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Scallop biomass and density estimates in the Southern Gulf of St Lawrence

by

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ABSTRACT

Density and biomass estimates were calculated for several areas of the Southern Gulf of St Lawrence. Results tend to indicate a sharp decrease from previously recorded values and confirm the decreasing gradient of density values from Western to Eastern Northumberland Strait . Overal, scallop density estimates are very low, averaging .5 individuals/m^2, taken into account a 8% gear efficiency coefficient.

RESUME

Des estimations de densité et de biomasse ont été faites pour plusieurs zones du sud du Golfe du St Laurent. Ces résultats semblent indiquer une forte diminution de densité par rapport aux valeurs enregistrées dans le passé. Ils confirment également le gradient de densité décroissant de l'ouest à l'est du détroit de Northumberland. Globalement, les densités estimées sont très basses, en moyenne 0,5 individus/m^2, compte tenu d'un coefficient d'efficacité de l'engin de 8%.

Introduction

After examining the report of the Invertebrates and Marine Plants CAFSAC Subcommittee on the status of Southern Gulf scallop stocks and considering the conclusion of this report, the Steering Committee asked for more precise information in order to better support the advice for a reduction of fishing effort in some of the main fishing areas of the Northumberland Strait.

The problem as described in our last report (Worms & Chouinard 1984) affects two of the most important scallop fishing areas in the southern Gulf of St Lawrence. Figure 1 shows the importance of Cape Tormentine and Pictou area landings to total landings of district 8 and 7b1 respectively. The percentages recorded in 1983 for both areas are the lowest ever experienced since 1967 , with the exception of 1974. They dropped from 44 to 18% in Cape Tormentine area and from 57 to 32% in Pictou area between 1982 and 1983. These are strong indications of possible depletion of the stocks in these areas.

Material and methods

During 1983 surveys, 586 tows were performed in lobster districts 7C, 8 and 7b1. Those sampling stations were plotted on a map. Commercial concentrations were delimitated by sorting out tows with medium or high yield of scallops (the definition of which varies from one survey area to the other and was based on information on what local fishermen considered as a good yielding tow). The bed limits were drawn around the location of "good" tows and exclude non productive tows. Precise identification of beds is given in Figs 2, 3 & 4. Area of each bed or group of beds was determined by a weighting method. Each bed, redrawn on a cardboard was carefully cut up and weighed to the 1/100 th of a gram. Knowing the precise weight of a square piece of the same cardboard and the scale of the map, surface of each bed was calculated accordingly.

A computer program (modified from John Wright, programmer, DFO Gulf Region) allowed us to calculate the length of each tow based on the Loran C coordinates at the beginning and end of the tow. Area covered by each tow and area covered by all tows on each bed were calculated (Table 1) based on the fishing width of the dredge (2.54 m).

To estimate biomass and biomass/m^2, we calculated biomass/m^2 for each of the N tows in a given bed and then the mean estimate for the bed and its variance. Approximate confidence limits for the mean estimates were determined for $\alpha = .05$, using critical values of Student's t distribution for N-1 degrees of freedom. To transform size of each individual into weight we used the Shell Height/Total Weight relationships computed from 1982 biometric measurements for most survey areas (Table 2).

In order to compare the results with available information in the literature, the same calculation was run on larger areas (Baie des Chaleurs, District 7C (Gulf), Western, Central and Eastern Northumberland Strait). This was done by pooling all beds comprised in each of those five areas and recalculating biomass/m^2 estimates and approximate confidence limits using the average biomass/m^2 for each tow performed on the beds of each area.

The variability of biomass as a function of the number of observations (tows) was calculated for beds on which more than 15 tows were available. In the procedure, approximate confidence limits for the mean biomass estimates were calculated for an increasing number of tows selected randomly. Using these set of data we also calculated the coefficient of dispersion $CD=\sigma/x$ (Sokal & Rohlf 1981).

Exploitation rates for major fishing beds were also calculated from data on fishable biomass and landings at the date of the survey. A rough estimate of fishable biomass at the beginning of the season was obtained by adding the biomass estimated from the survey to the cumulative landings to this date. Using total landings at the end of the fishing season, we calculated a final exploitation rate.

Based on estimates of biomass/m^2, the average catch of a boat fishing on a given bed was calculated. For each area, average drag width was obtained from a survey done by fishery officers in 1982. Average number of tows per day and mean tow time were obtained from log sheets reporting catches in the squares of interest. Average speed of dragging was calculated from our survey data. From this last number, the average surface covered by one tow was calculated. Then, with the biomass estimate, the catch per average tow in live weight was obtained. Live weight was transformed into meat weight using the ratio total weight/meat weight for the area. This last number was multiplied by the average number of tows per day to obtain an estimate of the average catch per day.

Historical data are of two types:

-Documents on early explorations between 1949 and 1964. Those surveys were made in the Southern Gulf by Chiasson (1949, 1951); by Dickie & McInnes (1958); by Bourne & McIver (1962); by Bourne & al. (1965); by Bourne & Rowell (1965a, 1965b).

-Documents released through CAFSAC since 1978 make available quantitative data on the scallop resource in the Northumberland Strait (Jamieson 1978, Jamieson & al. 1980, 1981a, 1981b). These documents contain information on economics, population structure and resource condition.

Results

1- Fishable biomass & biomass/m^2 (Figs 5 & 6)

Estimated biomass and biomass/m^2 are shown in Table 3 for major beds or groups of beds. In Table 4 estimates are provided for large areas. Baie des Chaleurs excepted, it appears that the average biomass/m^2 decreases from northwest to southeast of the Southern Gulf of St Lawrence varying from 5.35 g/m^2 off Neguac to 3.94 g/m^2 in Pictou area. In number of individuals, this will represent roughly 3 to 5 scallops per 100 m^2.

Values of biomass per square meter are highly variable from bed to bed. The spatial distribution of biomass/m^2 on major beds (eg. Figs 7 & 8) does not show any definite pattern at the scale studied. Scallops are distributed unevenly on the beds, patches of high density alternating with those of low density.

2- Exploitation rates (Table 5)

In Richibucto area the width of confidence limits on the biomass is too great (166.9%) to allow further calculations. Exploitation rates vary from 30% in Baie des Chaleurs to 56.6% in the Neguac/Tracadie area. Those figures relate to what we called "fishable biomass", i.e. what is instantly available to the gear during a given fishing operation. In Pictou and Cape Tormentine areas where confidence limits on the biomass estimates are narrow (14.4% and 10.1% respectively), results were 53.9% and 47.6% respectively.

From the calculations of average catch per fishing day based on estimated values of biomass/m^2 we obtained 62.7 kg of meat/day in Cape Tormentine area and 35.3 kg/day in Pictou Island area. These values are close to those reported through log-books (52.2 kg and 32.7 kg respectively).

Discussion

The original sampling procedures were not designed to provide a data base for biomass estimates. For example, when dredging for scallop, it is difficult to control the actual speed of the gear on the bottom without adapting sophisticated devices on the gear. Even keeping a constant towing time is problematic as the exact time when the dredge leaves the bottom when hauling back, is never precisely known. As a result, the precise and accurate determination of the distance towed is difficult. Local currents, winds and bottom types are highly variable in space and time. The distance estimated includes an additional term which we may at first approximation assumed to be a random variable. First results from underwater video surveys suggest that the behaviour of the drag on the bottom is highly variable depending on the type of bottom, the speed of the boat, the amount of cable, etc. Doing surveys prior to the commencement of the fishing season will allow getting an estimation of the biomass available at that time. Due to ice conditions in the southern Gulf, such cruises will require an ice resistant research vessel.

The landing statistics do not allow the evaluation of the quantity actually fished on a given bed. Due to the mobility of fishermen in some districts (especially district 7b1), breakdown of landings by port does not give a accurate breakdown by main fishing area. Moreover, official statistics may underestimate the actual landings (Worms & Chouinard 1983). Values of biomass (total or per m^2) do not bring too much information on the status of the stock. Exploitation rates expressed as percentage of initial biomass (fishable biomass or total biomass depending on the availability of an index of efficiency of the fishing gear) are a subjective concept. The important thing to know is the fraction of the secondary production fished each year by the fleet. An identical level of exploitation rate could be appropriate for a fast growing species and harmful for a slow growing species. All our biomass estimates relate to fishable biomass, i.e. the fraction of the biomass accessible to the gear due to bottom conditions, escapement and gear efficiency.

The method employed for calculating confidence limits of mean biomass estimates applies only to samples with 30 observations or more. This condition is not always realized in our case. We used this method as a first approach to the problem but a better method adapted to the type of data available should be instituted for more accurate estimates. The underdispersed spatial distribution calculated for an increasing number of tows may not be ecologically meaningful but a consequence of the type of data employed i.e. average biomass estimates on the total surface of each tow and not biomass estimates on a given unit of surface.

Qualitative observations from existing literature indicate the following:

1- The geographic limits of the most productive areas stayed the same through the past 45 years;

2- Major beds experienced drastic fluctuations in abundance over rather short periods of time due to occasional natural mass mortality affecting 50% or more of the population and possibly heavy fishing pressure.

3- Lined dredges were seldom used during early survey (1949 to 1964).

It is difficult to have a precise idea of precruitment in the size frequency distribution of a wealthy population (e.g. unexploited). In 1951 (Chiasson 1952) a limited number of tows were made using small mesh dredges. No small scallop were found either on Richibucto or Northeast Pictou Island beds. In the Northwest Pictou Island bed 74% of scallops caught were under 90 mm shell height. Over the past few years little evidence of major spatt setting was recorded. The lack of information between 1964 and 1979 makes it difficult to trace the history of the major fishing grounds. The occurrence of a relatively strong 1979 year class in the Western Strait in 1980 was not confirmed by later surveys, perhaps because of high mortality rates. Jamieson concluded in his last paper on Northumberland Strait scallop stocks (Jamieson & al, 1981b) that ..."there has been below average recruitment in the Western strait in the recent years... There are also signs (few pre-recruits) of impending recruitment failure in the Central Strait, where adult scallop stocks are also at low average densities". The results of the last two years of data (Worms & Chouinard 1983,1984) confirm this evaluation and did not indicate evidence of a possible improvement.

Little data are available in the literature on biomass or density estimates of scallops. Jamieson & al (1981a) noted the poor success of a study of gear selectivity due to low density (about 1 scallop/10 m^2) and stated that they would have required 1 scallop or more per m^2 for such a study.

Caddy (1968), working on the Richibucto beds with both divers and a 8 foot offshore scallop drag, observed densities of 1.43 scallops/m^2 on mud to 4.18/m^2 on sand with a mean density of 1.87/m^2. The drag efficiency was estimated to be less than 8.3% for the 75 to 100 mm size group and likely in excess of this value for more than 100 mm scallops (absent on the area surveyed). Dickie (1955) estimated the efficiency of a five (5) bucket Digby drag (total width: 5.5 m) to an average of 4.9 ±.9%. He noted that this type of drag is more efficient for large scallops (over 80 mm shell height) than for small scallops and that the efficiency toward larger individuals is highly dependant upon the type of bottom (efficiency is up to 12% or more on smooth offshore bottom). In the same work he mentionned densities between 0.6 and 7.6 scallops/m^2 in various inshore areas of the Bay of Fundy. If we assume a similar efficiency for Gulf dredges, our figure of 3 to 5 scallops per 100 m^2 will give actual densities between 0.36 and 0.60 scallop/m^2, far below estimated level of profitability as earlier mentioned. However, a quick calculation of fishing performance for a boat fishing a 4 m drag for 20 minutes on the bottom at 3 knots gives a meat yield of 3.2 to 5.3 kg (assuming 35 meat/500 g). A normal fishing day of 20 tows will then yield 64 to 106 kg of meat (i.e. 141 to 234 lb). Actual average values of daily yield, also difficult to precisely appraise, will fall under the minimum estimate of 64 kg.

Jamieson & al (1978) gave density estimates for the three regions he studied in the Southern Gulf: Western, Central and Eastern. Data were not available to recalculate the surface of the beds presented in Fig 9 of his document (see Fig. 10 in present paper). However the biomass estimates presented in Table 12 of the same document were recalculated (cf. Table 6). From the resulting values, an estimate was obtained of the number of individuals present in 1978 on total surface of beds as determined from 1983 resource survey (Table 7). The results tend to indicate a decrease in the available scallop resource over the 4 last years, ranging from 25.6 to 41.7% depending on the areas. Jamieson (1978) also found a decrease in scallop abundance from west to east of the Strait (see Table 7). Even considering the lack of accuracy of the calculations, the number of assumptions made and the lack of reference material which hampered detailed interpretation of results, two points should be outlined:

1- densities as evaluated in 1983 are much lower than the ones found by Dickie in the 1950-1953 period in the Bay of Fundy, by Caddy in 1967 and by Jamieson in 1979 in the Northumberland Strait.

2- exploitation rates average 50% of the fishable biomass. In view of the fact that the sea scallop is a slow growing species with a low secondary productivity, such rates of exploitation may exceed the long or even medium term sustainable yield of the resource.

Even if available information suggests that the fishable biomass is just a fraction of the standing biomass, the status of the resource should be evaluated on the basis of the way the fishery is operated. Gear efficiency allows access to just a small part of the population. The decrease in the overall scallop abundance will affect fishing performance by decreasing the fishable biomass accordingly. Levels of scallop density on the bottom as estimated (less than 1 scallop/m^2) may be too low to allow fishermen to reach the level of profitability, especially in Pictou area where relative weight of meat is much lower at equivalent size than in the remainder of the southern Gulf. the combination of low densities of scallops on the bottom, low gear efficiency and likely low secondary production may partly explain the apparent contradiction between low exploitation rates (calculated on standing biomass values) and poor fishing performances.

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Table 1 - Major fishing beds as determined from the 1983 survey in the Southern Gulf of St Lawrence.

Division	Area	Bed[1]	Total area (km^2)	Area covered by tows (m^2)	Number of tows	% of total area covered by survey	Average distance towed (m)
7C	B. des C.	Nepisiguit North	23.64	19,512.9	19	0.0825	404.3
		Nepisiguit South	25.71	34,104.6	21	0.1326	639.4
		Miscou West	6.79	7,291.3	5	0.1074	574.1
	7C Gulf	Miscou East	33.49	18,110.7	10	0.0541	713.0
		Neguac North	15.09	11,807.2	11	0.0783	422.6
		Neguac South	18.66	24,367.1	17	0.1306	564.3
8	Western	Richibucto	23.23	24,602.3	12	0.1059	807.2
		Miminegash	7.08	10,584.2	5	0.1494	833.4
		Egmont Bay North	14.59	6,491.63	4	0.0909	638.9
	Centr.	Cape Tormentine	59.53	57,719.1	35	0.0970	649.3
7b1	Eastern	Pugwash South East	34.81	37,632.6	23	0.0794	644.2
		Pictou					
		- Indian Rocks	29.44	27,565.9	16	0.0936	678.3
		- N.W. Pictou Isl.	67.83	43,371.6	25	0.0639	683.0
		- N.E. Pictou Isl.	18.59	11,242.7	7	0.0605	632.3

(1) For localisation of beds, see Fig. 2,3 & 4.

Table 2 - Shell height/total weight relationship as calculated from 1982 samples.

Survey area (# name)	Shell height/Total weight $TW = aH^b$ a	b	N
2. Bathurst	$5.19\ 10^{-5}$	3.186	148
4. Miscou West (1)	$5.19\ 10^{-5}$	3.186	-
Miscou East (2)	$4.91\ 10^{-5}$	3.243	-
5. Neguac North Neguac South	$4.91\ 10^{-5}$	3.243	153
6. Richibucto	$5.19\ 10^{-5}$	3.213	100
Miminegash	$1.03\ 10^{-4}$	3.066	182
Egmont Bay	$1.93\ 10^{-4}$	2.963	152
10. Cape Tormentine	$1.66\ 10^{-4}$	3.002	139
11. Pugwash (3)	$1.91\ 10^{-4}$	2.982	-
12. Indian Rocks Pictou Island	$1.91\ 10^{-4}$	2.982	288

(1) No data available from this area, relations from Bathurst were used.
(2) No data available from this area, relations from Neguac were used.
(3) No data available from this area, relations from Pictou were used.
N = Number of individuals used for calculating the relationship .

Table 3 - Estimates of the average biomass on major scallop beds and confidence limits for $\alpha = 0.05$.

	Number of tows	Biomass (g/m^2)	Total Biomass (MT)
Bathurst North	19	4.794 ± 0.924	113.33 ± 21.84
Bathurst South	21	3.356 ± 0.746	86.28 ± 19.18
Miscou West	5	6.376 ± 5.206	43.29 ± 35.35
Miscou Northeast	5	5.672 ± 3.903	} 145.21 ± 88.12
Miscou Southwest	5	3.000 ± 1.360	
Neguac North	11	5.505 ± 2.183	83.07 ± 32.94
Neguac South	17	5.832 ± 2.321	108.82 ± 43.31
Richibucto North	4	4.930 ± 8.230	} 102.44 ± 148.72
Richibucto South	8	4.150 ± 5.488	
Miminegash	5	5.556 ± 3.016	39.34 ± 21.35
Egmont Bay	4	5.979 ± 4.970	87.23 ± 72.51
Cape Tormentine	35	4.212 ± 0.605	250.74 ± 36.02
Pugwash West	4	5.290 ± 4.471	
Pugwash Central	7	4.979 ± 1.143	} 158.62 ± 67.45
Pugwash East	12	4.066 ± 1.234	
Pictou			
- Indian Rocks	16	3.476 ± 0.648	102.33 ± 19.08
- Pictou Island	32	3.588 ± 0.519	310.08 ± 44.85

Table 4 - Average biomass estimates in the Southern Gulf (g/m^2) and confidence limits for α = 0.05

	Estimated biomass (g/m^2)	# tows
Baie des Chaleurs	4.30 ± 0.67	45
District 7C, Gulf	5.35 ± 1.18	38
Western Strait	4.98 ± 2.15	21
Central Strait	4.21 ± 0.60	35
Eastern Strait	3.94 ± 0.38	71

Table 5 - Exploitation rates in major fishing areas of the Southern Gulf.

	Estimated biomass (MT)		Landings (MT)		Exploitation rate (%)	
	at date of survey	Initial	at date of survey	Total	at date of survey	Final
Bathurst	199.61	219.7	20.1	65.6	9.2	29.9
Neguac	191.89	308.9	117.0	174.7	37.9	56.6
Richibucto*	102.44	442.9	340.5	-	-	(76.9)
Cape Tormentine*	250.74	478.5	227.8	-	-	47.6
Pictou	411.38	780.1	368.7	421.0	47.3	54.0

* Survey made at the end of the fishing season.

Table 6 - Estimated scallop abundance in Northumberland Strait for each region (from Jamieson 1979, modified).

	West	Central	East
Mean no. scallops/tow	215	148	123
Total area(km)	516.6	313.2	1237.0
Total area/area covered per tow	185,894	112,702	445,124
Number of scallops (10^{-3})	39,967	16,680	57,750

Table 7 - Comparison of abundance in Northumberland Strait regions in 1979 (from Jamieson) and 1983.

	West*		Central		East	
	79	83	79	83	79	83
Density no. scallop/m^2	0.077	0.045	0.053	0.040	0.044	0.026
Estimated n°. of fishable scallop (10^{-6})	1.80	1.05	3.17	2.36	5.13	3.0
Difference %	- 41.7		- 25.6		- 41.5	

* Calculation made for Richibucto bed only.

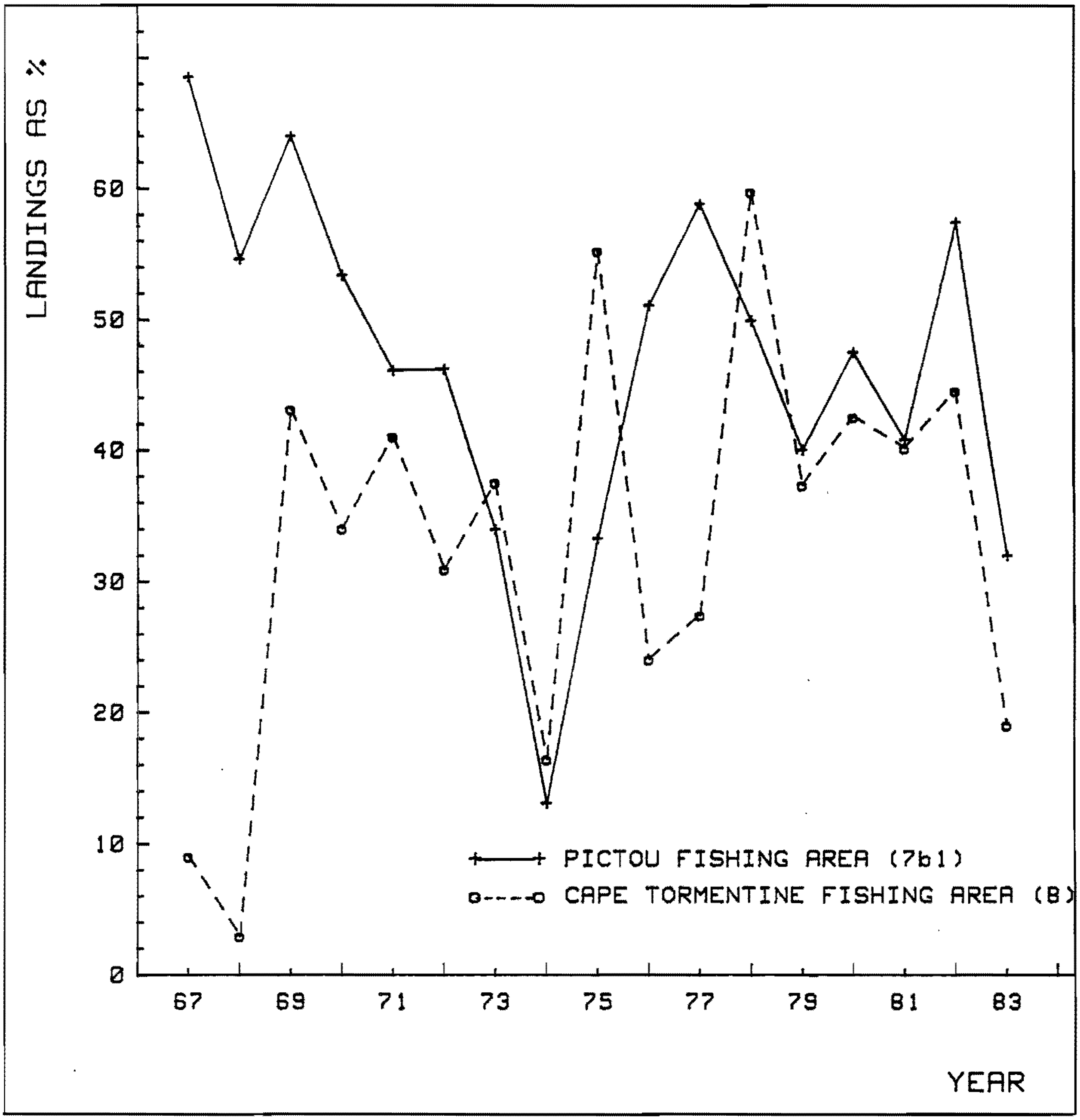

Fig. 1 - Scallop landings in the Cape Tormentine and Pictou areas as % of total landings in districts 8 and 7bl repectively.

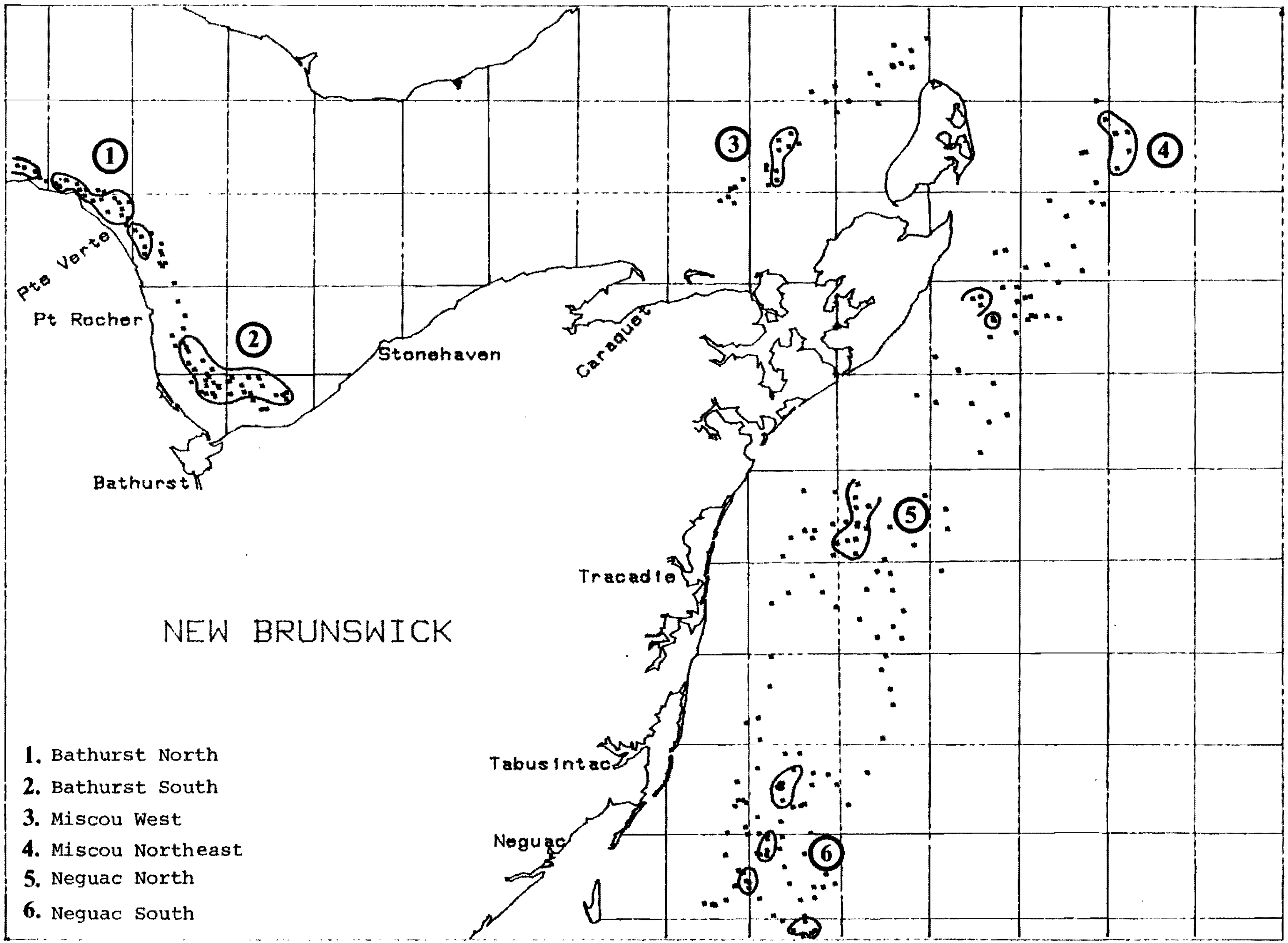

Fig. 2 - Identification of commercial scallop concentrations found in district 7c in 1983.

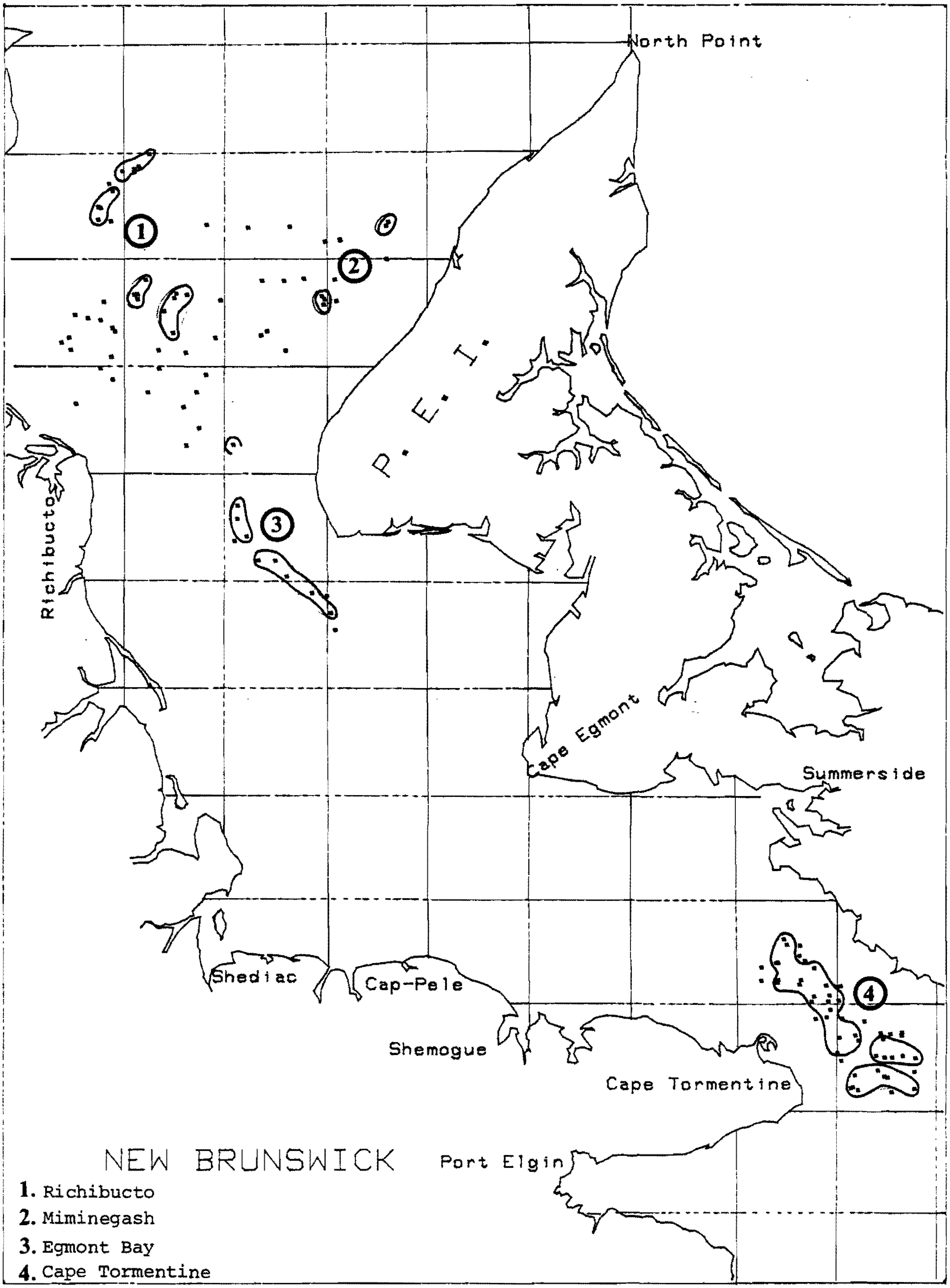

Fig. 3 - Identification of commercial scallop concentrations found in district 8 in 1983.

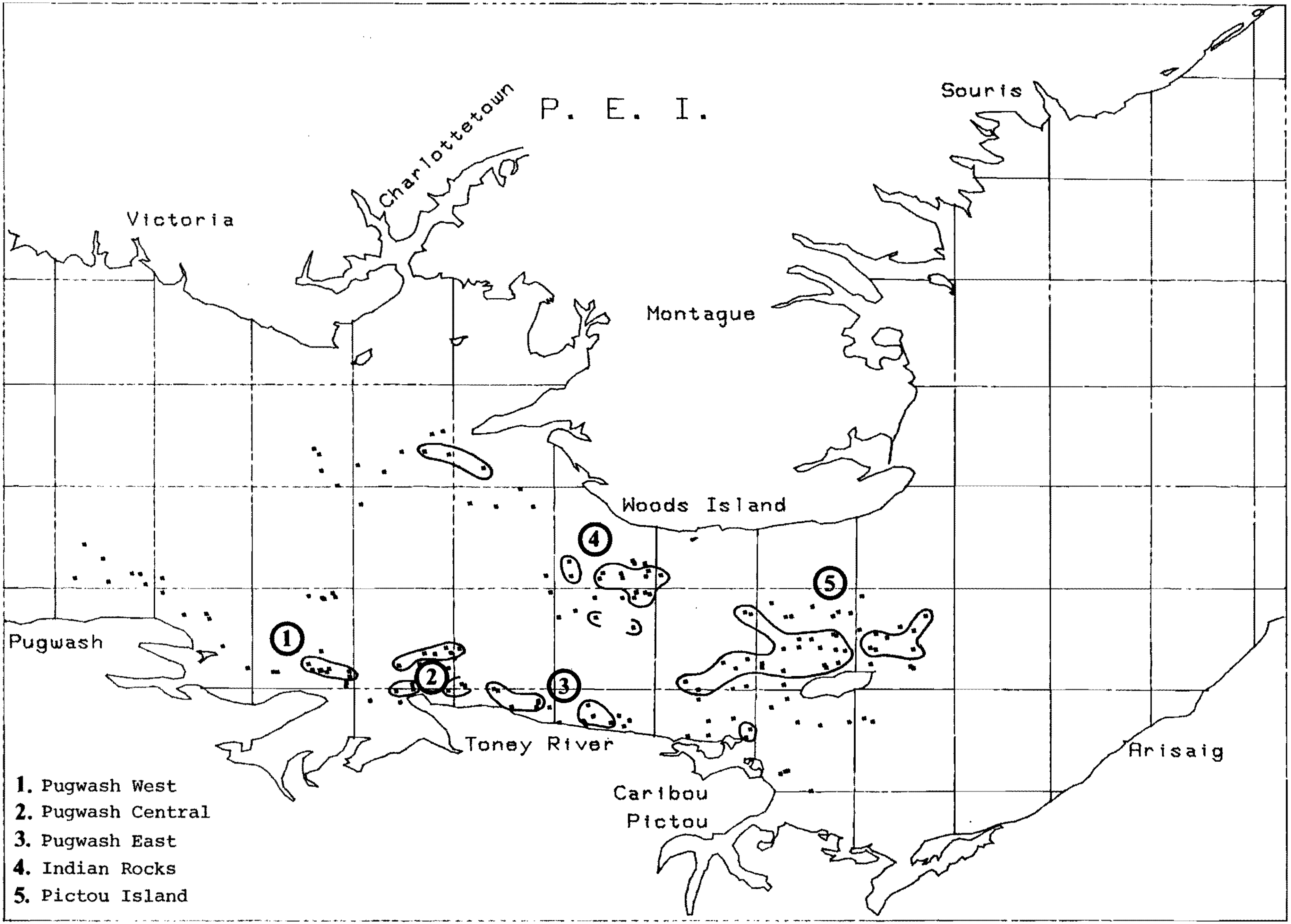

Fig. 4 - Identification of commercial scallop concentrations found in district 7bl in 1983.

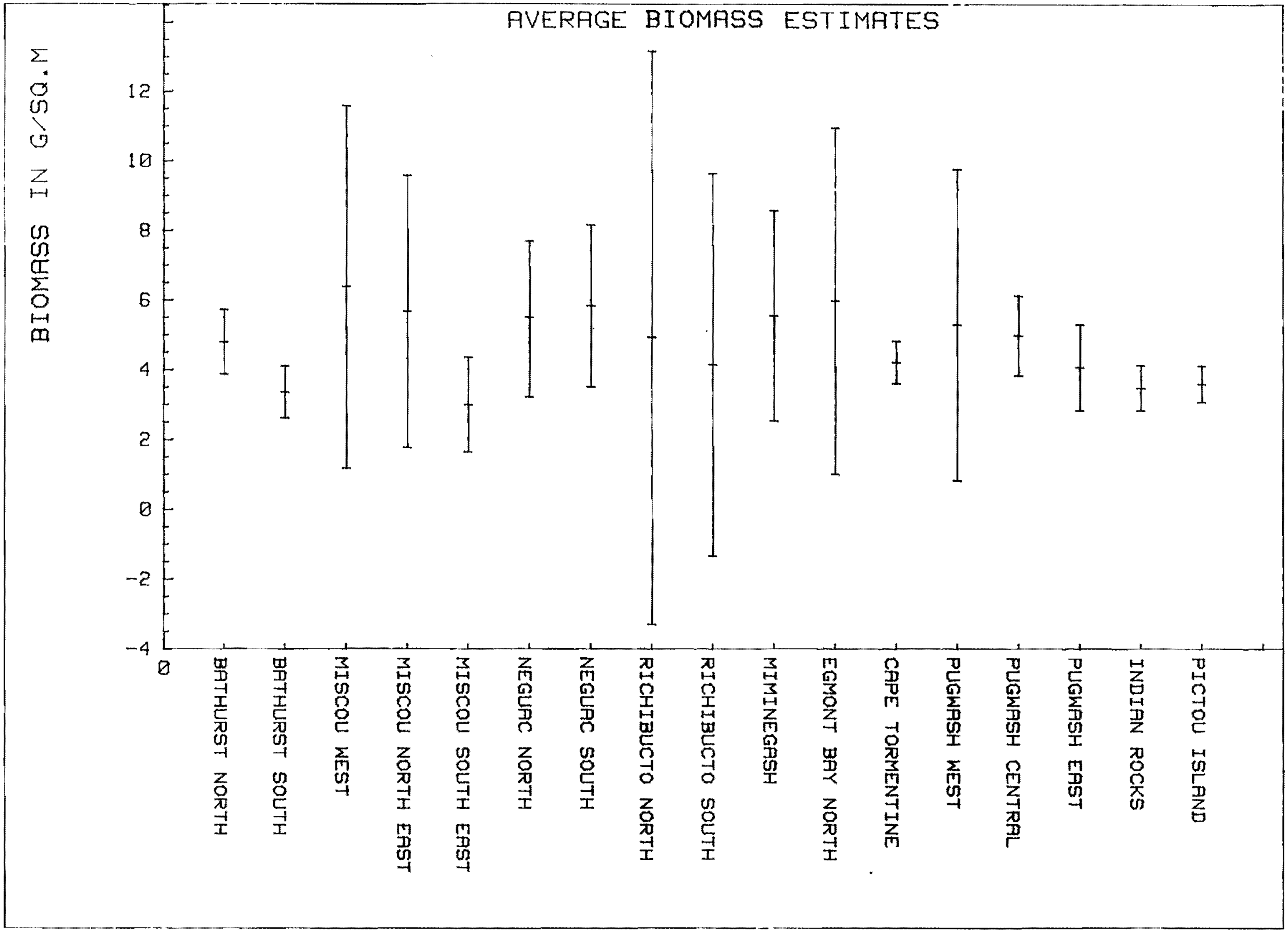

Fig. 5 - Average biomass estimates and approximate confidence limits for commercial scallop beds in the Southern Gulf of St Lawrence.

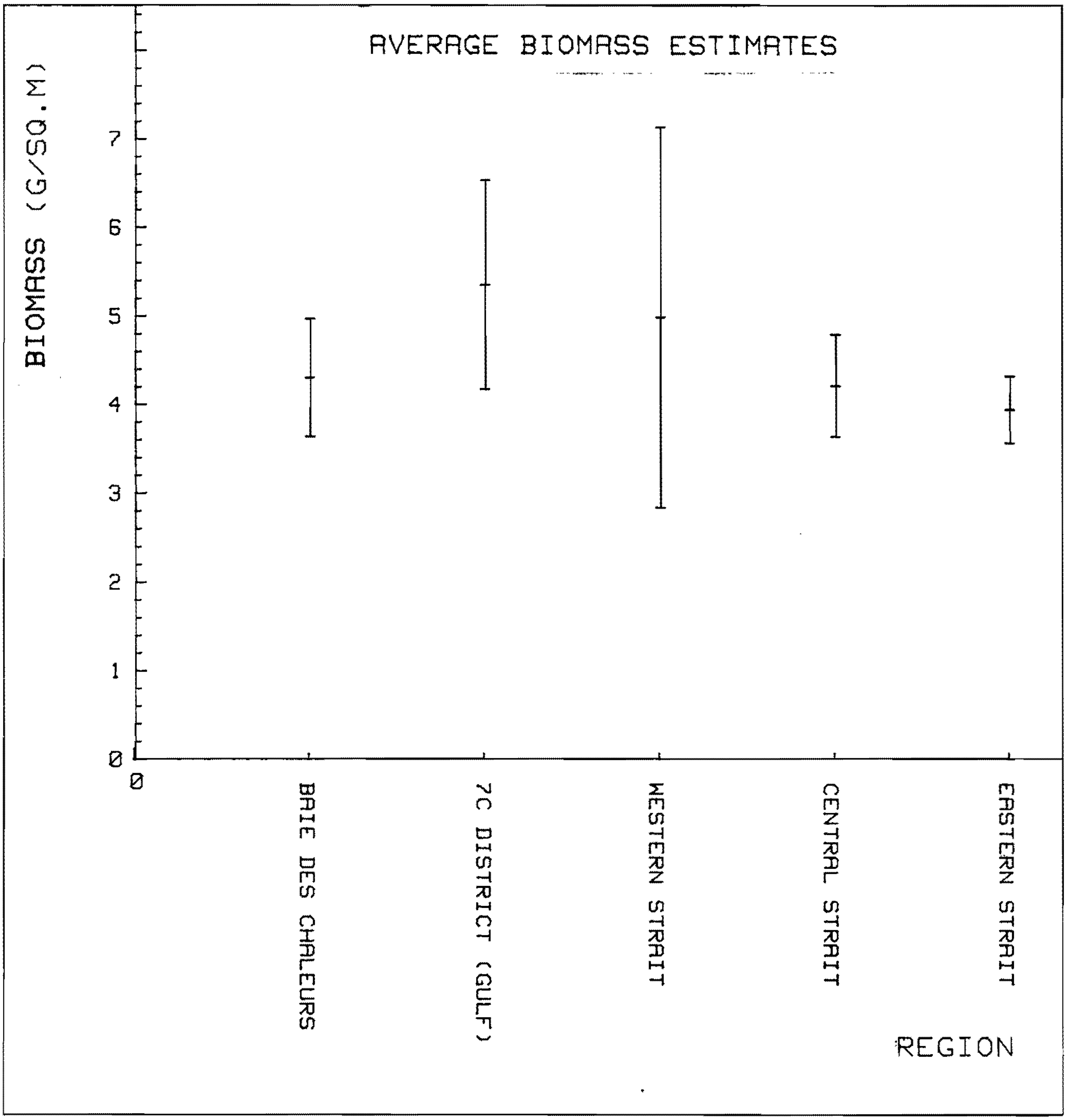

Fig. 6 - Mean biomass estimates and approximate confidence limits for commercial scallop concentrations in the Southern Gulf of St Lawrence (large areas).

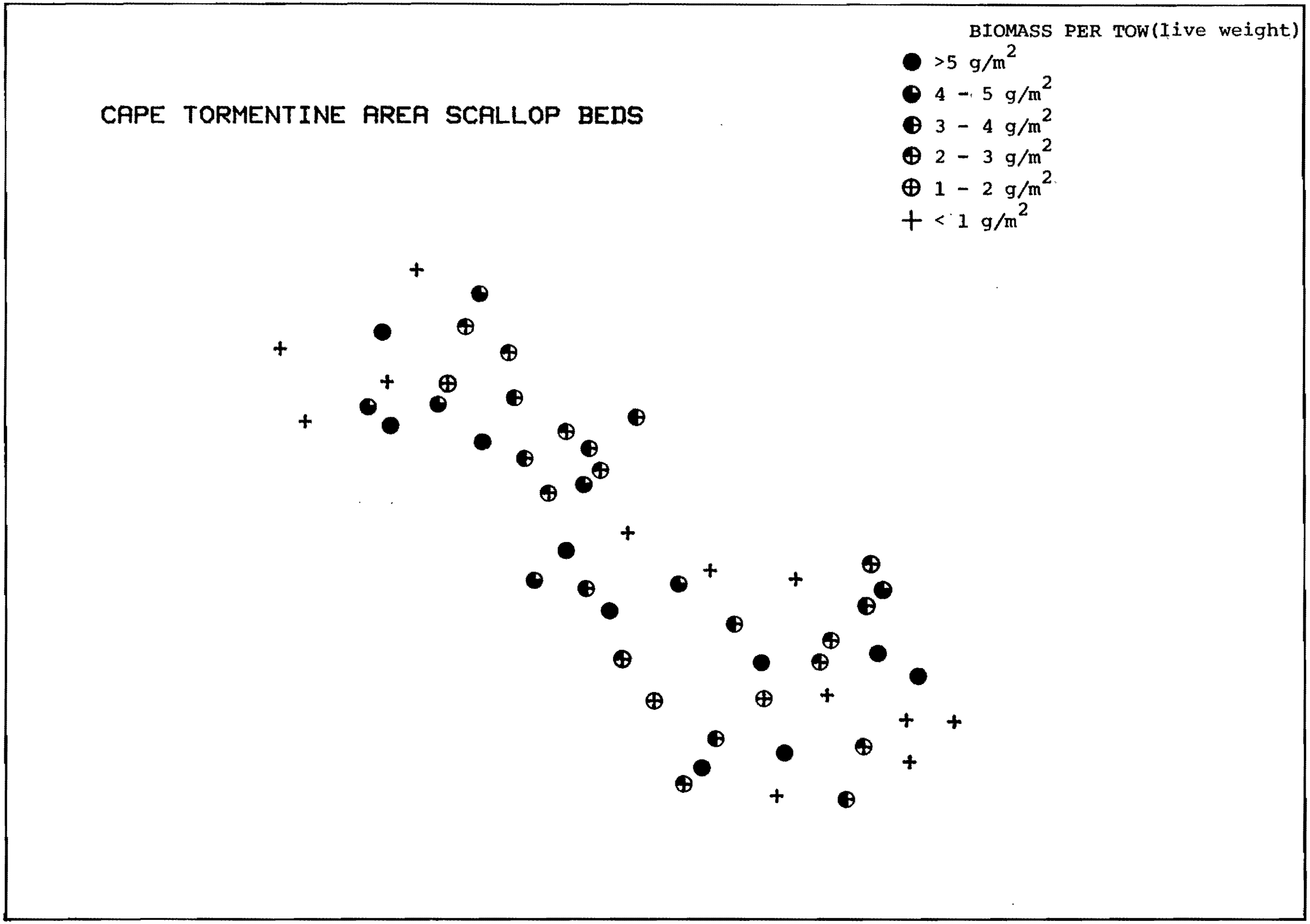

Fig. 7 - Distribution of biomass (in live weight) on the Cape Tormentine fishing bed.

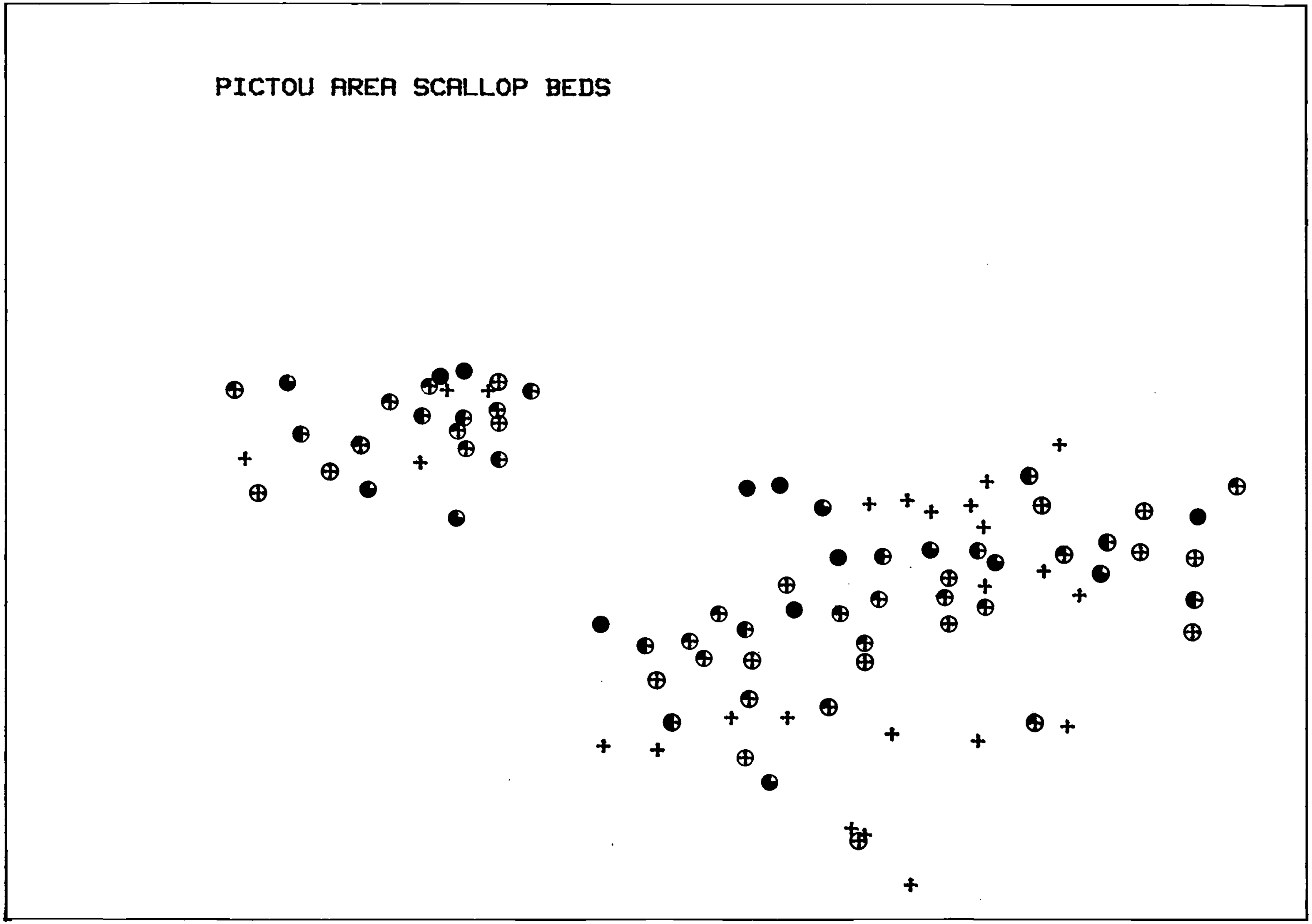

Fig. 8 - Distribution of biomass (in live weight) on the Pictou area fishing beds.
(see explanations on Fig. 7)

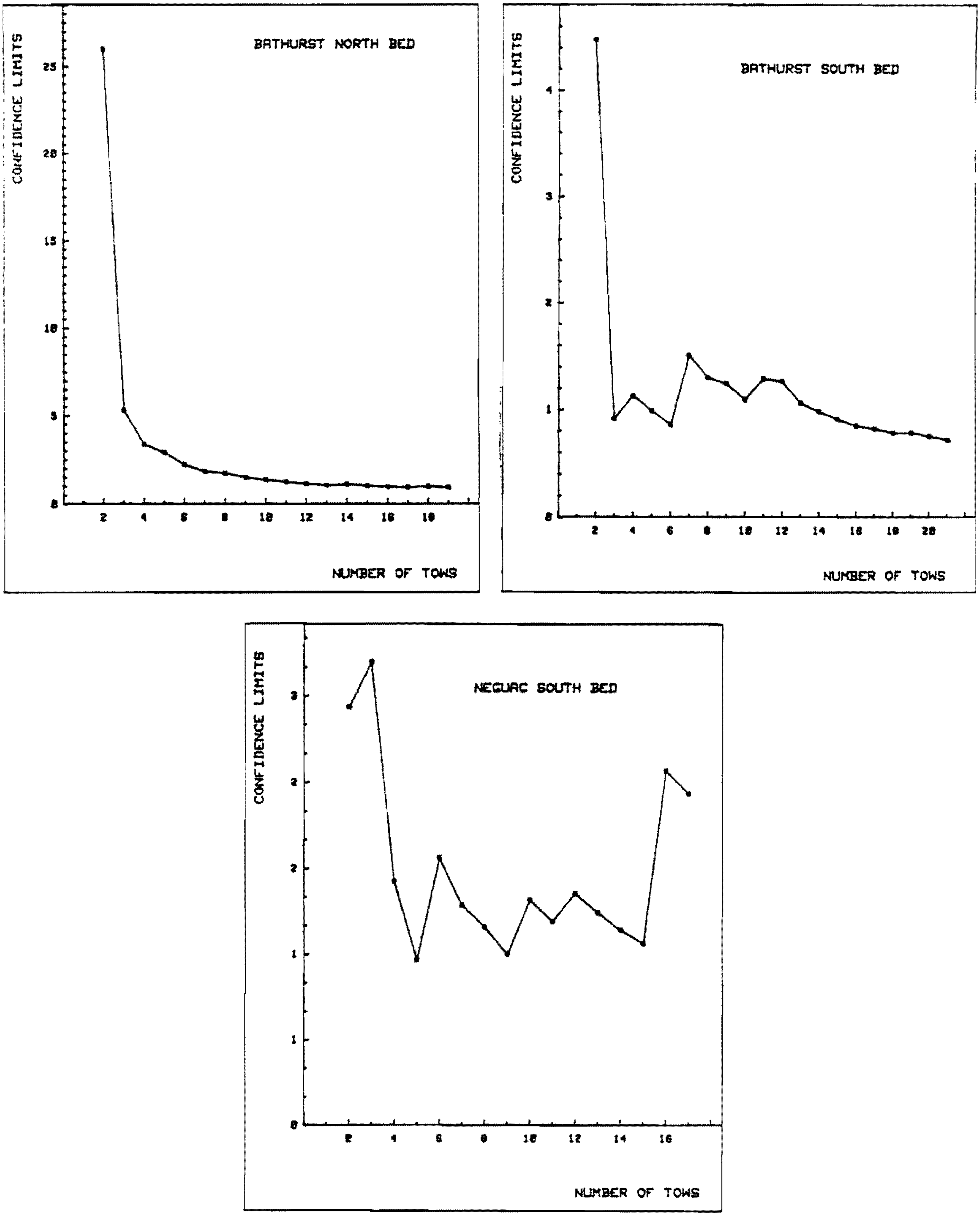

Fig. 9 - Precision in average biomass estimates vs number of observations (tows)

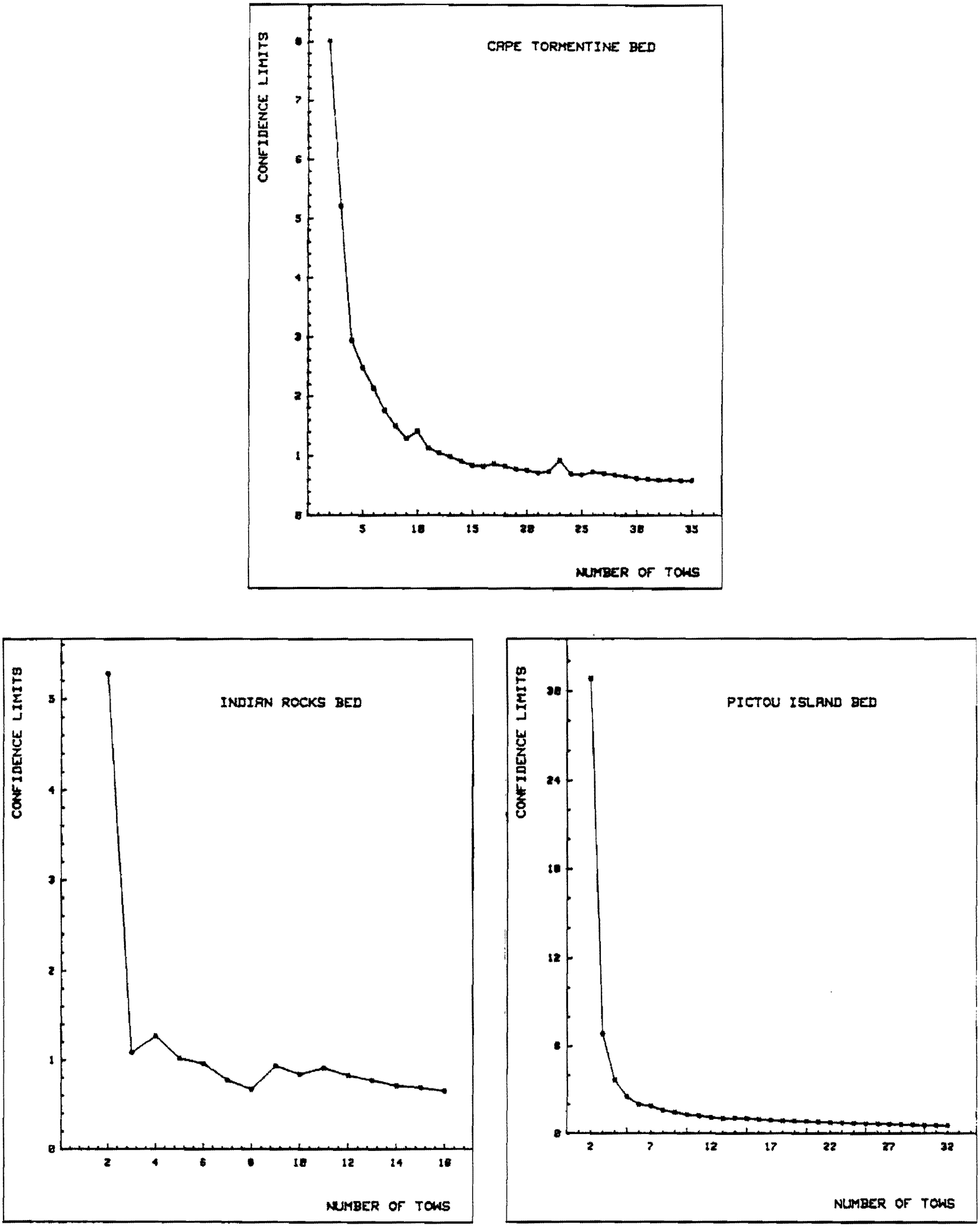

Fig. 9 - Continued

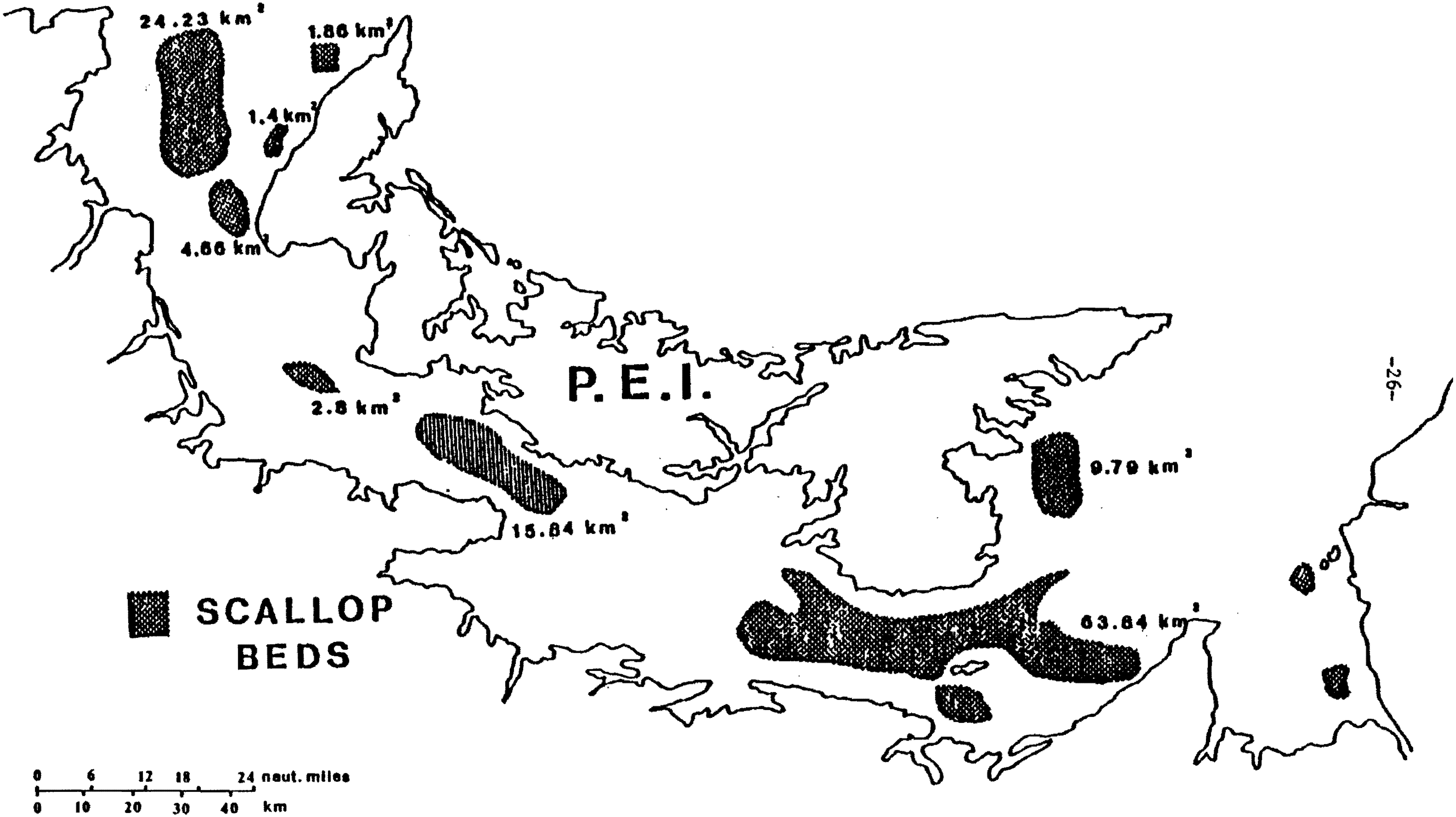

Fig. 10 - Map of historically productive scallop grounds in the Northumberland Strait presented by Jamieson (1979).
(scale was added for presentation in this document)