Canadian Atlantic Fisheries
Scientific Advisory Committee

CAFSAC Research Document 87/84

Comité scientifique consultatif des
pêches canadiennes dans d'Atlantique

CSCPCA Document de recherche 87/84

STATUS OF THE SOUTHERN GULF OF ST. LAWRENCE SCALLOP STOCKS - 1986

by

Marc Lanteigne, Leslie-Anne Davidson and Jean Worms
Department of Fisheries and Oceans
Gulf Region
Science Branch
P.O. Box 5030
Moncton, New Brunswick E1C 9B6

ABSTRACT

The assessment of the giant sea scallop (Placopecten magellanicus) stock in the southern Gulf of St. Lawrence was done by analysing data from experimental cruises, logbooks, landing statistics, and sea sampling onboard commercial vessels.

Results of the size frequency distribution analysis suggest that annual landing fluctuations correspond to fluctuations of the recruitment level into the fishery during the same years. The increase of pre-recruit (< 70 mm) percentages for 1986 seems to indicate an increase of the relative recruitment potential for all areas of the southern Gulf. This recruitment potential is promising and should ensure renewal of the stock for next year. The lack of catch and effort data has hampered the elaboration of more detailed analysis and comments on the status of the stock.

Preliminary yield per recruit calculations are presented with management options and guidelines for future research.

RESUME

L'évaluation de l'état de la population de pétoncle géant (Placopecten magellanicus) dans le sud du golfe du St.-Laurent a été effectuée en analysant les données de campagnes d'échantillonnage, de journaux de bord, de statistiques de débarquement et d'échantillonnage en mer à bord de navires commerciaux.

Les résultats de l'analyse des distributions de fréquences de tailles suggèrent que les fluctuations annuelles des débarquements correspondent aux fluctuations du niveau de recrutement dans la pêcherie au cours des mêmes années. L'augmentations du pourcentage de prérecrues (< 70 mm) en 1986 semble indiquer une augmentation du potentiel relatif de recrutement dans toutes les régions du sud du Golfe. Ce potentiel de recrutement est prometteur et devrait assurer le renouvellement de la population pour l'an prochain. L'absence de données de capture et d'effort n'a pas permis d'analyses plus élaborees et de commentaires plus détaillés sur l'état de la population.

Des calculs préliminaires de rendement par recrue sont présentés, ainsi que des options de gestion et des lignes de conduite pour les recherches futures.

INTRODUCTION

This paper comments on the status of the giant sea scallop (Placopecten magellanicus) fishery in the southern Gulf of St. Lawrence. The methodology used in 1986 was different from the one used in previous years by Worms and Chouinard, 1983, 1984; Worms and Lanteigne, 1985; and Worms et. al., 1986. Resource surveys were reduced to a minimum, resulting in only two small surveys in the Borden-Cape Tormentine region (area 22) and the Boughton Island region (area 24).

MATERIAL AND METHODS

1. Research surveys (Figure 1).

A total of 53 tows was performed in the southern Gulf in 1986.

The experimental dredge was a five bucket, toothed, Digby dredge (Figure 2a). Each bucket measured 50.8 cm wide, 35.0 cm high and 52.0 cm deep. They were rigged with 7.6 cm diameter steel rings (Figure 2b) joined together with steel washers. Undersized scallops (< 70 mm) were sampled by lining the inside of two (2) buckets with 2 cm stretched mesh shrimp netting. The shell height from umbo to distal margin was measured to the nearest millimeter, using a vernier caliper, for all live scallops and "clappers" (dead scallops with valves still attached). The data were used to plot size frequency histograms with three (3) millimeter size classes. Percentages of clappers were calculated as proportions of all scallops measured (dead and alive).

2. Commercial sea sampling (Appendix I).

In 1986 more effort was diverted toward the sea sampling program in order to increase the time and space coverage. The improvements were aimed at providing a general overview of the fisherman's catches and the fishing strategies for different regions of the Gulf.

For each selected tow, observers on fishing vessels measured shell height (to the nearest millimeter) of live scallops and clappers from one bucket of the dredge. The duration of the tows and the width of the buckets were also recorded. Data were used to plot size frequency distributions (3 mm size classes) of commercial catches during the regular fishing season. They were also used to calculate catch per unit of effort (CPUE).

3. Logbooks.

Since no mandatory logbook exists for the scallop fishery in the Gulf of St. Lawrence, Science Branch has organized, financed and monitored a voluntary logbook program since 1982.

To acquire more reliable data than previous years, a new approach was taken in 1986. Instead of distributing logbooks to all scallop fishermen (active and non-active), a number fishermen were selected. The selection was based on the level of interest showed by fishermen during the previous year and referrals from representatives of fishermen's committees. Each selected fisherman was contacted and a logbook was sent to him on agreement to fill it. Throughout the fishing season, correspondence provided direction and motivation. The selection was not based on the best or the most active fishermen, but was aimed at providing a spatial and temporal representation of the fishery.

The logbook was designed to acquire the following information;

- Location of the fishing activity, reported as one or more "fishing square(s)" (10.5 km x 9.8 km), of a numbered grid covering the southern Gulf.
- Estimation of the daily catch (meat weight).
- Total number of tows for each fishing day reported.
- Average duration of each tow.

4. Catch per unit of effort (CPUE) calculations.

CPUE's were calculated with commercial sampling and logbook data. Only commercial size scallops ($\geq$ 70 mm) were considered. The CPUE is expressed as kg of meat per meter of dredge, per hour of towing (kg/m hr). The calculation equation was as follow:

$$CPUE = W_i / (L_i \times T_i) \quad \text{where}$$

W_i = total meat weight (kg) of the catch for the i^{th} tow.

L_i = bucket width (m) for the i^{th} tow.

T_i = duration (hr) for the i^{th} tow.

The total meat weight of the catch was estimated by transforming shell height into meat weight using meat weight/shell height relationships calculated from samples collected in 1982 and 1985 for an allometric study (Worms and Chouinard, 1983; Worms, 1984; Worms and Davidson, 1986). The parameters of the allometric equations for each sub-area are presented in Table 1. Estimated total meat weights (W) were calculated as:

$$W_i = \left(\sum_{j=1}^{n_i} W_{ij} \right) / 1000$$ where

W_{ij} = calculated meat weight (grams) for the j^{th} scallop of the i^{th} tow.

n_i = total number of scallops $\geq$ 70 mm in the i^{th} tow.

Data provided by the logbook returns, the commercial sea sampling program, and the experimental surveys were sorted by sub-areas within fishing areas (Figure 3). The sub-area delimitations were chosen considering the fishing beds distribution and the fishing community boundaries created by fishermen.

5. Landing statistics.

Final landing statistics for each statistical district were not available. The preliminary landing values for 1986 were deemed too incomplete to be representative.

6. Yield per recruit calculations.

Yield per recruit, expressed as gram of meat weight for one recruit, was calculated for different instantaneous rates or fishing mortality (F), using the Thompson and Bell method (Ricker, 1975). Growth parameters necessary for the calculations are presented in Table 2. Shell height was transformed into meat weight using the allometric equations parameters in Table 1. Gear selectivity parameters were taken from a study done by Worms and Lanteigne (1986), with the experimental dredge. The logistic curve equation was:

$$R_i = 1 / (1 + e^{(9.1975 - 0.1247 \cdot X)})$$ where

R_i = percentage of scallop from size class i retained in the dredge.

X = i (size class in mm).

Table 3 presents the size (i) for each corresponding age, and the R_i value for each corresponding size, in different sub-areas.

Instantaneous rate of natural mortality (M) for each sub-area were estimated using two (2) equations based on the ratio of dead (clappers) to live scallops:

A - Dickie (1955)

$$A = 1 - e^{-(C/t)(1/L)(365)}$$
$$M = -\ln(1 - A)$$

B - Merrill and Posgay (1964)

$$M = (C/L)(364/t)$$

where A = annual rate of natural mortality.
C = number of clappers.
L = number of live scallops
t = average number of days required for separation of clapper's shells (t = 231 days, Merrill and Posgay, 1964).

RESULTS

A summary of results obtained from experimental surveys and sea sampling from 1982 to 1986 is presented in Table 4 for all sub-areas. Size frequency distributions are presented in Figures 4a to 4f. Modes were easily discernable for small size individuals (< 70 mm) but not for large sizes, due to overlapping.

Area 21 (Baie des Chaleurs and Miscou/Val Comeau).

No experimental survey was performed in this area in 1986. Commercial sea sampling was conducted in the two sub-areas: Baie des Chaleurs, and Miscou/Val Comeau. In Baie des Chaleurs (Figure 4a), the size frequency distribution ranged from 10 mm to 149 mm. It was characterized by five (5) size groups with modal shell height at 15 mm, 45 mm, 60 mm, 75 mm, and 105 mm. In Miscou/Val Comeau sub-area (Figure 4b), sizes ranged from 7 mm to 149 mm. Size groups had modes at 42 mm, 57 mm, 90 mm and 105 mm.

Area 22 (western and eastern sections).

The sea samples from the western section of area 22 yielded 2616 scallops (live and dead), with shell heights ranging from 33 mm to 150 mm (Figure 4c). Size groups had modes at 60 mm, 100 mm and 126 mm.

The experimental survey conducted in the eastern section of area 22 (Cape Tormentine survey) resulted in 950 scallops (live and dead) ranging from 32 mm to 121 mm in height (Figure 4d). Two major modes were observed at 72 mm and 93 mm. Other modes may have been present but were not clearly delimited. The sea sampling in the same sub-area yielded a size frequency distribution with a size range of 10 mm to 118 mm (Figure 4d).

Modes were detected at 66 mm and 96 mm. Other modes were not

clearly discernable.

Area 24 (Pictou Island and eastern section).

The size frequency distribution obtained from sea sampling in the Pictou Island sub-area ranged from 32 mm to 121 mm (Figure 4e). Modes were at 15 mm, 39 mm, 54 mm, and 96 mm.

In the eastern section of area 24, the sea sampling resulted in a size frequency distribution ranging from 10 mm to 138 mm in height (Figure 4f). A major mode was observed at 90 mm. The experimental survey in the sub-area yielded the same size distribution range (Figure 4f). Modes could be seen at 15 mm, 30 mm, 72 mm, and 93 mm.

Logbook program (Appendix II).

CPUE's calculated from logbook returns for 1982, 1983, 1985, and 1986 are presented in Figure 5. The fishing squares reported on the logsheets show that the same grounds were fished in 1985 and 1986. Baie des Chaleurs sub-area is not represented in 1986 due to the lack of logbook returns. Average CPUE's for each sub-area are presented in Table 5 for 1985 and 1986.

Landings.

Scallop landings (kg of meat) from 1970 to 1985 are presented in Figure 6. Landings for 1986 are not presented, as data were still arriving at the level of the Statistical Branch.

Yield per recruit analysis.

Table 6 gives values of instantaneous rate of natural mortality (M) as calculated with Dickie's (1955), and Merrill & Posgay's (1964) equations for each sub-area in 1986.

Yield per recruit isopleths are presented in Figure 7 for selected values of M, and different sub-areas. The M values used in the yield per recruit analysis were selected to fall within the range of M values calculated for 1986.

DISCUSSION

In all sub-areas, the ranges of the size frequency distributions of 1986 experimental surveys and sea samplings data are wider than the previous years, as a result of an increase in the occurrence of pre-recruits. Compared to 1985 data, the 1986 relative recruitment potential (% of prerecruits) increased between 2.7 % to 24.9 %, depending on the sub-area, and the source of data (see Table 4). Results from 1986 sea sampling

indicate that the relative recruitment potential for the eastern section of area 22 is the highest (26.5 %), followed by Baie des Chaleurs sub-area (12.0 %), Pictou Island sub-area (10.1 %), the eastern section of area 24 (9.5 %), Miscou/Val Comeau sub-area (7.5 %), and the western section of area 22 (3.5 %). The increase in the relative recruitment potential is promising and should ensure a renewal of the stock. Stock biomass changes will vary in each sub-area depending on the level of recruitment. In 1987 recruitment into the fishery is expected to continue to increase or to stabilize unless a natural disaster occurs (i.e. mass mortality).

Area 21 and western section of area 22.

A long time series of sea sampling and experimental survey data is starting to allow a better understanding of the stock fluctuations. Observations on size distributions from survey and sea sampling data from 1982 to 1986 indicate that the Baie des Chaleurs (fishing area 21), Miscou/Val Comeau (fishing area 21), and the western section of fishing area 22 (Figures 4a, 4b, and 4c) show similar characteristics. Size frequency distributions of commercial size scallops from these sub-areas are bimodal from 1982 to 1984, and in some cases in 1985. The two modes are well defined in 1982 but the delimitation between the modes fades each year to finally disappear in 1986 leaving only one mode. The low frequencies of sizes between the two modes could be related, among other possible causes, to a poor spat survival. Like most invertebrate species with high fecundity and larvae with long pelagic lives, survival as plankton and success of settlement are subject to large fluctuations (Hancock, 1973). Small changes in mortality and growth rates during the planktonic stages have been reported to have substantial effects on recruitment levels for different species (Houde, 1986). Dickie (1955) mentionned that variable spat survival level was primarily responsible for fluctuations in the fishery and that individual year-class strength was correlated with water temperature which prevailed at the time scallops were present as pelagic larvae. Using preliminary results of a growth study (Table 2), the low frequencies between the two modes correspond to scallops which should have been recruited into the fishery between 1978 - 1979. A low level of recruitment for these scallops may partly explain the drop in landings in 1978 - 1979 (fishing areas 21 and 22).

Eastern section of area 22.

The eastern section of fishing area 22 shows a deficit of large individuals (> 120 mm) for all years presented (Figure 4c). The low frequencies or absence of large sizes scallops may be due to a different growth rate than other sub-areas. The preliminary state of the growth study does not permit further discussion on the causes.

Area 24, Pictou Island sub-area.

In the Pictou Island sub-area (fishing area 24) landings decreased 63 % from 1983 to 1985. Even though Pictou Island sub-area has one of the best time series of experimental survey and sea sampling data since 1982, the causes of the decrease are difficult to assess. Contrary to other sub-areas, the yearly size distributions from surveys and sea sampling do not have the same patterns (especially in 1984 and 1985, see Figure 4e). Sea sampling strategies as used over the past 5 years may have introduced a bias. Prior to 1986, priority was put on experimental surveys, and sea sampling was then restricted in time and space (especially for area 24). Therefore, results cannot be considered as representative of the actual structure of catches over the entire fishing seasons the area fished (area 24). In 1986, reduction in survey effort allowed putting more effort on sea sampling and achieving a better time and space coverage. Results from 1986 sea sampling are therefore considered more reliable. Comparison of these results with previous year survey data indicates a good recruitment potential, as indicated by the presence of prerecruits in the commercial catches, despite the selectivity of the commercial gear.

Area 24, eastern section.

Only two years of experimental surveys and sea sampling data are available for the eastern section of area 24. Size frequency distributions for 1985 and 1986 show patternssimilar to those of other sub-areas in showing an overall increase in the percentage of prerecruits. The 30 mm to 45 mm size group characterized by low frequencies in 1985, is seen again as a low frequency size group 48 mm to 63 mm, in 1986. This latter size group will enter the fishery in 1987 and may result in landings lower than those of 1986. However, the abundant 15 mm to 45 mm size group seen in 1986 should enter the fishery in 1988 and may eventually increase the catchable biomass.

Catch per unit of effort (CPUE).

Available results of CPUE's from logbooks and sea samplings are showing trends with geographical peculiarities (Table 5). The lowest CPUE value is in the Baie des Chaleurs sub-area, followed by the Miscou/Val Comeau sub-area, and the western section of fishing area 22. The highest values are in the eastern section of fishing area 22, in the Pictou Island sub-area, and in the eastern section of fishing area 24. Values calculated for sub-areas in fishing areas 22 and 24 are overall slighty lower than Jamieson et. al.'s (1981a,b) CPUE's for 1979, 1980, and 1981. The change in CPUE can be related to a change in effort, or density, or a combination of the two. Any further uses of CPUE's to evaluate the scallop fishery of the southern

Gulf is hampered by the lack of catch and effort time series data.

Yield per recruit.

The yield per recruit values calculated in this paper are comparable to those of Jamieson (1978) and slightly higher than those of Worms et. al. (1986), which were calculated using the Beverton and Holt method. Differences in model and growth parameters used, may account for these variations.

Considering similar F and M values, the Baie des Chaleurs and Miscou/Val Comeau sub-areas, and the western section of area 22, show their maximum yield at higher ages at first capture than the eastern section of area 22. The Pictou Island sub-area and the eastern section of area 24 show the maximum yield at the lowest ages at first capture. These differences are reflecting the growth disparity (as it was seen with the preliminary growth study results), and the different meat weight/shell height relationships (Worms and Davidson, 1986) between sub-areas. These variations suggest a certain degree of sub-population isolation, which should be considered as separate entities for a proper management of the southern Gulf scallop resource. Results of ongoing stock discrimination studies should be available in the next few years, and supply more information on scallop stock structure in the southern Gulf of St. Lawrence.

The estimation of M varies with the calculation technique used and the sub-areas. This variability of the M values, in addition to the unknown values of F, and the preliminary growth parameters used for the calculations, are all factors affecting the reliability of the yield per recruit model. Therefore, the use of yield per recruit results for further evaluation of the fishery may presently be nonjudicial. A study of the meat weight/shell height relationships in the southern Gulf (Worms and Davidson, 1986), has shown that meat weight at size declined over the last few years. Data on standing biomasses and effort, with the results of ongoing studies (growth, meat weight/shell height relationships) are needed to use the yield per recruit models to their full extent and set the data base for more elaborate population dynamic analyses.

CONCLUSION

The scallop fishery in the Gulf of St. Lawrence is mainly governed by socio-economic factors. It has historically established habits and is a supplementary fishery with seasons and regulations often established around the lobster fishery. Due to the drastic decreases in landings from 1967 to 1978, management actions were taken. A number of regulations were implemented and agreements between fishermen of a same area were made to control the effort. Starting from 1978, no new fishing licenses were issued, fishing seasons were reduced, and the width of the fishing gear was standardized in some areas. A meat count was imposed in 1986 to control the scallop size at capture

(minimum shucking size). The reasoning behind these actions was to maintain the scallop population to a certain density level. However, the effectiveness of these actions may be vain, as non-active fishermen (back pocket licenses) are numerous. They are a pending threat to the fishery, because they can increase the effort by entering the fishery at any time. Another problem is the continuous state of unreported modifications (rubber washers, chafers, ring sizes) of the scallop dredge. Since a stock/recruitment relationship does not seem to exist, it cannot be assumed that a change in effort will result in a substantial change in the recruitment level. To maintain the density level of the scallop population, the recruitment level should be evaluated each year, and the effort set accordingly.

Data for scallop stock evaluation are acquired by sea sampling, experimental surveys, voluntary logbooks, and landing statistics. Analyses of historical data from experimental surveys and sea samplings have shown the need for both data sources for a sound evaluation. Unfortunately, the effort diverted for gathering data from both sources was variable throughout the years. From 1982 to 1984, the effort was put on experimental surveys for evaluation purposes and to map the resource distribution. This strategy was time consuming and therefore, limited in time and space considering the overall exploited fishing grounds of the Gulf. In 1985 and 1986, with a better knowledge of the resource distribution, the strategy was modified. The sea sampling effort was increased, in order to get a better time and space coverage of the catches fluctuations on the exploited fishing grounds. As a result, the number of surveys was reduced, being on a rotational schedule or on an as required basis after analysis of the sea sampling data.

Stock evaluation studies should be complemented with hydrographic data which are lacking for the Gulf of St. Lawrence. Fluctuations of salinity and temperature, and flushing of basins may be factors affecting the survival of the giant scallop at different stages of its development (Medcof and Bourne, 1964). Work done by Lauzier (1957a,b), in the Gulf (including the Baie des Chaleurs and the Northumberland Strait) have indicated high geographical variations in the physico-chemical characteristics. This may explain recruitment variation patterns between sub-areas and eventually, biomass fluctuations.

The data collected from the different sources, are used in population dynamics models. The reliability of these models will depend on the sound estimation of the parameters needed for the calculations and on the compliance to basic assumptions. Presently, most of these parameters are estimated from incomplete studies (growth, natural mortalities, and gear selectivity) or are unknown (stock structure, fishing mortality rates movements, and recruitment levels). This situation limits the application of models and precludes a more in depth analysis of the scallop fishery.

Proposed management options

All options proposed are aimed at improving the actual situation of the fishery and to allow Science Branch to provide sound evaluations of the resource.

1 - The effort should be limited in terms of the type of fishing gear used and/or the number of fishermen participating in the fishery. By limiting the number of fishermen in each fishing area, the possible threat of a massive arrival of previously inactive fishermen ("back pocket licences") could be controlled

2 - Management actions should be taken to standardize the specifications of the scallop dredge.

REFERENCES

DICKIE, L.M., 1955. Fluctuations in abundance of the giant scallop Placopecten magellanicus (Gmelin) in the Digby area of the Bay of Fundy. J. Fish. Res. Bd. Can., 12(6): 797-857.

HANCOCK, D.A., 1973. The relationship between stock and recruitment in exploited invertebrates in "Fish stocks and recruitment", B.B. Parrish ed., Cons. Inter. Explor. Mer, Rapp. et Proc. Verb, 164: 113-131.

HOUDE, E.D., 1986. Potential for Growth, Duration of Early Stages and Regulation of Recruitment in Marine Fish. Cons. Inter. Explor. Mer, L:28, 19 p.

JAMIESON, G.S., 1978. Status and assessment of Northumberland Strait Scallop stocks. Can. Atl. Fish. Sci. Adv. Com., Res. Doc. 78/42.

JAMIESON, G.S., G. ROBERT, and M.J. LUNDY, 1981a. Assessment of Northumberland Strait Scallop Stocks - 1981. Can. Atl. Fish. Sci. Adv. Com., Res. Doc. 81/72.

JAMIESON, G.S., N.B. WITHERSPOON, and M.J. LUNDY, 1981b. Assessment of Northumberland Strait Scallop stocks - 1980. Can. Tech. Rep. Fish. Aquat. Sci. 1017, 44 p.

LAUZIER, L., 1957a. Variation of the temperature and salinity in shallow waters of the Southwestern Gulf of St. Lawrence. Bull. Fish. Res. Bd. Canada, 111: 251-268.

_____, 1957b. Bottom temperatures on the Magdalen Shallows. Bull. Fish. Res. Bd. Canada, 111: 269-285.

MEDCOF, J.C. and N. BOURNE, 1964. Causes of mortality of the sea scallop Placopecten magellanicus. J. Fish. Res. Bd. Can., 53: 33-50.

MERRIL, A.S., and J.A. POSGAY, 1964. Estimating natural mortality rate of the sea scallop (Placopecten magellanicus). Int. Com. N.W. Atl. Fish., Res. Bull. 1: 88-106.

RICKER, W.E., 1975. Computation and interpretation of biological statistics of fish populations. Bull Fish. Res. Bd. Can. 191: 1-382.

WORMS, J., 1984. Scallop biomass and density estimates in the southern Gulf of St. Lawrence. Can. Atl. Fish. Sci. Adv. Com., Res. Doc. 84/90.

WORMS, J. and G.A. CHOUINARD, 1983. Status of southern Gulf of St. Lawrence scallop stocks - 1982. Can. Atl. Fish. Sci. Adv. Com., Res. Doc. 83/68.

WORMS, J. and G.A. CHOUINARD, 1984. Status of southern Gulf of St. Lawrence scallop stocks - 1983. Can. Atl. Fish. Sci. Adv. Com., Res. Doc. 84/57.

WORMS, J. and L.A. DAVIDSON, 1986. The variability of southern Gulf of St. Lawrence sea scallop meat weight-shell height relationships and its implications for resource management. Int. Council Exp. Sea, Shellfish committee C.M. K/24.

WORMS, J. and M. LANTEIGNE, 1985. Status of the southern Gulf of St. Lawrence scallop stocks - 1984. Can. Atl. Fish. Sci. Adv. Com., Res. Doc. 85/66.

WORMS, J. and M. LANTEIGNE, 1986. The selectivity of a sea scallop (Placopecten magellanicus) Digby dredge. Int. Council Exp. Sea, Shellfish committee C.M. K/23.

WORMS, J., M. LANTEIGNE, and L.A. DAVIDSON, 1986. Status of the southern Gulf of St. Lawrence scallop stocks - 1985. Can. Atl. Fish. Adv. Com., Res. Doc. 86/55.

Table 1. Regression parameters of the meat weight/shell height relationship ($W = aH^b$) for six sub-areas in the southern Gulf of St. Lawrence; N = number of individuals measured, H = shell height (mm), r = correlation coefficient, a and b are constants.

SUB-AREAS	N	a	b	r
Baie des Chaleurs (area 21) Miscou/Val Comeau (area 21) Western section of area 22	716	$3.263 \cdot 10^{-5}$	2.8126	0.9670
Eastern section of area 22	122	$2.291 \cdot 10^{-4}$	2.4198	0.8275
Pictou Island (area 24) Eastern section of area 24	964	$5.823 \cdot 10^{-4}$	2.1630	0.7817

Table 2. Parameters of the Von Bertalanffy growth equation for six sub-areas in the southern Gulf of St. Lawrence; N = number of rings measured, K = Brody growth coefficient, L_∞ = asymptotic length, t_o = hypothetical age at zero length, t_∞ = hypothetical age at asymptotic length, W_∞ = asymptotic meat weight.

SUB-AREAS	N	K	L_∞	t_o	t_∞	W_∞
Baie des Chaleurs (area 21) Miscou/Val Comeau (area 21) Western section of area 22	944	0.2074	131.02	0.7741	16.17	29.43
Eastern section of area 22	1446	0.2455	113.95	0.7339	12.39	21.74
Pictou Island (area 24) Eastern section of area 24	539	0.2958	106.92	0.7699	8.79	14.25

Table 3. Shell height values calculated for each corresponding age (using the growth equations presented in Table 2), and retention proportions (R_i) calculated for each corresponding shell height (using the logistic selectivity equation, see text), in each sub-area.

Age	Baie des Chaleurs (fishing area 21) Miscou/Val Comeau (fishing area 21) Western section of area 22		Eastern section of area 22		Pictou Island (fishing area 24) Eastern section of area 24	
	Size (mm)	R_i (%)	Size (mm)	R_i (%)	Size (mm)	R_i (%)
1	6.0	0	7.2	0	7.6	0
2	29.4	0	30.4	0	32.6	1
3	48.5	4	48.6	4	51.6	6
4	63.9	23	62.3	19	65.8	27
5	76.5	58	74.0	51	76.3	58
6	86.7	83	82.7	75	84.2	79
7	95.0	93	89.5	88	90.0	88
8	101.8	97	94.8	93	94.3	93
9	107.2	98	99.0	96	97.5	95
10	111.7	99	102.2	97	100.0	96
11	115.3	99	104.8	98	101.7	97
12	118.3	100	106.8	98	103.1	97
13	120.6	100	108.3	99	104.0	98
14	122.6	100	109.6	99	104.8	98
15	+	100	+	100	105.3	98
16					+	100

Table 4. Summary of results obtained from experimental surveys (A), and sea samplings (B), from 1982 to 1986.

Years and sub-areas	Size range (mm)	Number of scallops (live & dead)	% of scallops dead	% of scallops <70mm	Average size for scallops ≥70mm	(SD)
A						
1982						
Baie des Chaleurs (area 21)	--	--	--	--	--	(--)
Miscou/Val Comeau (area 21)	--	--	--	--	--	(--)
Western section of area 22	47-137	410	--	11.5	--	(--)
Eastern section of area 22	47-132	976	--	7.4	--	(--)
Pictou Island (area 24)	17-132	1625	--	18.3	--	(--)
Eastern section of area 24	--	--	--	--	--	(--)
1983						
Baie des Chaleurs (area 21)	30-147	2984	14.4	10.1	93.9	(16.4)
Miscou/Val Comeau (area 21)	28-141	2700	1.0	9.0	87.9	(15.3)
Western section of area 22	40-140	914	1.9	6.8	89.9	(16.3)
Eastern section of area 22	25-143	2457	13.0	4.0	89.8	(9.9)
Pictou Island (area 24)	11-144	2429	17.7	16.1	94.1	(14.3)
Eastern section of area 24	--	--	--	--	--	(--)
1984						
Baie des Chaleurs (area 21)	10-148	3864	22.0	8.2	99.9	(15.5)
Miscou/Val Comeau (area 21)	--	--	--	--	--	(--)
Western section of area 22	--	--	--	--	--	(--)
Eastern section of area 22	11-121	2297	20.2	16.0	91.4	(8.9)
Pictou Island (area 24)	12-133	4146	14.1	19.7	92.0	(14.1)
Eastern section of area 24	26-127	784	12.1	37.0	90.9	(12.7)
1985						
Baie des Chaleurs (area 21)	6-147	1713	23.9	24.1	103.7	(16.3)
Miscou/Val Comeau (area 21)	18-147	746	19.0	7.6	103.1	(11.9)
Western section of area 22	--	--	--	--	--	(--)
Eastern section of area 22	15-128	2114	20.1	22.5	92.2	(9.6)
Pictou Island (area 24)	6-135	2979	13.2	30.8	95.3	(13.5)
Eastern section of area 24	9-135	1449	13.2	11.7	92.6	(13.8)
1986						
Baie des Chaleurs (area 21)	--	--	--	--	--	(--)
Miscou/Val Comeau (area 21)	--	--	--	--	--	(--)
Western section of area 22	--	--	--	--	--	(--)
Eastern section of area 22	32-121	950	13.4	35.2	87.4	(11.0)
Pictou Island (area 24)	--	--	--	--	--	(--)
Eastern section of area 24	10-138	2724	6.8	24.8	95.6	(11.5)

Years and sub-areas	Size range (mm)	Number of scallops (live & dead)	% of scallops dead	% of scallops <70mm	Average size for scallops ≥70mm	(SD)
B						
1982						
Baie des Chaleurs (area 21)	22-142	2709	--	16.1	97.0	(16.2)
Miscou/Val Comeau (area 21)	42-152	2582	--	18.5	98.0	(19.8)
Western section of area 22	42-137	2021	--	13.2	101.9	(15.6)
Eastern section of area 22	47-127	6828	--	3.6	92.3	(10.0)
Pictou Island (area 24)	32-137	2810	--	5.7	96.5	(14.0)
Eastern section of area 24	22-137	1565	--	1.5	106.8	(13.2)
1983						
Baie des Chaleurs (area 21)	--	--	--	--	--	(--)
Miscou/Val Comeau (area 21)	--	--	--	--	--	(--)
Western section of area 22	55-136	1584	--	11.6	91.8	(17.8)
Eastern section of area 22	54-126	1754	--	2.0	94.1	(10.4)
Pictou Island (area 24)	16-132	3784	--	4.8	95.2	(12.0)
Eastern section of area 24	--	--	--	--	--	(--)
1984						
Baie des Chaleurs (area 21)	--	--	--	--	--	(--)
Miscou/Val Comeau (area 21)	36-149	5293	--	1.4	95.7	(14.1)
Western section of area 22	59-144	2000	--	1.0	91.1	(11.1)
Eastern section of area 22	--	--	--	--	--	(--)
Pictou Island (area 24)	52-137	5167	--	1.5	101.4	(15.0)
Eastern section of area 24	--	--	--	--	--	(--)
1985						
Baie des Chaleurs (area 21)	67-138	437	--	0.5	99.2	(16.0)
Miscou/Val Comeau (area 21)	18-138	433	--	3.9	102.3	(12.5)
Western section of area 22	13-139	834	--	0.8	96.6	(10.6)
Eastern section of area 22	53-123	306	--	1.6	92.9	(9.1)
Pictou Island (area 24)	43-131	2890	--	1.6	90.4	(9.8)
Eastern section of area 24	11-130	2886	--	3.7	87.1	(11.1)
1986						
Baie des Chaleurs (area 21)	10-149	5144	3.7	12.0	102.4	(15.0)
Miscou/Val Comeau (area 21)	7-147	2283	4.3	7.5	99.3	(13.0)
Western section of area 22	33-150	2495	4.6	3.5	99.6	(15.7)
Eastern section of area 22	10-118	1822	2.7	26.5	90.9	(10.8)
Pictou Island (area 24)	9-138	5903	10.7	10.1	96.9	(13.0)
Eastern section of area 24	3-129	5431	8.9	9.5	90.3	(12.1)

Table 5. Summary of average CPUE's (kg/m·hr) and standard deviations (SD) calculated from logbooks (A) and sea samplings (B), for all sub-areas in 1986.

SUB-AREA	A			B		
	1985			1986		
	CPUE	SD	n_1	CPUE	SD	n_2
Baie des Chaleurs (21)	0.08	0.26	10	--	--	--
Miscou/Val Comeau (21)	0.99	0.69	11	0.79	0.40	9
Western section of area 22	1.09	0.21	13	0.88	0.23	18
Eastern section of area 22	1.27	0.29	11	1.25	0.24	12
Pictou Island (24)	1.19	0.47	5	1.25	0.15	7
Eastern section of area 24	--	--	--	1.01	0.04	2
Baie des Chaleurs (21)	--	--	--	0.54	0.24	341
Miscou/Val Comeau (21)	--	--	--	0.60	0.33	279
Western section of area 22	--	--	--	1.11	0.79	178
Eastern section of area 22	--	--	--	0.90	0.46	129
Pictou Island (24)	--	--	--	1.12	0.69	400
Eastern section of area 24	--	--	--	1.05	0.63	264

n_1 = Number of fishing squares reported in the logbooks.
n_2 = Number of tows sampled by sea observers.

Table 6. Instantaneous natural mortality values (M) calculated for different sub-areas, using Dickie's (1955), and Merrill and Posgay's (1964) equations (see text). Disarticulation time was 231 days (Merrill and Posgay, 1964). a - data from experimental surveys, b - data from sea samplings.

SUB-AREAS	DICKIE (1955)		MERRILL & POSGAY (1964)	
	a	b	a	b
Baie des Chaleurs (area 21)	--	0.060	--	0.060
Miscou/Val Comeau (area 21)	--	0.071	--	0.071
Western section of area 22	--	0.077	--	0.076
Eastern section of area 22	0.244	0.043	0.243	0.044
Pictou Island (area 24)	--	0.182	--	0.191
Eastern section of area 24	0.114	0.154	0.115	0.154

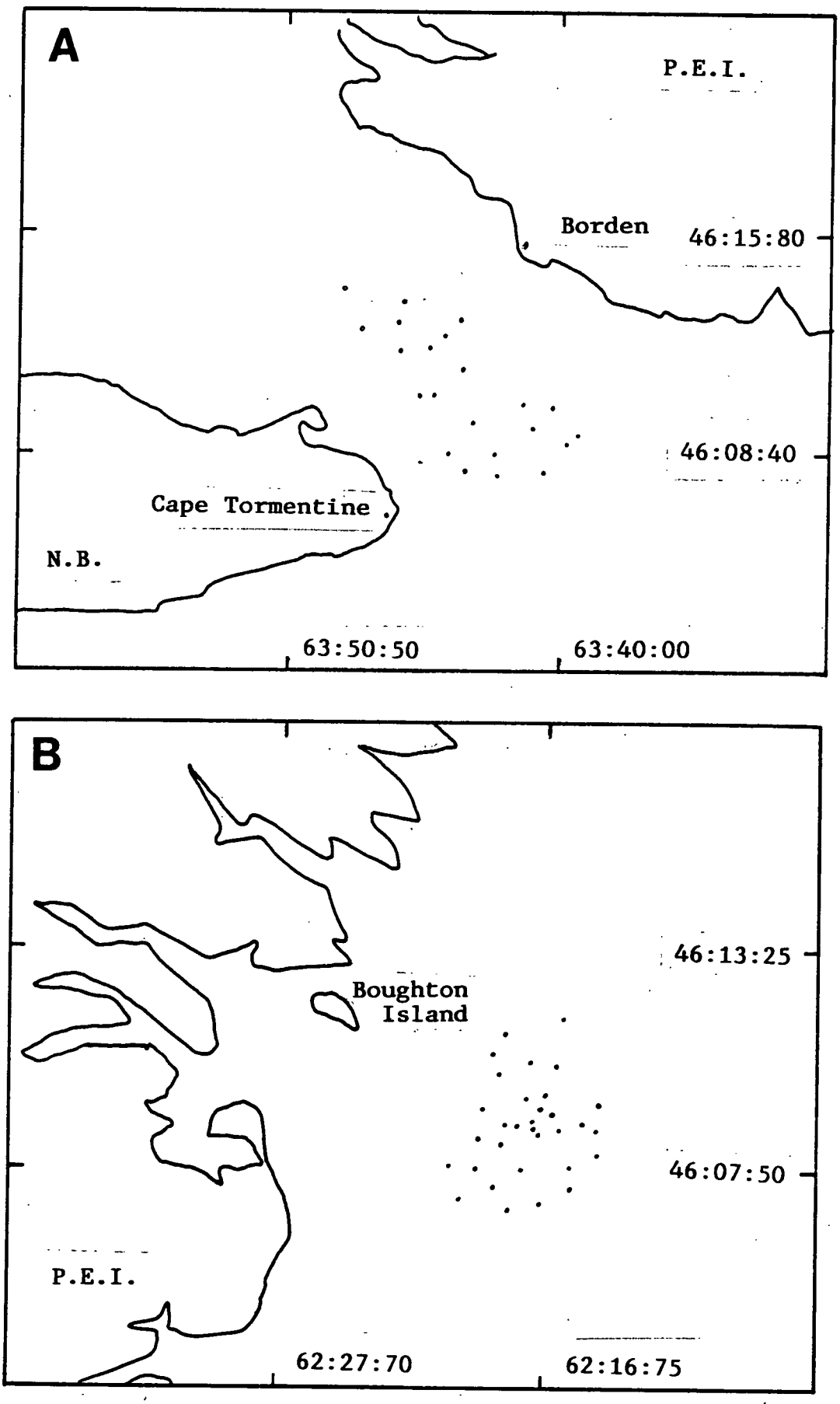
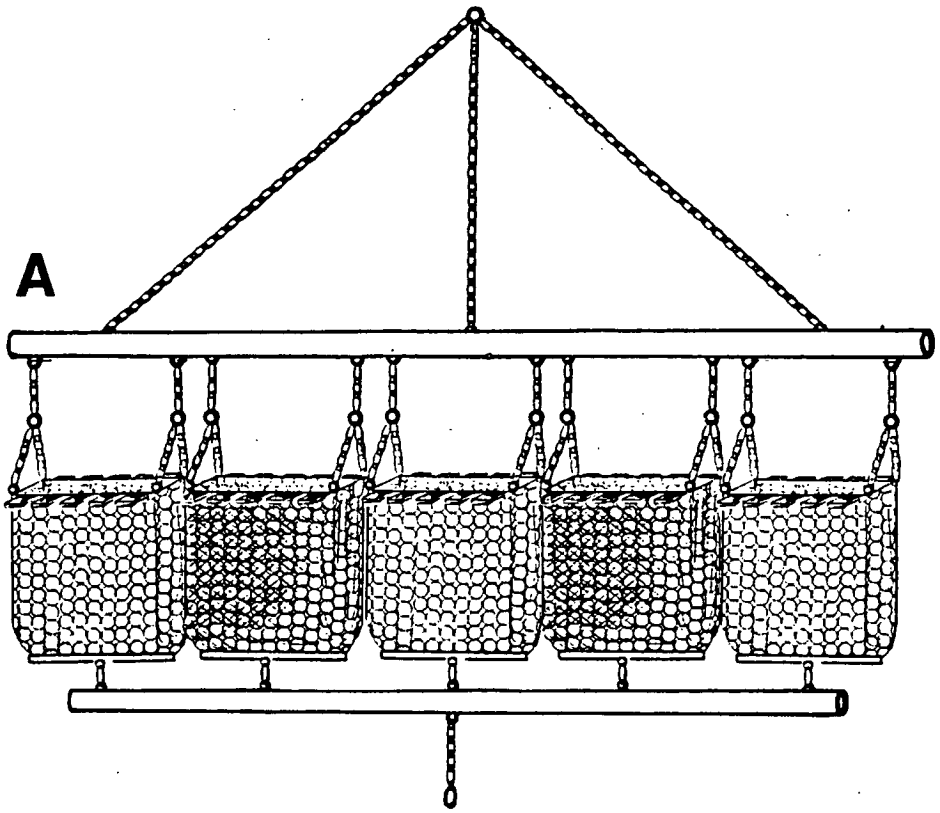


Figure 1. Position of the tows for each survey. A- Cape Tormentine survey (area 22), B- Boughton Island survey (area 24).



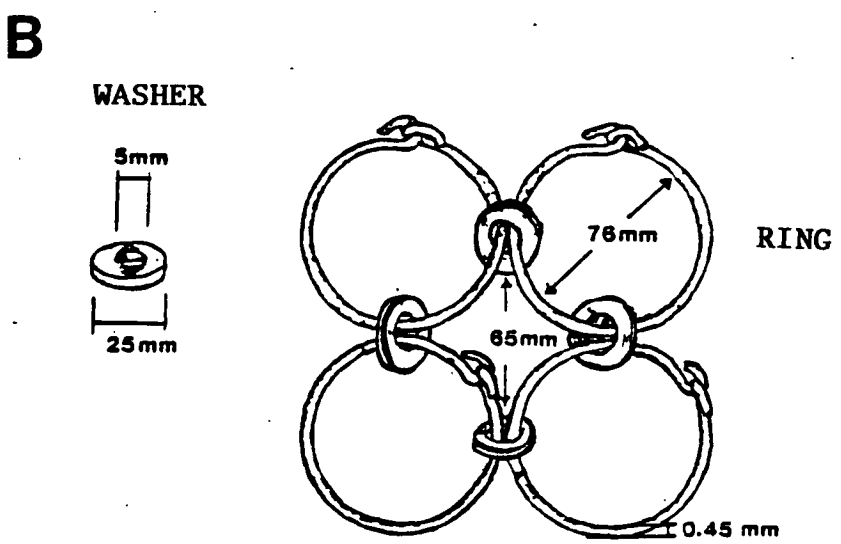


Figure 2. A- Five buckets Digby drag. B- Mesh details (washers and rings).

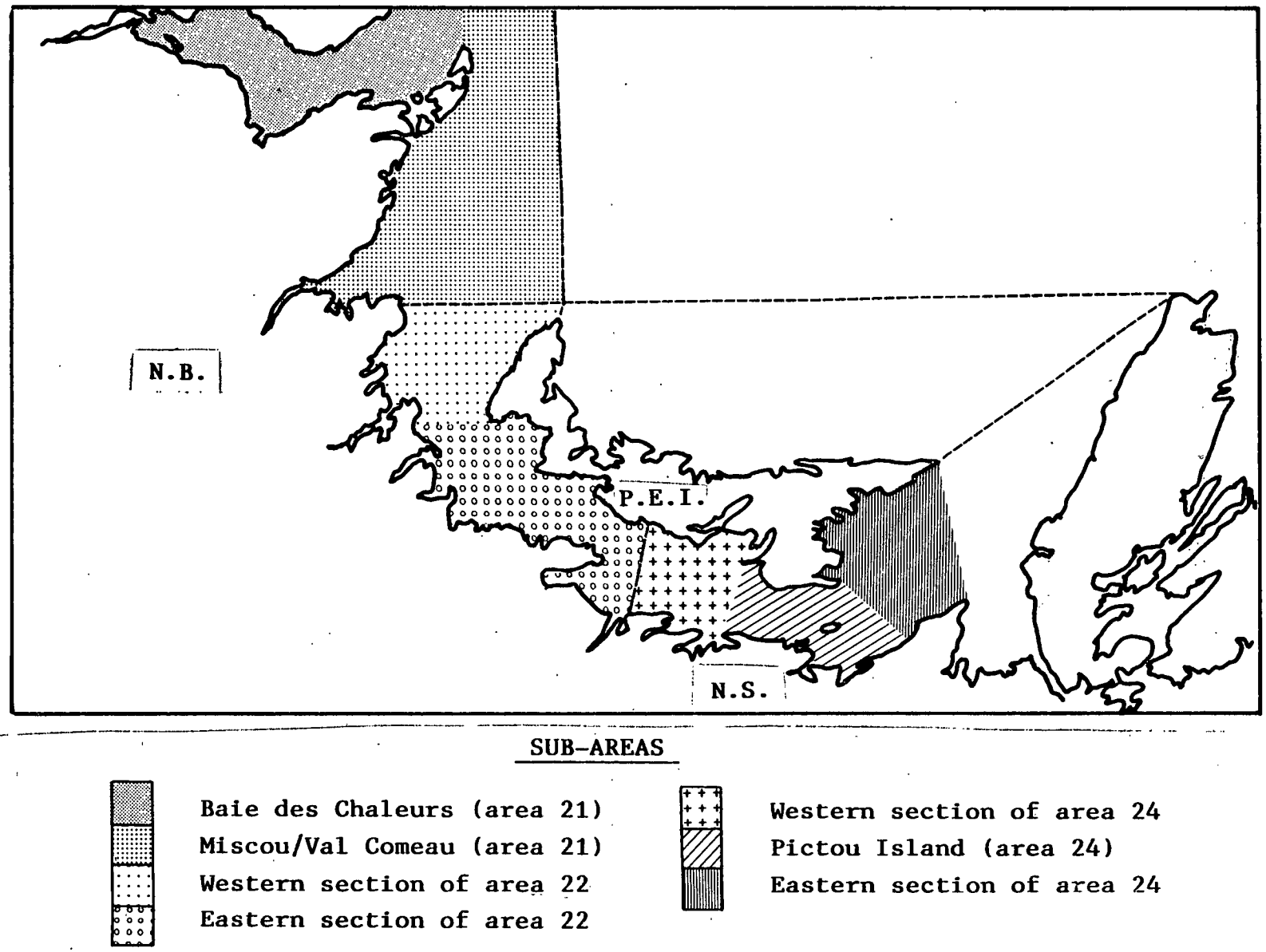
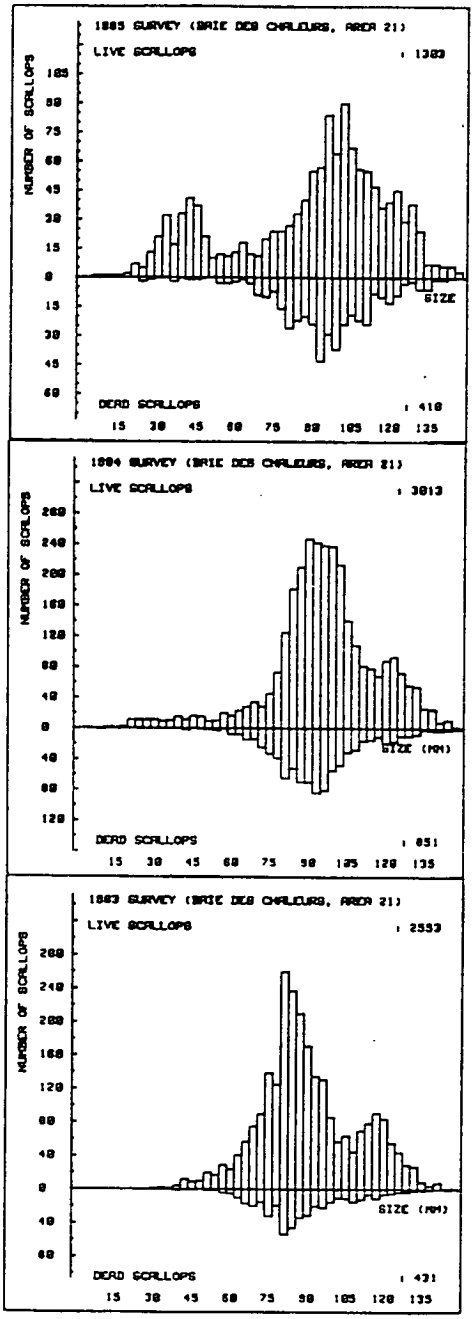


Figure 3. Map of the southern Gulf of St. Lawrence showing the limits of the management areas (broken lines), and the sub-areas used in the present paper.

I



II

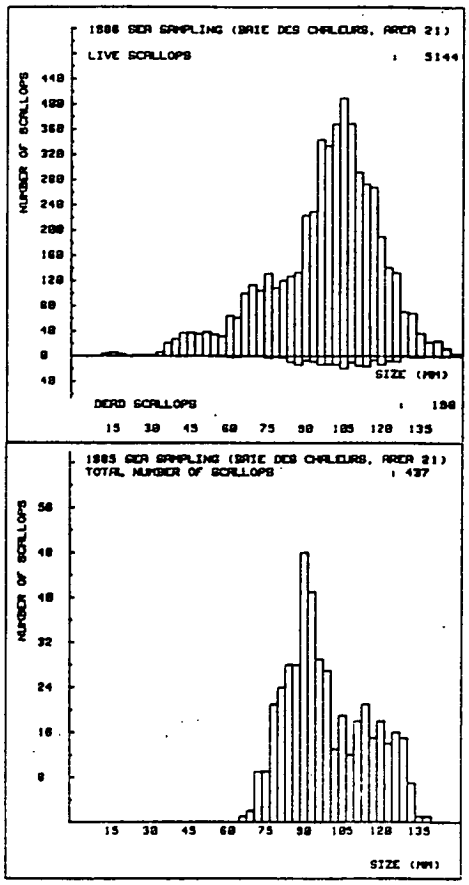


Figure 4. Size frequency distributions of live and dead scallops for experimental survey catches (I), and sea samplings (II) from 1982 to 1986, (1982 data are in 5 mm size classes).

A - Baie des Chaleurs sub-area.

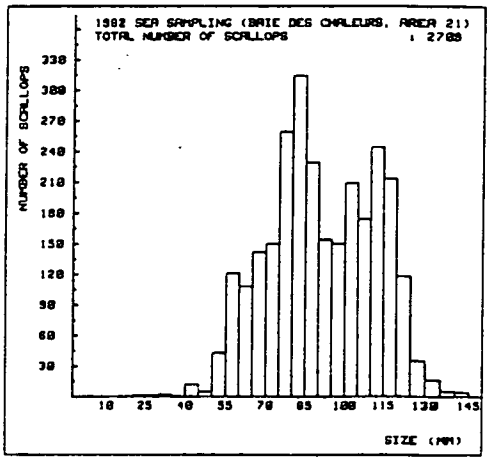
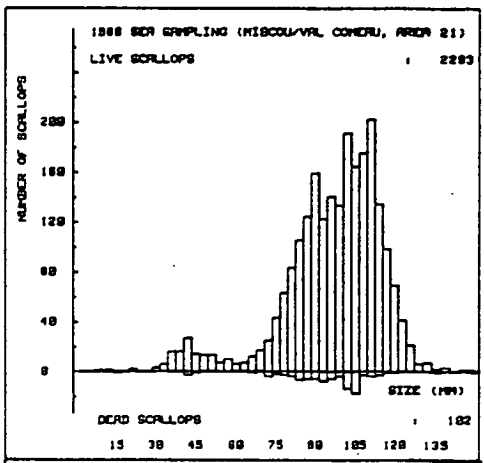
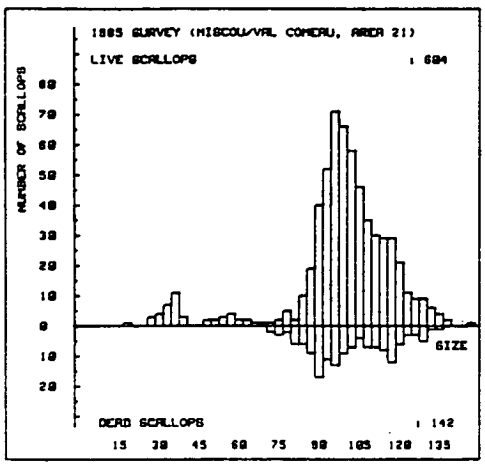
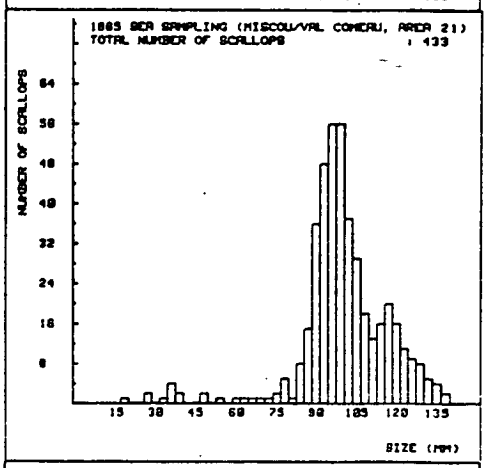


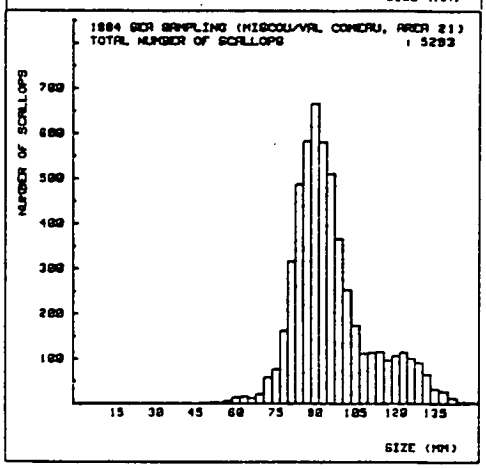
Figure 4. (continued)

A - Baie des chaleurs sub-area.









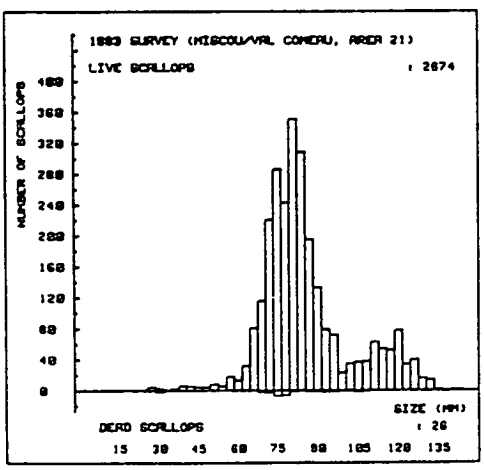


Figure 4. (continued)

B - Miscou/Val Comeau sub-area.

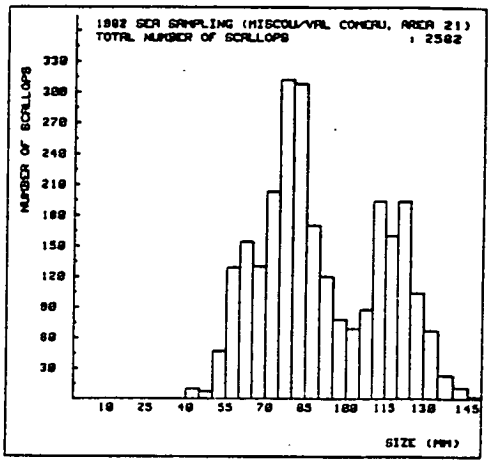
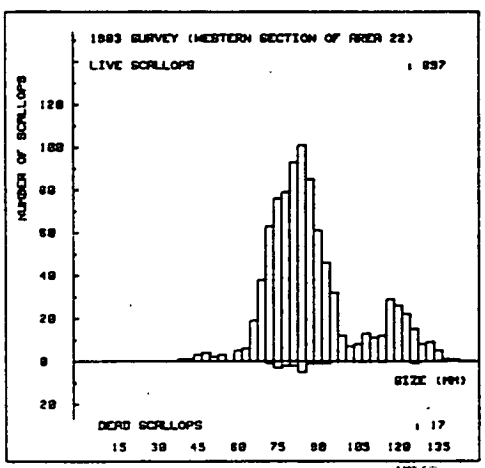


Figure 4. (continued)
B - Miscou/Val Comeau sub-area.



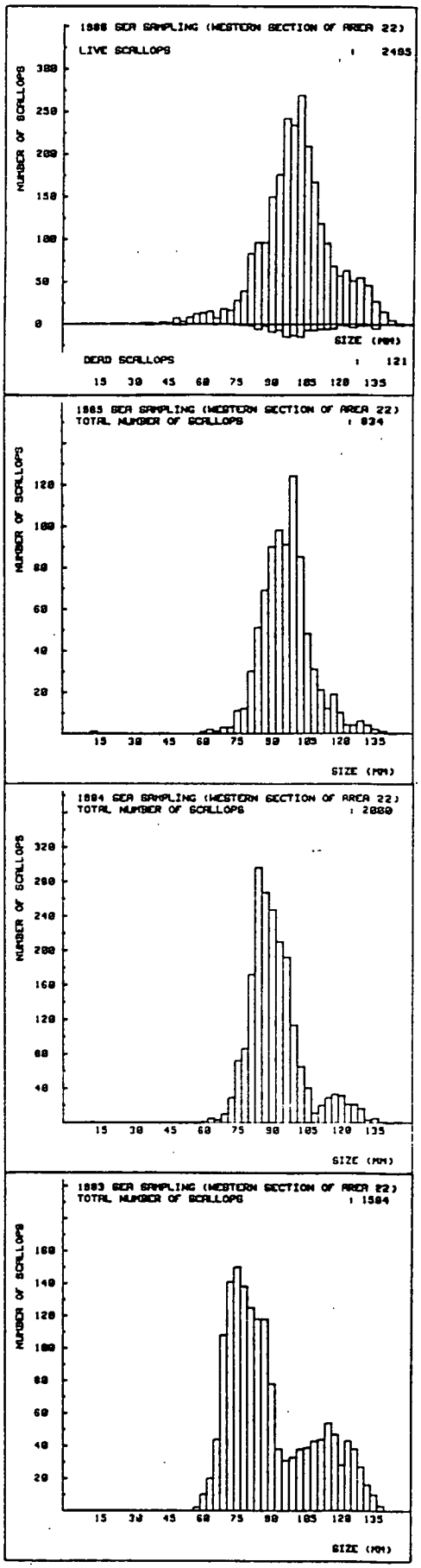
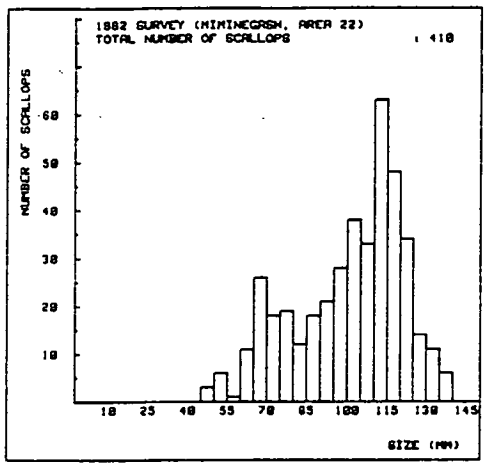


Figure 4. (continued)

C - Western section of area 22.



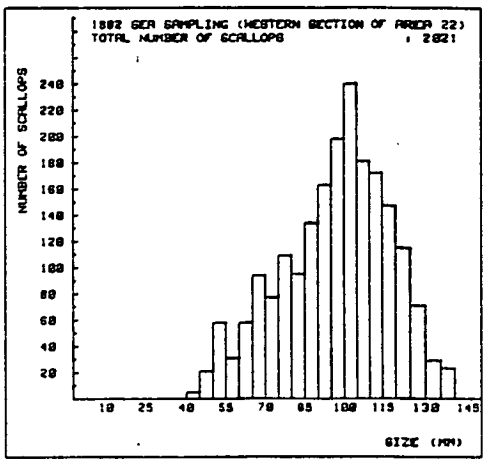
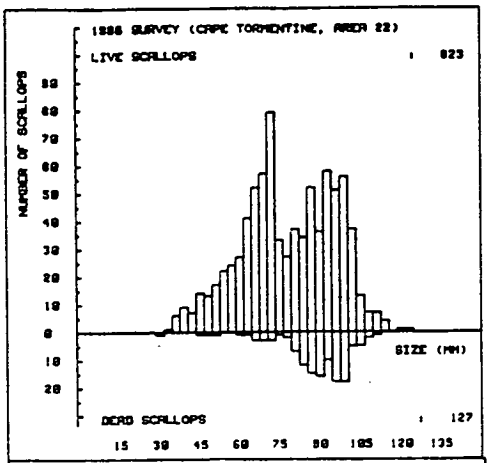
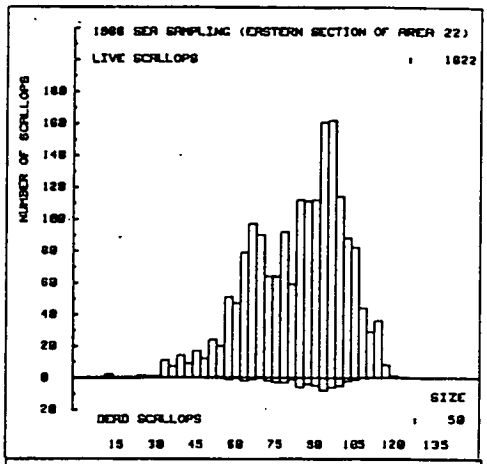
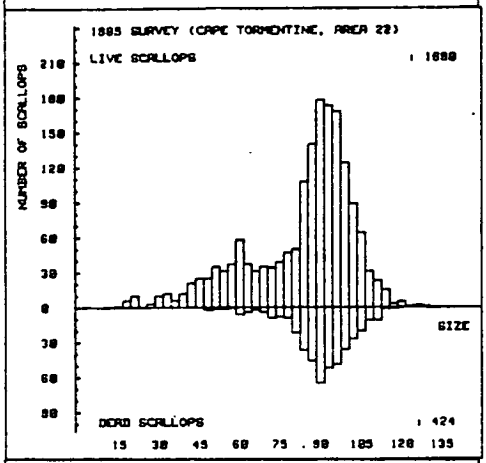
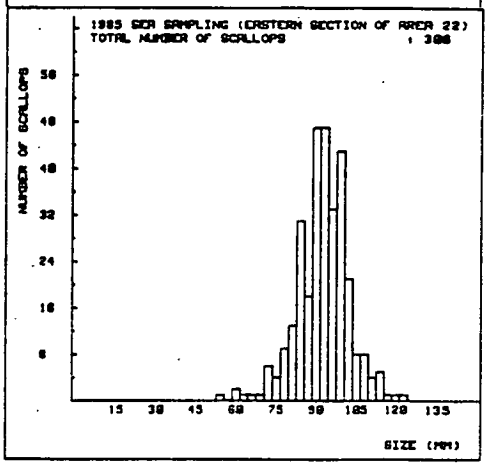


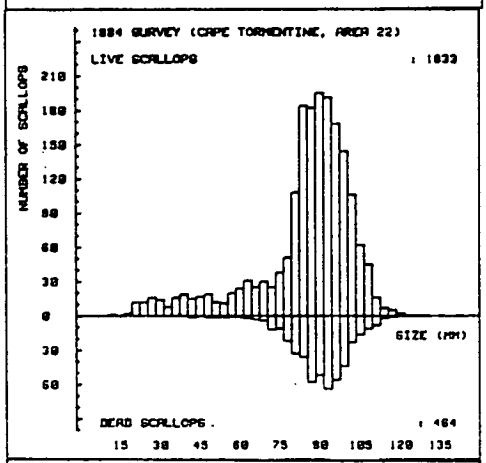
Figure 4. (continued)
C - Western section of area 22.

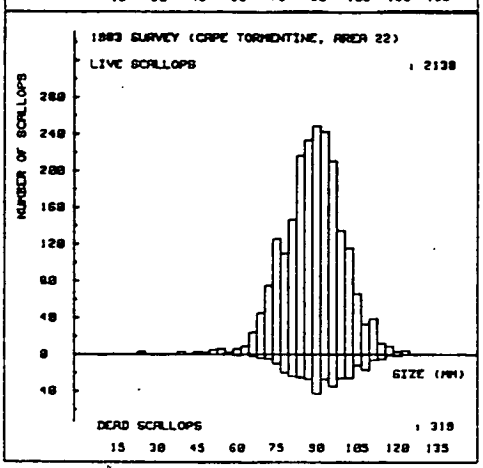












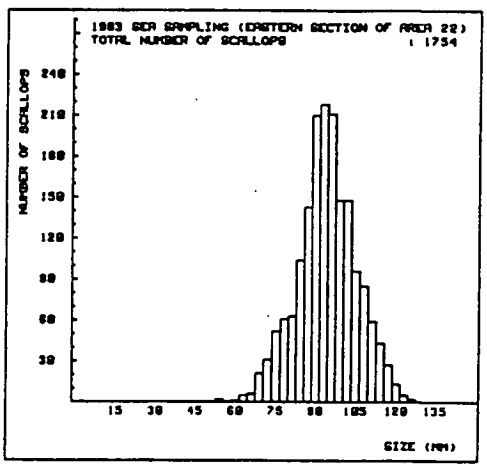
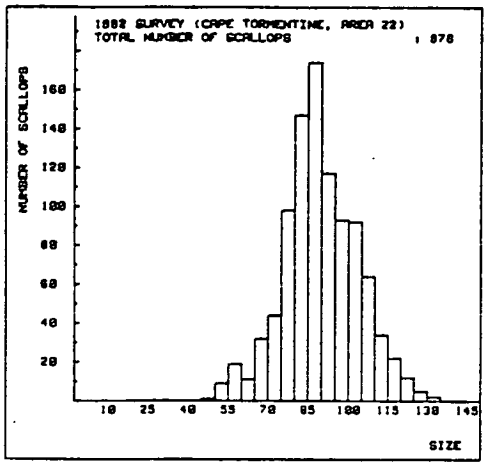


Figure 4. (continued)

D - Eastern section of area 22.



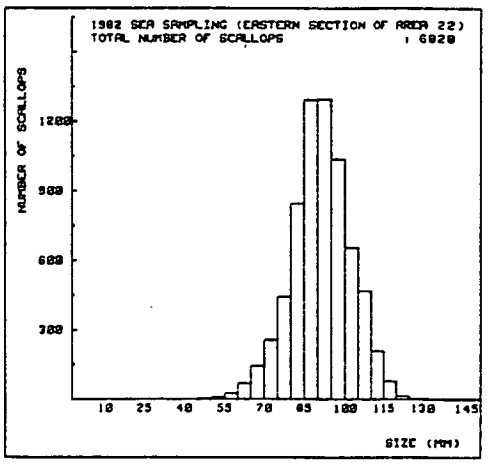


Figure 4. (continued)
D - Eastern section of area 22.

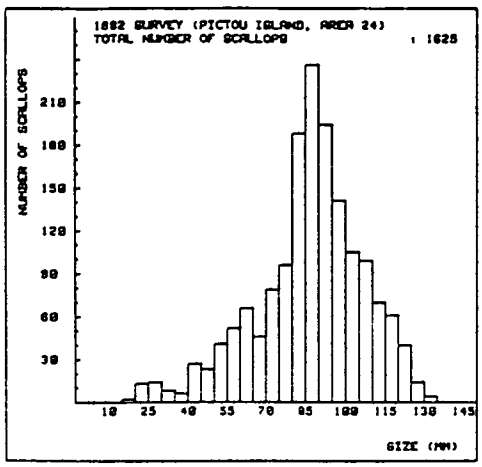
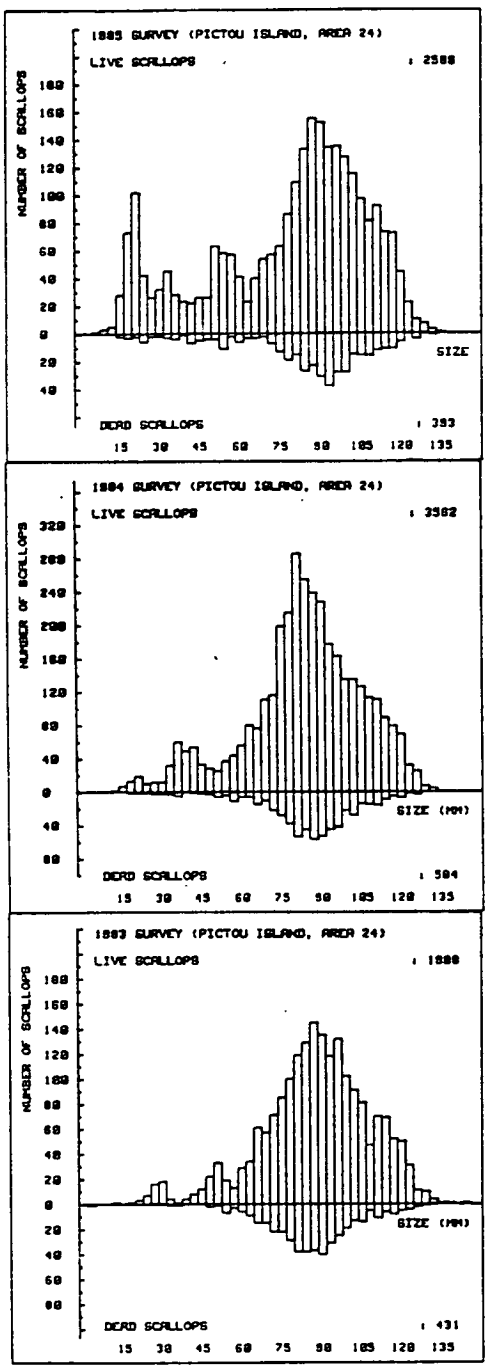


Figure 4. (continued)
E - Pictou Island sub-area.



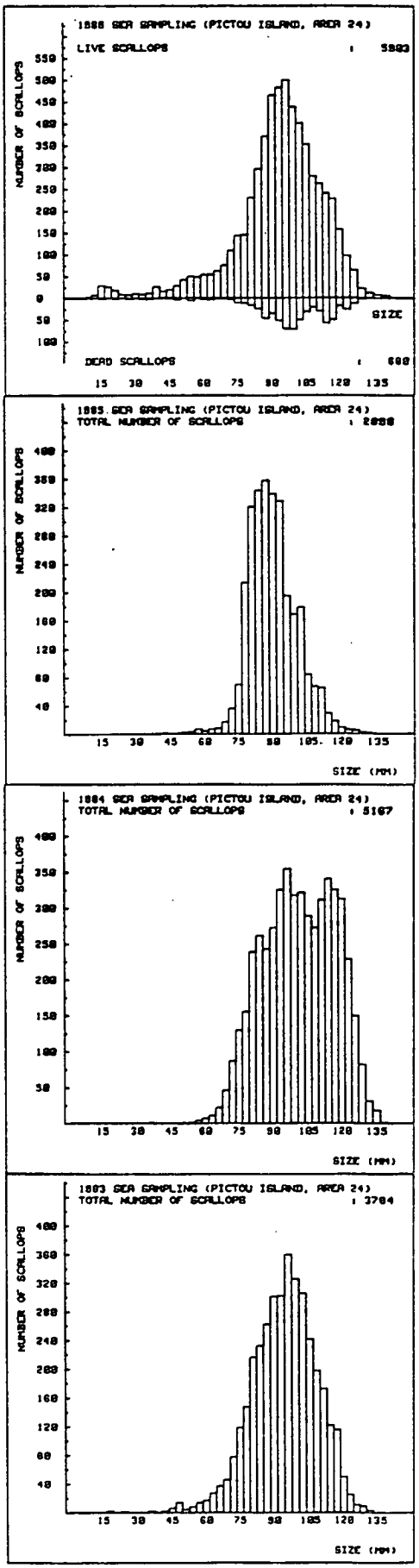


Figure 4. (continued)

E - Pictou Island sub-area.

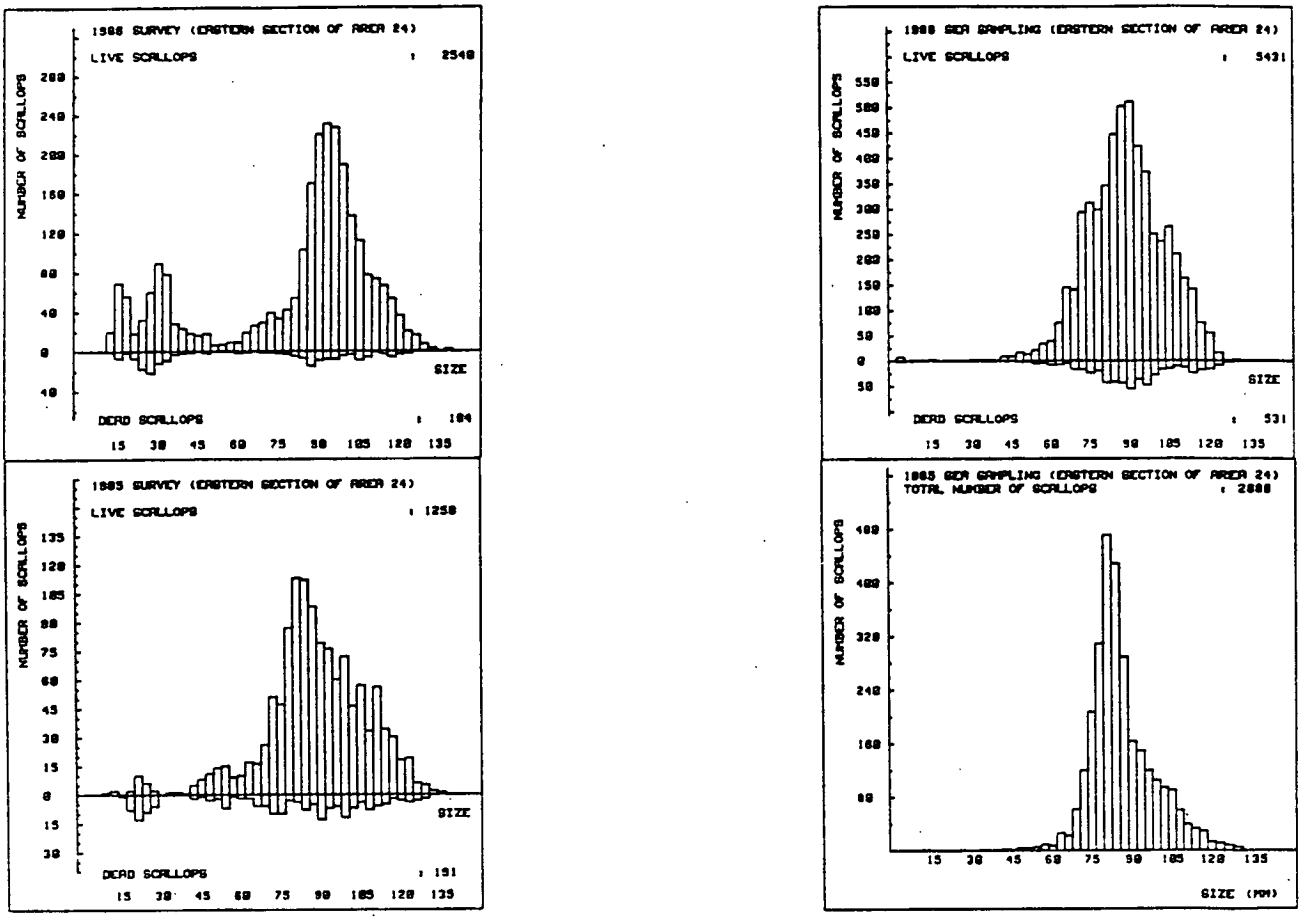


Figure 4. (continued)

F - Eastern section of area 24.

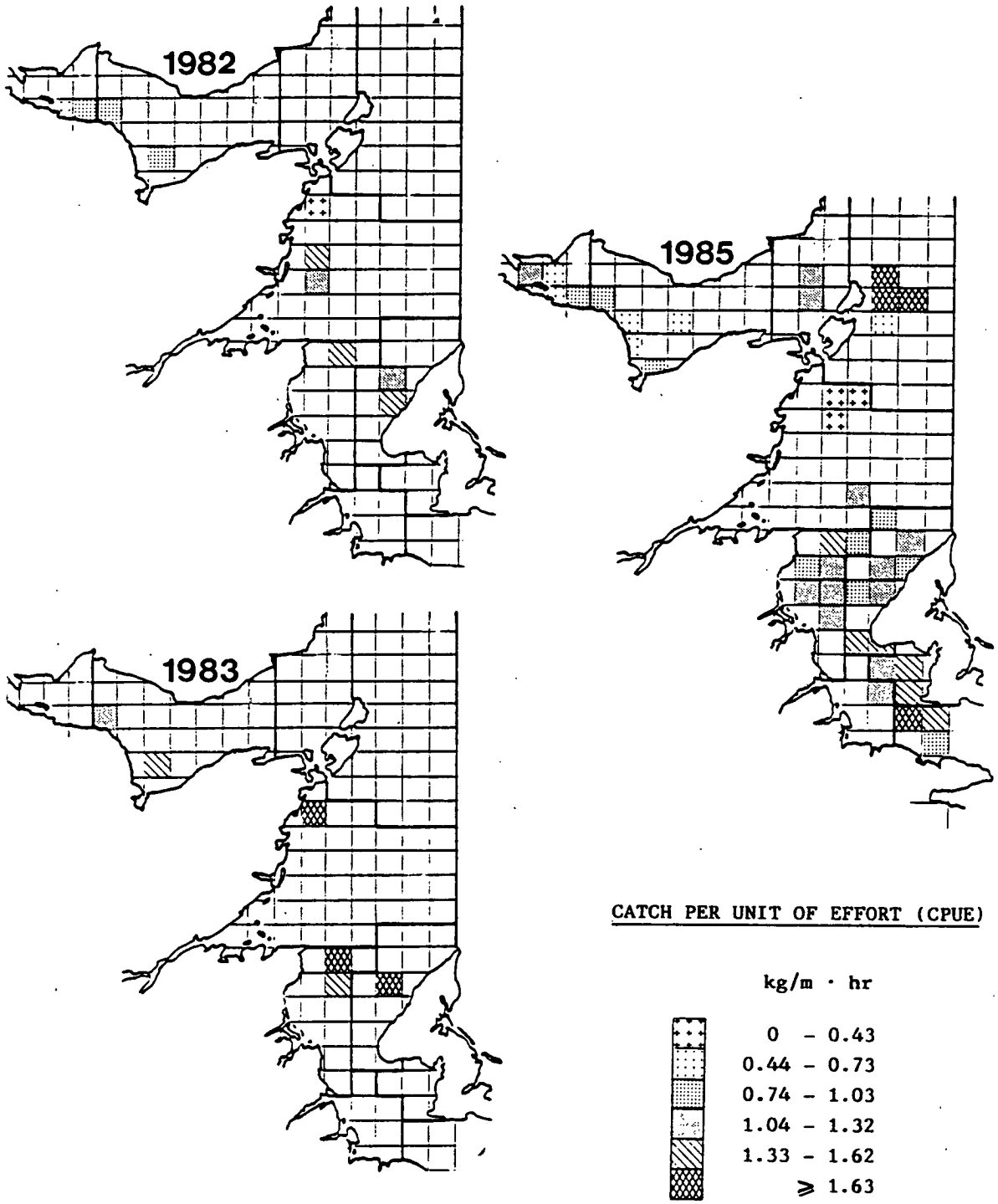


Figure 5. Average CPUE's calculated from logbook information for each fishing square reported from 1982 to 1986, (1984 data are missing).

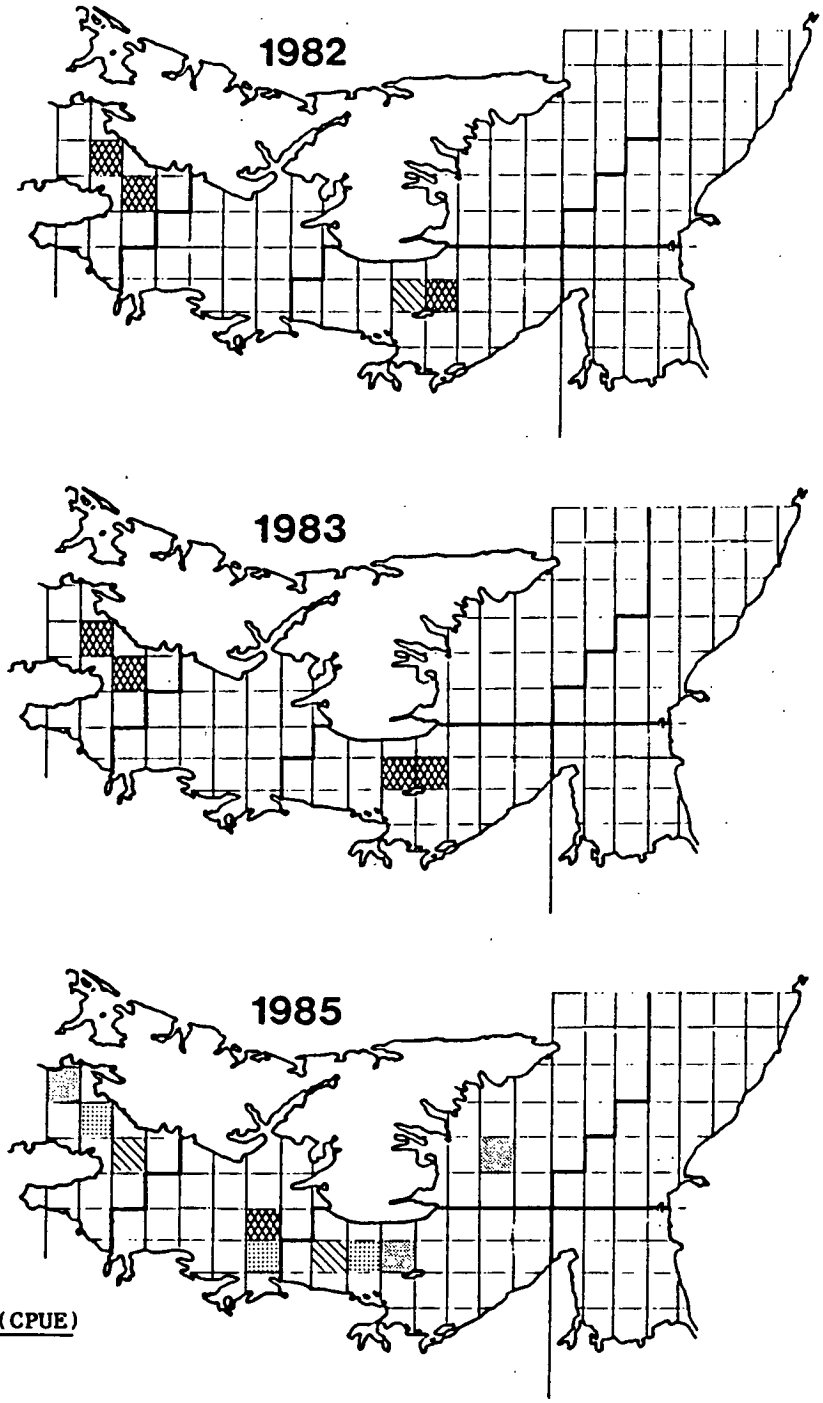


Figure 5. (continued)

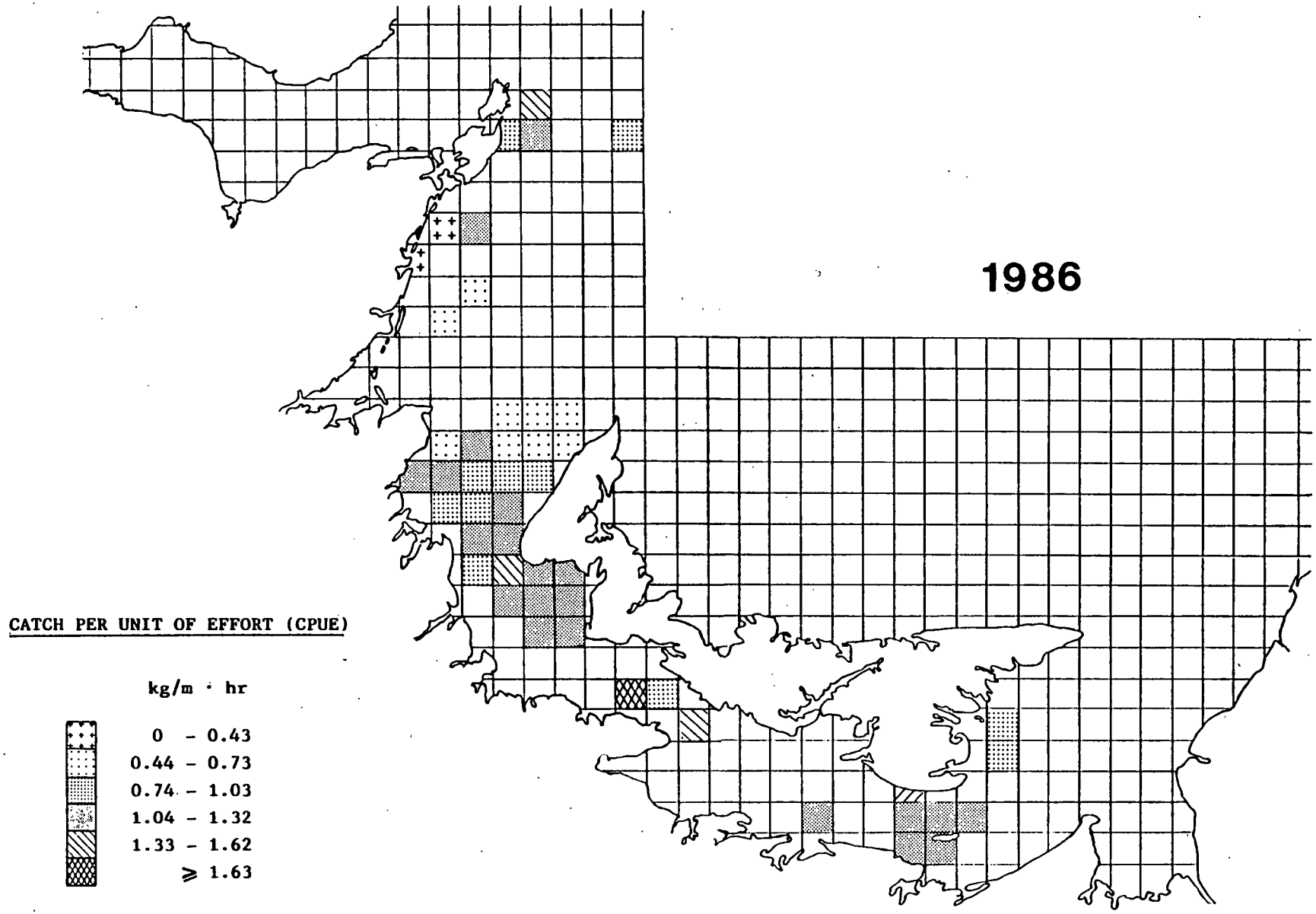


Figure 5. (continued)

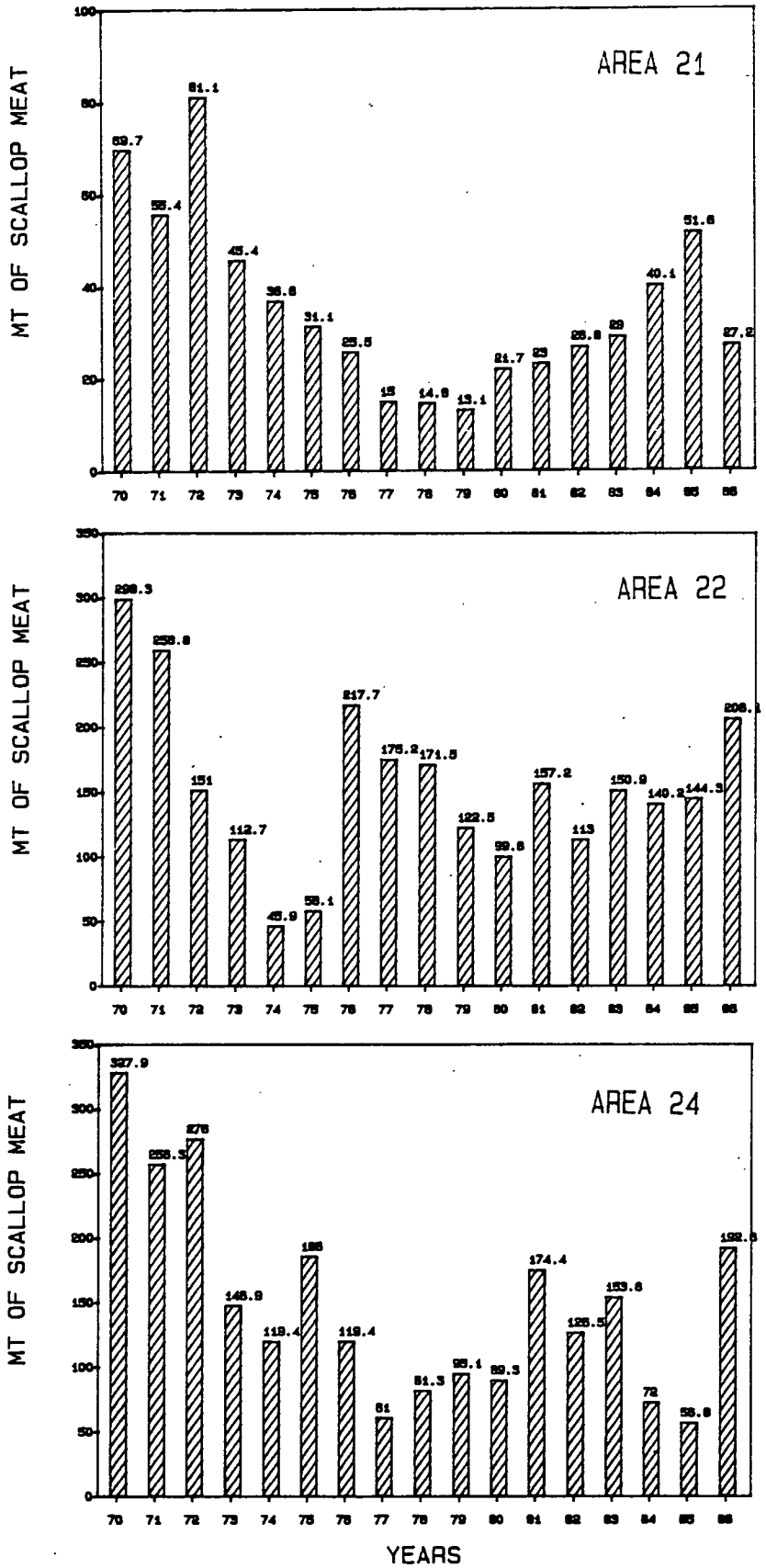


Figure 6. Yearly scallop landings in three fishing areas of the southern Gulf of St. Lawrence (1986 values are provisional, May 12, 1987).

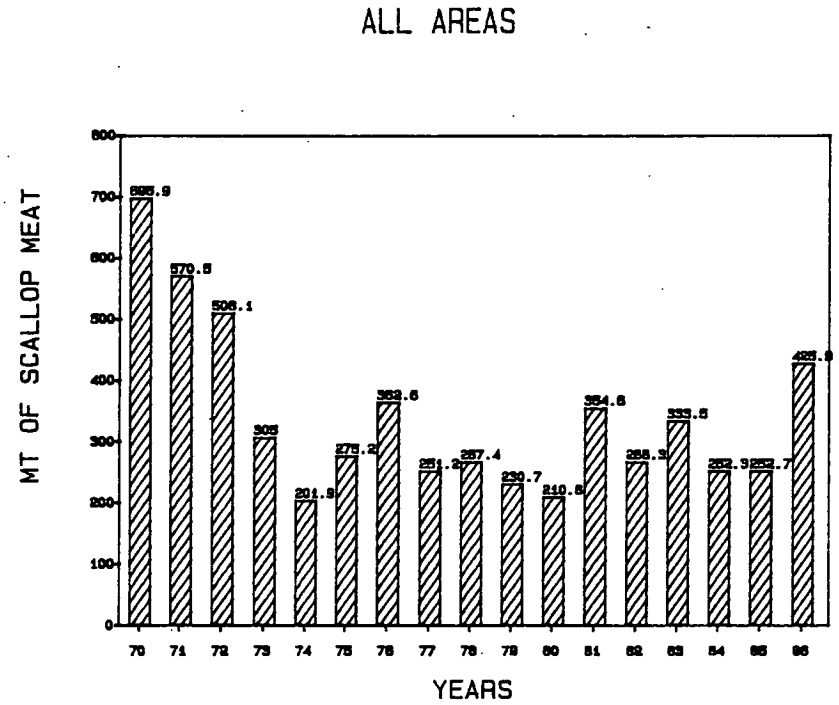


Figure 6. Continued.

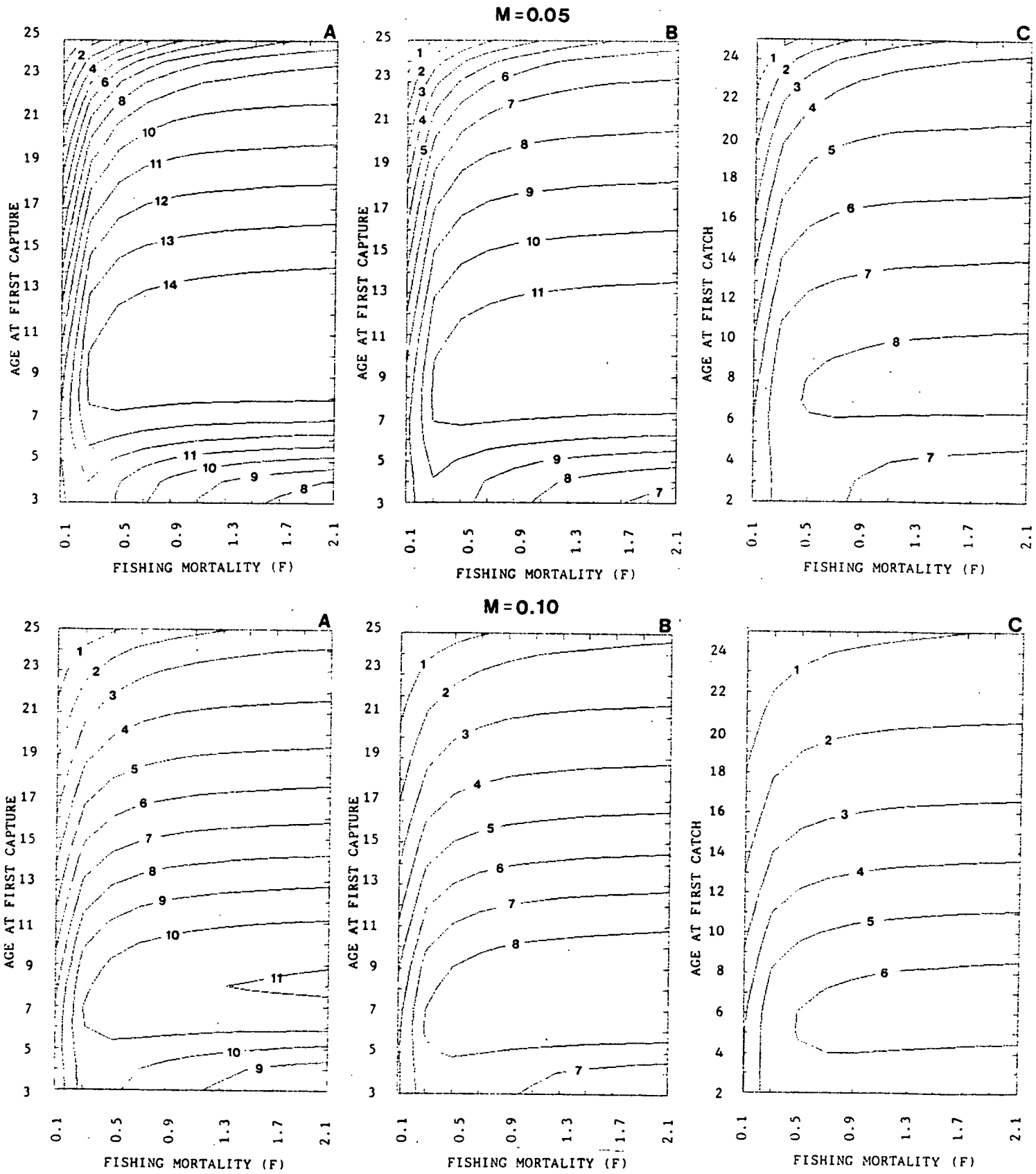


Figure 7. Yield per recruit isopleths for different values of natural mortality (M), for area 21 and the western section of area 21 (A), the eastern section of area 22 (B), and area 24 (C).

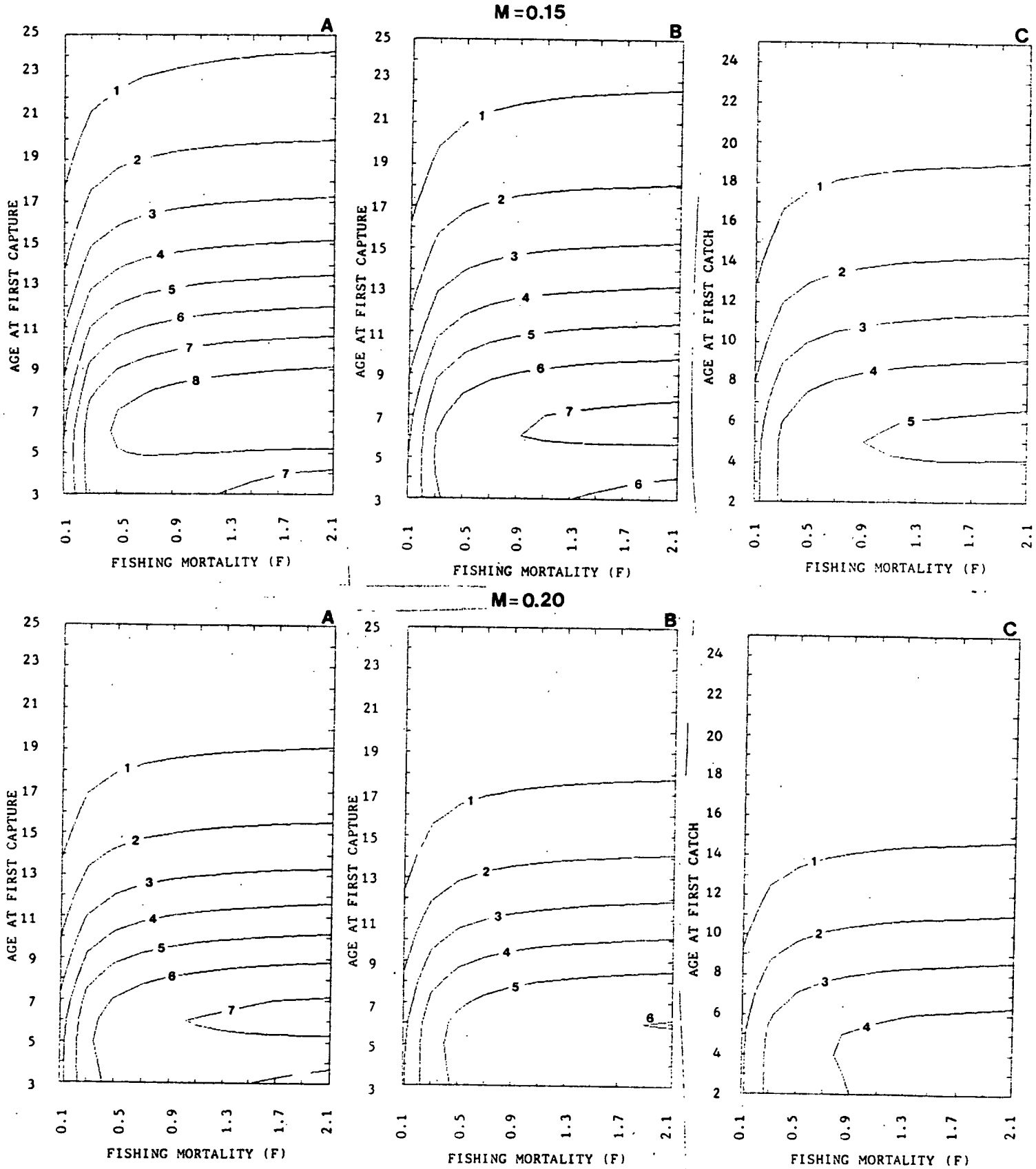


Figure 7. (continued).

APPENDIX I. Summary of the sea sampling program conducted in the southern Gulf of St. Lawrence, in 1986. Date of sampling, number of tows sampled, and number of scallops measured are presented for each sub-area.

Date	Number of tows sampled	Number of scallops measured	Date	Number of tows sampled	Number of scallops measured
Baie des Chaleurs sub-area (fishing area 21)					
28/06/86	17	184	10/09/86	8	87
05/07/86	25	274	14/09/86	8	345
12/07/86	21	335	18/09/86	11	152
19/07/86	23	264	21/09/86	11	389
24/07/86	5	46	27/09/86	5	67
26/07/86	15	181	11/10/86	17	336
30/07/86	5	128	11/10/86	21	178
02/08/86	18	141	14/10/86	13	91
06/08/86	6	148	21/10/86	21	211
09/08/86	8	72	29/10/86	21	289
16/08/86	3	29	06/11/86	19	192
21/08/86	28	320	11/11/86	12	120
30/08/86	19	225	18/11/86	5	45
01/09/86	28	235			
Miscou/Val Comeau sub-area (fishing area 21)					
02/07/86	7	120	22/08/86	5	54
08/07/86	5	64	29/08/86	18	183
12/07/86	12	73	02/09/86	8	100
16/07/86	5	73	04/09/86	7	63
23/07/86	20	138	04/09/86	20	158
04/08/86	10	144	09/09/86	2	10
05/08/86	6	35	15/09/86	18	124
05/08/86	23	123	29/09/86	18	114
08/08/86	21	152	03/10/86	18	102
13/08/86	9	114	06/10/86	18	103
18/08/86	7	95	16/10/86	17	120
19/08/86	5	21			
Western section of area 22					
05/05/86	8	131	11/06/86	12	204
15/05/86	14	140	11/06/86	7	204
19/05/86	12	111	19/06/86	7	92
22/05/86	11	152	19/06/86	7	31
28/05/86	8	249	19/06/86	17	212
30/05/86	3	76	20/06/86	16	241
04/06/86	9	165	24/06/86	6	98
05/06/86	8	176	27/06/86	4	40

APPENDIX I. Continued.

Date	Number of tows sampled	Number of scallops measured	Date	Number of tows sampled	Number of scallops measured
	Eastern section of area 22				
22/05/86	12	150	06/06/86	16	299
22/05/86	4	64	07/06/86	10	175
30/05/86	5	57	07/06/86	10	110
31/05/86	7	107	11/06/86	9	113
31/05/86	8	156	20/06/86	10	116
05/06/86	15	210	24/06/86	10	126
06/06/86	13	127			
	Pictou Island sub-area (fishing area 24)				
21/04/86	23	589	04/06/86	6	134
25/04/86	14	153	06/06/86	31	581
25/04/86	7	126	11/06/86	18	204
28/04/86	19	293	12/06/86	16	364
14/05/86	20	414	13/06/86	12	193
14/05/86	12	138	18/06/86	45	1068
22/05/86	8	149	30/06/86	16	249
22/05/86	22	261	16/10/86	18	382
28/05/86	28	567	17/10/86	7	152
29/05/86	31	547	23/10/86	30	225
03/06/86	17	206			
	Eastern section of area 24				
10/05/86	21	152	18/10/86	20	480
06/06/86	22	281	20/10/86	17	427
07/06/86	5	24	21/10/86	16	291
11/06/86	13	178	23/10/86	9	162
16/06/86	29	805	24/10/86	6	146
10/10/86	9	201	27/10/86	17	423
11/10/86	12	325	28/10/86	7	196
13/10/86	11	420	31/10/86	13	385
17/10/86	17	236			

APPENDIX II. CPUE's calculated from logbook data for all fishing squares reported in 1986.

SUB-AREA	FISHING SQUARE	CPUE (kg/m·hr)	STANDARD DEVIATION (SD)	NUMBER OF FISHING DAYS (n)
Miscou/Val Comeau (area 21)	57	1.47	0.32	4
	60	0.90	0.40	24
	71	0.95	0.25	2
	72	1.32	0.36	6
	100	0.41	0.13	11
	101	0.69	0.26	7
	107	0.40	--	1
	117	0.48	--	1
	125	0.47	0.27	5
Western section of area 22	201	0.52	0.14	5
	202	0.17	0.21	29
	203	0.72	0.16	21
	228	0.71	0.23	5
	229	1.03	0.31	37
	230	0.58	0.18	11
	231	0.70	0.25	18
	232	0.57	0.09	2
	256	1.19	0.39	3
	257	1.15	0.28	4
	258	0.86	0.25	15
	259	0.89	0.31	5
	260	0.89	0.27	19
	285	0.88	0.42	3
	286	0.81	0.38	3
	287	1.14	0.52	7
	314	1.18	0.36	9
	315	1.22	0.84	7
Eastern section of area 22	340	0.98	--	1
	341	1.56	0.50	15
	342	1.29	0.72	45
	343	1.33	0.05	3
	368	1.08	0.18	3
	369	1.15	0.45	4
	370	1.08	0.22	27
	395	1.27	0.31	8
	396	1.20	0.24	14
	440	1.68	0.35	4
	441	0.88	0.49	30
	455	1.45	0.18	6

APPENDIX II. Continued.

SUB-AREA	FISHING SQUARE	CPUE (kg/m·hr)	STANDARD DEVIATION (SD)	NUMBER OF FISHING DAYS (n)
Pictou Is. (area 24)	500	1.56	0.13	8
	515	1.18	0.30	20
	518	1.18	0.35	14
	519	1.22	0.30	17
	520	1.10	0.43	16
	533	1.27	0.21	16
	534	1.21	0.29	7
Eastern sec. of area 24	464	0.98	0.66	9
	484	1.03	0.23	4