Status of the southern Gulf of St. Lawrence scallop stocks - 1985

by

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ABSTRACT

The status of the southern Gulf of St Lawrence scallop stocks is reviewed in the light of results from resource surveys, log book returns and landing statistics. A downward trend in daily catches, average size of scallop fished and density was observed almost everywhere. As in 1984, high numbers of cluckers were recorded again in Baie des Chaleurs and Cape Tormentine. However high occurrence of prerecruits in most areas may be an indication of good potential recruitment for the next few years. A yield per recruit analysis, using a Beverton and Holt method, is presented as well as a complete analysis of the available landing statistics. Several problems such as the constant changes in gear design and dimensions, the lack of accuracy of official statistics and the difficulty of obtaining reliable effort data are raised and discussed.

RÉSUMÉ

Les auteurs examinent dans ce document l'état des stocks de pétoncle du sud du Golfe du St Laurent à la lumière des résultats des campagnes d'exploration, des carnets de bord et des statistiques de débarquement. Dans presque toutes les régions, les prises journalières, la taille moyenne des captures et les densités présentent une tendance à la baisse. Comme en 1984, le pourcentage de claquettes dans les prises était élevé en Baie des Chaleurs et au Cap Tourmentin. Cependant la présence d'une proportion élevée de prérecrues dans la plupart des régions pourrait indiquer un bon recruitement potentiel pour les années futures. Une analyse de rendement par recrue, avec la méthode de Beverton et Holt est également présentée ainsi qu'une analyse complète des statistiques de débarquement disponibles. Quelques problèmes sont évoqués et discutés, comme les constants changements de spécification des dragues, le manque de précision des statistiques officielles et la difficulté d'obtenir des données d'effort fiables.

INTRODUCTION

The scallop stock assessment in the southern Gulf of St. Lawrence in 1985 was similar to the ones used in the previous years (Worms and Chouinard, 1983; Worms and Chouinard, 1984; Worms and Lanteigne 1985). Resource surveys were conducted in five regions in three southern Gulf lobster districts (7C, 8 and 7B1) as follows:

1.	Baie des Chaleurs	District 7C
2.	Miscou - Val Comeau	
3.	Borden - Cape Tormentine	District 8
4.	Pictou - Wood Island	District 7b1
5.	Boughton Island	

An improved log book system in 1985 yielded better returns for most regions and this additional information was used in the preparation of the report.

MATERIAL AND METHODS

1. Commercial Sea Sampling (Appendix I)

Observers on fishing vessels during the regular fishing season yielded information on the size frequency distribution of commercial catches and cluckers. However, due to manpower and budget constraints, the planned sampling schedule was not completely achieved.

2. Research surveys (Fig. 1)

A total of 358 tows were performed in the southern Gulf. Appendix II gives the details for each region surveyed.

A five bucket toothed Digby drag (Fig. 2A) was used and each bucket measured 50.8 cm wide, 35 cm tall and 52 cm deep. Buckets were rigged with 7.6 cm diameter steel rings mounted with steel washers (Fig. 2B). Undersized scallops (< 70 mm) were sampled by lining, two buckets with 2 cm stretched mesh shrimp netting. All living scallops and cluckers (dead scallops with valves still attached) were measured with a calliper to the nearest millimeter. Percentages of cluckers were calculated as proportions of all scallops measured (dead and alive).

The data were used to construct size frequency histograms and to calculate densities (gram of round weight/m^2). Only scallops with shell heights ≥ 70 mm were used in the calculations. Shell height was transformed into round weight and meat weight using meat weight/shell height relationships calculated from additional samples collected for an allometric study (Table 2). When data for 1985 were not available for a given region, the equations calculated from 1982 samples were used. (Worms and Chouinard, 1983; Worms, 1984).

A yield per recruit analysis was performed for three areas sampled in 1985; Baie des Chaleurs, Cape Tormentine and Pictou. Measurements were made of the distance between the umbo and each successive growth ring on the shell and a retro-calculation method was used to calculate the von Bertalanffy growth curve parameters (Table 3). Shell heights were transformed into fresh meat weight as described previously (Table 2). The average minimum shucking size was set at 70mm. A Beverton and Holt method (1957) was used to calculate the yield per recruit. Natural mortality values were estimated using Dickie's (1955) method based on the ratio between the number of live scallops and the number of cluckers. Calculations were made for 1983, 1984 and 1985 using the following formula:

$$a = 1 - e^{-(C-t)(1/L)365}$$

where a is the annual rate of natural mortality, C the number of cluckers in the sample, t the average number of days required for the two valves to separate and L the number of live scallops. Yield per recruit calculations were made for values of natural mortality (M) between 0.1 and 0.4 with 0.1 increments. The fishing mortality (F) was varied from 0.1 to 1.5 with 0.1 increments. For the Beverton and Holt model, selectivity was considered to operate knife-edge from the S_{50} and corresponding age. It was not possible to estimate natural mortality at age from sample data and M was considered constant for all recruited age classes.

3. Log books

Information from log books was used to compute commercial CPUE's. Data were grouped by area and by fishing squares. When information on gear size was missing, an average gear size estimated for the given region was used.

4. Landing statistics

Landing statistics for each statistical district were obtained from the DFO Statistic Branch (Appendix III). In 1985, information was recorded for each sales slip individualy. It permitted information to be retrieved on the number of sale slips per individual vessel and the average landing per fishing day. The assumption was made that each sales slip corresponds to one fishing day.

RESULTS

1- Survey Data and Commercial Data

Results are presented separately for each area and area numbers refer to maps shown on Fig. 5. Table 1 summaries the results of the present and the previous surveys.

A District 7C:

1) Area 2.- Baie des Chaleurs

Due to the usual operating problems with Loran C in this area, only 10 tows were precisely located on the map. All others tow positions were estimated from land marks. Contours were drawn around two sampling zones (Fig. 3A). An average distance covered per minute was calculated from the 10 Loran C positioned tows and used for the other tows.

A total of 1303 scallops were collected from 49 tows. The size range was 6 to 147 mm shell height (Fig. 4A). Two modes are clearly visible in the size frequency distribution, one around 42 mm and one around 105 mm. Average height of commercial size scallops ($\geq$ 70 mm) was 103.7 mm (SD = 16.3). Prerecruits ($<$70mm) accounted for 24.1% of total catches. Percentage of cluckers was 39.1% overall.

A total of 437 scallops with sizes ranging from 67 to 138 mm (Fig. 4A) were sampled aboard commercial vessels fishing in Baie des Chaleurs. A strong mode appeared at 90 mm and the average size was 99.2 mm (SD = 16.0).

From the 160 daily log books returned by fishermen, CPUE's ranged from 0.45 to 1.19 kg/m/h with an average of 0.76 kg/m/h. (Fig. 5A).

2) Areas 4 and 5.- East Miscou to Val Comeau

A total of 94 tows were done in this area (Fig. 3B). Due to a malfunctioning Loran C unit, 25 tows were not precisely positioned. They were all located on a bed (shaded area on Fig. 3B) where many boats were dragging.

The size range of the 604 scallops collected was from 18 to 147 mm. Figure 4B shows a mode at 96 mm while the average size of commercial scallops is 103.1 mm (SD = 11.9). Prerecruits accounted for 11.3% of the total catch and cluckers for 26.9%. No commercial sampling was done in these areas. Only 17 and 19 log sheets were returned from areas 4 and 5 respectively (Fig. 5A). CPUE's calculation ranged from 0.60 to 2.08 kg/m/h with an average of 1.64 kg/m/h for area 4.

B. District 8:

1) Areas 6,7,8,9.

Research survey were not conducted in these areas. The results of commercial sampling data are presented in Fig. 4D. Sizes ranged from 60 to 139 mm with a mode at 99 mm with an average size of 96.6 mm (SD = 10.6).

CPUE's calculated from log book returns (276 returns) varied from 0.74 to 1.49 kg/m/h with an average of 1.19 kg/m/h. Several fishing squares between West Point and Cape Egmont (PEI) had high values of CPUE (Fig. 5A).

2) Area 10.- Cape Tormentine - Borden

A total of 67 tows was performed in this area (Fig. 3C). The size range of the catch was from 15 to 128 mm (Fig. 4C) with one mode around 60 mm and a second strong one around 90 mm. The average size of scallops > 70 mm shell height was 92.2 mm (SD = 9.6). Overall, 22.5% of caught scallops were prerecruits while cluckers accounted for 31.0% of the catch.

The 306 scallops sampled from commercial catches ranged in size from 53 to 123 mm with a mode at 89 mm (Fig. 4C). Average shell height was 92.9 mm (SD = 9.1).

Values of CPUE's computed from log books ranged from 0.89 to 1.79 kg/m/h with an average of 1.19 kg/m/h (Fig. 5A,B).

C. District 7b1:

1) Area 12.- Pictou - Wood Island

A total of 94 tows were done in this area (Fig. 3D) and 2586 scallops were collected. Sizes ranged from 7 to 134 mm and the average height for commercial size scallop was 95.3 mm (SD = 13.5). Percentage of prerecruits was 30.8% and cluckers accounted for 18.0% of catches. The size frequency distribution (Fig. 4E) showed 4 modes at 21,33, 54 and 90 mm.

The range of sizes observed from commercial sampling was 43 to 131 mm (Fig. 4E) with a strong mode around 90 mm and an average size of commercial size scallops of 90.6 mm (SD = 9.8).

CPUE's calculated from log books (37 returns) ranged from 0.74 to 1.93 kg/m/h with an average of 1.19 kg/m/h.

2) Area 14.- Boughton Island

Lobster fishing gear interfered with the survey and tows were restricted to an area off Boughton Island (Fig. 3E). A total of 54 tows collected 1260 scallops with sizes ranging from 9 to 136 mm (Fig. 4F). The size frequency distribution shows a primary mode around 81 mm and secondary modes at 21 and 54 mm. The average size of commercial sized scallops was 92.6 mm (SD = 13.8). Prerecruits accounted for 11.1% of total catches and cluckers accounted for 11.1%.

Commercial catches ranged from 42 to 130 mm with an average of 87.1 mm (SD = 11.1). Size frequency distribution shows a mode around 81 mm (Fig. 4F).

2- Yield per recruit analysis

Table 4 gives values of natural mortality as calculated using Dickie's formula.

Yields per recruit are expressed as grams of meat weight for one recruit. Fig. 6 A,B,C present the curves of yields per recruit (Y/R) as a function of Tc for selected values of F and M. Yield isoplethes were drawn using a matrix of yield per recruit (Y/R) values calculated for different values of F and Tc. Results are presented in Fig. 7 A,B,C and Tables 5 to 7 present estimated Tc corresponding to maximum Y/R at various levels of F and M.

In Baie des Chaleurs, assuming M = .3 and F = .4, the maximum yield per recruit would be 4.64 g of meat for an age at first capture of 5 years. Under the same conditions, the maximum Y/R in

Cape Tormentine would be 3.37 g of meat for an age at first capture of 4 years. In Pictou, the maximum Y/R would be 3.64 g for an age at first capture of 4-5 years, assuming M = .25 and F = .4. Increasing F to .1 will result in increases of Y/R by 11.2%, 13.3% and 20.9% in Baie des Chaleurs, Cape Tormentine and Pictou respectively.

3- Landing statistics

Table 8 and Fig. 8 summarize the annual landings for the three management districts of the southern Gulf for the period 1970 - 1985.

The steady increase as observed over the last 6 years in district 7C persisted in 1985 with a 30% increase in landings over 1984 (40 MT and 52 MT of meat in 1984 and 1985 respectively). The sharp decrease recorded in sub-district 68 (Acadian Peninsula) was more than compensated by better results in the remainder of the area (Fig. 9A).

In district 8, landings remained stable in 1985 (144,7 MT) as compared to 1984 (140.2 MT). Although sub-district 80 (Cape Tormentine) recorded low catches, good landings in the northern end of the district (sub-districts 76 and 82) resulted in a good overall result (Fig. 9B).

The sharp decrease documented in 1984 in district 7B1 continued in 1985 with a further 21% drop in total landings despite a good result in sub-district 87 (eastern P.E.I.). Poor yields from the Pictou Island area (sub-districts 86 and 11) were responsible for this situation (Fig. 9C).

In 1985, 417 scallop fishing boats landed scallops in the three southern Gulf districts (85 in district 7C, 176 in district 8 and 145 in district 7B1). Fig. 10 shows that 50% of these fishermen were active for five days or less and more than 77% for 15 days or less. As indicated in Table 9 the average price per kg of meat over the season was better in district 7B1 ($12.79/kg or $5.80/lb) as compared to district 8 ($11.96/kg or $5.43/lb) and district 7C ($11.58/kg or $5.25/lb) for a total catch value of over 3 million dollars. The price paid to fishermen in 1985 was comparable to that paid in 1983.

Assuming each sales slip represents one day of fishing the average catch per day as shown on Table 9 is highly variable and may not be a good index of the fishing efficiency (see our comments in the discussion). It should be noted that the roe is landed by a only few fishermen from district 7C where it represents 5.6% of the total landed weight.

DISCUSSION

As a whole, 1985 was not a good year for scallop fishermen as compared to previous years. With few exceptions (Richibucto/ Miminegash) feedback from fishermen and research data indicated a downward trend in yields, average size of catches and density. A high occurrence of cluckers was reported in all areas except Pictou and eastern P.E.I. which confirmed the results from surveys.

In 1985, many fishermen used rubber washers to construct their drags thus significantly reducing the mesh size. This may explain the decrease in the average size of commercial catches compared with the average size of survey catches in 1985, as fishermen caught more small scallops than usual. The higher prerecruit abundance detected in all areas, despite an increased mortality due to fishing, may be an indication of good recruitment in the next few years. On the short term, the shifting of commercial catch size distributions to smaller sizes may result in better yields. However, on the long term, it might affect the stock recruitment, likely resulting in lower yields. It should be noted that a number of fishermen are removing the rubber washers and going back to the steel washers for this reason.

Scallop densities in the Baie des Chaleurs area (area 2), as calculated from survey data in 1985, have decreased slightly from 1984 (2.35 g/m^2 and 2.46 g/m^2 respectively). The decrease documented in 1984 from 1983 (4.04 g/m^2; Worms and Lanteigne, 1985) did not continue in 1985. Percentage of cluckers ($\geq$ 70mm) in the catch increased between 1983 and 1984 from 13.5 to 36.0% and stabilized at approximately 39% in 1985. This high occurrence of dead scallops in survey catches was confirmed by interviews with fishermen. Whether this is the result of the high temperature prevailing in summer during the last two years or due to increased predation is still unknown. The high temperatures, if not lethal, probably reduce the mobility of scallops and cause them to gape, thus more vulnerable to predation (Johannes, 1957). It should be noted that in Baie des Chaleurs, the high scallop concentrations are found mainly between 4 and 7 fathoms. The buffering capacity of depths of water is rather low and the effects of temperature perturbations will be more drastic.

Log book returns from this area were too low in 1983 and 1984 to allow comparisons with 1985 returns. The average CPUE in 1985 was 0.74 kg of meat/m/h which is lower than the southwestern Gulf average (1.1 kg of meat/m/h). Prerecruits were much more abundant catches (103.7 mm and 99.2 mm respectively) might be the result of the change in commercial fishing gear (increased use of rubber washers).

The lowest densities in the southern Gulf were recorded in the Miscou/Val Comeau area (area 5) with an average of 1.06 g/m2. The percentage of cluckers increased significantly although less than in

Baie des Chaleurs. Most fishermen operating in area 5 reported decreased yields especially over the last two years. Some relocated their fishing effort by moving north (area 4) or into Baie des Chaleurs, looking for better results. East of Miscou (area 4) CPUE's ranged from 0.6 to 2.08 kg/m/h, among the highest in the southern Gulf. On the contrary CPUE's recorded in area 5 (0.3 kg/m/h) are the lowest recorded in the Gulf. The lack of quantitative effort data precludes an adequate explanation. Fishermen continue to blame it on overfishing but it is not possible to infer this from existing data. The present situation probably results from a combination of adverse environmental conditions, modifications of gear selectivity and fluctuations in fishing effort over the last few years. Since the abundance of prerecruits is low compared to the other areas, the recruitment is expected to be low in the next few years. Several management options may be considered for this area: 1) shortening of the fishing season; 2) closing zones; 3) control of gear construction methods and material. Monitoring the condition of the resource is required in order to follow the recovery, thus permitting the implementation of appropriate regulations at the proper time.

In the Cape Tormentine area (area 10), as in the other areas, density decreased from 1983 values. Differences between 1984 and 1985 cannot be statistically considered as the confidence interval on the 1985 estimate overlaps the 1984 value (Table 1). However, the low 1985 density estimate may be an indication of a continuing downward trend. The percentage of cluckers increased in 1984 but stabilized in 1985. In 1985, CPUE's from log books were lower than in 1983 (1.2 kg/m/h and 2.0 kg/m/h respectively). Prerecruits as first recorded in 1984 (Worms and Lanteigne, 1985) were more abundant in 1985 where 40.8 individuals/m/h were estimated in survey catches. These young individuals, especially those around the 60 mm mode, should enter the fishery next year and further monitoring should allow us to estimate their contribution to this exploited population. Inadequate commercial sampling precludes the use of this data for valid comparisons with research data.

Log book returns from the north part of district 8 (areas 6.7 and 8; Fig. 5 A,B) were good in 1985. CPUE's ranged from 0.74 to 1.5 kg/m/h, slightly lower than 1984 values (Worms and Lanteigne, 1985).

Results from survey in the Pictou/Wood Island area (area 12) revealed a decrease in density estimates from 2.36 g/m^2 in 1984 to 1.41 g/m^2 in 1985. Meanwhile, the percentage of cluckers stayed almost identical in 1984 and 1985 and relatively low if compared with other areas. As mentioned for Cape Tormentine, the difference between density estimates made in 1984 and 1985 is not statistically interpretable because the confidence intervals overlap. Commercial catches show a reduction in individuals greater than 110 mm if compared to survey data and this may once again be the result of the use of rubber washers in the construction of the drag. The average

CPUE for 1985 (1.19 kg/m/h) was higher than in 1984 (1.02 kg/m/h). However, because the 1984 value (Worms and Lanteigne, 1985) was not calculated with the same type of data as in 1985, a valid comparison is not possible. The occurrence of prerecruits in survey catches increased from 21.3 individuals/m/h in 1984 to 41.8 individuals/m/h in 1985. This is the highest ever recorded, indicating possible strong recruitment for the future. A major obstacle in this area is that the meat yield relative to size is lower than in other areas of the southern Gulf of St. Lawrence (Worms and Davidson, 1986).

The percentage of prerecruits detected in the Boughton Island area (area 4) is 11.7%, which is lower than recorded in 1982 (23.8%). Occurrence of cluckers, although lower than in the rest of southern Gulf (11.7%), is higher than that recorded for 1982 (4.6%). The average density estimate of 2.20 g/m^2 is comparable to values recorded in Baie des Chaleurs and Cape Tormentine areas (2.35 and 2.64 g/m2, respectively). Mean sizes of commercial size individuals from survey and commercial sampling are lower in this area than in Pictou. Further information is lacking for this area as log book returns were low in 1985 and non-existent in the previous years.

In 1985, DFO Statistic Branch processed the information on commercial catches from sales slips, boat per boat with an identification code for each boat. It should be possible to obtain a fairly good index of fishing effort through number of days fished and information on the type of gear used. However, several problems exist in the raw data transferred to Fisheries Research Branch from Statistic Branch. Based on the type of sorting used, (according to boat code and statistical districts, Appendix III) one major problem was the apparent duplication of sales slips in the master file; which may be the result of an actual double entry or of the splitting of the daily catch between several sales slips for U.I.C. purposes. In some regions of the southern Gulf, fishermen pay their helpers by giving them a fraction of the catch which they will sell under their name for U.I.C. declarations. However, these sale slips will be identified with the originating boat code. It then appears inadequate to assign one day of fishing to one sales slip. We took this into account in the estimate of the number of days fished presented in Table 9.

Another problem is raised by sales slips recording landings obviously too high for a single day of fishing. It should be noted that a number of landings are recorded without boat identification. Among these are estimates made by fishery officers of the amount of scallop meat which is not marketed through registered buyers (supplementary B's). Most of the above mentioned sales slip account for these estimates, for a total amount of 40 MT of meat. The average catch per sales slip (or per day) shown in Table 9 for some subdistricts (64,65,66,67,76,77,45) are inaccurate due to the uncertainty in the way sales slips match to days fished. In most statistical districts, it appears that the average daily catch

calculated from sales slips is too high as compared with actual daily yields recorded from logbooks or interviews with fishermen and fishery officers. It would seem that the number of fishing trips is, in most cases, largely underestimated by adding up the number of sales slips.

Yield per recruit analysis was developped to determine the optimal conditions of exploiting a given population without knowing the exact number of recruited fish or fish retained by the gear. The value of a yield per recruit analysis will obviously depend on the stock-recruitment relationship. Placopecten magellanicus, as most Pectinidae, has a high fecundity (Mottet, 1979) and planktonic larvae. Hancock (1973) noted that invertebrate species with high fecundity and larvae with a long pelagic life will be subjected to large fluctuations in numbers. He listed several factors which influence larval production, survival in the plankton and the success of settlement. Following settlement, surviving scallops will not be exploited until reaching a suitable commercial size, i.e., after 4 to 5 years in the southern Gulf, as shown by available growth curves (Chouinard, 1983; unpublished data).

The role of the parent stock in determining the success of recruitment to the fishery is highly variable and so far no stock-recruitment relationship has been established for scallop species. It is then difficult to infer the long term potential of a given stock based on the size of brood stock and the yield per recruit analysis.

Although natural mortality is assumed to be constant all over the life of the scallop, it is certainly not true. Medcof and Bourne (1964) listed several causes of natural mortality which can affect the giant scallop at different stages of its development. These include fluctuations of temperature and salinity, flushing of basins, predators and parasites. Even though mass mortalities are known to occur in scallop populations in the Gulf of St. Lawrence (Dickie and Medcof, 1963), these factors will have a different impact on the various cohorts present on the bottom. Estimations of natural mortality using changes of cohort abundance through time, mark-recapture experiments or presence of cluckers produce estimates between 0.05 and 0.2. Posgay (1962), considering the different methods and their basic assumptions, believed that the best estimate would range between 0.06 and 0.12 with an average around 0.09, while Merrill and Posgay (1964) had originally estimated M to average 0.1. Jamieson (1978) used a value M = 0.1. Naidu et al. (1982) calculated natural mortality at age for Chlamys islandica and showed M to increase with age from .077 (age 5) to .364 (age 14). The rate of natural mortality of a population is likely to vary from year to year and from cohort to cohort (Naidu et al., 1982). Fluctuating environmental factors will affect the survival of scallops and this makes it difficult to extrapolate age-specific M values from one year to the other. Values of M as calculated from the ratio of cluckers to live scallops using a disarticulation time of 250 days

(Merrill and Posgay, 1964) (Table 4) averaged .45 in Baie des Chaleurs, .37 in Cape Tormentine area in 1985 and .22 in Pictou area. These high values, as those recorded in 1984, likely account for two successive years of accidental mass mortalities. Lack of environmental data precludes definite explanations although temperature is likely to play an important part in these phenomena (Dickie, 1955; 1958; Johannes, 1957; Dickie and Medcof, 1963). A direct estimation of the rate of fishing mortality is even more difficult because data from the commercial fishery are not available to calculate them. Posgay (1962) used a value of 1.0 for estimating yield per 10,000 recruits in NAFO subarea 52 while Jamieson (1978) estimated F to be from 0.5 to 0.7 for age cohorts 3-5 and 0.2 to 0.4 for older age cohorts. In 1985 data suggested that fishing pressure was targetted mainly at age groups 5-8 in Baie des Chaleurs and 5-10 in Pictou. The commercial data from Cape Tormentine are incomplete. The basic assumptions of the calculation, such as constant F and M for all age classes may introduce an important relative bias. Factors affecting natural mortalities will not have the same influence in deep waters as in shallow waters. This would be true for the whole populations but differences may even be more accentuated when comparing individual age or size classes. Thus the impact of adopting a constant M value for all age classes might be quite different when considering deep water or inshore populations.

Posgay (1962) calculated the Y/R for Placopecten magellanicus of Georges Bank and found a maximum to occur for ages over 8 years and F values greater than 0.7. Jamieson (1978) showed the maximum for P. magellanicus in the Northumberland Strait to occur for ages over 6 years and F values greater than 0.6. The Y/R reported by Posgay (1962) are much higher than those from Jamieson (1978) or the present study (Table 10). These differences may reflect the differing neographical locations of the respective studies. Scallops grow faster and yield higher meat weight at age in deep offshore water as compared with shallow inshore areas and this becomes obvious when comparing Northumberland Strait with more southern, deeper water locations, as the Northumberland Strait is at the northern limit of the geographical range of the species. Preliminary calculations made using a Thompson and Bell method gave Y/R lower than those presented in this paper.

The Y/R values of this study are comparable with those from Jamieson, 1978 (Table 9). Differences observed in Table 9 account for differences in growth parametres and meat weight/shell height relationships used for calculations. A study of the meat weight/shell height relationships in the southern Gulf (Worms and Davidson, 1986) shows that meat weight at size declined over the last few years. It also shows that meat weight at size in Pictou is much lower than in Cape Tormentine or northeastern New Brunswick, explaining lower Y/R recorded in Pictou. It should be noted that the lower M values recorded for Pictou in 1984 and 1985 make up part of the difference in yield per recruit with the other areas.

CONCLUSION

Despite alarming statements and complaints heard from fishermen, the 1985 scallop fishing season in the southern Gulf yielded comparable landings to those of the few preceeding years in most areas. The upward trend recorded in district 7C over the last 5 years was confirmed in 1985 while district 8 landings leveled to the 1984 value. Only district 7B1 displayed a continuing downward trend with the lowest landing recorded in the last 20 years. The lack of reliable effort data precludes an in depth analysis of these results. However, the new commercial data acquisition process enforced in 1985 by DFO Statistics Branch should provide better information in the coming years.

The occurrence of large amounts of prerecruits in most areas seems to indicate a successful spat settlement over the last 3 to 4 years. Considering the higher fishing mortality of prerecruits (due to smaller mesh size of commercial gears), the relatively low capturability of small scallops and the presence of strong modes below 70 mm shell height in most size frequency distributions it is assumed that there should be a steady renewal of stocks through recruitment.

The use of rubber washers together with other attachments (cow-skins, rubber flap sweepers, etc.,) raises a new problem in the scallop fishery management. Over the last few years, fishermen experimented with a variety of gear modifications which changed the overall efficiency of the scallop drags. Those changes, generally introduced on a local scale, are rapidly adopted by the majority once they prove rewarding in terms of yield. Taking into account the tendency to increase the width of towed gears, the actual change in fishing effort becomes almost impossible to evaluate, despite all the efforts made to document this aspect of the fishery. The unit of effort commonly used for scallop stock assessments, (one meter of drag fishing for one hour on the bottom) should be reevaluated. It does not integrate all the aspects of the fishing operation inherent to the skipper's experience and the changes introduced by fishermen. Therefore, an effort of standardization should be initiated to ensure more homogeneity within the fleet. Any modification in the fishing gear used should first be evaluated by qualified staff in terms of its impact before it spreads throughout the fishing fleet.

The use of a Beverton and Holt model for calculating yield per recruit was dictated by the quality of data available. Application of yield per recruit analysis models is a tempting approach in cases where data from commercial fishing are too scarce or not reliable enough to allow catch and effort data analysis. However, the interpretation of results must be conducted with care as many basic hypothesis are assured which are seldom verified in reality. The problem is especially acute when dealing with benthic invertebrate populations. Most existing methods over-simplify the basic parameters to keep the computation to a reasonable time and

complexity. By doing so, the confidence one may have in the resulting values is weak and any change in existing regulations or introduction of new regulations based on such results should be fully evaluated before being implemented as a management tool. Using a model which accounts for such parameters as fishing and natural mortalitites at age, selectivity curves and standard deviation as a function of mean height at age (as per growth curve) would certainly lead to more reliable results. In the present study, the major problem for further use of a yield-per-recruit analysis is the likely absence of an index of recruitment levels as would be given by a stock/recruitment relationship (Hancock, 1973). Establishing such a relation if any, involves costly and lengthy collection and analysis of data. As suggested by Gulland (1973) in an article entitled "Can a study of stock and recruitment aid management decisions?", "...it would seem that the answer posed in the title of this paper must often be a "no", though a number of cases may occur in which an adequate stock recruitment relation can be distinguished."

Our confidence in the results of any yield-per-recruit analysis for scallop stocks is limited, whatever the model used.

The availability of reliable catch and effort data will certainly be an asset. From past years experience, the collection of landing statistics and related information proved to be inefficient due to long delays in sale slip routing procedures and data acquisition through EDP. In an attempt to make the effort of data collection more rewarding to the researchers, several actions will be implemented during the next season:

1. The resource survey program, using chartered boats will be abandoned. It will be replaced by an observer program which will provide information on commercial catch structure with a better repartition in space and time. Resource surveys as conducted over the last four years did not yield to much new information considering the amount of time and money involved. Spot-checking, using available vessels, will be performed in some areas to monitor the occurrence of prerecruits.

2. Instead of giving log books to all scallop fishermen (with expected very low returns), the decision was made to select fishermen from each region with the help of local fishermen's associations. If the selected fishermen agree, they will commit themselves to fill their log book accurately each fishing day throughout the season. This will provide us with a better set of data to evaluate CPUE's and their change over the fishing season.

Meanwhile, as our knowledge of the life cycle of the species and its changes in space and time will be better known, sounder approaches to scallop stock management may be developped which will hopefully benefit to the fishing community while ensuring an optimum level of exploitation of the available resource.

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Table 1. Summary of results obtained from surveys in 1983, 1984 and 1985, showing densities, CPUE's and weight/height regression parameters.

		Number of tows	Duration of tows	Total numbers of individuals			Individuals < 70mm	CPUE for individuals ≥ 70 mm	Mean size of individuals ≥ 70 mm	Densities for individuals ≥ 70 mm in grams of live weight / m^2	% of cluckers ≥ 70 mm	Meat weight/shell height regression parameters ($LW = aH^b$)		Live weight/shell height regression parameters ($LW = aH^b$)		
				Lined	Unlined	Total						a	b	a	b	
Baie des Chaleurs	1983	79	647	1162	1321	2483	231	17.4	96.0	4.04 ± 0.83	15.5	1.70×10^{-5}	2.959	5.19×10^{-5}	3.186	*
	1984	110	970	981	1368	2349	106	1.1	99.9	2.46 ± 0.23	36.0	1.70×10^{-5}	2.959	5.19×10^{-5}	3.186	*
	1985	49	416	710	593	1303	314	42.6	103.7	2.38 ± 1.67	39.1	3.26×10^{-5}	2.813	1.08×10^{-5}	3.028	
Miscou/Val Comeau	1983	206	1660	2999	1009	4009	310	7.9	93.8	5.35 ± 1.18	16.4	1.29×10^{-5}	3.020	4.91×10^{-5}	3.243	*
	1984	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
	1985	94	947	296	308	604	68	4.1	103.1	1.02 ± 1.13	26.9	1.29×10^{-5}	3.020	4.91×10^{-5}	3.243	*
Borden/Cape Tormentine	1983	52	436	790	1406	2196	88	7.4	89.2	4.21 ± 0.61	14.9	2.29×10^{-5}	2.420	1.66×10^{-4}	3.002	*
	1984	69	600	793	1040	1833	299	17.0	91.4	3.10 ± 0.45	29.4	2.29×10^{-5}	2.420	1.66×10^{-4}	3.002	*
	1985	67	548	836	854	1690	380	40.8	92.2	2.64 ± 1.75	31.0	2.29×10^{-5}	2.420	1.66×10^{-4}	3.002	*
Pictou/Wood Island	1983	91	794	464	798	1262	317	19.9	95.8	3.59 ± 0.52	15.1	9.89×10^{-5}	2.599	1.91×10^{-4}	2.982	*
	1984	94	881	1628	1934	3562	702	21.3	92.0	3.29 ± 0.33	17.7	9.89×10^{-5}	2.599	1.91×10^{-4}	2.982	*
	1985	94	915	1319	1267	2586	796	41.8	99.1	1.41 ± 1.00	18.0	5.82×10^{-4}	2.163	2.17×10^{-4}	2.926	
Boughton Island	1983	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
	1984	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
	1985	54	470	530	730	1260	147	17.1	92.6	2.20 ± 1.59	11.1	5.82×10^{-4}	2.163	2.17×10^{-4}	2.926	

* Relationships from 1982 were used.

Table 2. Regression parameters of the meat weight/shell height relationship ($W = aL^b$) for three areas of the southern Gulf of St. Lawrence. N = number of individuals; R = correlation coefficient.

	N	a	b	r
Bathurst*	716	$3.263\ 10^{-5}$	2.8126	0.9670
Cape Tormentine**	122	$2.291\ 10^{-4}$	2.4198	0.8275
Pictou*	964	$5.823\ 10^{-4}$	2.1630	0.7817

* 1985 data
** 1982 data

Table 3. Parameters of the von Bertalanffy growth equation for three areas of the southern Gulf of St. Lawrence. N = number of ring measured; K = Brody growth coefficient; L_∞ = asymptotic length; W_∞ = asymptotic meat weigth; t_o = hypothetical age at zero length; t_b = hypothetical age at asymptotic length.

	N	K	L_∞	W_∞	t_o	t_b
Bathurst	944	0.2074	131.02	29.43	0.7741	16.17
Cape Tormentine	1446	0.2455	113.95	21.74	0.7339	12.39
Pictou	539	0.2958	106.92	14.25	0.7699	8.79

Table 4. Values of instantaneous rates of natural mortality for sea scallop of the southern Gulf computed using the formula of Dickie (1955) for the period 1983-1985.

	Baie des Chaleurs	Cape Tormentine	Pictou
1983	0.231	0.215	0.312
1984	0.411	0.369	0.239
1985	0.458	0.366	0.222

Table 5. Estimated age at first capture (a) corresponding to (b) maximum yield per recruit (in grams of meat) at various levels of fishing mortality (F) and natural mortality (M) for the Bathurst area.

F \ M		.1	.2	.3	.4
.1	a	5	4	4	4
	b	6.10	3.81	2.66	2.00
.2	a	7	5	4	4
	b	8.24	5.20	3.81	3.03
.3	a	7	5	4	4
	b	9.18	5.80	4.34	3.60
.4	a	8	6	5	4
	b	9.74	6.17	4.64	3.93
.5	a	8	6	5	4
	b	9.95	6.35	4.85	4.13
.6	a	9	6	5	4
	b	10.13	6.46	4.97	4.26
.7	a	9	6	5	4
	b	10.24	6.51	5.06	4.34
.8	a	9	7	5	4
	b	10.30	6.58	5.11	4.39
.9	a	9	7	5	4
	b	10.33	6.63	5.14	4.42
1.0	a	9	7	5	5
	b	10.35	6.66	5.16	4.46
1.1	a	8-10	7	5	5
	b	10.36	6.69	5.18	4.50
1.2	a	10	7	5-6	5
	b	10.38	6.71	5.19	4.54
1.3	a	10	7	6	5
	b	10.40	6.73	5.22	4.57
1.4	a	10	7	6	5
	b	10.42	6.74	5.24	4.59
1.5	a	10	7	6	5
	b	10.43	6.75	5.26	4.61

Table 6. Estimated age at first capture (a) corresponding to (b) maximum yield per recruit (in grams of meat) at various levels of fishing mortality (F) and natural mortality (M) for the Cape Tormentine area.

F \ M		.1	.2	.3	.4
.1	a	4	4	4	4
	b	4.37	3.19	2.66	1.96
.2	a	5	4	4	4
	b	6.26	4.59	3.68	3.06
.3	a	6	5	4	4
	b	7.29	5.32	4.32	3.74
.4	a	7	5	4	4
	b	7.85	5.71	4.66	4.11
.5	a	7	5-6	4	4
	b	8.26	5.91	4.84	4.37
.6	a	7	6	5	4
	b	8.49	6.10	4.99	4.54
.7	a	8	6	5	4
	b	8.64	6.21	5.11	4.65
.8	a	8	6	5	4
	b	8.80	6.28	5.19	4.73
.9	a	8	6	5	4
	b	8.90	6.33	5.24	4.78
1.0	a	8	6	5	4
	b	8.96	6.36	5.28	4.82
1.1	a	8	6	5	4
	b	9.00	6.38	5.31	4.84
1.2	a	8	6	5	4
	b	9.03	6.39	5.34	4.86
1.3	a	8	6	5	4
	b	9.04	6.40	5.35	4.87
1.4	a	9	6	5	4
	b	9.06	6.41	5.36	4.88
1.5	a	9	6	5	4
	b	9.09	6.41	5.37	4.89

Table 7. Estimated age at first capture (a) corresponding to (b) maximum yield per recruit (in grams of meat) at various levels of fishing mortality (F) and natural mortality (M) for the Pictou area.

F \ M		.1	.2	.25	.3
.1	a	4	4	4	4
	b	2.17	1.78	1.62	1.48
.2	a	4	4	4	4
	b	3.43	2.86	2.63	2.43
.3	a	4.5	4	4	4
	b	4.19	3.51	3.26	3.03
.4	a	5	4-4.5	4	4
	b	4.70	3.90	3.64	3.41
.5	a	5	4.5	4-4.5	4
	b	5.07	4.19	3.87	3.66
.6	a	5.5	5	4.5	4
	b	5.35	4.37	4.06	3.82
.7	a	5.5	5	4.5	4
	b	5.56	4.53	4.18	3.92
.8	a	6	5	4.5-5	4.5
	b	5.72	4.63	4.26	4.01
.9	a	6	5-5.5	5	4.5
	b	5.87	4.70	4.34	4.08
1.0	a	6	5.5	5	4.5
	b	5.97	4.78	4.40	4.12
1.1	a	6	5.5	5	4.5
	b	6.05	4.83	4.44	4.15
1.2	a	6.5	5.5	5	4.5
	b	6.13	4.87	4.47	4.18
1.3	a	6.5	5.5	5	4.5-5
	b	6.21	4.90	4.49	4.19
1.4	a	6.5	5.5	5	5
	b	6.27	4.92	4.50	4.21
1.5	a	6.5	5.5-6	5-5.5	5
	b	6.32	4.93	4.51	4.23

Table 8 - Scallop landings (in kg of meat) in the three southern Gulf of St Lawrence lobster districts from 1970 to 1985.

	Lobster districts		
Year	7C	8	7B1
1970	69,673	298,373	327,917
1971	55,444	258,752	265,310
1972	81,098	151,032	275,966
1973	45,428	112,652	146,861
1974	36,567	45,932	119,429
1975	31,082	58,083	185,955
1976	25,465	217,738	119,446
1977	14,927	175,219	60,969
1978	14,553	171,505	81,307
1979	13,094	122,049	95,143
1980	21,693	99,569	89,284
1981	23,035	157,179	174,379
1982	26,819	113,002	126,539
1983	28,952	150,861	153,555
1984	40,140	140,205	71,957
1985	51,631	144,297	56,759

Table 9 - Summary of landing statistics for the three management districts of the southern Gulf, by statistical districts (see explanations in the text).

		Landings in kg					Landing value			catch per day	
		Estimated # of day	Meat from sale slips with boat code	Supplementary B's	Total meat	Roe	Total $	$/kg	$/lb	kg	lb
7C	63	57	1449	-	1449	-	18799	12.87	5.88	25	55
	64	162	16572	1510	18082	409	218302	11.80	5.30	102	225
	65	10	1748	4536	6284	-	77162	12.38	5.57	175	386
	66	45	4472	-	4472	60	51838	11.44	5.19	101	223
	67	42	2824	-	2824	112	33546	11.43	5.18	70	154
	68	192	6046	2291	8337	1639	106043	10.63	4.82	31	68
	70	153	5648	1259	6907	61	80158	11.50	5.22	47	82
	73	212	3276	-	3276	758	47424	11.76	5.33	19	42
Total	7C	873	42035	9596	51631	3039	633272	11.58	5.25	52	114
8	75	163	7117	998	8115	-	93992	11.58	5.25	44	97
	76	527	30682	1678	32360	-	362200	11.19	5.08	58	128
	77	33	4051	13744	17795	-	210763	11.84	5.37	123	271
	78	112	4999	168	5167	-	59841	11.58	5.25	42	93
	80	289	10106	907	11013	-	123298	11.28	5.08	35	77
	82	1456	64675	689	65355	-	819760	12.54	5.69	44	97
	83	153	4492	-	4492	-	56761	12.64	5.73	29	64
Total	8	2733	126122	18184	144297	-	1726615	11.96	5.43	46	101
7B1	10	1	20	389	409	-	5792	14.16	6.42	20	44
	11	68	2457	3402	5859	-	80118	13.67	6.20	36	79
	12	2	43	1247	1290	-	18198	14.11	6.40	22	49
	13	21	722	265	987	-	13564	13.74	6.23	34	75
	45	10	1001	-	1001	-	10539	10.53	4.78	100	220
	46	24	615	1798	2413	-	33884	14.04	6.37	26	57
	85	13	277	-	277	-	3660	13.21	5.99	21	46
	86	208	9162	1814	10976	-	133533	12.17	5.52	44	97
	87	629	29633	3357	32990	-	420297	12.74	5.78	47	104
	88	16	557	-	557	-	6421	11.53	5.23	35	77
Total	7B1	992	44487	12272	56759	-	726006	12.79	5.80	45	99
Total		4598	212644	40052	252687	3039	3085893	12.21	5.54	47	104

Table 10. Yield per recruit values computed for Placopecten magellanicus on Georges Bank (Posgay, 1962) and in the southern Gulf of St Lawrence (Jamieson, 1978, Present study) with F = .8 and M = .1

	AGE							
Author	4	5	6	7	8	9	10	11
Posgay (1962)	24	30.5	35.7	38.5	40	40		
Jamieson (1978)	9.1	10.2	11	11.3	11.4	11.2		
Worms (Present paper)								
Bathurst	5.8	7.4	8.7	9.6	10.1	10.3	10.2	9.9
Cape Tormentine	5.8	7.2	8.2	8.7	8.8	8.5	7.6	5.8
Pictou	4.7	5.5	5.7	5.1	3.2			

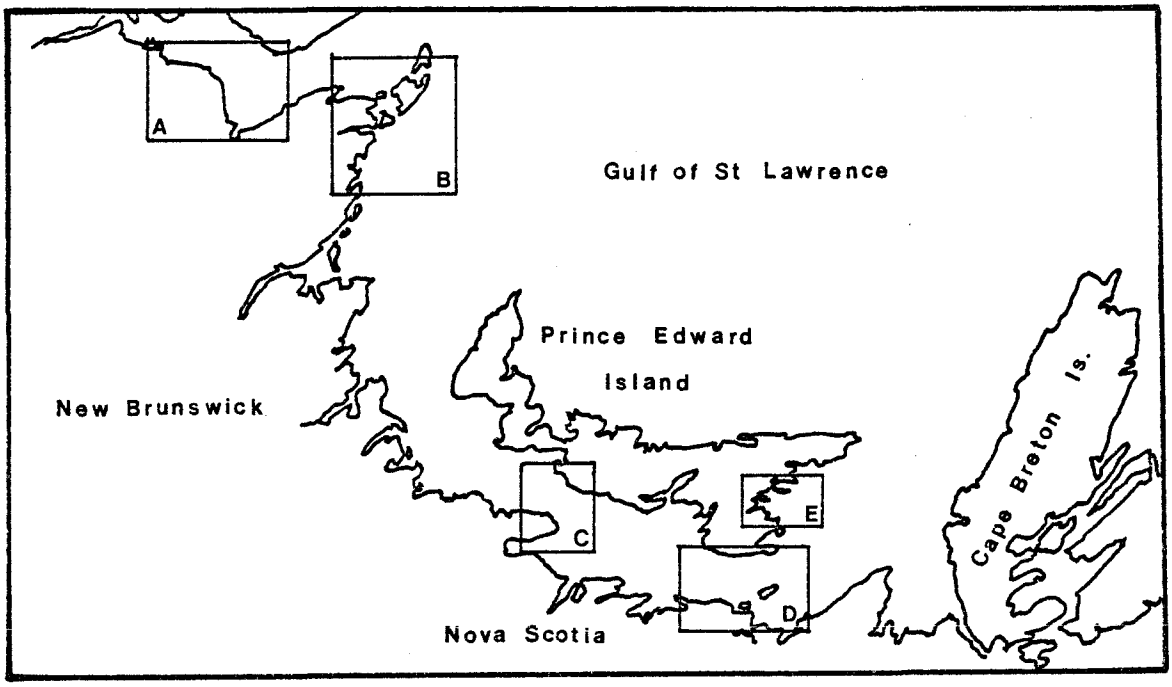


Fig. 1. Location of 1985 survey areas in the southern Gulf of St Lawrence.

A. Baie des Chaleurs
B. Acadian Peninsula
C. Cape Tormentine
D. Pictou
E. Boughton Island

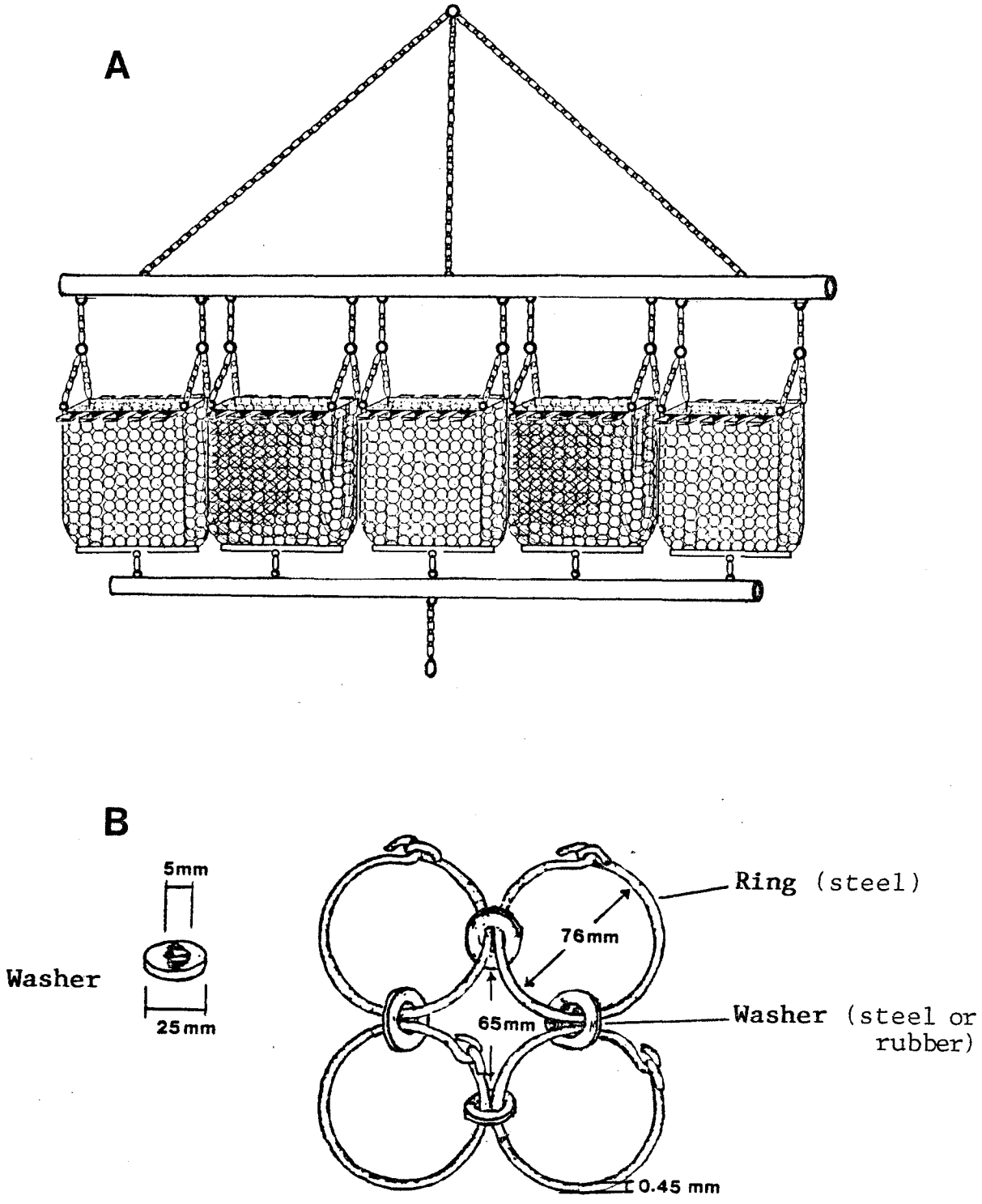


Fig. 2. A- Five buckets Digby drag. B- Mesh details (washers and rings).

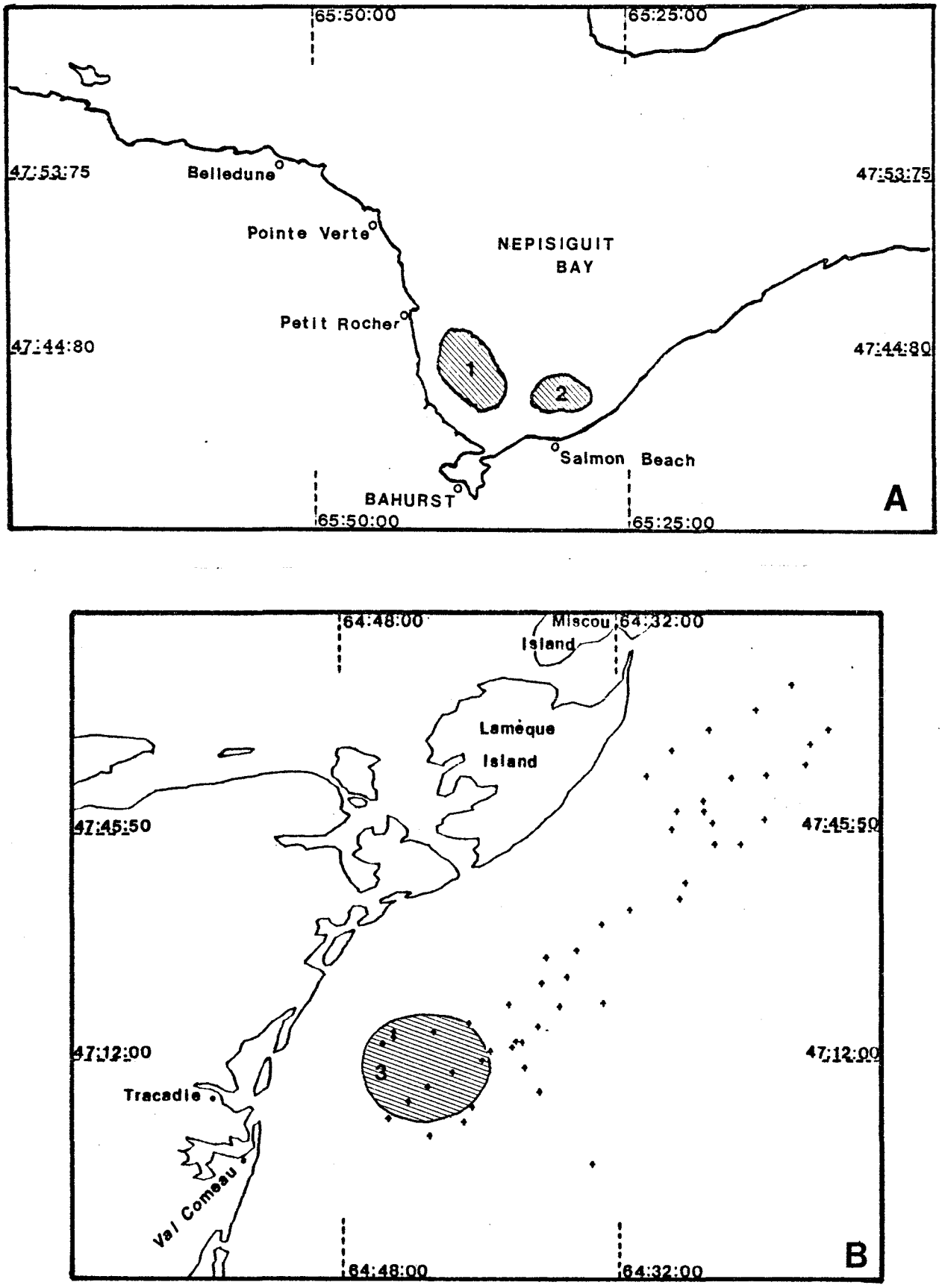
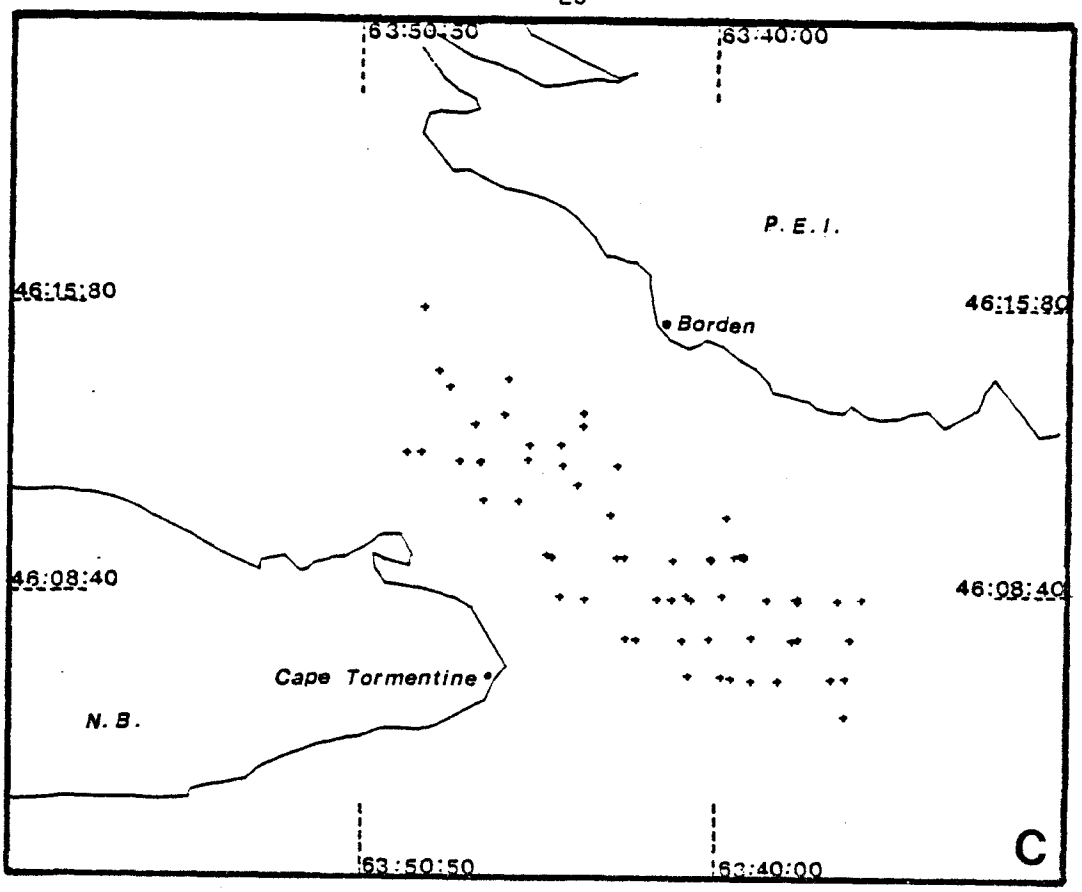


Fig. 3. Position of tows for each survey. Cross-lined sections represent zones where non-positionned tows were performed. A- Baie des Chaleurs (area 2); 1 - 33 tows, 2 - 16 tows. B- Miscou/Val Comeau (area 4 and 5); 3 - 25 tows.



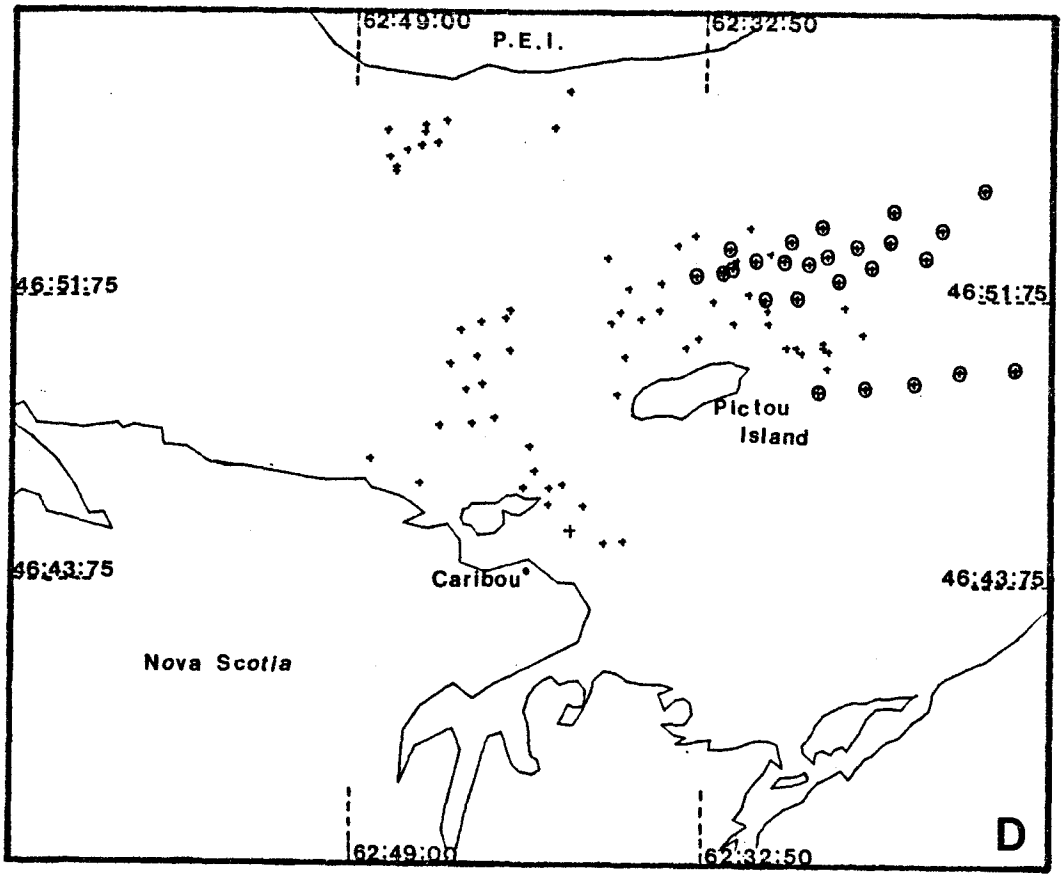


Fig. 3. (continued).
C- Borden/Cape Tormentine (area 10).
D- Pictou/Wood Island (area 12); ⊕ - May 24-25 survey, + - July 3-7 survey.

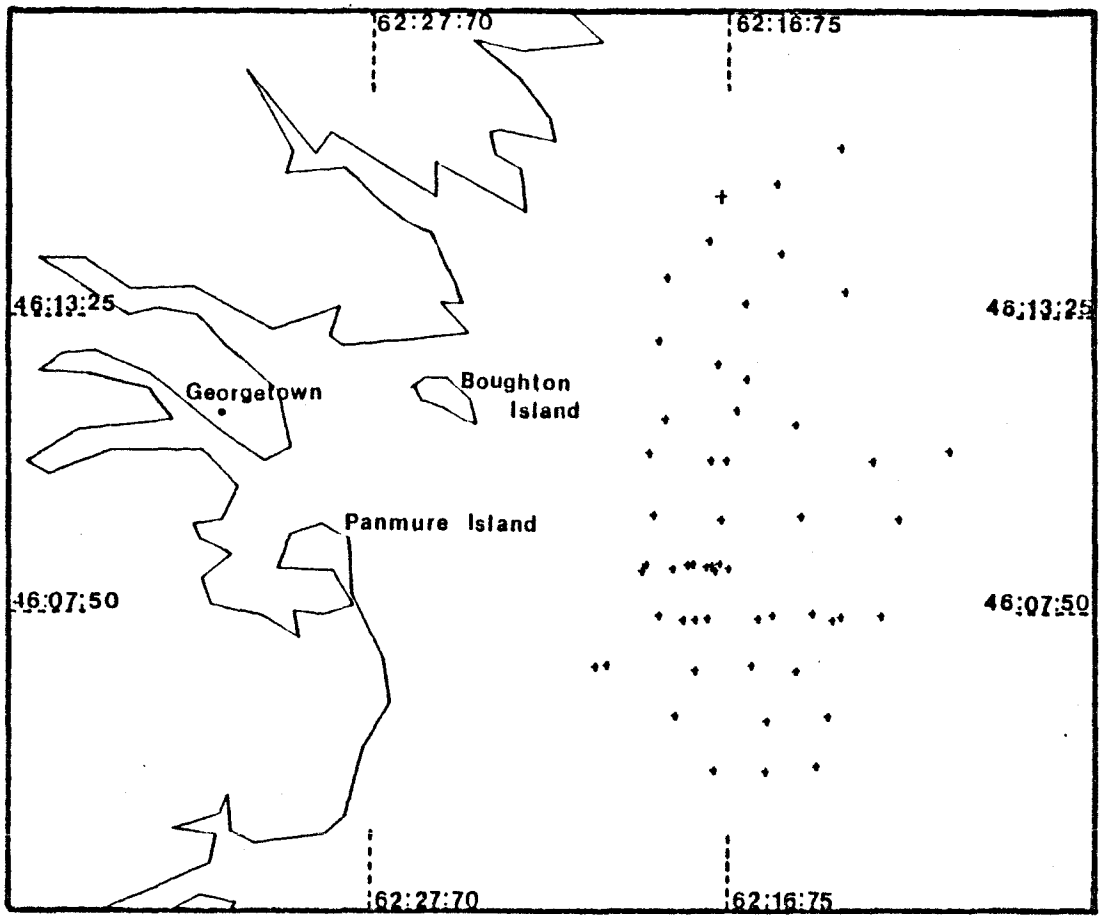


Fig. 3. (continued).
E- Boughton Island (area 14).

A

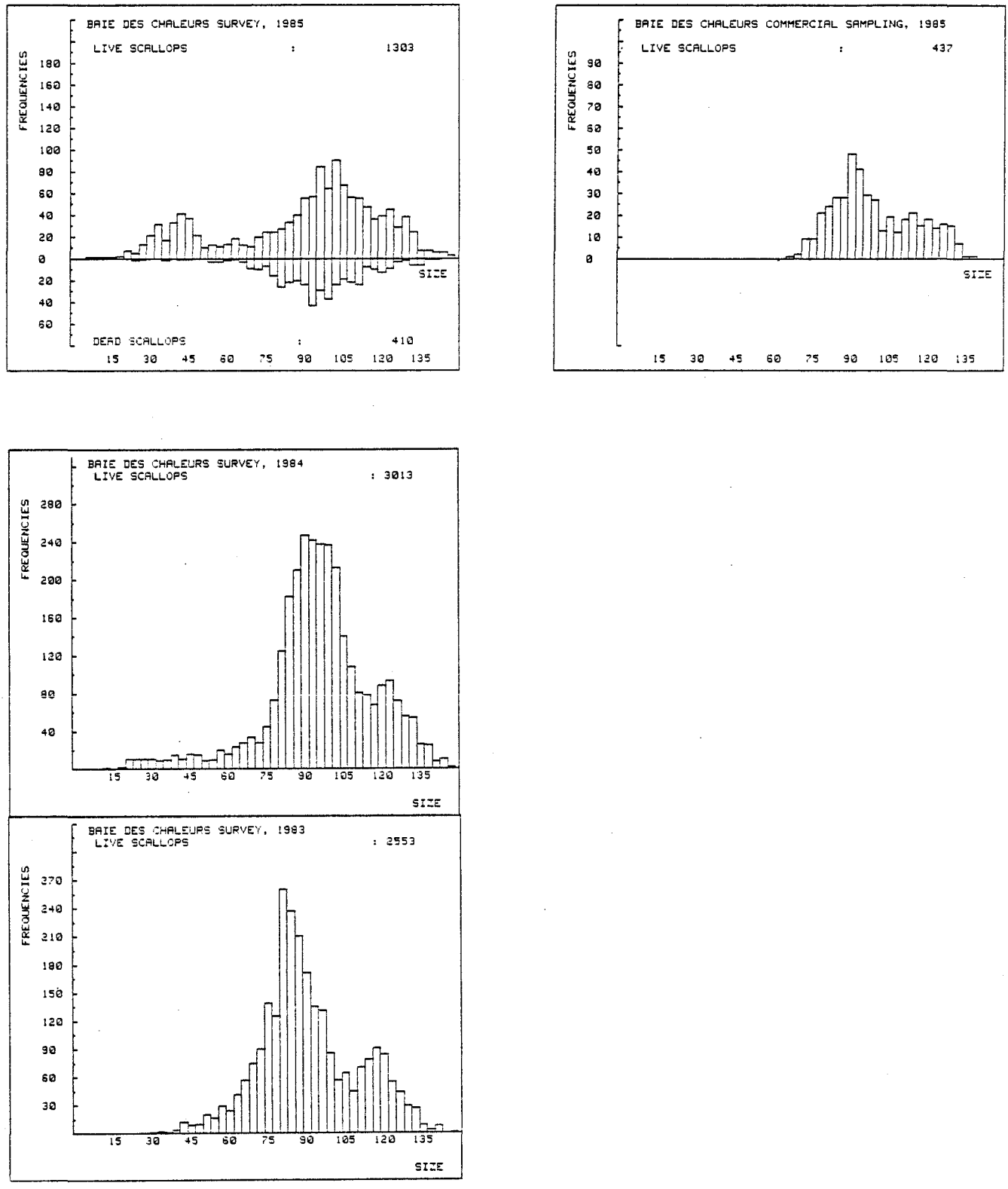
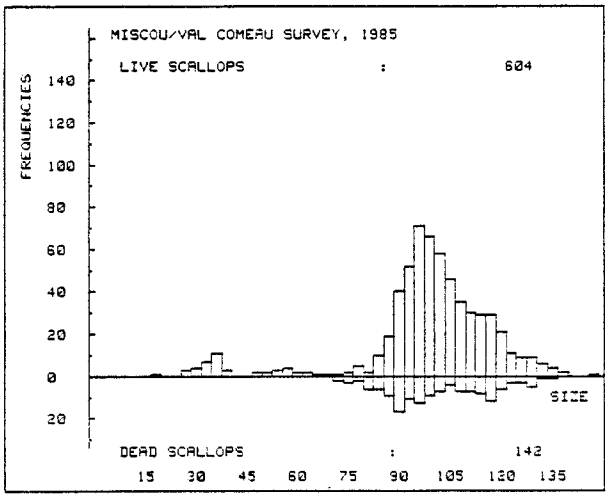
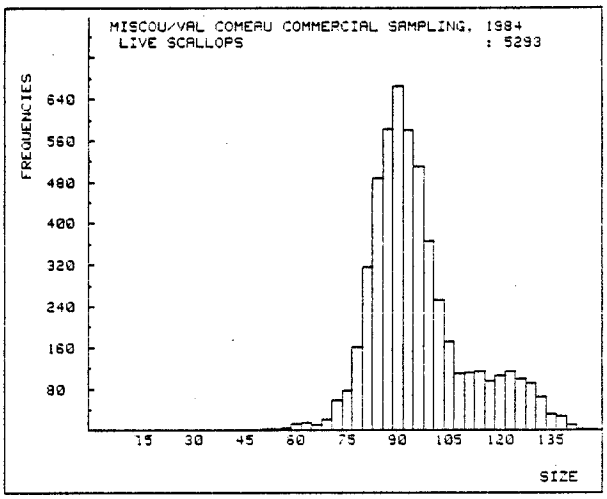


Fig. 4. Size distributions of live (above line) and dead scallops for survey catches and commercial samplings in 1983, 1984 and 1985.
A. Baie des Chaleurs.

B





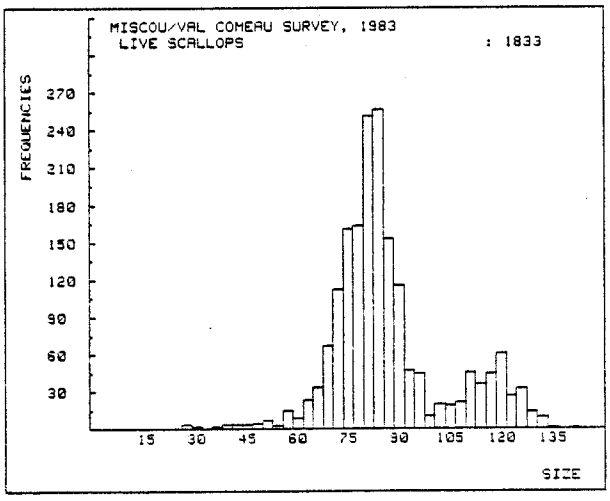
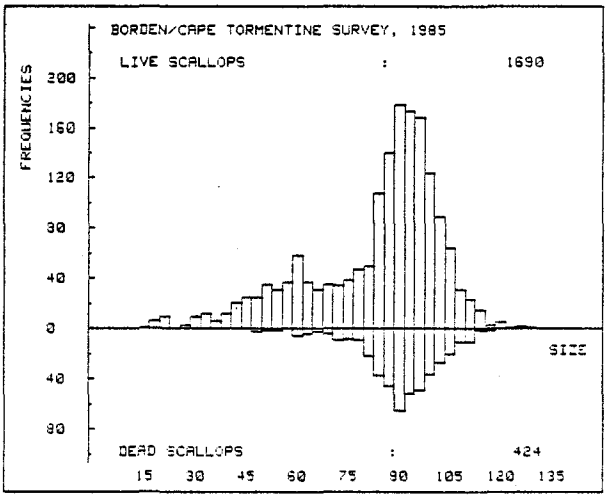
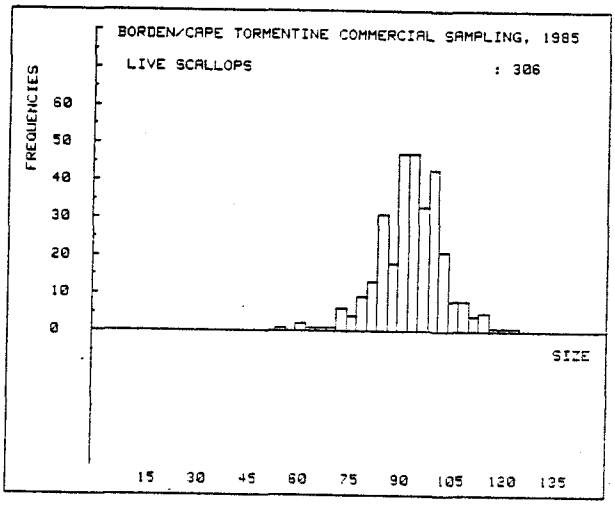
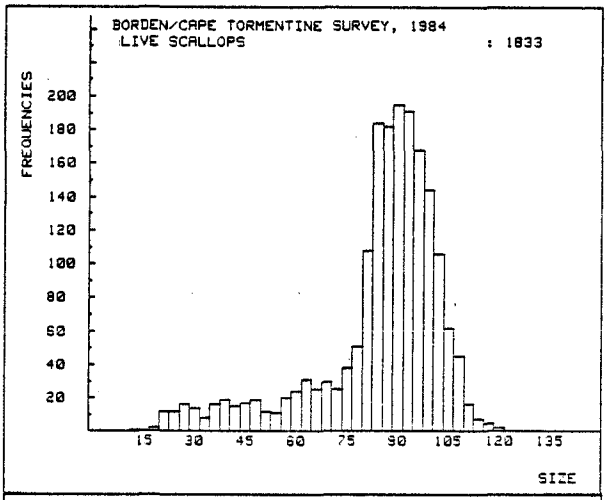


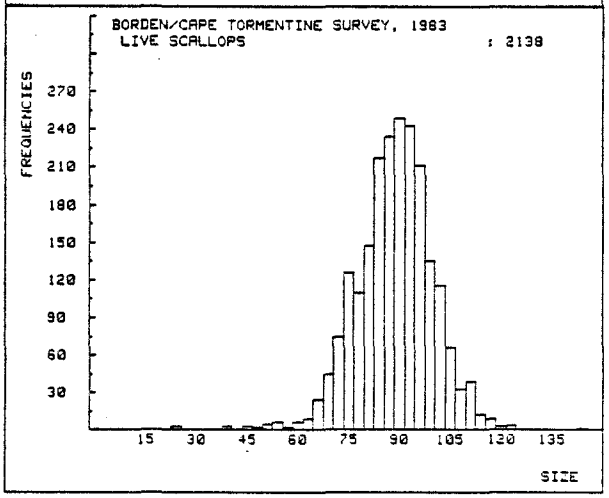
Fig. 4. (continued).
B- Miscou/Val Comeau area.

C









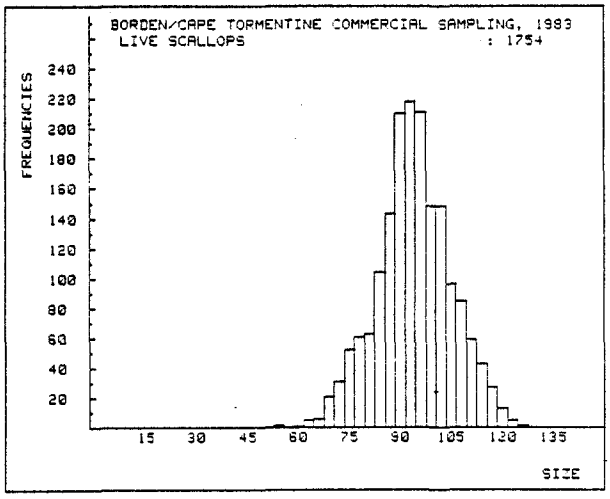
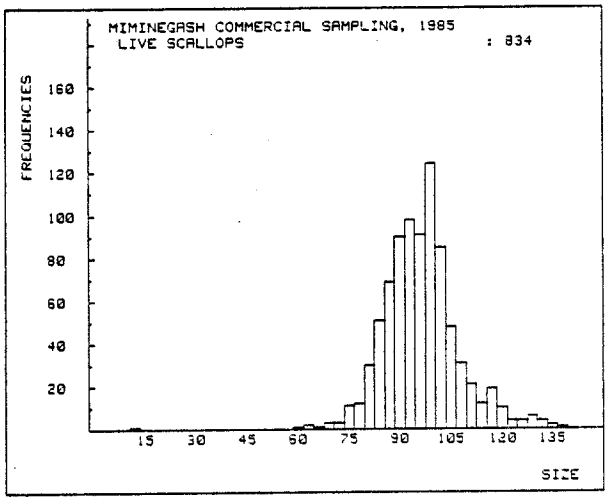


Fig. 4. (continued).
C- Borden/Cape Tormentine area.

D



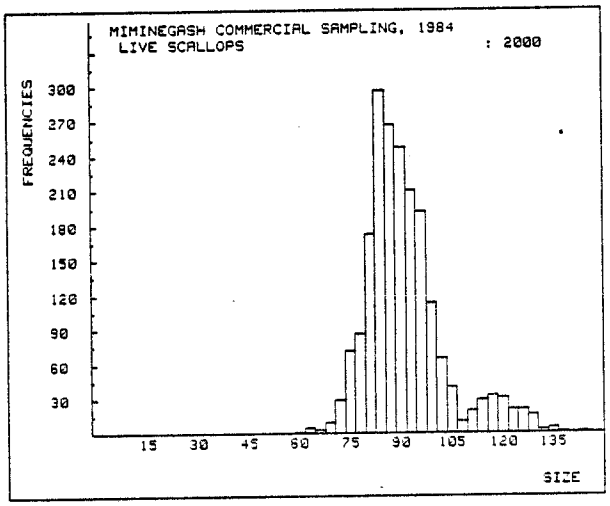
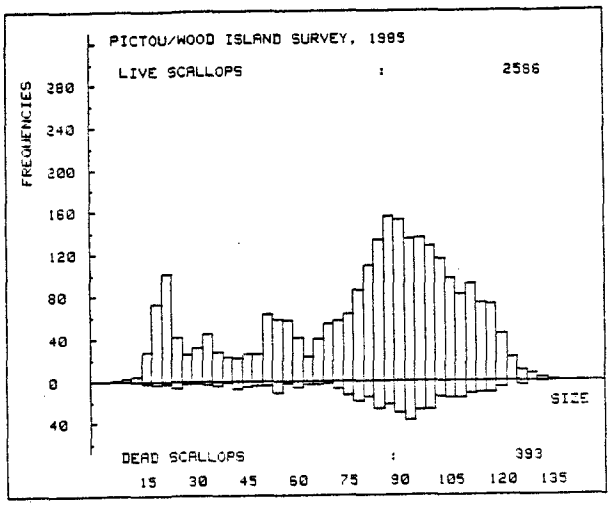
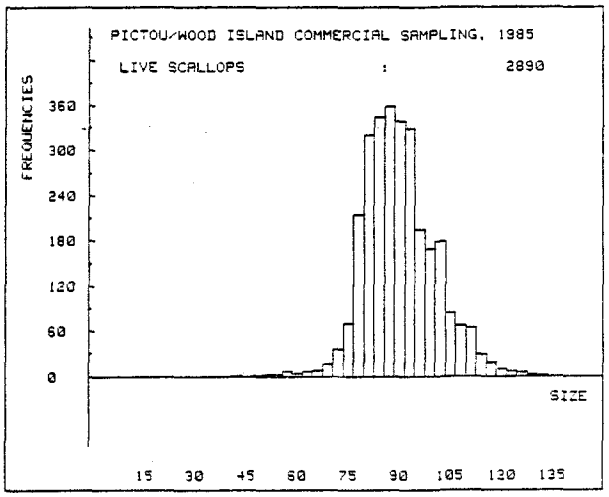
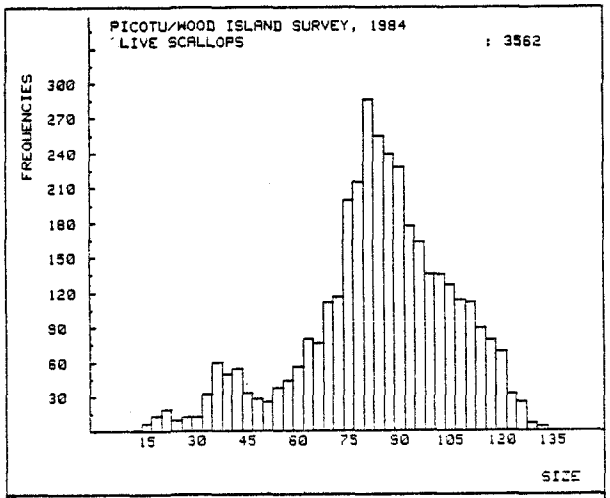


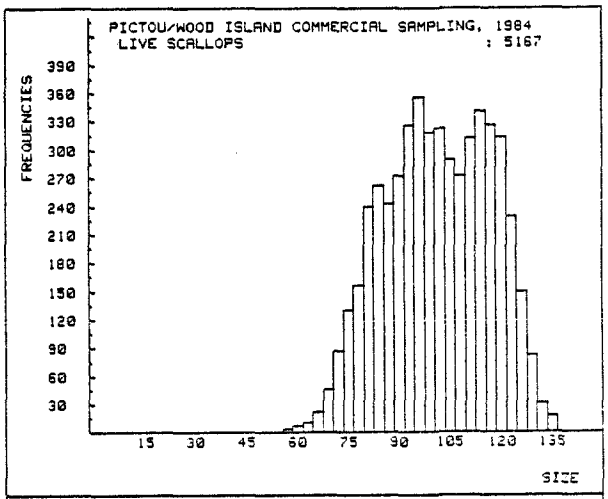
Fig. 4. (continued),
D- Miminegash area (commercial samplings only).

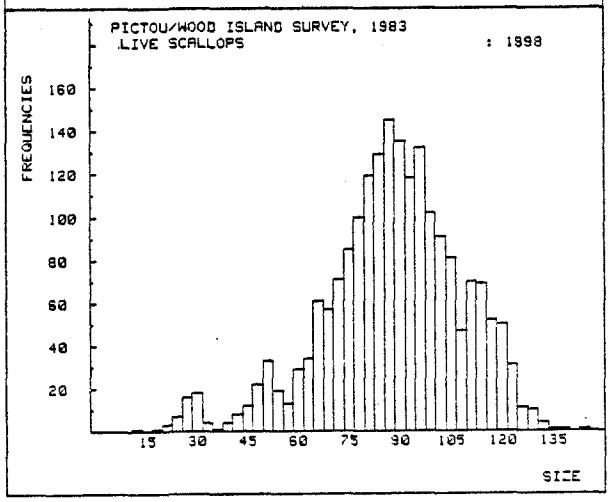
E











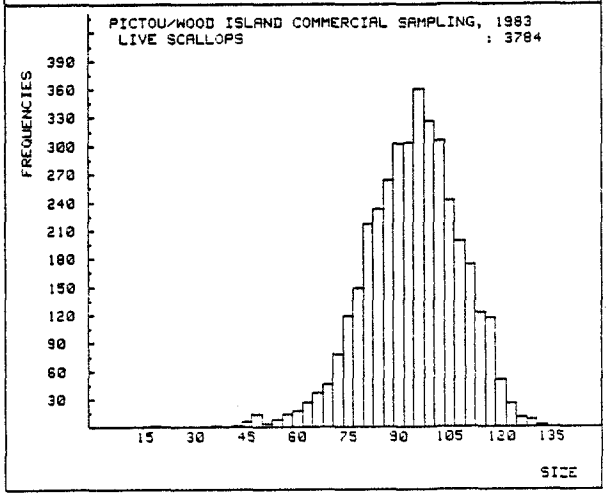
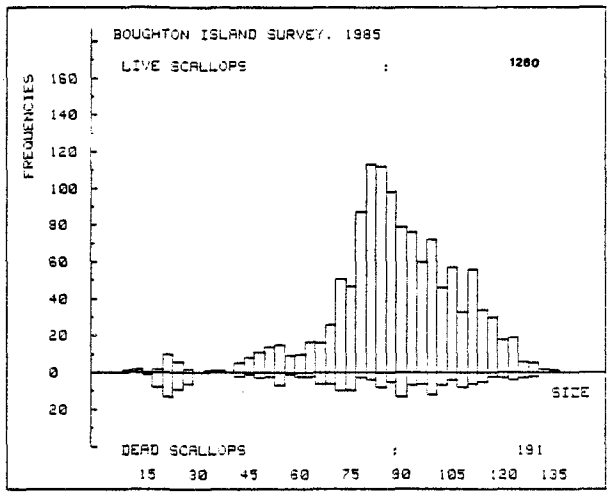


Fig. 4. (continued).
E- Pictou/Wood Island area.

F



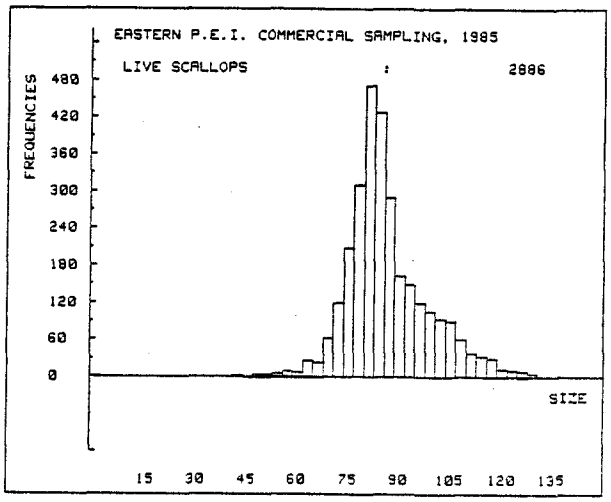
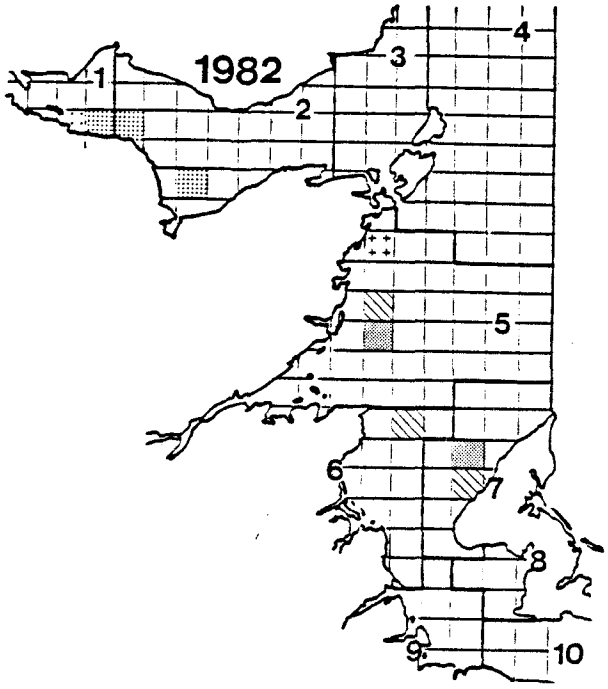
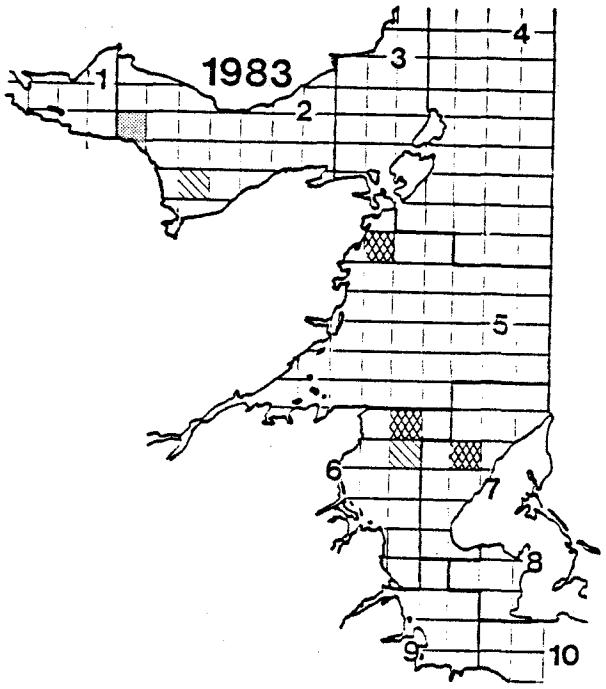
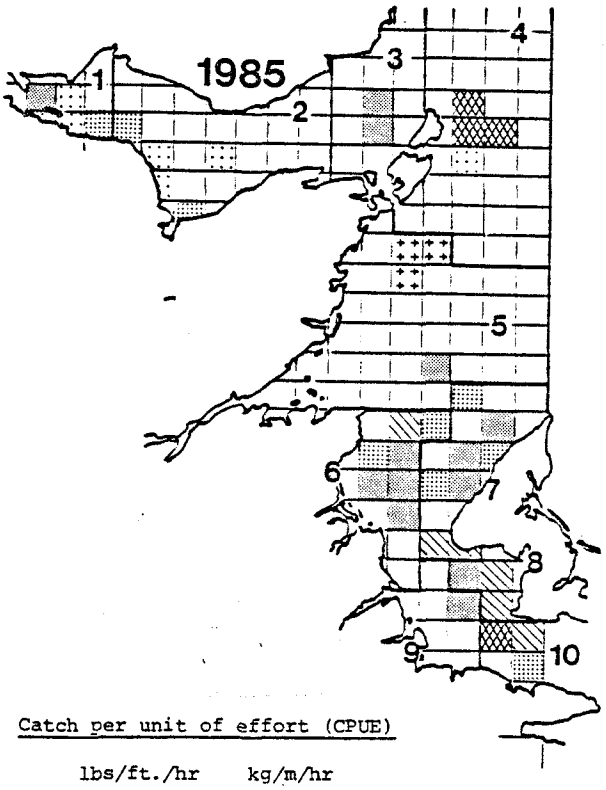


Fig. 4. (continued).
F- Boughton Island area.

A







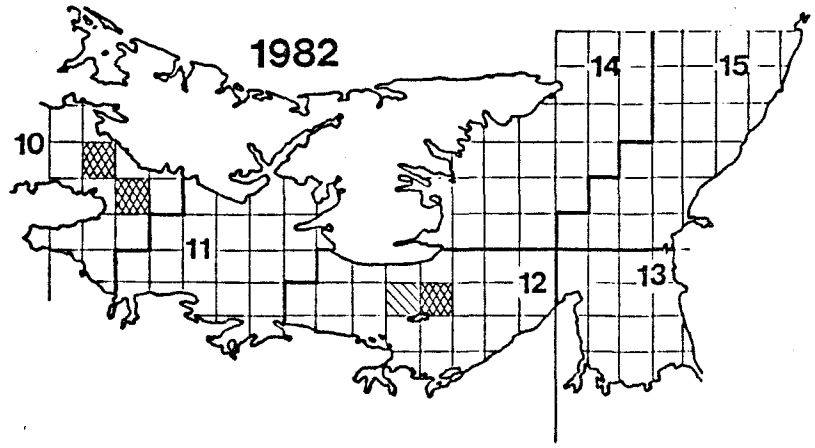
Catch per unit of effort (CPUE)

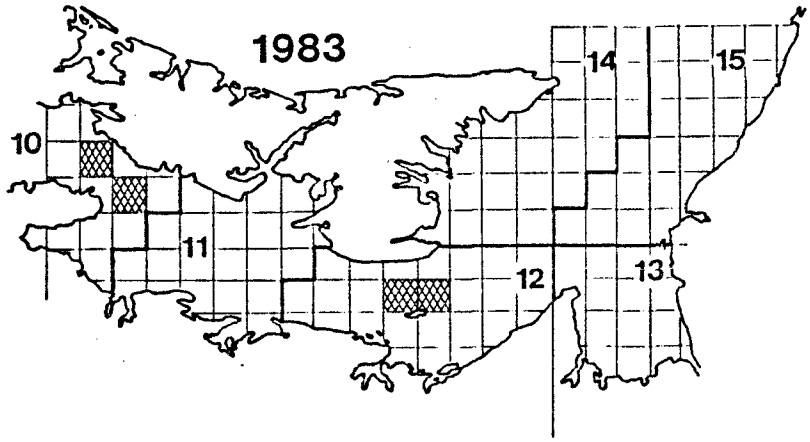
	lbs/ft./hr	kg/m/hr
	0 -0.29	0 -0.19
	0.30-0.49	0.20-0.33
	0.50-0.69	0.34-0.46
	0.70-0.89	0.47-0.60
	0.90-1.09	0.61-0.73
	≥ 1.10	≥ 0.74

Fig. 5. Mean CPUE's calculated from log book information, for each square. (bold numbers refer to survey area numbers)

B Catch per unit of effort (CPUE)

	lbs/ft./hr	kg/m/hr
	0 -0.29	0 -0.19
	0.30-0.49	0.20-0.33
	0.50-0.69	0.34-0.46
	0.70-0.89	0.47-0.60
	0.90-1.09	0.61-0.73
	≥ 1.10	≥ 0.74





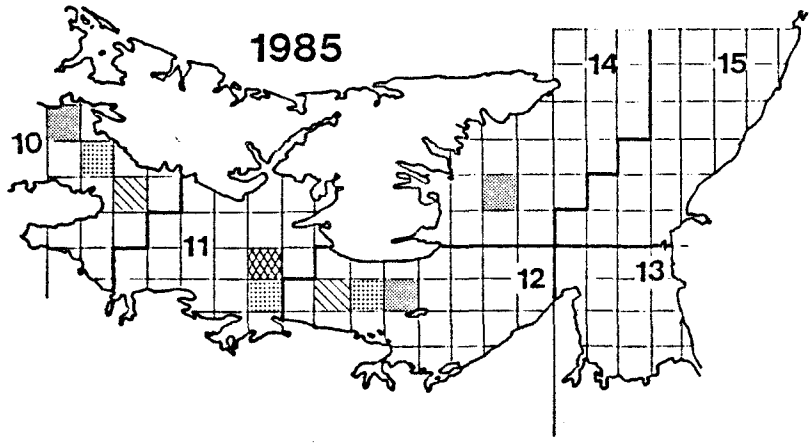
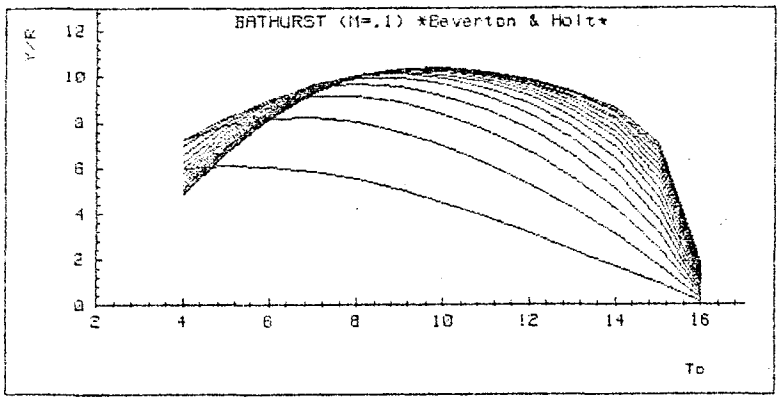
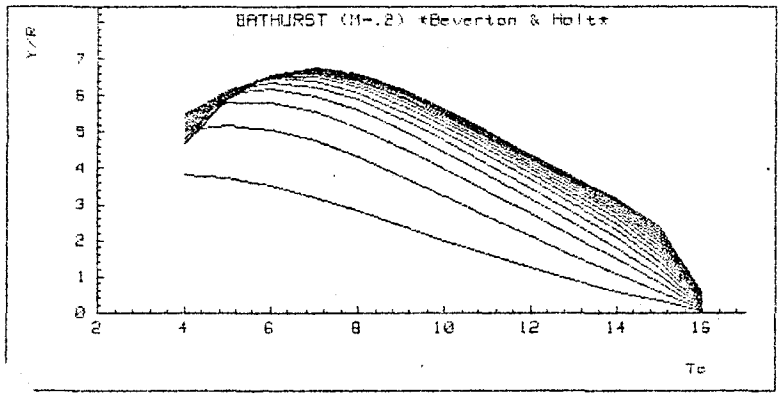
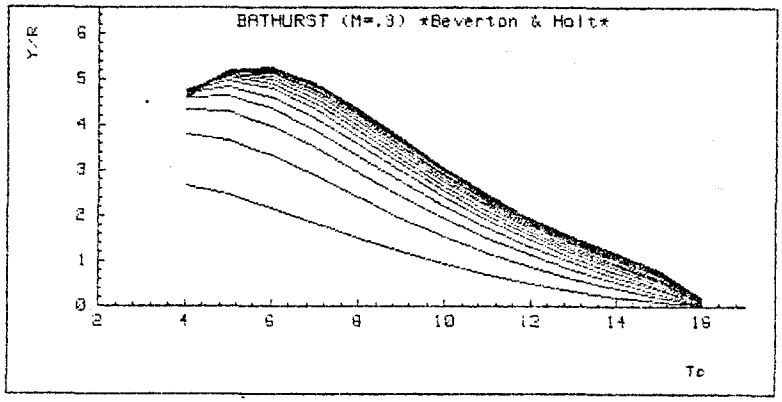


Fig. 5. (continued).







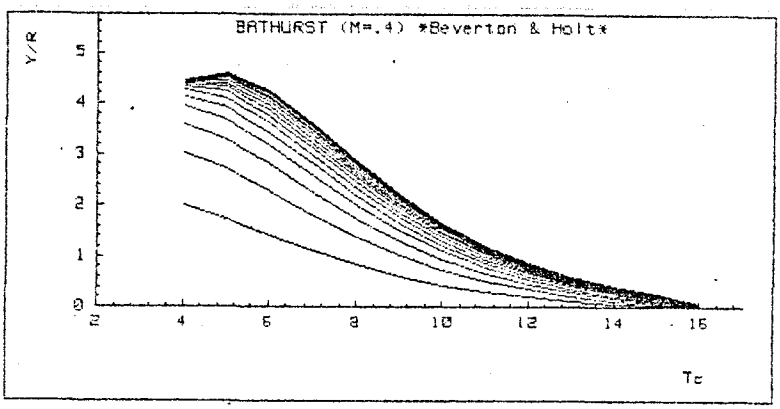


Fig.6A– Yield per recruit **Y/R** (in grams of meat) as a function of age at first capture T_c for different values of fishing mortality **F** for the Bathurst area.

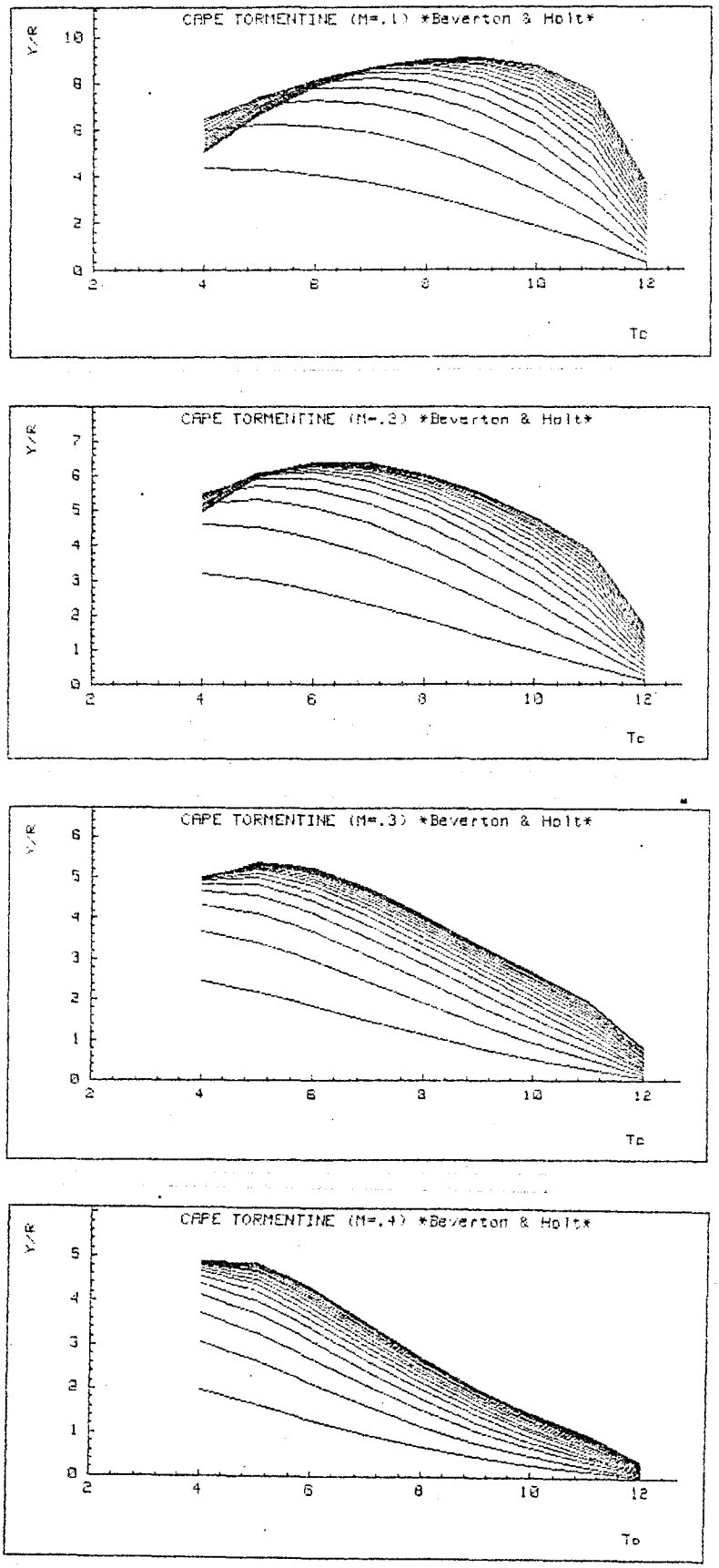


Fig.6B – Yield per recruit **Y/R** (in grams of meat) as a function of age at first capture T_c for different values of fishing mortality **F** for the Cape Tormentine area.

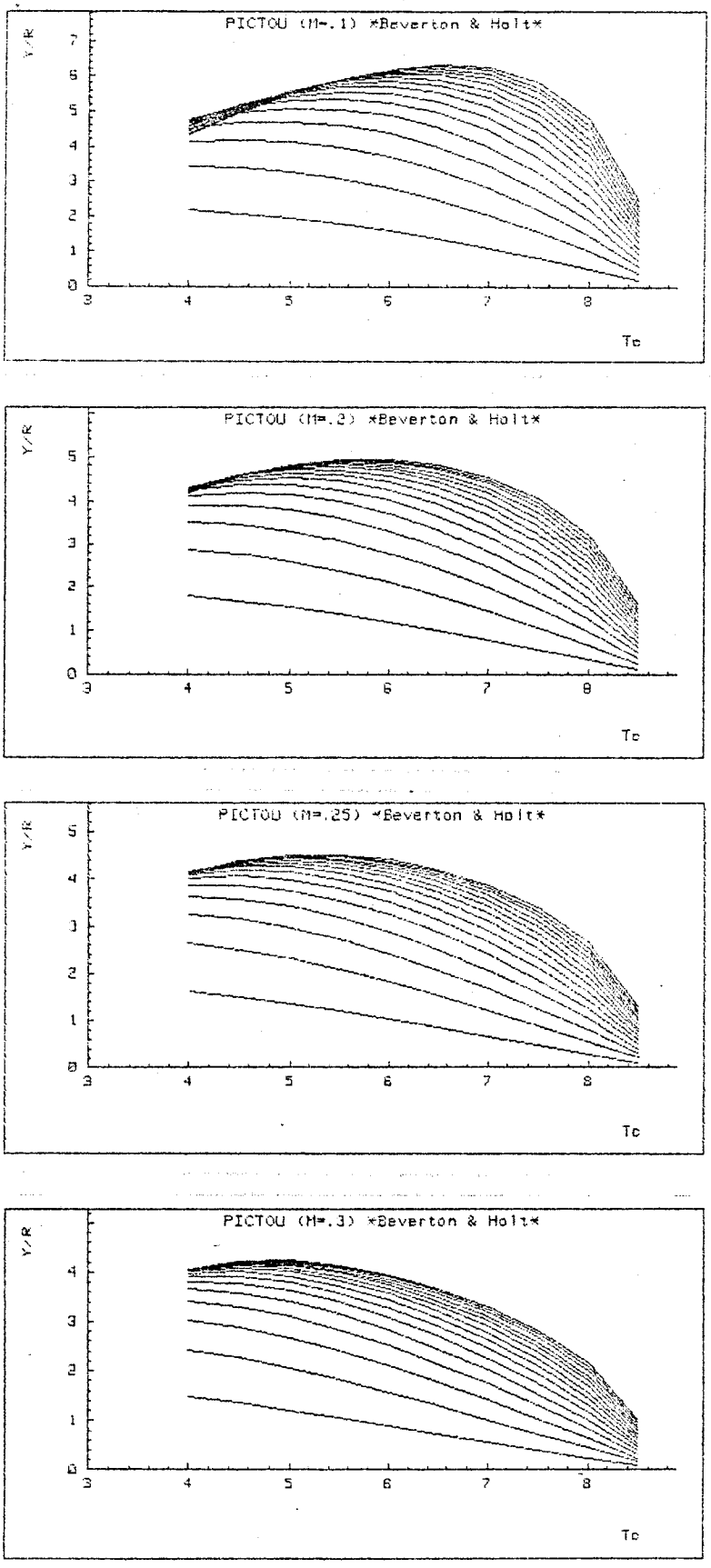


Fig.6C – Yield per recruit **Y/R** (in grams of meat) as a function of age at first capture T_c for different values of fishing mortality **F** for the Pictou area.

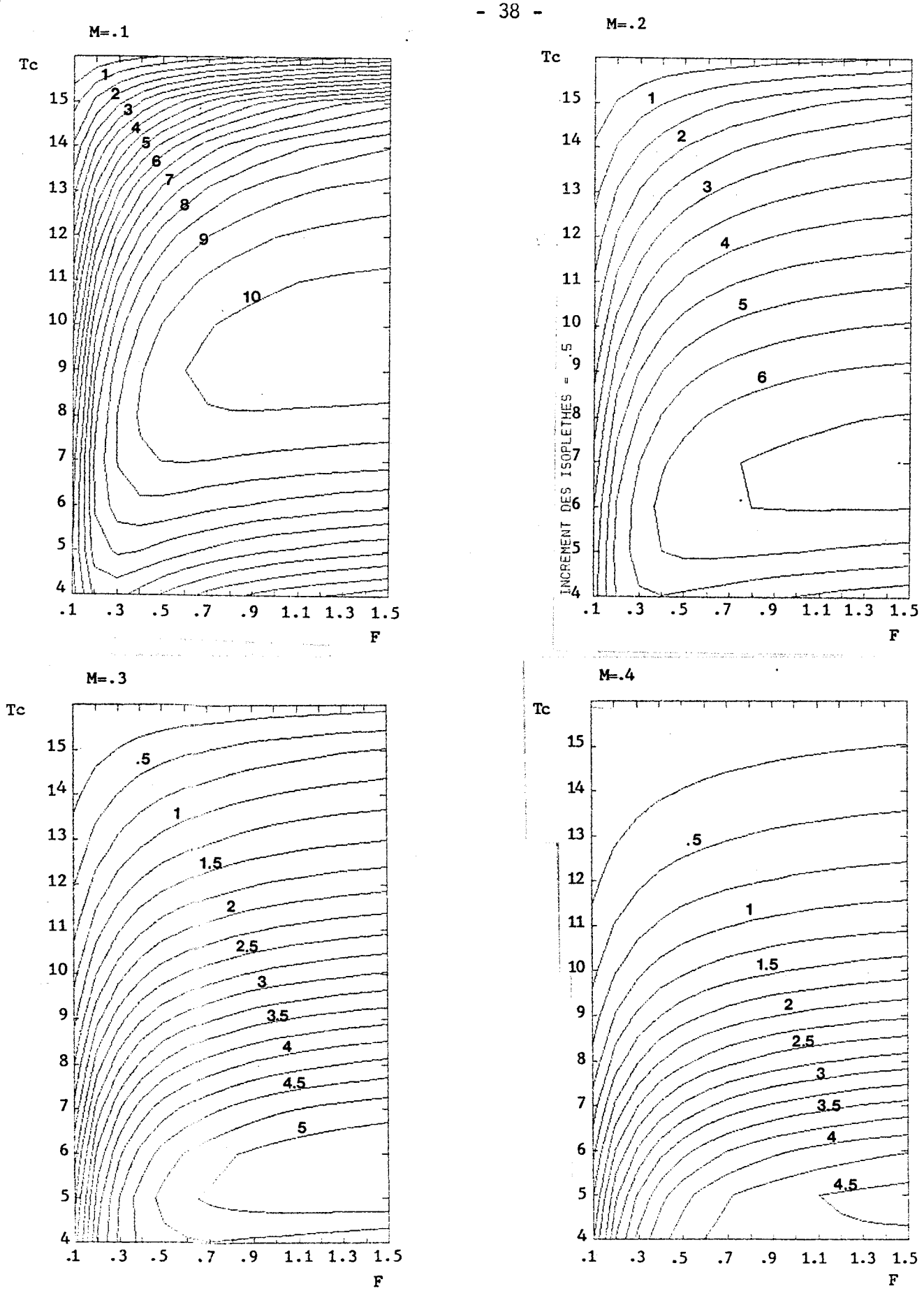


Fig.7A – Yield per recruit isopleths for different values of natural mortality **M**, for the Bathurst area.

F : instantaneous rate of fishing mortality; T_c : age at first capture.

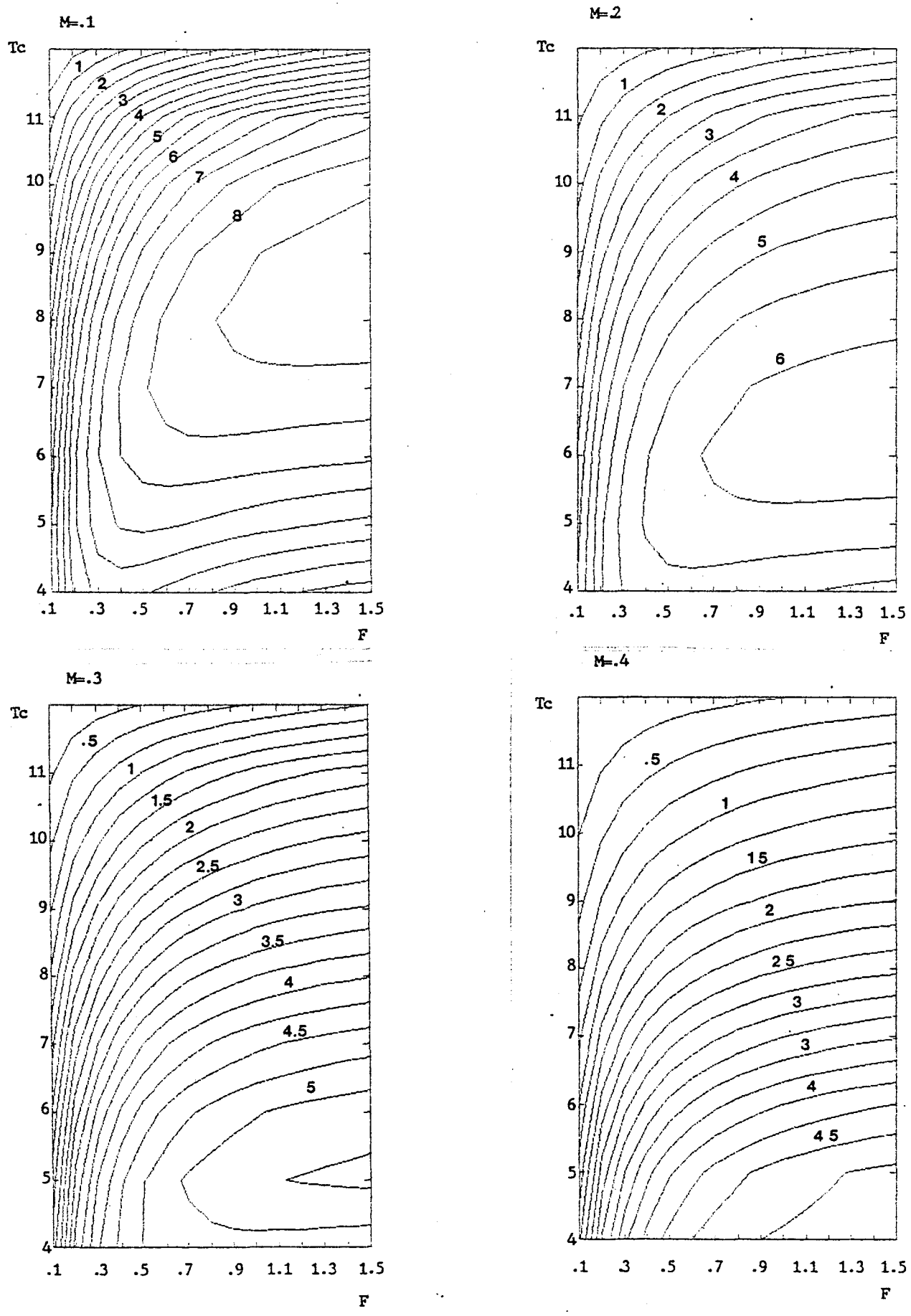


Fig. 7B– Yield per recruit isopleths for different values of natural mortality M, for the Cape Tormentine area.

F : instantaneous rate of fishing mortality; T_c : age at first capture.

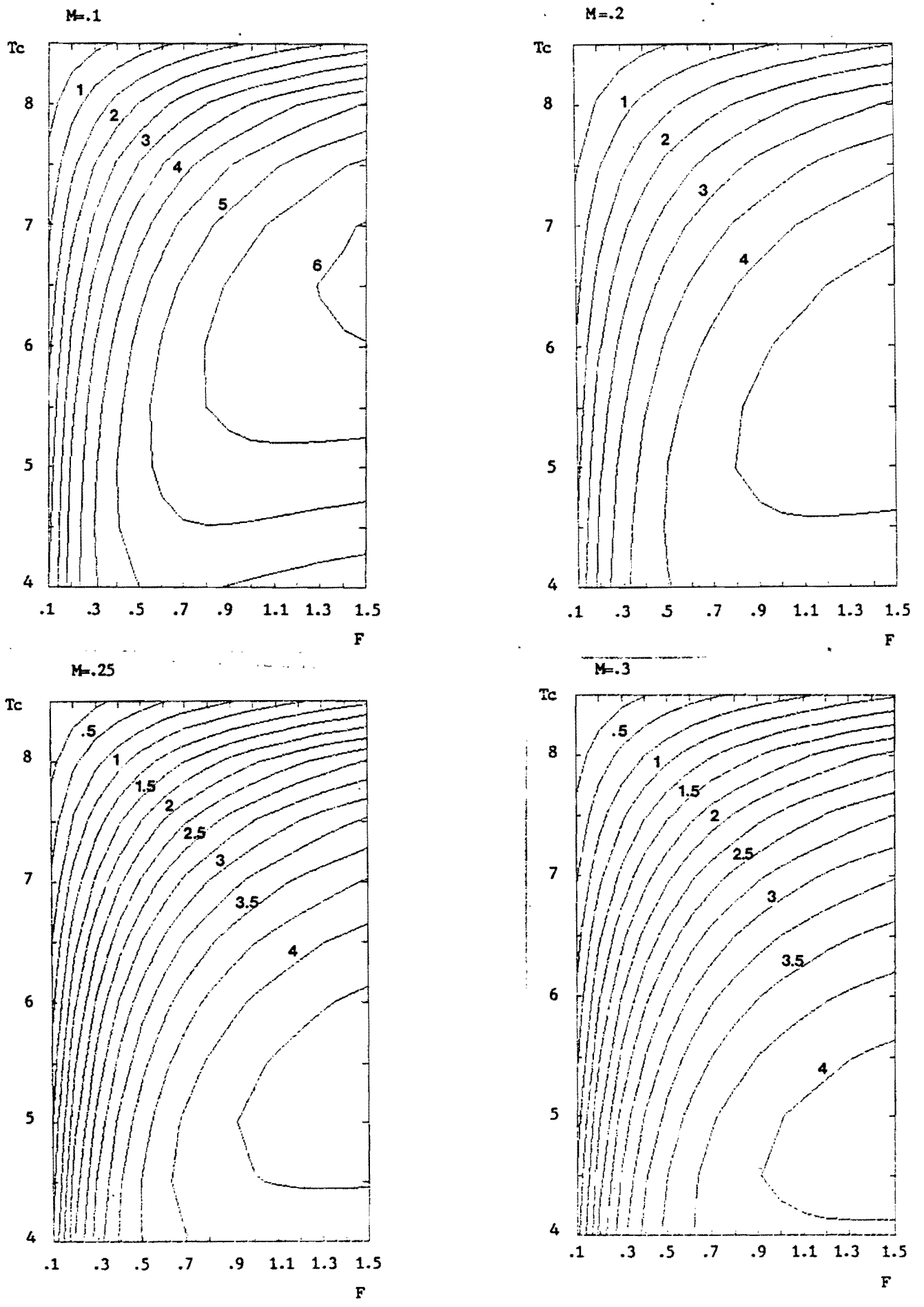


Fig. 7C– Yield per recruit isopleths for different values of natural mortality M, for the Pictou area.

F : instantaneous rate of fishing mortality; T_c : age at first capture.

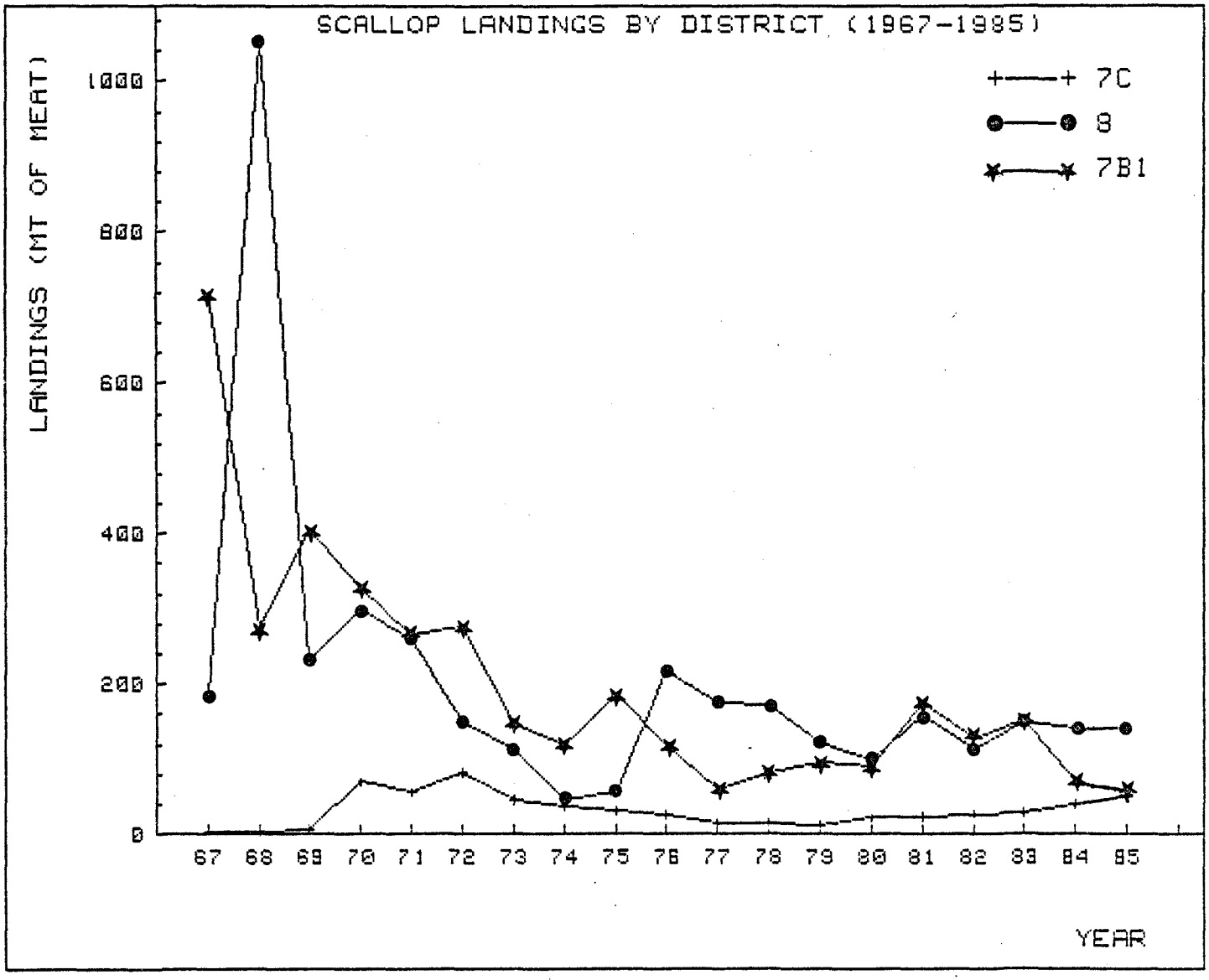
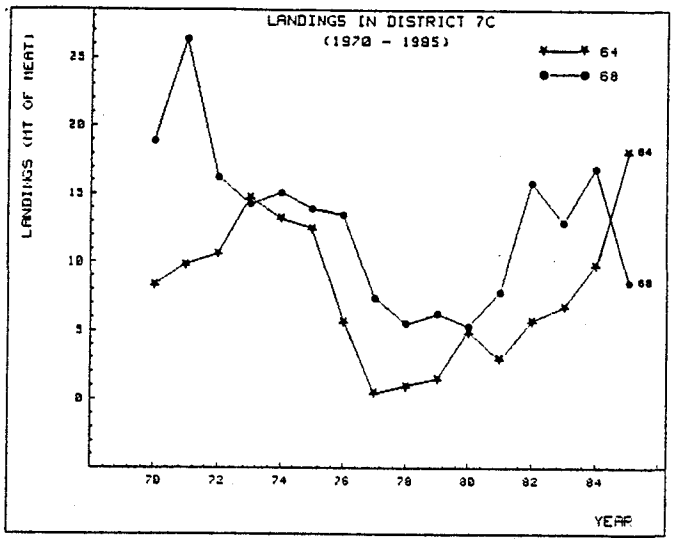
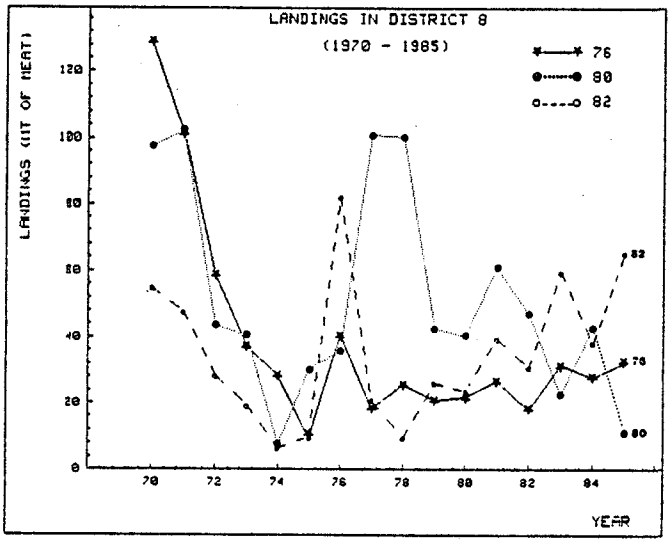


Fig. 8. Yearly scallop landings in the three lobster districts of the southern Gulf (1967-1985).

A



B



C

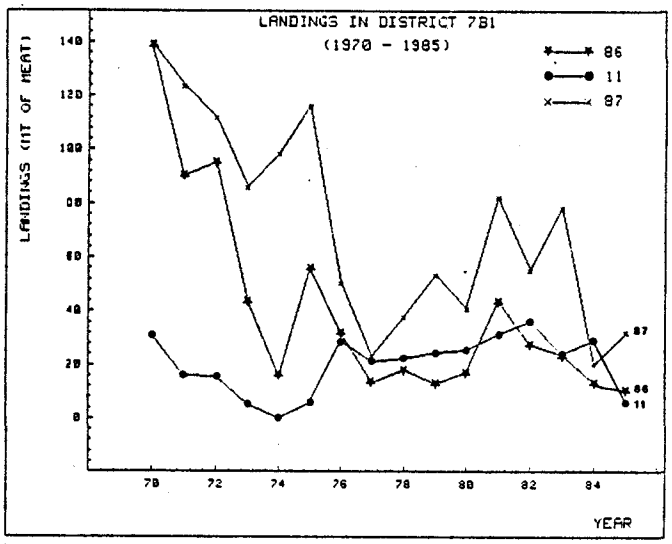


Fig. 9- Yearly scallop landings in the major statistical districts of management districts 7C (A), 8(B) and 7B1 (C).

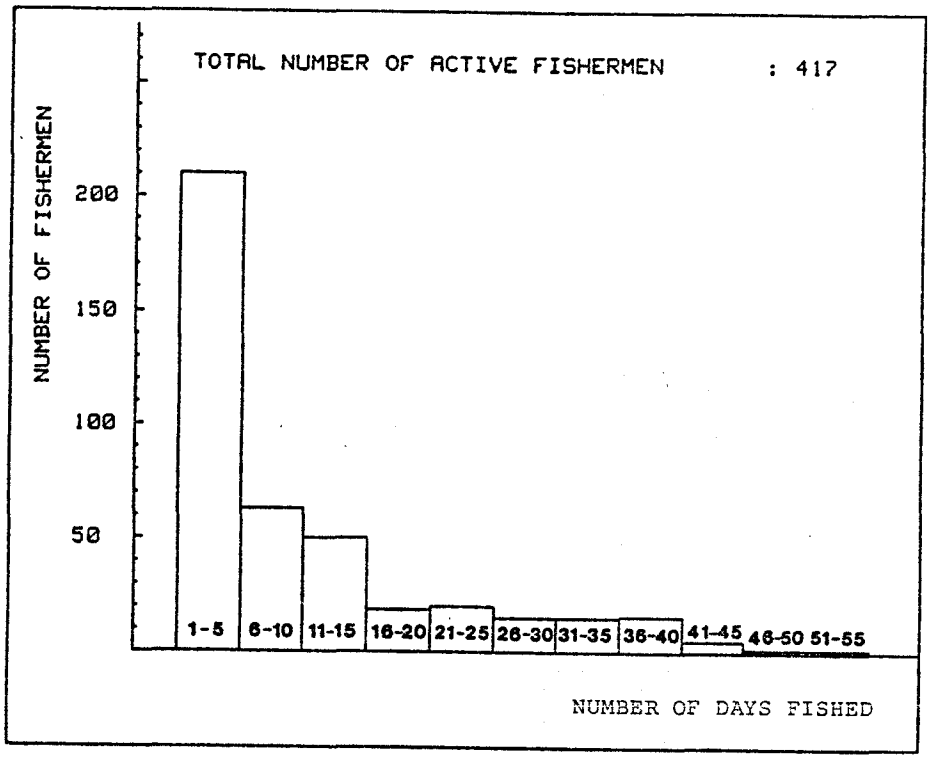


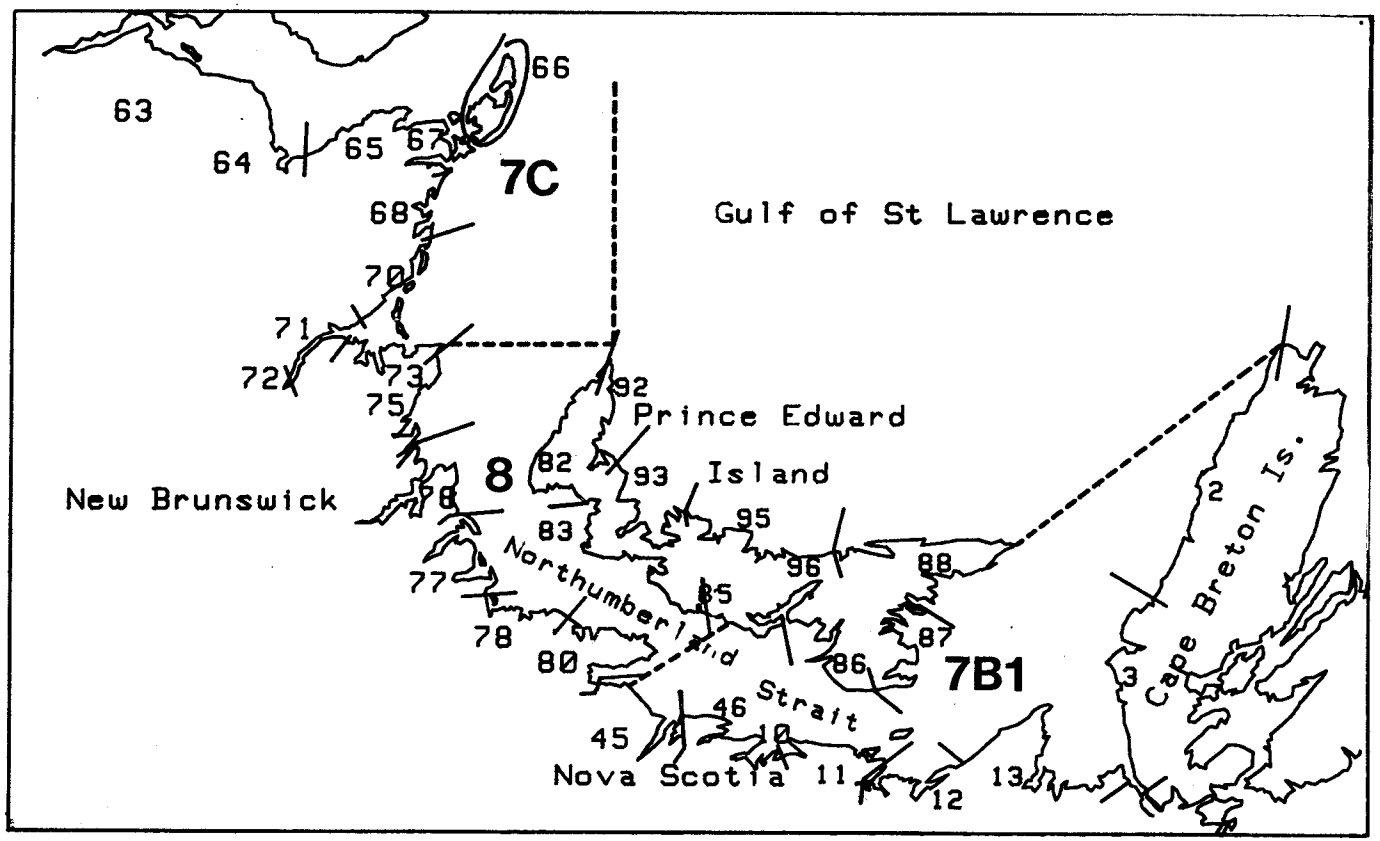
Fig. 10- Distribution of the southern Gulf scallop fishermen according to the number of days recorded through sale slips.

Appendix 1. 1985 commercial sampling.

District	Landing port	Date of sampling
7C	Petit Rocher	July 23 July 25
8	Miminegash	May 20 May 29 June 5 June 14 June 15
	Cape Tormentine	May 22
7B1	Caribou	April 26 May 1 May 2 May 3
	Murray Harbour	May 20 May 24 May 27 May 31 June 6 June 10 June 14 June 18 June 24

Appendix 2. Description of boats chartered and dates for 1985 survey program.

Area	Overall lenght(ft)	Type	Date
Baie des Chaleurs	42	A-frame	July 30 - August 10
Eastern Miscou/ Val Comeau	44	A-frame	August 26 - Sept. 10
Borden/Cape Tormentine	43	A-frame	May 17 - May 19 July 9 - July 16
Pictou/Wood Island	62 40	Side A-frame	May 24 - May 25 July 3 - July 7
Boughton Island	62	Side	May 21 - May 25
Strait of Belle Isle	53	A-frame	August 9 - August 13



Appendix III. Map of the southern Gulf of St Lawrence showing the limits of the management districts (large bold numbers) and the statistical districts (small numbers)