105

René E. Lavoie

Dynamics of an Exploited Population of Bar Clam, *Spisula Solidissima*

G. Robert

Department of Fisheries and Oceans Canada
Resource Branch
Invertebrates and Marine Plants Division
Halifax, Nova Scotia B3J 2S7

March, 1981

Canadian Manuscript Report of Fisheries and Aquatic Sciences 1607

Government of Canada Fisheries and Oceans
Gouvernement du Canada Pêches et Océans

Canadian Manuscript Report of Fisheries and Aquatic Sciences

These reports contain scientific and technical information that represents an important contribution to existing knowledge but which for some reason may not be appropriate for primary scientific (i.e. *Journal*) publication. They differ from Technical Reports in terms of subject scope and potential audience: Manuscript Reports deal primarily with national or regional problems and distribution is generally restricted to institutions or individuals located in particular regions of Canada. No restriction is placed on subject matter and the series reflects the broad interests and policies of the Department of Fisheries and Oceans, namely, fisheries management, technology and development, ocean sciences, and aquatic environments relevant to Canada.

Manuscript Reports may be cited as full publications. The correct citation appears above the abstract of each report. Each report will be abstracted by *Aquatic Sciences and Fisheries Abstracts* and will be indexed annually in the Department's index to scientific and technical publications.

Numbers 1-900 in this series were issued as Manuscript Reports (Biological Series) of the Biological Board of Canada, and subsequent to 1937 when the name of the Board was changed by Act of Parliament, as Manuscript Reports (Biological Series) of the Fisheries Research Board of Canada. Numbers 901-1425 were issued as Manuscript Reports of the Fisheries Research Board of Canada. Numbers 1426-1550 were issued as Department of Fisheries and the Environment, Fisheries and Marine Service Manuscript Reports. The current series name was changed with report number 1551.

Details on the availability of Manuscript Reports in hard copy may be obtained from the issuing establishment indicated on the front cover.

Rapport manuscrit canadien des sciences halieutiques et aquatiques

Ces rapports contiennent des renseignements scientifiques et techniques qui constituent une contribution importante aux connaissances actuelles mais qui, pour une raison ou pour une autre, ne semblent pas appropriés pour la publication dans un journal scientifique. Ils se distinguent des Rapports techniques par la portée du sujet et le lecteur visé; en effet, ils s'attachent principalement à des problèmes d'ordre national ou régional et la distribution en est généralement limitée aux organismes et aux personnes de régions particulières du Canada. Il n'y a aucune restriction quant au sujet; de fait, la série reflète la vaste gamme des intérêts et des politiques du Ministère des Pêches et des Océans, notamment gestion des pêches; techniques et développement, sciences océaniques et environnements aquatiques, au Canada.

Les Manuscrits peuvent être considérés comme des publications complètes. Le titre exact paraît au haut du résumé de chaque rapport, qui sera publié dans la revue *Aquatic Sciences and Fisheries Abstracts* et qui figuera dans l'index annuel des publications scientifiques et techniques du Ministère.

Les numéros de 1 à 900 de cette série ont été publiés à titre de manuscrits (Série biologique) de l'Office de biologie du Canada, et après le changement de la désignation de cet organisme par décret du Parlement, en 1937, ont été classés en tant que manuscrits (Série biologique) de l'Office des recherches sur les pêcheries du Canada. Les numéros allant de 901 à 1425 ont été publiés à titre de manuscrits de l'Office des recherches sur les pêcheries du Canada. Les numéros 1426 à 1550 ont été publiés à titre de Rapport manuscrits du Service des pêches et de la mer, Ministère des Pêches et de l'Environnement. Le nom de la série a été changé à partir du rapport numéro 1551.

La page couverture porte le nom de l'établissement auteur où l'on peut se procurer les rapports sous couverture cartonnée.

Canadian Manuscript Report of
Fisheries and Aquatic Sciences 1607

April 1981

DYNAMICS OF AN EXPLOITED POPULATION OF BAR CLAM, *SPISULA SOLIDISSIMA*

by

Ginette Robert

Fisheries & Oceans Canada
Resource Branch
Invertebrates & Marine Plants Division
P.O. Box 550
Halifax, Nova Scotia
B3J 2S7

Cat. No. Fs 97-4/1607 ISSN 0706-6457

Correct citation for this publication:

Robert, G. 1981. Dynamics of an exploited population of bar clam, *Spisula solidissima*. Can. MS Rep. Fish. Aqua. Sci. 1607: iv + 12 p.

CONTENTS

(20 ha; 50 acres). 100 randomly distributed 1 m^2 -quadrats, dug 20 cm deep provided the numerical information to estimate the biomass production. Different locations were sampled each tide to get a cross-section of the sand bars from shore to extreme low water mark. All clams longer than 40 mm were collected effectively while smaller ones were more difficult to observe ans are likely underestimated. The sampling schedule did not allow investigation of the 1980 set.

Clam measurements

The length of clams, the maximum distance between the anterior and posterior end of the shell, was measured with a vernier caliper to the nearest mm. Clams were grouped in 10-mm size classes. Clams 50 mm long are minimum harvestable (legal) size according to the Prince Edward Island Fishing Regulations. However, a larger size (75 mm) is considered as recruiting size by the local clam-diggers. The shell and meat were weighted separately. The shell was air-dried before weighing. The meat was removed from the shell and drained before weighing to 0.1 g. The condition index ratio was established as % live meat weight / live meat weight + shell weight for a set of legal size clams.

Growth analysis

Growth rate of bar clams was measured by shell growth rings following Kerswill (1944), Caddy and Billard (1976), and Bernier and Poirier (1979). A mixed size sample of 100 shells were aged and a growth curve fitted to the Von Bertalanffy model using the unweighted estimates of mean length at age (Allen, 1966).

Mortality estimate

Mortality rate (Z) was investigated by anlysing the age composition of samples (30 clams) from the harvest of 4 diggers at one tide (Robson and Chapman, 1961). We recognize the limitations of using harvest data from a single season and the simplifying assumption of steady state population over the range of recruits' age groups. A Chi-square statistic tests the significance of this simple model.

Production modeling

Long-term sustainable yields are difficult to assess with one year's data. Short-term production estimates are arrived at by models like the yield per recruit. Three different models, the Beverton-Holt, the Thompson and Bell, and the Ricker piece-wise integration method were examined (Ricker, 1975).

RESULTS AND DISCUSSION

Density and distribution of the stocks

The survey indicated 3 zones of bar clam abundance. A near shore zone about 100 m wide had important concentrations of bar clams, especially pre-recruits (Table 1) with one modal size-class (40-50 mm). It is estimated that this zone contains over 3 times as many pre-recruits than recruits.

Table 1. Density of bar clams for the near shore zone (10 ha).

size-class	N	s.e.		biomass estimate	
				N	N x 10^{-3}
(mm)	100 m^2			100 m^2	km of shore
≤30	14	42	pre-recruits		
30-40	22	62	40 ≤ length ≤ 75	74	74
40-50	33	116			
50-60	23	57			
60-70	12	18			
70-80	11	10	recruits		
80-90	10	9	length ≥ 75	21	21
90-100	4	8			
≥100	2	3		95	95
	131				

A frontal zone located at the extreme low water mark and 50 to 75 m wide had a density of 125 clams per 100 m^2 (Table 2). This population was made up almost exclusively of recruits. Over 80 % of the digging was observed to take place in this zone. The fishing season was well under way by the time the frontal zone was surveyed; one could therefore estimate a higher standing crop for recruits.

An intermediate zone had low abundance of bar clams, less than 1 bar clam per 10 m^2 but sustained an estimated 10 razor clams (Ensis directus) per m^2.

Summing up clam densities for all zones, nearly 160,000 bar clams over 40 mm long were present per km of shore; 50 % were recruits. Medcof and MacPhail (1955) found, in the southwestern Gulf of St.Lawrence, bar clams most abundant at the edge of the tidal zone and scarce in subtidal waters. Similarly Younker and Judson (1971) reported "few" clams while working in subtidal waters in the vicinity of the study site.

Table 2. Density of bar clams for the frontal zone (5 ha).

size-class	N	s.e.		biomass estimate N	biomass estimate $N \times 10^{-3}$
(mm)	100 m^2			100 m^2	km of shore
≤ 70	7	24	pre-recruits	9	4.5
70-80	26	30			
80-90	7	9	recruits	116	58
90-100	21	18			
100-110	28	24		125	62.5
110-120	24	32			
120-130	10	16			
≥ 130	2	3			
	125				

Growth rate

From the ageing of shells the Von Bertalanffy equation is:

$$L_t \text{ (mm)} = 172.25 \, (1 - e^{-0.152 \, (t - 0.365)})$$

Table 3. Statistics of growth parameters.

	s.e.	95 % confidence interval	
L_∞	1.162	169.98	174.53
K	0.0017	0.149	0.156
t_0	0.0079	0.349	0.380

This equation is similar to the one obtained from a Buctouche bar clam population on the New Brunswick side of the Strait (Caddy and Billard, 1976) except that growth appears faster during the first 5 growing seasons at Mont-Carmel. This growth pattern also matches Kerswill's (1944) findings for Malpeque Bay. The legal size is reached during the third growing season and recruit size after 4 years.

Reproduction

Size at maturity was determined at 50 mm for bar clams from Massachusetts (Yancey and Welsh, 1968). Such information is not available for Gulf of St.Lawrence populations which are at the northern end of the species distributional range. As is the case in a number of molluscan species (Segal, 1961) bar clams may mature later in life at the northern limit of their distribution.

Kerswill (1944) mentions that spawning takes place in July-August in the Gulf. The condition index data collected at the end of July and the first visual observations of 1980 set at this time concur with a summer spawning. As in other clam species ripe gonads contribute significantly to the meat weight and a condition index may also be used as a spawning index. The Mont-Carmel data (Table 4) suggests a higher condition index (C.I. = 37 %, July) than Caddy and Billard (1976) 32 % (March) or Bernier and Poirier (1979) 35 % (July). Seasonality of sampling may cause this variation. Older clams have a higher meat ratio and may be the first to spawn as shown by a wider range of C.I. in clams aged 5+, physiological heterogeneity being associated with the different stages of gonad maturation (Lubet, 1959).

Table 4. Mean condition index (C.I.) for Mont-Carmel bar clams

age	n	C.I. (%)	s.d.	range
2	12	35	2.3	32 - 40
3	22	38	2.4	32 - 41
4	12	39	1.5	36 - 42
5	10	36	4.8	26 - 43
6	6	38	3.4	33 - 41
7	1	39	-	-
8	1	37	-	-

The end of July spring tide exposed bar clams 3 to 5 mm long creeping on the bottom and leaving tracts in a hook-like pattern. They were noticed in small scale patches (1 m^2).

Mortality estimate

Conversations with clam-diggers and samples from their harvest revealed that even though 75 mm recruits enter the fishery, they are not always retained by the digger. However, 100 mm clams (age 6) are always retained. Therefore we used this figure as age at full recruitment in the harvest analysis

(Table 5). Assuming steady state conditions, the mortality rate (Z) would be 0.6 approximately (Table 6). The interval range is wide; this is to be expected from limited data. The relative frequency of 6-year old was tested against the frequency of older age groups by a chi^2 statistic ($P < 0.05$). No significant variation from the expected frequency under constant recruitment was found.

Table 5. Pooled data of harvest according to the age composition. n = 120. Clams less than 100 mm (age 6) are not fully recruited to the fishery and are not included in the analysis.

age	<6	6	7	8	9	10	11
n	6	48	26	20	12	6	2

Table 6. Estimate of mortality rate (Z) for recruits age 6 and older.

instantaneous mortality rate = 0.594
variance = 0.007
standard error = 0.081
95 % confidence interval = 0.433 - 0.756

Previous studies in the Gulf had established an instantaneous rate of natural mortality (M) of 0.2 (Caddy and Billard, 1976) and 0.3 (Bernier and Poirier, 1979). These seem reliable estimates for mortality of unfished stocks. When Z equals 0.6, M and F could have similar values.

Biomass production modeling

The growth parameters used in the yield computations were derived from the growth equation presented in an earlier section or from $G_t = \ln (W_{t+1}/W_t) / t_{+1} - t$. Natural mortality (M) for the age groups considered was assumed at 0.2. Using M = 0.3 decreases yields slightly. W_∞ (Beverton-Holt method) and average weights at successive age (Thompson and Bell method) were derived from the log-log regression between shell length and meat weight of 100 legal size clams.

$$\log \text{meat weight (g)} = -3.927 + 2.812 \log \text{shell length (mm)}$$

Seasonal changes are likely to occur in the meat yield. Meat yield is approximately 35 % of total weight.

In all models yields have been calculated for fishing intensities $0.2 \leqslant F \leqslant 1.2$, and for a minimum age at entry in the fishery (t_r) corresponding to the legal size (50 mm).

The Beverton-Holt model (Table 7) suggests that yield per 100 recruits may almost double by delaying t_r for 3 years (from 3 to 6; Y from 1.6 to 2.6 kg) for $F \geqslant 0.4$. Optimal yield would be reached by fishing 7-year old recruits at F = 0.8. However, at optimal recruiting age, yield differences are small for the fishing rates considered (Fig. 2). A yield of 2.5 kg / 100 recruits corresponds to recruits at least 6 years old (100 mm long) with $F \geqslant 0.4$.

According to the Thompson and Bell model, increasing t_r to 7 leads to increased yields. Lowest yields are obtained by harvesting minimum legal size clams (50 mm). Twice as much may be harvested by digging 100-mm clams. Best yields are obtained with $t_r \geqslant 7$ and $F \geqslant 0.8$.

Yield results from the Ricker model also show that the legal size does not optimize yield. Digging clams age 6 increases the yield by 25 %. For age at entry of 5 or less a low fishing rate ($F \leqslant 0.6$) brings the best yields. Maximum yield corresponds to delaying digging until recruits are 7 years old and harvesting almost all of them at once ($F \geqslant 0.8$).

Table 7. Yield per 100 recruits (kg) calculated according to:

a) the Beverton-Holt model (t_r: age at entry in the fishery, F: annual instantaneous fishing mortality rate).

t_r \ F	0.2	0.4	0.6	0.8	1.0	1.2
3	1.9	1.8	1.6	1.5	1.4	1.3
4	2.1	2.2	2.1	2.0	1.9	1.9
5	2.2	2.4	2.4	2.4	2.3	2.3
6	2.2	2.5	2.6	2.6	2.6	2.6
7	2.1	2.5	2.6	2.7	2.7	2.7
8	2.0	2.4	2.6	2.6	2.7	2.7
9	1.8	2.3	2.4	2.5	2.6	2.6
10	1.6	2.1	2.2	2.3	2.4	2.4

b) the Thompson and Bell model (assuming that only 30 % of the 3-year old were fully available to the fishery).

t_r \ F	0.2	0.4	0.6	0.8	1.0	1.2
3	1.4	1.4	1.3	1.1	1.1	1.0
4	1.6	1.7	1.7	1.6	1.5	1.5
5	1.6	1.9	1.9	1.9	1.9	1.9
6	1.6	2.0	2.1	2.1	2.1	2.1
7	1.5	2.0	2.1	2.2	2.2	2.2
8	1.3	1.8	2.1	2.2	2.2	2.2
9	1.1	1.6	1.9	2.0	2.1	2.2
10	0.9	1.4	1.7	1.8	1.9	2.0

c) the Ricker model (annual increment under arithmetic mode).

t_r \ F	0.2	0.4	0.6	0.8	1.0	1.2
3	2.6	2.8	2.5	2.3	2.2	2.1
4	2.8	3.3	3.3	3.1	3.0	3.0
5	2.9	3.6	3.9	3.9	3.9	3.9
6	2.8	4.0	4.4	4.6	4.7	4.8
7	2.5	3.8	4.6	5.0	5.3	5.5
8	1.9	3.3	4.2	4.8	5.4	5.6
9	1.1	2.0	2.8	3.5	4.2	4.7

The values calculated by Ricker's model are sustantially higher than the ones from the two other models because it uses a nominal weight while the latter two use a nominal number of recruits and weight variability is much greater. More important than the absolute values is the fact that the three methods are in rough agreement. In practice, any one of them would lead to the same management recommendations given the same conditions. It appears that, given the limitations of assuming a steady state population for the age groups considered, age at entry = 6 and fishing rate = 0.4 is the combination of youngest recruits and lowest fishing rate to bring optimum catches. Maximum catches would come from much higher fishing rates ($F \geq 0.8$) directed at a larger size recruit, 110 mm or greater (age 7+) (Fig. 2).

A low growth rate and a long life span contribute to the fact that the critical age (age at which the biomass is at a maximum in the absence of fishing) for this species is late in life; it is about 7. The maximum biomass is almost twice the biomass of legal size clams (age 3). It is obvious that the maximum yield per recruit is reached by harvesting all recruits at the critical age.

Table 8 presents the standing stocks of bar clams ≥ 75 mm for the study site based on the size-specific distribution and the length-weight relation derived earlier. The greatest size-specific biomass corresponds to the numerical mode (100-110 mm) and refers to age 7 recruits. The biomass of recruits presently available is roughly equal to 3.8 MT (meat weight) or 10.9 MT of bar clams in the shell per km of shore.

Table 8. Standing stocks of recruits for the study site. Meat weight corresponds to a recruit of median size in each size-class.

size-class (mm)	N	x meat weight (g)	= size-specific biomass (g)
≥ 75	19	22.17	421
80-90	13	31.52	410
90-100	14	43.09	603
100-110	16	57.09	913
110-120	12	73.74	885
120-130	5	93.22	466
≤ 130	1	115.74	116
	80		3,814 g

80,000 bar clams ≥ 75 mm
3.8 kg / 80 recruits x 80,000 = 3.8 MT meat weight / km shore
3.8 MT meat → 35 % total weight
10.86 MT → total weight
4.8 kg / 100 recruits actual meat yield

Inadequacy of the minimum legal size

Based on the data collected and yield per recruit models the optimal harvesting strategy would be to dig bar clams age 7 (110 mm) at fishing rates equal to or greater than 0.8. Such results show the inadequacy of the minimum legal size (50 mm). Assuming constant recruitment, yields can be optimised, doubled in some instances along the Northumberland Strait shores by raising the legal size at which bar clams are dug. In addition increasing the size at entry in the fishery would likely insure that a few year-classes serve as brood stock. The stability of brood stock is seriously jeopardised by harvesting clams as they reach size at maturity. Scarcity of brood stock could lead to localised recruitment failure.

The harvesting strategy of local clam-diggers is near-optimal as they retain clams longer than 100 mm. Their digging effort could be described as moderate. Fisheries records suggest that it is somewhat stable. For the past 25 years, landing variations have been small in this district. Older clam-diggers report that their catches are quite even from year to year. Moreover they can presently take advantage of the high densities of 4 and 6 years old clams. These levels may be supported for a short period. Good yields could still be achieved by higher rates (F = 0.8) but directed at a larger size at entry in the fishery.

High fishing rates of legal size clams may only achieve overfishing and depletion of the stocks. The available stocks could not support a fishery as carried out by non-resident seasonal participants involved in "digging clam beds out", and retaining any clam over the legal size. These itinerant clam-diggers operated on the eastern shore of New Brunswick in previous years. According to anecdotal information it appears that clam beds are slow to recover after their passage.

CONCLUSIONS

Bar clam studies in different locations of the Gulf of St.Lawrence characterize the northern populations of this species by the following:

1. Bar clams occur near the surface of clean sand shoals at or below the extreme low water mark on exposed shores.

2. They are most abundant at the edge of the tidal zone and become scarce in subtidal waters.

3. Stocks of bar clams have a low growth rate (k = 0.152) and a life expectancy of about 30 years with an asymptotic size

over 15 cm long.

4. Spawning takes place during mid-summer.

5. Meat yield corresponds to about 35 % of total weight.

6. Natural mortality rates vary from 0.2 to 0.3.

7. Because of a low growth rate and a long life the critical age, when biomass is maximum, is late in life. Maximum yield is reached only when all large recruits are fished.

Studies of a bar clam population located on the north shore of Northumberland Strait showed the following:

1. Nearly 160,000 bar clams over 40 mm long were present per km of shore with 50 % recruiting to the fishery.

2. According to a Von Bertalanffy growth curve, legal size is reached during the third growing season and recruit size (size of clams which the digger may wish to retain) after 4 years. Optimal age at entry in the fishery is however greater (age 7).

3. Yield per recruit models show that the best yields are obtained by harvesting clams at least 110 mm long at rates equal to 0.8 or greater. Such yields are almost twice the ones obtained by digging for minimum legal size clams.

4. The biomass of recruits presently available is roughly equal to 11 MT per km of shore. The greatest size-specific biomass of these stocks corresponds to the critical age in a population under equilibrium conditions.

RECOMMENDATION

Given the present conditions for assessment of these stocks it appears that the minimum legal size is not adequate. It removes brood stock and could lead to localised recruitment failure; it is also well below recruiting size for optimal yields. As a first step it should be raised to 75 mm. Since there is no reason to believe that biological parameters of bar clam stocks from the north shore of Northumberland Strait would differ from the ones of the south shore, this increased legal size would be appropriate throughout the southwestern Gulf of St.Lawrence.

ACKNOWLEDGEMENTS

I extend thanks to the following: the Field Services Branch in Charlottetown, P.E.I. for their interest in this study; to Dr. Robert Mohn who provided a program for computing yields by the Thompson and Bell model and to the latter and Dr. John Pringle for reviewing the manuscript.

REFERENCES

Allen, K.R. 1966. A method of fitting growth curves of the Von Bertalanffy type to observed data. Journ. Fish. Res. Bd Can. 23: 163-179.

Bernier, L. and L. Poirier 1979. Evaluation sommaire du stock des mactres de l'Atlantique, Spisula solidissima Dillwyn, des Iles-de-la-Madeleine, M.I.C., Dir. gén. Pêches marit., Dir. Rech., Cah. Inf. 92, 42p.

Caddy, J.F. and A.R. Billard 1976. A first estimate of production from an unexploited population of the bar clam, Spisula solidissima. Fish. Mar. Serv. Res. Dev., Tech. Rep. 648, 13p.

Kerswill, C.J. 1944. The growth rate of bar clams. Fish. Res. Bd Can. Prog. Rep., Atl. Coast Sta. 35: 18-20.

Lubet, P. 1959. Recherches sur le cycle sexuel et l'émission des gamètes chez les Mytilidés et les Pectinidés (mollusques bivalves). Revue Trav. Inst. Pêch. marit. 23: 387-548.

Medcof, J.C. and J.S. MacPhail 1955. Survey of bar clam resources of the Maritime Provinces. Fish. Res. Bd Can. Bull. 102, 6p.

Ricker, W.E. 1975. Computation and interpretation of biological statistics of fish populations. Fish. Res. Bd Can. Bull. 191, 382p.

Robson, D.S. and D.G. Chapman 1961. Catch curves and mortality rates. Trans. Am. Fish. Soc. 90: 181-189.

Segal, E. 1961. Acclimation in molluscs. Amer. Zool. 1: 235-244.

Yancey, R.M. and W.R. Welch 1968. The Atlantic coast surf clam - with a partial bibliography. Fish. & Wildl. Serv., Bur. Comm. Fish. Circ. 288, 14p.

Younker, D. and W.I. Judson 1971. Inshore bar clam survey. P.E.I. Dept. of Fisheries and I.D.B. Dept. of Fisheries and Forestry. 23p.

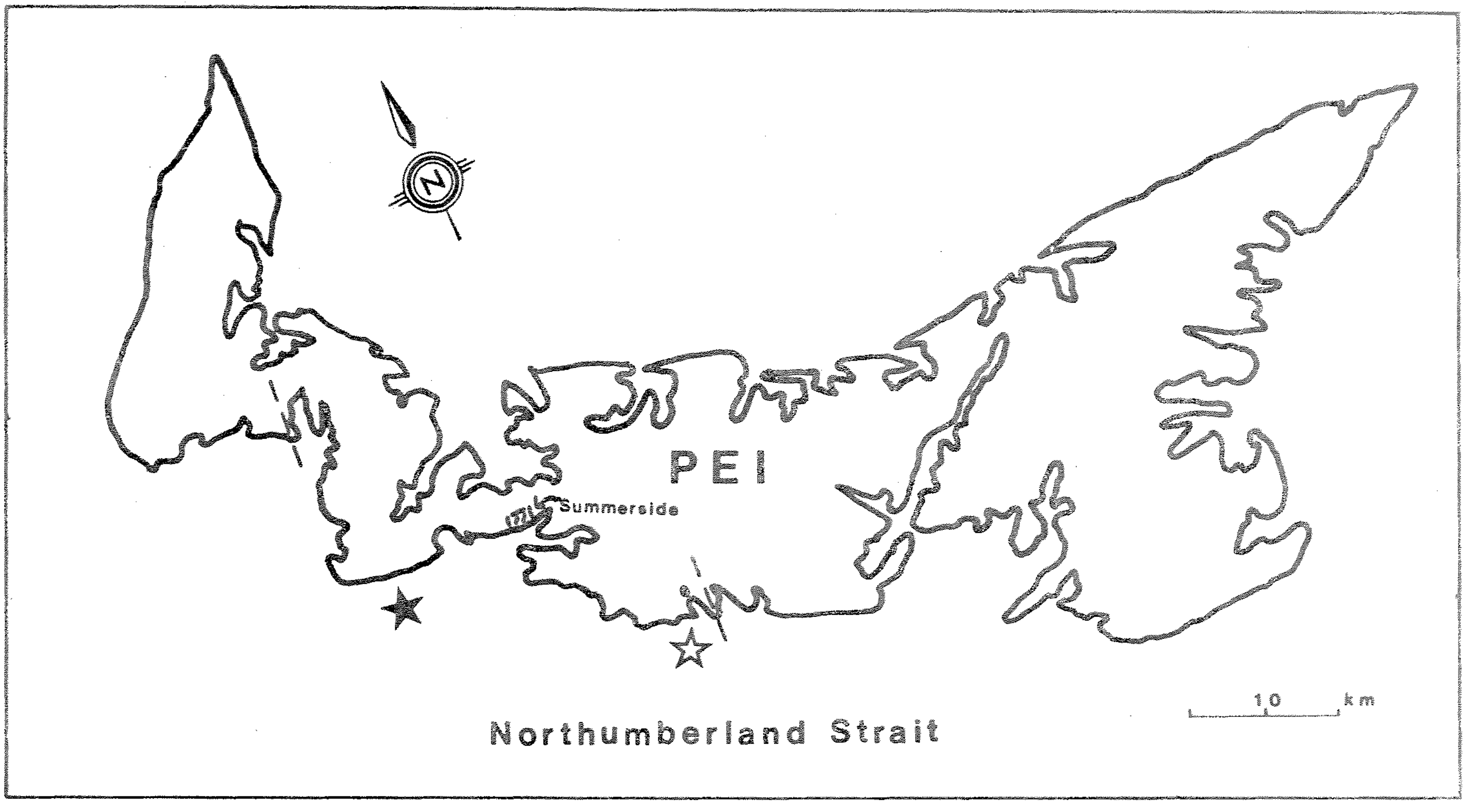

Figure 1. Prince Edward Island. The Mont-Carmel study site is indicated with a solid star and the Tryon shoals are located at the hollow star. The boundaries of the statistical district are marked with broken lines.

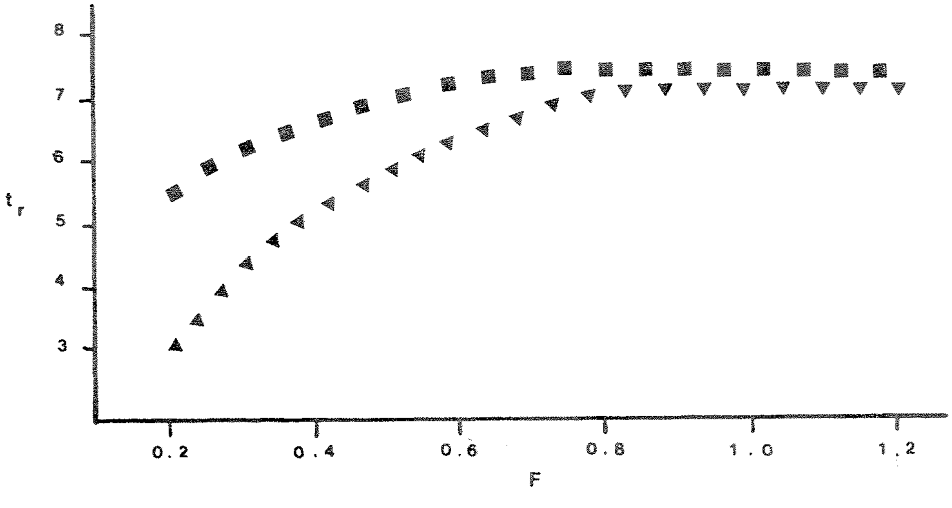

Figure 2. Effect of changes in optimal age at entry (t_r) with respect to the annual fishing rate (F) ■■ and changes in optimal F with respect to t_r ▲▲ on the yield per 100 recruits.