0 F\ (1-e^{-Z})}{Z}$	Option 3 $Y = 25\%B_O$	Average
Cape Breton (4VA, 4VB)	1930	1197	1532	1553
Cape Breton (4VC)	2961	1836	2350	2382
Cape Breton (4WD, 4WE)	1464	631	1162	1086
South Esquiman	6297	3324	4998	4873
North Anticosti	5254	2900	3808	3987

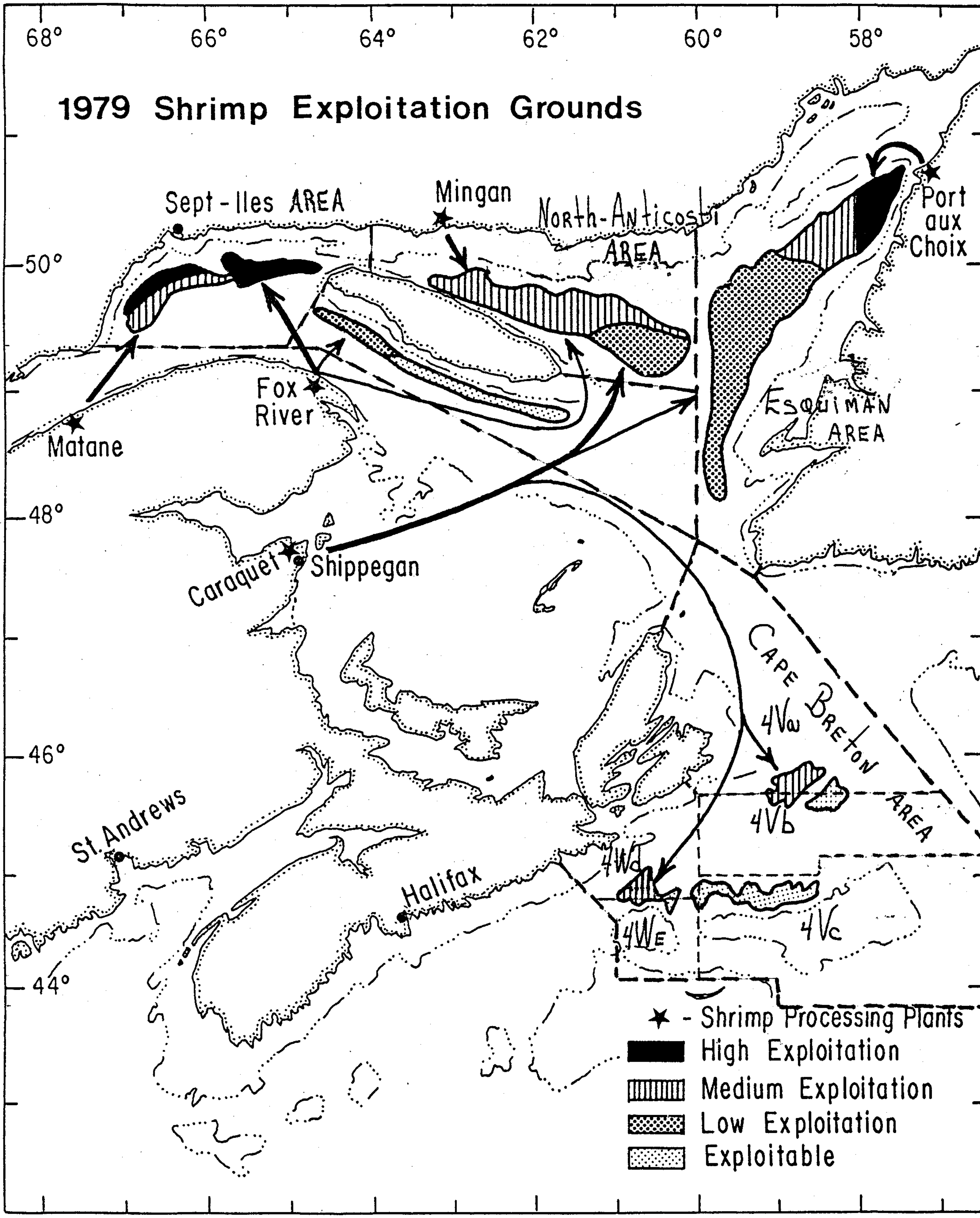


Fig. 1. Shrimp grounds in the Gulf of St, Lawrence and S,E, Cape Breton.

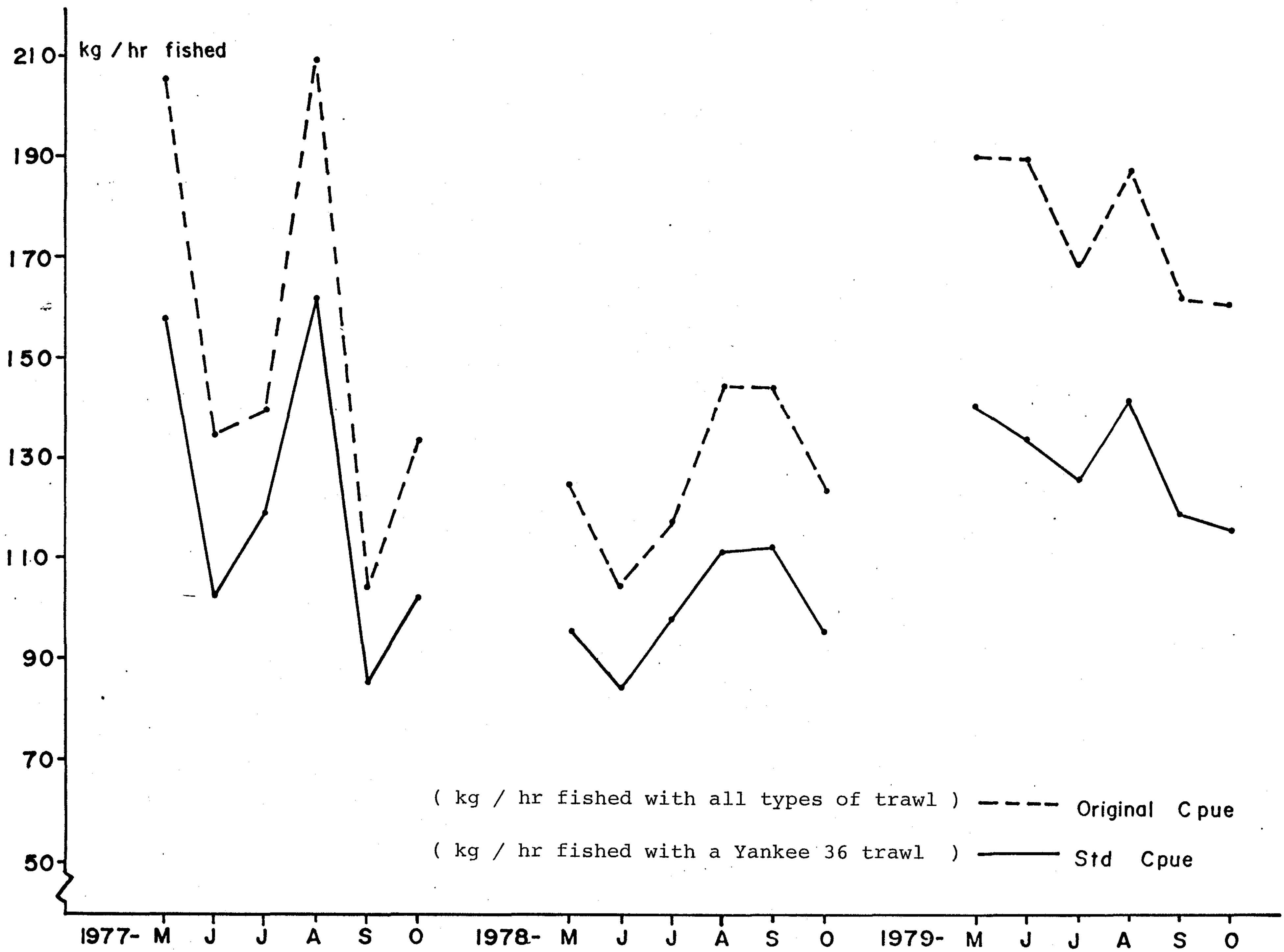


Fig.2 : Monthly CPUE - Cape Breton area

Fig.3 : Monthly CPUE - South Esquiman area

Fig.4 : Monthly CPUE - North Anticosti area

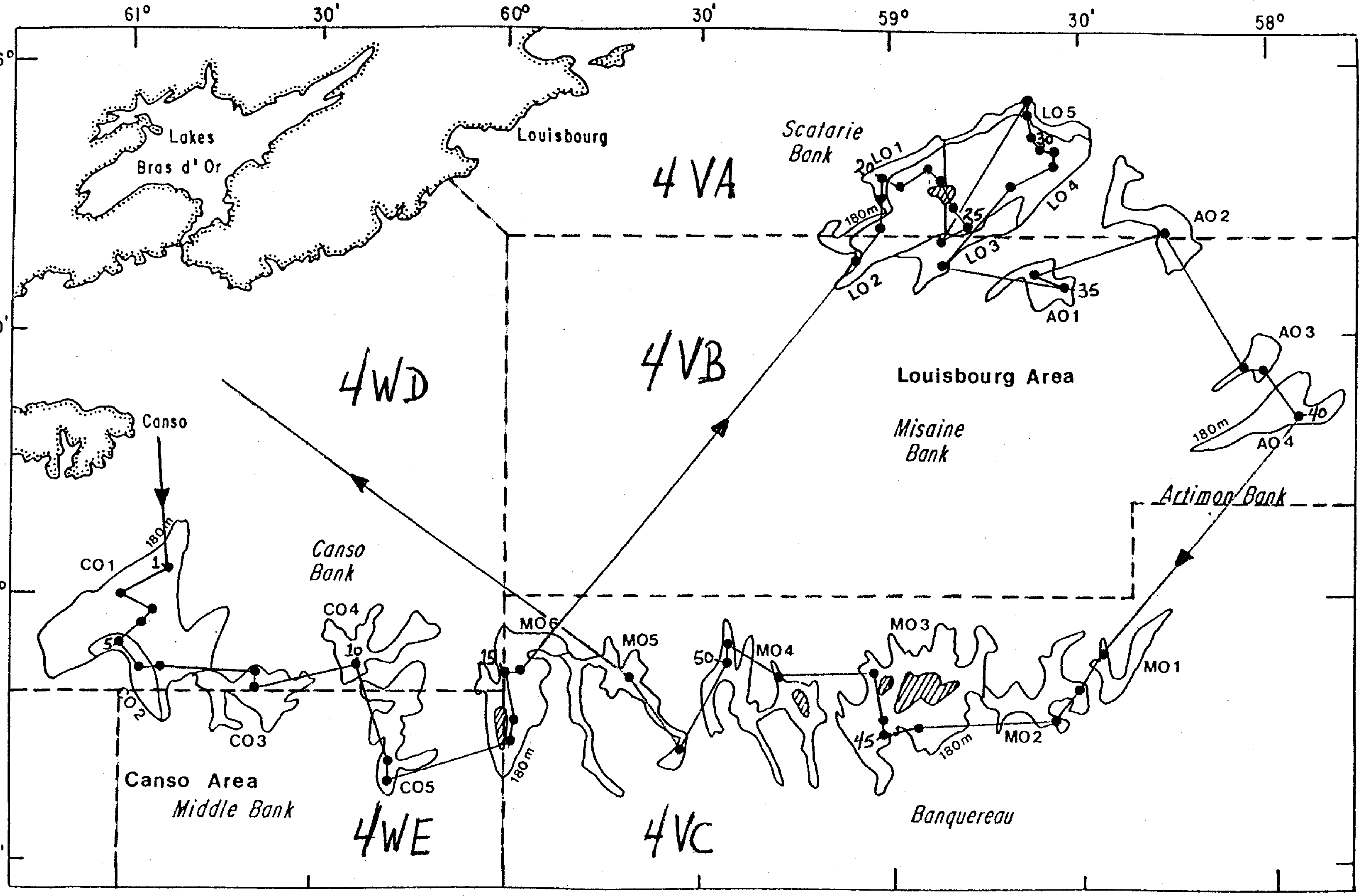


Fig. 5. Stratification scheme and stations occupied during the October 1979 survey.

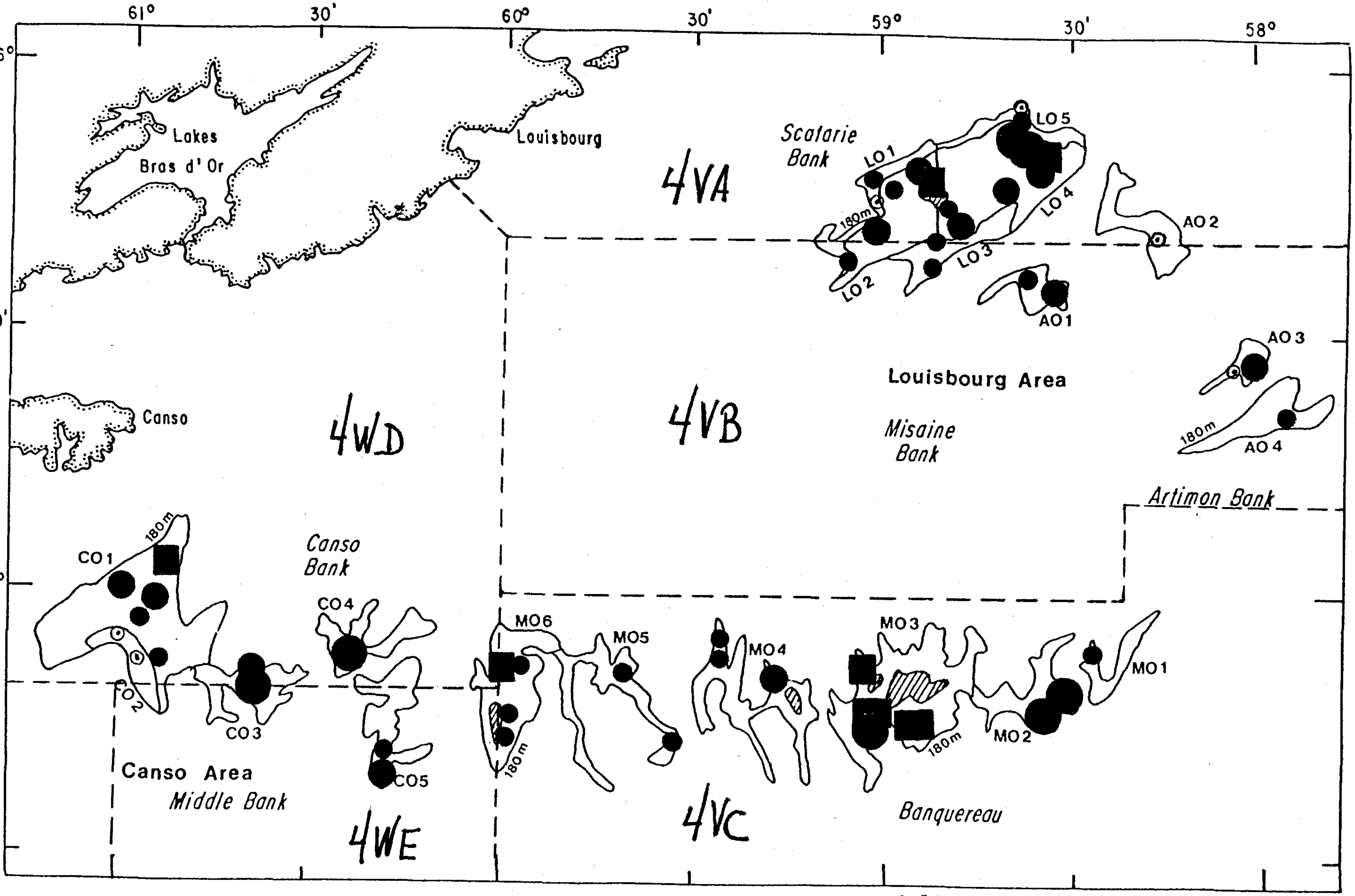


Fig. 6. Catches of shrimp per 30-min. tow during the October 1979 survey.

0-10 kg/30 min.
10-50 " "
50-100 " "
100-150 "
150-200 kg/30 min.
> 200 " "

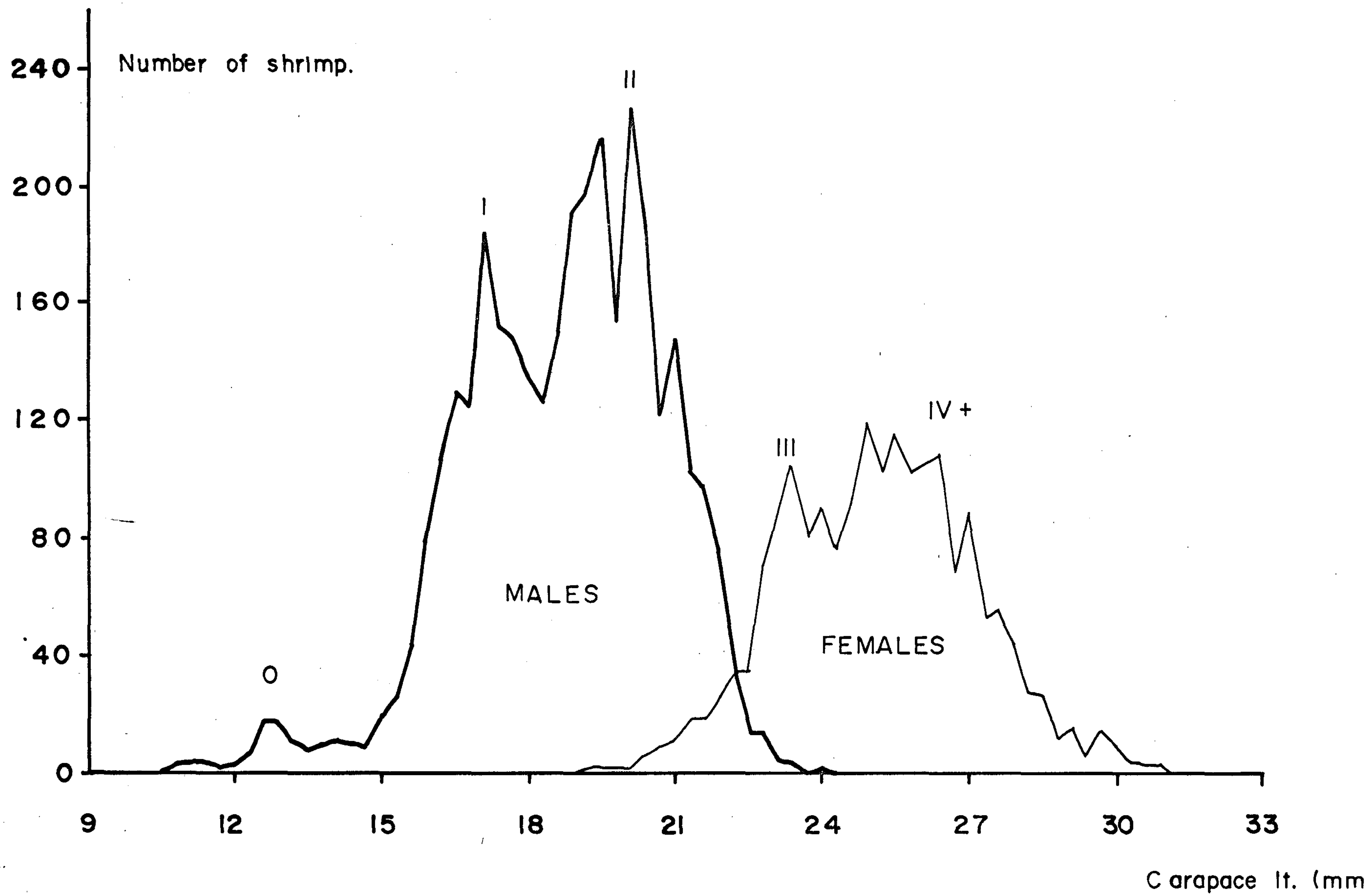


Fig. 7 : Length frequency distribution - Cape Breton (4Va, 4Vb), Oct. 1979.

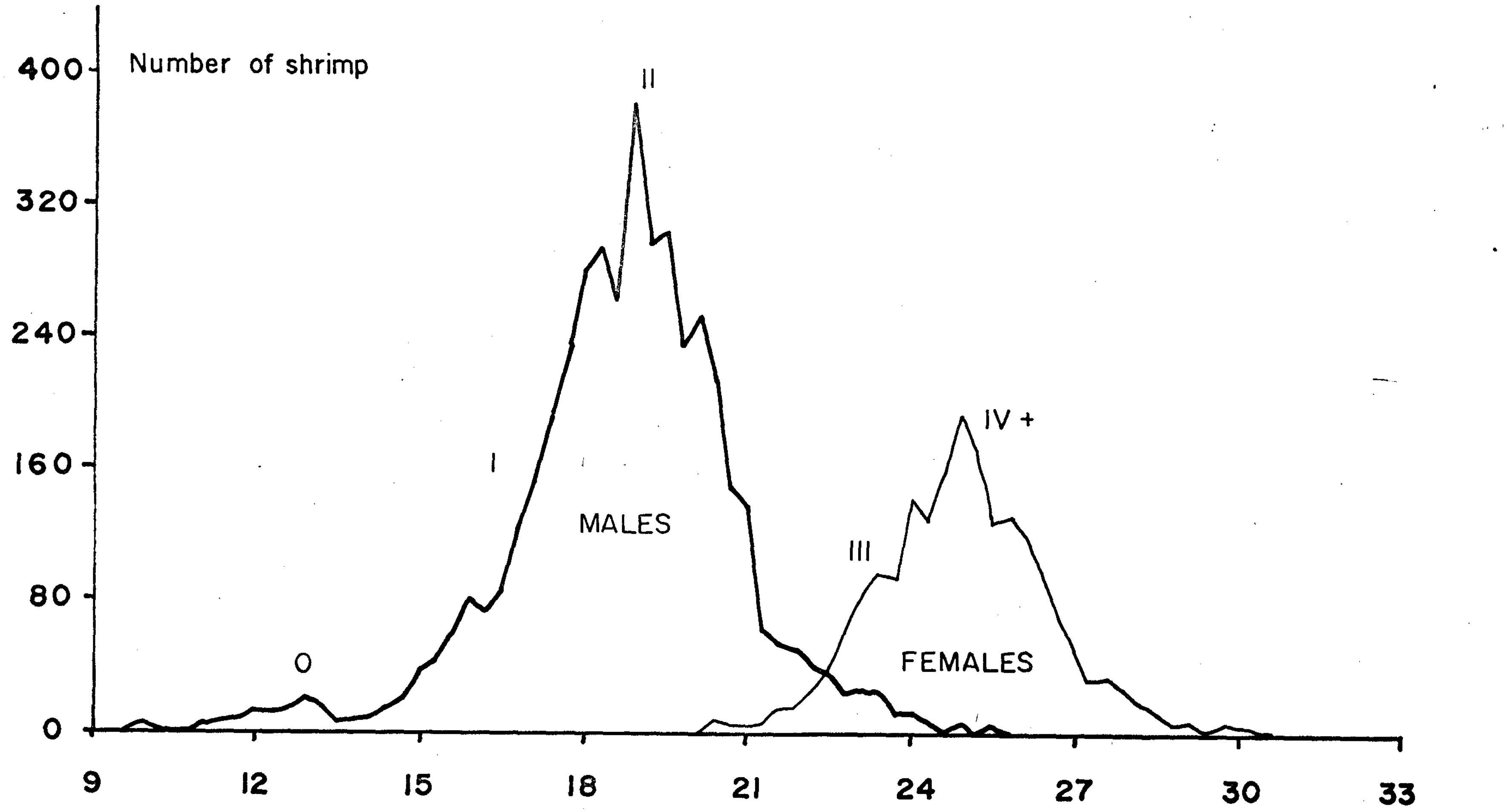


Fig. 8 : Length frequency distribution - Cape Breton (4Vc), Oct. 1979.

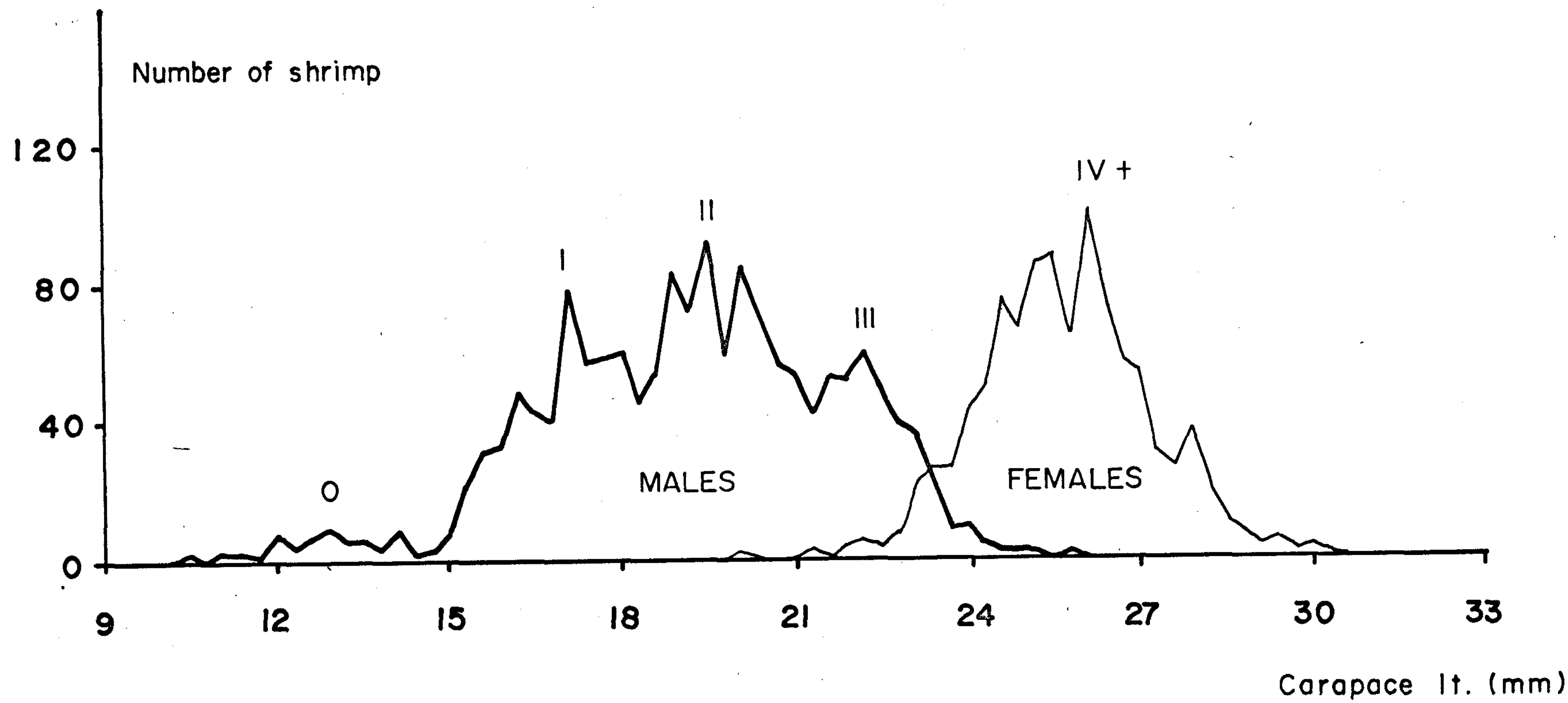


Fig. 9 : Length frequency distribution - Cape Breton (4Wd, 4We), Oct. 1979.

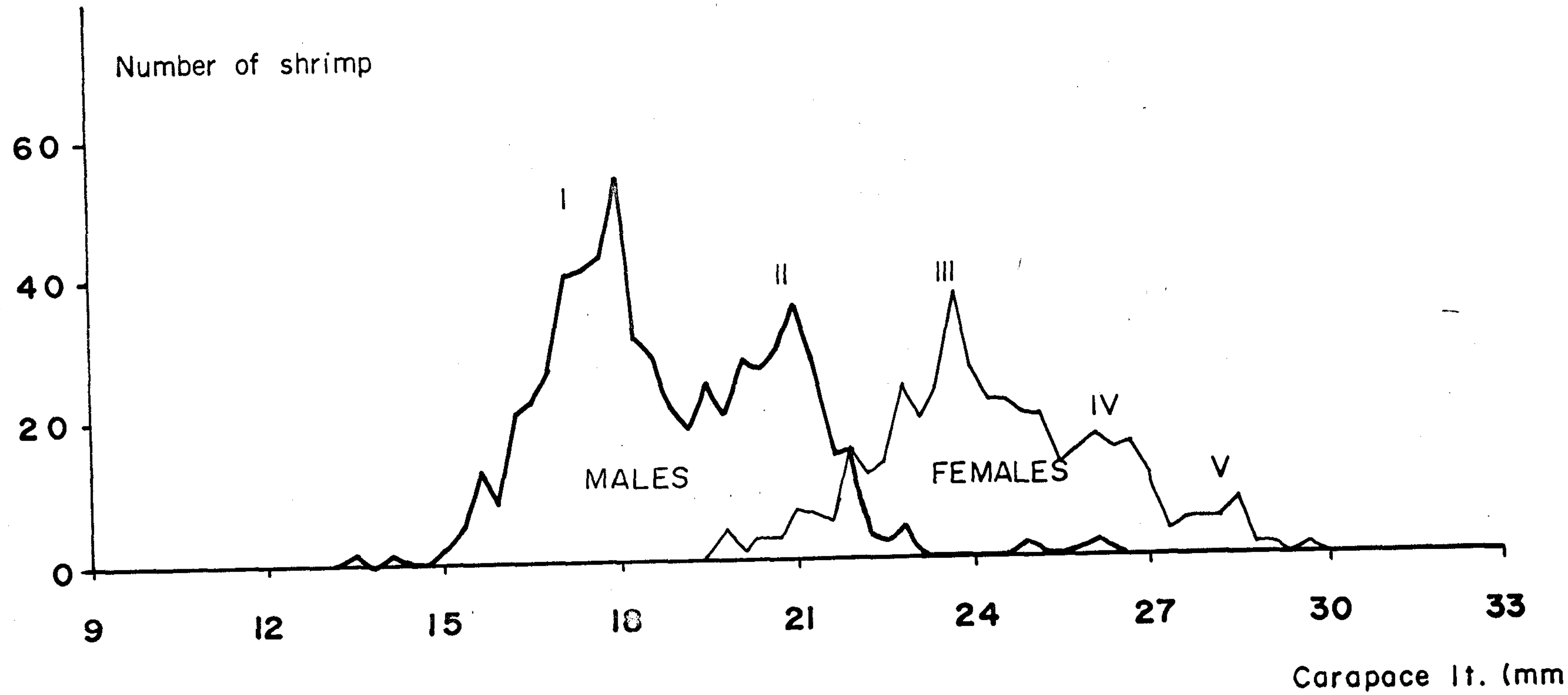


Fig. 10 : Length frequency distribution - South Esquiman, July/August 1979.

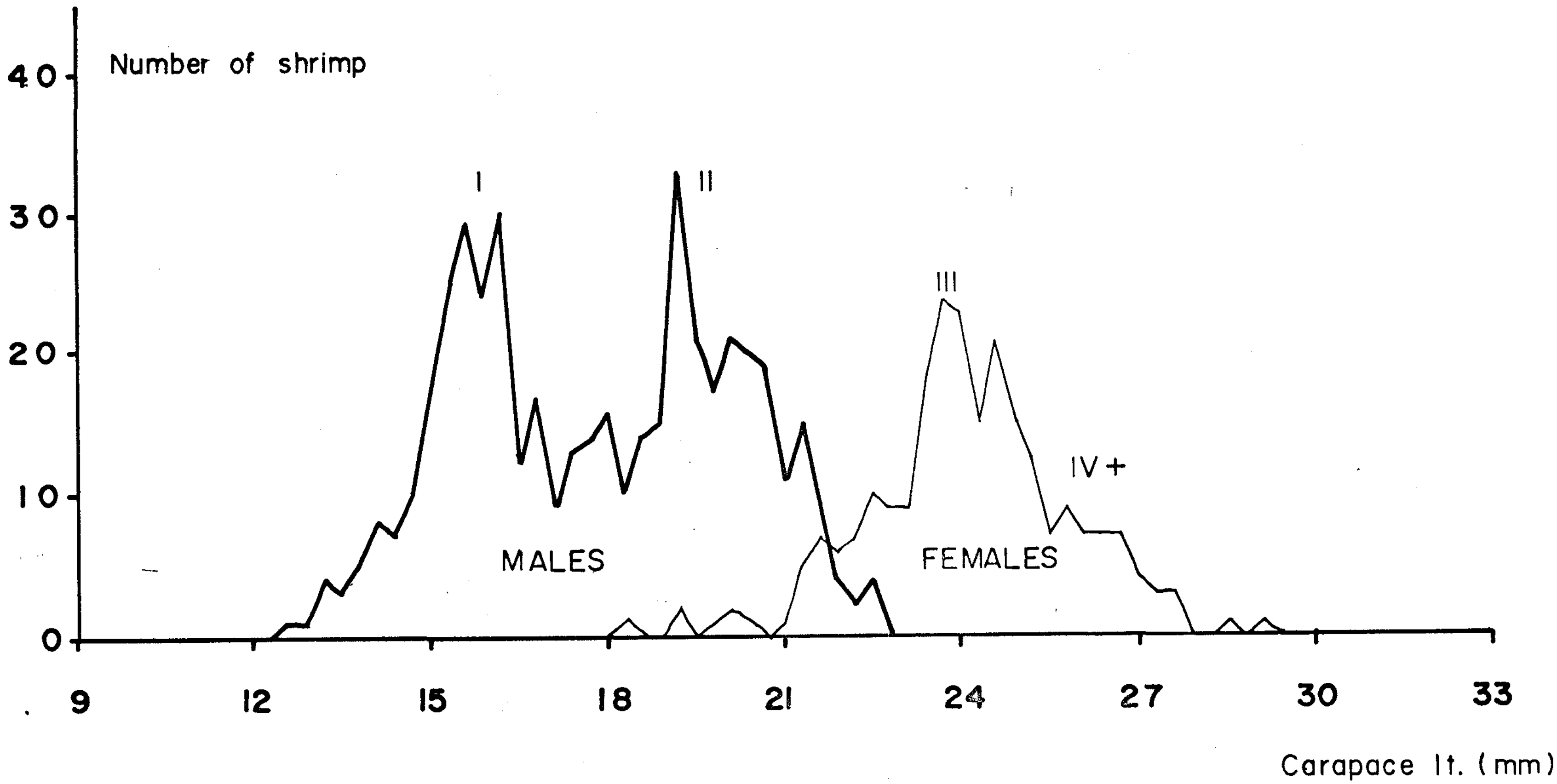
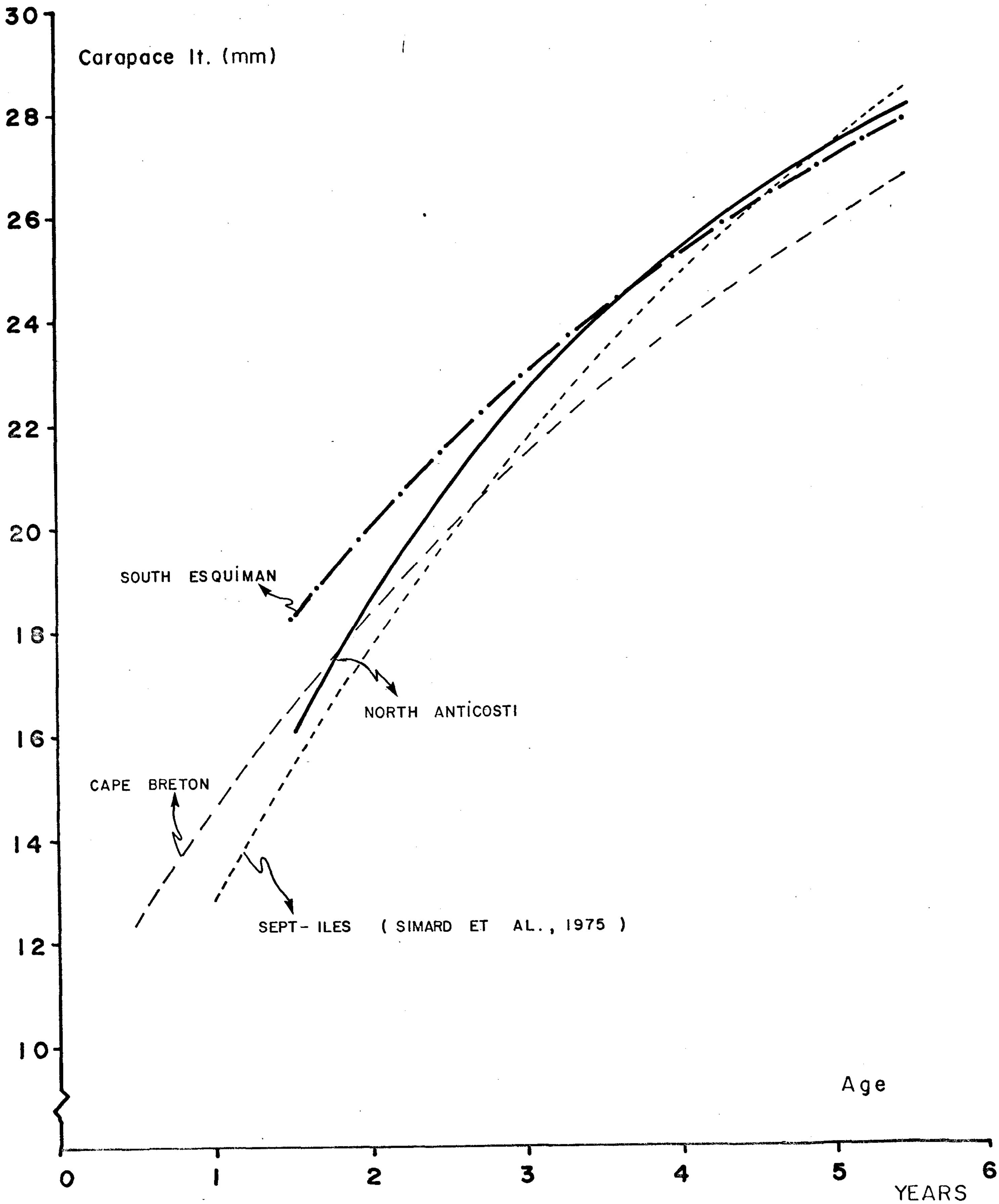


Fig. 11 : Length frequency distribution - North Anticosti, Sept. 1979.

Fig. 12: Growth curves for Pandalus borealis in the Gulf of St-Lawrence and S.-E. of Cape Breton.



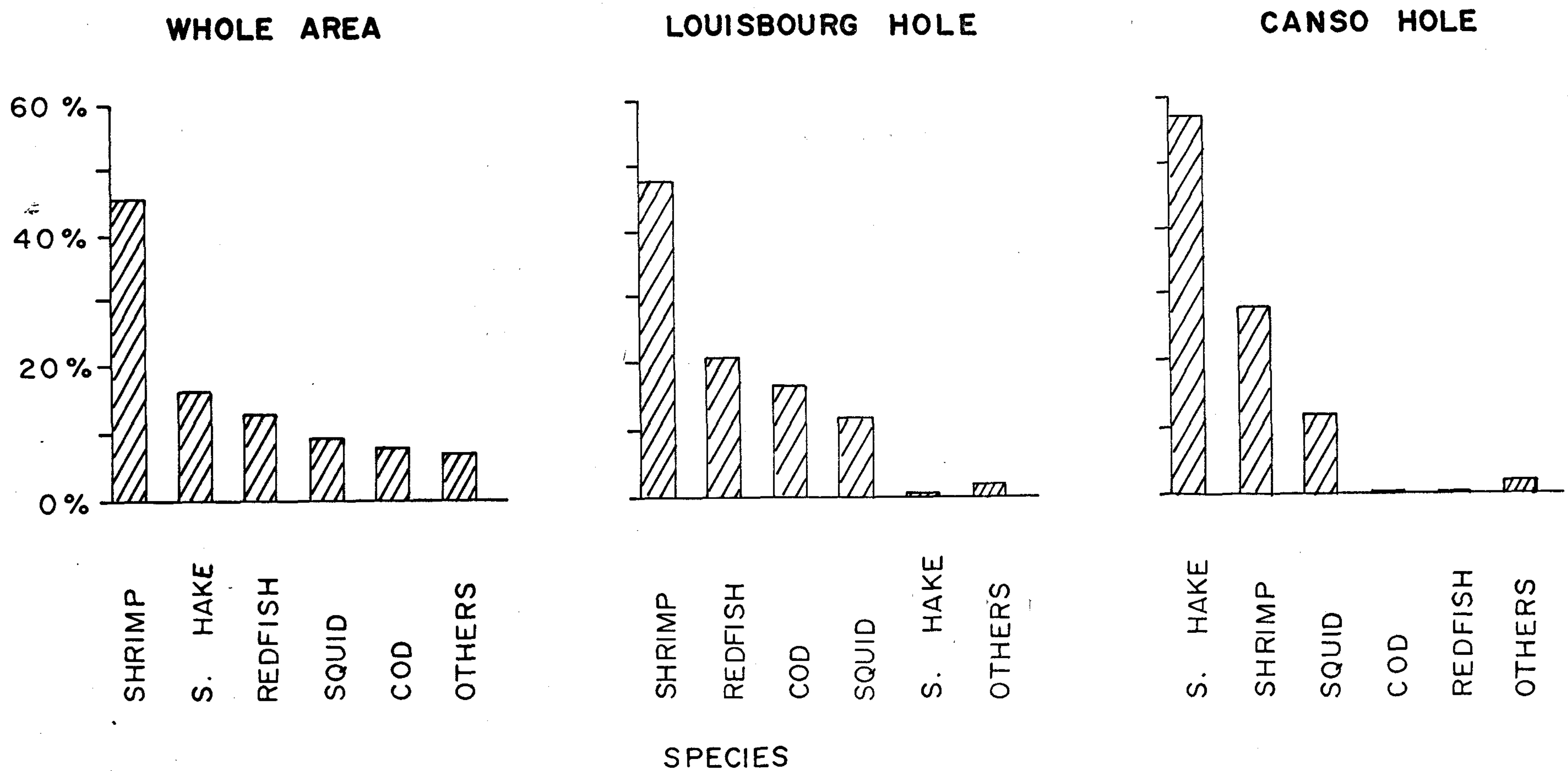


Fig. 13 : Percentage of different species in the catch during the Cape Breton shrimp survey, Oct./Nov. 1979.

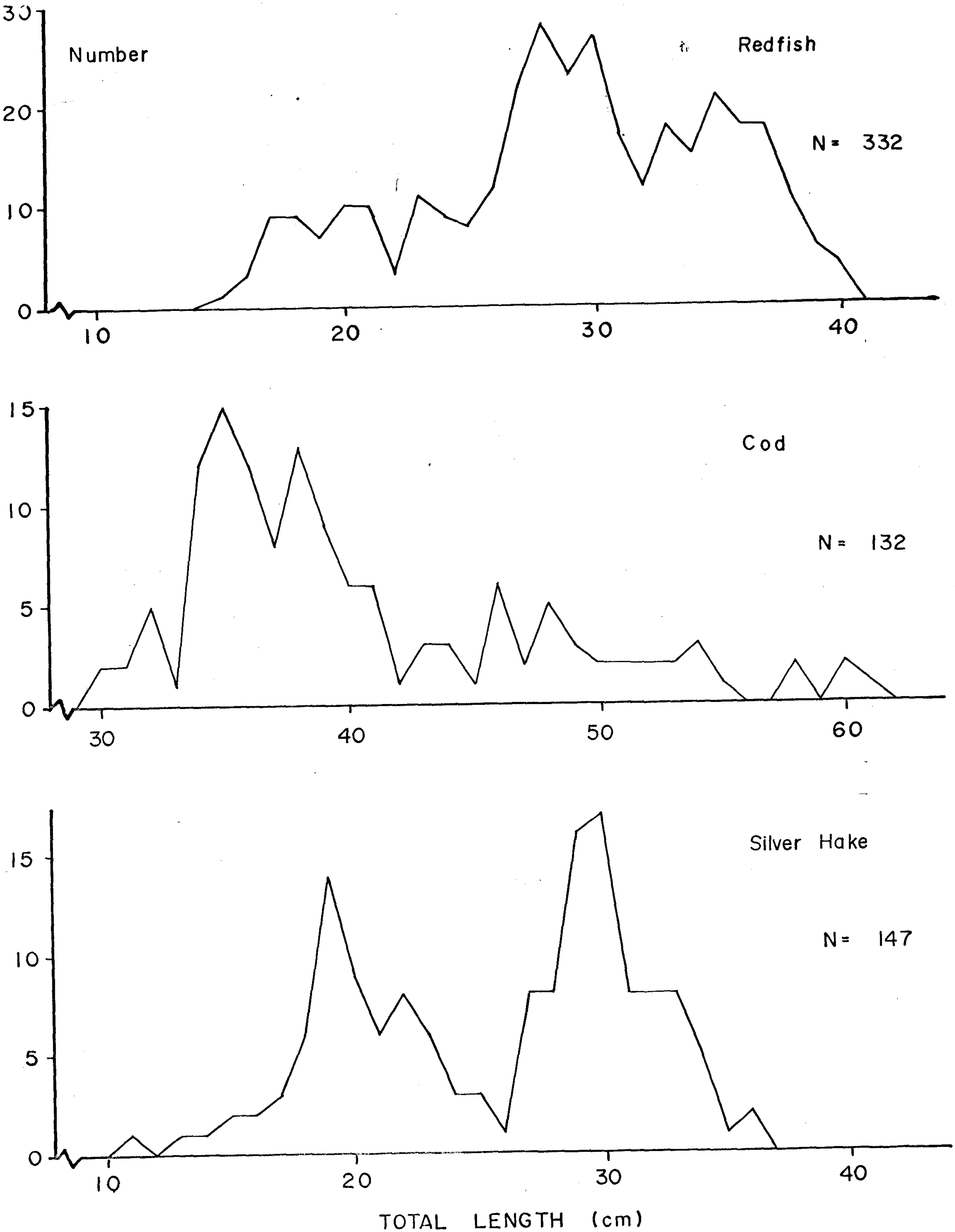


Fig.14 : Size composition of main by-catches - S.E. Cape Breton, Oct. 1979.