1982 Shellfish Management Advice, Pacific Region

G. S. Jamieson (Editor)

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Fisheries and Aquatic Sciences 1774

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ABSTRACT

Jamieson, G. S. (Editor). 1984. 1982 Shellfish Management Advice, Pacific Region. Can. MS Rep. Fish. Aquat. Sci. 1774: 71 p.

Biological advice given to resource managers by staff of the Shellfish Section in December, 1982 is presented as a series of documents. Topics discussed include the status of abalone (Haliotis kamtschatkana) and pink shrimp (Pandalus jordani) stocks; minimum size limits recommendations for prawns (P. platyceros), sea urchins (Stronglyocentrotus franciscanus), and scallops (Patinopecten caurinus, Chlamys rubida and C. hastata); and observations on British Columbia sea otter (Enhydra latris) abundance.

RÉSUMÉ

Jamieson, G. S. (Editor). 1984. Shellfish Management Advice, Pacific Region. Can. MS Rep. Fish. Aquat. Sci. 1774: 71 p.

Les conseils biologiques donnés, en décembre 1982, aux gestionnaires des ressources par le personnel de la Section des mollusques et crustacés sont présentés comme une série de documents. Les sujets traités comprennent la situation des stocks d'ormeau (Haliotis kamtschatkana) et de crevette océanique (Pandalus jordani), les recommandations sur la taille légale minimale de la crevette tachée (P. platyceros), de l'oursin (Stronglyocentrotus fransciscanus) et des pétoncles (Patinopecten caurinus, Chlamys rubida et C. hastata) et des observations sur l'abondance de la loutre marine (Enhydra latris) en Colombie-Britannique.

INTRODUCTION

The Fisheries Research Branch in the Pacific Region provides biological and scientific advice for managing, protecting, and developing the region's freshwater and marine resources. It consists of a number of sections, one of which is the Shellfish Section, and specific functions and areas of responsibility of this section are as follows:

1. to undertake research on the distribution, life history, ecology, physiology, and behavior of commercial and potentially commercial invertebrate and marine plant species;

2. to carry out resource surveys and the sampling of commercial catches for stock assessments of invertebrate and marine plant species;

3. to participate in research on the impact of natural and man-induced factors on the habitat of invertebrate and marine plant stocks;

4. to maintain fishery data bases and to develop analytical methods, including the use of theoretical models, to achieve the above;

5. to provide biological management advice to the management biologists and senior management, and to communicate research results to fishermen, industry, and the scientific community.

This collection of manuscript documents is the scientific basis for shellfish fisheries management advice given in December, 1982 by the Fisheries Research Branch in the Pacific region. As such these documents address the issues of the day in the time frames required and are not intended as definitive statements on the subjects addressed. Rather, they should be considered as progress reports on ongoing investigations.

BIOMASS, YEAR-CLASS ABUNDANCE, AND DISTRIBUTION OF PINK SHRIMP

by

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A. INTRODUCTION

This document summarizes the data collected on the May 1982 G.B. REED shrimp biomass survey of shrimp grounds off Tofino, Nootka Sound and in Queen Charlotte Sound. The survey was designed to collect data for estimating the total biomass, year-class abundance, and distributions of the smooth pink shrimp, Pandalus jordani. In addition to the trawl survey, oceanographic temperature observations were collected.

B. METHODS

The biomass trawl survey was carried out in all three areas using a standard 61-ft, high-rising, N.M.F.S. shrimp sampling trawl. This trawling gear has been described in detail. The temperature observations were made using expendable bathythermographs (XBTs).

The trawl locations for the biomass of Tofino and Nootka grounds were established on a systematic grid pattern based on Loran C blocks. Tows were made diagonally through adjacent 5990-X blocks along 5990-Y lines. Successive 5990-Y lines were 20 microseconds apart. The trawl locations for the Queen Charlotte Sound biomass survey were made on a Loran C grid in which tows were made diagonally through 5990-X blocks 20 microseconds apart along successive 5990-Y lines 15 microseconds apart. Variations in the grid patterns occurred when exploring new areas, avoiding bad bottom, or being set off by the tide and wind.

Tows lasted 30 min and covered a range of distances from 1.2-1.9 M. Upon completion of each tow, the large fish were removed from the invertebrates, and small fish was put into tubs and weighed. One tub was then sorted into shrimp and scrap, the percentage of shrimp by weight per tub was determined, and the total shrimp catch for the tow was then extrapolated. Random samples of shrimp were weighed and the number of shrimp per kilogram determined. The samples were then sexed and measured and the information obtained was used to determine the various year-class strengths.

The biomass for each area was calculated by using a planimeter to measure the areas of concentration in square nautical miles. This area was then multiplied by the mean catch per nautical mile towed and the number of tows required to sweep a square nautical mile using the NMFS shrimp survey trawl (174). The 95% confidence levels on the estimated biomasses for the different areas were calculated by assuming a normal distribution within any concentration. This assumption may not be correct and further calculations on transformed data will be calculated at a later date.

C. RESULTS

Total catch (kg) by species for the west coast of Vancouver Island (Tofino and Nootka grounds) and Queen Charlotte Sound is given in Tables 1 and 2, respectively.

1. Tofino ground

The Tofino shrimp ground is a fishing area which lies offshore of the west coast of Vancouver Island between 48°40' and 49°15'. The concentration of shrimp for this survey was found to be distributed in four concentrations.

The major area of concentration was a 27 M^2 area located in the southern portion of the ground from Loran C 5990-Y-29145 and 5990-Y-29205 between 68 and 82 fathoms. The catch rates in this area ranged from 7 to 653 kg per half-hour towed.

The next major concentration was found in a 16 M^2 located in the northern portion of the ground from Loran C 5990-Y-29285 to 5990-Y-29325 between 67 and 79 fathoms. The catch rates in this area ranged from 11 to 180 kg per half-hour towed.

The remaining two concentrations of shrimp were both small 5 M^2 areas located at the southern and northern extremes of the ground. The catch rates for the southern and northern areas averaged 3 and 15 kg half-hour towed, respectively.

The total combined shrimp biomass for all four areas was estimated at 813 metric tonnes which is only 53% of the 1982 estimated biomass. Within these areas the shrimp ranged in size from 153 to 476 shrimp per kilogram with a weighted mean count of 195 shrimp per kilogram.

At the 95% confidence level the biomass estimate ranged from 0 to 1,108 M.

2. Nootka ground

The Nootka ground is a fishing area which lies offshore off the west coast of Vancouver Island between 49°15' and 49°35'. During this survey the shrimp were only located in one 26 M^2 area in the central portion of the ground from Loran C 5990-Y-29465 to 5990-Y-29525 between 68 and 77 fathoms.

The estimated biomass for the shrimp concentration in this area was 171 M which was on 12% of the 1981 estimated biomass. Within this area the shrimp ranged in size from 166 to 264 shrimp per kilogram with a weighted mean count of 246 shrimp per kilogram.

At the 95% confidence level the biomass estimate ranged from 0 to 398 metric tonnes.

Table 1. The total catch for the survey off the west coast of Vancouver Island (Tofino and Nootka grounds) summarized by important species.

Total number of hauls = 82

Species	Kg	Percent
Pink (Jordani)	1612.	15.58
Sun starfish	1.	0.01
Brittle stars	8.	0.08
Sea urchins	3.	0.03
Heart urchin	4.	0.04
Sea cucumber	36.	0.35
Box crab	3.	0.03
Dab (Pacific)	41.	0.40
Dover sole	30.	0.29
English sole	8.	0.08
Flathead sole	426.	4.12
Halibut	68.	0.66
Petrale sole	9.	0.09
Rex sole	80.	0.77
Slender sole	99.	0.96
Turbot	105.	1.01
Rockfish	37.	0.36
S. borealis	2.	0.02
S. brevispinis	34.	0.33
S. crameri	31.	0.30
S. elongatus	5.	0.05
S. flavidus	49.	0.47
S. paucispinis	278.	2.69
S. pinniger	185.	1.79
S. proriger	14.	0.14
S. ruberrimus	10.	0.10
S. zacentrus	12.	0.12
Blackcod	29.	0.28
Cymatogaster	5.	0.05
Eulachon	2602.	25.15
Hake	4.	0.04
Herring	76.	0.73
Lingcod	848.	8.20
Pacific cod	89.	0.86
Walleye pollock	279.	2.70
Sculpins	1.	0.01
Shad	4.	0.04
Tomcod	137.	1.32
Dogfish	3046.	29.44
Ratfish	1.	0.01
Skates	26.	0.25

3. Queen Charlotte Sound

The survey in Queen Charlotte Sound was conducted in the N.E. and N.W. corners of the Goose Island grounds. Shrimp were caught in 7 of the 10 tows made in the N.E. corner grounds with the catch rates varying from 2 to 46 kg per half-hour towed. Shrimp were caught in 5 of the 7 tows made in the N.W. corner grounds with the catch rates varying from 4 to 13 kg per half-hour towed. The shrimp counts ranged from 182-250 shrimp per kilogram with the entire area having a weighted mean count of 222 shrimp per kilogram. In comparing the size of shrimp from this survey with the mean count of 312 shrimp per kg in the 1981 survey, it can at first glance be speculated that there is a paucity of juvenile shrimp in the catches of this year's survey.

Biomass estimates were not attempted for these grounds since time constraints prevented conducting sufficient survey trawls to delineate the total area of shrimp concentrations. A non-parametric Mann-Whitney U test was carried out comparing the 1982 tows (number of shrimp per M towed) with the 1981 and 1980 tows for both the N.E. and N.W. corners of the Goose Island grounds. The results of the tests indicate that the catch rates for the N.E. Goose Island grounds have not changed significantly over the last three surveys, but that the catch rates for the N.W. grounds were significantly higher (at a 0.05 level of significance) in 1981 than in either the 1982 or 1980. The comparison between 1982 and 1980 catch rates for the N.W. grounds showed no significant change.

Table 2. The total catch for the survey in Queen Charlotte Sound summarized by important species.

Total number of hauls = 17.

Species	Kg	Percent
Pink (Jordani)	133.	5.47
Sidestripe	1.	0.04
Sponges	6.	0.25
Gonatus magister	1.	0.04
Heart urchin	1.	0.04
Sea cucumber	7.	0.29
Dover sole	70.	2.88
English sole	1.	0.04
Flathead sole	25.	1.03
Halibut	55.	2.26
Turbot	888.	36.51
Rockfish	4.	0.16
S. aleutianus	6.	0.25
S. alutus	573.	23.56
S. babcocki	45.	1.85
S. brevispinis	11.	0.45
S. entomelas	1.	0.04
S. flavidus	8.	0.33
S. helvomaculatus	1.	0.04
S. pinniger	6.	0.25

Cont'd

Species	Kg	Percent
S. proriger	51.	2.10
Seb. alascanus	5.	0.21
Blackcod	92.	3.78
Eulachon	46.	1.89
Herring	8.	0.33
Lingcod	44.	1.81
Pacific cod	4.	0.16
Walleye pollock	7.	0.29
Dogfish	292.	12.01
Ratfish	15.	0.62
Skates	25.	1.03

D. DISCUSSION

Generally the Tofino and Nootka fisheries are managed on a quota system. In order to set precautionary total allowable catches for the areas, the estimated biomasses are applied to exponential yield at equilibrium models.

$$Ye = B_{\infty} \; Fe^{-m \frac{1}{K} n F}$$

The resulting TACs are implemented as of May 1 of the current year, with the areas remaining open until the quota is taken or until May 1 of the following year when new TACs are recommended.

For the Tofino grounds the 1982 stock assessment estimated the biomass at ~813 M which indicated a decline in virtual growth from the 1981 levels. Because of the low biomass estimates the recommended quota of 113 M was derived by applying a reconstructive strategy to an exponential model of the grounds (Fig. 1). This reconstructive strategy only allowed for an exploitation rate of approximately 40% of the yield at equilibrium (~280 M). No quota was set for either the Nootka ground or Queen Charlotte Sound as it was believed that it would be uneconomical to fish these areas. These areas are to remain open to fishing as it was felt that any information obtained from a commercial fishery which might help explain the apparent decline in stocks would be worth the risks of fishing on an apparently uneconomical stock. To date any attempted fishery in the area has met with an apparent lack of success.

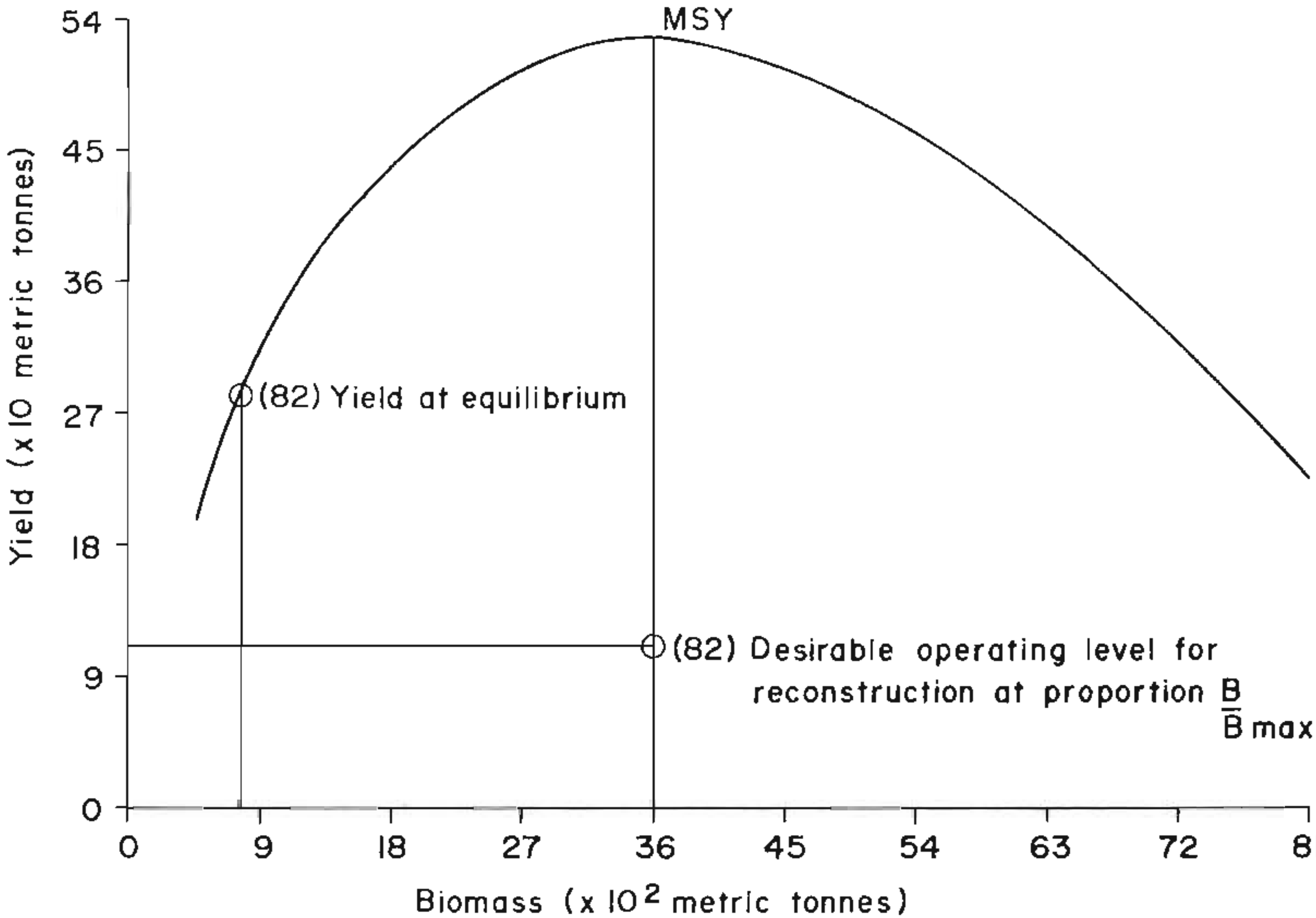

Fig. 1. Tofino Grounds exponential model yield at equilibrium.

PRAWN - MINIMUM SIZE LIMIT

by

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A. INTRODUCTION

This document discusses the rationale for the adoption of a minimum size limit for prawns (Pandalus platyceros) into the shellfish regulations.

B. METHODS

The analysis used in this document was Ricker's method of estimating equilibrium yield per given recruit.

$$Y_E = \sum_{t=t_R}^{t=t_b} \frac{(F_t B_t [1 + e^{G_t - Z_t}])}{2}$$

This method was chosen as it incorporates age specific differences in growth rates, natural mortality rate, rate of fishing; and it easily allows for examination of varying fishing strategies such as different minimum size limits, open and closed seasons, etc. Implicit in the use of this analysis is that the situation hypothesized has been in effect long enough to allow the population to establish an equilibrium condition.

The estimates of age specific growth rates, natural mortality rates, and availability to fishing mortality were obtained from a series of research surveys carried out on the prawn stocks in Knight Kingcome Inlet. No estimate of an equilibrium F was available for this analysis because the information from the commercial fishery is so poor.

C. RESULTS

The results of the analysis are presented in two parts. The first part will discuss estimates of realistic F values and the second part will deal with a manipulation of age at first capture and the resulting yield to the fishery. An important part of the analysis to determine the benefits with changing age at first capture, is the inclusion of a price differential of .75 for small (13-24 month) prawns to 3.00 for medium (25-36 month), and large (37-48 month) prawns. The initial analysis looked at the monthly F max and $F_{0.1}$ for all cohorts combined with recruitment starting at 13 months. The results of this analysis gave a monthly $F_{0.1}$ of .14 (Fig. 1). An important consideration that arises with a level of F as large as this is that these animals are protandic hermaphrodites and only function as females in the final year of life. This life history strategy necessitates that a certain proportion of a cohort must be available to function as females at the time of terminal spawning, i.e., the 48 month mark. It is evident in Fig. 2 that at a level of $F \geq .14$ there would be little if any female spawning biomass escaping. It was felt that a more realistic level of F could be obtained by adopting the approach of estimating the F max and $F_{0.1}$ for a fishing strategy which maximizes the yield from the 36+ month individuals. The results of this analysis can be seen in Fig. 3A which indicates an F max of .051 and an $F_{0.1}$ of .041. These are much more realistic levels of F as they still allow for a female terminal spawning biomass.

For the purposes of the comparative portion of this analysis it will be assumed that the levels of F max and $F_{0.1}$ would still allow the population to remain at equilibrium. In viewing the resulting changes in biomass when the population is unfished (Fig. 4) it is evident that the maximum biomass of a cohort is obtained at the age of 28 months. Since the nature of the fishery does not allow for a knife edge harvesting strategy it was felt that the more beneficial strategy was to evaluate the results of increasing the age of first capture from 13 months to 25 months. The results of the changing shape of the yield curve can be seen in Fig. 3B. From this analysis it was evident that firstly the Fmax has increased and results in a higher production from 37+ month portion of the life history.

Table 1 shows the results of a comparison of the total yield and economic return of the two F max (37+) and $F_{0.1}$ (37+) for the 13-48 and 25-48 month exploitation strategies. It is seen in Fig. 5A that if F remains constant the value of the catch is higher at any monthly F>.028. It is also evident in Fig. 5B that for any constant F, a delay of the age at first capture results in an increased spawning biomass.

D. RECOMMENDATIONS

It is evident from this analysis that at a monthly $F \geq .028$ an increase in age of first capture will almost surely benefit the industry if the assumptions are correct about price differential, growth rates, natural mortality rates, and availability qualifiers. Even with a monthly $F < .028$ (Fig. 5A) the benefits to the industry are not appreciably reduced by increasing the age of first capture to 25 months. It is, therefore, recommended that an increase in age of first capture would be a positive regulation to institute. Using the growth rates from the Knight and Kingcome Inlet study, increasing the age at first capture to 25 months would be equivalent to putting a minimum size limit of 30.0 mm carapace length or 106 mm (4.2 inches) in total length, as measured from the posterior margin of the orbit of the eye to the tip of the telson when the prawn is fully extended but not stretched. The problems that are inherent in this regulation are: (1) the variability of growth rates between areas, (2) the release of undersize prawns.

Table 1. Comparisons of the total yield and economic return of the two fishing strategies F Max and F 0.1.

At F Max

F (13 to 48)		Yield	F (25 to 48)		Yield	
F Max = .051	1+	1021.83	F Max = .066	1+	-0-	
	2+	1258.55		2+	1888.39	+50%
	3+	545.74		3+	696.53	+27.6%
	Total	2826.12		Total	2584.92	-08.5%
	Spawning biomass	266.60		Spawning biomass	234.62	-12.0%
	Value *	$6179.24		Value *	$7754.76	+25.5%

*Values of the resource are based on a value of $.75/pound for 1+ and $3.00/pound for 2+ and 3+ animals.

At F 0.1 = .041 monthly

Age (months)		Yield (13-48)		Yield (25-48)		Econ.
1+ 13-24		836.63		-0-		.75/pound
2+ 25-36		1104.15		1311.64	+18.8%	3.00/pound
3+ 37-48		533.31		633.53	+18.8%	3.00/pound
		2474.09 lb.		1945.17 lb.	-21.4%	
	Value	$5539.85	Value	$5835.51	Value +5.1%	
	Spawning biomass	349.24		414.87	+18.8%	

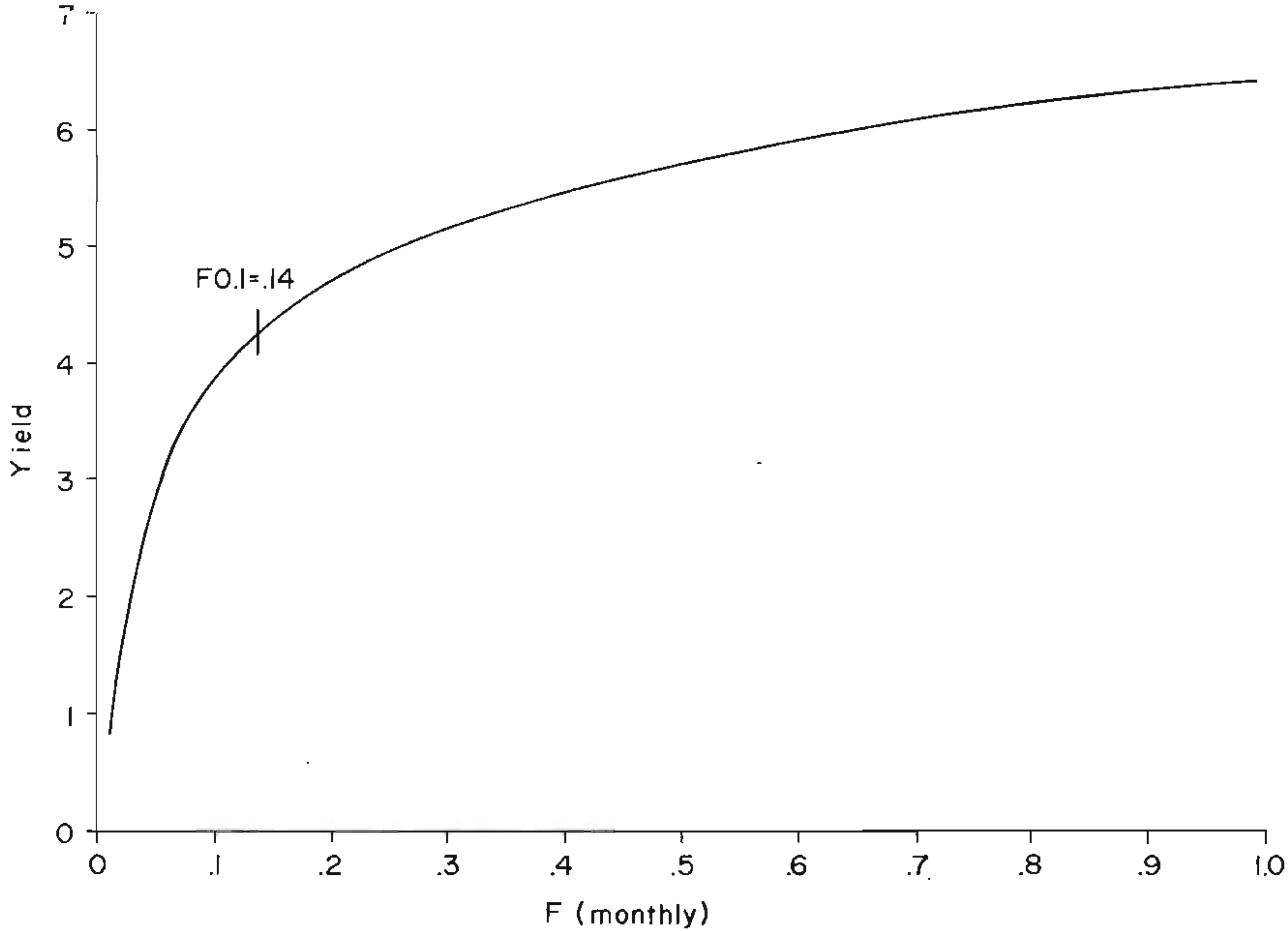
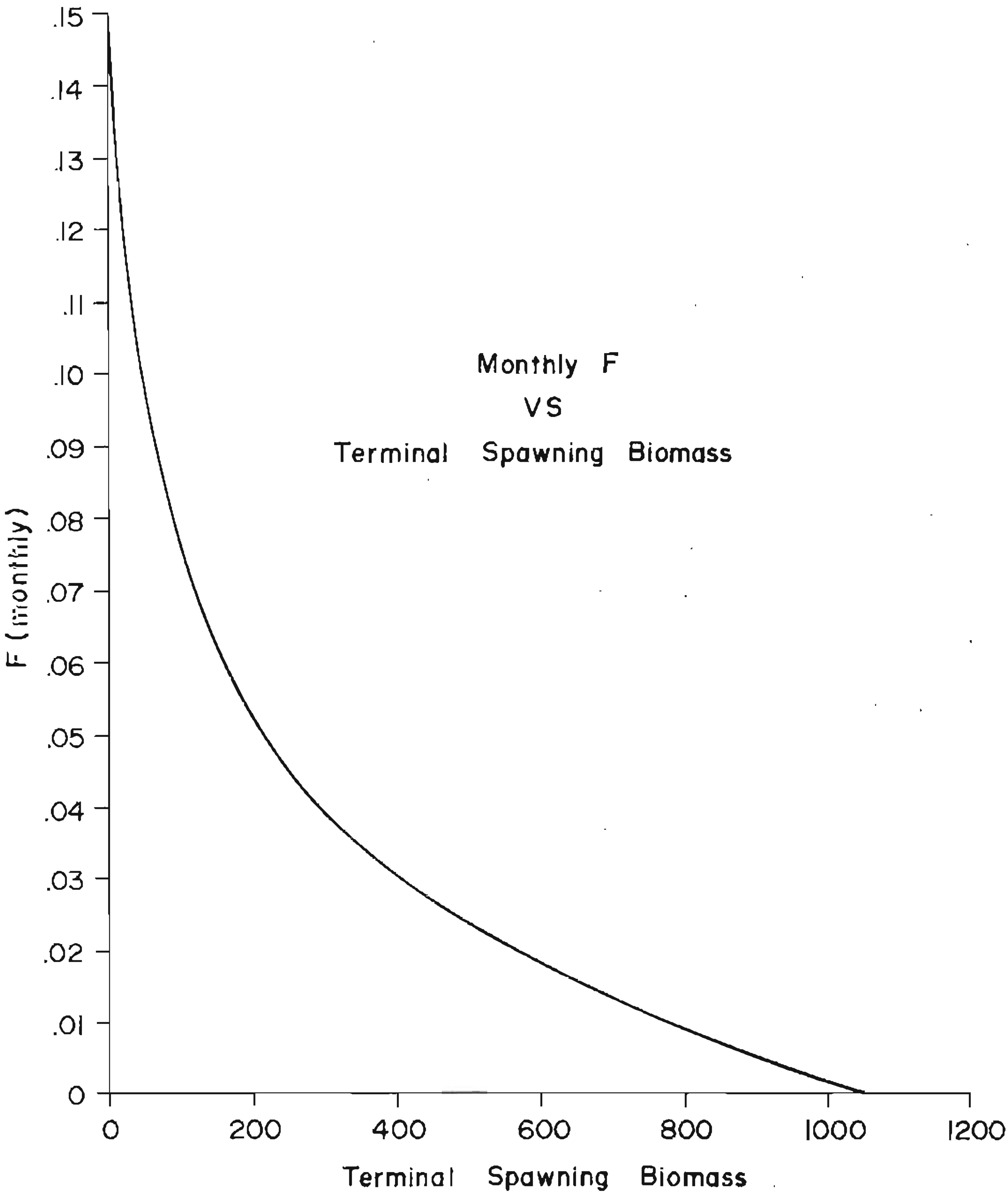


Fig. 1. Ricker yield/recruit all cohort.

Fig. 2


.15
.14
.13
.12
.11
.10
.09
.08
.07
.06
.05
.04
.03
.02
.01
0
F (monthly)
Monthly F
VS
Terminal Spawning Biomass
0
200
400
600
800
1000
1200
Terminal Spawning Biomass

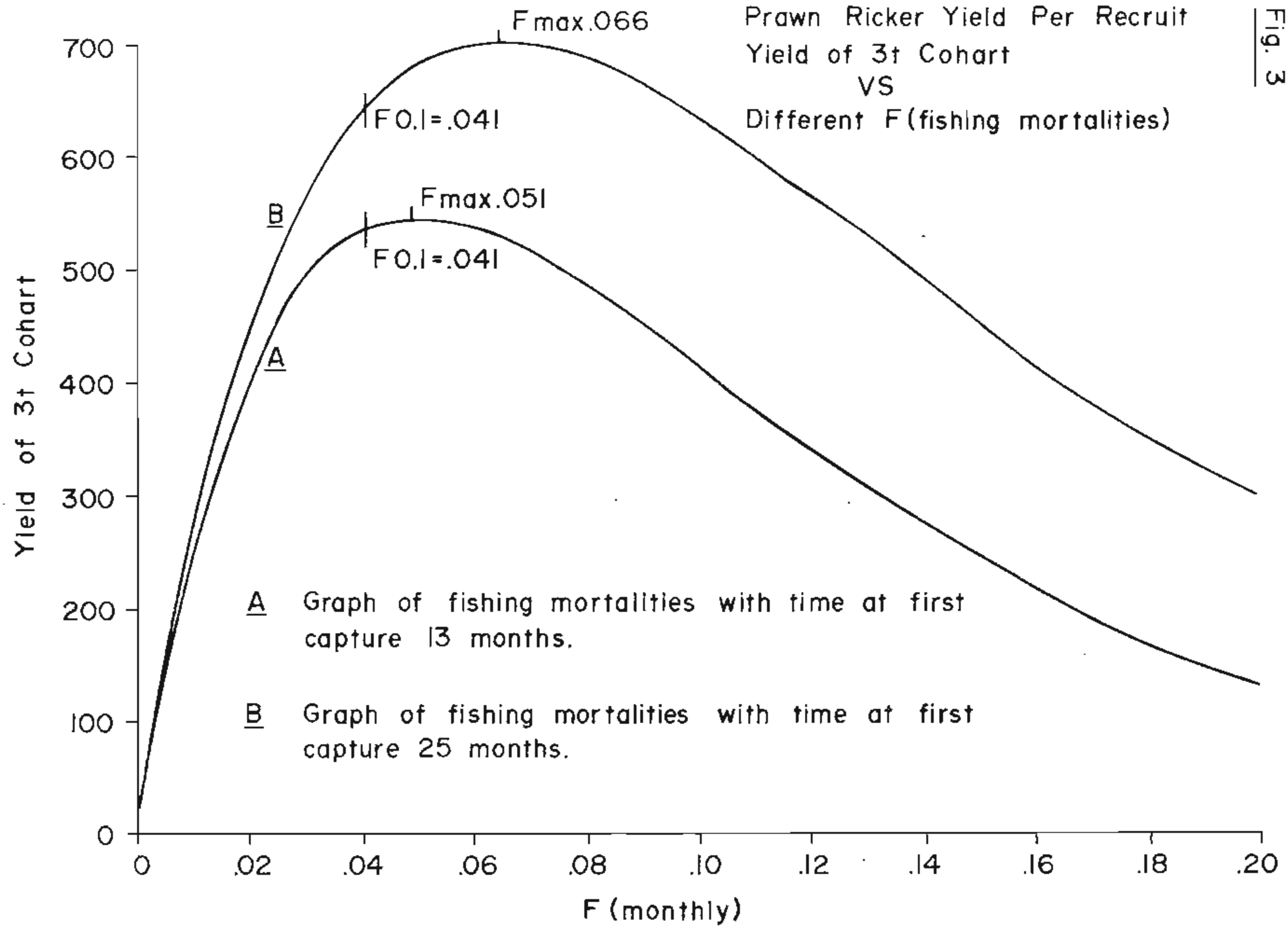

Prawn Ricker Yield Per Recruit
Yield of 3+ Cohart
VS
Different F(fishing mortalities)
Fmax.066
F0.1=.041
Fmax.051
F0.1=.041
B
A
A Graph of fishing mortalities with time at first capture 13 months.
B Graph of fishing mortalities with time at first capture 25 months.
Yield of 3+ Cohart
700
600
500
400
300
200
100
0
0
.02
.04
.06
.08
.10
.12
.14
.16
.18
.20
F (monthly)

Fig. 3

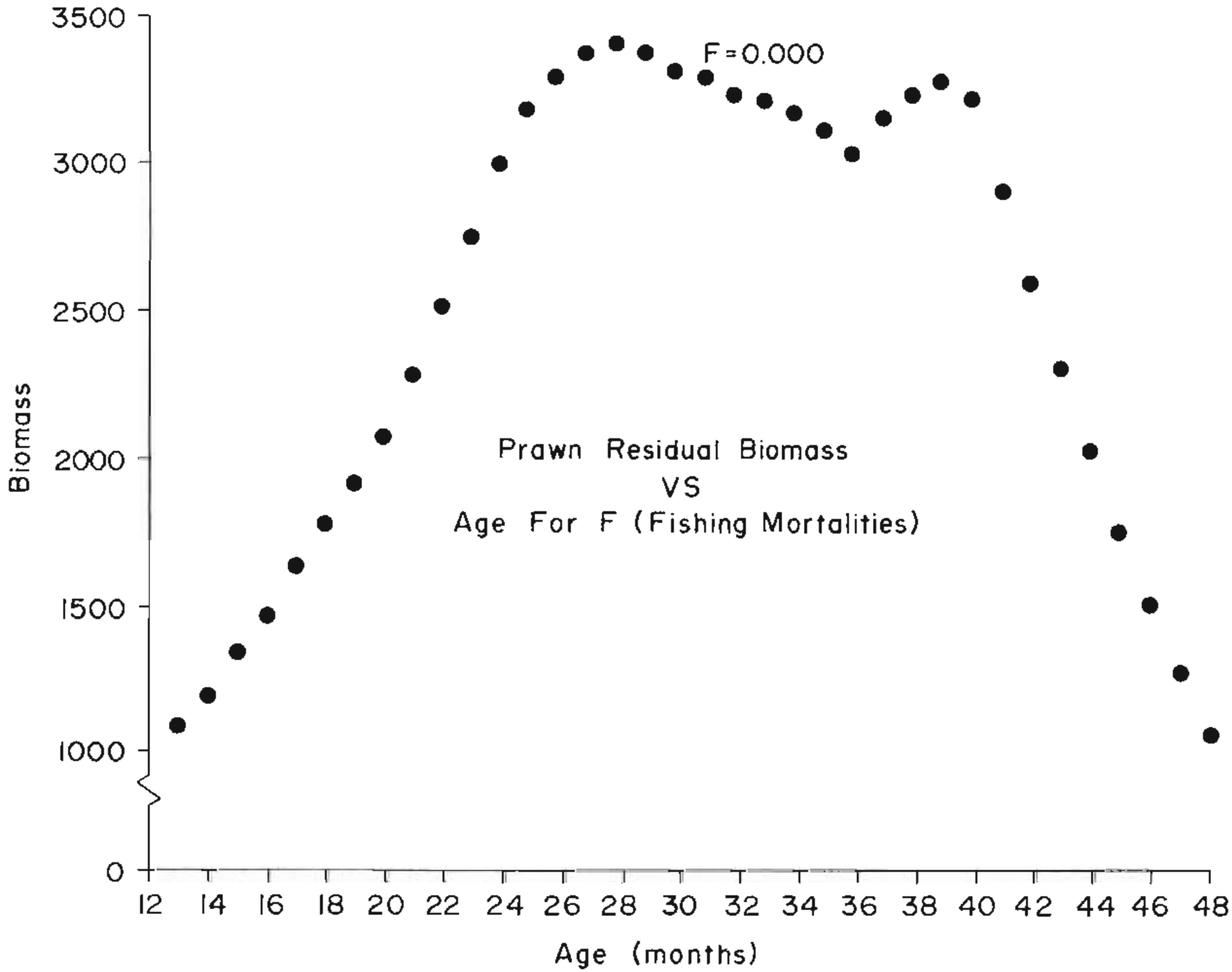
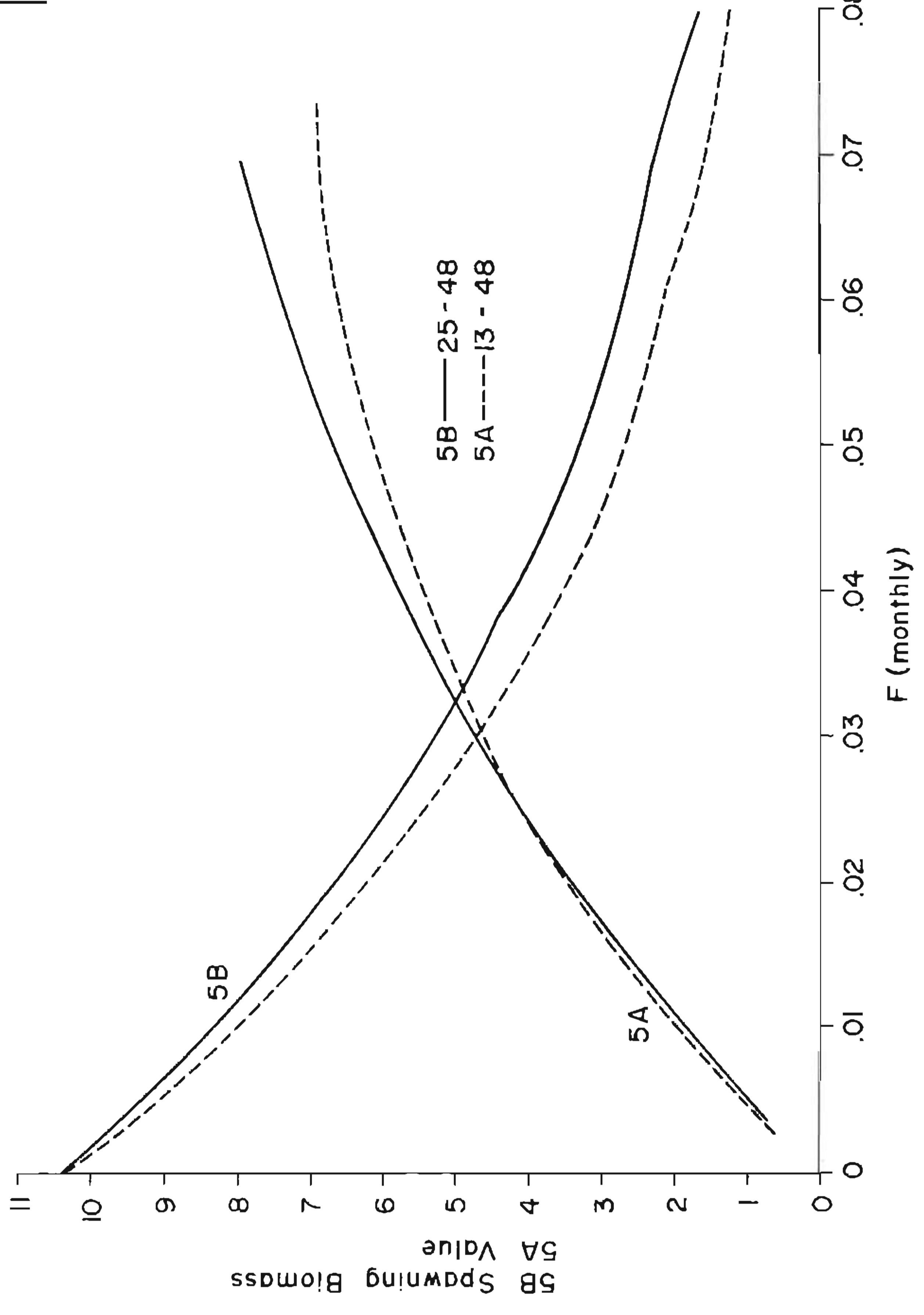

F=0.000
Prawn Residual Biomass
VS
Age For F (Fishing Mortalities)
Biomass
Age (months)
3500
3000
2500
2000
1500
1000
0
12 14 16 18 20 22 24 26 28 30 32 34 36 38 40 42 44 46 48

Fig. 4

Fig. 5


5B —— 25 - 48
5A - - - - 13 - 48
5B
5A
F (monthly)
5B Spawning Biomass
5A Value
0
.01
.02
.03
.04
.05
.06
.07
.08
0
1
2
3
4
5
6
7
8
9
10
11

SEA URCHINS: SUITABILITY OF THE PRESENT MINIMUM SIZE LIMIT

by

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This report is in response to a management biologists request for advice concerning the minimum size limit in the roe fishery for red sea urchins (Strongylocentrotus franciscanus), based on present knowledge of sea urchin biology. The present size limit is 100 mm in test diameter. The industry has complained that sea urchins larger than about 125 mm have poorer quality gonads (roe) than smaller individuals; and they argue that the size limit should be reduced to the minimum size which can be processed (about 75 mm).

A. RATIONALE BEHIND THE PRESENT LIMIT

When the present size limit of 100 mm was imposed, Dr. F. R. Bernard was in charge of sea urchin research. I asked him about the rationale, and received the following response:

"A size was set because Field Services Branch felt some limit was necessary. We believed a size limit was not necessary as the fishery economics would look after this. The 4" (100 mm) test-diameter was reasonable, as it did not in fact hinder the fishery and allowed probably 3 spawning years prior to harvest."

B. POSSIBLE FUNCTIONS OF A MINIMUM SIZE LIMIT

There are several possible purposes for enacting a minimum size limit. These are:

1) To prevent individuals being harvested at a small average size, when a greater yield per recruit could be taken by allowing the average size at harvest to increase.

This consideration is not independent of the level of fishing effort. If effort is very low, then average size at harvest will be close to the average size of available individuals in the virgin population. At very high levels of effort, average size at harvest will be close to the minimum size available. In situations where yield is being maximized, the average size at harvest should be close to 'critical size' of a cohort, which is the point where growth balances natural mortality. To do this, the minimum size should be smaller when effort is low, and larger when effort is higher.

It isn't possible to find the best minimum size without knowing something about effort. However, the minimum size doesn't matter much if effort is low. If effort is high, then to maximize yield per recruit minimum size should approach critical size.

2) The minimum size can be used to protect part of a population as a breeding reserve. If fishing effort is very high, the minimum size can be made large enough so that significant reproduction occurs before individuals are available to harvest. The minimum size in such a case is designed to prevent 'recruitment over-fishing'. For many fisheries, it has been suggested that a suitable minimum size could function to manage the fishery by itself, in the way just described. At high levels of effort, however, reproductive effort can be reduced to a point where recruitment 'fails' (falls below replacement levels), and the population declines.

3) In red sea urchins, a special argument for a size limit might appear. A high percentage of juveniles in their first year of life are found underneath the 'spine canopy' of adults. This appears to result from active behaviour in both the adults and juveniles. Thus it might be necessary to ensure that enough adults remain to protect the settlement of juveniles. This, and the market preference, is the basis for the two-part size limit used to manage the roe fishery in Washington State. The Washington State limits are 3.75 and 5.0 inches (95.3 and 127.0 mm) for outside waters, and 4.5 and 5.5 inches (114.3 and 139.7 mm) for essentially inside waters.

In a related way, a two-part limit might also function to spread out the effort. When most of the adults are removed from a local area, red sea urchins re-group in a small part of their former local range. In this situation, recovery is very slow, as juveniles are found only in the habitat occupied by adults (Breen, Adkins and Miller 1978).

As with the other two functions of a minimum size limit, the effect of a two-part limit is dependent on fishing effort. At high levels of fishing mortality, few individuals would survive the period of vulnerability to the fishery to reach the upper size limit. As protected large adults died out, the upper size limit would protect fewer individuals.

C. CONSIDERATIONS BASED ON AVAILABLE DATA

1. Are smaller sea urchins more suitable for the roe industry?

The scientific information on this point are scarce. Bernard & Miller (1973a) give a relation (their Figure 10, reproduced here as Figure 1) showing that gonad weight increases with test diameter at a decreasing rate. Unfortunately, they do not plot the actual data; and among their figures relating test diameter, body weight and gonad weight contain some inconsistency. Figure 2 shows one of their data sets selected at random and plotted (Bernard & Miller 1973b). There is no evidence in this figure of a decreasing rate of gonad weight increase. Kramer & Nordin (1975) show monthly plots of gonad weight as a function of test diameter: one of these is shown here as Figure 3. The data would be described better by a power function than by the straight linear relation used by these authors. The data clearly support a continuing upward curve with none of the S-shape imagined by Bernard & Miller.

These data show that gonad weight is continuously greater in larger sea urchins. Kramer & Nordin (1975) examined gonad quality in their study; but they do not relate quality to size. No other authors have examined gonad quality in the local species. Thus there is no information on the relative quality of gonads from large and small individuals, except for the preference of the processors.

2. What is critical size?

To estimate the critical size, one compares growth and mortality rates. Both might vary with size; but mortality is usually so difficult to estimate that it is considered to be constant over a wide range of sizes.

a. Growth

Bernard & Miller (1973a) published a suggested growth rate based on size frequency shifts. The method by which they elucidated these shifts is not given. Figure 4 shows a Ford-Walford plot based on the positions of clearly-defined year classes within all those sea urchin populations measured by Breen (unpub. data) from 1979 to the present. From this relation, a growth curve was constructed. This curve and the curve of Bernard & Miller are seen in Figure 5.

The relation between gonad weight and test diameter was determined from the data set for December 1974 published by Kramer & Nordin (1975) (these are the same data already seen as Figure 3). This relation was determined to be:

$$\ln \text{gonad wt(g)} = -7.466 + 2.519 \ln \text{test diameter (mm)}$$

The growth curve and gonad-test diameter relations were combined to produce the age-gonad weight relation seen in Figure 6, and from this the instantaneous rate rate of gonad growth was calculated:

$$G = \ln (wt_{(t+1)}/wt_{(t)})$$

b. Mortality

Mortality rate was examined with the method of Breen & Fournier (1983). This method uses known growth parameters and the observed length frequencies to estimate total mortality. For the method to work well, annual recruitment to the population should be reasonably constant. Repeated observations at several sites, and the appearance of size frequencies observed at many sites (for examples see Breen & Adkins 1981), indicate that in many locations recruitment is instead quite erratic. Accordingly, 7 sites were chosen where gaps in recruitment were not seen, and where extensive measurements from quadrats had been taken.

Table 1 shows the instantaneous mortality rates estimated from these sites. Estimated total mortality was negative at four of the 7 sites, and ranged from 0.016 to 0.22 at the remaining three sites. It is not possible to have a negative mortality rate. The explanations might be one of the following, or a combination of them:

- mortality rate is not constant over the range of sizes analysed; it is instead high in small individuals and low in larger individuals;
- there has been a consistent decrease in recruitment;
- growth parameters have been estimated with large biases;
- the data were collected with a sampling bias.

For several reasons, the first of these possible explanations seems most likely. Sea urchins are least vulnerable during their first year of life, when they are protected by the spine canopy of adults; then they become highly vulnerable to predators as they grow, finally they become less vulnerable as they reach a refuge in size. Total mortality rate of adults must be low for this explanation to work. A value of of 0.1-0.2 could be accepted, as the table suggests. This would correspond with annual survival rates of 82-91%. Such an estimate would imply a critical size of at least 130 mm. Critical size might be even larger if mortality is, lower.

3. When do sea urchins first reproduce?

Bernard & Miller (1973a) suggest first reproduction at 50 mm.

4. What would be the immediate impact of changing the size limit?

Table 2 gives the length frequency of sea urchins measured at 22 sites in Barkley Sound, Clayoquot Sound and various parts of the north coast in recent work. The collective frequency is shown in Figure 7. The median size is just below 100 mm. Between 100 and 125 mm lies 30% of the total population. Only 16% are larger than 125 mm, the size which is reported to be rejected by the processors. If the size limit were reduced by (25 mm) 1" to (75 mm) 3", an additional 23% of the population would become vulnerable to fishing.

5. What are the sizes of adults which are 'parental'?

Figures 8 and 9 show the sizes of 'parental' adults (those with juveniles <50 mm diameter under their spine canopy) and non-'parental' adults measured at Kunga Island in April 1982. 'Parental adults range from about 95 mm upward. Although their mean size is larger than non-'parentals', they represent a good cross-section of the adult sizes available. Results from Barkley Sound are similar.

D. RECOMMENDATIONS

1. The two-part size limit

The advantages of a two-part size limit are that it could allow smaller sizes to be taken than at present, that it would protect 'parental' size adults, and that it would spread the effort out over a larger area.

There are two disadvantages to using a two-part size limit as the main conservation tool. First, at high levels of fishing effort, few individuals would recruit to the protected group of large individuals, which would eventually die out. Thus, the two-part size limit provides little real protection at high levels of effort. Second, gonad quality is dependent as food supply (Mottel 1976), and there may be strong competition for food in sea urchin populations (Breen unpub. data). The industry claims that reducing stock size, and especially removing the larger individuals, results in increased gonad quality in the target sizes. A two-part size limit would largely prevent this effect.

For these reasons, it is recommended that a two-part size limit not be employed.

2. The present minimum size limit

It is not clear what function the present size limit performs. At high levels of effort, the size limit will not maximize yield per recruit, will allow most of the breeding potential to be removed, and will not protect 'parental' adults. At the same time, if the anecdotal information concerning market quality is correct, the present limit prevents the fishery from using the best part of the stocks.

It seems unlikely that the red sea urchin fishery should be managed by a size limit alone. Size limit capable of protecting the breeding stock would probably be larger than the industry's upper limit for market quality. A better method of managing would be by controlling effort or catch in such a way as to protect local stocks from over harvesting.

REFERENCES

Bernard, F. R., and D. C. Miller. 1973a. Preliminary investigation on the red sea urchin resources of British Columbia (Strongylocentrotus franciscanus (A gassi)). Fish. Res. Bd. Tech. Rept. 400: 37 pp.

Bernard, F. R. and D. C. Miller. 1973b. Morphometric data for a preliminary investigation on the red sea urchin resources of British Columbia (Strongylocentrotus franciscanus Ag.). Fish. Res. Bd. Can. MS Rept. 1256: 97 pp.

Breen, P. A., and B. E. Adkins. 1981. Observations of abalone populations on the north coast of British Columbia, July 1980. Can. MS Rep. Fish. Aquat. Sci. 1633: 55 pp.

Breen, P. A., B. E. Adkins, and D. C. Miller. 1978. Recovery rate in three exploited sea urchin populations from 1972 to 1977. Fish. Mar. Serv. MS Rep. 1446: 27 pp.

Breen, P. A., and D. A. Fournier. 1983. Estimation of mortality rate in abalone with growth analysis. Trans. Am. Fish Soc. 112: 403-411.

Kramer, D. E., and D. M. A. Norden. 1975. Physical data from a study of size, weight and gonad quality for the red sea urchin (Strongylocentrotus franciscanus) (Agassiz)) over a one-year period. Fish. Res. Bd. Can. MS Report 1372: 91 pp.

Mottet, M. G. 1976. The fishery biology of sea urchins in the family Strongylocentrotidae. Wash. Dept. Fish. Tech. Rep. 20: 66 pp.

Table 1. Mortality rate estimated from seven sea urchin populations.

Place	Total mortality rate (Z)
Lyell Island	-0.039
Hoskins Islet	0.016
Pelican Point	0.219
Section Cove	0.128
Ohiat Island 1979	-0.154
Ohiat Island 1982	-0.061
Taylor Islet	-0.089

Table 2. Size frequency of all sea urchins observed at 22 sites, percent frequency and cumulative percent frequency.

Size (mm)	Number	Percent	Cumulative percent
0	0.0	0.00	0.00
2	0.0	0.00	0.00
4	0.0	0.00	0.00
6	1.0	0.02	0.02
8	17.0	0.33	0.35
10	15.0	0.29	0.64
12	23.4	0.45	1.09
14	23.0	0.44	1.53
16	22.4	0.43	1.96
18	57.7	1.11	3.08
20	55.4	1.07	4.15
22	62.7	1.21	5.36
24	56.1	1.08	6.44
26	61.3	1.18	7.62
28	74.3	1.43	9.06
30	65.3	1.26	10.32
32	61.4	1.19	11.50
34	63.1	1.22	12.72
36	53.1	1.02	13.75
38	36.4	0.70	14.45
40	41.7	0.80	15.25
42	51.0	0.98	16.24
44	37.7	0.73	16.97
46	36.0	0.69	17.66
48	36.8	0.71	18.37
50	43.7	0.84	19.22
52	34.7	0.67	19.89
54	26.7	0.52	20.40
56	32.0	0.62	21.02
58	26.4	0.51	21.53
60	25.7	0.50	22.02
62	31.0	0.60	22.62
64	51.0	0.98	23.61
66	43.0	0.83	24.44
68	38.7	0.75	25.18
70	59.0	1.14	26.32
72	55.0	1.06	27.38
74	77.0	1.49	28.87
76	63.0	1.22	30.09
78	103.0	1.99	32.07
80	71.0	1.37	33.45
82	111.0	2.14	35.59
84	114.0	2.20	37.79
86	107.0	2.07	39.85
88	92.0	1.78	41.63
90	114.0	2.20	43.83
92	106.0	2.05	45.88

Table 2 (cont'd)

Size (mm)	Number	Percent	Cumulative percent
94	97.0	1.87	47.75
96	96.0	1.85	49.60
98	87.0	1.68	51.28
100	84.0	1.62	52.90
102	113.0	2.18	55.08
104	121.0	2.34	57.42
106	101.0	1.95	59.37
108	99.0	1.91	61.28
110	123.0	2.37	63.65
112	135.0	2.61	66.26
114	135.0	2.61	68.87
116	117.0	2.26	71.12
118	136.0	2.63	73.75
120	137.0	2.64	76.39

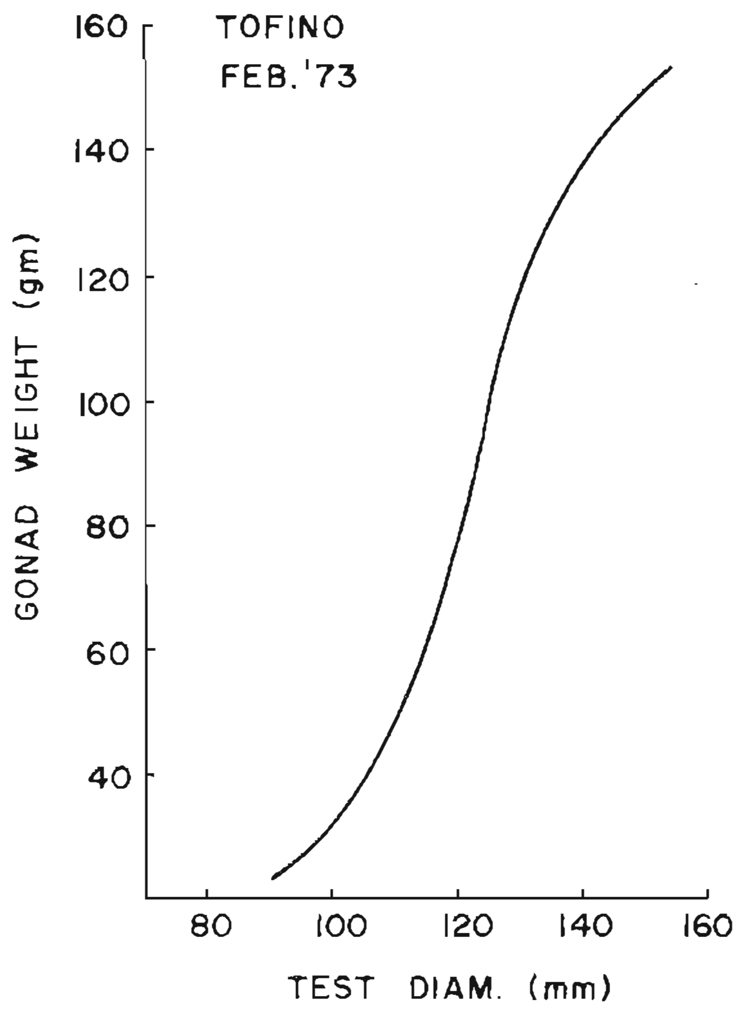

Fig. 1. Gonad weight-test diameter relationship for red urchins from west coast of Vancouver Island, from Bernard and Miller (1973a).

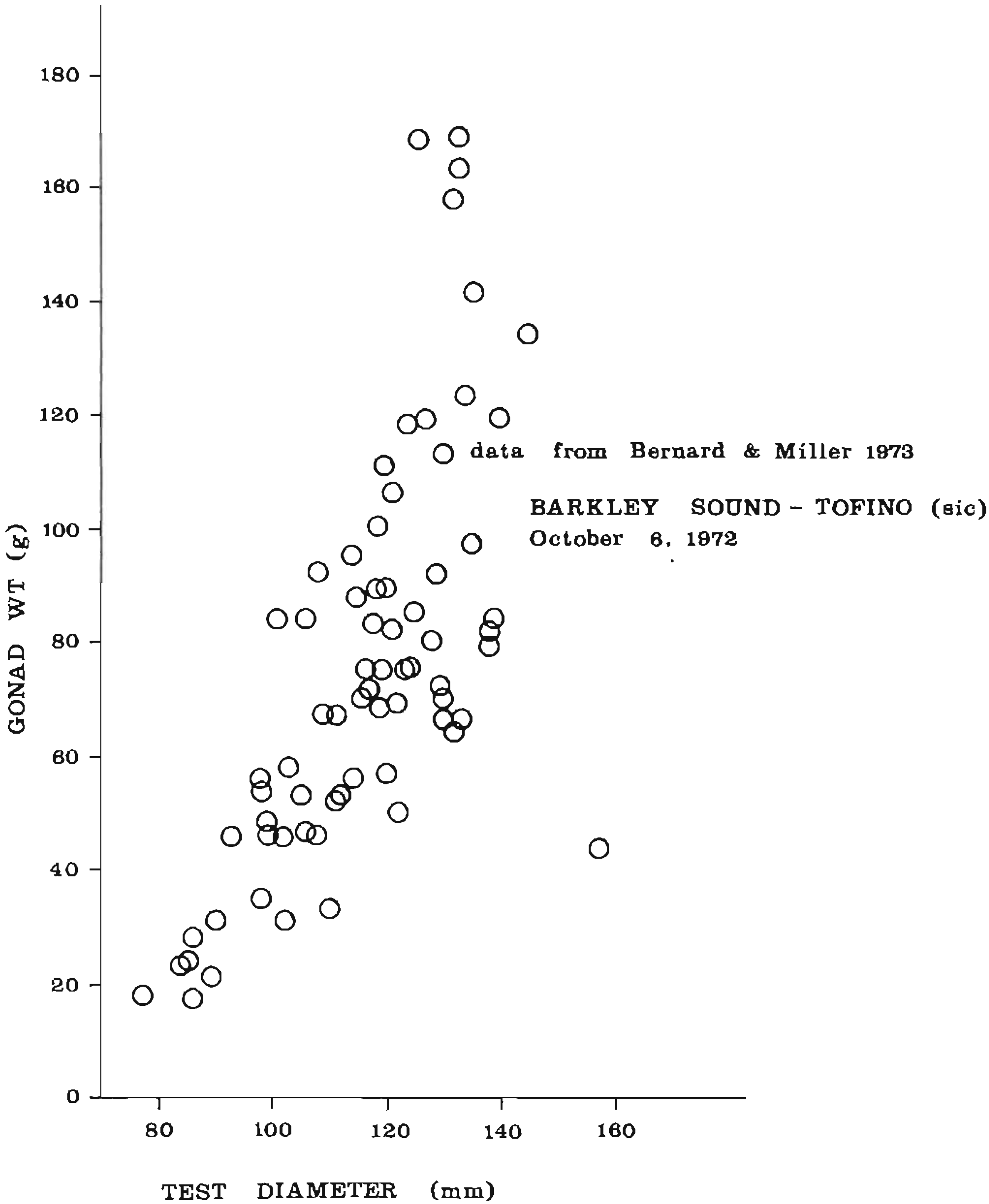

Fig. 2. Gonad weights vs test diameter from Bernard and Miller (1973b).

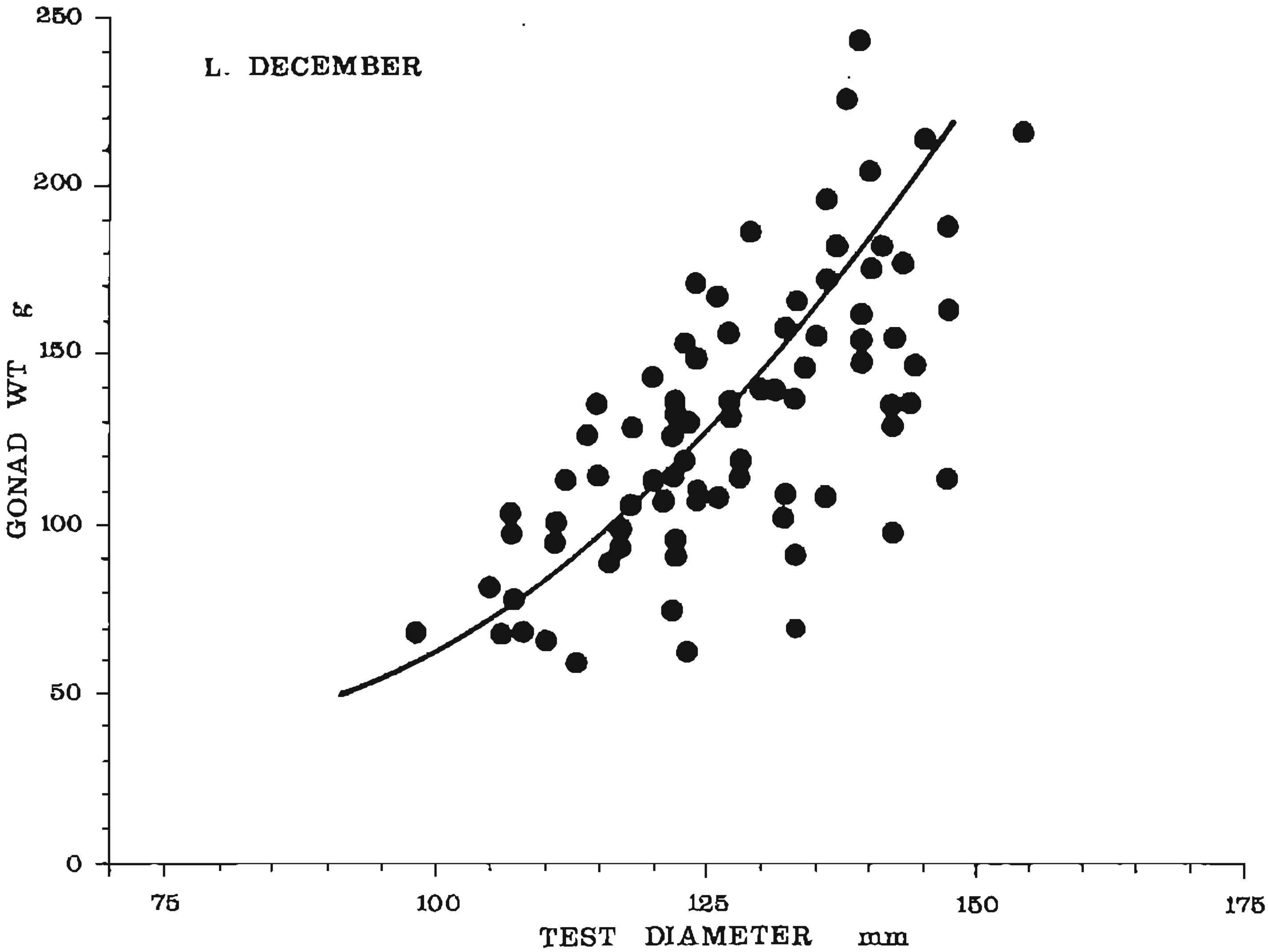

Fig. 3. Gonad weight vs test diameter from Kramer and Nordin (1975).

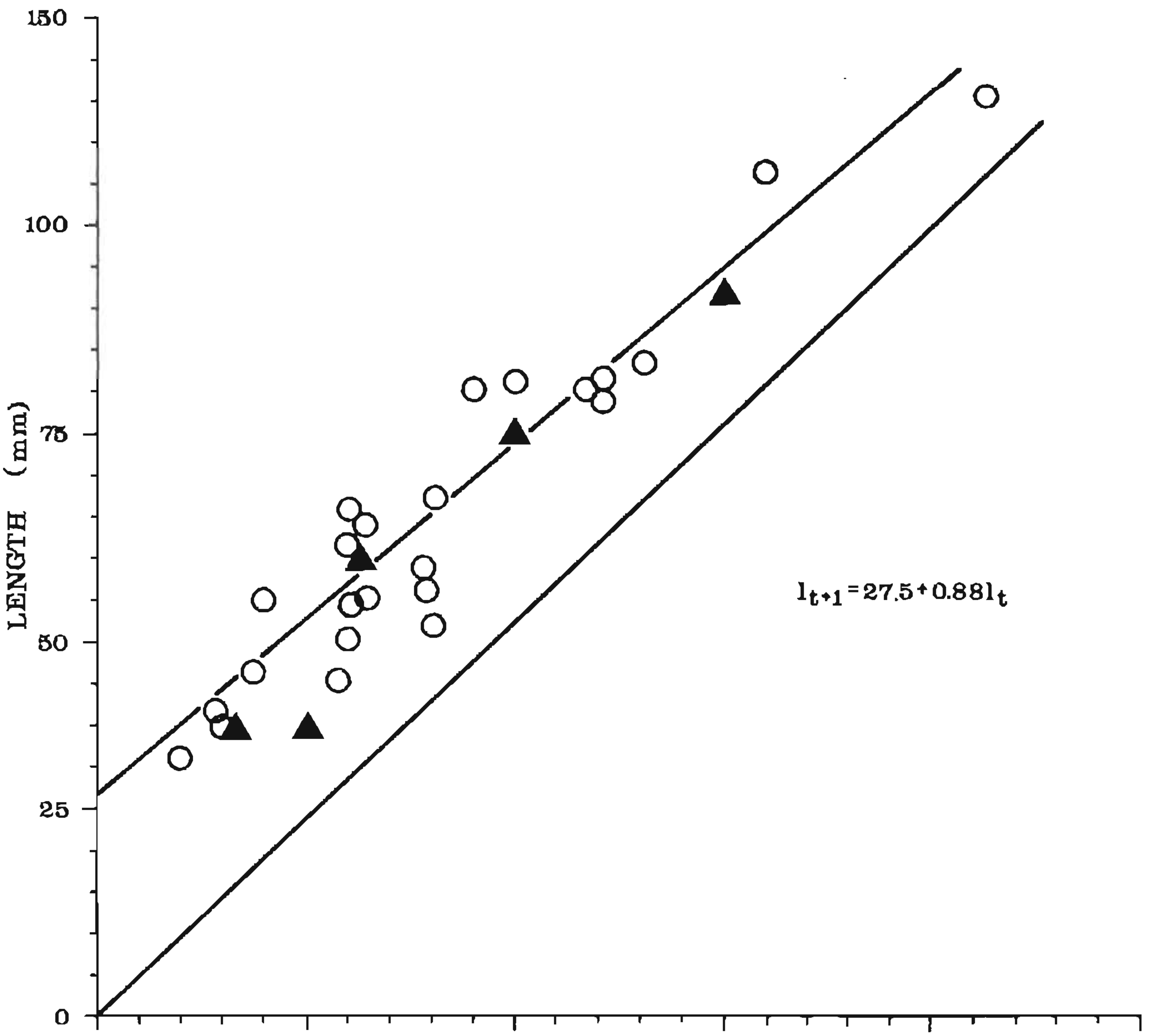

Fig. 4. Ford-Walford plot based on mean lengths of distinct size classes in all sea urchin samples 1979-1982.

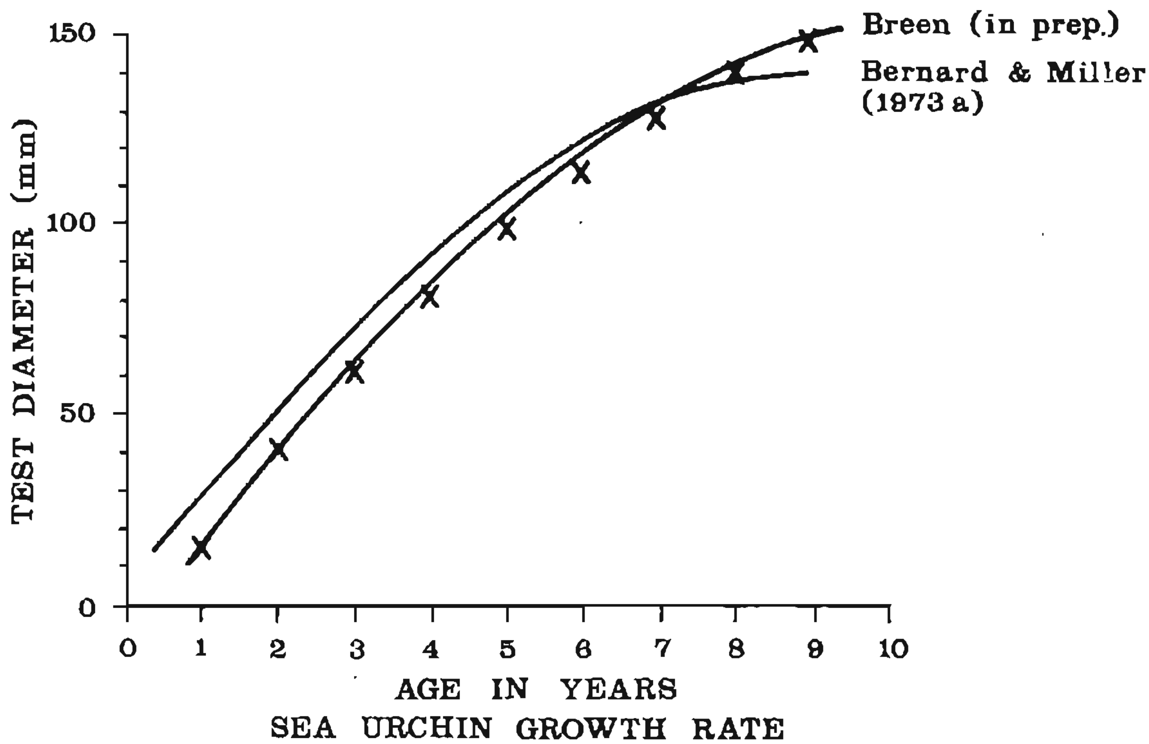

Fig. 5. A suggested growth curve based on Fig. 4, compared with the curve of Bernard and Miller (1973a).

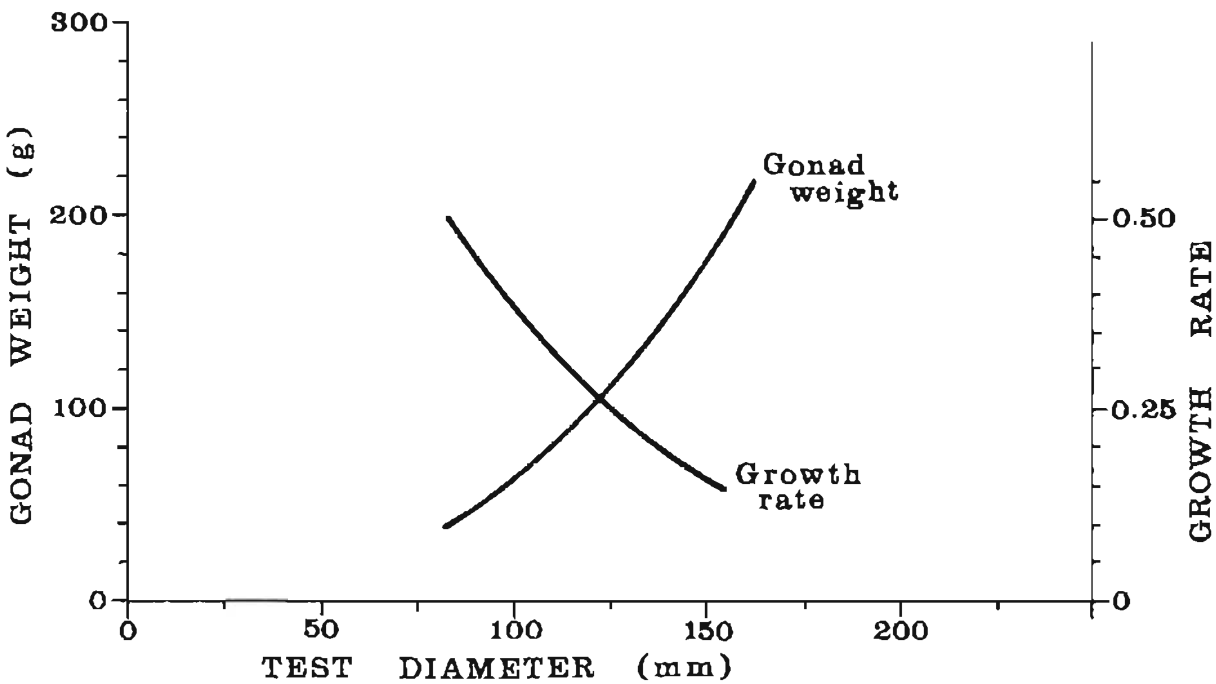

Fig. 6. Growth and growth rate of gonads, based on the growth curve in Fig. 5 and data from Kramer and Norden (1975).

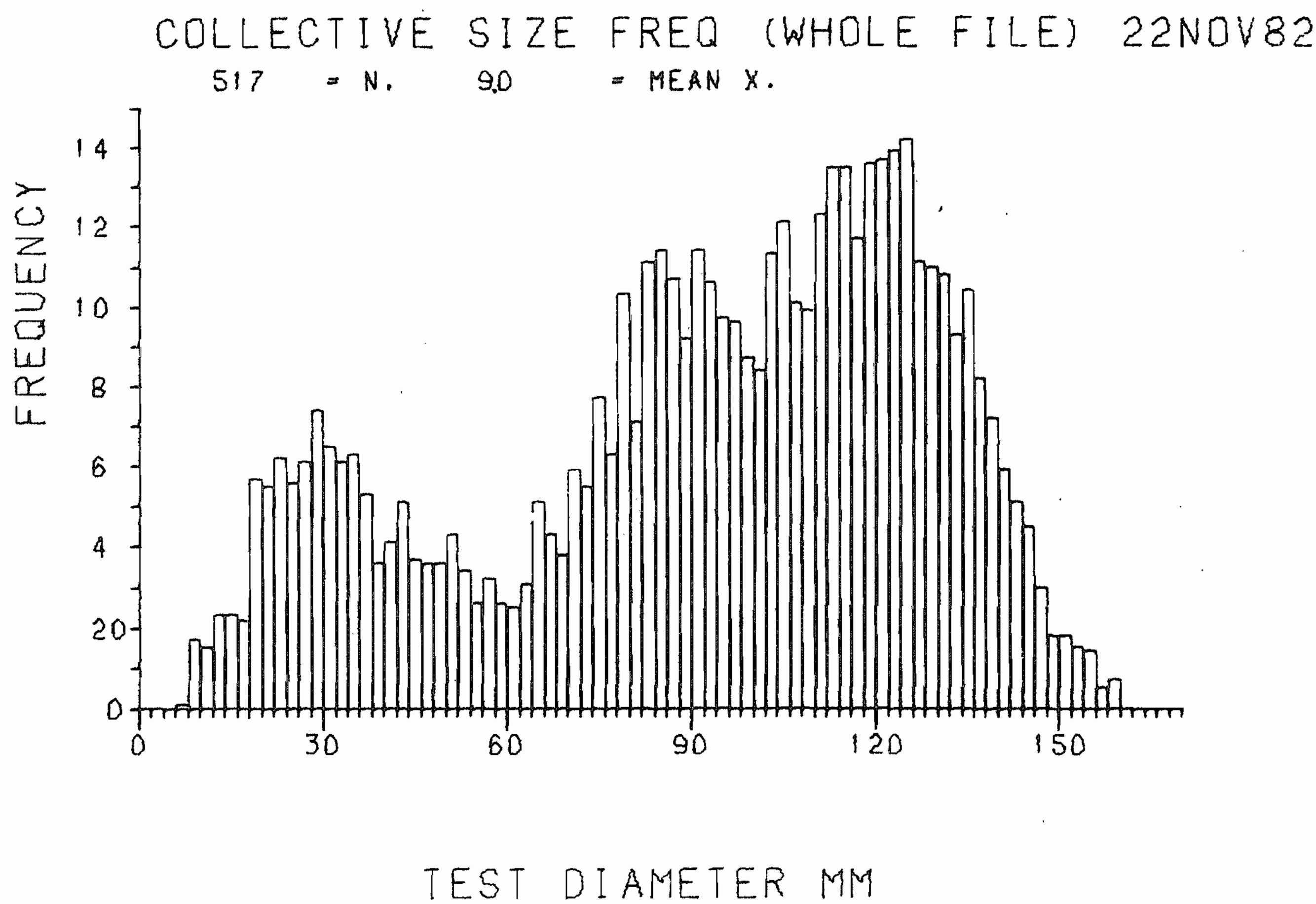

Fig. 7. Size frequency of all sea urchins in 22 population samples, 1979-1982.

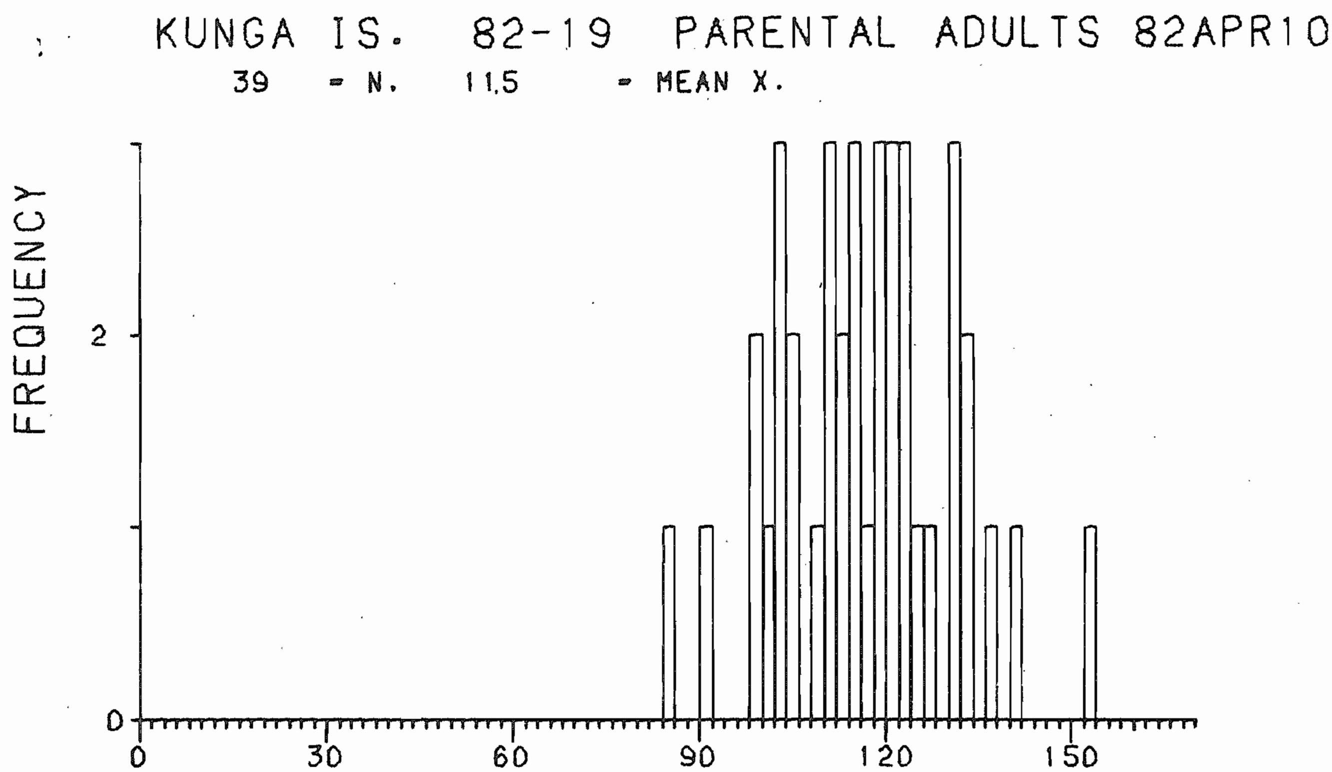

Fig. 8. The size frequency of parental adult sea urchins at Kunga Island, April 1982.

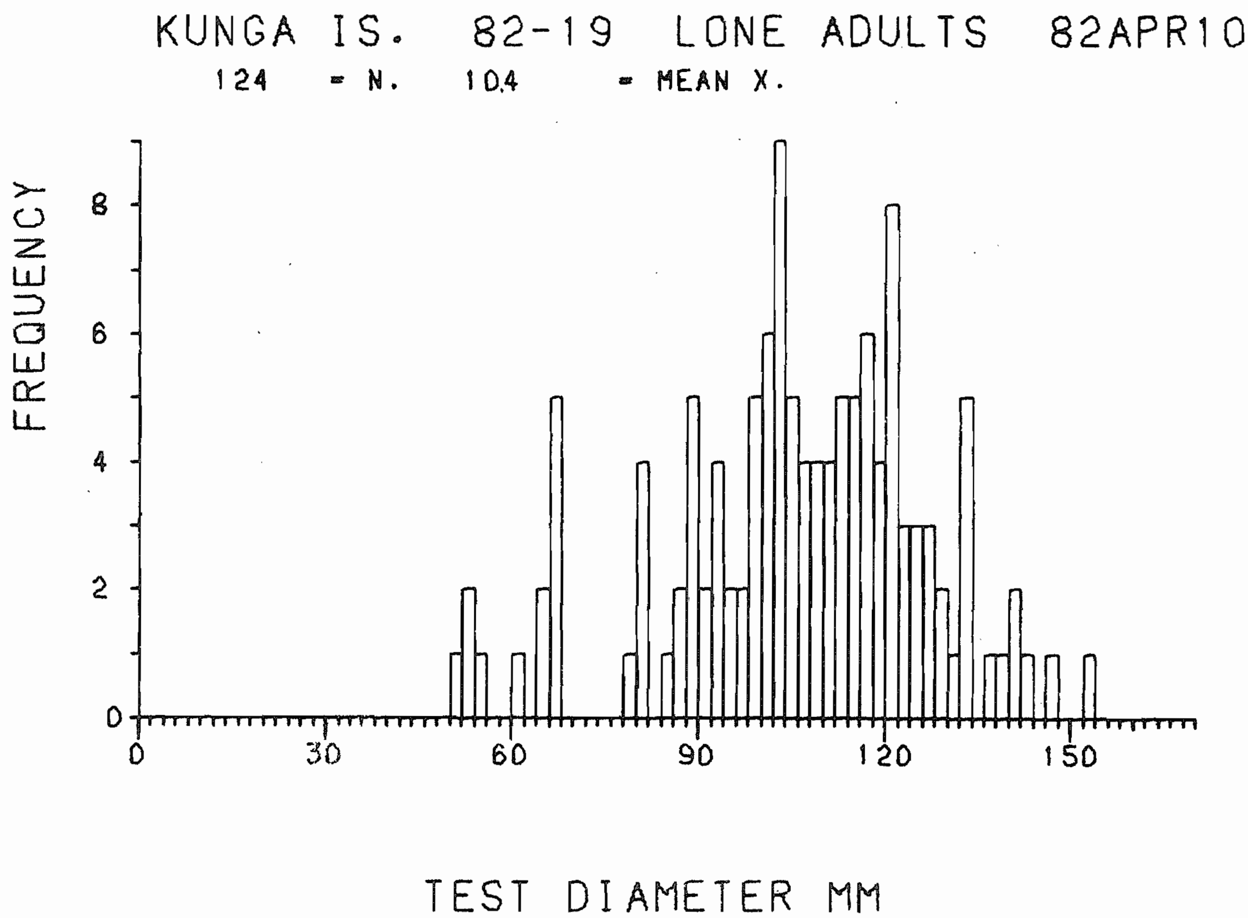

Fig. 9. The size frequency of non-parental adult sea urchins at Kunga Island, April 1982.

RECOMMENDATIONS FOR THE 1983 ABALONE SEASON

by

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A. CONCERNS ABOUT THE FISHERY

For at least two years, I have made the following comments to managers and the industry:

1) We cannot realistically measure abalone stock size with present and reasonable future resources.

2) Without a very significant increase in resources, we have learned all that we reasonably can about growth, mortality and recruitment rates.

3) The method of estimating sustainable yield (Breen 1980) contains some assumptions that further work (Breen and Adkins 1982) has shown to be faulty. These include the assumptions of constant recruitment and no sublegal mortality. The failure of these assumptions means that yield cannot be as high as the estimate of 115 t initially made in 1980.

4) Some areas, which were included in the total area for which the quota was calculated, are no longer actually available to the fishery. This means that the remaining area is perhaps being harvested at a higher rate than the estimated sustainable rate. The 1982 quota was 90.7 t.

5) Stocks are at a low level of abundance that with the natural variance around mean density (Breen 1980), it is difficult to measure further changes in abundance. If the present quota management comes at all close to producing an equilibrium fishery, it will not be possible to measure any small decreases or increases in density.

Based on these points, in 1981 it was recommended that the quota be reduced from 90.7 t to 57 t. After some discussion, management biologists decided to let the 1982 quota stand at 90.7 t and to watch the fishery carefully.

While there is no hard evidence that abalone stocks are continuing to decline (which at this point might be ipso facto evidence of over-fishing), there are several indications that this is the case. These are:

1) Both the relative catch and catch per unit effort (catch/diver day) continue a long decline in the Charlottes and in the north coast as a whole. Area 6 holds its own. The south coast shows an increase in effort, catch, and catch/effort. The increased catch/effort probably does not reflect an increased stock size. Instead, it may reflect the deflection of boats to the south coast, which has not been fished as hard as the north coast.

2) Fishery Officers report boats having difficulties finding their quotas in areas previously having good stocks; this is particularly true in the Queen Charlotte Islands.

3) Poaching, which was unimportant previously, has become a problem in the Victoria area, as shown by a number of arrests and convictions. The extent of poaching is unknown in the north coast. Poaching removes stock that should be included in the quota.

B. RECOMMENDATIONS

If stocks really are declining, then this small fishery is in trouble until a few good year-classes rebuild the stocks. The following recommendations are made:

1) that a joint FSB-FRB survey be made in 1983 to measure density where it was measured during the period 1978-1980. This survey should involve the industry; both so that the work is credible to them, and so that they have a chance to direct the surveyors to any good beds they know.

2) For the reasons outlined above, the quota should be reduced from 90.7 t.

3) It is recommended that unused parts of the quota at the end of a year not be carried over into the next year.

4) Since stocks were estimated to have declined by 60-75% (Breen 1980) as early as late 1978, they may now be at a small part of their virgin level. Although the relation between abalone stock and recruitment is unknown, the conservative course would be to protect as much breeding potential as possible. Since the breeding stock includes stunted sub-legal abalone, it is recommended that requests for permits to transplant surf abalone on a commercial scale be restricted to limited experimental studies.

REFERENCES

Breen, P. A. 1980. Measuring fishing intensity and annual production in the abalone fishery of British Columbia. Can. Tech. Rept. Fish. Aquat. Sci. 947: 49 pp.

Breen, P. A. and B. E. Adkins. 1982. Observations of abalone populations on the north coast of British Columbia, July 1980. Can. MS Rep. Fish. Aquat. Sci. 1633: 55 pp.

OBSERVATIONS OF THE B.C. SEA OTTER TRANSPLANT

by

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This report describes observations made in the area of the British Columbia sea otter transplant in the Bunsby Islands, 24-28 August 1982.

A. BACKGROUND

For most of this century, sea otters (Enhydra lutris) have been absent from British Columbia, or practically so, after very heavy hunting for their pelts. The last known native animal was shot near Kyuquot in 1928 (Cowan and Guiget 1965). From 1969 through 1972, 89 animals were transplanted from Alaska to the Bunsby Islands near Kyuquot. These transplants are described by Bigg and MacAskie (1978).

In the summers of 1977 and 1978 the transplant colony was counted from the air by Graeme Ellis of the Pacific Biological Station. His estimates were 55 individuals in the Bunsby Islands and 15 on the Bajo Reefs off Nootka Sound. From the air, Farr (pers. comm.) obtained a maximum count of 58 in the Bunsby Islands in 1980.

Derek Ellis, University of Victoria, and his students made observations in the summer of 1978, as part of the Cook Bicentennial year. They described the feeding habits and the area occupied by the population (Morris et al. 1981). In 1979, underwater communities where sea otters had fed were examined, and the area that had been foraged by sea otters was surveyed (Breen et al. 1982). We found that sea otters had eliminated sea urchins almost completely from their feeding range, that other large prey organisms were absent, and that these areas were characterized by large, dense stands of kelp.

Sea otters are of particular interest because they are voracious eaters of shellfish. In Alaska and California their ability to destroy large numbers of sea urchins has been well described (Estes and Palmisano 1974). In turn, this allows kelp to increase, with further effects in increased fish, marine mammal and bird populations (Simenstad et al. 1978). In California the sea otter is surrounded by considerable controversy because of its alleged destruction of abalone resources and other commercial shellfish such as the Pismo clam and crabs (Cicin-Sain et al. 1977).

B. PRESENT STUDY

The work described here was carried out by Anne Stewart of Canadian Benthic Ltd., Wolfgang Carolsfeld, and me. We spent four days in the Bunsby Islands in early September 1982, and made 11 dives in the area (Fig. 1). Our goals were: (1) to examine changes in plant and animal communities at some sites we had examined in 1979; and (2) to examine any changes in the distribution of sea otters in the area. We had not planned on estimating the number of sea otters, but because of exceptional sea conditions on the last day we were able to do so.

1. Distribution of sea otters.

Figure 2 shows the 1979 feeding range of sea otters, based on underwater observations of their food items. Figure 1 shows the area in which we saw sea otters from the surface in 1982. If one accepts these two methods as being roughly comparable, it appears that sea otters have spread through the Acous Peninsula to the west, as far as Thomas Island to the east, and along the chain of isolated rocks the the southeast.

That sea otters have expanded their range was suppported by direct observation of underwater communities. Several sites which had had abundant red sea urchins (Strongylocentrotus franciscanus) in 1979 now had many fewer, or none. These were places where sea otters were observed from the surface. At one site in the Cuttle Islands, sea urchins were still present but were absent from the shallow part of their previous range. They were scarce at the top part of their vertical distribution, indicating the effect of predation.

Surface observations of kelp cover (Nereocystis luetkaeana) also supported these results. Where we saw sea otters, kelpbeds were wide; outside the range of sea otters, kelpbeds were restricted to a narrow fringe near the shore, or were absent. Although we made no formal measurments, it was obvious to us that Nereocystis was now far more abundant in the Cuttle Islands and at Thomas Island than it had been in 1979.

Decreased sea urchin abundance and increased kelp cover appeared to be limited to the area where we saw sea otters. At Quineex Reef, sea urchins and kelp were the same in numbers and distribution as they had been in 1979. Similarly, there was little kelp at the next reef east of Quinneex. The changes we observed were, we think, caused by expansion of the sea otters' range.

2. Changes in subtidal communities.

The changes we saw in sea urchin and kelp distributions between 1979 and 1982, at several sites to which sea otters moved during that period, have just been discussed. We also re-examined two sites which had been within the sea otter feeding range in 1979, to look for changes in plant community structure over that period. One site supported a thick Nereocystis canopy, and a rich understory of mixed Laminaria setchellii, Pterygophora Californica and Eisenia arborea. The other site had a thick canopy of Macrocystis integrifolia and Nereocystis, with a dense understory of Pterygophora. None of these observations were quantitative (nor could they be in the time we had). In any case, there appeared to have been no major changes in existing seaweed communities between 1979 and 1982. This is contrary to expectations based on the literature (e.g. Duggins 1980), which were that the annual Nereocystis would have been out-competed by the stiff-stiped perenniel kelps below.

It was not possible to survey food resources of otters within the old feeding range, which still supports considerable feeding. As in 1979, there were no apparent food species in the area covered by diving. The intertidal zone, which may contain sea mussels and gooseneck barnacles, could not be examined because of the heavy surge present (even though the swell was relatively low). The sea otters may be feeding on the sand and shell bottom below the feet of the rocky islets, but these areas were too deep for us to explore.

2. Numbers of sea otters.

During causal observations from a rubber boat in the late afternoon of 27 August, we counted at 15 sea otters in the Cuttle Islands. On the next morning, we saw the following number of sea otters from the boat in the area from Clara Islet east:

Clara complex:	50 (at least 6 pups included) (possibly several more)
Farout Rocks:	5 (possibly 3 more)
West Rock:	1
Stink Rock:	13 (including at least 5 pups)
Double Rock:	0
Flat Top Rock:	0
Six Foot Rock:	0

These counts were made on a very clear day in a flat calm with little swell. In these conditions, it was possible to spot otters from a long way off, and we checked all the major outlying rocks to the east of the Clara Islet complex. The 50 sea otters we saw in Clara were in a compact group when we first approached. The number of this large group was determined from photographs; and also by landing an observer on a small rock, then moving the boat so that the group swam past him.

It is not possible to know whether the counts on August 28 included otters that were counted the previous afternoon; but clearly the minimum number of otters present was the least number counted on August 28: 69 animals. If the Cuttle Islands group were not counted again the next day, there may be 90 sea otters in this area.

C. DISCUSSION

The persistence of this small colony for at least 10 years, and its expansion from 55 to at least 69 over the last 3 years, are grounds for optimism that the transplant will be a success. At the same time, any population this small is obviously extremely vulnerable. The colony is especially vulnerable because of the small area it occupies, and because of the degree to which it is concentrated socially - we saw more than half the total population in one tight group; and nearly all the mothers and pups in two groups. Dangers invited by these facts include damage from an oil spill or chemical spill (sea otters would not survive being oiled), harassment by people, predation by whales.

The existing Ecological Reserve merits recognition by the Department of Fisheries and Oceans for the following reasons:

1) Most of the area now occupied by the colony is within a large marine Ecological Reserve which was established in 1981 to protect this sea otter colony. Reserves are not automatically recognized by the Department, and some scouting for commercial geoduc (Panope abrupta) beds (possibly some fishing as well) has taken place. Commercial geoduc fishing could interfere with sea otters in several ways. First, sea otters are known to take 'white clams' from the area (Morris et al. 1981). It is unlikely (but not totally impossible) that these are geoducs. The resource of these clams could be damaged incidentally by geoduc harvesting. Second, the physical presence of commercial fishing boats in the area (especially in the Clara group, where most of the mothers and pups were seen) might cause disturbance damage. Third, sea otters may be using the siphons of geoducs as prey.

A more immediate conflict exists over red sea urchins. There is continuing interest in a commercial red sea urchin fishery, and the Kyuquot/Fair Harbour area has extensive stocks accessible to a road-head. There are still substantial numbers of sea urchins within the ecological reserve.

This population, resulting from a transplant carried out by the Department with other agencies, appears to be increasing and expanding. The evidence from elsewhere (particularly California) is clear that serious conflicts may develop as the population spreads: some prime areas for conflict are crabs in the Tofino area, sea urchins on the whole outer coast of Vancouver Island, and abalone in the area from Port Renfrew to Victoria. Against these problems, sea otters provide several potential opportunities: scientific, economic and esthetic. For a more complete discussion see Farr and Bunnell (1980) and Cicin-Sain et al. (1977).

One possible approach might be to prevent sea otter expansion to avoid conflict. This would be a short-term solution only: sea otters have expanded into southeastern Alaska and will re-colonize B.C. from there by the end of this century (Bigg, pers. comm.) It is important to recognize and discuss the problems and opportunities now, while the situation is still small and is still calm.

3) The work described above, by three people working out of a small boat for four days, is the only work that has been done on this population since 1979. Apart from that, no work has been done on the numbers or the distribution of sea otters. Since we know that the colony will cause interest and perhaps problems if it increases and expands, we should know how fast (if at all) it is increasing and expanding.

To follow the numbers of individuals present, aerial surveys should be conducted at least every 2 years, using the techniques developed in Alaska and California. To follow the expansion of the colony, I suggest aerial photography of kelpbeds. The British Columbia Marine Resouces Branch and the Herring Section of the Fisheries Research Branch have both used aerial photgraphy successfully to delineate kelp distributions; MRB made overflights in the mid-70's in the Bunbsy Island area. At least the area from Cape cook to Fair Harbour, and if possible the area from Nootka to Cape Scott, should be photographed for baseline purposes, and the area occupied by sea otters should be photographed every alternate year.

REFERENCES

Bigg, M.A., and I.B. MacAskie. 1978. Sea otters re-established in British Columbia. J. Mammal. 59(4): 874-876.

Breen, P.A., T.A. Carson, J.B. Foster, and E.A. Stewart. 1982. Changes in subtidal community structure associated with the British Columbia sea otter transplants. Mar Ecol. Prog. Ser. 7(1): 13-20.

Cicin-Sain, B., J.E. Moore, and A.J. Wyner. 1977. Management approaches for marine fisheries: the case of the California abalone. University of California Sea Grant Program, Sea Grant Publication 54: 1-223.

Cowan, I. McT. and C. J. Guiget. 1965. The mammals of British Columbia. British Columbia Prov. Mus. Handbook 11: 414 pp.

Duggins, D.O. 1980. Kelp beds and sea otters: an experimental approach. Ecology 61(3): 447-453

Farr, A. C. M. and F. L. Bunnell. 1980. The sea otter in British Columbia - a problem or opportunity. pp. 110-128. In R. Stace-Smith, Lois Johns and Paul Joslin (eds): Threatened and endangered species and habitats in British Columbia and the Yukon. B.C. Fish and Wildlife Branch, Victoria, B.C.

Morris, R.L., D.V. Ellis, and B.P. Emerson. 1981. The British Columbia transplant of sea otters (Enhydra lutris). Biol. Cons 20: 291-295.

Simenstad, C.A., J.A. Estes, and K.W. Kenyon. 1978. Aleuts, sea otters and alternate stable-state communities. Science 200: 403-411.

Stewart, E.A., J.B. Foster, T.A. Carson, and P.A. Breen. 1982. Observations of kelp, sea urchins and other invertebrates made in the area of the British Columbia sea otter transplant. Can. MS Rep. Fish. Aquat. Sci. 1655: 28 pp.

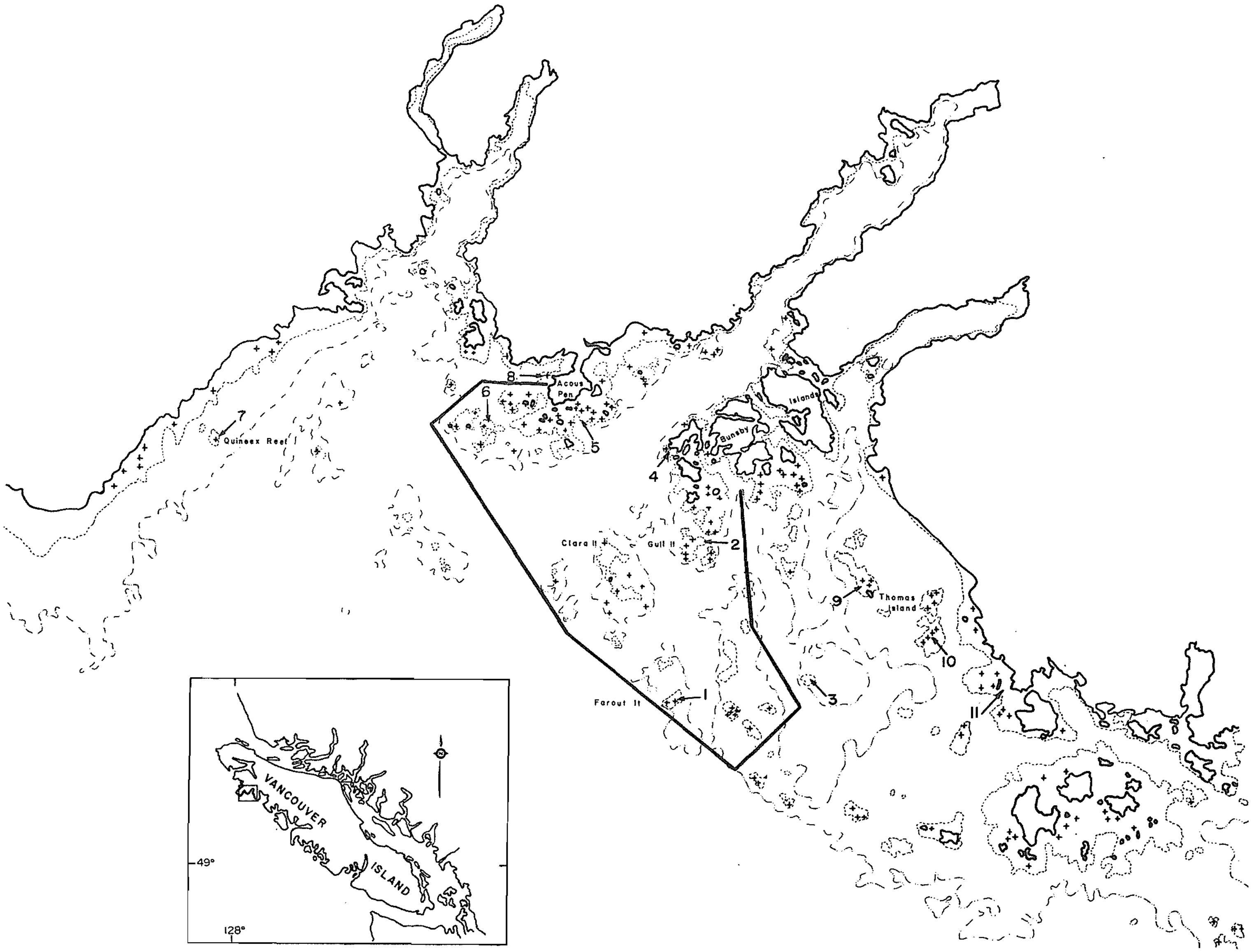

Fig. 1. The sites of 1982 dives. The line encloses the area in which sea otters were seen from the surface in August 1982.

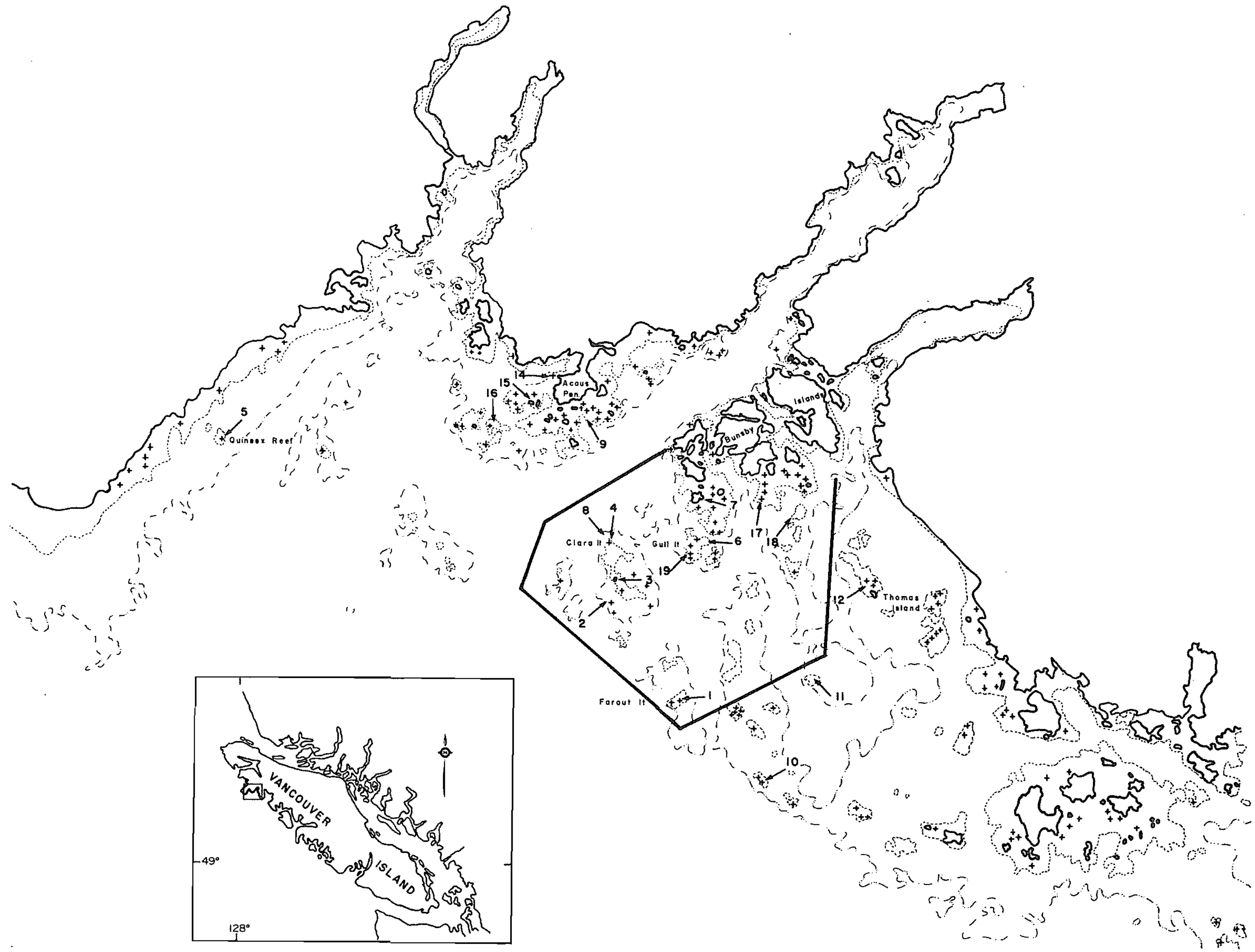

Fig. 2. Area of British Columbia sea otter transplant. Sea otter feeding range determined underwater in September 1979 delineated by solid straight lines.

SCALLOP SIZE LIMITS

by

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Scallop resources along the British Columbia coast are erratic in distribution and limited in abundance and fisheries that develop for stocks will be minor but could have some importance locally to a few fishermen. The fisheries could be quite sporadic; populations could be exploited for a month or two or perhaps a year and then not be touched for a period of years; this could be dependent on population size but also on markets and socio-economic conditions. With such minor fisheries it is questionable how much time, manpower, and funds Fisheries will be able to devote to enforcing any proposed regulations. The following are suggestions that can be considered in formulation of any regulations for management of scallop fisheries that might develop.

Four species of scallops are either large enough or occur in sufficient abundance to offer some potential in either the commercial or recreational fisheries:- weathervane, *Patinopecten caurinus*; rock, *Chlamys gigantea*; pink, *C. rubida*; and spiny, *C. hastata*.

Rock scallops attain a large size and have a scattered distribution although there are few if any dense centers of concentration. They are found firmly cemented to rocks and do not lend themselves to a dragging type fishery. At present they may be harvested only in the recreational fishery and a bag limit of six per person per day south of Cape Caution and 12 per person per day north of it is in place. The present regulations are felt to be adequate. A size restriction is probably not warranted because people aren't interested in harvesting this species until it is a reasonable size by which time they have been sexually mature and capable of spawning for several years.

Weathervane scallops have an erratic distribution but there are two small centers of population; one in McIntyre Bay and one in the Plumper Sound - Trincomali Channel area in the Gulf Islands (Bourne 1969). There is the possibility that local dense beds may be found at some time in the future off the British Columbia coast because of recruitment of one or two strong year classes as occurred off Oregon in 1981.

The two small populations in McIntyre Bay and Trincomali Channel will not support sustained fisheries at even modest levels. A recent estimate of population density in the Trincomali Channel area was 1 scallop per 65 sq meters. If a fishery is permitted in either location the most practical management scheme is probably a size limit. Establishment of quotas isn't warranted since the population is so small and quotas would have to be monitored. It will probably be difficult to manage the fishery by a gear regulation since a variety of home-built gear will be used with a variety of mesh types although total gear width could be used. If the fishery is managed by a size regulation it is suggested the minimum size limit be 120 mm shell height (=4.7 y), distance from the hinge to the ventral margin of the shell. Our work (unpublished) and that of Haynes and Hitz (1971) indicates weathervane scallops of this size would be about four years of age, would have been sexually mature for two years and could have spawned for two years prior to entering the fishery. While maximum Y/R would be achieved with exploitation at 135 mm (=6 yr) (Fig. 1), an initial lower size limit should facilitate establishment of a fishery. If scallops were landed whole there would be no problem in enforcing a size limit. If they are shucked at sea a shell height to weight of adductor muscle relationship would have to be established.

If offshore beds of weathervane scallops, sufficient to support a commercial fishery, are found off the British Columbia coast it is suggested the most practical management scheme would be a size regulation. A minimum size should probably be smaller than inshore because growth of offshore scallops is considerably slower than those inshore (Haynes and Hitz 1971). It is suggested it be 100 mm shell height.

Pink and spiny scallops have a scattered distribution but they occur in beds of sufficient density to permit small scale fisheries; e.g. off Victoria. We have little information on the size of these beds. Size frequency distribution of the population off Victoria indicates recruitment is reasonably consistent. Growth is slow, maximum size is about 85 mm and they are 4-5 years at this size. Fisheries for these two species will probably be minor, they will depend on population size and markets. It is unlikely that Fisheries could or would survey each bed to establish sustained yields or quotas. Management by gear is also impractical. The most expedient management scheme is probably a size limit. It is arbitrarily suggested that the minimum size be 60 mm shell height for both species. Natural mortality rates are poorly documented and so Y/R analyses are felt to be inappropriate at this time. Initial studies indicate animals of this size would be over two years and would have been sexually mature and capable of spawning for one year. Our studies indicate growth after this size slows markedly.

REFERENCES

Bourne, N. 1969. Scallop resources of British Columbia. Fish. Res. Board Canada Tech. Rep. 104: 60 pp.

Haynes, Evan B., and Charles R. Hitz. 1971. Age and growth of the giant Pacific sea scallop, Patinopecten caurinus, from the Strait of Georgia and outer Washington coast. Fish. Res. Board Can. 28(9): 1335-1341.

Table 1. Growth and natural mortality parameters used in the yield per recruit calculations for inshore weathervane scallops.

Parameter	Value
M	0.1
K	0.36
t_0	0.6
L	156.8 mm
W	346 g (whole weight)

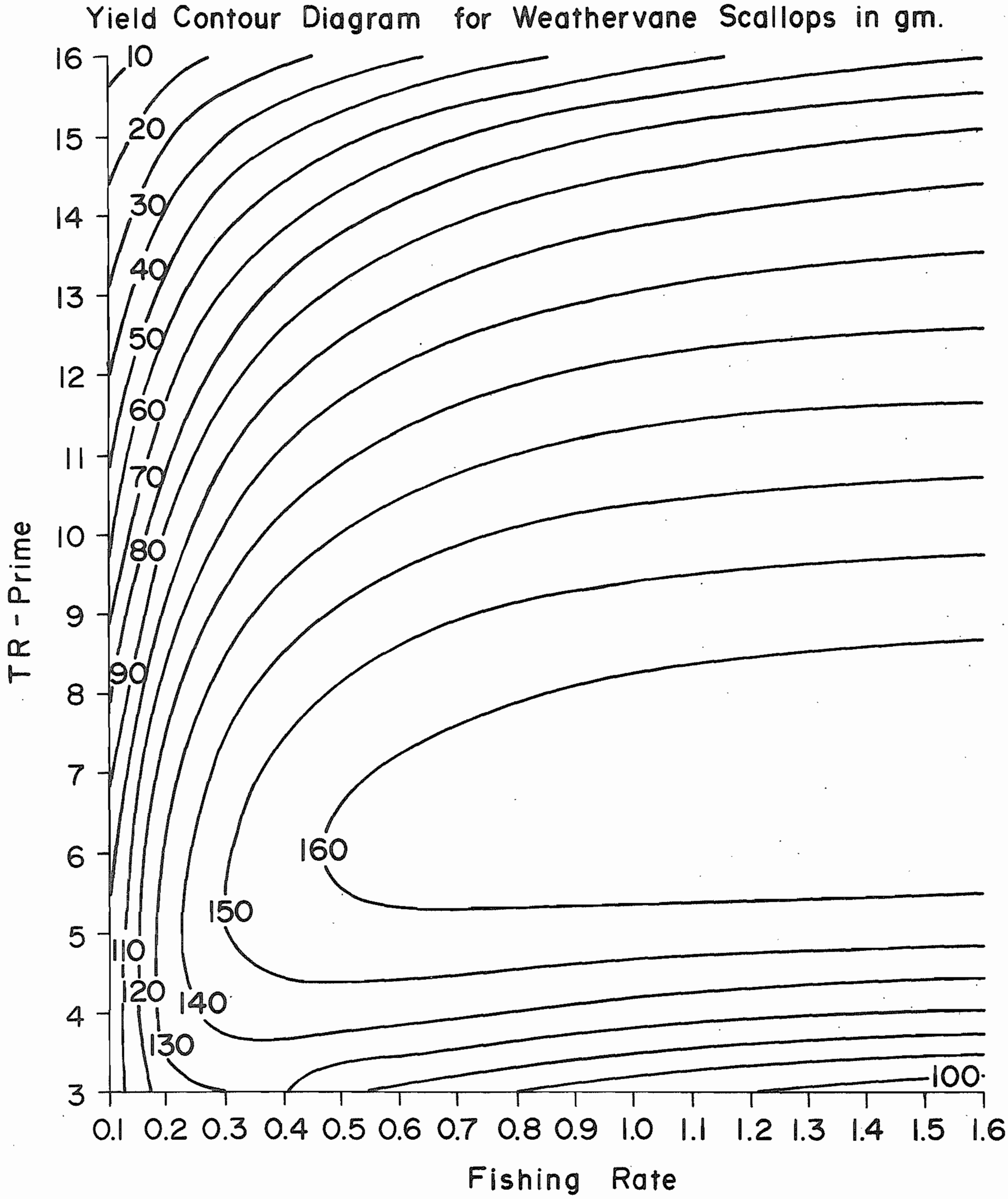

Fig. 1. Yield isopleths (gm) per scallop calculated for Gulf Island scallops as per parameters in Table 1.