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Shellfish Stock Assessments for the West Coast of Canada in 1990 as Reviewed by the Pacific Stock Assessment Review Committee (PSARC)

G. A. Thomas
Editor

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of Fisheries and Aquatic Sciences

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SHELLFISH STOCK ASSESSMENTS FOR
THE WEST COAST OF CANADA IN 1990

by



G. Thomas

Editor

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ABSTRACT

Thomas, G. (Editor). 1990. Shellfish Stock Assessments for the West Coast of Canada in 1990. Can. MS Rep. Fish. Aquat. Sci. 2099:vi + 307p.

This manuscript contains shellfish management advice for the Pacific Region in 1990, provided in the form of position papers and fishery updates by the Shellfish Subcommittee of the Pacific Stock Assessment Review Committee. Position papers contain recommendations to management and were subject to scientific review, while fishery updates summarize recent progress in species fisheries. Management advice is provided for intertidal clams, geoduck (Panope generosa), abalone (Haliotis kamtschatkana), shrimp (Pandalus jordani), euphausiids, and purple urchin (Strongylocentrotus purpuratus). Dungeness crab (Cancer magister), and horseclam (Tresus sp.) papers were published elsewhere. Reviews are provided for ten major and six minor shellfish fisheries.

RESUME

Thomas, G. (Editor). 1990. Shellfish Stock Assessments for the West Coast of Canada in 1990. Can. MS Rep. Fish. Aquat. Sci. 2099:vi + 307p.

Ce document presente des conseils pour la gestion des mollusques et crustaces dans la Region du Pacifique pour 1990. Il contient des exposes de principes et des mises a jour sur la situation des peches fournis par le sous-comite des mollusques et crustaces du Comite d'examen de l'evaluation des stocks du Pacifique. Les exposes de principes contiennent des recommandations destinees aux gestionnaires, recommandations qui ont ete soumises a un examen scientifique, tandis que les mises a jour font etat des developpements recents dans les differentes peches. Les recommandations aux gestionnaires portent sur les especes suivantes : myes intertidales, geoducks (Panope generosa), ormeau (Haliotis kamtschatkana), crevette (Pandalus jordani), euphausiaces et oursin violet (Strongylocentrotus purpuratus). Des articles sur le crabe dormeur (Cancer magister) et les horse clams (Tresus sp.) ont ete publies ailleurs. Des donnees sur dix especes largement pechees et sur six especes moins exploitees de mollusques et crustaces sont presentees.

Introduction

This manuscript contains reports presented at the 1990 meeting of the Shellfish Subcommittee of the Pacific Stock Assessment Review Committee (PSARC), August 28 and 29. Presentations, in the form of Working Papers and Fishery Updates, were made by representatives of Science Branch and Fisheries Branch, and a representative of the Department of Agriculture and Fisheries, Province of British Columbia. Working Papers describe the results of current invertebrate research and contain recommendations for fisheries management. Fisheries Updates review the status of shellfish fisheries and detail catch statistics.

Recommendations for management issuing from the stock assessments are ratified by the Regional Management Executive Committee, then used by the Shellfish Working Group to formulate management plans for industry review.

Management strategies employed in shellfish fisheries vary considerably between species and include catch quotas, time and area closures, size limits, and gear restrictions. Licensing and management of shellfish fisheries continue to evolve in reaction to rapid changes in the structure of the fishing industry. In 1989 a trial vessel quota system was introduced in the geoduck fishery and area licensing was introduced in the clam fishery. In 1990 a crab R licence was introduced and prawn licences were limited (see Appendix 1 for a list of shellfish licence categories in 1989).

Annual shellfish landings continue to decline overall with reductions in intertidal clam and geoduck catches, though participation and effort in most fisheries is increasing substantially. Total shellfish landings in 1989 were 16,752 t (Table 1) valued at \$41 million (Table 2).

Documents which follow are ordered first by document type, then by fishery type and species group (see Appendix 2 for a list of common and scientific species names). Eleven Position Papers are provided and Fishery Updates are provided for 9 major and 6 minor species.

Table 1. Landings of invertebrates in tonnes in British Columbia, 1981-1989

	1981	1982	1983	1984	1985	1986	1987	1988	1989
INTERTIDAL CLAMS									
Razor	30	68	31	101	90	142	142	155	117
Butter	120	103	77	131	252	159	69	83	42
Manila	317	597	1049	1677	1914	1894	3608	3833	2728
Nat. Ln.	179	241	325	295	192	285	373	288	428
Mixed	161	155	280	409	478	369	87	27	159
TOTAL INTERTIDAL C	807	1164	1762	2613	2926	2849	4279	4386	3474
GEODUCK	2704	3135	2636	3483	5370	5006	5734	4553	4087
HORSE CLAM	57	321	21	7	6	96	355	328	115
SHRIMP	581	415	411	408	678	768	2644	2211	2211
PRAWN	358	274	331	381	514	550	620	708	894
CRAB	1317	1002	960	1155	1165	1321	1631	1406	1406
ABALONE	85	54	56	58	42	52	49	48	49
OCTOPUS			37	25	34	53	130	205	205
SEA URCHIN									
RED			982	1764	1815	2067	2223	1951	2645
GREEN								434	570
SEA CUCUMBER				95	346	786	1722	1930	1101
SCALLOP		8	11	18	53	68	66	66	77
PLANKTON	19	0	47	103	131	166	130	249	380
SQUID			71	14	111	79	86	8	70
MUSSELS			tr	1	tr	2	2	3	4
GOOSENECK BARNACLES						2	32	18	34
TOTAL TONNES	5909	6373	7325	10125	13191	13865	19703	18070	16752

Table 2. Landings in thousands of dollars of invertebrates in British Columbia, 1981-1989

	1981	1982	1983	1984	1985	1986	1987	1988	1989
INTERTIDAL CLAMS									
RAZOR	24	55	24	123	95	127	126	137	124
BUTTER	42	36	33	55	138	75	40	40	44
MANILA	323	611	1043	1813	2278	2762	6003	7023	5919
NAT. LN	195	263	329	311	202	327	474	357	580
MIXED	175	169	293	455	575	510	132	36	196
TOTAL INTERTIDAL C	759	1134	1722	2757	3288	3801	6775	7593	6863
GEODUCK	2434	2814	1818	2937	4777	4294	6184	9762	12967
HORSE CLAMS	42	235	12	5	6	63	309	300	144
SHRIMP	912	652	1095	1022	1180	1240	4609	2802	2985
PRAWN	2019	1545	2154	2464	3379	3734	4326	5724	7694
CRAB	3556	2703	3320	4558	4719	5661	6452	5555	5012
ABALONE	721	457	464	530	442	734	973	1076	1170
OCTOPUS			80	56	82	136	381	629	655
SEA URCHIN									
RED			358	712	763	1011	1276	1108	1627
GREEN								569	953
SEA CUCUMBER				22	94	236	768	961	998
SCALLOP		17	45	56	139	212	244	285	321
PLANKTON	6	0	19	42	89	113	102	192	223
SQUID			95	17	184	127	132	113	94
MUSSELS		tr	tr	tr	0	tr	tr	tr	tr
GOOSENECK BARNACLES						5	221	478	397
TOTAL VALUE	10449	9557	11182	15178	19142	21367	32752	36578	41150

I. POSITION PAPERS

1. Results of the 1990 Shrimp Survey

by

J. Boutillier

SUMMARY

This report summarizes results of the area-swept trawl survey off the west coast of Vancouver Island during a shrimp biomass survey in the spring of 1990. This survey is one in a continuing series conducted during the same time period each year to assess abundance and distribution of the pink shrimp, Pandalus jordani. Detailed catch records and resulting evaluations of biomass and year-class strength are presented. A comparison with previous surveys to the same area is shown. Biomass estimate was ~2665 metric tonnes in areas of density >1 metric tonnes. This is about 76% of the 1989 abundance. In terms of age class distribution it shows a 15% increase of 3+ animals, a 39% decline in 2+ animals and a 82% decline in 1+ animals (N.B. 1+ indices are very suspect as the animals are not fully recruited to the fishing gear).

INTRODUCTION

A shrimp biomass survey of the Tofino ground, [fisheries statistical area (FSA) 124] and to a lesser extent, Nootka ground (FSA 125) was conducted April 24 - May 2, 1990 using the research vessel W. E. RICKER. The Tofino shrimp ground lies offshore from the west coast of Vancouver Island between 48°40' and 49°15' north latitude and Nootka ground lies between 49°15' and 49°35' N latitude. Since 1973, this type of survey has been conducted on these grounds 14 times in spring (April-May) and 3 times in late summer (August-September). The purpose of these cruises is to provide relative estimates of total biomass, year-class abundance, and distribution of the smooth pink shrimp, Pandalus jordani.

SURVEY DESIGN AND FISHING GEAR

The biomass trawl survey was carried out using a standard 18.6m, National Marine Fisheries Service (NMFS) high-rising, shrimp-sampling trawl (Boutillier et al. 1977). Trawl locations for the biomass survey were established using a systematic grid pattern based on Loran C blocks. Tows were made diagonally through adjacent 5900-Z 10 microsecond blocks along successive 5900-Y lines, 20 microseconds apart. Tow duration, except when tows were fouled, was 30 minutes and the distance covered, depending on tide and wind, ranged from 1.2 to 1.7 nautical miles (M) with an average distance of 1.44 M. From each trawl catch dumped on deck, large species were sorted, weighed and discarded. A small, random, bucket sample of shrimp was collected and processed to determine the number of shrimp per kilogram (No./kg). The 1 kg sample was

then sorted by sex, and the carapace length measured (orbit of the eye to mid-dorsal, posterior margin of the carapace). The balance of each catch, consisting of shrimp, small fish, and invertebrates, was shovelled into baskets and weighed. One or two tubs of this mixed catch were then sorted by species and each species weighed to determine the proportional catch composition. The calculated percentage of species by weight was then used to extrapolate the total weights of shrimp and other species in the catch.

Biomass and year-class abundance indices were calculated using a bicubic spline. For this analysis the Tofino ground is defined as a rectangular area that starts at 126°05' longitude and 48°35' N latitude and extends 50 M at 322° True (T) and 15 M at 52°T. This area is divided into 2 sq M cells which are 1 M wide and 2 M long. The towable area within this large area is identified by a set of untowable boundary points which were determined from problem areas found in all previous surveys. The calculation of biomass assumes that all the towable area inside the boundary is potential shrimp grounds. This analysis sets the density [(kg or #)/0.2 sq. M towed] obtained in the tow or, in the case of repeated tows, the mean of the two tows, equivalent to the density at the grid point which corresponds to the centre point of the tow. The 2 sq M matrix is divided into smaller 0.2 sq. M areas and a bicubic spline is used to fill blank grid cells with interpolated values. The biomass and areas of concentration are then calculated by adding the values greater than some minimal density to determine biomass and by counting the grid cells and multiplying by 0.2 to determine the areas.

RESULTS

A total of 82 trawl tows were completed; 61 during the first phase on Tofino ground, 10 on Nootka ground, and 11 during the second phase on Tofino ground. Total catch by important species is summarized in Table 1.

TOFINO GROUND PHASE 1 AND PHASE 2

This area-swept biomass survey found that shrimp were in concentrations >1 tonne/sq M in a 190 sq. M area. All Tofino Ground tows were usable, of the 72 tows, 60 contained shrimp varying in amounts from a trace to 258 kg per nautical mile towed (kg/M), with a mean catch rate of 58 kg/M (Table 2). An unweighed estimate of the age-class structure of the shrimp determined that the length frequency samples (Fig. 1) were composed of <1% 1-year-old, 37% 2-year-old, and 62% 3-year-old animals (Fig. 2). Mean carapace size for these three age groups were 12.3, 16.8, and 20.4 mm, respectively. The number of shrimp per kilogram ranged from 162 to 308 while the size and density of shrimp for each tow combined to give an overall weighted mean of 240 shrimp/kg.

NOOTKA GROUND

During this survey, insufficient time precluded a thorough assessment of this area. As a result, only 10 tows were completed. All 10 tows contained shrimp in concentrations which ranged from trace to 116 kg/M. An unweighted estimate of the age-class structure of the shrimp determined that the samples were composed of <1% 1-year-old, 37% 2-year-old, and 62% 3-year-old animals. Mean carapace size of these three age groups were 12.2, 16.8, and 20.4 mm, respectively. The number of shrimp per kilogram ranged from 204 to 358 while the size and density of shrimp for each tow combined to give an overall weighted mean of 286 shrimp/kg.

DISCUSSION

Total biomass of pink shrimp on the Tofino ground continues to decline (Fig. 4). The 1990 biomass estimate of 2,665 metric tonnes is about 78% of the 1989 assessment. The proportion of age classes contributing to the total biomass has again shifted (Fig. 2). The number of 3+ animals has increased from 1989 to 1990 by 15% (3.2×10^8 to 3.7×10^8) but the number of 2+ animals has declined by 39% (5.4×10^8 to 3.3×10^8). Moreover, the number of 1+ animals has declined by 82%. The biomass prediction for 1991 is for a further decline in overall abundance. The weak 2+ age class will result in a weak 1991 3+ age class and if the estimate of 1+ animals is accurate and resulting recruitment to 2+ animals is in the same ratio as the 1989 1+ to 1990 2+ then the 1991 2+ age class will be extremely weak. Estimating the 2+ recruitment in year "X" from 1+ estimates in year "X-1" is very difficult at the best of times but it is confounded by the fact that the 1989 survey was conducted approximately 2 weeks later than this survey and the 1+ animals in 1990 were smaller and may not have been as fully recruited to the survey as in 1989. However, discussions with colleagues in Washington State fisheries indicate that the 1989 year class appears to be weak along most of the west coast from California to British Columbia. If this is followed by a weak 1990 year class then we will see the total collapse of the shrimp trawl fishery in 1992 off the west coast of Vancouver Island.

In the PSARC document I88-6 (Boutillier 1989) there was a discussion of the Ricker yield-per-recruit model (Ricker 1975) using varying values of natural mortality (M) (Fig. 5) and varying values of fishing mortality (F) (Fig. 6). The results of that exercise indicated that in terms of growth the best time to have a 4-month intensive fishery is in the later summer and fall period.

The U.S. fishery starts in April and ends depending on the fishing pressure. If the 1989 year class is weak, then the 1991 fishery off Washington will be carried by 3+ animals and could probably end in the late summer. If this scenario is correct then a scarcity of shrimp on the market would probably drive the price up in the fall.

RECOMMENDATIONS

The Area 124 fishery in 1990 should close at the end of October when the U.S. fishery ends, protecting the spawners that are still on the grounds. The hope is that the larvae from these spawners will settle on the grounds, the gamble is that this will not happen as in 1989 and that the fishery forgoes a chance to harvest the 3+ animals during a time when fishing pressure is generally fairly low. There will be a fishery in 1991, but if the indices remain consistent then it will be very small and we should try to maximize the production by delaying the opening to late summer, early fall to take advantage of growth and perhaps a lull in the U.S. shrimp fishery. With the delay of the fishery in 124, industry should still be allowed to exploit shrimp populations in 121 along the Canada/USA border. This area has only been exploited by illegal US fishing and it is one of the few grounds on the coast that is reported to have much sign of 1+ animals.

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

Table 1. Total catch, by species, from W. E. RICKER shrimp biomass survey 90-S-1, April 24-May 2, 1990.

Species		Weight (kg)	% of catch
Pink shrimp	<i>Pandalus jordani</i>	6491	38
Dogfish	<i>Squalus acanthias</i>	3683	22
Eulachon	<i>Thaleichthys pacificus</i>	2544	15
Yellowtail rockfish	<i>Sebastes flavidus</i>	692	4
Dab	<i>Citharichthys</i> spp.	580	3
Turbot	<i>Atheresthes stomias</i>	470	3
Pacific cod	<i>Gadus macrocephalus</i>	405	2
Lingcod	<i>Ophiodon elongatus</i>	351	2
Skate	<i>Rajidae</i>	268	2
Herring	<i>Clupea harengus pallasii</i>	205	1
Canary rockfish	<i>S. pinniger</i>	199	1
Slender sole	<i>Lyopsetta exilis</i>	187	1
Others ^a		1,045	6
Totals		17,120	100

^aSpecies amounting to <1% each of the total catch. (See footnotes to Appendix Table 1 for list.)

Table 2. *P. jordani* catch (kg) per nautical mile (M) for Tofino and Nootka ground, 88-S-1, April 26-May 8, 1988.

Tow No.	Depth (metres)	Duration (min)	M	Weight (kg)	No./kg	Kg/M
a) Tofino Ground						
1	133-137	30	1.4	4	3	249
2	115-116	30	1.3	0	-	-
3	100-101	30	1.5	0	-	-
4	102-104	30	1.5	0	-	-
5	121-122	30	1.4	4	3	208
6	139-144	30	1.4	28	20	215
7	150-153	30	1.4	29	21	234
8	158-161	30	1.5	17	11	214
9	144-146	30	1.6	27	17	160
10	128-129	31	1.6	72	17	221
11	108-109	30	1.4	0	-	-
12	110-110	30	1.5	0	-	-
13	129-130	30	1.4	42	30	198
14	142-148	30	1.2	45	38	178
15	152-154	31	1.5	102	68	218
16	158-162	30	1.6	2.5	16	233
17	174-175	29	1.3	0	-	-
18	125-127	30	1.4	73	52	200
19	115-116	30	1.2	9	8	206
20	137-138	30	1.3	107	82	219
21	146-147	30	1.3	145	112	228
22	158-161	30	1.5	220	147	265
23	148-150	30	1.4	161	115	242
24	137-137	30	1.3	58	45	211
25	122-125	30	1.5	220	147	220
26	123-124	29	1.5	93	62	203
27	109-115	30	1.6	47	29	192
28	111-115	30	1.3	192	148	195
29	94-100	30	1.4	0	-	-
30	135-139	30	1.4	91	65	218
31	143-146	30	1.4	169	121	308
32	140-143	33	1.5	213	142	290
33	130-135	30	1.5	199	133	247
34	119-124	30	1.5	173	115	229
35	107-111	30	1.5	0	-	-
36	103-107	30	1.4	0	-	-
37	119-122	30	1.7	167	98	197
38	129-129	30	1.5	205	137	192
39	134-137	30	1.5	166	111	270
40	150-152	32	1.7	Tr	-	-
41	142-144	31	1.5	34	23	288
42	131-134	29	1.6	74	46	267
43	124-128	30	1.5	55	37	231
44	122-122	30	1.5	84	56	162

Table 2, Continued

Tow No.	Depth (metres)	Duration (min)	M	Weight (kg)	No./kg	Kg/M
45	108-111	30	1.4	10	7	185
46	94-98	30	1.5	0	-	-
49	123-124	30	1.6	280	175	220
50	125-126	30	1.2	25	21	240
51	91-92	30	1.5	Tr	-	-
52	94-97	31	1.5	58	39	195
53	104-106	30	1.6	55	34	204
54	113-113	30	1.6	102	64	225
55	120-120	30	1.4	6	4	230
56	115-115	30	1.4	93	66	240
57	108-109	30	1.4	62	44	207
58	100-101	30	1.5	Tr	-	-
59	92-94	30	1.5	0	-	-
60	104-105	30	1.4	0	-	-
61	111-112	30	1.6	22	14	214
72	116-116	30	1.5	19	13	234
73	121-122	30	1.5	268	179	235
74	127-127	30	1.4	125	89	257
75	129-129	30	1.5	387	258	312
76	124-129	30	1.4	214	153	276
77	138-141	30	1.4	240	171	267
78	127-130	30	1.4	116	83	216
79	125-131	30	1.2	148	135	258
80	137-143	30	1.4	82	59	239
81	142-145	30	1.6	56	35	185
82	127-132	30	1.4	86	61	206
(b) Nootka Ground						
62	139-140	27	1.4	6	4	352
63	127-130	30	1.4	162	116	328
64	117-118	30	1.5	19	13	238
65	118-119	30	1.5	41	27	204
66	129-131	30	1.3	140	108	265
67	136-137	30	1.5	34	23	358
68	141-141	30	1.5	45	30	280
69	128-131	30	1.4	7	5	188
70	147-147	25	1.2	34	28	273

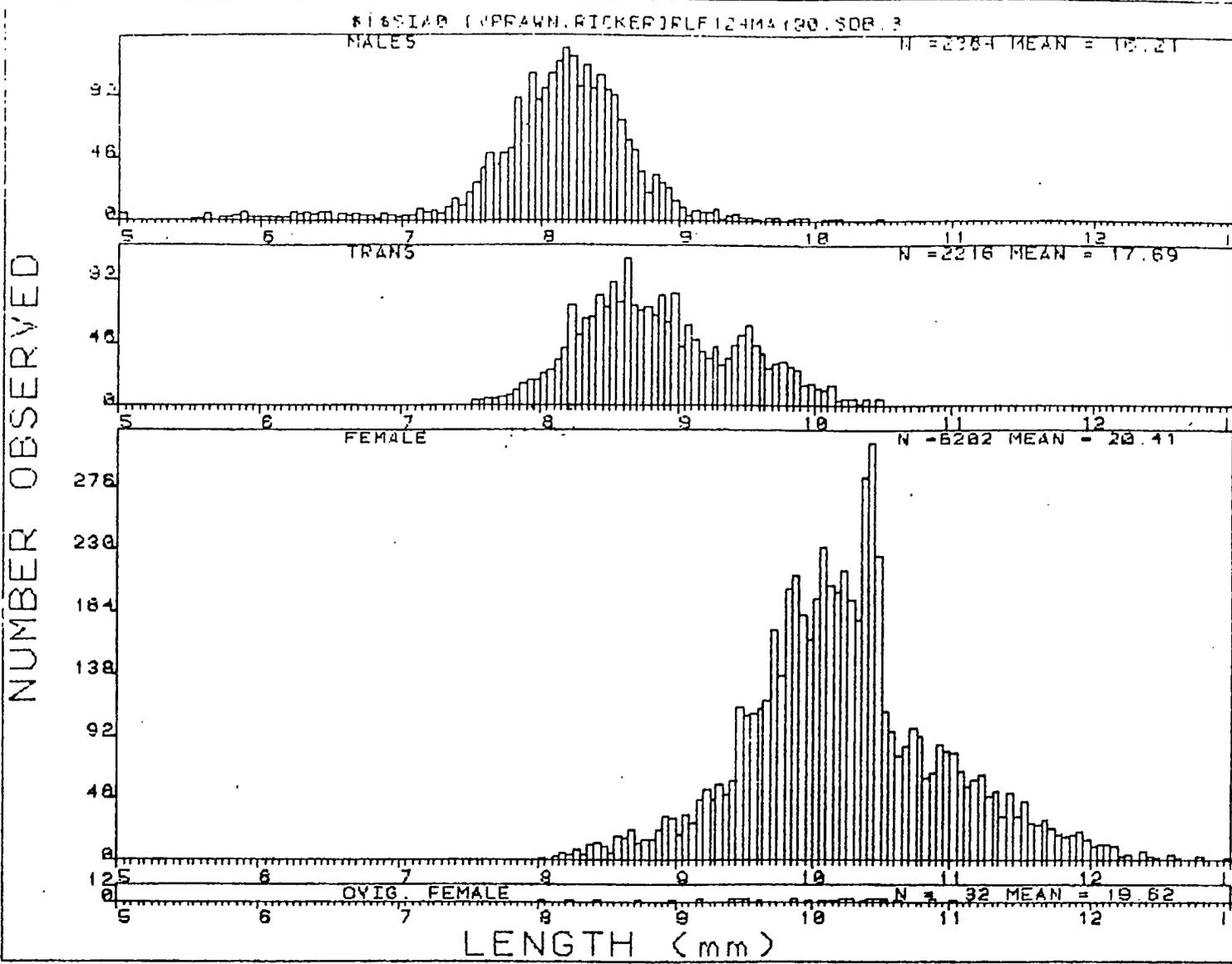
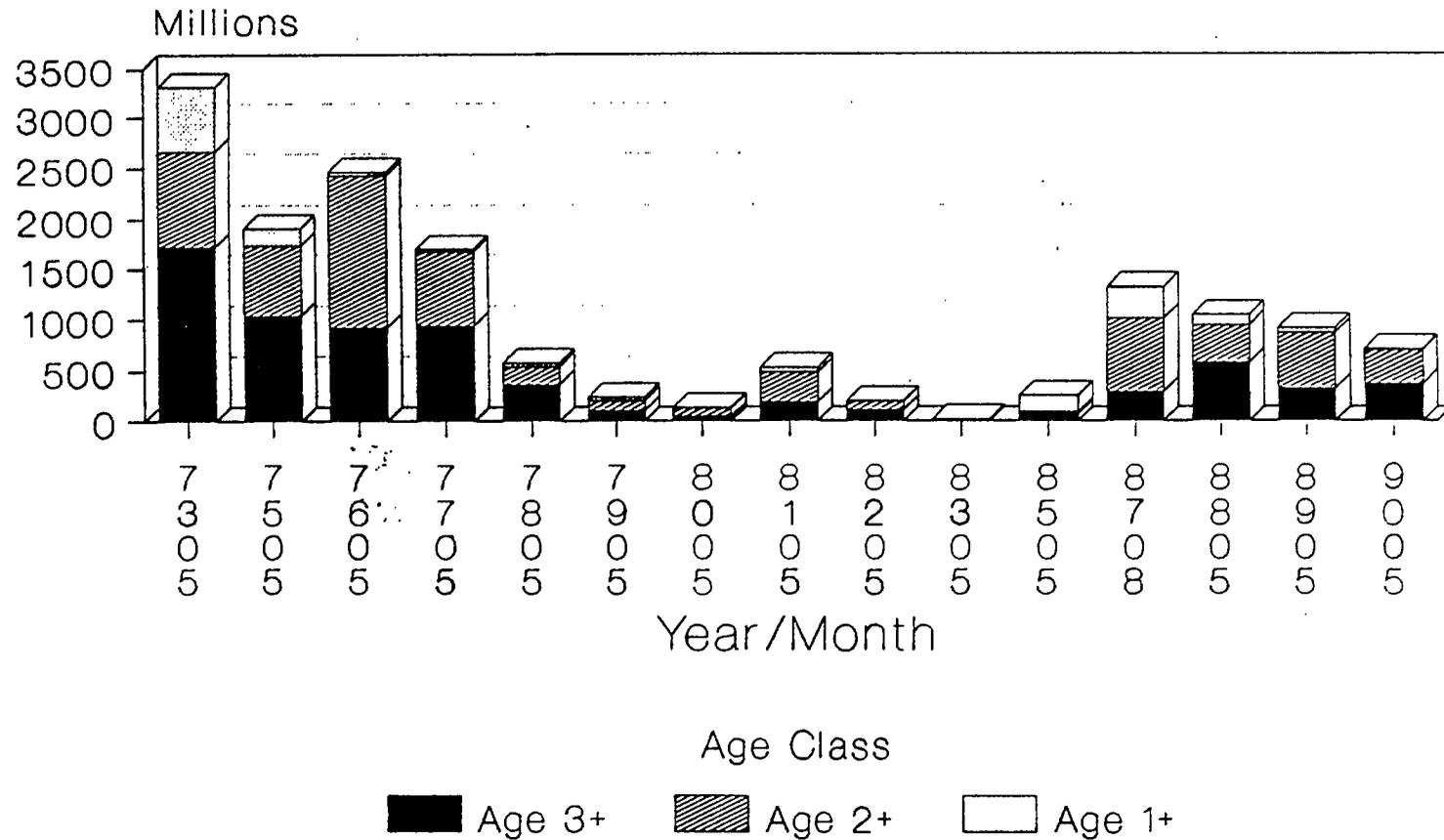


Fig. 1.

Area 124 *P. jordani* Survey Results



Surveys prior to commercial fishery

Fig. 2.

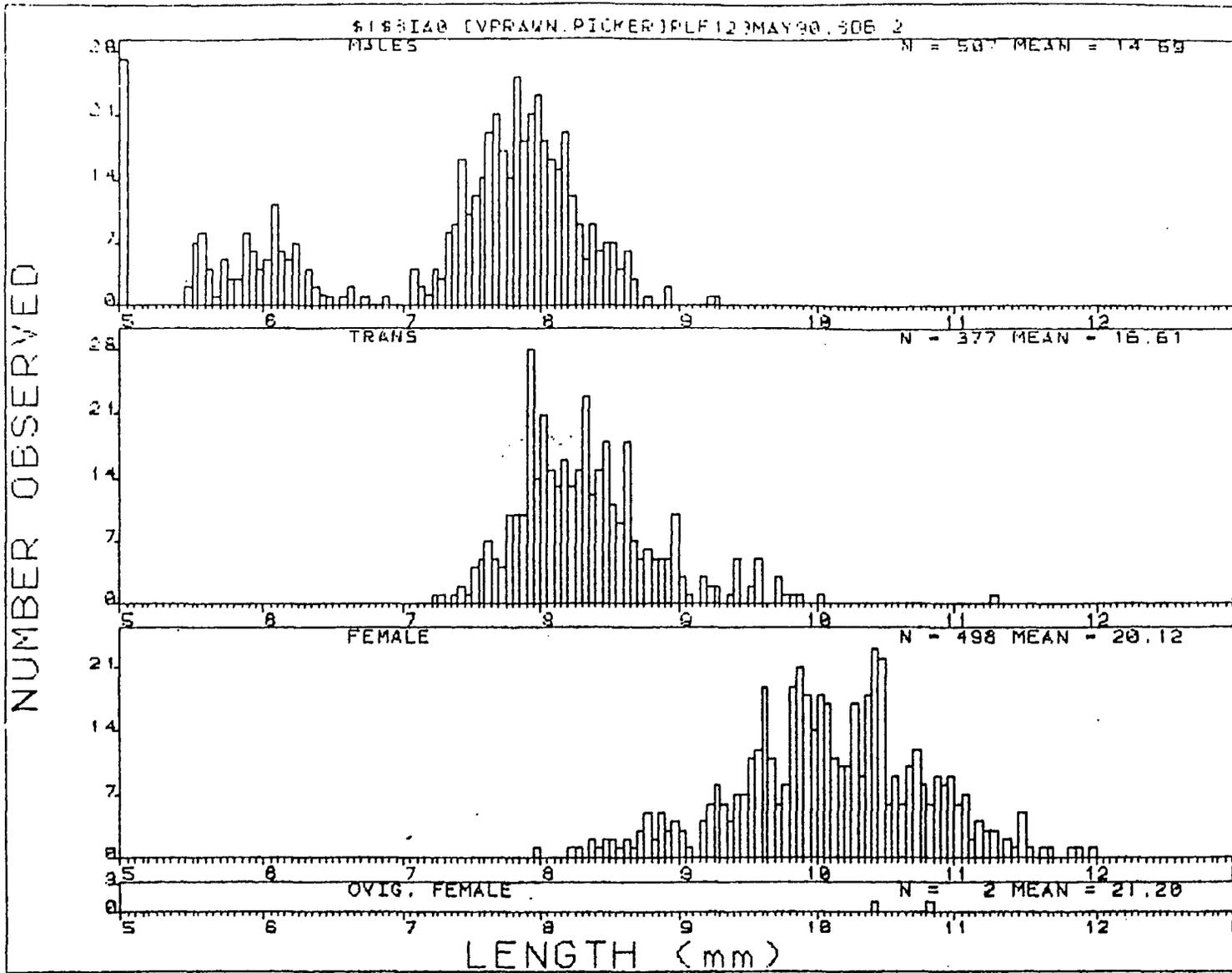
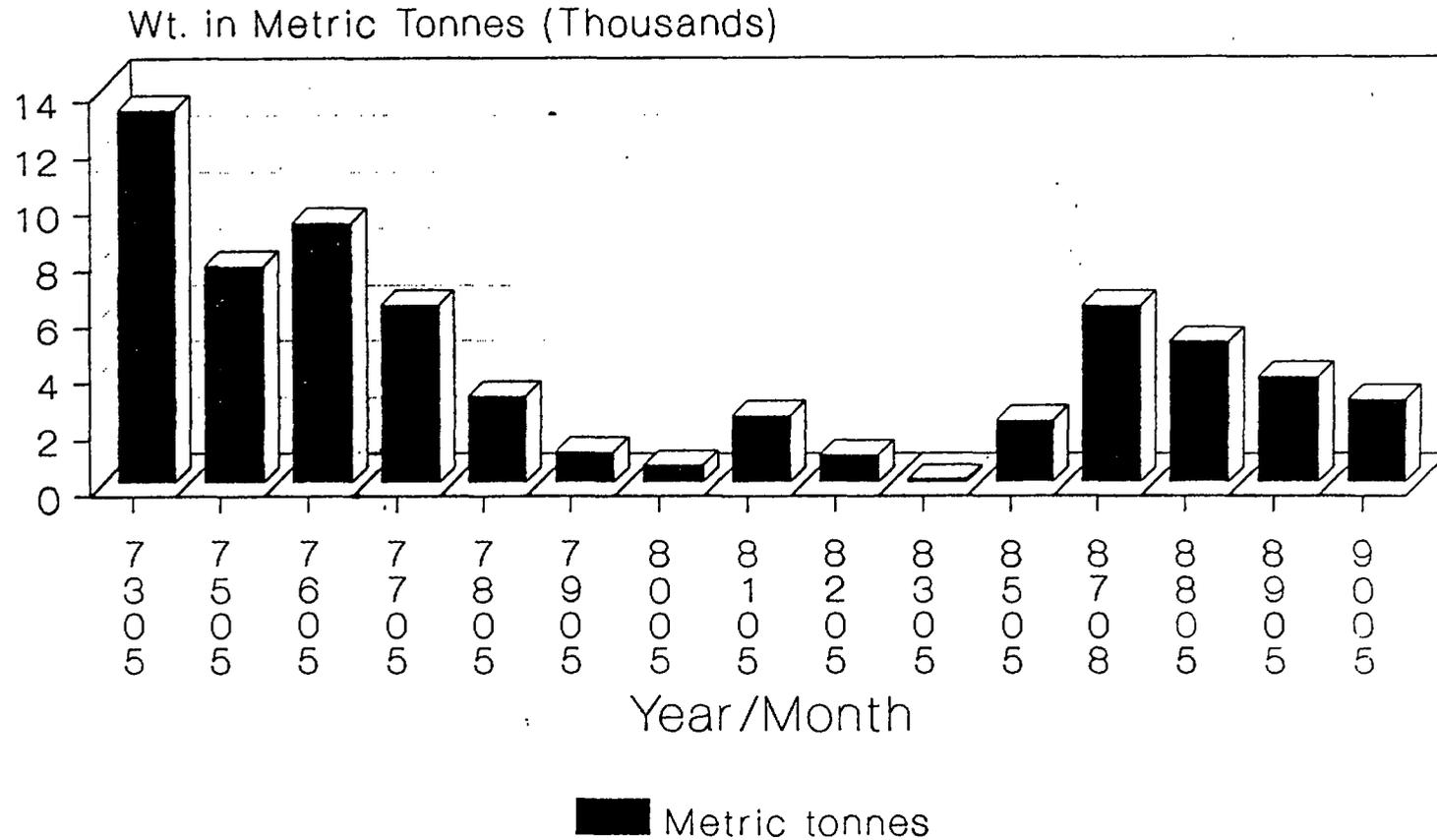


Fig. 3

Area 124 *P. jordani* Survey Results Biomass Index

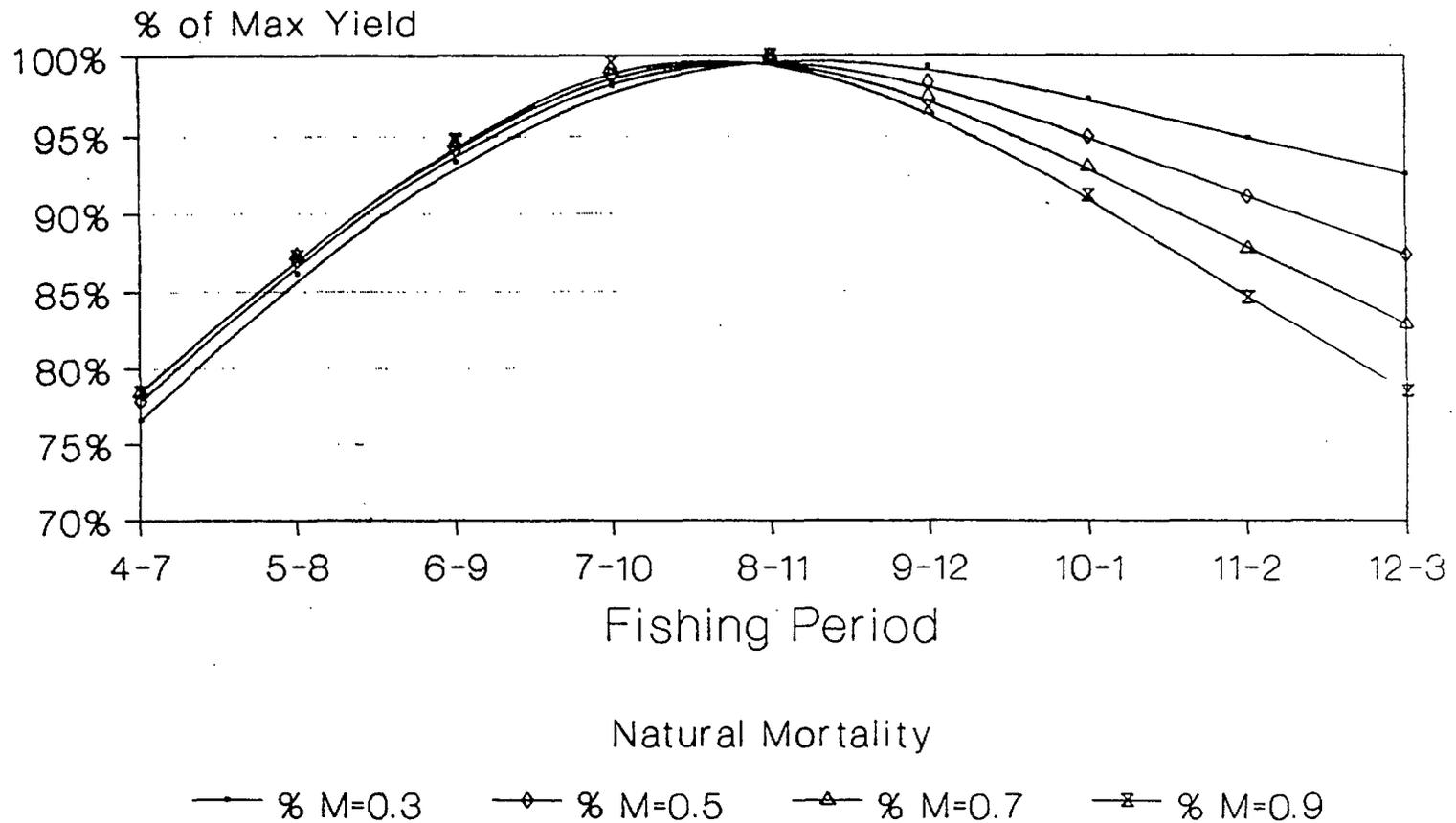


Survey prior to commercial fishery

Fig. 4.

Pandalus jordani

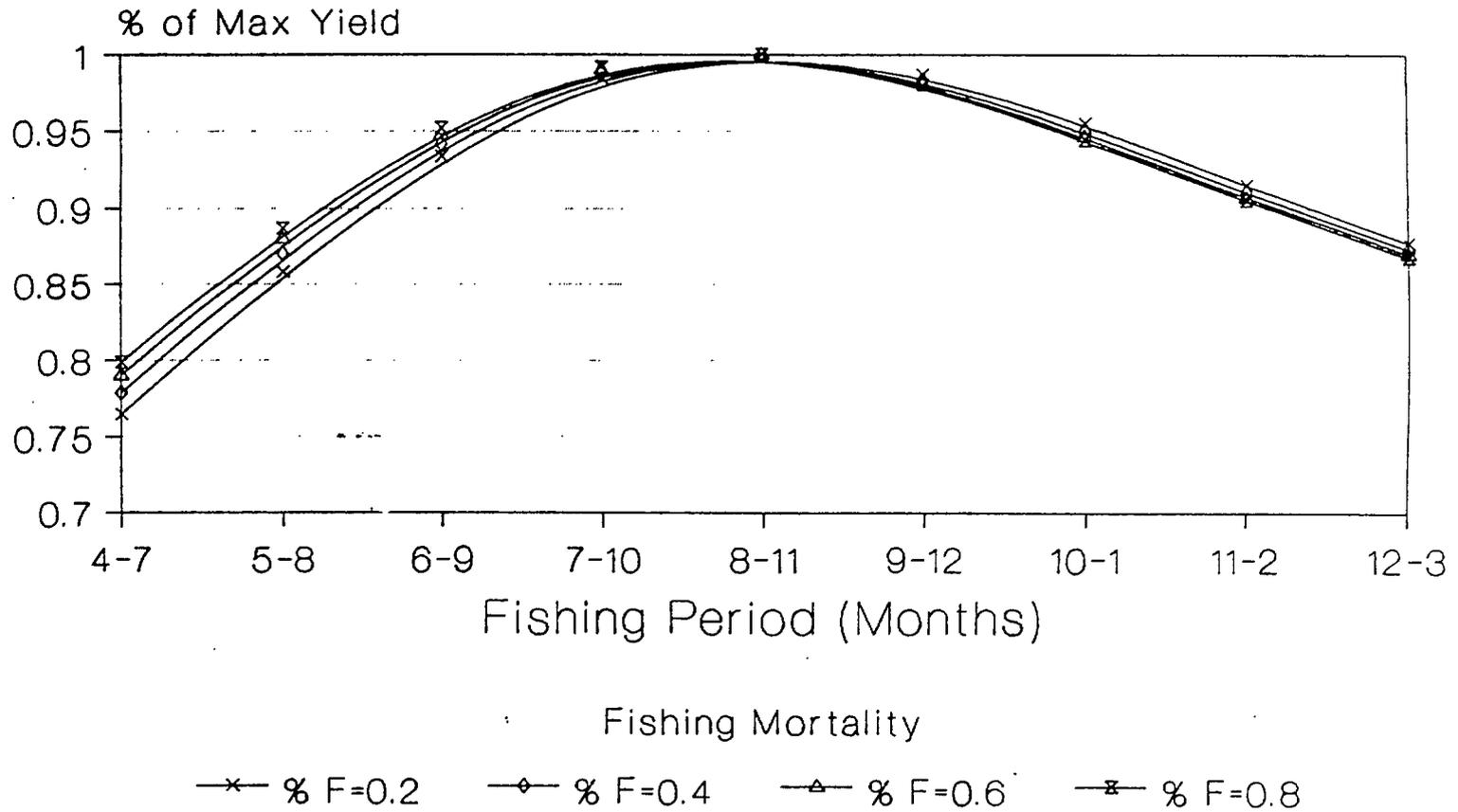
Fishing Mortality ($F=0.4$)



4 month fishing period

Pandalus jordani

Yield per recruit (M=0.5)



4 month fishing period

Fig. 6.

2. Euphausiid Fishery Review Regarding Potential Expansion Concerns

by

G. Jamieson, J. Fulton, D. Mackas,
G. A. McFarlane, and D. Wave

SUMMARY

Recent interest from industry in expanding quotas for the B.C. euphausiid fishery has resulted in this review of 1) history of euphausiid fishing to date, 2) knowledge of the biology of the species involved, and 3) concerns about the impact of possible expansion on the dynamics of other commercial species. Research recommendations to improve our understanding of euphausiid biology and its importance to other species are suggested. To permit collection of additional biological data, exploratory quotas on an area basis are recommended. Quota levels should be pre-emptive, conservative and should be set so as to have minimal impact on the dynamics of other species.

INTRODUCTION

This committee was established by the Director, Biological Sciences Branch, on February 14, 1989, to review available data to determine if there is a sufficient euphausiid resource off the west coast of Vancouver Island and in the Strait of Georgia to permit expansion of the existing fishery. The current fishery is limited to a maximum of 500 t (215 t in the Strait, 285 t in adjacent inlets). This review was specifically to consider what euphausiid stocks might be fished and to indicate how the fishery should proceed so that good scientific data can be obtained. It is recognized that with currently available data, an accurate estimate of euphausiid abundance cannot be determined at this time.

Industry recognizes that currently available biological data is insufficient to allow estimation of what scale of fishery is possible to permit a sustainable level of euphausiid harvest without significant disruption of existing finfish fisheries. Industry has expressed a willingness to work with DFO to improve both our understanding of euphausiid life history and production parameters, and our estimation of total euphausiid biomass in the offshore. Resources within DFO to undertake research on euphausiids are limited, and so this report brings together all available data, discusses their limitations, and recommends research which needs to be undertaken to allow establishment of a sustainable offshore fishery.

GENERAL BIOLOGY, DISTRIBUTION, MIGRATION AND AGGREGATION

1. Species occurrence

About twenty species of euphausiids occur in B.C. waters, but total biomass is strongly dominated (>90%) by five species: Euphausia pacifica, Thysanoessa spinifera, T. inspinata, and T. longipes on the outer coast, plus T. rashii at some inshore locations. These are all "cold-water" species belonging to the Subarctic Pacific faunal group, but there are significant within-region differences in distribution. Under present climatic conditions, the range for E. pacifica, T. spinifera, and T. inspinata extends south to southern California. Southern limits for T. longipes and T. rashii are circa 48-49 N. Typically only one or two species contribute significantly (>10%) to the biomass at any single location. E. pacifica is almost always one of the dominants. It often accounts for 70-100% of the euphausiid biomass at deep water locations off southern Vancouver Island and in the Strait of Georgia. The relative importance of the four Thysanoessa species increases in more northerly and inshore locations. T. spinifera is a major component of finfish diets on the continental shelf off the lower west coast of Vancouver Island (LWCVI) and off Washington, it is the principal prey of Pacific hake.

2. Life history, Growth, Reproduction and Survivorship

Life history of T. spinifera is not well known but we assume that it is similar to E. pacifica. Breeding takes place in spring and summer with the male transferring a spermatophore to the female, attaching it at the opening of the oviduct. Fertilization occurs when eggs are expelled into the water column. The egg (about 350-400 microns in diameter) hatches and metamorphoses through three distinct larval stages, the nauplii, calyptopis, and furcilia, before becoming a sub-adult. Rates of hatching and development are a function of temperature and food supply. Growth is accomplished by frequent moults during the furcilia and sub adult stages. Both E. pacifica and T. spinifera become sexually mature in one year. Since mature adult T. spinifera are nearly one and a half times as large in weight as E. pacifica, we assume that their feeding strategies are significantly different. Although both are omnivorous and filter feed in surface water at night, T. spinifera likely also feeds on bottom sediments during daytime.

Reproductive timing, somatic growth rate, and lifespan of the major euphausiid species vary widely over their respective ranges. Seasonal cycles of both temperature and food availability have been cited as controlling factors. Seasonality of spawning is stronger at higher latitudes. Spawning in the Strait of Georgia and adjoining inlets occurs episodically from April through September and is believed to be correlated with timing of phytoplankton blooms (Heath 1977). Larval abundance peaks late (July - September) on the outer coast of B.C. (Mackas, published and unpublished data 1979-1988) and still later (October through December) off central Oregon (Smiles and Percy 1971). Off

California, spawning occurs year-round. Peak reproduction is from April to September and appears to be associated with summer upwelling events rather than with temperature (Brinton 1976). Both Brinton (1976) and Heath (1977) note that, throughout its zoogeographic range, reproduction of E. pacifica occurs within a rather narrow temperature band (ca. 9-16°C). Timing of reproduction appears to be locally adjusted to match the intersection of the seasonal temperature cycle with this preferred range.

Heath (1977) and Fulton and Lebrasseur (1984) report growth curves for local inshore and offshore euphausiid populations. Growth of larvae and juveniles is rapid, ca. 0.07-.09 mm.d⁻¹, in spring, summer and early autumn, slows or halts in winter, and resumes in late winter or early spring. It is unclear whether the winter reduction in growth is controlled solely by temperature or also by low winter food supply. Most of the reproduction appears to be by year old animals (15-18 mm body length in E. pacifica), but a few older and larger individuals are often present. Because of the winter slow-down, growth averaged over the lifespan is about 40% slower off British Columbia than off Oregon (Smiles and Pearcy 1971) or California (Brinton 1976), but substantially faster than in the central and western Subarctic Pacific. Survival rate estimates for post-larval E. pacifica in Saanich Inlet and the Strait of Georgia are 50-70% month⁻¹ (Heath 1977).

3. Vertical distribution and migration

Until they reach about 5-6 mm in length (roughly 50 days post-hatching), juvenile euphausiids inhabit the upper 20-30 m of the water column both day and night. They are transported and dispersed strongly by surface layer currents. Drifter buoy and current meter measurements off Vancouver Island suggest an alongshore residence time substantially shorter than a month. Later developmental stages migrate vertically about 50-200 m on a daily cycle. By leaving the surface layer in daytime, they presumably reduce their vulnerability to visual predators. By moving up at night, they are then able to feed on surface layer phytoplankton and small zooplankton (usually non- or weakly-migratory). Daytime distribution is strongly layered and often separated vertically from concentrations of other organisms. Daily vertical migration is typically across a 70-200 m depth range and can result in significant changes in advective transport rate (both speed and direction). In situ light intensity (a function of surface incident intensity and water transparency) is the major environmental cue setting scattering layer depth, but vertical stratification of temperature and dissolved oxygen concentration can be secondary controls. Estimated population densities are usually low where bottom depth is shallower than the preferred daytime isolume. However, several species are known from other regions to be epibenthic in daytime. Together with visual avoidance of nets, this behaviour may contribute to the frequently large day-night differences in vertically-integrated catches.

Despite the normal strong migratory behaviour, high concentrations of euphausiids are occasionally observed at the sea surface in daylight (Endo et al. 1985; Hammer 1984). These aggregations are actively exploited by seabirds, fish, baleen whales, and, at least in Japan, commercial fishermen. The physical and behavioural mechanism(s) responsible for daytime surface aggregation of normally migratory euphausiids are poorly understood; possibilities include passive upward advection by strong currents, flight from predatory fish, pursuit of smaller prey, and reproductive activity. No one mechanism seems adequate to explain all, or even most, recorded occurrences but there is often a strong spatial association with localized patches of cold surface water.

The horizontal spatial distribution of euphausiids is intensely patchy. Population densities can vary by several orders of magnitude over separations of a few kilometres or less, and patch locations shift over time. Recent work off the outer coast of Vancouver Island (Mackas, Brown and Denman, in prep.) shows a strong association of patch location with regions of steep bottom slope, especially where currents at the daytime scattering layer depth are convergent toward shoaling bathymetry. The strong sample-to-sample variability, combined with potential biases due to sampler avoidance, make statistically reliable estimates of total stock size difficult to obtain.

4. Stock separation and recolonization potential

A recent thesis (Blanton, 1990) used enzyme electrophoresis to examine genetic differentiation among local *E. pacifica* populations (Saanich Inlet, Strait of Georgia, Jervis Inlet, Barkley Sound, outer coast continental shelf and shelf break). Genetic "distance" between samples was very low, implying extensive gene flow between regions. This suggests that a locally overfished stock would be recolonized over the course of a number of generations (roughly 10-20 years). However, although the exchange rate appears to be rapid compared to genetic drift and differential selection, the probability for within-year or next year recovery is uncertain.

5. Size selection by predators and by potential fishing

Available data (Ware and Tanasichuk, unpub. data) indicates hake are eating almost exclusively the largest euphausiids (mostly >20 mm body length). Although our plankton nets may select for small animals because of their weaker sampler avoidance capability, it seems likely that many fish predators are selecting for large animals. If small euphausiid predation mortality is relatively low and euphausiid growth is not food limited (both plausible at present), this would be prudent behaviour by the fish. It would be difficult for a commercial euphausiid fishery to be as selective: net mesh will damage, if not retain, smaller euphausiids from the same volume of water, and the fishery will probably be at night when there is little or no depth stratification of euphausiids by body size. The relative implications of fish removing a lot of

biomass with little potential further productivity versus the potential of commercial fishing to remove rapidly growing younger animals cannot be assessed at this time, in part because the impact of other predatory species, probably mostly invertebrate, on small euphausiids is unknown.

EUPHAUSIID FISHERY MANAGEMENT IN BRITISH COLUMBIA

The present euphausiid fishery in British Columbia is confined to the Strait of Georgia. In the 1970's, interest in development of an euphausiid fishery resulted in the setting of a rather arbitrary quota of 500 t for the Strait, with the impression that once fishermen had developed optimal fishing techniques, the fishery would then expand and become focused in outer coast waters along the continental shelf. However, the fishermen that initially became involved all had vessels too small to fish in the rough offshore waters, so they remained in the Strait and have continued fishing to the present. The relatively small quota available has meant that potential large euphausiid markets could not be met, so the fishery has focused on supplying product to the relatively small aquarium fish food market. Over the past few years, some fishermen have acquired the capital resources to fish offshore waters, and these fishermen are now requesting that DFO consider allowing the fishery to expand into those waters.

HISTORY OF THE EUPHAUSIID FISHERY IN THE STRAIT OF GEORGIA

A fishery for euphausiids began in the Strait in 1970 as an experimental fishery. Until 1985, annual landings have been less than 200 t, with fishing concentrated initially in Saanich Inlet, then Howe Sound and most recently, in Jervis Inlet. In 1976, quotas were established to limit the fishery as a result of concerns about the importance of euphausiids as a food source for salmon and other commercial species. The annual catch quota was set at 500 english tons (453 metric tonnes), with an open season from November to March to minimize incidental capture of larval and juvenile fish and shellfish, which are mostly present in the spring through fall. The total quota established was crudely estimated to be less than 3% of the annual consumption of euphausiids by all predators in the Strait, although the concentration of fishing effort in only one inlet at a time has meant that local exploitation is probably at a considerably higher rate. Jervis Inlet has been primarily exploited since 1985, but while there have been some concerns expressed about declining catch per unit effort (CPUE), our inadequate knowledge about factors affecting euphausiid aggregations and overall abundance make it impossible to draw any clear conclusion. In 1989, the quota was raised to 500 metric tons (t) for the Strait, plus 20-75 t for major inlets, giving a total quota of 785 t. However, landings, which primarily reflect fish food market demand, were only 327 t. In 1990, the inlet quotas were subtracted from the total quota of 500 t, rather than being added to it, leaving only 215 t for the main body of water of the Strait. However, there is unanimous consensus by industry that the 1989 year-class is well above average, with catch rates recently

achieved in Jervis Inlet reportedly being as high as in the virgin fishery. Although the quota was only 35 t in Jervis Inlet for 1989, actual landings were 119 t, with most being landed in November - December. The potential for significant annual fluctuation in abundance, even during periods of active fishing, is thus demonstrated, as is the difficulty in establishing optimal quota levels for a species which is harvested at 1-2 y of age.

HISTORIES OF OTHER EUPHAUSIID FISHERIES IN THE WORLD

1. Antarctic

Exploratory fishing for krill in the Antarctic Ocean began in 1961-62 by the USSR. Commercial fishing has been conducted by Japan since 1972-73, while at least 5 other countries started exploratory fishing around 1975. Regular large-scale fishing began in 1976-77 because of the closure of traditional fishing grounds to international participants in many areas of the world with the establishment of 200-mile exclusive fishing zones. Landings peaked in 1981-82 at 528,000 t, with a rapid decline to 128,000 t in 1983-84, entirely due to a reduction in the fishery by the USSR because of difficulties in the marketing and processing of krill. Most landings come from the Atlantic Ocean, with fishing in the Indian and Pacific Oceans relatively minimal. Estimates of the standing stock of krill have varied from some tens of millions of tons to more than 1350 million tons. There appear to be large annual fluctuations in abundance, as well as seasonal fluctuations. Highest values are in the southern summer and lowest are in the spring. Sahrhage (1989) calculated that a total of 400-500 million tons of krill per year may be eaten by predators. The reduction of whale stocks over the past few decades is estimated to have generated a "surplus" of about 150 million tons, and this has been coincident with observed increases in a number of other predator species, which Sahrhage (1989) suggests may be due to the increased availability of krill.

Although fishery landings are relatively small relative to the size of the krill resource, there is nevertheless concern that a major krill fishery expansion might have an impact on predator species. Although the standing stock is high in the Antarctic, net production is relatively low and quite variable among different areas of the Antarctic seas. Based on primary productivity and a conversion rate of phytoplankton to krill ranging from 1:10 to 1:40, krill production was estimated at about 100-500 million tons per year. This means there may be relatively little surplus to be harvested by man, but the question has been raised as to whether krill fishing should be renounced for the benefit of a further increase in penguin and crab-eater seal populations that are already larger than in an unexploited system.

Research priorities (Sahrhage 1989) were further improvement in the determination of key biological parameters, such as growth, longevity and mortality of krill, coupled with better stock definition. An overall management strategy for all species, prey

as well as predator, is also required. However, it was concluded that any influence of a fishery on krill stocks and their predators could presumably only be detected after the catch of very large quantities of krill.

2. Japan

Published data on euphausiid (*E. pacifica*) fishing off Japan are scarce, but Odate (1979) provides some data for a fishery off the Sanriku and Joban coast. The fishery began in the 1950's, with fluctuating but steady expansion to about 3000 t by 1965. It then expanded more rapidly, reaching 8662 t in 1971 and 41,215 t by 1978. The fishery off Miyagi Prefecture in 1971 extended over an area about 20 k long but by 1978, the fishery extended over about 225 k of coast. We do not know what has happened in this fishery subsequent to 1978.

Fishing success appeared to be correlated with local oceanographic conditions, and in particular with the southward extension of cold water, ie. $<5^{\circ}\text{C}$. below 100 m depth, in the area between $35-42^{\circ}\text{N}$, west of 145°E during February through May. There is often a sharp temperature gradient along the southward edge of this cold water extrusion southwards, and euphausiid concentrations were often found along this transition zone.

The commercial catch consisted of a homogenous size group with a single mode at 17-19 mm body length, while more variability in size occurred in more offshore waters. Again, as in the Antarctic, better life history data, including the process of immigration from offshore waters, was needed to permit assessment of stock abundance.

EUPHAUSIID STOCK ESTIMATES FOR B.C. WATERS

1. Available sampling methods and their limitations

Four types of data are now or potentially available: a) trawl catch by the commercial fishery, b) research cruise catch data, which is mostly from plankton sampling with relatively small nets, c) acoustic sampling using sound scattering, and d) a mixture of research and acoustic data in the benthic boundary area.

a) Catch from the commercial fishery

The commercial fishery is at present operating in only a few locations (Jervis Inlet, Howe Sound and Malaspina Strait). Catch data have not yet been used to estimate stock size. The commercial nets are large (20-30 m² typical mouth area) and are fished at night when the euphausiids migrate into the near-surface layer. Bias due to sampler avoidance should be minimal; however, the distribution of effort is highly localized and biased toward preferred fishing sites. Fishing is often acoustically targeted on dense aggregations, so extrapolation to large-area average stock density will require careful examination of assumptions about the

dynamics of local spatial aggregations. Seasonal closures (to prevent by-catch of other species, but also coinciding with vessel availability) also mean that data is available for only a few months out of the year. Because of the very limited spatial and temporal coverage, confidence limits on estimates of total stock size will be very wide. The best use for now of these data are likely to be for assessment of sampling bias of smaller research nets and to provide time series of catch per unit effort (CPUE) in the small number of regions where the fishery has been operating. However, CPUE must be used with caution when fishing a species which swarms since the density of animals, and therefore CPUE, within a swarm may be constant until the swarm is scattered or disappears.

b) Plankton samples from research cruises

Research cruises off B.C. have used plankton nets ranging in size from about 0.1-1 m² mouth area, towed day and/or night at speeds ranging from 0.5-1.5 m.s⁻¹. Because late juvenile and adult euphausiids are large, agile, and have well-developed sensory organs, they are at the extreme upper end of the size range of organisms that can be sampled "quantitatively" using plankton nets. Underestimation of population density due to sampler avoidance is known to occur. It is probably most severe for nets that are small, highly visible (daylight tows using nets with high albedo), towed slowly, and/or emit vibrational signals from towing harness leading the net mouth. Unfortunately, published estimates of appropriate multiplicative correction factors (Brinton and Townsend 1981) range from 1.0 to about 30. Most recent west coast sampling has used nets designed to minimize avoidance ("Bongo", BIONESE, or Tucker trawl designs equipped with non-reflective net frames and cloth); our best estimate is that correction factors for these samplers should be <10. If we are to continue to rely on these gear types, cross-calibration with a "zero avoidance" standard (the best candidate is commercial trawls) should be a near-term priority. However, the required level of effort will be substantial (circa 1-2 weeks joint operation of a research vessel and a commercial boat, circa 1 PY for sample processing and statistical analysis).

c) Acoustic sampling

Acoustic sampling is an attractive alternative to nets for two reasons. First (at least for echo-sounders in the 50-500 kHz frequency range) the echo-sounder transducer can be separated by tens of meters from the euphausiid population being sampled; bias due to sampler avoidance is eliminated (except as transmitted through net tow "calibration" samples). Second, detailed spatial resolution (e.g. 1 m vertical, 50-200 m horizontal) is obtainable without exorbitant expenditure of ship-time and technical labour. This is important because very large numbers of individual population density measurements are needed to integrate the spatial

patchiness of euphausiids and thereby provide a stable estimate of their total stock size (eg. Sameto 1980). We also believe that spatially-resolved maps of patch shape and location will be important to understanding interaction with other species and with the fishery.

The most significant limitation of acoustic sampling for euphausiids is its non-specificity. Sound is scattered (with varying efficiency) by all particles in the transducer beam. Target strength per particle varies strongly with particle size, acoustic frequency, and angular distance off the axis of the acoustic beam; less strongly but significantly with particle shape and orientation (Pieper 1979). The received signal is proportional to the variously weighted sum of individual biomass of all scatterers (euphausiids, fish, other zooplankton, and physical inhomogeneties) within an along-axis segment of the transducer beam pattern. Three different approaches are used to make the biomass estimates from echo sounders more specific for euphausiids.

- i For single-frequency (usually 105-110 Khz for euphausiids), single beam echo integration (the method used by Daly and Macaulay 1988, Simard and Mackas 1989, and more recent surveys by Ocean Ecology staff), the only basis for target discrimination is spatial segregation of target types. In daylight, biological sound scattering layers occur at various depths in the water column and the euphausiid scattering layer is often relatively uncontaminated by other taxa (at night the distributions of most scatterers overlap in the near-surface layer). Frequent net tow samples within the scattering layer are needed to confirm the location and broad taxonomic composition of the target layer, and to provide information on within layer variability in size and detailed species composition. The net tow samples are also used to provide an empirical "calibration" between euphausiid biomass and acoustic signal strength. Individual paired samples show a spread of about a factor of two on either side of the overall regression line. It is unclear how much of this variability is "real" and how much is due to the relatively small spatial mismatch between the volumes sampled by the net and by the echo-sounder. An additional concern is that bias in the net tow catch (e.g. due to net avoidance) will carry over to the "calibrated" echo-integration data. This equipment is readily available and off-the-shelf, tested systems can be acquired.
- ii) Multiple-frequency echo-integration (eg. Macaulay et al. 1984) makes use of the fact that individual target strength as a function of body size varies with acoustic frequency (loosely, "large" organisms such as fish scatter strongly at all acoustic frequencies, while small organisms such as copepods show detectable scatter only at very high acoustic frequencies). If a target volume

of water is simultaneously sampled at several acoustic frequencies (typically 4-10 frequencies in the range 50 Khz-2 MHz), the vector of echo-return vs. frequency can be converted to a vector of estimated biomass vs. body size. Target types can therefore overlap spatially, allowing e.g. night sampling in the surface layer and studies of feeding interaction between fish and euphausiid aggregations. This technique is well established elsewhere (especially the U.S. and Norway) but is at the developmental stage in Canada. Equipment cost is relatively high (\$0.5-1 M) but will probably decline to circa \$100-200 K in the near future. Operating range from transducer to target population is set by the attenuation curve for the highest acoustic frequencies (typically 10-50 m).

- iii) Dual-beam techniques measure the return from individual targets (vs. integrating over a "large" volume of water containing many individuals). The ratio of return from two axially aligned acoustic beams (one wide, one narrow) is used to estimate angular distance of the target off the beam axis, and thereby correct a received signal to its on-axis maximum value. This number provides an estimate of body size for each individual target. The technique is well established for fish, but is new for macrozooplankton. Size-resolution is likely to be better than that provided by multi-frequency systems; however, the necessity of resolving single targets results in very short working range (5-20 m for euphausiid sized targets). Spatial coverage is therefore poorer than for single or multi-frequency echo integration. The method also does not work well when targets are extremely aggregated.

d) Benthic boundary layer

The net tow and acoustic methods discussed above do not sample the layer immediately adjacent to the seabed. There is increasing evidence that at least some euphausiid species (the strongest evidence is for the Atlantic species Meganyctiphanes norvegica) aggregate in the benthic boundary layer of continental shelf and slope regions. Seabed aggregation is strongest in daylight but may occur at night as well. It is therefore possible that a significant fraction of the coastal euphausiid population is unavailable for census by standard net tow and acoustic methods. In support of this hypothesis is the fact that small benthic grab samplers used on the southern Vancouver Island continental shelf have captured adult euphausiids in relatively high densities (order 1-10 per m²; Brinkhurst, 1987; B. Burd pers. Comm.). More appropriate epibenthic sampling methods (fine-mesh bottom trawl, photography or video) should be developed and used in selected B.C. coastal regions to test for the quantitative significance of

epibenthic aggregation. Based on horizontal distribution and taxonomic affinity, T. spinifera is the B.C. species most likely to show this behaviour (both T. spinifera and E. pacifica were identified from the bottom grabs).

2. Stock size estimates by region

a) Outer coast of Vancouver Island

Three sources of data are available for the B.C. outer coast: the winter-spring 1980 PBS Ichthyoplankton Survey (oblique bongo net tows, results reported by Fulton et al. 1982, Fulton and LeBrasseur 1984); detailed acoustic surveys off southern Vancouver Island in June and August of 1986 (single frequency echo-integration ground-truthed against daytime BIONESS tows, results reported by Simard and Mackas 1989); and 1985-89 La Perouse Project "standard grid" plankton samples (vertical net hauls, Mackas in prep.). Of these, the acoustic survey estimates are probably the most precise because they resolve the intense cross-shore spatial variability. Raw data from both the ichthyoplankton and acoustic surveys are subject to moderate downward bias due to sampler avoidance. Fulton et al. (1982) and Fulton and LeBrasseur (1984) suggested a multiplicative correction factor of 10 to daytime samples from the ichthyoplankton surveys. However, they estimated standing stock by taking the average of all night stations deeper than 200 m and assuming that most of the stock is distributed in a band 5-10 km wide running the length of the coast (ie. $10 \text{ km} \times 864 \text{ km} = 8,640 \text{ km}^2$). No correction factor was applied to the BIONESS samples used to ground-truth the acoustic surveys.

Both the acoustic and the ichthyoplankton surveys showed high euphausiid biomass along the shelf break and in the Juan de Fuca Eddy region. Population densities are typically at least an order of magnitude less dense both on the inner continental shelf where depths are <100 m and seaward of the 1000 m isobath. Area integrated stock size estimates for the La Perouse Project study area (the continental shelf and slope region from Cape Flattery to Estevan Point) are about $20 \times 10^3 \text{ t}$ for April 1980, $29 \times 10^3 \text{ t}$ for June 1986, and $61 \times 10^3 \text{ t}$ for August 1986. No extensive surveys have been done since 1986; however, tow cruises scheduled for late April and early October 1990 should provide additional (and updated) acoustic surveys.

Data from the La Perouse Project plankton grid provide better resolution and integration of seasonal and interannual variability but have low within-time-period reliability for several reasons. Spatial patchiness is poorly integrated because only a small number of point samples (usually 10-12) are obtained per time period. The raw data are numerical abundance by species in three size classes; weight estimates are obtained by multiplying the abundance data by size coefficients and summing over size classes and species. Two potential sources of bias are present: downward because of sampler avoidance and upward because several sampling sites were selected to coincide with regions of fish aggregation (and therefore

probable high density of euphausiid prey). Despite these uncertainties, multi-year average estimates of total stock size (no correction factors) for the La Perouse study area are comparable to those from the spatially detailed surveys: minimum 11×10^3 t (April), maximum 169×10^3 t (August), grand average 75×10^3 t.

b) Inner Coast (Strait of Georgia and Inlets)

Ichthyoplankton surveys were carried out in the Strait of Georgia from January through June in 1980 and 1981. Sampling protocols were similar to outer coast surveys except that all sampling was done during daylight (Mason and Phillips 1985).

Biweekly daytime sampling of a grid pattern (spacing approximately 9 km) in the southeast Strait of Georgia from February - June in 1980, and 1981 gave standing stock estimates varying from $2.4 - 6.1 \times 10^3$ t. Average biomass for the sampling period ranged from $1.3 - 3.3 \text{ g.m}^2$ with an average of 1.4 g.m^2 for 1980 and 2.1 g.m^2 for 1981. These estimates are based on daytime sampling and are not comparable to outer coast sampling based on nighttime sampling.

Euphausiid densities varied from place to place by a factor of 50 or more (Fig. 1). Comparison of the distribution of biomass in 12 cruises showed no consistent patterns. Cruise to cruise stations located off the passes between the Gulf Islands showed especially high variability with both extremely high and extremely low concentrations appearing at the same location on consecutive cruises. Throughout the sampling period there was a continuous increase in total size of standing stock from about $2.4 - 5.5 \times 10^3$ t. The increase can be accounted for by a growth rate of $0.9\% \text{ d}^{-1}$ except for a twofold increase in the early April cruise (Fig. 2) calculated from length-frequent data. We attribute this to a massive immigration of euphausiids from the northeast on a scale of tens of kilometres. Anecdotal information from fishermen suggests that euphausiids from the Strait of Georgia might overwinter in Jervis Inlet and enter the Strait in springtime. Timing and magnitude of such migrations are essential for accurate estimates of biomass and production. Estimates of very high euphausiid biomass (25 g.m^2) for Jervis inlet by Heath (1977) may be due to migrations rather than in situ production.

3. Trophic constraints on local euphausiid productivity

For the La Perouse study area, annual primary productivity is almost certainly in the range $300 - 500 \text{ gC.m}^2 \text{ y}^{-1}$. Transfer efficiency from primary producer to herbivore is unlikely to be higher than 15%. Based on La Perouse Project data, the ratio of euphausiid biomass to total herbivore biomass is about 10-30%, after net avoidance effects are allowed for. Because of a faster turnover of smaller-bodied zooplankton, the ratio of euphausiid: total herbivore productivity should theoretically be lower, say 5-15%. Assuming that the euphausiids are getting most of their food intake as herbivores, and with some regional stratification of

total productivity and percentage of euphausiids within the above ranges, the annual productivity of euphausiids could be $840 \cdot 10^3$ tonnes. Assuming an annual P:B of 6 (see Table 1 for world ranges), this predicts an annual average locally-fed stock size of about $140 \cdot 10^3$ tonnes (advective transport could augment or reduce the resident stock). The productivity estimate is considered an upper limit, because a substantial fraction of the local primary productivity appears to be transported out of the region before it is consumed. In other words, there is little evidence for particularly high total zooplankton grazing rates. Note also that this is the total productivity for all euphausiid size classes; both the fishery and the fish prefer >15 mm animals, which was perhaps 50% of total stock from Smiles and Pearcy (1971) size distribution data off Oregon.

Table 1. P:B estimates from various sources.

Author	Site & Species	Annual P:B
Heath (1977)	(Inner coast E. pacifica)	8.4-9.5
Mauchline (1977)	(Calculated from Smiles & Parcy 1971)	8.7
Lindley (1978)	(western Atlantic T. longicaudata) (eastern Atlantic T. longicaudata)	2-3 4-8
Landley (1980)	(Atlantic T. inermis & T. raschii)	1.3-4.2
Banse and Mosher (1980)	P:B vs. adult body size equation	2.1

INTERSPECIFIC IMPLICATIONS OF A EUPHAUSIID FISHERY OFF THE LOWER WEST COAST OF VANCOUVER ISLAND

La Perouse bank predator-prey linkages

Euphausiids are the most important prey supporting the dominant fish stocks off the west coast of Vancouver Island. In fact, euphausiids provide more than 80% of the food for roughly 342,000 t of fish which spend the summer feeding in the fertile waters off the LWCVI. This area supports major commercial herring, hake, chinook salmon, sablefish and groundfish fisheries. A multi-disciplinary study of the physical oceanography, zooplankton and fish community in the vicinity of La Perouse bank has been operating since 1985, so we probably know more about this system than any other piece of the continental shelf off British Columbia.

To date, the stomach contents of over 27,000 fish have been examined to determine the major components of their diet and the daily rations. This information has been used to develop a multispecies predator-prey model of the La Perouse bank food chain. Results indicate that the single most important prey species in the area is euphausiids, with herring ranking a distant second. The dominant predators are Pacific hake, dogfish, coho and chinook salmon, sablefish, lingcod and halibut. Their average biomass (thousands of tonnes) and principal prey (in order of importance) are:

Predator	Biomass	Principal prey species		
		#1	#2	#3
Pacific hake	175	euphausiids	herring	
Dogfish	51	euphausiids	hake	herring
Coho	15	herring	euphausiids	
Chinook	11	herring	euphausiids	
Sablefish	15	euphausiids	herring	
Pacific cod	15	herring	hake	
Lingcod	10	herring		
Pacific halibut	2	herring		
Herring	48	euphausiids		

Preliminary calculations indicate that during the upwelling season (May - October), the offshore predator community eats, on average, over 380 thousand tonnes of euphausiids, 66 thousand tonnes of herring and 31 thousand tonnes of hake. These figures clearly highlight the overwhelming importance of euphausiids in the food chain. It also appears that more euphausiids may be consumed on the inner continental shelf than are produced there, so some resupply from the shelf-break and possibly the Strait of Georgia is required to satisfy demand.

Potential impacts of a euphausiid fishery

Although our knowledge is far from complete, the research that has been conducted so far enables us to identify a number of potential risks, and possible benefits, to some established commercial fisheries if a significant (ca. 50 thousand tonne) euphausiid fishery were developed off the LWCVI. A large reduction of the euphausiid biomass on the inner continental shelf could change the summer distribution pattern of the dominant, migratory hake population, which in turn could either lessen, or aggravate, the impact of hake on herring, depending on how hake respond. When hake first migrate into the La Perouse bank area in early June, they tend to move into the deep basins off Barkley sound and near the Juan de Fuca eddy. By July, presumably as the local euphausiid prey (principally T. spinifera) is grazed down, the centre of the hake distribution shifts southward to the Juan de Fuca eddy. By August, again presumably in response to a depletion of the euphausiid stock around the eddy, hake begin moving to the shelf-break where they feed on deeper water euphausiids (principally E. pacifica) that are thought to be advected southward by the shelf-break current. Hake typically feed along the shelf-break during September and October, before beginning their long migration back to California, where they spawn the following winter. If the supply of euphausiids on the inner bank was significantly reduced by a euphausiid fishery, the migratory hake stock might simply remain in the area and supplement their ration by eating more of their secondary prey, herring. This could significantly decrease the size of the herring stock, and consequently the size of the roe fishery. Alternatively, if the supply of euphausiids on the inner bank is low, hake may migrate to the shelf-break earlier, which in turn, might reduce their incidental capture of herring (assuming the herring biomass is lower at the shelf-break). Thus, the question as to whether herring will fare better, or worse, as a consequence of a euphausiid fishery depends on how hake respond to a reduction in the supply of euphausiids, and how their distribution overlaps with herring. In addition to these potential interactions, any significant change in hake distribution will undoubtedly alter the way the hake fishery is promulgated, and could increase operating costs if the fishery is relocated to the shelf-break.

The food demand by dogfish represents another unknown. There are about 50 thousand tonnes of this species in the La Perouse bank area, making it the second most abundant predator. During the

upwelling season, the stock currently eats more than 69 thousand tonnes of euphausiids, 31 thousand tonnes of hake and 5 thousand tonnes of herring. How dogfish respond to a reduction in the supply of euphausiids, or hake (assuming they migrate earlier to the shelf-break), could be significant for the herring stock. If the supply of euphausiids and hake on the inner bank diminishes, dogfish may switch to herring, with potentially significant consequences considering the large food rations of dogfish in the summer. Alternatively, but probably less likely, dogfish could maintain the current species mix in their ration by following hake to the shelf-break.

The same concerns about dogfish also apply to sablefish, lingcod, Pacific cod, and some rockfish. Collectively, these species are almost as abundant as dogfish, so a significant change in their distribution and diet could have a measurable, negative impact on herring biomass.

There is also a potential impact of a large euphausiid fishery on larval and juvenile fishes, depending on the timing of the fishery and fishing gear. The hake fishery off the LWCVI has averaged about 90-100,000 tonnes for the past 3 y. Thirty trawlers fish for 4 about months to secure this quota. If a euphausiid fishery of about 50,000 t were prosecuted in the spring and summer in this area, the small mesh nets used to harvest euphausiids might remove enough larval and juvenile fishes of a number of valuable species (e.g. sablefish, herring, and rockfish) to significantly affect their later recruitment.

Necessary Research

1. We need to determine more accurate confidence limits for euphausiid stock sizes (e.g. current estimates are 20-200 x 10³ tonnes for the La Perouse region). These should be related to finfish demands, recognizing that fish ration is large relative to instantaneous euphausiid biomass. Annual P:B is probably about 5-7, and almost certainly in the range 2-10. Offshore predators currently remove most of the production.
2. In an equilibrium ecosystem, recognizing that species will show normal annual fluctuations in abundance, there is no such thing as surplus production. Any quota for a fishery should be considered as a re-allocation of biomass to a new predator, ie. man. When all trophic levels are being exploited, interactions are obviously complex and particular consideration of the dynamics of the whole ecosystem has to be implemented.
3. Economic considerations are great, so more basic information is needed to establish a justifiable quota for a large euphausiid fishery. The following questions in particular need to be addressed:

- a) What is the biomass of the 2 principal species, E. pacifica and T. spinifera? Euphausiids are very difficult to sample quantitatively. With the methods currently available in the region we do not know how accurately we are estimating biomass. Are we low by a factor of 2 or 5? More calibration and testing are needed to resolve this fundamental problem. An improved hydroacoustic system and software need to be obtained or developed to assess the size of the stocks.
- b) How large should the harvest rate be? Once the biomass of the euphausiid stocks is reasonably well known, the potential impacts of various harvest rates on established commercial fisheries for other species that rely on euphausiids need to be worked out.
- c) What is the best place and time to catch euphausiids to minimize the effects on other established commercial fisheries? Having determined the harvest rate, timing and area, a fishing plan has to be worked out that will consider the effect on the herring, hake, sablefish and groundfish fisheries.
4. We need better data on the growth dynamics of euphausiids, and in particular for T. spinifera.

To help DFO secure these data, we recommend that an experimental euphausiid fishery be established with area specific quotas. The following potential catches are considered to be conservative in terms of the impact of a euphausiid fishery on other established fisheries, and were derived by considering the relative abundance of euphausiids and average productivity of the pelagic and groundfish fisheries in each area:

Area	Euphausiid Quota (t)	Statistical Area
Lower West Coast Vancouver Is.	2000	123-124
Upper West Coast Vancouver Is.	2000	125-127
Queen Charlotte Sound	1000	130, 107-111, 7-11
Hecate Strait	500	102-106, 3-6
West Coast Queen Charlotte Is.	1000	142, 101
Strait of Georgia	1000	14-19, 28-29
Total	7500	

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FIGURE CAPTIONS

- Fig. 1. Spatial distribution of euphausiid wet weight biomass in the south and central Strait of Georgia, 30 March - 6 April 1981.
- Fig. 2. Standing stock of all euphausiids, February - June 1981. Trend line is our subjective interpretation of the probable seasonal growth - minus mortality for the south and central Strait of Georgia population. The high value in April probably represents a brief advection of animals in and out of the sampled region.

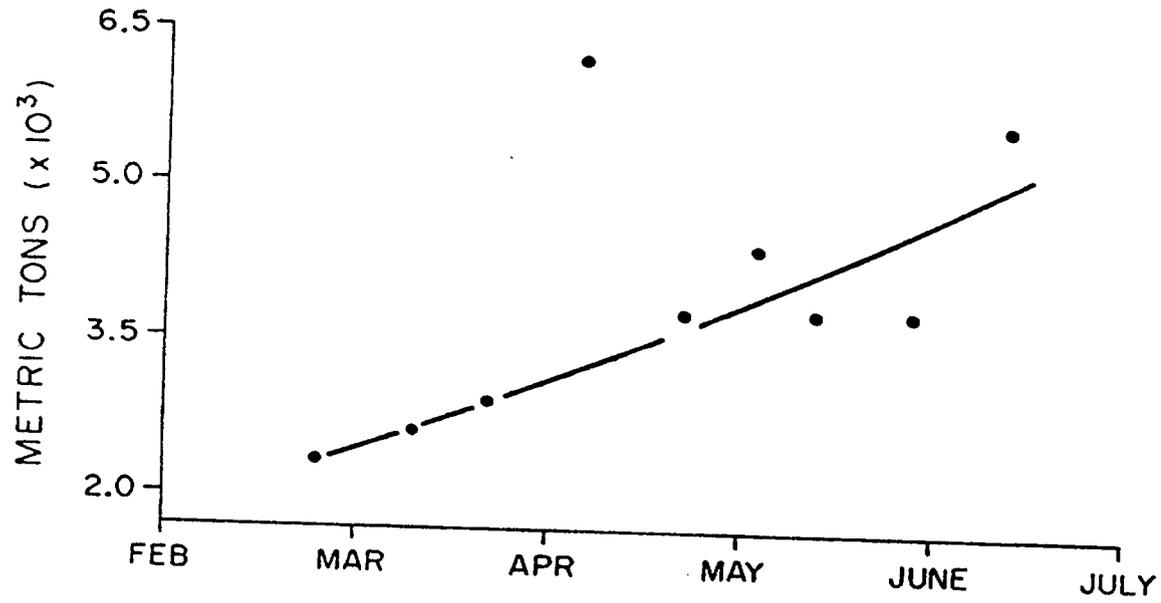
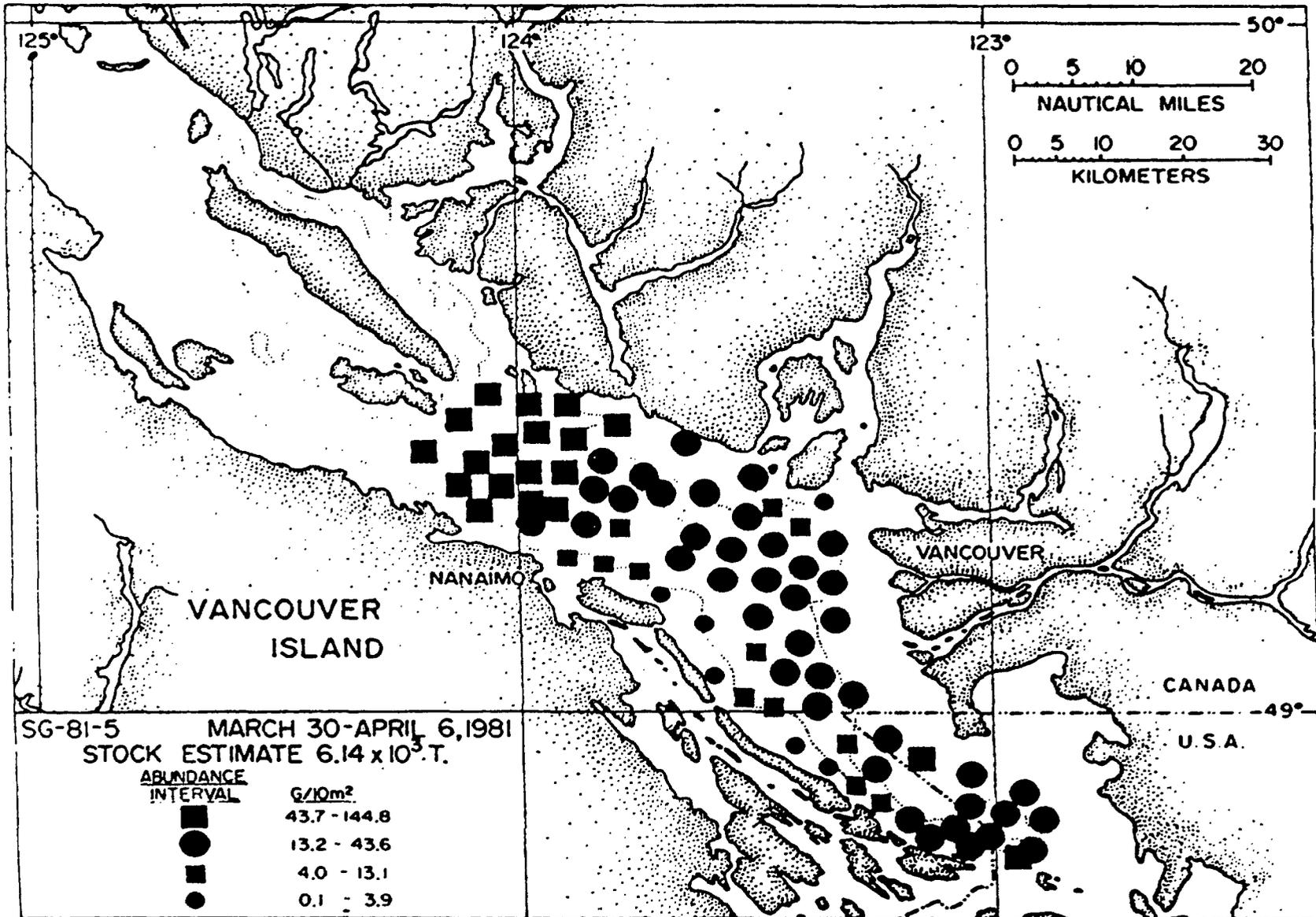


Figure 1



3. Crab Trap Escape Ports

by

G. Jamieson

SUMMARY

Dungeness crab traps containing various escape port sizes and frequencies and with either 2 or 4 entrance mouth triggers were tested to evaluate trap selectivity. Eighty experimental traps were fished during each of 2, 2-week periods in 1989 in the Tofino area. In each trap one of five escape port diameters was used: 100, 106, 108, 110 and 112 mm; in combination with the two port and trigger frequencies. In addition, 10 double wired traps with no escape ports were fished as controls. During the study a total of 2000 male and 1188 female crab were captured and sampled. The catch rate of sublegal sized crab (<165 mm carapace width) was considerably reduced with increasing ring size. There was little difference in retention of legal sized crab between the 108 and 110 mm ring sizes but catch rate decreased significantly with a 112 mm ring. Having 1 or 2 ports or 2 or 4 triggers had little effect on trap selectivity.

The escape port size of 100 mm presently in Canadian regulation has no biological basis. Adjacent American states all require 2 escape ports of at least 108 mm diameter, although the biological data supporting a regulation indicated a 114 mm ring was most optimal. Evidence from this study supports increasing escape port size to 110 mm in Canadian regulation.

Note: Only a summary of this Position Paper is provided here, as the document has been prepared for publication elsewhere. Contact the author for the appropriate reference.

4. Review of the Biological Basis for Management of the British Columbia Abalone Fishery

by

S. Farlinger

SUMMARY

Quotas for the abalone fishery were originally set in 1979 and based on an estimate of annual production (115t). Since that time quotas have been reduced with the following rationale:

1. Continuing decrease in stock size as measured by surveys in two major fishing areas.
2. Concern that assumptions in the original analysis were unmet.
3. Recruitment estimated at less than replacement levels even before the fishery might have had an effect. Since 1985 the quota has remained at the same level (47t) as surveys in the mid 1980's showed no further decline. Resurveys done in 1989 and 1990 show further decline, although it is widely accepted that the survey methodology may not measure changes at the present low densities of abalone. Other information examined includes port sampling data, catch per unit effort and literature from studies on this and other abalone stocks. All indications are that abalone abundance continues to decline. Recruitment (as measured in surveys) also continues at levels less than that required to produce the densities in the 1970's.

It is not known if recruitment overfishing has caused the decline; however, the stock will be even more vulnerable to overfishing at low stock sizes such as have been reported here. The high value of abalone and its accessibility support a high, but undetermined level of landings in excess of the quota. If the amount of these landings is larger than the quota, then any reduction in allowable catch other than closure would be fruitless. With the total landed value of the legal fishery at one million dollars annually, the cost of dealing with illegal fishing and the risks associated with continued fishing may not be reasonable. Surveys to monitor abundance of abalone should continue regardless of the management action taken. Research into the relationship between recruitment and adult abundance is required to elucidate the effect of harvest on these stocks.

INTRODUCTION

The northern abalone, Haliotis kamtschatkana, is the only abalone species occurring in British Columbia, Washington State and Alaska. Abalone are harvested in B.C. and Alaska by native people for food, commercial fishermen and recreational divers. There is no commercial fishery in Washington State (Bargmann, 1984). The biology of abalone and history of the B.C. fishery is well documented (Breen, 1980; Federenko and Sprout, 1982, Bates, 1984, 1985; Bates and Farlinger, 1985; Breen 1986; Jamieson and Francis, 1986; Sloan and Farlinger, 1987; Farlinger and Thomas, 1988; Sloan and Breen, 1988). Before the common use of scuba gear, the commercial fishery landings were low and variable (Figure 1). The Indian food fishery and recreational fishery were also small as most collecting was restricted to shores at low tides. The commercial fishery expanded rapidly in the mid 1970's and by 1977 landings reached 474t. Reasons for the expansion included improved SCUBA gear, reduced fishing times in the salmon and herring fisheries, acceptance of H. kamtschatkana into the Japanese market, and introduction of larger vessels with freezing capacity. Restrictions on the fishery of various types have reduced the landings to their present level of 47t. These restrictions and development of current management are examined in this paper. Quotas were introduced in 1979 based on an estimate of sustainable yield (Breen, 1980), and have been substantially reduced since that time based on several sources of information described below. As SCUBA gear has become widely available, first recreational and more recently native food harvest is taken by diving as well as shore-picking. Only one study describes recreational use in a limited area (McElderry and Richards, 1984); no data is available for Native food use. The commercial fishery in Alaska followed a similar pattern to that seen in B.C. with a quota introduced in 1980 which has declined to the present level of 34t (Koeneman and Botelho, 1989).

MANAGEMENT HISTORY

The first management measure used for the abalone fishery was the minimum size limit; it was originally implemented at 102 mm shell length in 1908. It was decreased to 89 mm during 1914 to 1937, and to 64 mm (width) from 1938 to 1977. The size limit was changed to length of 101.6 mm (4 inches) in 1977. For practical purposes the limit was amended to 100 mm in 1981 where it remains today.

In 1976 when the fishery escalated there was no yield estimate available, but biologists and managers considered the 1976 level (274t) to be above sustainable yield (Sloan and Breen, 1988). The high vulnerability of abalone populations to excessive fishing is well recognized (Breen, 1980). Numerous restrictions were put on the fishery for the 1977 season (Federenko and Sprout, 1982), but landings continued to increase to 474t that year. Changes included:

- 1) Limited entry 29 individuals who had fished in 1975 and 1976; final 1978 number of 26 in effect to date.
- 2) Limited effort per licence 3 divers per vessel; this was ineffective and was rescinded in 1980.
- 3) Harvesting procedure rules abalone measured underwater and returned immediately if sublegal; in effect to date.
- 4) Limited season limited to 8 months, then to 3 months in 1978; this has varied, but is presently in effect.
- 5) Size limit returned to 101.6 mm shell length; amended to 100 mm in 1981 where it remains to date.
- 6) Harvest logs fishermen required to turn in harvest logs as a condition of licence renewal; this remains in effect to date.
- 7) Area closures for allocation to Indian food and sport fisheries, some closures for conservation (Appendix 1,2). These are still in effect with minor changes.

These measures did not slow the fishery. By 1979 an estimate of yield was available and a quota was set at twice that level based on the assumption that numerous unfished stocks remained available. In 1980, the quota was reduced to the yield estimate (115t); from 1981 to 1985 it was reduced further to the existing 47t quota (Table 1) where it has remained to date. Data relied upon to substantiate these further reductions (Table 2,3,4) are provided below.

The other significant change was to divide quota equally (Table 1) among licence holders (individual quotas (IQ)). Numerous landing and reporting requirements were set to manage the quota system. At this time in British Columbia only the Herring Spawn on Kelp fishery was managed in this manner. IQs were implemented to accommodate small vessels and to maintain a fresh market. Their implementation succeeded in slowing the fishery as evidenced in the duration of the two seasons that year. The first, an open fishery for half the quota, took place in 18 days; the second, an IQ fishery, was nearly 7 months long. In Alaska, no limitation on the number of vessels or the individual catch has been imposed.

After the quotas were reduced to their present level in 1985, the value of abalone continued to rise (Figure 1) and all indications were that illegal fishing was escalating. Based on anecdotal information and licences holders' estimates, levels of illegal landings may be as high as twice to four times the quota. In the Japanese abalone fishery, it is estimated that illegal catch is 1.5 times the 5000t quota (Y. Uno, pers. comm). In the 1989 season, fishing time was again reduced to eight months to reduce the time that the landing of abalone was legal. If a review of a tagging program proposed by licence holders concludes that this method would be effective in controlling illegal product, it may be used for management. This is seen as a method of implementing the 1989 PSARC recommendation to reduce abalone harvest, although it is not yet clear that it would be effective in doing so. Enforcement of the restrictions in this quota fishery is costly relative to the value of the fishery.

BIOLOGICAL INFORMATION AND QUOTA DERIVATION TO 1990

Only a summary of relevant abalone biology is presented here since a recent comprehensive review is available in Sloan and Breen (1988). Abalone occur in a wide variety of habitats from intertidal to subtidal depths of 100 m; most adults are found at less than 10 m in B.C. (Sloan and Breen, 1988). Abalone are mass spawners and broadcast gametes synchronously in shallow subtidal areas during the summer (Mottet, 1978; Breen and Adkins, 1980a). Eggs hatch in a few days into larvae which swim in the water column for about a week (Olsen, 1984). Juvenile abalone are cryptic in habit and occur mostly deeper than adults (Breen and Adkins, 1982). Growth varies considerably between sites depending on availability and quality of food, and exposure (Breen, 1980). Quayle (1971) suggests that northern abalone take about 7.4 years to reach 100 mm shell length. Natural mortality is considered to be low (0.15 to 0.20) (Breen, 1986). Recruitments observed in surveys since 1978 are less than calculated replacement values (pre-recruits $.554/m^2$; recruits $.453/m^2$ (Breen, 1986); recent surveys indicate a continuing decline in recruitment in the Central Coast area to the levels seen in the Queen Charlotte Islands in 1984 (Table 3).

MINIMUM SIZE LIMIT. Using the growth curve of Quayle (1971), the age of harvestable abalone is 7 to 12 years. Breen's (1980) estimates of critical size are at or below 100mm; therefore cohort biomass is decreasing by the time that abalone are recruited to the fishery. Yield per recruit analysis (Breen, 1986) using $M = 0.2$, $K = 0.25$ and $L = 130$ mm suggest that the present size limit is optimum. The effect of fishing on recruitment was examined by the same author using an assumed fecundity in an egg per recruit analysis. His conclusion was that the present minimum size should have ensured egg production at 35 to 50% of virgin population rate, and that recruitment overfishing would not have resulted from this level of removal. This conclusion was also reached for red abalone (Haliotis rufescens) by Tegner et al, 1989.

QUOTAS. A theoretical maximum sustainable yield of legal sized abalone of $30g/m^2/year$ was derived (Breen, 1980) and applied to the postulated pre-fishery density to produce an annual productivity of 6.5% (of original standing stock). The original standing stock was estimated by relating the postulated percent decline to total catch. From this, production was estimated to be 113.4 to 150t annually. This estimate which was used to set quotas (Bernard, 1982) was subject to several assumptions which are probably unmet: that recruitment was constant, that sub-legal mortality from fishing was negligible and that no habitat change was caused by fishing. Quotas have been dropping (Table 1) since their introduction to the fishery in 1978 at 227t at twice the yield estimate as it was thought that numerous unfished areas remained. In 1981 the quota was reduced to the 113.4t estimate of production (Breen, 1980). The quota was dropped to 94t (8000 lb per licence) in 1981 from 113.4t in 1980 for the following reasons: it was clear from surveys that recruitment to many populations was failing, although probably not as a result of fishing pressure

(Sloan and Breen, 1988); illegal handling practices causing sublegal mortality were common amongst the fishermen and the fishery was taking place in a somewhat smaller area than original estimates were derived from. In 1982 Breen (1984) argued that the quota should be dropped further based on examination of the assumptions discussed above and managers did set the quota at a lower 71t (6000 lb per licence) in 1983. Declines in legal and total abalone densities of 75 to 80% from 1978/79 until 1983/84 in the Queen Charlotte Island and Central Coast survey areas (Table 2) prompted the final decrease from 1984 to 1985 season to 47t (4000 lb per licence). In the mid-80s (Carolsfeld et al, 1988; Farlinger and Bates, 1986) no further decline could be observed, although it was recognized that the stock might be at a level where stock changes would not be detectable. A survey repeated in 1989 (Farlinger and Thomas, MS) in the Central Coast area showed a further decline from levels seen in the mid-1980's; a resurvey of the other area was done this year (Farlinger and Thomas, MS) to determine if the decline was widespread before serious management measures were recommended. No evidence of a decrease in size of landed abalone was seen in port sampling (Table 4). Catch and effort data were not particularly informative for reasons outlined below. The quota has remained at 47t to date.

CURRENT INFORMATION

The most recent surveys show a continuing decline in total and legal-sized abalone densities (Table 2). The 1990 survey in the Queen Charlotte Islands indicate a small but significant drop in recruit densities as well (Table 3). Low levels of prerecruits seen in 1984 in this area were observed again. A drop in the number of prerecruit and recruit abalone per square meter (Table 3) seen in the Central Coast in 1989 (.08 and .03 per square meter) to the same level as seen in the Queen Charlotte Islands in 1984 (.06 and .04 per square meter) indicate that both major areas remain at about 25% of 1978/79 levels summarized in Breen (1986). Landings did not drop off as quickly in the Central Coast as in the Queen Charlotte Islands after coastwide quotas were dropped (Appendix 3); if declining recruitment is an effect of fishing, this may explain the more recent decline in number of recruits in that area. As mentioned earlier, changes at the current stock size may not be well described or even identified in the surveys which were designed to measure abalone abundance at much higher levels (Sloan and Breen, 1988; A. Campbell, pers. comm.).

Several other sources of information have been collected and examined in developing management plans for this fishery. Port sampling (Table 4) of commercial landed abalone has been carried out since 1985 in Prince Rupert. The average size of abalone sampled in those years range from 111 to 117 mm and does not exhibit any obvious trend. These sizes suggest that abalone have had at least one or often two years of growth since reaching legal size if mean annual growth at 100 mm are similar to those described by Breen (1980) for a Nereocystis community at 4.42 mm annually. Conflicting evidence of the availability of legal sized abalone is

provided by the movement of fishing activity into non-traditional areas (area 11 and area 12) in recent years as shown in harvest logs (Figure 2) and in information from fishermen (area 2W).

Catch and effort data has been gathered from harvest logs and examined (Figure 3). Sloan and Breen (1988) discuss numerous problems with the information, which include: diver learning, influence of individual quotas on effort, and sequential harvest of virgin beds. Prince (in press) discusses the masking effect of abalone patterns of distribution and movement on catch per unit effort, and concludes that it is a poor measure of stock abundance. His model suggests that only an extreme decrease in abundance will be marked by a decline in catch per unit effort. Catch per diver hour (Figure 3) for the entire coast fluctuates through a decline of an order of magnitude from 1977 to date, substantiating the decline indicated in the surveys; more detailed conclusions are probably not merited.

The conclusions drawn by Tegner et al, 1989 and Breen (1986) concerning the size limit suggest that recruitment overfishing (or at least limited egg production) is not the cause of the decline in abalone stocks. However, Tegner et al argue that intense local harvesting could cause long lasting changes in local populations if dispersion is limited as Prince et al (1987) suggest. They also suggest that at low densities fertilization efficiency may be affected. The abalone fishery in British Columbia involves intense local harvesting as evidenced by the distribution of landings (Figure 2). This situation is probably exacerbated by the aggregation of licences; the 26 licences were fished by 12 operators in 1989 (Farlinger and Campbell, in press).

Evidence of some required level of abundance of adults for successful recruitment to occur is presented in results of a transplant study in Palos Verdes, California for Haliotis fulgens (Tegner, in press). After an importation of reproducing adult abalone, a "pulse" of recruits was observed in the local area; no comparable increase in recruitment was seen in areas more than a few kilometers from the transplant sites.

CONCLUSION

All indications are that the stock continues to decline. Although reduction in egg production potential may not be the cause, local overfishing is likely to be having a significant effect. Movement of fishermen from the two traditional fishing areas into new areas as well as an increase in licences offered for sale are developments which lend support to the conclusion of further decline in stock. The question of the actual level of illegal fishing has significant implications for the management action that would be recommended.

1) If the amount of abalone taken illegally is small relative to the quota, a reasonable conclusion is that a sustainable yield is less than 47t, and a reduction in the quota could be effective.

2) If, as fishermen believe (Abalone Licence Holders and Operators Meeting, November 8, 1989), illegal fishing takes substantially more than the quota, then it is only clear that some level greater than 47t is too much. In this case reductions in the quota would penalize commercial fishermen, and perhaps enhance the value of the product making it even more lucrative for illegal fishing activity; therefore, control of illegal fishing (by closure of the commercial fishery, or increased enforcement) is the more logical approach.

An increase in enforcement activity is unlikely if the cost of the program is disproportionately large relative to the value of the fishery. If the commercial fishery is closed, restrictions or closures for the recreational and native food fishery are also appropriate. Determination of the amount of abalone harvested by the recreational and native food fish users is imperative if the effect of fishing on the stock is to be determined.

3) Surveys to monitor abalone abundance should be updated and continued regardless of management actions taken.

4) Research into the relation between adult stock size and recruitment success is required.

5) New methods of harvest should be explored.

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TABLES, FIGURES, AND APPENDICES

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Table 1. Annual quotas for British Columbia and Guideline Harvest Ranges for Alaska abalone fisheries from 1979 to the present.
(Alaska data courtesy of T. Koeneman, ADFG)

YEAR	BC	ALASKA
1978	none	none
1979	227t	none
1980	113t	113t
1981	94t	45-57t
1982	94t	45-57t
1983	71t	45-57t
1984	59t	45-57t
1985	47t	15-26t
1986	47t	15-26t
1987	47t	15-26t
1988	47t	15-26t
1989	47t	15-26t
1990	47t	15-26t

Table 2. A summary of total and legal abalone densities (no./m²) from surveys conducted in British Columbia, 1978-1990.

YEAR	CENTRAL COAST 25 sites		QUEEN CHARLOTTE IS. 58 sites		REFERENCE
	Total	Legal	Total	Legal	
1978/79	-	-	2.82	0.36	Breen and Adkins, 1979
1979/80	2.74	0.65	-	-	Breen and Adkins, 1980
					Breen and Adkins, 1981
					Breen and Adkins, 1982
1983	1.91	0.31	-	-	Boutillier et al, 1984
1984	-	-	0.54	0.09	Boutillier et al, 1985
1985	1.53	0.36	-	-	Farlinger & Bates, 1986
1987	-	-	0.75	0.20	Carolsfeld et al, 1988
1989	0.55	0.11	-	-	PSARC Working Paper I89-7
1990	-	-	0.62	0.11	PSARC Working Paper I90-9

Table 3. A summary of pre-recruit and recruit abalone densities (No./m²) from surveys conducted in British Columbia, 1983-1990.

YEAR	CENTRAL COAST		QUEEN CHARLOTTE IS.		REFERENCE
	Pre-recruit (94-101mm)	Recruit (102-107mm)	Pre-recruit (94-101mm)	Recruit (102-107mm)	
1983	.18	.10	-	-	Boutillier et al, 1984
1984	-	-	.06	.04	Boutillier et al, 1985
1985	.25	.14	-	-	Farlinger & Bates, 1986
1987	-	-	.05	.05	Carolsfeld et al, 1988
1989	.08	.03	-	-	PSARC Working Group I89-7
1990	-	-	.06	.04	PSARC Working Group I90-9

Table 4. Annual abalone port sampling summary, Prince Rupert, B.C., 1985 to 1990.

Date	Statistical Area	Sample Size	Mean Length (mm)	Standard Deviation	% Legal Size
1985					
Apr. 22	1	65	113	9.8	100
Dec. 7	3	65	108	5.4	99
Feb. 18	5	40	114	8.1	98
Nov. 14	6	100	113	7.7	99
Nov. 12	8	50	109	6.8	97
Nov. 18	8	105	108	6.3	99
Total		425	111		
1986					
Feb. 6	1	149	116	9.0	100
Oct. 27	1	100	108	4.8	100
Nov. 14	1	50	115	6.9	100
Aug. 27	3	103	111	6.9	100
Aug. 18	3	101	109	6.7	99
May 12	6	100	110	12.2	99
Aug. 13	6	105	115	8.8	100
Sep. 29	6	121	109	6.4	96
Total		829	112		
1987					
Feb. 13	6	100	115	8.9	99
Mar. 4	1	100	118	9.6	99
Oct. 14	6	100	114	7.2	100
Nov. 18	2E	102	115	8.1	100
Dec. 14	3	105	117	5.9	100
Dec. 15	3	50	110	5.2	100
Total		557	115		
1988					
Feb. 19	3 and 5	105	112	8.1	100
Mar. 10	1 and 3	101	114	7.8	99
Apr. 27	3	100	109	6.3	100
Oct. 13	2E and 3	100	110	7.1	100
Nov. 1	3	65	108	6.0	95
Nov. 1	6	52	110	8.0	98
Nov. 2	6	100	112	10.2	99
Nov. 23	1	100	110	7.4	96
Total		723	111		

Table 4 continued

Date	Statistical Area	Sample Size	Mean Length (mm)	Standard Deviation	% Legal Size
1989					
Feb. 8	2E	65	113	7.8	99
Feb. 8	5	35	115	10.1	100
Mar. 1	1	100	115	9.1	99
Jun. 5	2E	100	110	8.1	96
Jun. 8	6	48	107	5.2	96
Oct. 6	3 and 6	116	112	7.8	97
Oct. 27	1, 2E, 2W	479	113	8.0	99
Nov. 6	3	148	107	5.3	98
Nov. 6	6	161	111	6.9	99
Nov. 21	6	271	114	8.6	100
Nov. 22	3	29	110	5.2	100
	Total	1552	112		
1990					
Feb. 8	6	104	114	8.0	100
Apr. 6	1	73	119	9.8	99
May 10	2E	200	110	8.5	92
Jun. 20	2E	100	132	8.7	100
	Total	477	117		

Annual Abalone Landings and Value

1952 - 1988

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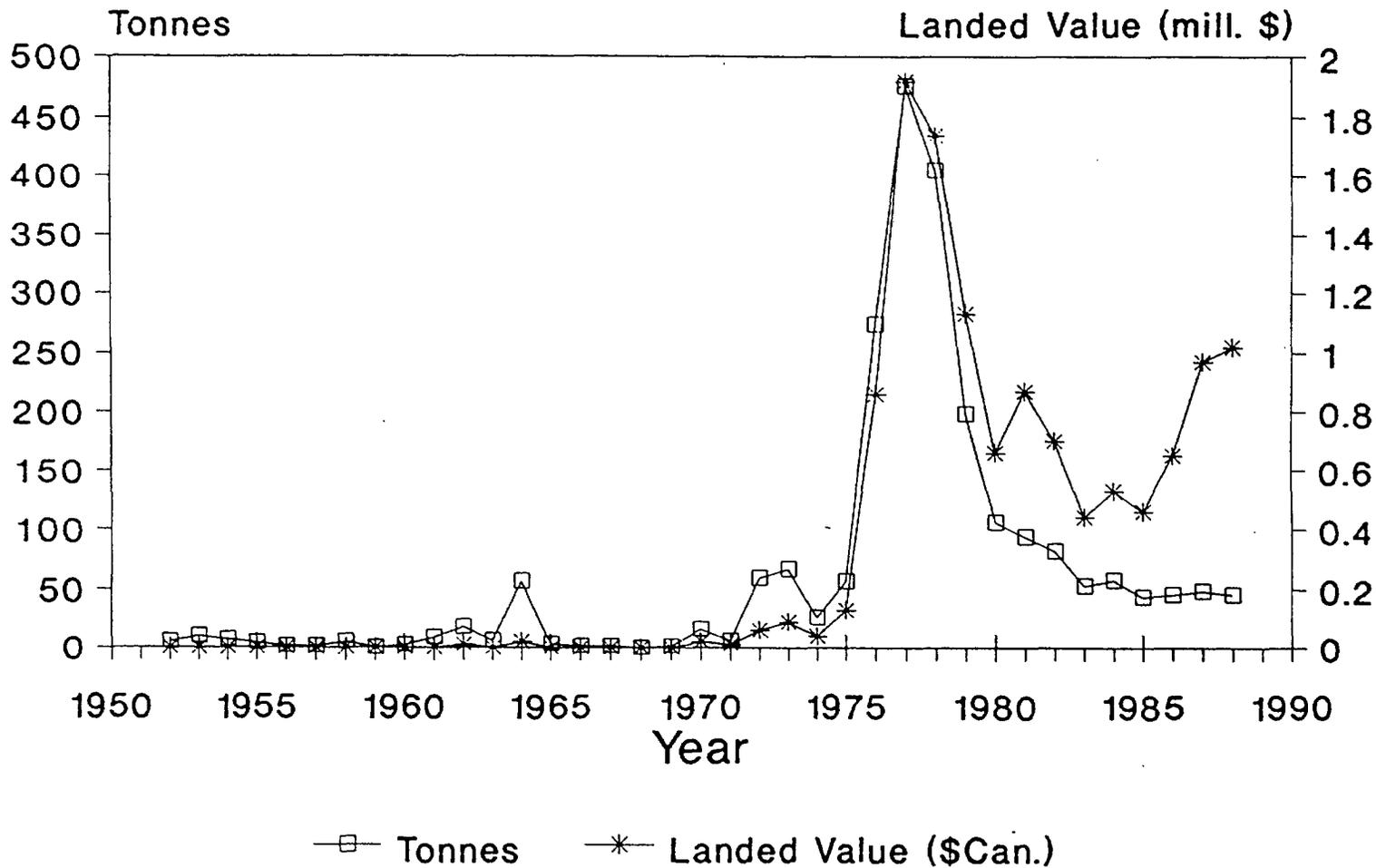


Fig. 1. Abalone Landings and Value (\$ Can.) in the British Columbia Fishery, 1952 - 1988.

Commercial Abalone Landings

1977 - 1989

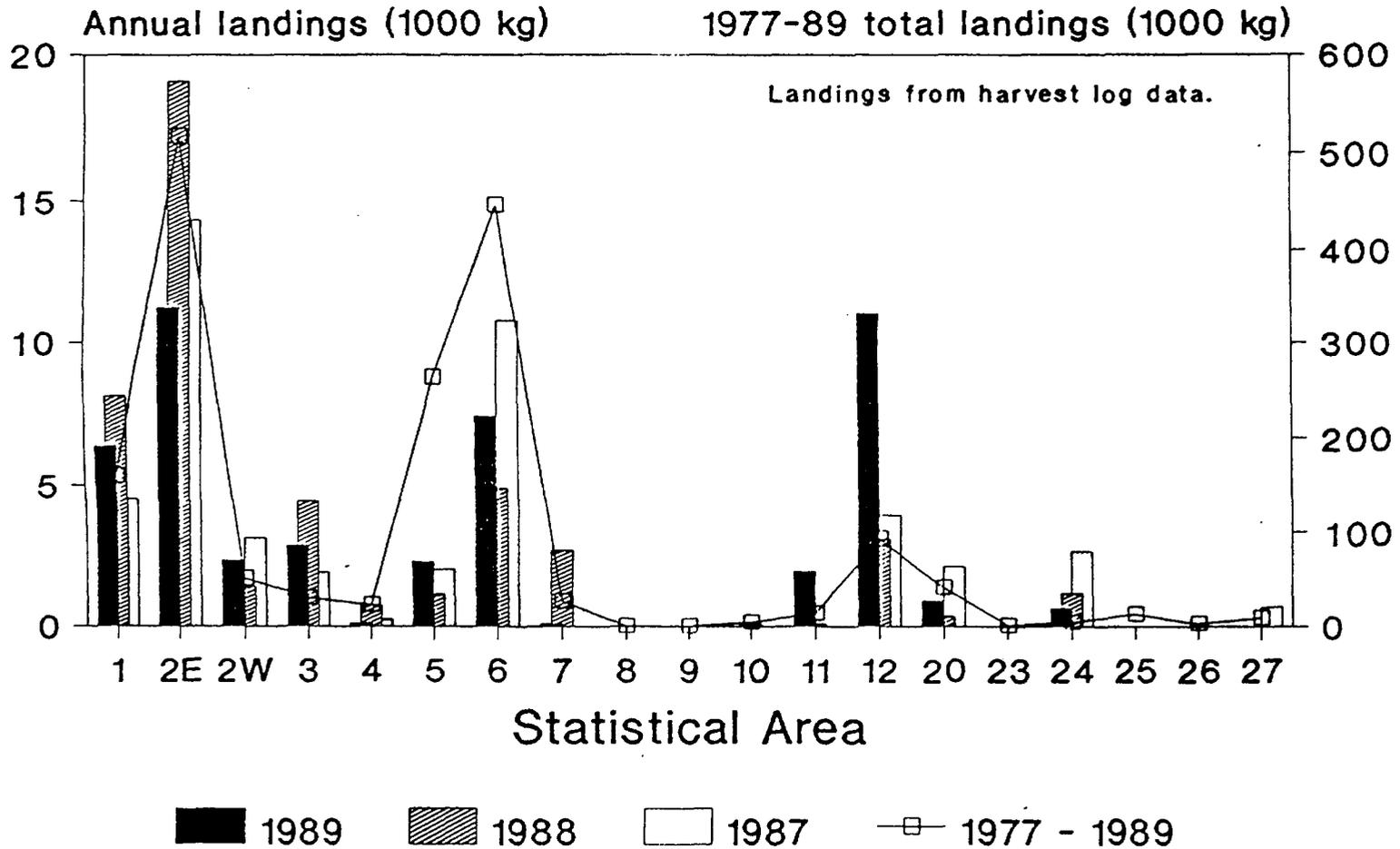


Fig. 2. Commercial abalone landings in B.C. 1977 - 1989.
 Note: Saleslip landings used for 1 tab in 1988 and 1989 data

5:

Annual B.C. Commercial Abalone CPUE 1977 - 1989

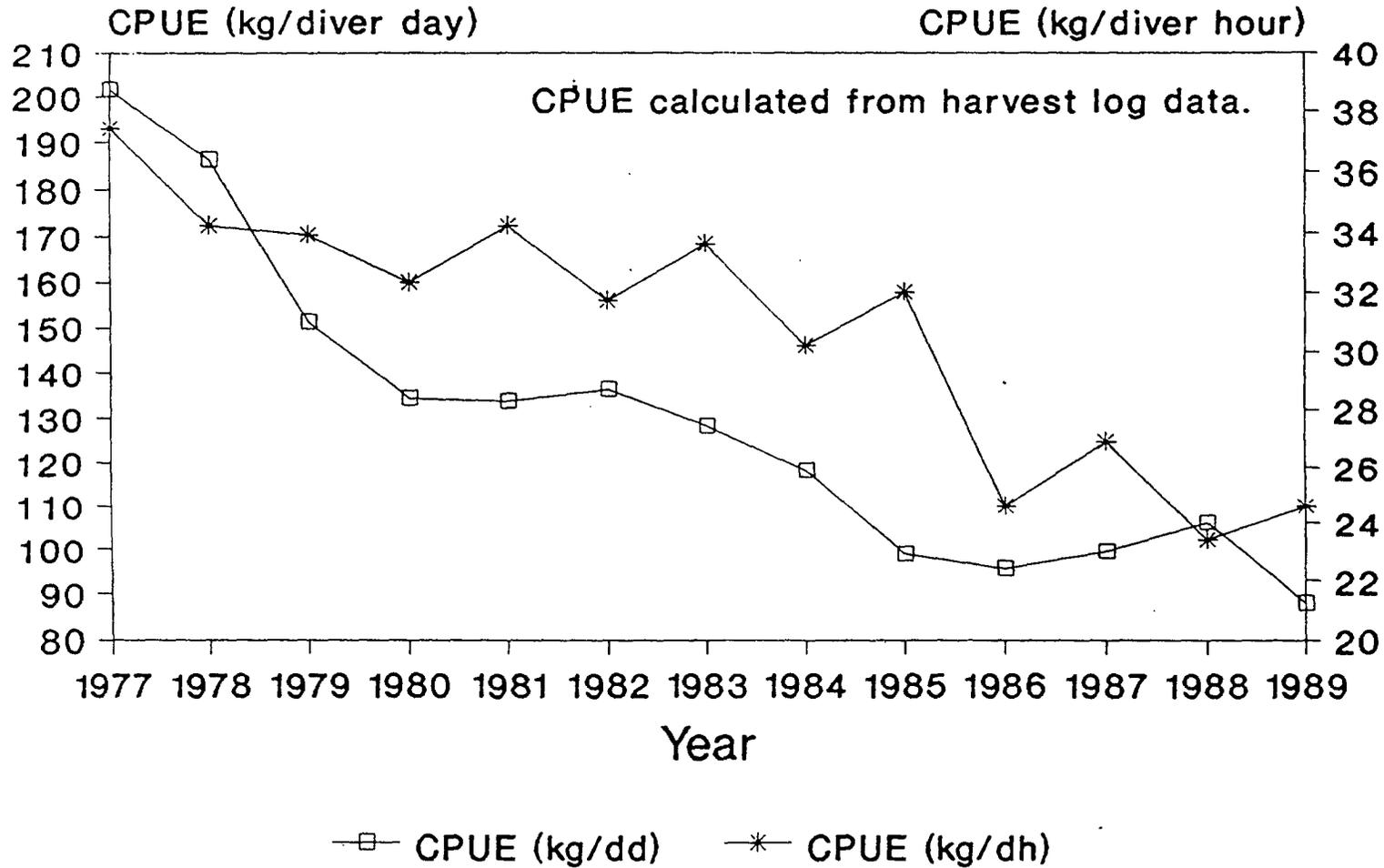


Fig. 3. Annual commercial abalone CPUE by diver day and diver hour for all statistical areas, 1977 - 1989.

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Appendix 1. Commercial abalone area closures, dates implemented and reasons for closures, B.C., up to and including 1990 (for specific area descriptions see Appendix 2).

	Area	Implemented/ Rescinded	Comments
Area 1	Masset Inlet, Masset Sound, McIntyre Bay	1977	- recreational harvest - native harvest
Area 1	Virago Sound	1978	- low stock levels - recreational harvest - native harvest
Area 2E	Juan Perez	1973	- traditional native harvest - recreational harvest, in conjunction with Hotspring Island
Area 2E	Cumshewa Inlet	1977	- low levels of old individuals; few juveniles and sublegals; possibility of "recruitment" overfishing - test fishing payment area
Area 2E	Skedans	1985	- native harvest
Area 2E	Skincuttle Inlet, Carpenter Bay	1979	- low stock levels
Area 2E	Skincuttle Inlet, Carpenter Bay	1982	- closure rescinded
Area 2W	Rennell Sound	1977	- recreational harvest; one of two areas in 2W that is accessible by road from the east coast
Area 2W	Skidegate Channel	1977	- traditional native harvest - recreational harvest; same as Rennell Sound
Area 2W	Tasu Sound	1977	- recreational harvest - surveys in this area by

Appendix 1 (cont'd).

Area	Implemented/ Rescinded	Comments
		DFO in June 1981 have indicated very low abundance of legal-sized abalone; area has been closed to recreational harvesting since 1980
Areas 4 & 5	Parts of Porcher Island, North end Banks Island	- native harvest (Kitkatla Band) - recreational harvest
Areas 4 & 5	Stephens Island 1980 Banks Island closure extended southward	- native harvest (Kitkatla Band) - recreational harvest
Area 6	Campania Island 1977	- native harvest (Klemtu, Bella Bella Bands) - recreational harvest - concerns by Fishery Officers that recreational divers are overfishing the resource - closure was modified in 1981
Area 6	Portions of Campania Island reopened 1981	- closure was changed to exclude Squally Channel
Area 7	Inside Price Island, Swindle Island, Princess Royal Island, Don Peninsula 1977	- native harvest (Klemtu, Bella Bella Bands)
Area 8	North End of Calvert Island 1977	- low stock abundance (Fishery Officer Estimates) - sport fishing
Areas 9 & 10	Rivers and Smith Inlets 1978	- low stock abundance

Appendix 1 (cont'd)

Area	Implemented/ Rescinded	Comments
Areas 12 & 19	Lower Johnstone Strait, Strait of Georgia, Strait of Juan de Fuca	1971 - low stock abundance - recreational harvest thought to meet or exceed what stocks can sustain already
		1986 - area 12 reopened excepting Hardy Bay
Area 20	Sooke	1986 - concern for illegal harvest
		1987 - some areas reopened - area 20-5 closed for sport and native harvest
Area 21	Southwest coast of Vancouver Island	1978 - concern by Fishery Officers for low stock abundance
Areas 23 & 24	Barkely Sound and Clayoquot	1978 - these areas were fished heavily during 1970-1973; stocks have not recovered sufficiently to permit reopening
		1987 - some areas in 24 reopened - 24-1 and 24-2 closed for sport and native harvest
Area 25	Nootka/Esperanza	1987 - some areas reopened after 1986 closure - portions of 25-6, Bajo Reef and 25-13, Port Eliza Inlet closed for sport and native harvest
Areas 26 & 27	Kyuquot Sound/ Quatsino Sound	1980 - conservation; concern by Fishery Officers for low stock abundance
		1987 - some areas reopened - portion of 26-1, 26-2, 27-3 and 27-9 closed for sport and native harvest - Checleset Bay Biological Reserve as established by Province of B.C.

Appendix 2. Description of closed areas from 1990 'E' licence.

Areas 1, 2E and 2W

- i) Those waters bounded inside a line from Fuller Point on Lyell Island true east to the surfline, thence southerly along the surfline to a point true east of Andrew Point on Ramsay Island, thence true west to Andrew Point, thence westerly along the northern shoreline to Ramsay Point, thence to Werner Point on Moresby Island, thence to Richardson Point on Lyell Island, thence northeasterly along the shoreline to the point of commencement, which includes all of sub-area 2-11.
- ii) The waters of Rennell Sound inside a straight line from Cone Head to Clonard Point.
- iii) The waters of Skidegate Channel and adjacent areas (Dawson Inlet, Dawson Harbour, Trounce Inlet), inside a line from Ellis Point on Graham Island to Teenakum northern shoreline of Caatl Island to Exact Point, thence in a straight line to Demeriscous Point on Moresby Island, thence easterly along the north shoreline of Moresby Island to McLellan Point (East Narrows), thence a straight line true north to Graham Island, thence along the south shoreline of Graham Island to the point of commencement (Ellis Point).
- iv) The waters of Tasu Sound and adjacent areas inside a straight line from Davidson Point to Tasu Sound.
- v) The waters of Masset Inlet, Masset Sound and McIntyre Bay inside a straight line from Wiah Point to Skonun Point.
- vi) The waters of Cumshewa Inlet inside a line from Cumshewa Head to Skedans Point, and including waters of Carmichael Passage and Selwyn Inlet bounded on the south by a line from Selwyn Point Light on Morseby Island to a boundary sign opposite on Talunkwan Island, and on the east by a line from Nelson Point to Louise Island to Heming Head on Talunkwan Island.
- vii) The waters from Virago Sound inside a straight line true north from Inskip Point to point of interception with a straight line from Cape Naden to Cape Edenshaw thence westerly along the line between Cape Naden and Edenshaw to Cape Naden.
- viii) Those waters inside a straight line from Nelson Point on Louise Island to the easterly tip of South Low Island, thence in a straight line to the south eastern tip of Low Island, thence following the easterly shore of Low Island to the north westerly tip of Low Island, the most easterly islands of the Skedans Islands, thence in a straight line to Skedans Point on Louise Island, thence following the easterly shoreline of Louise Island to Nelson Point on Louise Island, which is the point of commencement.

Area 4

i) All of sub-areas 4-2, 4-4, 4-9 and 4-13.

Area 5

i) All of sub-areas 5-3, 5-4, 5-6, 5-7, 5-8, 5-10, 5-11, 5-12, 5-13, 5-20 and 5-21.

Area 6

i) All of 6-6, 6-11, 6-12, 6-14, 6-15, 6-16, 6-18, 6-19, 6-25, 6-26 and a portion of 6-10 easterly of a line from the most southern tip of Campania Island to Oswald Point on Rennison Island, and that portion of 6-5 inside a line one nautical mile off the west shore of Gil Island from Blackfly Point to Fawcett Point.

Area 7

i) Bounded on the north by a straight line true east from Jorkins Point on Swindle Island to Dowager Point opposite, and bounded on the south by a line true west from Keith Point on Dowager Island to Prince Island opposite.

ii) Bounded on the west from Promise Point on Cecilia Island along the westerly shore of Cecilia Island to Rankin Point, thence by a straight line to Providence Rock near Cape Mark; and bounded on the south by a straight line to the most northerly point on Limit Island, thence by a straight line to Fingal Point of Princess Alice Island; and bounded on the east by a straight line to Bush Point on Don Peninsula; and bounded on the north from Bush Point on Don Peninsula along the south westerly shore of Don Peninsula to Schubert Point, thence by a straight line to Promise Point on Cecilia Island opposite.

Area 8

i) Subarea 8-2 and that portion of 8-1 north of 51 degrees 39 minutes north latitude.

Southern B.C.

i) "All waters of Johnstone Strait, Straits of Georgia, Strait of Juan de Fuca, or any bay, inlet or other tidal water tributary thereto in the area bounded on the north by a line drawn from Neville Point at the westerly entrance of Port Neville Inlet to Hickey Point Light on Vancouver Island and bounded on the south by a line drawn from William Head through Race Rocks due south magnetic to the International Boundary."

ii) All waters of Hardy Bay bounded on the north by a straight line from Dillon Point on Vancouver Island to Duval Point on Duval Island, thence by a straight line due south to Vancouver Island, thence along the shore of Hardy Bay to Dillon Point, the point of origin.

iii) All of sub-area 20-5.

iv) All of Management Areas 21, 22 and 23.

v) All of sub-areas 24-1 and portions of 24-2; Barney Rocks and Hotsprings Cove.

vi) (a) That portion of sub-area 25-6 bounded by a line commencing at Nootka Cannery thence to the most northerly island in the Savaadra Island chain hence along the most easterly side of the Savaadra Island chain to the easterly tip of San Rafael Island and San Miguel Island thence to Maquinna Point. (see map).

vi) (b) That portion of Bajo Reef from Callicum Creek to the marker buoy thence northerly to a point approximately 1.5 miles southerly of Skuna Bay then northerly to Skuna Bay. (see map).

vi) (c) That portion of sub-area 25-13 bounded by a line commencing at Belmont Point thence westerly to Colwood Rocks thence westerly to Pin Rock thence N 2 degrees true to the most westerly of the major Nuchatlitz Island thence N.E. to Flower Islet thence easterly 76 degrees true to the shore of Nootka Island. (see map).

vi) (d) Port Eliza Inlet inside a line across the entrance to Port Eliza Inlet seaward of Harbour Island. (see map).

vii) (a) Checleset Bay Ecological Reserve as established by the Province of British Columbia, Provincial Lands Branch in Area 26.

vii) (b) Those waters of sub-areas 26-1 and 26-6 westerly of a line commencing at the most easterly point of Amos Island then true north to Vancouver Island. And, a line commencing at Amos Island Light then magnetic south to a point of intersection with the surfline.

viii) All of sub-areas 27-3 and 27-9.

Appendix 3. Annual abalone landings (kg) (from logbooks) by statistical area in B.C., 1977 to 1989.

Statistical Area	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	Total
1	45,668	12,888	2,613	3,169	1,923	13,024	12,113	14,442	9,368	15,320	4,504	6,244	4,450	145,726
2E	251,669	102,431	29,528	12,538	21,321	13,539	17,935	12,670	4,409	6,453	14,342	19,060	11,238	517,133
2W	13,174	13,362	5,726	3,724	6,047	161	0	938	0	2,115	3,130	1,441	2,369	52,187
Q.C.I. Total	310,511	128,681	37,867	19,431	29,291	26,724	30,048	28,050	13,777	23,888	21,976	26,745	18,057	715,046
3	10,186	254	0	2,143	0	1,667	0	3,181	3,407	738	1,952	4,438	2,872	30,838
4	0	6,388	2,928	2,692	5,186	1,383	875	236	539	1,815	238	760	103	23,143
5	94,586	88,289	40,408	13,483	2,858	2,201	3,970	4,990	3,663	3,534	2,041	1,168	2,324	263,515
P.R. Total	104,772	94,931	43,336	18,318	8,044	5,251	4,845	8,407	7,609	6,087	4,231	6,366	5,299	317,496
6	33,751	160,269	87,000	44,519	37,756	27,058	7,538	9,899	10,820	4,170	10,783	4,884	7,448	445,895
7	5,601	10,922	2,704	1,943	1,778	898	552	0	0	0	0	2,714	97	27,209
8	0	0	0	245	0	0	145	0	0	0	0	0	0	390
9	0	0	0	0	553	0	0	0	0	13	0	0	0	566
10	0	0	0	0	0	1,124	0	0	0	3,015	0	64	0	4,203
C.C. Total	39,352	171,191	89,704	46,707	40,087	29,080	8,235	9,899	10,820	7,198	10,783	7,662	7,545	478,263
11	186	0	5,548	1,001	1,828	3,541	0	0	0	45	0	95	1,998	14,242
12	9,135	459	17,312	14,047	9,595	5,052	2,452	3,270	5,545	8,349	3,915	3,077	11,022	93,230
20	1,430	3,026	924	2,004	4,805	8,604	7,684	6,593	3,776	0	2,138	358	929	42,271
23	0	0	0	0	0	1,000	0	0	0	0	0	0	0	1,000
24	180	0	0	0	0	18	0	0	0	0	2,666	1,178	665	4,707
25	4,554	5,718	577	0	0	0	0	389	1,964	0	0	0	0	13,202
26	2,332	0	209	0	0	0	0	0	0	0	0	0	0	2,541
27	2,361	0	1,756	0	0	2,866	0	907	287	0	693	0	0	8,870
S.C. Total	20,178	9,203	26,326	17,052	16,228	21,081	10,136	11,159	11,572	8,394	9,412	4,708	14,614	180,063
Unknown	0	0	0	4,507	0	0	0	0	0	0	0	0	0	4,507
B.C. Total	474,813	404,006	197,233	106,015	93,650	82,136	53,264	57,515	43,778	45,567	46,402	45,481	45,515	1,695,375

5. Abalone Resurvey in the Southeast
Queen Charlotte Islands in 1990

by

G. Thomas, S. Farlinger and W. Carolsfeld

SUMMARY

Abalone stocks at 69 standard sites on the east coast of the Queen Charlotte Islands (Area 2E) were resurveyed in 1990 and the results compared to previous surveys. Present abalone abundance in area 2E is similar to that observed in 1984, remaining at 20% of levels in 1978-79. Mean densities of total, legal (>100 mm), and pre-recruit (94-101 mm) sized abalone were significantly less in 1990 than in 1987, while there was no change in new recruit density. There was an increase in the number of zero sites and decrease in number of sites containing legal abalone between the two years. The present mean density of legal sized abalone (0.1/m²) is far below estimated prefishery levels (2.5/m²). Densities in sites open and closed to commercial fishing were of similar magnitude in 1990.

The failure of abalone abundance in area 2E to return to initial levels may be attributed to a variety of causes. It is possible that large removals by the commercial fishery in the late 1970's (and by other undocumented sources) may be a contributing factor.

INTRODUCTION

Assessment of northern abalone (Haliotis kamtschatkana) stocks in B.C. is based primarily on surveys of standard sites carried out alternately on the east coast of the Queen Charlotte Islands (area 2E) (Figure 1) and the central coast (area 6). Area 2E has consistently been a major producer of commercial abalone (Table 1) and has been resurveyed in 1984 and 1987 following baseline studies in 1978 and 1979 (Breen and Adkins, 1979 and 1981). These surveys indicated a decline in total abalone abundance of 80% between 1978/79 and 1984 (Boutillier et al, 1985). No differences could be shown between 1984 and 1987 (Carolsfeld et al, 1988) and it is not clear that the survey technique can detect changes at these low levels of abundance. The present survey in area 2E is a continuation of the abalone assessment program with a specific goal of determining the geographic extent of a further decline noted in area 6 in 1989.

METHODS

As in the past, this was a joint Fisheries/Science Branch project, augmented by a chartered abalone vessel and crew. Of those participating, two DFO personnel and one commercial operator had experience from previous surveys. Care was taken to follow procedures consistent with those of previous surveys to facilitate between year comparisons of abundance indices.

Standard sites, selected in 1984 for resurvey, were non-zero sites from 1978-79. Sites examined in 1987 were all non-zero sites from 1984. With only minor exceptions, all standard sites covered in the 1987 survey were re-examined in 1990.

Indices of abundance in the form of # abalone/m², were derived using the standard methodology developed during early surveys (Breen and Adkins, 1979). The technique is well documented in survey reports and in a previous report to PSARC (I89-7) so only the most pertinent points will be highlighted here.

Standard sites were relocated from chart positions and written descriptions with a concern for precisely replicating site position. At each site, a total of 16 x 1 m² quadrats, arranged along four transect lines and encompassing an area 7 m x 16 m in the abalone zone, were sampled. At each quadrat all abalone visible on the surface of rocks (exposed) and all those under rocks (cryptic) were removed and measured. Data was tabulated both for sites in areas open and closed to commercial fishing and abundance indices compared between years.

RESULTS

A total of 69 sites were sampled in 1990 of which only one site was new. Appendices 2 and 3 compare total and legal abalone densities by site for the four survey years. Mean total abalone density in 57 comparable sites declined by 80% from 2.74 to 0.53, between 1978-79 and 1984, and remains at low levels (0.66) in 1990. Mean legal density showed a similar considerable decline, decreasing from 0.38 in 1978-79 to 0.10 in 1990. Figure 2 illustrates the change in distribution of total densities between years.

Between 1978-79 and 1984, pre-recruit and new recruit densities declined by 80% from 0.27 and 0.22 to 0.06 and 0.04, respectively (Boutillier, et al., 1985). A comparison of pre-recruit and new recruit densities for common sites in 1990 and previous surveys is not possible but, because selection of non-zero sites over the years would tend to partially mask a decline in abundance, it is assumed that pre-recruit and new recruit densities (0.06 and 0.04) are low relative to 1978-79.

Table 2 compares mean densities for all size categories in 1987 and 1990. There was a significant decline in total, legal, and new recruit densities between the two years, while no change was

noted for pre-recruits (significance tested with a Wilcoxon signed rank test at $p = .025$). An increase in number of zero sites and a decrease in the number of sites with legal abalone (Table 3) provides further evidence of a decline in abundance between the two most recent surveys.

In 1987, no significant difference was noted in mean total abalone density between open and closed sites (Table 2). The present survey showed no change in the relative status of open and closed sites.

A total of 129 cryptic abalone were collected in 1990, accounting for a slightly larger proportion of total abalone than in 1987 (Table 4).

The mean length of all abalone collected in 1990 was 71 mm. Figure 3 illustrates the length frequency of all abalone collected in the present survey. Between 1987 and 1990 the mean length of abalone from comparable sites declined in most sectors, dropping from 77 mm to 72 mm (6% reduction) overall (Table 5). Figure 4 compares length frequencies from comparable sites in 1987 and 1990. The relative frequency distributions were similar in the two years, although the 1990 sample contained a smaller proportion of legal abalone (18% vs 26%).

DISCUSSION

Evidence from the present survey suggests that abalone abundance in area 2E has declined significantly since 1987 and remains at 20% of levels reported in 1978-79. Low abundances were observed in most sectors of area 2E, across all size categories, and in both open and closed areas. The present estimate of legal density of $0.1/m^2$ is far below prefishery (pre-1976) abundances of $2.5/m^2$ (Breen, 1986). Similarly, prerecruit and new recruit densities of 0.06 and 0.04 are well below levels of 0.55 and 0.45 required to maintain prefishery abundances (Breen, 1986).

Sloan and Breen (1988) have described the inherent weakness of the standard survey technique in discerning minor reductions in abundance. However, changes in density observed over the entire period of the fishery are sufficiently large to provide strong evidence of a major decline in abalone abundance.

Possible causes of the population decline between 1978-79 and 1984, discussed by Boutillier et al. (1985), included sublegal mortality from fisheries, natural fluctuations in population abundance, and recruitment overfishing. The former two factors may still effectively contribute to a population decline. The decline noted in 1984 could not be attributed to recruitment overfishing, but a period greater than the 7 to 10 years required to recruit to the fishery has now past. In that time, 517 tonnes equal to 30% of B.C. landings have been harvested from area 2E, primarily during 1977 and 1978. It is possible that the effects of large removals in the late 1970's is expressed in a reduction in both legal and sub-

legal abundances. To date, there has been no attempt to determine a stock and recruitment relationship in northern abalone; however, Sloan and Breen (1988) have reported evidence for other abalone species.

RECOMMENDATIONS

1. Annual harvest of northern abalone should be reduced. This goal could be achieved through reduction in illegal catch or closure of the commercial fishery.
2. Methods of ascertaining levels of sport and native harvest should be implemented.
3. The northern abalone resource is difficult to protect because of high market value and susceptibility of stocks to illegal harvest. If a commercial fishery is to be maintained, innovative management schemes must be explored, including transplants, outplanting seed, bottom modification, predator control, and increasing kelp supply as discussed by Breen (1980). The Japanese system of outplanting cultured stock is one possibility.

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Table 1 Annual B.C. commercial abalone landing quota, landings from Area 2 Est and percent (%) of B.C. quota landed from Area 2 East, 1977 - 1989.

Year	B.C. Quota (kg)	Area 2 East Landings (kg)	Area 2E Landings as % of Quota
1977	None	251,669	
1978	None	102,431	
1979	226,400	29,528	13.0
1980	113,400	12,538	11.1
1981	94,347	21,321	22.6
1982	94,347	13,539	14.4
1983	70,760	17,935	25.3
1984	58,967	12,670	21.5
1985	47,174	4,409	9.3
1986	47,174	6,453	13.7
1987	47,174	14,342	30.4
1988	47,174	19,060	40.4
1989	47,174	11,238	23.8
Total 1979-1989	894,091	163,033	18.2

Note: Landings data from harvest logs.

Table 2. Comparison of numbers and mean densities of Haliotis kamtschatkana between the 1987 and 1990 surveys in Area 2E, based on 67 usable sites common to both surveys. Data are presented separately for exposed, cryptic, pre-recruit, new recruit and legal sized abalone.

Abalone	Shell Length (mm)	1987		1990		Mean Density Changes	
		No.	No./m ²	No.	No./m ²	No./m ²	%
Total		816	0.761	704	0.620	-0.141	18.5
Legal sized	≥100	208	0.194	119	0.105	-0.089	45.9
Pre-recruit	94-101	56	0.052	63	0.055	0.003	5.8
New Recruit	102-107	57	0.053	40	0.035	-0.018	34.0
Exposed		702	0.655	575	0.506	-0.149	22.7
Cryptic		114	0.106	129	0.114	0.008	7.5
Open (Total/m ²)		484	0.658	486	0.566	-0.092	14.0
Closed (Total/m ²)		265	1.184	174	0.778	-0.406	34.3

Note: 1) In 1987 the 67 usable sites corresponded to 1,072 m² quadrats. Because 48 quadrats (instead of 16) were sampled in 2 sites in 1990 the 67 sites corresponded to 1,136 m².

2) Does not include sites recently closed (after 1984).

TABLE 3. Number of "zero sites" and number of "legal abalone sites" in the 67 sites common to the 1987 and 1990 surveys in Area 2E.

	No. Zero Sites	No. Legal Abalone Sites
1987	2	40
1990	5	32

^a"zero sites" - sites in which no abalone were found.
^b"legal abalone sites" - sites in which one or more legal sized abalone were found.

TABLE 4. Total number of exposed and cryptic abalone by sector in Area 2E from the 69 sites surveyed in 1990.

Sector	Total Exposed Abalone	Total Cryptic Abalone
Cumshewa Inlet	19	0
Selwyn Inlet	20	8
Tanu Island	36	0
Upper Juan Perez Sound	275	38
Lower Juan Perez Sound	21	1
Skincuttle Inlet	76	31
Carpenter Bay	59	27
Kunghit Island	85	24
Total	295	129

TABLE 5. Mean Abalone Lengths (mm) by sector in Area 2E for 67 comparable sites in 1987 and 1990.

SECTION	MEAN LENGTH (mm)		% CHANGE
	1987	1990	
Cumshewa Inlet Mean	130	113	13
Selwyn Inlet Mean	73	68	7
Tanu Island Mean	94	83	12
Upper Juan Perez Sound Mean	69	72	4
Lower Juan Perez Sound Mean	57	55	4
Skincuttle Inlet Mean	81	66	19
Carpenter Bay Mean	69	64	7
Kunghit Island Mean	71	75	6
Total	77	72	6

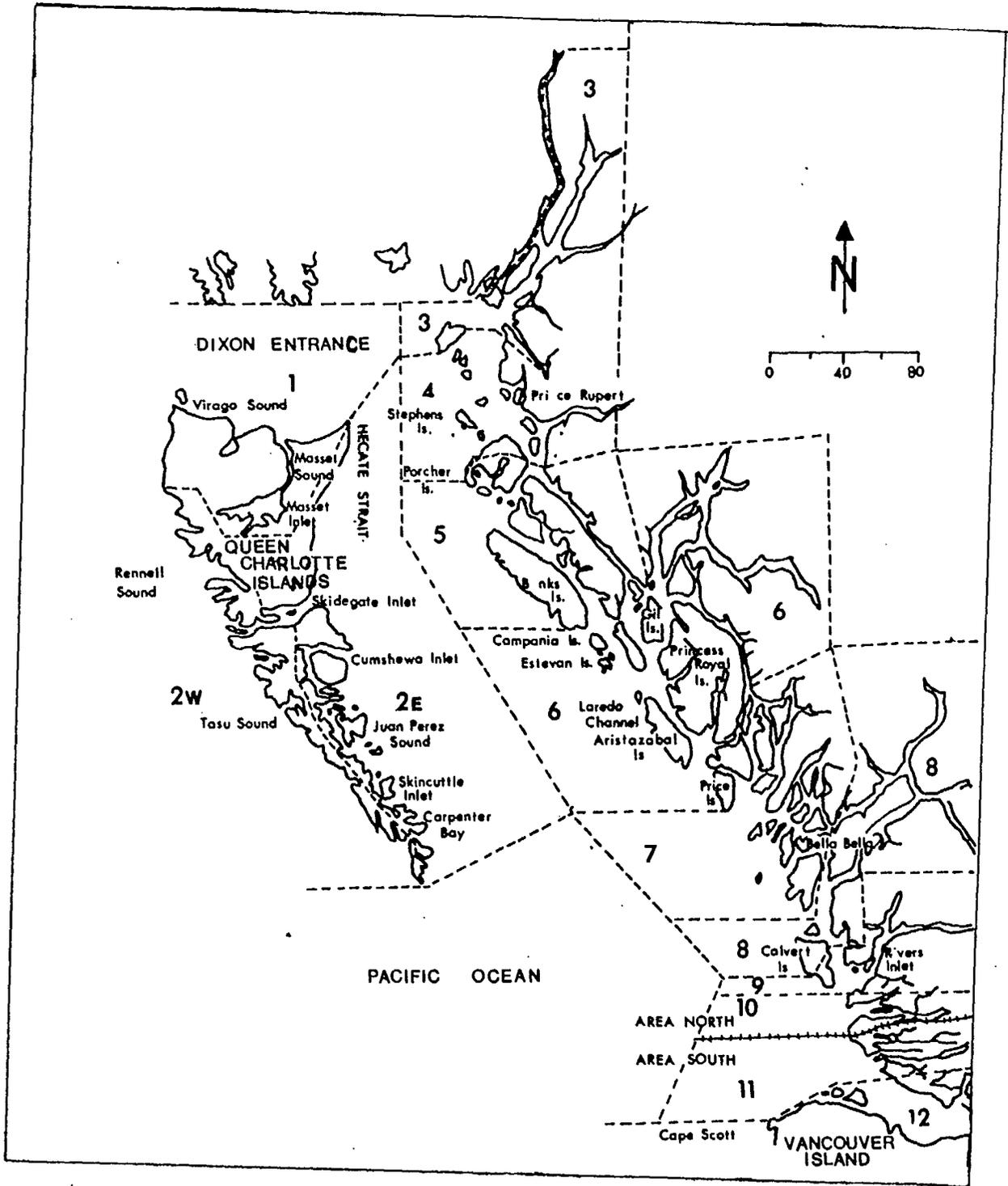
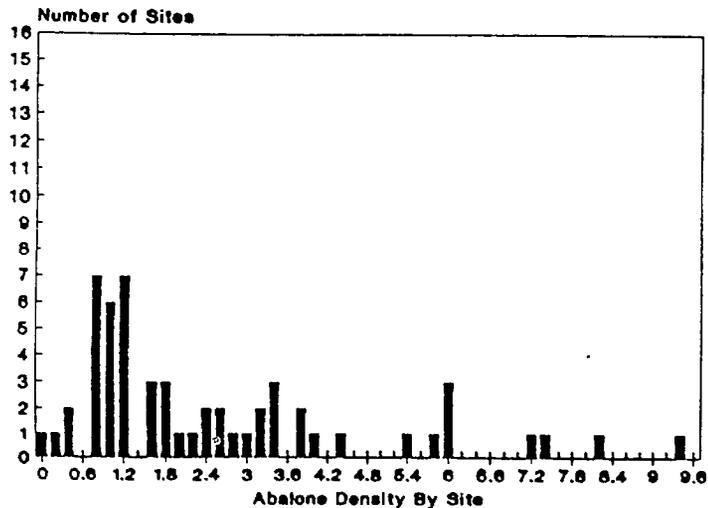
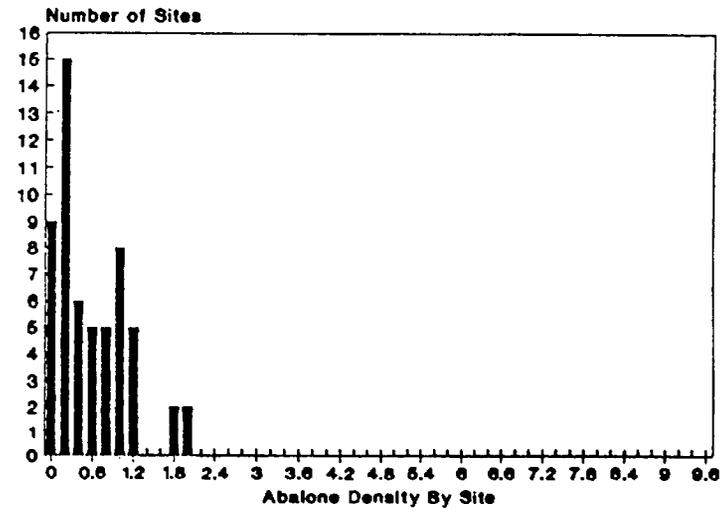


Figure 1. Pacific Fishery Management Areas in northern British Columbia.

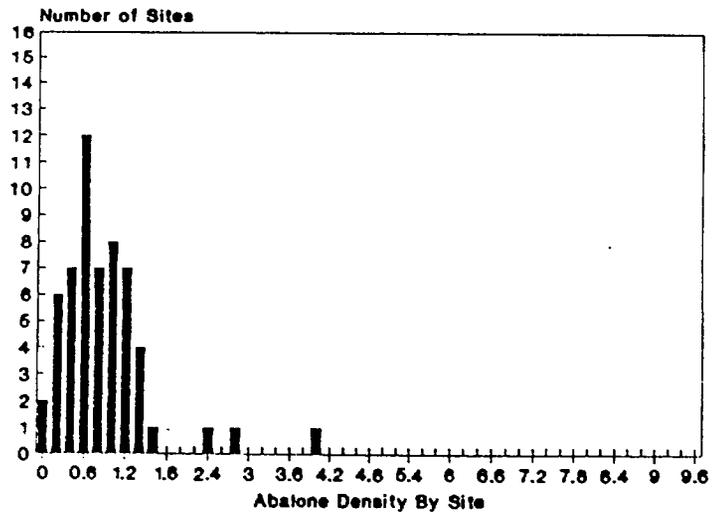
Abalone Densities (N/M2)
1979



Abalone Densities (N/M2)
1984



Abalone Densities (N/M2)
1987



Abalone Densities (N/M2)
1990

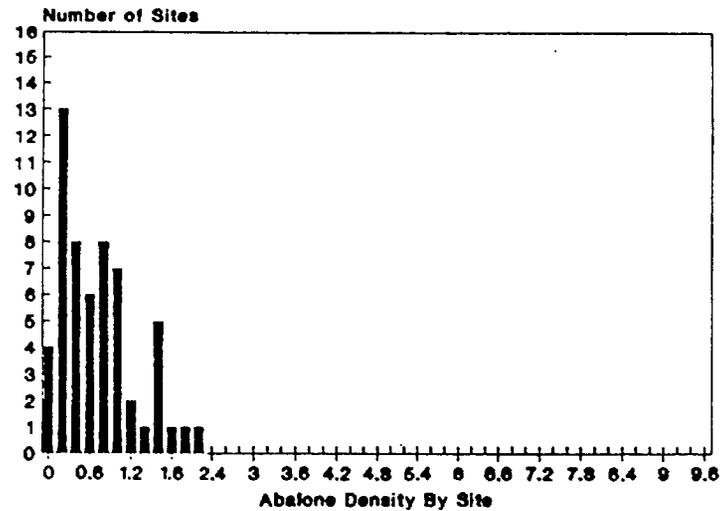


Figure 2. Frequency distribution of total abalone densities at 57 comparable sites in Area 2 East for 1979*, 1984, 1987 and 1990.

*Note: In 1979, 1 site was recorded with a density of 16.63 abalone/m2.

Total Abalone Length Frequencies

From 69 comparable sites, 1990

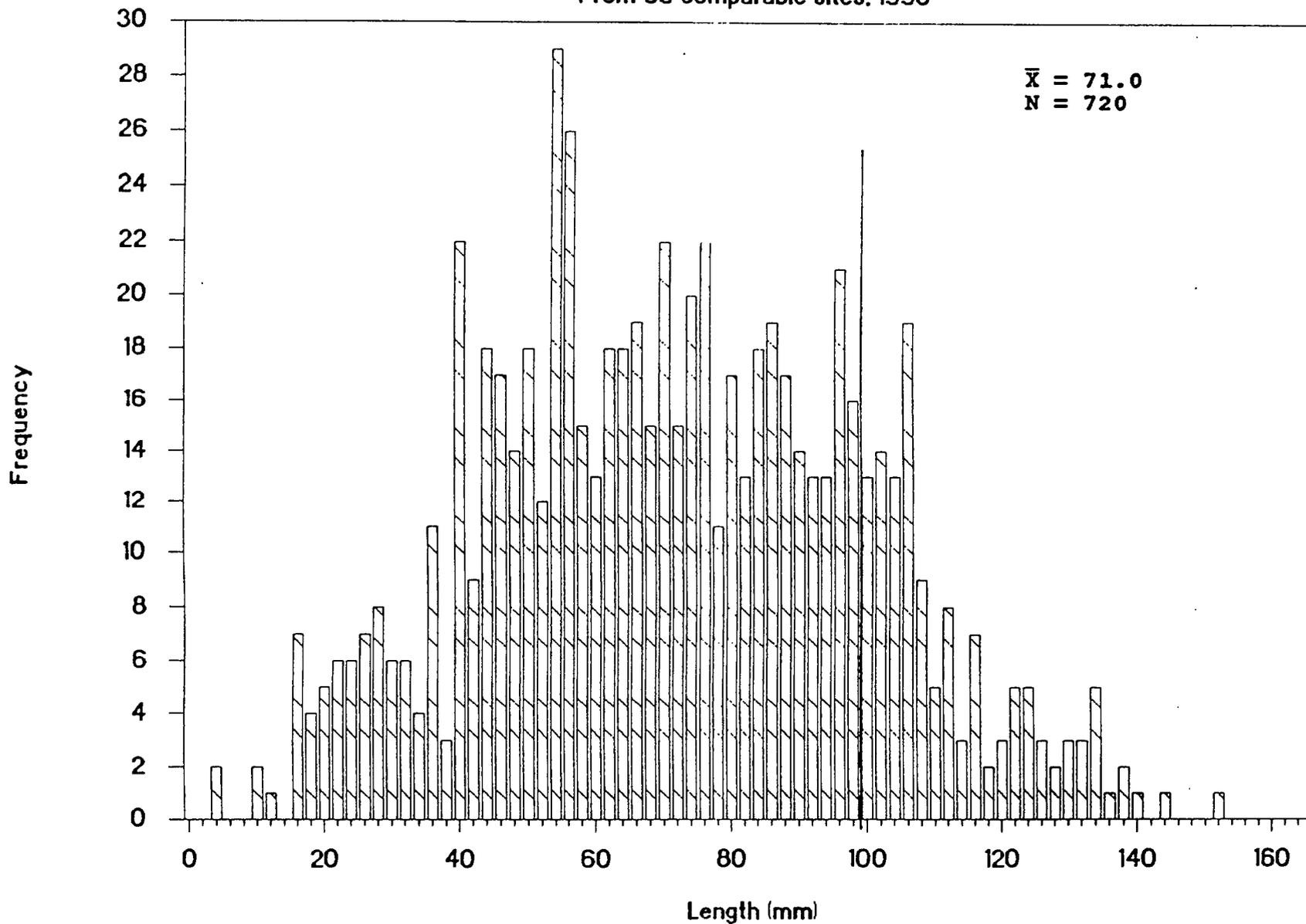


Figure 3. Length frequency distribution of all abalone collected from 69 sites in Area 2 East 1990.

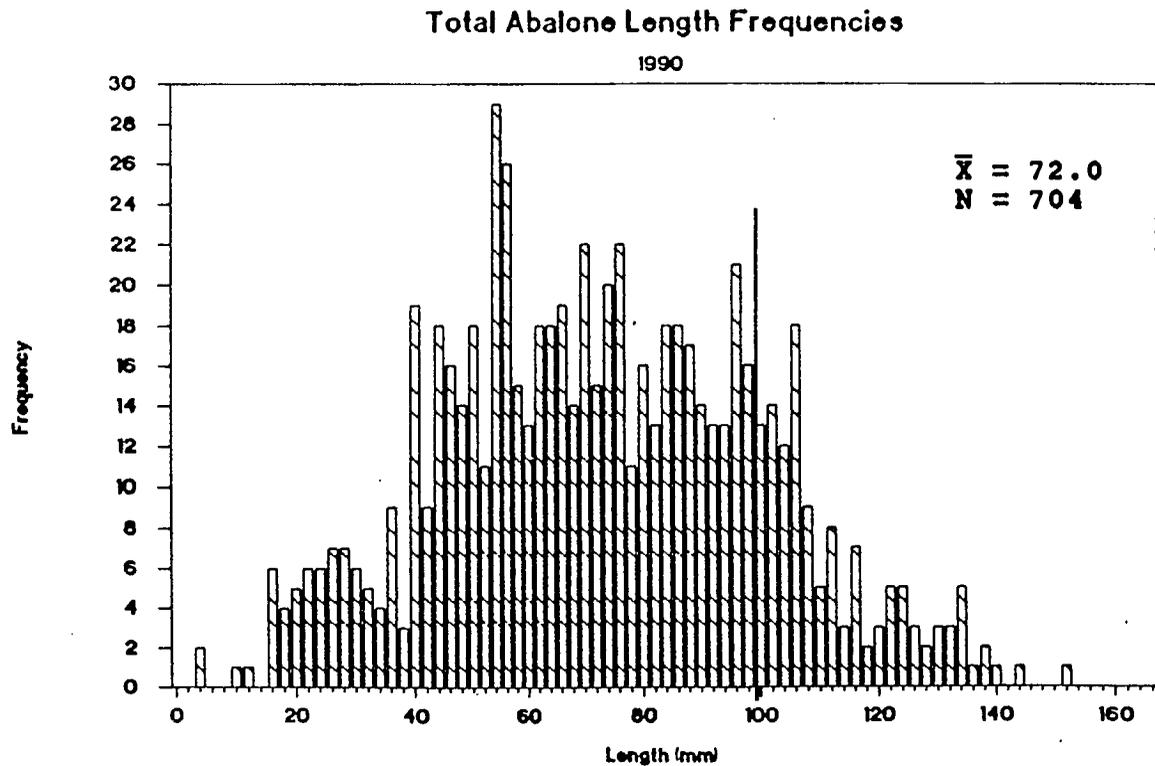
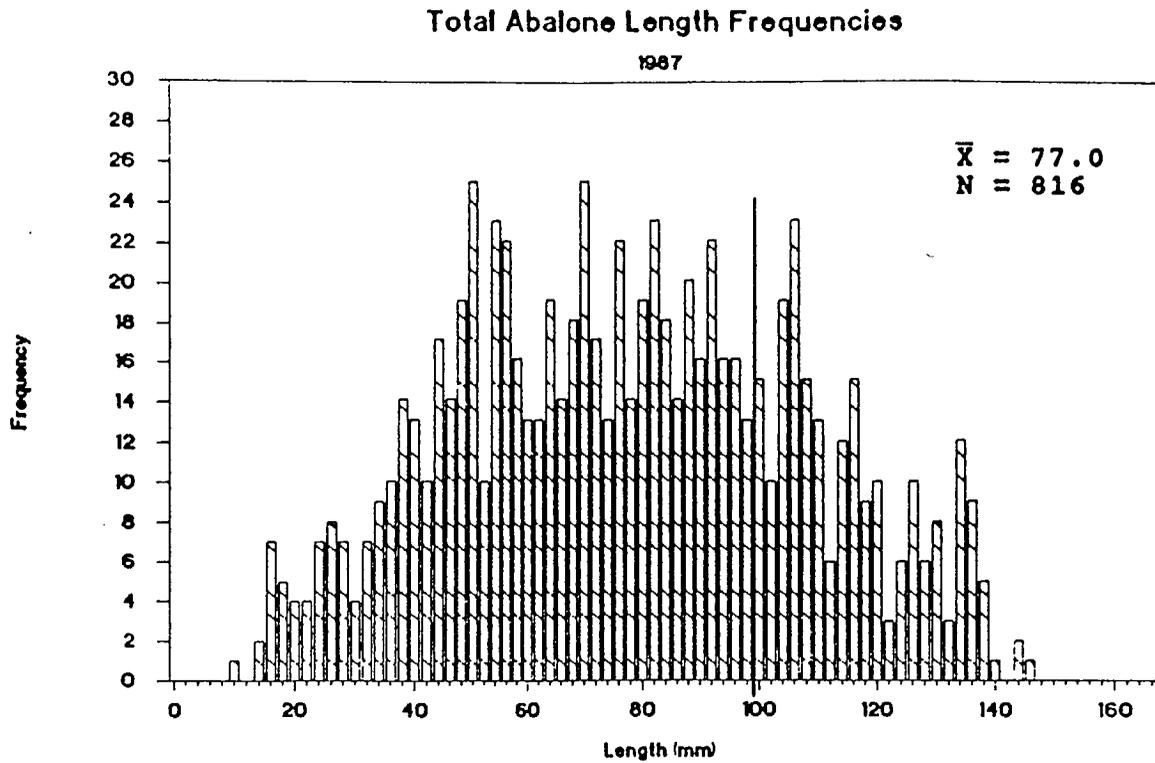


Figure 4. A comparison of total abalone length frequency distributions from 67 comparable sites in Area 2 East for 1987 and 1990.

APPENDIX 1. Mean total Abalone Densities by Section in Comparable Sites surveyed in 1979, 1984, 1987 & 1990.

SITE NO.		TOTAL DENSITY (#/m ²)				CHANGES			
1978-79	1984, 87, 90	1979	1984	1987	1990	1979-84	1979-90	1984-87	1987-90
	75	*	*	0.44	0.06	N/A	N/A	N/A	-0.38
	76	*	*	0.13	0.38	N/A	N/A	N/A	0.25
	78	*	*	1.50	0.75	N/A	N/A	N/A	-0.75
Cumshewa Inlet Mean		N/A	N/A	0.69	0.40	N/A	N/A	N/A	-0.29
78-30	65	1.06	0.13	0.50	0.19	-0.93	-0.87	0.37	-0.31
78-31	66	0.63	0.13	0.38	0.06	-0.50	-0.57	0.25	-0.32
78-19	67	0.94	0.00	0.56	0.50	-0.94	-0.44	0.56	-0.06
78-34	68	1.13	0.19	1.19	0.63	-0.94	-0.50	1.00	-0.56
78-32	69	3.88	0.06	0.25	0.25	-3.82	-3.63	0.19	0.00
78-33	70	3.63	0.31	0.25	0.13	-3.32	-3.50	-0.06	-0.12
Selwyn Inlet Mean		1.88	0.14	0.52	0.29	-1.74	-1.59	0.39	-0.23
78-40	59	1.44	0.88	1.19	0.69	-0.56	-0.75	0.31	-0.50
	60	*	1.38	0.69	0.00	N/A	N/A	-0.69	-0.69
78-50	61	3.06	0.31	0.06	0.00	-2.75	-3.06	-0.25	-0.06
	62	*	0.56	1.06	0.63	N/A	N/A	0.50	-0.43
78-38	63	1.44	0.13	0.25	0.69	-1.31	-0.75	0.12	0.44
78-41	64	2.19	0.06	1.38	0.06	-2.13	-2.13	1.32	-1.32
	73	*	*	1.13	0.13	N/A	N/A	N/A	-1.00
	74	*	*	0.13	0.06	N/A	N/A	N/A	-0.07
Tanu Island Mean		2.03	0.55	0.74	0.28	-1.69	-1.67	0.22	-0.45
78-65	36	2.44	0.00	0.44	0.00	-2.44	-2.44	0.44	-0.44
78-67	37	1.13	0.00	0.81	0.19	-1.13	-0.94	0.81	-0.62
78-69	38	2.44	1.00	0.69	1.44	-1.44	-1.00	-0.31	0.75
78-71	39	5.31	1.81	1.19	0.63	-3.50	-4.68	-0.62	-0.56
78-80	40	1.00	0.13	0.06	0.08	-0.87	-0.92	-0.07	0.02
78-82	41	0.25	0.06	0.06	0.00	-0.19	-0.25	0.00	-0.06
78-68	44	5.94	0.13	0.44	0.06	-5.81	-5.88	0.31	-0.38
78-78	45	4.25	0.75	0.63	0.81	-3.50	-3.44	-0.12	0.18
78-72	46	7.06	0.56	4.00	1.44	-6.50	-5.62	3.44	-2.56
78-64	48	3.75	1.19	0.81	0.44	-2.56	-3.31	-0.38	-0.37
78-75	49	1.81	0.50	0.94	2.10	-1.31	0.29	0.44	1.16
78-70	50	0.63	1.19	0.94	0.56	0.56	-0.07	-0.25	-0.38
78-74	51	0.75	0.00	0.50	0.44	-0.75	-0.31	0.50	-0.06
78-59	53	8.13	0.19	0.75	0.94	-7.94	-7.19	0.56	0.19
78-79	54	0.63	0.81	1.38	0.81	0.18	0.18	0.57	-0.57
78-55	55	5.88	0.88	2.69	1.19	-5.00	-4.69	1.81	-1.50
78-57	56	7.25	1.75	1.13	1.75	-5.50	-5.50	-0.62	0.62
78-53	57	2.63	1.00	0.25	0.88	-1.63	-1.75	-0.75	0.63
78-51	58	3.38	0.06	0.56	0.75	-3.32	-2.63	0.50	0.19
Upper Juan Perez Sound Mean		3.40	0.63	0.96	0.76	-2.77	-2.64	0.33	-0.20

APPENDIX 1. continued

SITE NO.		TOTAL DENSITY (#/m ²)				CHANGES			
1978-79	1984, 87, 90	1979	1984	1987	1990	1979-84	1979-90	1984-87	1987-90
78-88	42	16.63	0.06	1.56	0.63	-16.57	-16.00	1.50	-0.93
78-91	43	9.38	0.31	0.81	0.75	-9.07	-8.63	0.50	-0.06
Lower Juan Perez Sound Mean		13.01	0.19	1.19	0.69	-12.82	-12.32	1.00	-0.50
78-94	22	1.63	0.19	0.00	1.00	-1.44	-0.63	-0.19	1.00
78-96	23	1.13	0.63	0.63	0.38	-0.50	-0.75	0.00	-0.25
78-100	24	0.81	0.75	1.13	0.38	-0.06	-0.43	0.38	-0.75
78-103	26	0.63	1.94	2.31	1.56	1.31	0.93	0.37	-0.75
78-95	27	0.63	0.00	0.06	0.06	-0.63	-0.57	0.06	0.00
78-99	28	2.88	1.06	1.13	0.31	-1.82	-2.57	0.07	-0.82
78-107	29	0.94	0.63	0.38	0.19	-0.31	-0.75	-0.25	-0.19
78-105	30	3.31	1.19	0.44	0.94	-2.12	-2.37	-0.75	0.50
78-104	31	1.75	0.56	1.00	0.25	-1.19	-1.50	0.44	-0.75
78-102	32	5.63	0.00	0.50	0.13	-5.63	-5.50	0.50	-0.37
78-109	33	3.06	0.81	1.38	0.75	-2.25	-2.31	0.57	-0.63
78-111	34	5.94	0.94	0.81	0.56	-5.00	-5.38	-0.13	-0.25
78-106	35	0.31	0.38	0.50	0.19	0.07	-0.12	0.12	-0.31
Skinnuttle Inlet Mean		2.20	0.70	0.79	0.52	-1.51	-1.69	0.09	-0.27
78-119	10	1.06	0.75	0.69	0.38	-0.31	-0.68	-0.06	-0.31
78-122	11	0.19	0.00	0.19	0.13	-0.19	-0.06	0.19	-0.06
78-123	12	0.00	0.19	0.25	0.31	0.19	0.31	0.06	0.06
78-114	14	2.31	0.56	0.63	1.56	-1.75	-0.75	0.07	0.93
78-124	15	3.31	0.50	0.44	0.94	-2.81	-2.37	-0.06	0.50
78-126	17	1.19	0.06	0.88	0.13	-1.13	-1.06	0.82	-0.75
78-115	18	1.44	0.81	0.44	0.31	-0.63	-1.13	-0.37	-0.13
78-113	19	1.00	0.00	0.56	0.56	-1.00	-0.44	0.56	0.00
78-127	20	1.13	1.63	0.06	1.06	0.50	-0.07	-1.57	1.00
78-125	21	0.94	0.00	0.00	0.00	-0.94	-0.94	0.00	0.00
Carpenter Bay Mean		1.26	0.45	0.41	0.54	-0.81	-0.72	-0.04	0.12
79-42	1	1.63	1.06	1.31	2.00	-0.57	0.37	0.25	0.69
79-43	2	2.38	0.38	1.19	1.56	-2.00	-0.82	0.81	0.37
79-44	3	0.75	0.38	0.63	1.38	-0.37	0.63	0.25	0.75
	4	*	0.88	1.06	1.00	N/A	N/A	0.18	-0.06
	7	*	0.19	0.44	0.38	N/A	N/A	0.25	-0.06
	71	*	*	0.31	0.19	N/A	N/A	N/A	-0.12
Kunghit Island Mean		1.59	0.58	0.82	1.09	-0.98	0.06	0.35	0.26
All Sites Mean		2.74	0.53	0.78	0.66	-2.21	-2.08	0.25	-0.12

- NOTE: 1. Sites 40 and 49 contained 48 quadrats in 1990.
 2. All Sites Means are calculated using 57 comparable sites.

APPENDIX 2. Mean Legal Abalone Densities by Section in Comparable Sites surveyed in 1979, 1984, 1987 & 1990.

SITE NO.		LEGAL DENSITY (#/m ²)				CHANGES			
1978-79	1984, 87, 90	1979	1984	1987	1990	1979-84	1979-90	1984-87	1987-90
	75	*	*	0.44	0.06	N/A	N/A	N/A	-0.38
	76	*	*	0.06	0.13	N/A	N/A	N/A	0.07
	78	*	*	1.50	0.69	N/A	N/A	N/A	-0.81
Cumshewa Inlet Mean		N/A	N/A	0.67	0.29	N/A	N/A	N/A	-0.37
78-30	65	0.05	0.00	0.13	0.00	-0.05	-0.05	0.13	-0.13
78-31	66	0.31	0.06	0.13	0.00	-0.25	-0.31	0.07	-0.13
78-19	67	0.14	0.00	0.19	0.06	-0.14	-0.08	0.19	-0.13
78-34	68	0.38	0.00	0.25	0.25	-0.38	-0.13	0.25	0.00
78-32	69	0.39	0.00	0.06	0.00	-0.39	-0.39	0.06	-0.06
78-33	70	0.54	0.06	0.00	0.06	-0.48	-0.48	-0.06	0.06
Selwyn Inlet Mean		0.30	0.02	0.13	0.06	-0.28	-0.24	0.11	-0.07
78-40	59	0.36	0.13	0.69	0.25	-0.23	-0.11	0.56	-0.44
	60	*	0.38	0.44	0.00	N/A	N/A	0.06	-0.44
78-50	61	0.75	0.19	0.00	0.00	-0.56	-0.75	-0.19	0.00
	62	*	0.25	0.25	0.13	N/A	N/A	0.00	-0.12
78-38	63	0.19	0.00	0.00	0.00	-0.19	-0.19	0.00	0.00
78-41	64	1.38	0.00	0.63	0.06	-1.38	-1.32	0.63	-0.57
	73	*	*	1.06	0.13	N/A	N/A	N/A	-0.93
	74	*	*	0.13	0.06	N/A	N/A	N/A	-0.07
Tanu Island Mean		0.67	0.16	0.40	0.08	-0.59	-0.59	0.18	-0.32
78-65	36	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
78-67	37	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
78-69	38	0.31	0.00	0.06	0.25	-0.31	-0.06	0.06	0.19
78-71	39	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
78-80	40	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
78-82	41	0.00	0.06	0.00	0.00	0.06	0.00	-0.06	0.00
78-68	44	0.06	0.00	0.13	0.00	-0.06	-0.06	0.13	-0.13
78-78	45	0.13	0.19	0.06	0.25	0.06	0.12	-0.13	0.19
78-72	46	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
78-64	48	0.56	0.38	0.13	0.06	-0.18	-0.50	-0.25	-0.07
78-75	49	1.63	0.38	0.75	0.33	-1.25	-1.30	0.37	-0.42
78-70	50	0.57	0.75	0.44	0.44	0.18	-0.13	-0.31	0.00
78-74	51	0.67	0.00	0.44	0.31	-0.67	-0.36	0.44	-0.13
78-59	53	1.22	0.00	0.00	0.00	-1.22	-1.22	0.00	0.00
78-79	54	0.00	0.06	0.38	0.19	0.06	0.19	0.32	-0.19
78-55	55	3.54	0.06	0.25	0.56	-3.48	-2.98	0.19	0.31
78-57	56	0.36	0.13	0.50	0.44	-0.23	0.08	0.37	-0.06
78-53	57	0.13	0.00	0.00	0.00	-0.13	-0.13	0.00	0.00
78-51	58	0.13	0.00	0.00	0.00	-0.13	-0.13	0.00	0.00
Upper Juan Perez Sound Mean		0.49	0.11	0.17	0.15	-0.38	-0.34	0.06	-0.02

APPENDIX 2. continued

SITE NO.		LEGAL DENSITY (#/m ²)				CHANGES			
1978-79	1984, 87, 90	1979	1984	1987	1990	1979-84	1979-90	1984-87	1987-90
78-88	42	1.19	0.00	0.13	0.00	-1.19	-1.19	0.13	-0.13
78-91	43	0.47	0.00	0.00	0.00	-0.47	-0.47	0.00	0.00
Lower Juan Perez Sound Mean		0.83	0.00	0.07	0.00	-0.83	-0.83	0.07	-0.07
78-94	22	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
78-96	23	0.11	0.25	0.19	0.19	0.14	0.08	-0.06	0.00
78-100	24	0.44	0.06	0.19	0.00	-0.38	-0.44	0.13	-0.19
78-103	26	0.56	0.44	0.81	0.25	-0.12	-0.31	0.37	-0.56
78-95	27	0.13	0.00	0.06	0.06	-0.13	-0.07	0.06	0.00
78-99	28	0.06	0.00	0.00	0.00	-0.06	-0.06	0.00	0.00
78-107	29	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
78-105	30	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
78-104	31	0.00	0.31	0.69	0.06	0.31	0.06	0.38	-0.63
78-102	32	0.44	0.00	0.00	0.00	-0.44	-0.44	0.00	0.00
78-109	33	1.13	0.31	0.44	0.00	-0.82	-1.13	0.13	-0.44
78-111	34	0.25	0.19	0.06	0.00	-0.06	-0.25	-0.13	-0.06
78-106	35	0.00	0.31	0.13	0.00	0.31	0.00	-0.18	-0.13
Skincuttle Inlet Mean		0.24	0.14	0.20	0.04	-0.10	-0.20	0.05	-0.15
78-119	10	0.06	0.06	0.31	0.25	0.00	0.19	0.25	-0.06
78-122	11	0.06	0.00	0.00	0.00	-0.06	-0.06	0.00	0.00
78-123	12	0.00	0.06	0.13	0.06	0.06	0.06	0.07	-0.07
78-114	14	0.93	0.06	0.00	0.00	-0.87	-0.93	-0.06	0.00
78-124	15	0.13	0.00	0.00	0.00	-0.13	-0.13	0.00	0.00
78-126	17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
78-115	18	0.44	0.38	0.06	0.13	-0.06	-0.31	-0.32	0.07
78-113	19	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
78-127	20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
78-125	21	0.19	0.00	0.00	0.00	-0.19	-0.19	0.00	0.00
Carpenter Bay Mean		0.18	0.06	0.05	0.04	-0.13	-0.14	-0.01	-0.01
79-42	1	0.31	0.13	0.19	0.38	-0.18	0.07	0.06	0.19
79-43	2	0.90	0.13	0.13	0.31	-0.77	-0.59	0.00	0.18
79-44	3	0.28	0.25	0.06	0.13	-0.03	-0.15	-0.19	0.07
	4	*	0.00	0.06	0.00	N/A	N/A	0.06	-0.06
	7	*	0.13	0.00	0.06	N/A	N/A	-0.13	0.06
	71	*	*	0.31	0.13	N/A	N/A	N/A	-0.18
Kunghit Island Mean		0.50	0.13	0.13	0.17	-0.33	-0.22	-0.04	0.04
All Sites Mean		0.38	0.10	0.23	0.10	-0.29	-0.29	0.06	-0.12

NOTE: 1. Sites 40 and 49 contained 48 quadrats in 1990.

2. All Sites Means are calculated using 57 comparable sites.

6. A Review of Geoduck Quotas and Their Derivation

by

S. Farlinger, R. Harbo and K. Hobbs

SUMMARY

The commercial fishery for geoduck clams began in British Columbia in 1976. Annual quotas were first set in 1979, at an arbitrary 8,000,000 lb. (3628 tonnes) for the coast. The quotas decreased over the period, 1981 to 1985, due to uncertainties in the stock size. Quotas have increased to 8,800,000 lb. (3391 t) in 1990, based on an evaluation of logbook data. The commercial fishery has landed approximately 95.6 million lb. (43,346 t) over the period 1976 to 1989.

There is a great uncertainty as to the stock size of subtidal geoduck clams. Initial dive surveys were not intended for stock assessment. No attempts at stock assessment on a large scale have been undertaken other than from logbook data supplied by the fishermen.

Harvest rates recommended in 1979 were from 2 to 5% of virgin biomass, but in 1980 yield options of 1.5% were used. Recommended yields were revised down to 0.75 to 2% of the original biomass in 1981. The yield options are useful only if there are reliable stock estimates.

The recommended 1991 quota for the south coast is 5,280,000 lb. (2395 t). At a harvest rate of 1%, to support this quota over 16,611 ha an average density of 1.35 geoducks/square metre would be required. Quotas for individual areas were set based on historical levels of harvest. For the south coast a range of stock estimates and quota options that could be applied to this fishery is presented. Present quotas fall within this range. The ranges are great due to the large range of possible geoduck densities over large areas.

For the north coast the recommended 1991 quota is 2,970,000 lb. (1597 t) based on geoduck bed area identified from harvest logs for Areas 1 to 10. Quotas have been calculated at 1% harvest rates, at densities of geoducks at 3.5 or 5 clams/square metre, over the 1989 estimated area of 3734 ha in the north coast.

It is recommended that quotas continue to be based on logbook data and that other assessments are required before quota derivations are significantly changed.

Note: Only a summary of this Position Paper is provided here,

as the document has been prepared for publication elsewhere. Contact the authors for the appropriate reference.

7. Growth and Size at Maturity of the
Horseclam Tresus nuttallii (Conrad) in
Southern British Columbia

by

A. Campbell, N. Bourne and W. Carolsfeld

SUMMARY

Size at maturity occurs at about 68 mm SL or at age of 3 years when T. nuttallii loses its redigging ability if disturbed. Few individuals <100 mm SL are caught in commercial fisheries; most horse clams are >150 mm SL (average 173 SL). A commercially desirable horse clam takes about 12 years to reach about 173 mm SL in Lemmens Inlet. Rotational closures of 3 years are probably not sufficiently long to provide protection to the stocks. Spawning period is in the summer.

MANAGEMENT IMPLICATIONS

Size at maturity occurs at about 68 mm SL or at age of 3 y when T. nuttallii loses its redigging ability if disturbed. Few individuals <100 mm SL are caught in commercial fisheries; most horse clam are >150 mm SL (average 173 mm SL). A commercially desirable horse clam takes about 12 years to reach about 173 mm SL in Lemmens Inlet.

A minimum size limit regulation would not be useful at this time since horse clams >70 mm SL would not be able to rebury themselves and survive predation.

RESEARCH REQUIREMENTS

1. Determine density estimates before and after fishing to estimate fishing efficiency and optimum harvest rate for quota system.
2. Determine recruitment rates to help estimate optimum harvest quota and rotational time closures.

ABSTRACT Measurements were made to determine growth rates and size at maturity of horse clams, Tresus nuttallii (Conrad) (family: Mactridae) from two areas in southern British Columbia. Growth was determined by measuring shell length at annuli. Growth rates of T. nuttallii were slower from Newcastle Island than from Lemmens Inlet. Shells became heavier than the soft body parts at a faster rate for horse clams from Newcastle Island compared to those from Lemmens Inlet. Examination of histological sections of gonads indicated that size at maturity occurred at about 68 mm

shell length or at 3 y of age for T. nuttallii from Lemmens Inlet. Although samples were taken only in the May - August period, the gonad histological sections indicate that T. nuttallii is a summer (April - August) spawner.

INTRODUCTION

The horse clam, Tresus nuttallii (Conrad 1837) (Bivalvia:Macridae), occurs commonly along the west coast of North America from California to Alaska (Latitude 28° to 58°N) (Bernard 1983). The clam is found in coastal waters of British Columbia (B.C.) in mud-sand substrates from low intertidal beach levels to subtidal depths of at least 50 m. A small subtidal commercial dive fishery has recently developed for horse clams (includes two species) which was worth about Can. \$300,000 for 325 t during 1988 in B.C. Although the other horse clam species, T. capax (Gould 1850), is more common intertidally (Bourne and Smith 1972b), T. nuttallii is the more abundant (>75%) subtidally of the two horse clam species found in B.C. (A. Campbell, unpubl. data).

No detailed biological information has been published on T. nuttallii from B.C. (Quayle 1960, Quayle and Bourne 1972, Bourne and Smith 1972b). Most biological data on T. nuttallii is from intertidal populations in Washington (Swan and Finucane 1952, Pearce 1965; Goodwin and Shaul 1978) and California (MacGinitie 1935, Fitch 1953, Armstrong 1965, Stout 1967, 1970, Laurent 1971, Clark 1973, Clark et al. 1975, Kvitek et al. 1988). Studies on inter and subtidal T. capax biology extend throughout the clam's range (Lat. 28° to 58°N) (Pearce 1965, Reid 1969, Machell and DeMartini 1971, Bourne and Smith 1972a,b, Wendell et al. 1976, Goodwin and Shaul 1978, Breed-Willeke and Hancock 1980, Robinson and Breese 1982). A third species T. pajarohana (Conrad 1875) has a limited subtidal distribution from California to Washington (Dinnell and DeMartini 1974).

This paper presents information on the growth and sexual maturity of T. nuttallii from two subtidal areas in B.C. which will be needed for fishery management of the species.

MATERIALS AND METHODS

Samples from as wide a size range as possible of T. nuttallii were obtained from Lemmens Inlet, near Tofino (Lat. 49°12.2' Long 125°52.3') during 25 May and 10 August, 1989, and Newcastle Island, near Nanaimo (Lat. 49°12.2' Long. 123°56.5') during 11 July, 1989, at depths between 4-8 m. The clams were transported to the laboratory in coolers (2°C) and kept in running sea water (ambient temperature) until processed within 48 h of capture. For each clam, the shell length (SL) was measured as the straight line distance between anterior and posterior margin of the shell to the nearest mm with vernier calipers, wet weights of drained total body and shell, shell only, whole soft body and siphon (neck) only (cut at base of siphon) were recorded to the nearest 0.01 g.

Growth of T. nuttallii was determined by measuring shell length at each annulus after Weymouth et al. (1925) and discussed by Bourne and Smith (1972b). Horse clams from both areas had pronounced annuli; clams with indistinct annuli (<1%) or with broken shells were discarded.

The reproductive condition of T. nuttallii was determined by removing the central portion of the gonad and preserving the tissue in Davidson's Solution. Histological slides, stained with haematoxylin-eosin were prepared from sections of the gonad. Five stages (1. inactive, 2. active, 3. ripe, 4. partially spent, and 5. spent) according to Machell and DeMartini (1971) and Laurent (1971) were used to classify the histological sections of the gonads of each horse clam. Sexual maturity was determined from the histological sections by categorizing them as either (1) immature (no differentiation in gonadal tissue; loose vesicular connective tissue in gonad), or (2) mature (connective tissue well developed, primary germ cells evident on follicle walls on eggs or sperm development evident).

Allometric relationships between body, shell and neck weights (Y) and shell length (X) were estimated using the exponential equation of the form $\log_e Y = \log_e a + b \log_e X$, where a and b are constants calculated using the least squares method. The relationships between the ratios, shell weight/body weight and neck weight/body weight (Y) and shell length or age (X) were estimated using the linear equation $Y = A + BX$. Comparison between the two sample areas for each relationship was accomplished by testing comparable size ranges of 100-202 mm SL and ages 7-16 yr for homogeneity between slopes and subsequently comparing intercepts of lines by adjusting the Y variables and testing for differences by analysis of covariance (ANCOVA) using shell lengths or age as covariates (Snedecor and Cochran 1967) using SYSTAT computer programs (Wilkinson 1989).

Average von Bertalanffy growth curves were fitted to all data points of size at age using the equation:

$$l_t = L_{\infty} (1 - e^{-k(t-t_0)})$$

where t = age in years, l_t = shell length at t , L_{∞} = theoretical maximum size, k = constant, determining rate of increase or decrease in length increments, and t_0 = hypothetical age at which the organism would have been at zero length. The parameters L_{∞} , k and t_0 were estimated using a nonlinear least squares method (Wilkinson 1989). Growth rates between males and females between May and August 1989, from Lemmens Inlet were similar when compared graphically and therefore the data were combined for each area. Only growth rates from the annuli data are presented since growth rates from total shell length and annuli produced similar curves

for horse clams from each area. Lee (1912) suggested that older individuals may exhibit slower growth rates than smaller individuals due to differential mortality rates but this was not the case in this study.

The proportion of mature clams (0) at shell length (1) was estimated using the equation:

$$0(1) = \frac{1}{1+e^{-(a-b1)}}$$

where a and b are constants determined using maximum likelihood methods (e.g. Welch and Foucher 1988). Male and female data were combined since the curves for each sex were similar. There were no immature horse clams obtained from Newcastle Island so size at maturity ogives were not attempted for this area.

RESULTS

Growth

A) Shell Length-Age

The oldest T. nuttallii collected was 16 y from both study areas. Growth rates of T. nuttallii from Newcastle were slower than those from Lemmens Inlet (Fig. 1). Within 5 y the horse clams had reached a mean of 106 mm SL from Lemmens Inlet and 97 mm SL from Newcastle, at 10 y 161 and 145, and at 16 y 187 and 169 mm SL, respectively. The von Bertalanffy growth parameters were similar for T. nuttallii from both areas except for L_{∞} which was estimated to be higher for those from Lemmens Inlet than those from Newcastle Island (Table 1). The largest horse clam was 195 mm SL collected at Lemmens Inlet and 202 mm SL from Newcastle Island in this study. The largest T. nuttallii specimen from an unsubstantiated report was as long as 250 mm (Nicol 1964).

B) Length-Weight

The size range of horse clams collected from Lemmens Inlet was 36-195 mm SL (N = 146) and from Newcastle Island was 107-202 mm SL (N = 52). All the length-weight relationships were highly positively correlated indicating that shell and body weights increased with increasing SL (Table 2, Fig. 2,3). There were no differences (ANCOVA, $p > 0.05$) in all pair comparisons between the two sample areas in slopes of the power regressions of weight-length and linear regressions of ratios-length for comparable size ranges of 100-202 mm SL which allowed subsequent comparison of intercepts (Table 2,3). For the power regressions, although there were no differences in intercepts of body and neck (siphon) weights, there were significant differences (ANCOVA, $p < 0.01$) for total weights and shell weights at the equivalent SL between the two areas. For the ratio-length equations, there were no differences in intercepts for the neck/body and neck/total ratios

(ANCOVA, $p > 0.05$), but significant differences (ANCOVA, $p < 0.01$) for the shell/body ratios between the two areas. Consequently the rate of increase in weight was greater for the shells than for the soft body parts with increases of SL of horse clams from both areas (Table 2,3 Fig. 3). The shell weights were heavier for horse clams of the equivalent SL from Newcastle than from Lemmens Inlet (Fig. 3, Table 2,3). There were no significant differences in weight (ANCOVA, $p > 0.05$) of soft body parts at equivalent SL of horse clams collected from both areas. Neck weights increased at a slower rate than shell or the whole soft body weights (Fig. 3, Table 2) which is indicated also by a general decline in ratios of neck/body weights with increase in SL (Table 3).

C) Weight-age

The total age range of horse clams collected from Lemmens Inlet was 2-16 y and Newcastle Island was 7-16 y. Weight increases by age were all greater for horse clams from Lemmens Inlet than Newcastle Island (Table 4). Although there were no significant differences (ANCOVA, $p > 0.05$) between areas for all slopes of power and linear regressions (Table 2,3) for comparable ages (7-16 y), intercepts were significantly different (ANCOVA, $p < 0.01$) for all weight-age relations (Table 2) and shell/body ratios, except for neck/body ratios and neck/total (%) -age relations (Table 3). Shell/body ratios were higher for the equivalent age for horse clams from Newcastle than from Lemmens Inlet. In contrast, neck/body ratios and neck/total (%) were similar for horse clams from both areas (Table 3,4).

SIZE AT MATURITY

Size at 50% maturity was 68 mm SL for horse clams from Lemmens Inlet (Fig. 4). The largest immature clam was 86 mm SL and smallest mature clam was 51 mm SL. All horse clams collected from Newcastle Island were mature.

Sex ratio was 1:1 for all horse clams that had mature gonads in which sex was discernable.

There were insufficient data to determine the exact spawning period(s) because seasonal monthly samples were not collected. However, from the reproductive phase examined of horse clams > 100 mm SL, spawning started in Lemmens Inlet just prior to the 25 May 1989 sample (42% in stage 2-active, 2% in stage 3-ripe, and 56% in stage 4-partially spent, $N=41$, and was nearly complete by 10 August 1989 (47% stage 4-partially spent and 53% stage 5-spent, $N=57$). For Newcastle Island horse clam spawning was nearly complete by 11 July (3% stage 3, 5% stage 4, and 92% stage 5, $N=40$).

DISCUSSION

Growth of T. nuttallii from Newcastle Island was slower than those from Lemmens Inlet. Shells became heavier than the soft body parts at a faster rate for horse clams from Newcastle Island compared to Lemmens Inlet. Growth for juvenile T. nuttallii from Elkhorn Slough, California, was about 50 mm SL in their first year (Laurent 1971, Clark 1973) which was faster than recorded from either of the two B.C. study areas. Slower growth rates of other species of bivalves have been reported with northward distribution; razor clams (Bourne and Quayle 1970; Weymouth and McMillin 1930), butter clams (Quayle and Bourne 1972) and littleneck clams (Quayle and Bourne 1972). The reasons for the differences in T. nuttallii growth rates is not known, but could be attributed to a variety of environmental factors associated with different habitats, e.g. substrate type, food availability, temperature. However, both B.C. study areas had similar mud sand substrate and temperature regimes. Growth rates directly associated with food availability and length of feeding period in various clam species have been documented (Smith 1928, Coe and Fitch 1950, Stickney 1964).

Our limited seasonal data indicate that spawning T. nuttallii in B.C. probably occurs during April - August. This adds support to the suggestion by Quayle (1960), Quayle and Bourne (1972) and Bourne and Harbo (1987) that T. nuttallii spawns during summer in B.C. In contrast, T. nuttallii may spawn continuously throughout the year in Elkhorn Slough, California, with bimodal spawning peaks during April - June and November - February (Laurent 1971, Clark 1973, Clark et al. 1975). Tresus capax spawning occurs during one annual period from mid February to May in B.C. (Bourne and Smith 1972b). Bimodal spawning for T. capax for Humboldt Bay, California has been reported by Wendell, et al. (1976). Breed-Willeke and Hancock (1980) suggested that T. capax populations from southern latitudes have slightly earlier spawning periods than horse clams from more northern latitudes along western North America.

Size at maturity of T. nuttallii from Lemmens Inlet was estimated at approximately 68 mm SL or at about 3 y of age. Clarke (1973) suggested that T. nuttallii females mature at about 70 mm SL in Elkhorn Slough. Bourne and Smith (1972b) found that T. capax at Seal Island, B.C. became sexually mature at about 70 mm SL.

As juvenile horse clams mature they lose their ability to dig into the substrate. Pohlo (1964) found there was a change in burrowing ability and shell morphology with growth of T. nuttallii juveniles, with the capability to reburying lost at about 60 mm SL (probably near maturity). Armstrong (1965) found that T. nuttallii juvenile survival was sensitive to reburying positions.

No pinnotherid pea crabs (eg. Pinnixa faba (Dana 1851)) were found in T. nuttallii although they were found in the T. capax also collected from Lemmens Inlet in this study. Although pea crabs are found to live commensally in the mantle cavity of T. nuttallii in southern California where T. capax does not occur (MacGinitie 1935,

Laurent 1971), in areas further north pea crabs are found only in T. capax, but not in T. nuttallii (Pearce 1965, Stout 1967, N. Bourne and A. Campbell personal observation in B.C.). The genus Tresus also serves as host to a variety of parasitic invertebrates (MacGinitie 1935, Ricketts et al. 1968) and commensals (Stout 1970). Besides man, the most important natural predators of horse clams are probably sea stars (eg. Pisaster brevispinus (Stimpson 1857)), moon snails (Polinices lewisii (Gould 1847)), crabs (eg. Cancer magister Dana 1852) (Bernard 1967, Wendell et al. 1976, Sloan and Robinson 1983), elasmobranchs (eg. skates and rays) (Stout 1967) and sharks (eg. Triakis semifasciatus Girard 1854) that feed off clam siphons (Laurent 1971) and sea otters (Enhydra lutris (Merriam 1923)) that dig for whole horse clams (Kvitek et al. 1988).

Results of the life history information in this study and the recent developing subtidal horse clam fishery suggests that conservative harvest levels should be maintained for B.C. horse clam stocks to monitor changes in biological parameters that may result from fishing pressures. Long term studies are required to determine the effect of the fishery on horse clam densities, mortality and recruitment rates.

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LEGEND TO FIGURES

Figure 1. Growth curves for I. nuttallii collected from Lemmens Inlet (solid line and closed dots) and Newcastle Island (broken line and open circles). Curves from von Bertalanffy growth parameters, means (dots) and 95% confidence intervals (vertical lines) from raw data. Equations in Table 1.

Figure 2. Total weight and shell length relationship for I. nuttallii collected from (A) Lemmens Inlet and (B) Newcastle Island. Equations in Table 2.

Figure 3. Body, shell and neck weight and shell length relationships for I. nuttallii collected from (A) Lemmens Inlet and (B) Newcastle Island. Equations in Table 2.

Figure 4. Size at maturity ogive for I. nuttallii (sexes combined) collected from Lemmens Inlet. Solid dots N=1, open circles N=2, open triangle N=3. Equation for the predicted curve is shown in graph.

TABLE 1.

Von Bertalanffy growth parameters for I. nuttallii from Lemmens Inlet and Newcastle Island. Values in brackets are approximate 95% confidence intervals.

Area	L_{∞}	K	t_0
Lemmens Inlet	202 (± 3)	0.167 (± 0.006)	0.50 (± 0.05)
Newcastle Island	183 (± 5)	0.168 (± 0.012)	0.51 (± 0.10)

TABLE 2

Regression coefficients for various morphological relationships of *I. nuttallii* from (1) Lemmens Inlet and (2) Newcastle Island for equation $\log_e Y = \log_e A + B \log_e X$, where X = shell length (SL in mm) or age (in years) and Y variables are weights in g. All R^2 values are significant at $p < 0.01$. Body includes all soft body parts. All horse clam data used Lemmens Inlet 36-195 mm SL (N=146) and Newcastle 107-202 mm SL (N=52) for equations.

Variables		Area	Regression Coefficients		SE of Estimate	R^2
Y	X		A	B		
Total	SL	1	-10.029	3.219	0.118	0.993
		2	- 9.310	3.087	0.116	0.914
Body	SL	1	- 9.325	2.969	0.130	0.991
		2	- 8.442	2.786	0.139	0.857
Neck	SL	1	- 9.751	2.883	0.165	0.984
		2	- 7.608	2.456	0.185	0.725
Shell	SL	1	-13.059	3.642	0.152	0.991
		2	-12.159	3.499	0.171	0.863
Total	Age	1	1.550	2.039	0.392	0.932
		2	2.592	1.489	0.739	0.739
Body	Age	1	1.370	1.874	0.378	0.922
		2	2.539	1.247	0.234	0.596
Neck	Age	1	0.620	1.825	0.372	0.920
		2	2.200	1.048	0.260	0.450
Shell	Age	1	0.046	2.306	0.412	0.937
		2	1.044	1.807	0.207	0.799

TABLE 3

Relationships between ratios of shell weight/body weight, neck weight/body weight (Y), and neck weight/total wt (%), with shell length (SL) or Age (years) (X) for *I. nuttallii* from (1) Lemmens Inlet and (2) Newcastle Island using equation $Y = A + BX$. Body includes all soft body parts. R^2 are all significant at $p < 0.01$ except where indicated with * $P < 0.05$. All data used as per Table 2.

Variables		Area	Regression Coefficients		SE of Estimate	R^2
Y	X		A	B		
Shell/Body	SL	1	0.133	0.004	0.100	0.762
		2	0.285	0.004	0.182	0.139*
Neck/Body	SL	1	0.482	-0.0004	0.057	0.082
		2	0.582	-0.0009	0.055	0.085*
Neck/Total (%)	SL	1	39.109	-0.093	4.227	0.518
		2	38.799	-0.099	3.984	0.174
Shell/Body	Age	1	0.298	0.041	0.093	0.795
		2	0.421	0.041	0.167	0.271
Neck/Body	Age	1	0.460	-0.003	0.057	0.056
		2	0.526	-0.007	0.054	0.099*
Neck/Total (%)	Age	1	34.417	-0.925	4.527	0.451
		2	34.206	-0.918	3.730	0.276

TABLE 4

Predicted mean length, weights and ratios at age values for *I. nuttallii* from Lemmens Inlet and Newcastle Island. Equations in Table 1, 2 and 3.

Age y	Shell length mm	Total wt g	Body wt g	Neck wt g	Shell wt g	Shell/ Body	Neck/ Body	Neck/ Total (%)
Lemmens Inlet								
2	45	19	14	7	5	0.38	0.45	33
3	68	44	31	14	13	0.42	0.45	32
4	89	80	53	23	26	0.46	0.45	31
5	107	126	80	35	43	0.50	0.44	30
6	121	182	113	49	65	0.55	0.44	29
7	134	249	151	65	93	0.59	0.44	28
8	144	327	194	83	127	0.63	0.43	27
9	153	416	242	103	166	0.67	0.43	26
10	161	516	295	124	212	0.71	0.43	25
11	167	627	352	148	264	0.75	0.43	24
12	172	749	415	173	323	0.79	0.42	23
13	177	881	482	201	388	0.83	0.42	22
14	181	1025	554	230	460	0.88	0.42	21
15	184	1180	630	261	540	0.92	0.41	21
16	187	1346	711	293	626	0.96	0.41	20

Age y	Shell length mm	Total wt g	Body wt g	Neck wt g	Shell wt g	Shell/ Body	Neck/ Body	Neck/ Total (%)
Newcastle Island								
7	121	242	143	69	96	0.71	0.48	28
8	131	296	169	80	122	0.75	0.47	27
9	139	352	196	90	150	0.79	0.46	26
10	146	412	224	101	182	0.83	0.45	25
11	152	475	252	111	216	0.87	0.44	24
12	156	540	281	122	253	0.91	0.44	23
13	161	609	310	133	292	0.95	0.43	22
14	164	680	340	143	334	0.99	0.43	21
15	167	754	371	154	379	1.03	0.42	20
16	170	830	402	165	425	1.07	0.41	20

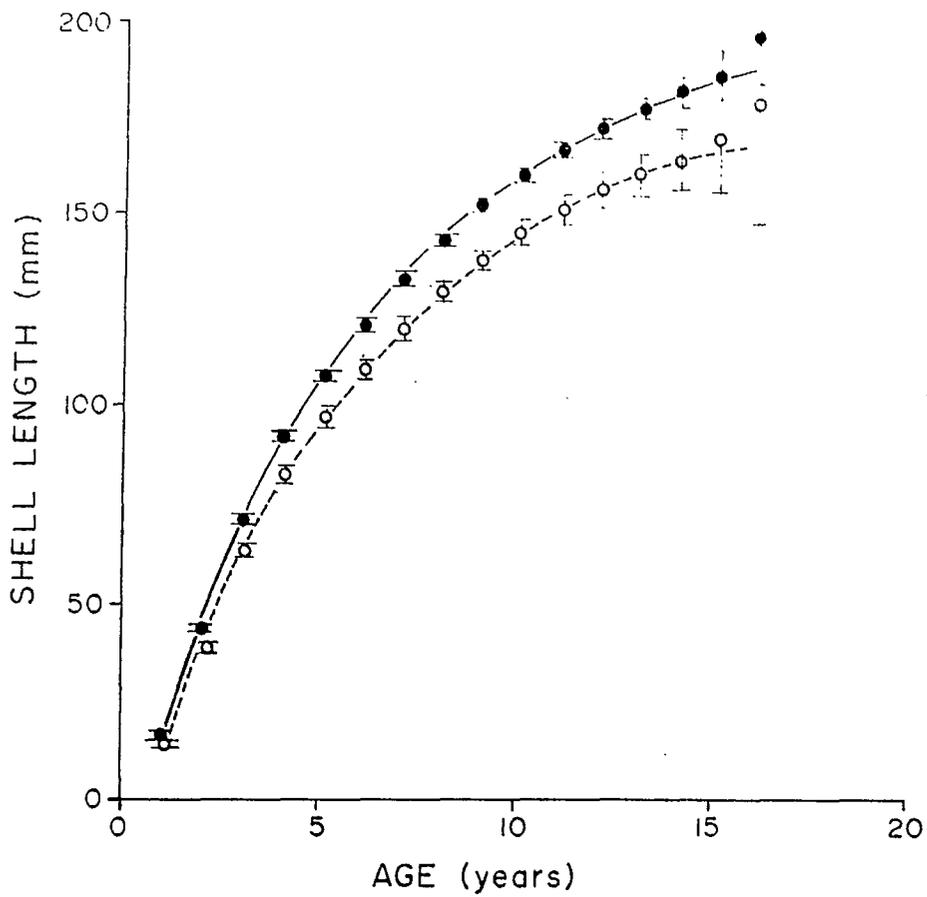


Figure 1. Growth curves for *I. nuttallii* collected from Lemmens Inlet (solid line and closed dots) and Newcastle Island (broken line and open circles). Curves from von Bertalanffy growth parameters, means (dots) and 95% confidence intervals (vertical lines) from raw data. Equations in Table 1.

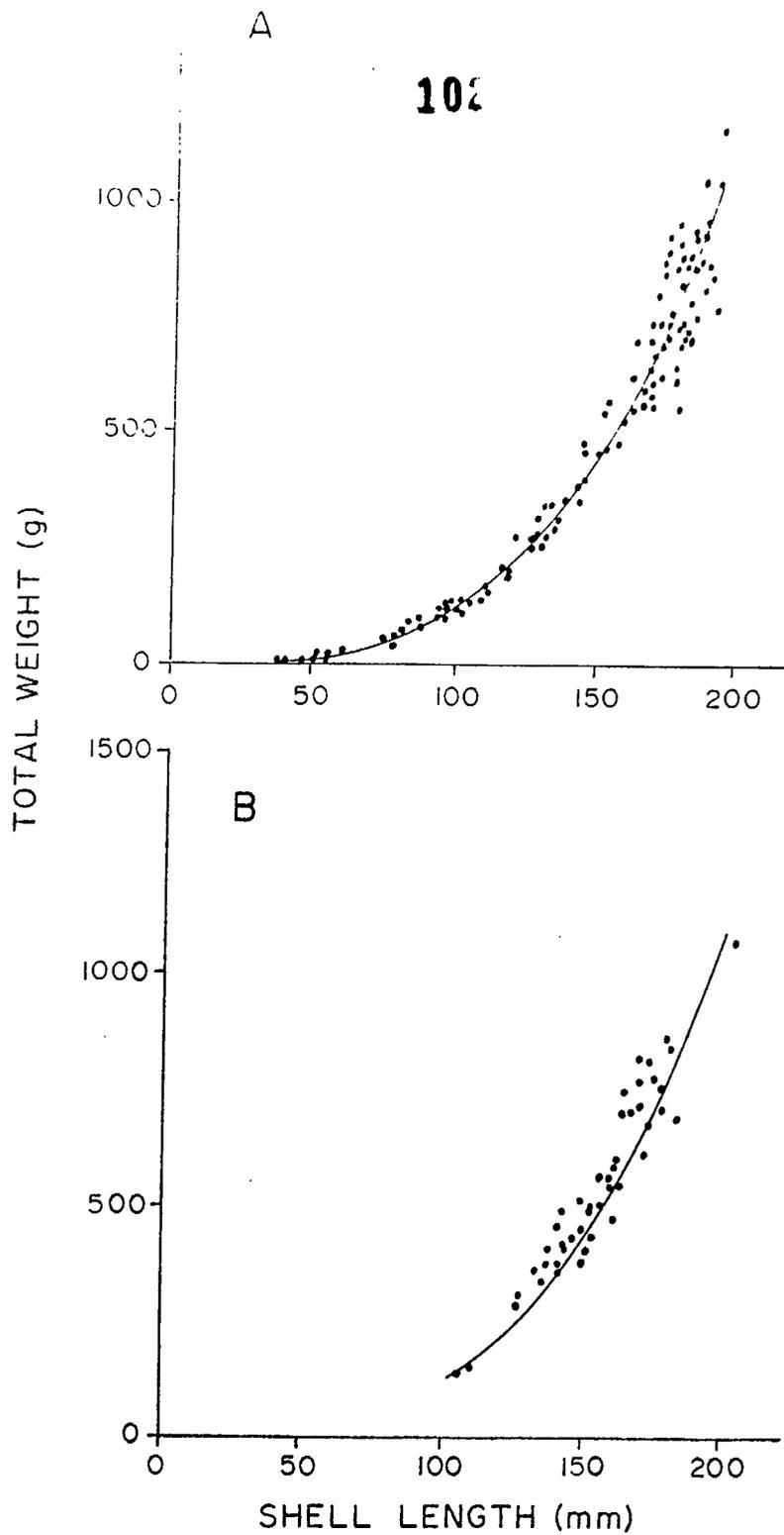


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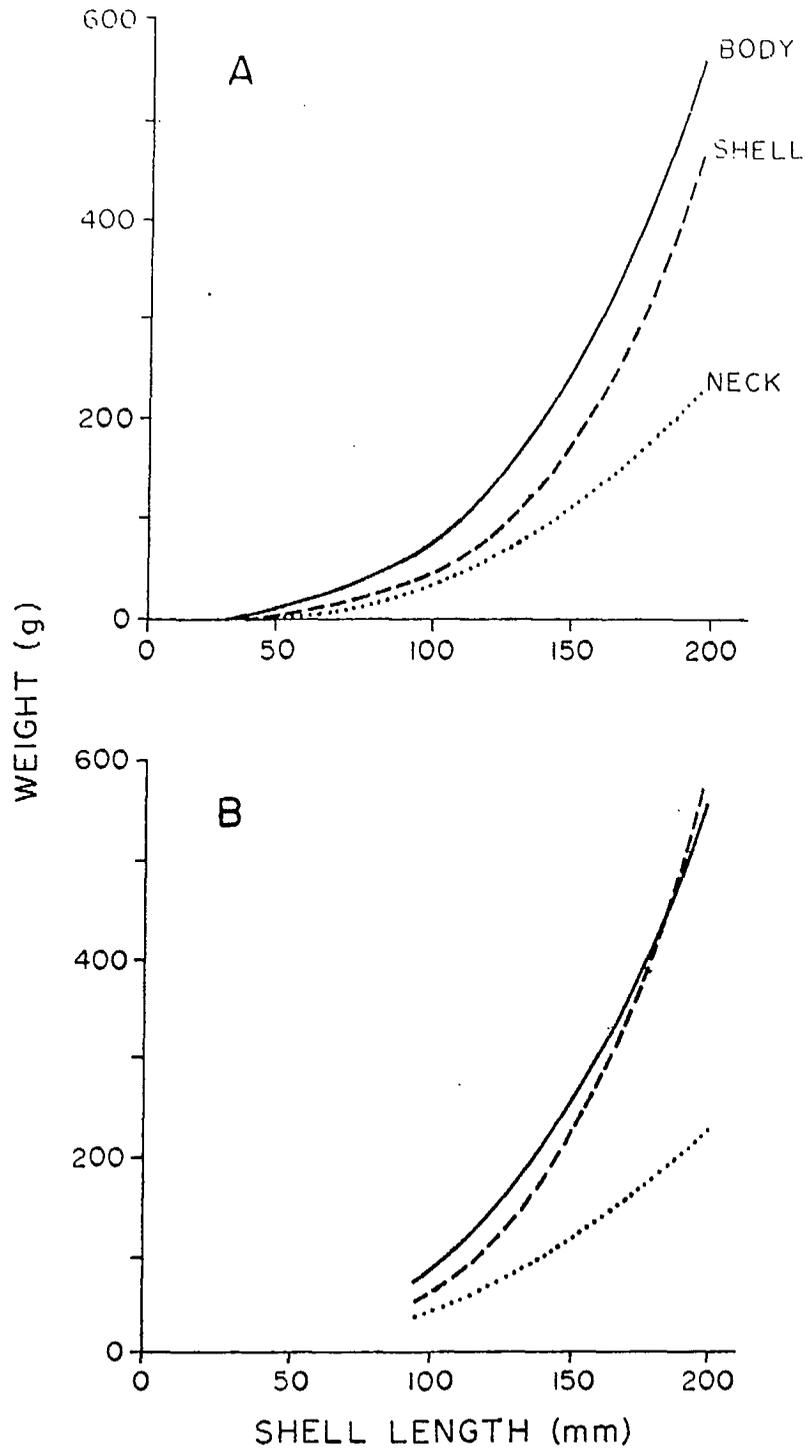


Figure 3. Body, shell and neck weight and shell length relationships for *I. nuttallii* collected from (A) Lemmens Inlet and (B) Newcastle Island. Equations in Table 2.

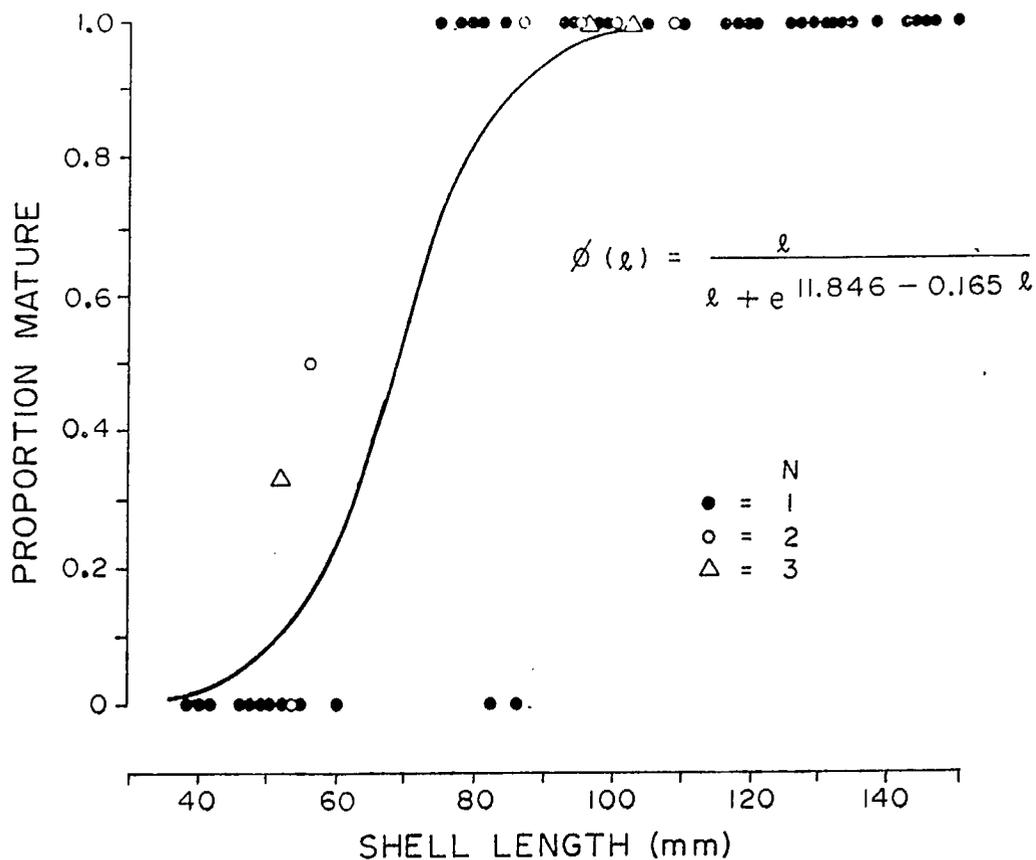


Figure 4. Size at maturity ogive for *I. nuttallii* (sexes combined) collected from Lemmens Inlet. Solid dots N=1, open circles N=2, open triangle N=3. Equation for the predicted curve is shown in graph.

8. Size Structure of Purple Sea Urchins,
Strongylocentrotus purpuratus, in
Southern British Columbia

by

A. Campbell

SUMMARY

Size frequency samples indicate low recruitment of subtidal S. purpuratus on the southwestern coast of Vancouver Island. Purple sea urchins are difficult to collect since they occur in high wave action areas. Although S. purpuratus can occur in dense populations (>100 m²) their distribution is irregular and gonadal quality may not be consistent. Based on published literature, purple sea urchins from the intertidal are shown to have slow growth rates (large individuals can be over 50 years old), are mature by >40 mm test diameter, reproduce annually with large gonads during fall - winter and have low and sporadic recruitment and larval settlement. A great deal more information is required on the biology, distribution and abundance of subtidal S. purpuratus in British Columbia.

INTRODUCTION

The purple sea urchin, Strongylocentrotus purpuratus (Stimpson 1857), is found on the Pacific Coast of North America from Alaska to Baja California (Ricketts and Calvin 1962). Occurring intertidally on rocky shores with considerable wave action, S. purpuratus is also found subtidally to 64 m depth (McCauley and Carey 1967). A considerable amount of research has been conducted on growth (e.g. Ebert 1988, Russell 1987), chemistry (eg. Boolootian 1966), predation (Duggins 1983), reproduction (Boolootian 1966, Gonor 1970, 1973a, b) and recruitment (Ebert 1983, Ebert and Russell 1988) of S. purpuratus. However, little information on the biology of S. purpuratus from British Columbia (B.C.) is available (Kramer and Nordin 1975, Russell 1987). See Biology section for further discussion.

An experimental purple sea urchin fishery was started in B.C. (statistical areas 11, 12, 20, 21, 23, 24, 25, 27) from October 1989 to June 1990 with 17 permits issued to 11 fishing boats on an area by area and 2-3 mo period basis. All fishermen were asked to provide size frequency and density information on the purple sea urchins sampled from each area fished through biological consultants. Three fishermen to date provided size frequency and density data.

The purpose of this paper is to present size frequency data recorded by the fishermen and by a research survey and provide biological data that may be relevant to a purple sea urchin fishery in southern British Columbia.

BIOLOGY

This section reviews relevant biological data from published literature on S. purpuratus. Most research to date has been conducted on S. purpuratus from intertidal areas.

S. purpuratus is a broadcast spawner and has a fall swimming larval period of 2-3 mo before settling to the benthic stage (Strathmann 1978).

Growth rates of young benthic S. purpuratus (1-2 yr) are not known; however, growth of larger purple urchins has been studied extensively. Growth is not constant during a year. Highest growth occurs during July - December, lowest from January to March and intermediate during March to July (Ebert 1968). Growth can be variable from area to area, but is generally slow in S. purpuratus. Growth of S. purpuratus from tidal pools near Pachena Point, B.C. (Fig. 1) was determined by Russell (1987) by tagging the sea urchins with tetracyclines and collecting the individuals a year later. From various equations provided by Russell (1987) I calculated age-test diameter relationships for S. purpuratus from four tide pools from Pachena Point during 1981-82 (Fig. 2). Growth was variable and slow. Longevity of purple sea urchins can be up to or greater than 50 yr (T.A. Ebert pers. comm.). Growth of subtidal S. purpuratus has not been studied.

Factors affecting growth are numerous. Exposure to wave action can reduce growth and cause loss of species in purple urchins (Ebert 1968). Food availability can vary growth rates with growth being negative under crowded conditions and/or low quantities of food (Ebert 1968). The purple sea urchin is a herbivore utilizing algae as the chief food source although animal matter (eg. dead fish) is eaten. Starvation changes metabolism of calcium in order to preferentially allocate calcium for building of larger teeth over other body parts of S. purpuratus (Lewis et al. 1990).

In Oregon, intertidal S. purpuratus begin to produce mature gametes at 24 mm test diameter (TD) during the second year of life; by 40 mm TD all individuals have mature gametes (Gonor 1972).

Reproduction occurs as an annual cycle. Gonads tend to increase in size during fall (Oct. - Dec.), decrease during winter (January. - March) and are smallest during summer (June - Aug.) (Booolootian 1966, Gonor 1973a, b). Spawning time seems synchronous from Washington to Mexico with the gametogenic process commencing in late summer for 5 mo to spawning (January - March) (Booolootian 1966, Gonor 1973a, b). This reproductive cycle is probably similar for S. purpuratus in B.C. (Russell 1987) although no seasonal

(monthly) samples of gonads have been taken on a regular basis from field populations. Kramer and Nordin (1975, Appendix C) found the mean gonad index (wet wt. gonad/total wet wt. drained) was 20.5% (\pm 0.52, N=98) for S. purpuratus males and females (combined) collected off Albert Head, October, 1974. Dramatic increases of gonad weight can be obtained by providing excess algae food in laboratory (closed areas) compared to natural field conditions (eg. Russell 1987).

Recruitment of purple sea urchins can be sporadic in time and space. Ebert (1983) studied S. purpuratus annually from 1964-78 in tidal pools at Sunset Bay, Oregon. Recruitment occurred in 1963 then none occurred during 1964-78 (over a 12 yr period) at the same location. This suggests that to examine these long-lived urchins, at least 20 yr may be necessary to document recruitment variability. Ebert and Russell (1988) examined size structures of S. purpuratus from central California to central Oregon and correlated size frequencies and inferred recruitment with major topographic features. They found that sites without predictable upwelling or regions between headlands had size frequencies that indicated substantial annual recruitment of S. purpuratus. Capes and headlands with predictable upwelling and cold water plumes had size frequencies indicating low recruitment.

Overall mortality (Z) rates estimated from size frequency data of S. purpuratus in tidal pools at Pachena Point, 1981-82 was a mean 0.119 (min 0.087, max 0.159) (Russell 1987).

Total and gonad drained wet weight related to test diameter regressions (Fig. 3) were calculated from data on purple sea urchins at Albert Head, October 1974 provided by Kramer and Nordin (1975, appendix C). Total and gonad weights increase with test diameter as expected, but there is greater variation in gonad weight than total weights for the equivalent test diameter. This suggests variation in seasonal gonadal development or maturity.

SIZE FREQUENCIES

Purple sea urchins collected and counted in one m² quadrants were measured for test diameter (TD) to nearest mm with vernier callipers. Median TD were similar for sea urchins sampled from southern Barclay Sound, Amphetrite Point and Tofino (West of Wickaninnish Island) (Fig. 4, Table 1). Purple sea urchins tended to be smaller off Port Renfrew than for those sampled further west during 1989-90. The largest (TD = 104 mm) purple urchins were recorded off Albert Head during October 1974 (Fig. 5, Table 1) by Kramer and Nordin (1975). Russell (1987) recorded purple urchins between 5-80 mm TD in tidal pools off Pachena Point during 1981-82 (Fig. 6).

The percentage of prerecruit sizes (legal minimum, recruit size = 55 mm TD) varied from one area to another (Table 1). Recruitment is highly variable from area to area and year to year (Ebert 1983, Ebert and Russell 1988). Few purple urchins <20 mm TD were found at any sample site (Fig. 4, 5, 6, Table 1).

DENSITIES

Many dives had to be made to find appreciable densities of S. purpuratus. In areas where purple urchins were found subtidally densities ranged from 9 to 130/m². Densities estimated by the fishermen are unreliable because only a riped estimated of /m² was used. Only the DFO sample at Tofino was a one m² quadrat used. Gonor (1972) found densities of >100 urchins/m² common along the Oregon coast; these aggregations were predominantly composed of individuals 50-60 mm TD.

IMPLICATIONS FOR EXPERIMENTAL MANAGEMENT

Although part of an experimental fishing permit was the requirement for fishermen to measure the TD and density of purple sea urchins few fishermen complied for each area they fished. The fishery was not valuable enough for fishermen to contract biological consultants frequently. The quality of data especially in terms of sea urchin density was poor. Relying on fishermen in providing data collections using biological companies in an ad hoc basis and in remote sampling areas is a nebulous method of monitoring the S. purpuratus fishery especially if fishermen are unwilling to comply. To improve this situation various alternatives need to be considered. Stricter rules could be required to obtain a permit, or all monitoring of the fishery could be conducted by DFO personnel or by biology consultants contracted through DFO funded by either DFO funds or from another source (fishermen's poll tax). Reliability of data collection would improve, especially abundance and density estimates, if conducted by DFO and/or contract divers.

Since gonadal development in S. purpuratus is probably optimal in fall and early winter a fishing season should be set for fall - winter (Oct - March).

Growth of S. purpuratus (at least intertidal populations) is slow (some individuals have longevity >50 yr), but variable. Growth of subtidal S. purpuratus is unknown. However, if we assume growth of S. purpuratus is generally slow and recruitment into legal size is low and variable depending on location and year, then exploitation should be kept low through small quotas, or by using rotational closure areas of 2-5 yrs or severe license limitations.

The recruit size of 55 mm TD is probably adequate although size at maturity in B.C. is unknown at present for subtidal S. purpuratus. All intertidal individuals >40 mm TD in Oregon were mature during the midwinter spawning (Gonor 1972).

The fishery may be self-regulated anyway. The purple sea urchins are difficult to collect since they are found in high wave action areas. There may be considerable wastage of purple sea urchins if the gonad quality varies between urchin individuals from similar areas. This problem could be overcome by enhancing gonadal quality and growth by allowing some operators to "grow out" urchins in enclosed areas which are provided with plenty of food algae over 1-2 mo.

SUMMARY

Size frequency samples indicate low recruitment of subtidal S. purpuratus on the southwestern coast of Vancouver Island. Purple sea urchins are difficult to collect since they occur in high wave action areas. Although S. purpuratus can occur in dense populations ($>100/m^2$) their distribution is irregular and gonadal quality may not be consistent. Based on published literature, purple sea urchins from the intertidal are shown to have slow growth rates (large individuals can be over 50 yr old), are mature by >40 mm test diameter, reproduce annually with large gonads during fall - winter and have low and sporadic recruitment and larval settlement. A great deal more information is required on the biology, distribution and abundance of subtidal S. purpuratus in British Columbia.

MANAGEMENT CONSIDERATIONS

- Fishing season could be restricted to fall - winter (Oct.- March).
- Exploitation could be restricted by license limitation, low quotas and/or rotational closure areas of 2-5 yr.
- Minimum legal recruit size should be maintained to at least 55 mm test diameter.
- Granting of each fishing permit should be contingent of fishermen having size distribution, location, density, catch and effort data collected in a timely and accurate way.

RESEARCH PRIORITIES

- Growth, seasonal gonadal development and size at maturity should be determined for subtidal purple sea urchins.
- Survey of density and distributions of S. purpuratus.
- Technology be developed to assist fishermen/processors for "grow out" to improve gonadal quality of sea urchins by providing algae to urchins in enclosures.

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FIGURE LEGENDS

Figure 1. Map of southern British Columbia showing sample locations for purple sea urchins: 1. Barclay Sound (South); 2. Amphetrinite Point; 3. Port Renfrew (Sombrio Point); 4. Tofino (Wickaninnish Island); 5. Albert Head (Kramer and Nordin 1975); 6. Pachena Point (Russell 1987).

Figure 2. Growth rates for S. purpuratus from four tidal pools near Pachena Point during 1981-82. Curves calculated from data on individuals tagged with tetracycline. After Russell (1987).

Figure 3. Relationship between (A) total drained wet weight and (B) gonad drained wet weight with test diameter of S. purpuratus from Albert Head, October 1974. Data after Kramer and Nordin (1975, Appendix C).

Figure 4. Size frequencies of S. purpuratus from subtidal (3-14 m depth) areas along the southwestern coast of Vancouver Island, 1989-90.

Figure 5. Size frequency of S. purpuratus from subtidal (3-9 m depth) areas off Albert Head, October 1974. After Kramer and Nordin (1975, Appendix C).

Figure 6. Size frequency of S. purpuratus from tidal pools off Pachena Point, 1981-82. After Russell (1987, Fig. 2).

Table 1. Summary of size frequency and density data of *S. purpuratus* collected subtidally (3-14 m depth) on the south-west coast of Vancouver Island. Data collected by a. fishermen, b. DFO personnel, C. after Kramer and Nordin (1975, appendix C). Legal size = 55 mm Test diameter, TD. N=total number.

Location	Statistical Area	Date	Test Diameter (mm)				<55 mm TD,% of		Density
			mean	median	min.	max.	total	N	min-max No./m ²
Barclay Sound	23	29 Jan. 90 ^a	62	62	43	86	16	459	9-80
Amphetrile Point	23	16 Dec. 89 ^a	63	63	48	87	9	137	10-130
Port Renfrew	20	18 April 90 ^a	52	53	28	70	63	511	49-105
Tofino	24	24 May 90 ^b	59	61	19	99	27	348	4-41
Albert Head	19	October 74 ^c	79	81	48	104	2	100	-

FIGURE LEGENDS

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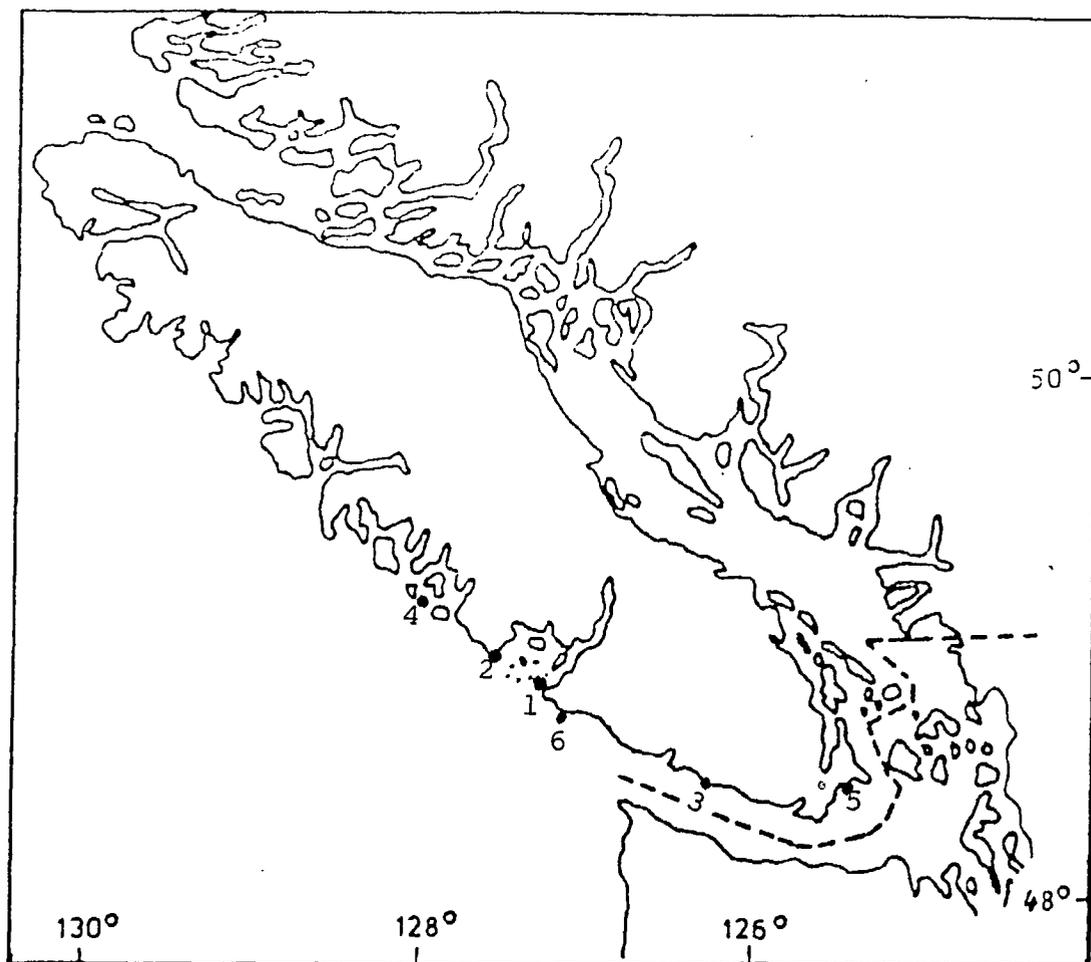


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PURPLE URCHIN GROWTH (RUSSELL 1987)

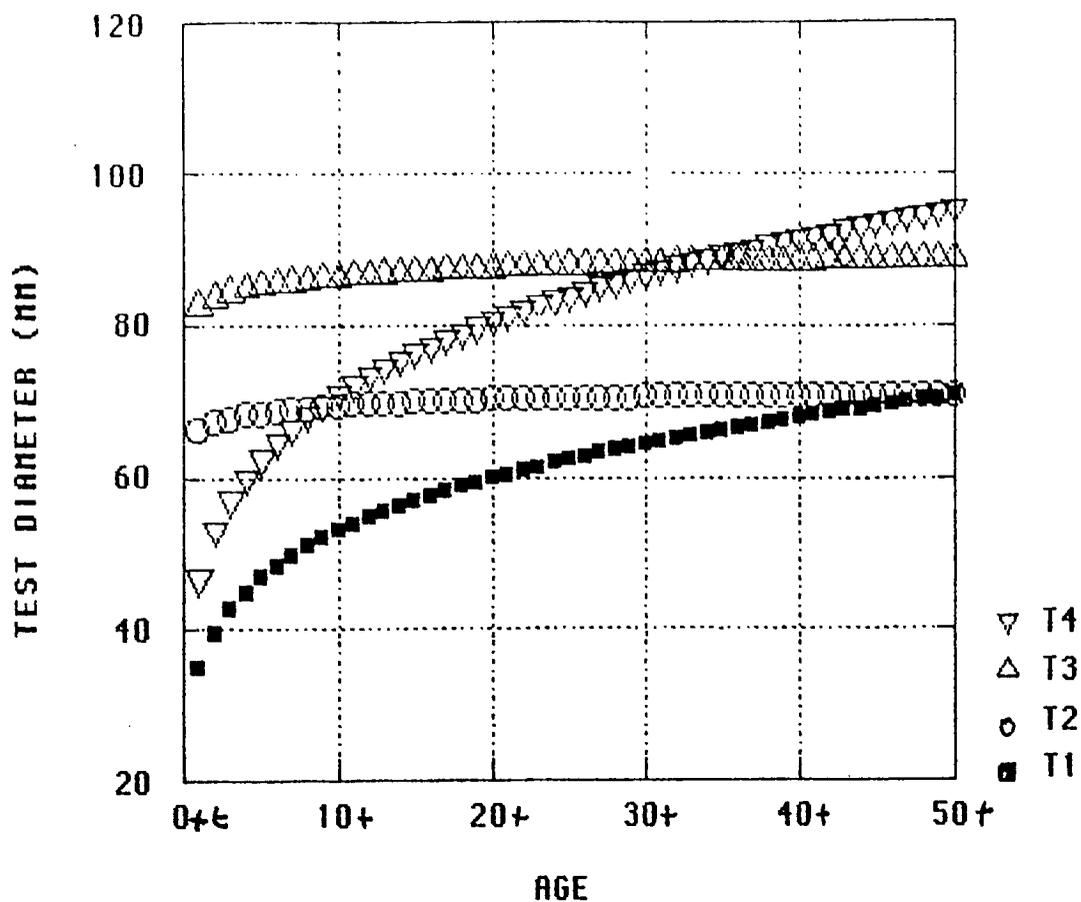


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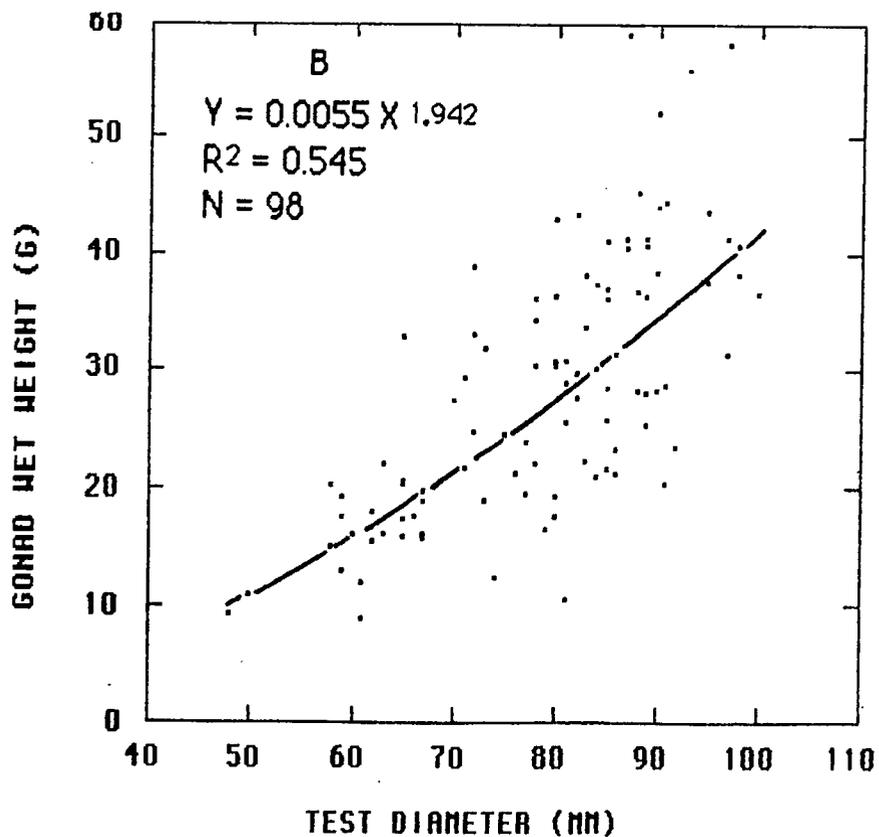
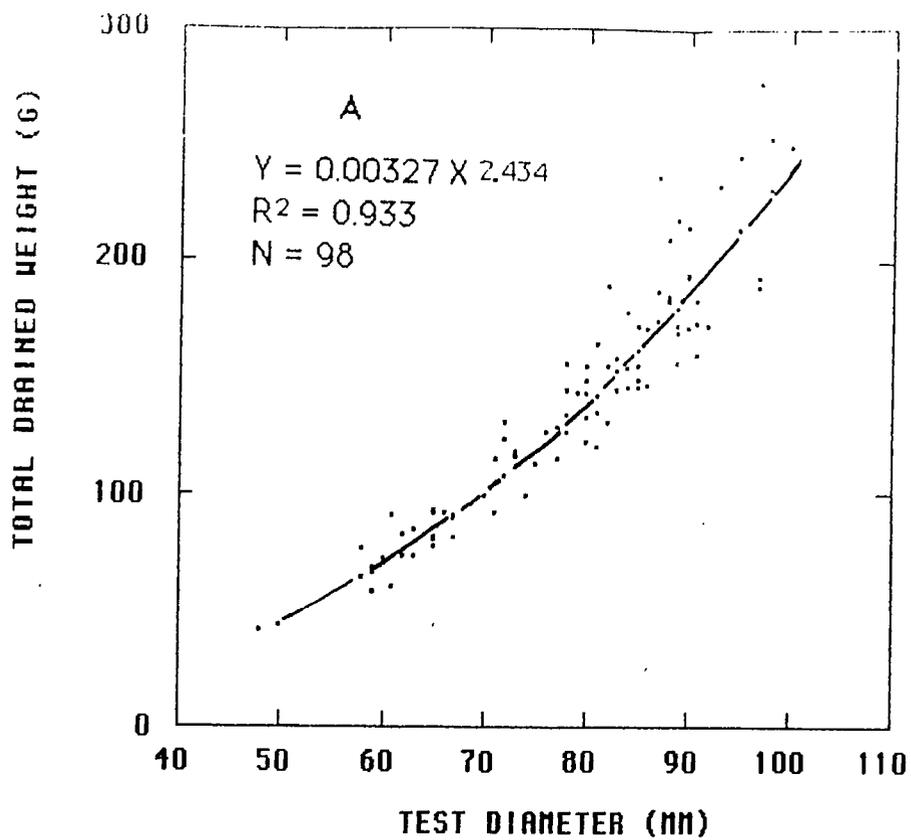
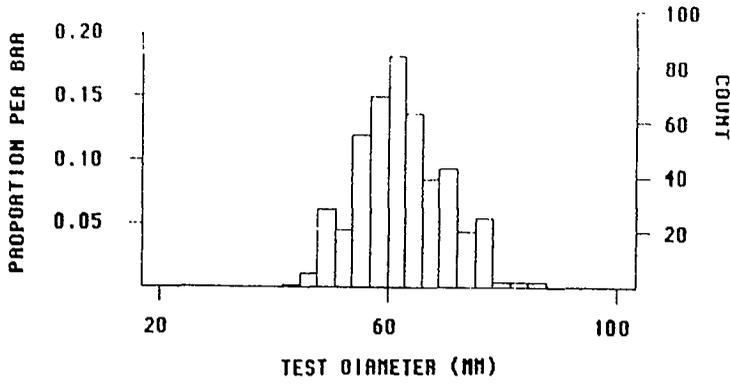
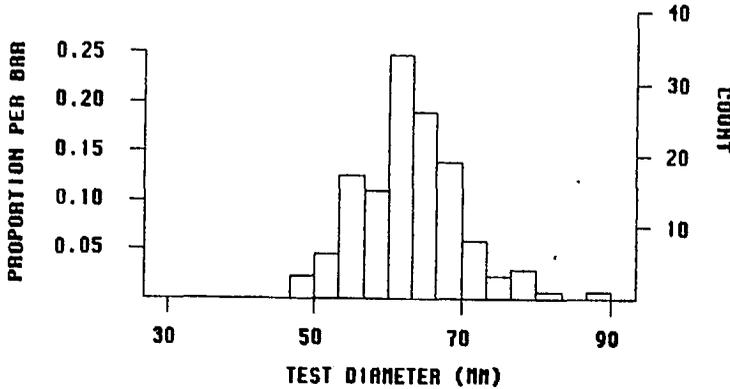


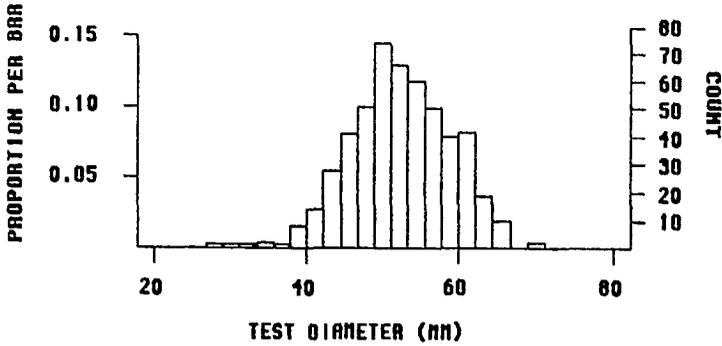
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B. AMPHETRITE PT. 16 DEC. 89



C. PORT RENFREW AREA, 18 APRIL 90



D. TOFINO 24 MAY 90

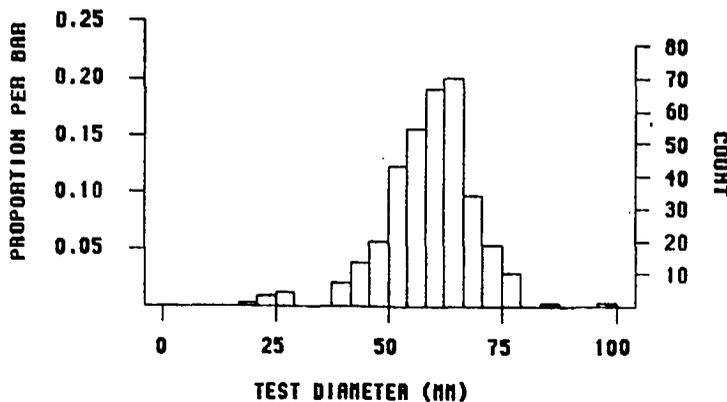


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ALBERT HEAD, OCTOBER 1974

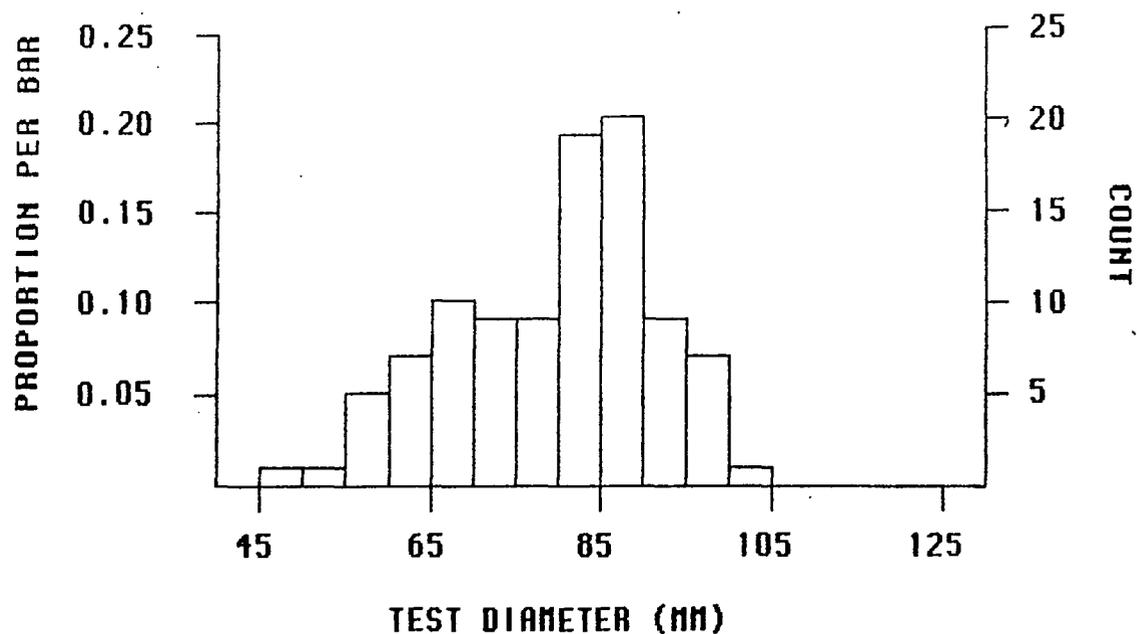


Figure 5. Size frequency of *S. purpuratus* from subtidal (3-9 m depth) areas off Albert Head, October 1974. After Kramer and Nordin (1975, Appendix C).

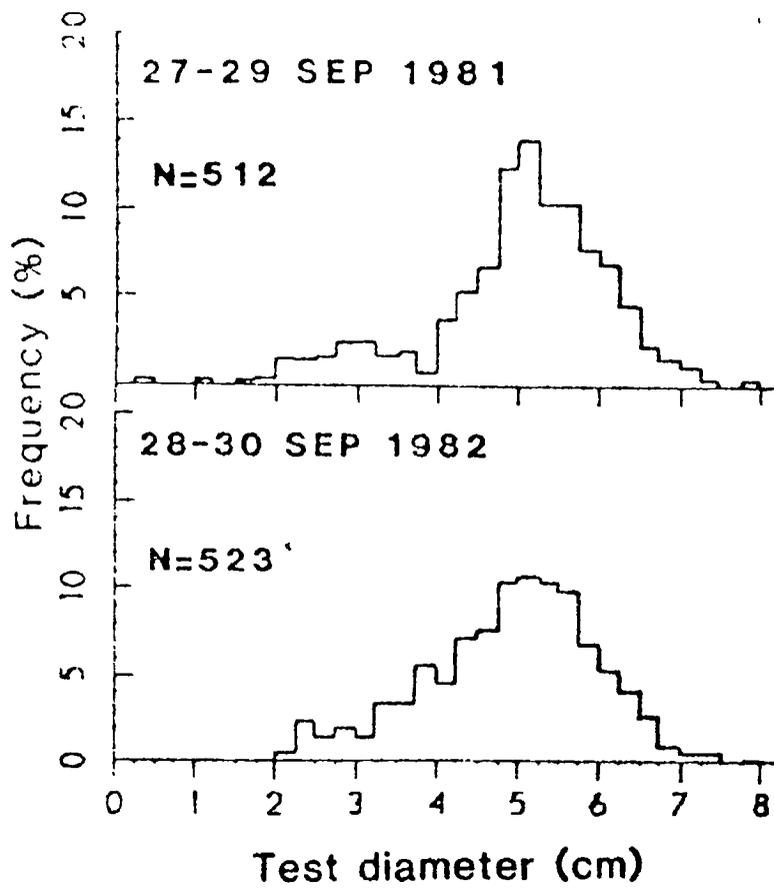


Figure 6. Size frequency of S. purpuratus from tidal pools off Pachena Point, 1981-82. After Russell (1987, Fig. 2).

9. A Preliminary Report of an Intertidal
Clam Survey in the North Coast District - 1990

by

N. Bourne and G. Cawdell

SUMMARY

A survey to assess intertidal clam stocks in eight areas in the north coast district (Areas 4-7) was undertaken from June 20-27, 1990. Beaches selected for survey extended from Kitkatla Inlet in the north (Area 4) to two areas in Area 6 and to several beaches in the Bella Bella area (Area 7). Estimates of abundance and growth were determined for butter clams, Saxidomus giganteus, littleneck clams, Protothaca staminea, and manila clams, Tapes philippinarum. The area of the clam bearing part of the beach and substrate type was determined. Additional sampling was undertaken to determine the northward distribution of manila clams and to assess if commercially harvestable quantities of this species exist in the north coast district.

Butter and littleneck clams were found in all areas surveyed. Density of butter clams ranged from 0-204 per square meter for legal sized clams (63 mm shell length and larger) and 1-292 for sublegal sized clams. At most sites sublegal sized butter clams comprised at least half the catch indicating that consistent recruitment has occurred in recent years. Growth was similar in most areas, the legal size was attained in 7-8 years.

Littleneck clams were the most abundant bivalve sampled during the survey. Density of legal (38 mm shell length and larger) and sublegal sized littleneck clams ranged from 0-224 and 0-436 per square meter respectively. Sublegal sized clams were abundant at most sampling sites indicating that consistent recruitment has occurred in recent years. Growth was similar at most sampling locations, the legal size was generally attained in 3.5-4 years.

Manila clams were not found in abundance north of Milbanke Sound, the farthest north specimen was at Hird Point in Mathieson Channel (Area 6). South of Milbanke Sound density of legal (38 mm shell length and larger) and sublegal sized manila clams ranged from 14-170 and 3-168 per square meter respectively. In other plots dug specifically to assess numbers of manila clams, density ranged from 0-248 per square meter. There were large accumulations of manila clam shell on many beaches in area 7 indicating there have been substantial populations of manila clams in this area for

at least the past ten years. On many beaches there was a preponderance of larger sized manila clams indicating that recruitment has not been consistent in recent years. Growth was similar in most areas, the legal size was generally attained in 3.5 years.

Commercially harvestable quantities of all three species, butter, littleneck and manila, exist in the north coast district.

INTRODUCTION

The north coast district has supported an intertidal clam fishery for many years (Quayle and Bourne 1972). Since 1924 there has been a razor clam, Siliqua patula, fishery on the oceanic beaches that extend from Masset Inlet to Rose Spit on Graham Island in the Queen Charlotte Islands. Landings have never been large, in general under 100 t since 1951, although there has been a resurgence in the fishery in the past four years when landings ranged from 116-155 t.

The main intertidal clam species harvested in the coast wide commercial fishery was the butter clam, Saxidomus giganteus. In previous years approximately half of the butter clams dug in the commercial fishery were from the north coast district, the other half were from the south coast district. In 1963 the north coast district was closed to the harvest of intertidal clams, except for razor clams, because of PSP (paralytic shellfish poisoning). A permit system was developed to allow clam harvesting in the north coast district and landings were made there from 1968-1982 but they were generally small. Processing butter clams became uneconomic and the harvest of butter clams has declined to under 100 t coastwide in the last three years.

Although there are extensive populations of littleneck clams, Protothaca staminea, in the north coast district, they have never been harvested commercially, probably because of the PSP closure and difficulties in transporting them to markets.

Manila clams, Tapes philippinarum, are an exotic to British Columbia and probably first appeared in the southern part of the north coast district in the late 1960's (Bourne 1982). Surveys conducted in 1980 and 1981 showed that populations of manila clams extended to just north of Bella Bella. However, reported commercial landings of manila clams from the north coast district are believed to be in error.

Recently there has been renewed interest in harvesting clams in the north coast district because of the strong markets for steamer clams, particularly manila clams. The 1990 survey was undertaken to assess intertidal clam populations on selected beaches in the north coast district, observe whether manila clams had spread farther north than recorded in 1980 and determine if commercial harvest of steamer clams, particularly manila clams, is possible on beaches in area 7.

This is a preliminary report giving salient information from the survey. A more comprehensive report summarizing the complete results of this survey and comparing them to information in the 1980 and 1981 surveys will be published later.

METHODS

Beaches selected for sampling were chosen from chart surveys, previous experience or from information supplied by Fishery Officers. Eight areas were surveyed during a cycle of low tides from June 20-27, 1990, inclusive (Table 1).

The area of the clam bearing part of each beach was estimated and substrate type recorded. Random plots in the clam bearing part of a beach were marked out that were 1.0, 0.5 or 0.25 sq m in area. Sampling was done after the manner described by Bourne and Farlinger (1981). All sampled clams were placed in bags and labelled for later measurement.

Additional sampling was undertaken to determine the presence or absence of manila clams on beaches and to estimate populations of manila clams when they were present. These plots were dug with rakes in sand-gravels parts of the central portion of intertidal beaches and to a depth of about 15 cm. Harvested clams from some plots were put in plastic bags, labelled and measured later. In other plots only the number of manila clams dug in a plot was recorded.

Shell length of each clam was measured to the nearest mm with vernier calipers. The age of each clam was determined by counting annuli. In addition a sample of butter, littleneck and manila clams was selected from each area and the shell length at each annuli measured to the nearest mm with vernier calipers. This provided two estimates of age for butter, littleneck and manila clams at each location. The means of shell lengths at annuli were calculated along with standard deviations.

Observations were also made for the presence or absence of manila clam shell on beaches at the high tide line and on large rocks used by birds to drop and break clams.

RESULTS

Results are summarized briefly in Tables 2-3 and in Figs 1-23.

BUTTER CLAMS

Butter clams were found in abundance at all sampling locations. Density of legal and sublegal sized butter clams ranged from 0-204 and 1-292 per square meter respectively. At most sites sublegal sized butter clams comprised at least half the catch indicating that consistent recruitment has occurred in past years.

Few large clams, i.e. over 85 mm shell length, were found in any samples. Many of the older clams showed signs of stunting, thickened ventral margins of the shell, which may have contributed to the lack of numbers of large clams.

Growth was similar for butter clams throughout the sampling area, (Figs 1, 4, 6, 8, 14, 17, 20). The legal commercial size, 63 mm shell length, was attained generally at 7-8 years of age.

LITTLENECK CLAMS

Littleneck clams were found in all areas and were the most abundant bivalve sampled during the survey. Density of legal and sublegal sized clams ranged from 0-224 and 0-436 per square meter respectively. Sublegal sized littleneck clams were abundant at most sampling sites indicating that consistent recruitment has occurred in the past.

Many of the littleneck clams showed signs of severe stunting, thickened ventral margins of the shell, erosion of older parts of the shell and abnormal shape of the shells. Cause of the stunting is unknown but it may have been a density dependant factor. In spite of the large amount of stunting, large littleneck clams were found on most beaches.

Growth of littleneck clams was similar throughout the sampling area, (Figs 2, 5, 7, 9, 15, 18, 21). The legal size, 38 mm shell length, was attained generally when the clams were 3.5-4 years of age. These growth rates are similar to those for growth rates of littleneck clams in the south coast district. The fast growth rate recorded for north coast clams may be due in part to a sampling bias. Few stunted clams were used when measuring shell length at annuli. This may have resulted in measuring growth rates of faster growing clams.

MANILA CLAMS

Manila clams were not found in abundance north of Milbanke Sound. They were not found at the first two sampling locations, Kitkatla Inlet and Weinberg Inlet in spite of the numerous samples and observations for old shell. One live manila clam and two empty shells lying on the beach were found at Kitasu Bay indication they have spread at least this far north. However, no manila clams were found in Meyers Passage which is located about 15 km north of the beaches at Kitasu Bay. Manila clams were found in Mathieson Channel at Rescue Bay and about 8 km farther north on a beach at Hird Point. This is the farthest north distribution recorded for manila clams.

On beaches in Milbanke Sound and southward, density of legal and sublegal sized clams ranged from 14-170 and 3-168 per square meter respectively (Table 3). In other plots dug specifically to assess number of manila clams, density ranged from 0-248 per square meter (Table 4).

On many of the beaches there was a preponderance of larger sized manila clams indicating that recruitment had not been consistent in recent years. Only in the Seaforth Channel-Raymond Passage area did sublegal sized manila clams occur in similar numbers to legal sized clams (Table 3). The low number of manila clams may have been due to poor recruitment or to poor survival of spat in areas with high densities of larger sized clams. Not only were most manila clams on many beaches larger than the legal size but they were large clams, most were over 45 mm shell length, many were over 50 mm shell length. The largest was 63 mm shell length. This probably reflects an accumulation of an unharvested stock.

There were large accumulations of manila clam shell on many beaches surveyed in statistical area 7. Some of the shell may have resulted from the winter kill that was observed on south coast beaches after the severe low temperatures in February 1989. Some of the shell had been on the beach for periods of 3-5 years. The accumulation of the shell indicates there have been substantial populations of manila clam beaches in this area for at least the past ten years.

Growth was similar for manila clams on most beaches, it was slightly slower on beaches in Mathieson Channel (Figs 10, 11, 12, 13, 16, 19, 22, 23). The legal commercial size, 38 mm shell length, was attained in approximately 3.5 years. This is surprising since this is approximately the optimum growth rate for manila clams in the Strait of Georgia area. Manila clams occupy the same intertidal zone in the northern area as in the south coast district, the mid intertidal zone, and growth rates between the two areas are similar.

OTHER SPECIES

Small numbers of horse clams, Tresus capax, cockles, Clinocardium nuttallii, and soft-shell clams, Mya arenaria, were recorded on some beaches. The lower portion of the intertidal beach at Parsons Anchorage in Kitasu Bay had large numbers of geoducks, Panope abrupta.

DISCUSSION

This survey confirms findings of previous work that reported commercially harvestable quantities of butter and littleneck clams present on many beaches in the north coast district. As in other intertidal clam fisheries, harvesters would soon determine where the most profitable digging occurred.

Results of this survey show that commercially harvestable quantities of manila clams occur on many beaches in statistical area 7. The preponderance of larger sized clams on many of the beaches indicates that the fishery may have to be carefully managed if it is to be a continuing fishery.

Whether commercial fisheries develop for these resources in the north coast district will depend on several factors. Sanitary surveys of all protective harvesting areas would have to be undertaken first by the Environmental Protection Service. DFO would have to establish an adequate program to monitor levels of PSP. Finally it will depend on the economics of the fishery and whether it would be profitable to harvest these species from the northern district.

RECOMMENDATIONS

1. Surveys should be undertaken of intertidal beaches south of area 7, statistical areas 8, 9 and 10, to determine if they have commercially harvestable populations of manila clams.
2. Intensive surveys should be undertaken of selected beaches in area 7 to obtain better estimates of the abundance and population structure of manila clams on them.
3. A program should be initiated to monitor recruitment of manila and littleneck clams in area 7.
4. A survey should be undertaken of more beaches north of area 7, particularly in area 6 to determine the northward distribution of manila clams.

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FIGURES

1. Growth rate of butter clams from Kitkatla Inlet, June 1990.
2. Growth rate of littleneck clams from Kitkatla Inlet, June 1990.
3. Growth rate of horse clams from Kitkatla Inlet, June 1990.
4. Growth rate of butter clams from Weinberg Inlet, Campania Islands, June 1990.
5. Growth rate of littleneck clams from Weinberg Inlet, Campania Islands, June 1990.

6. Growth rate of butter clams from Kitasu Bay, June 1990.
7. Growth rate of littleneck clams from Kitasu Bay, June 1990.
8. Growth rate of butter clams from Rescue Bay, Mathieson Channel, June 1990.
9. Growth rate of littleneck clams from Rescue Bay, Mathieson Channel, June 1990.
10. Growth rate of manila clams from Rescue Bay, Mathieson Channel, June 1990.
11. Growth rate of manila clams from Salmon Bay, Mathieson Channel, June 1990.
12. Growth rate of manila clams from St. John Harbour, June 1990.
13. Growth rate of manila clams from Dearth Island, Seaforth Channel, June 1990.
14. Growth rate of butter clams from Joassa Channel, June 1990.
15. Growth rate of littleneck clams from Joassa Channel, June 1990.
16. Growth rate of manila clams from Joassa Channel, June 1990.
17. Growth rate of butter clams from Fannie and Lizzie Coves, Lama Passage, June 1990.
18. Growth rate of littleneck clams from Fannie and Lizzie Coves, Lama Passage, June 1990.
19. Growth rate of manila clams from Fannie and Lizzie Coves, Lama Passage, June 1990.
20. Growth rate of butter clams from Sans Peur Passage, Huynter Channel, June 1990.
21. Growth rate of littleneck clams from Sans Peur Passage, Hunter Channel, June 1990.
22. Growth rate of manila clams from Sans Peur Passage, Hunter Channel, June 1990.
23. Growth rate of manila clams from Raymond Passage, June 1990.

KITKATLA BUTTER CLAMS

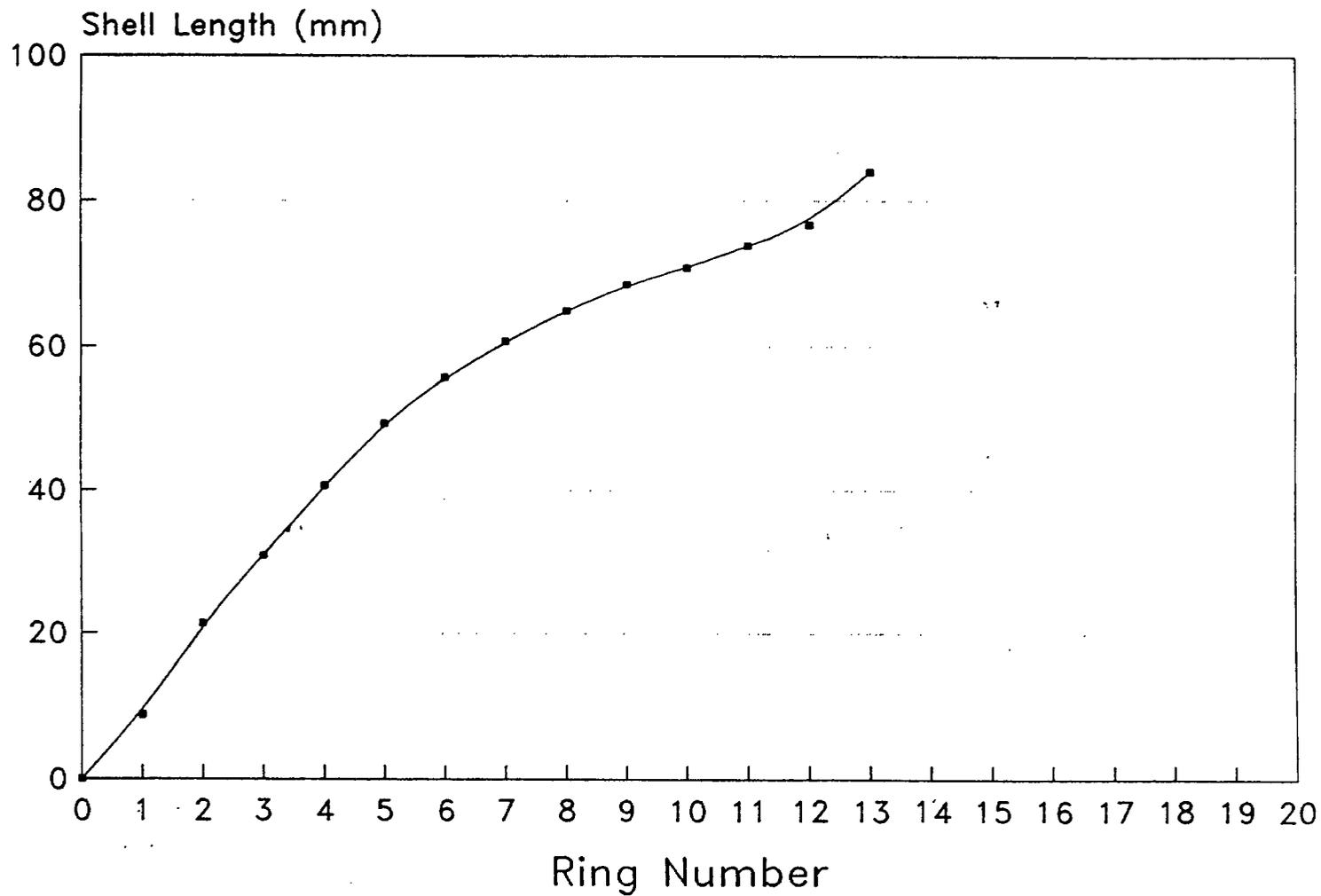


Fig. 1

KITKATLA LITTLENECK CLAMS

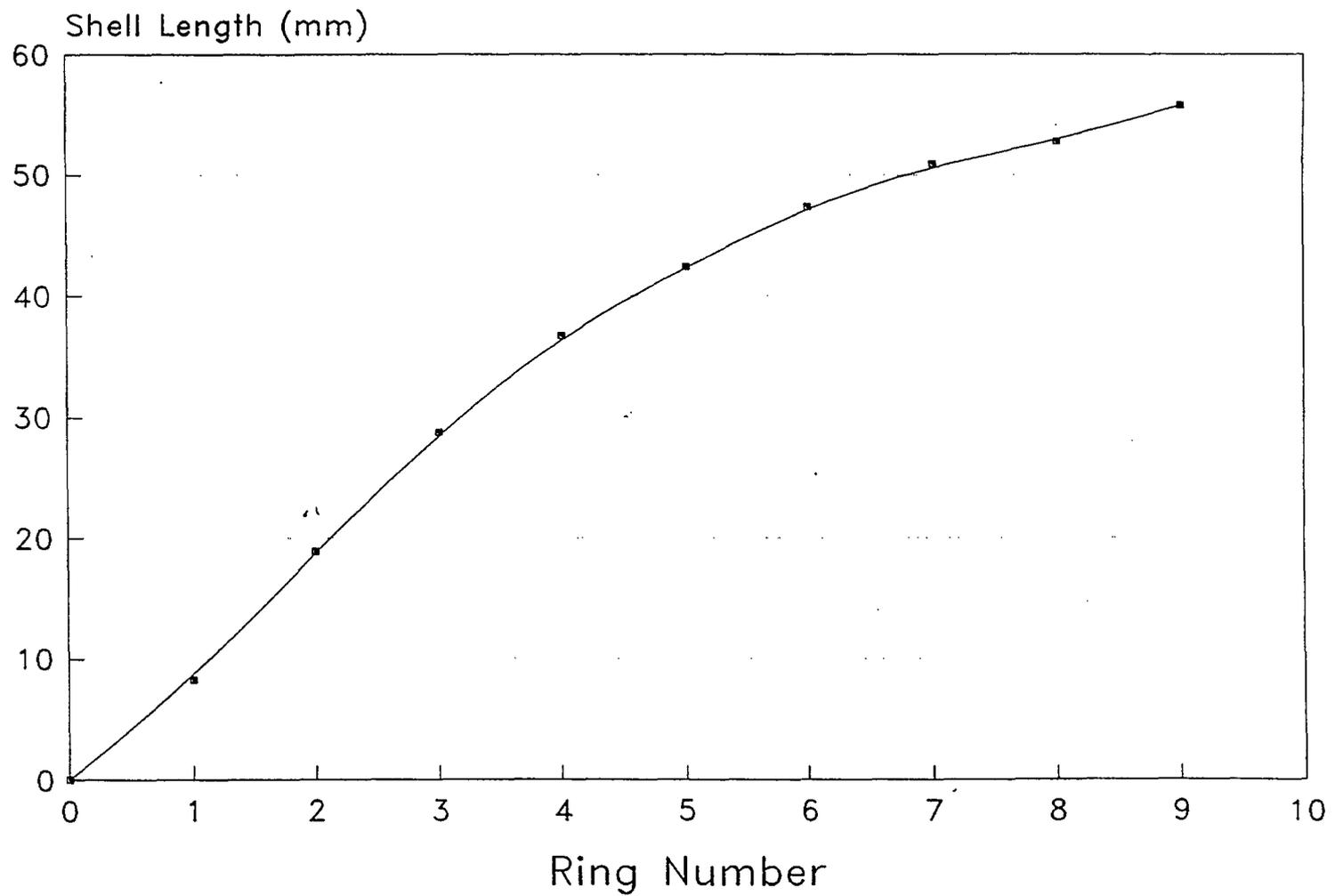


Fig. 2

KITKATLA HORSECLAMS

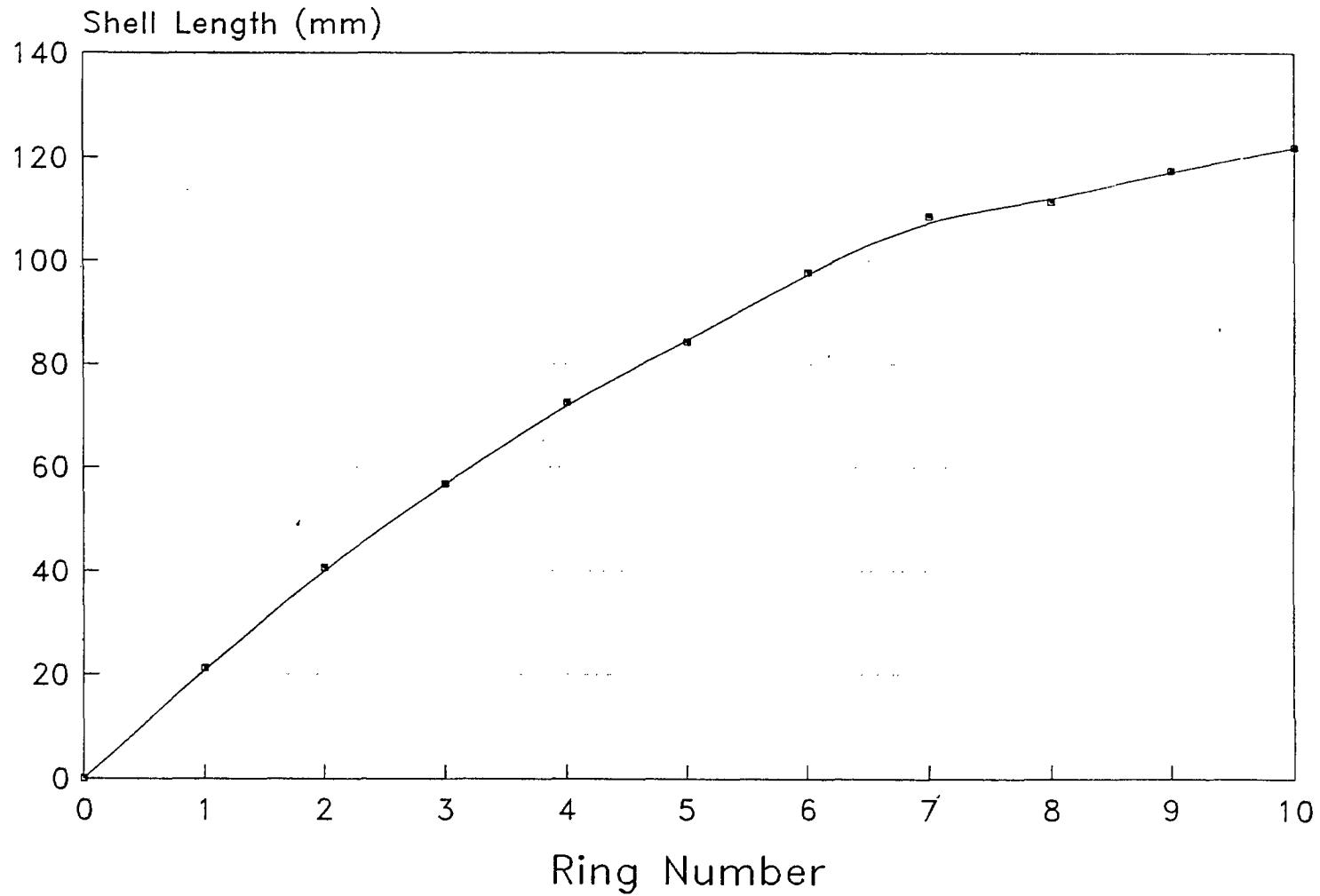


Fig. 3

CAMPANIA ISLANDS BUTTER CLAMS

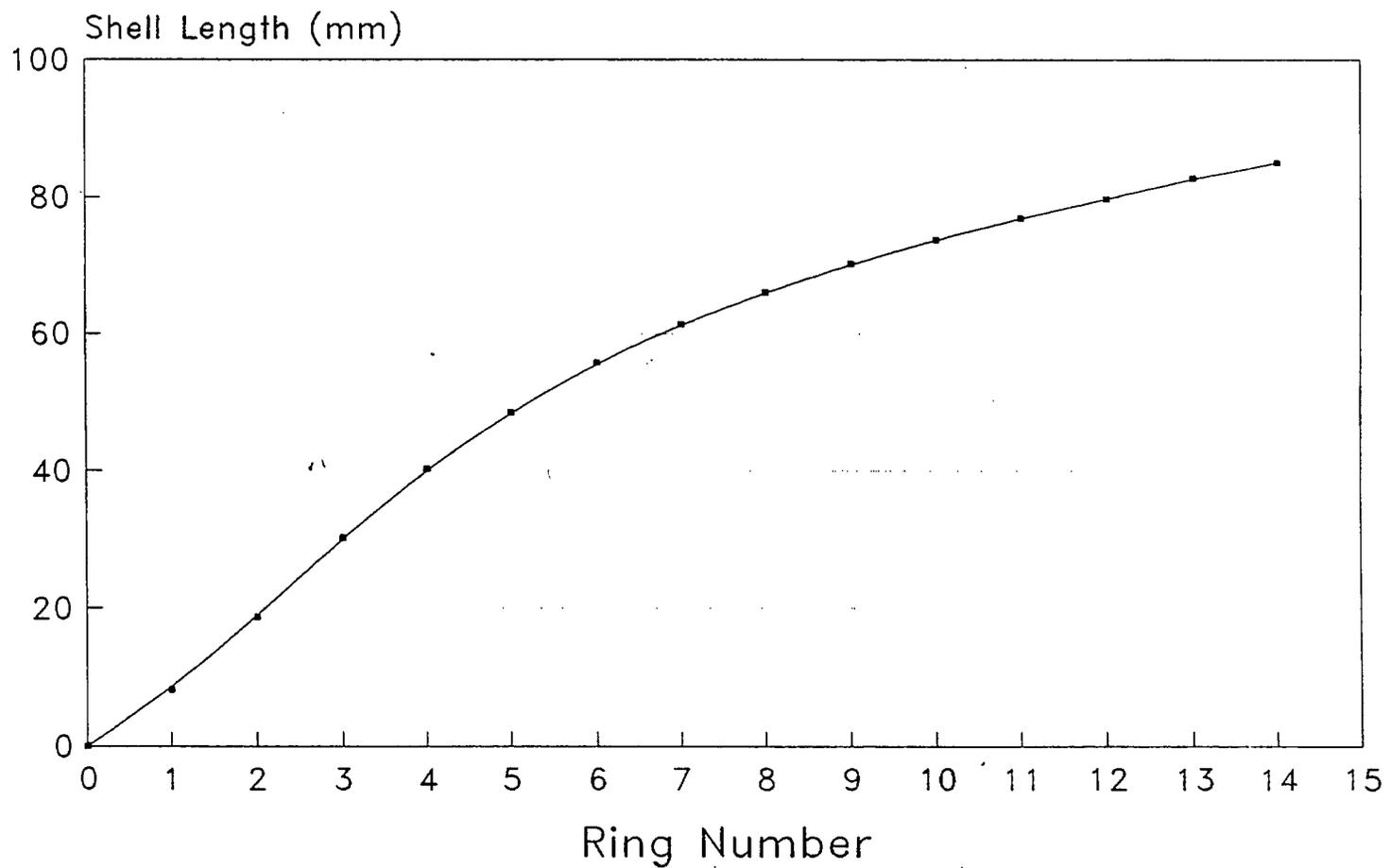


Fig. 4

CAMPANIA ISLANDS LITTLENECK CLAMS

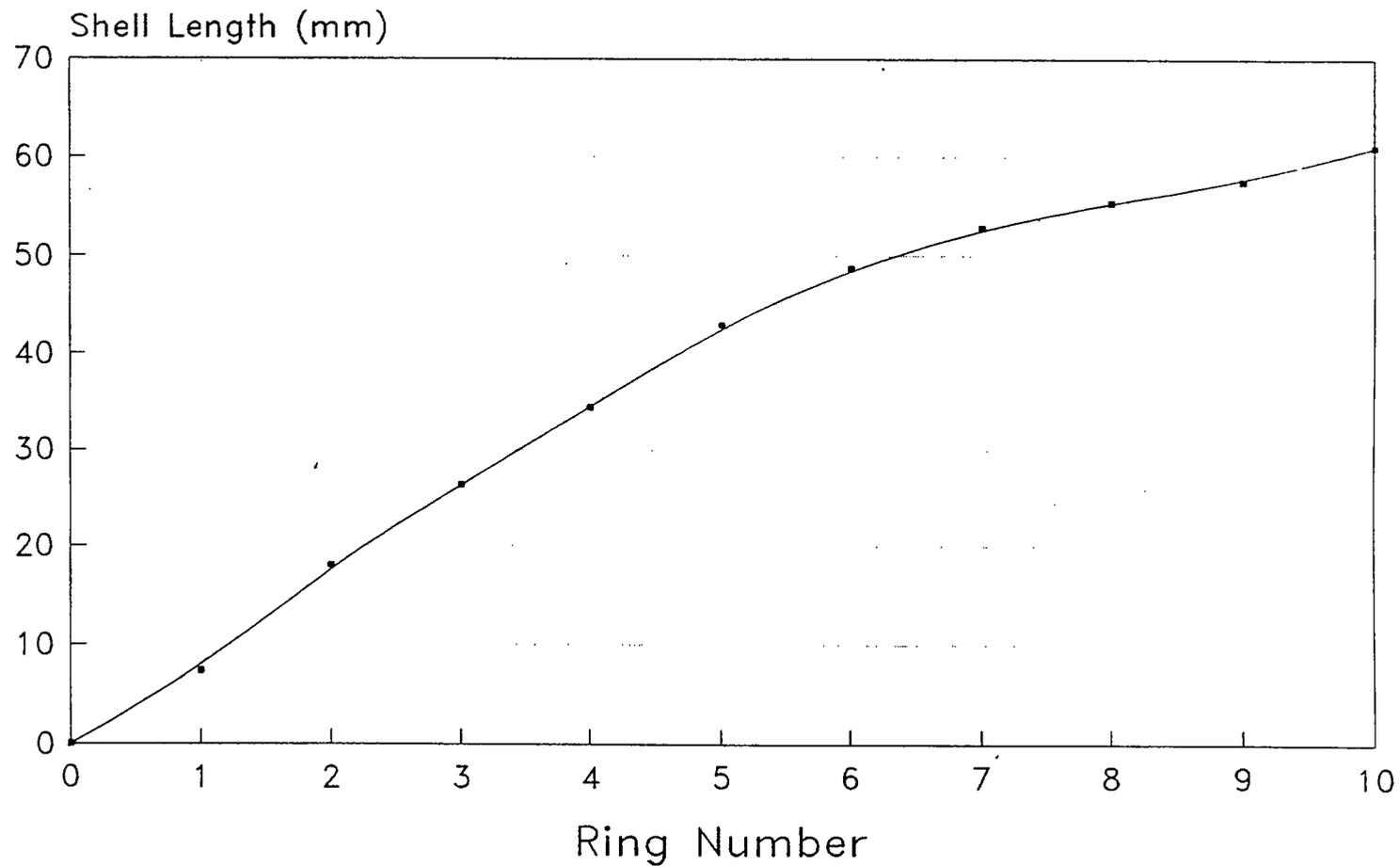


Fig. 5

KITASU BAY BUTTER CLAMS

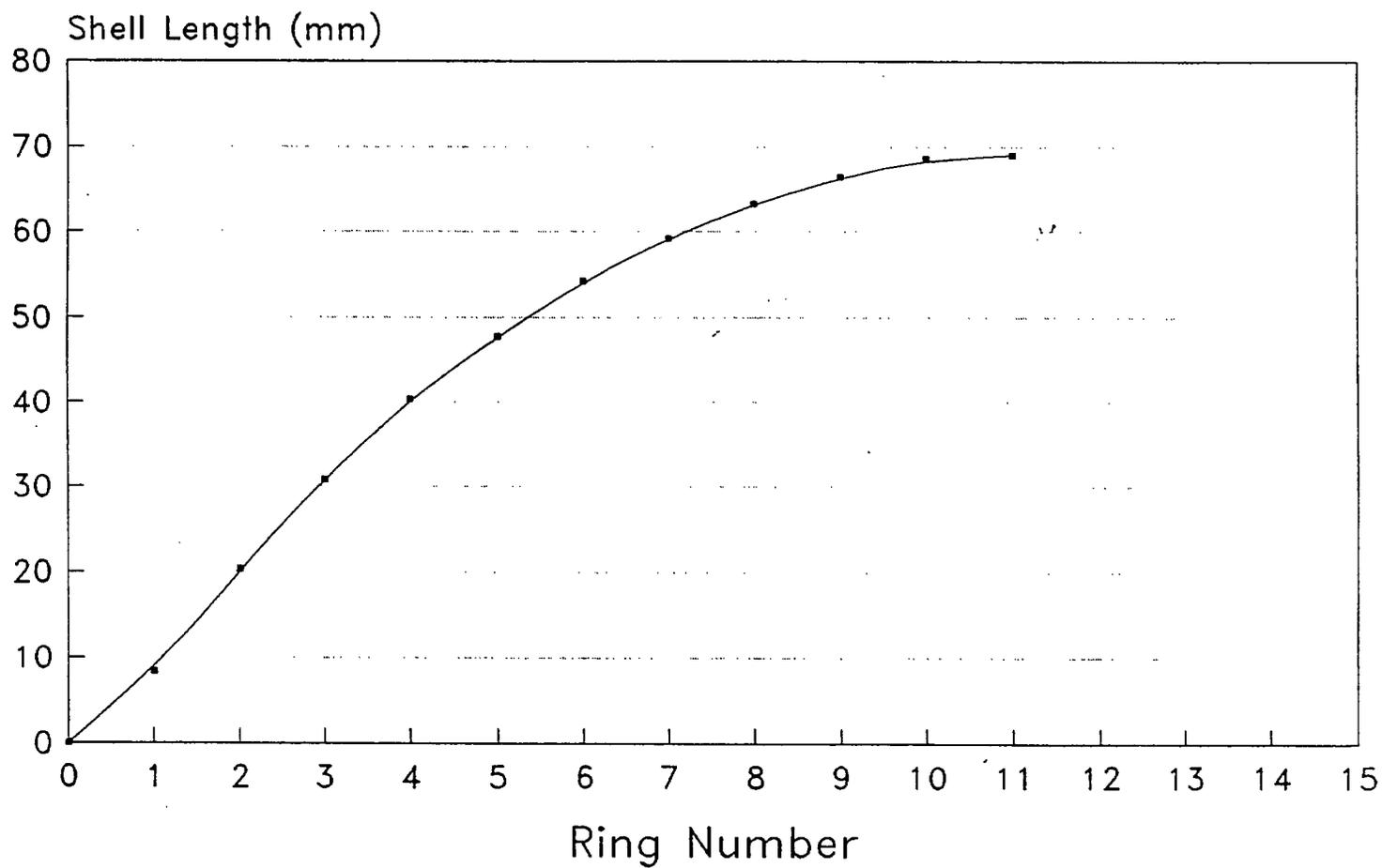


Fig. 6

KITASU BAY LITTLENECK CLAMS

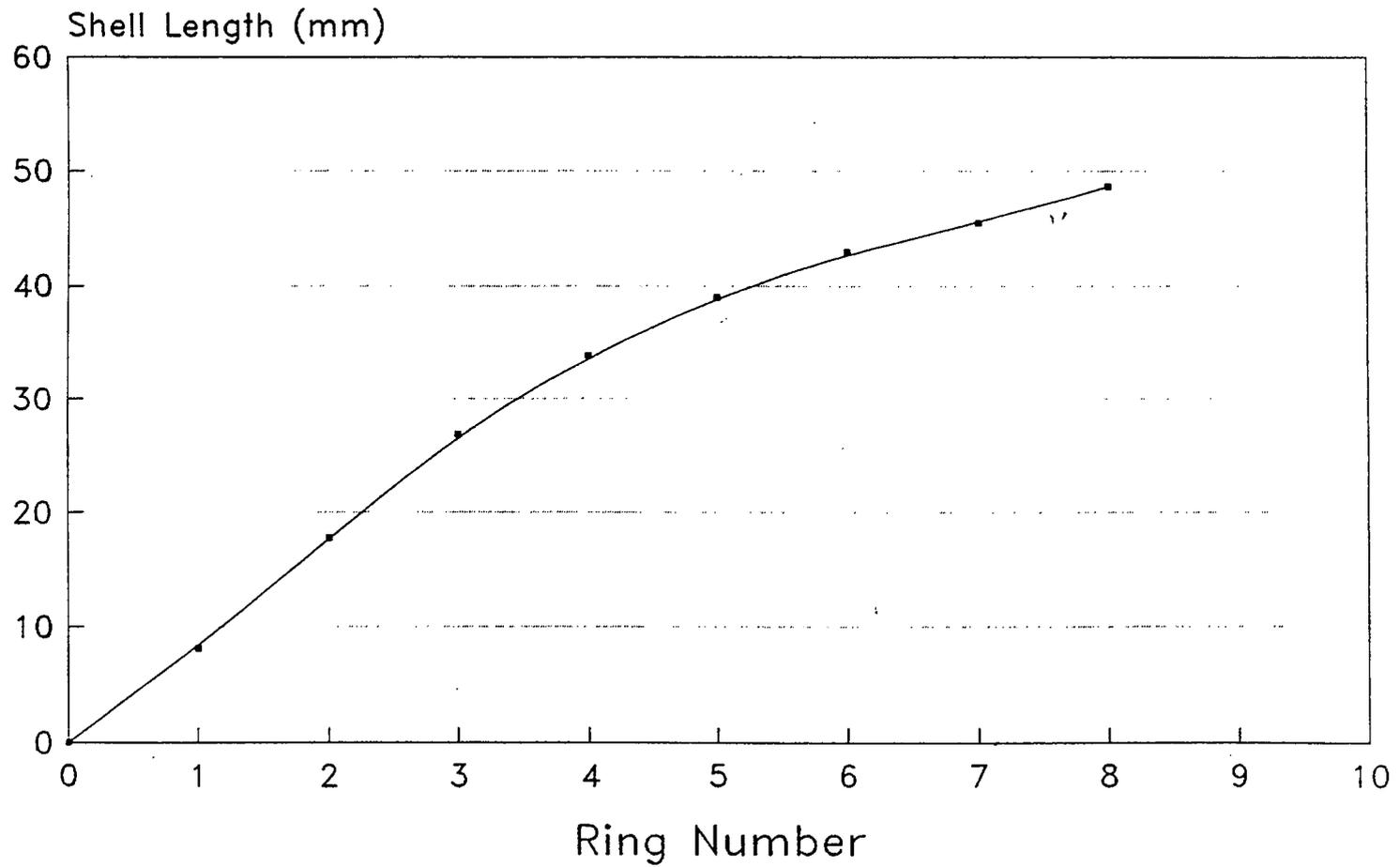


Fig. 7

RESCUE BAY BUTTER CLAMS

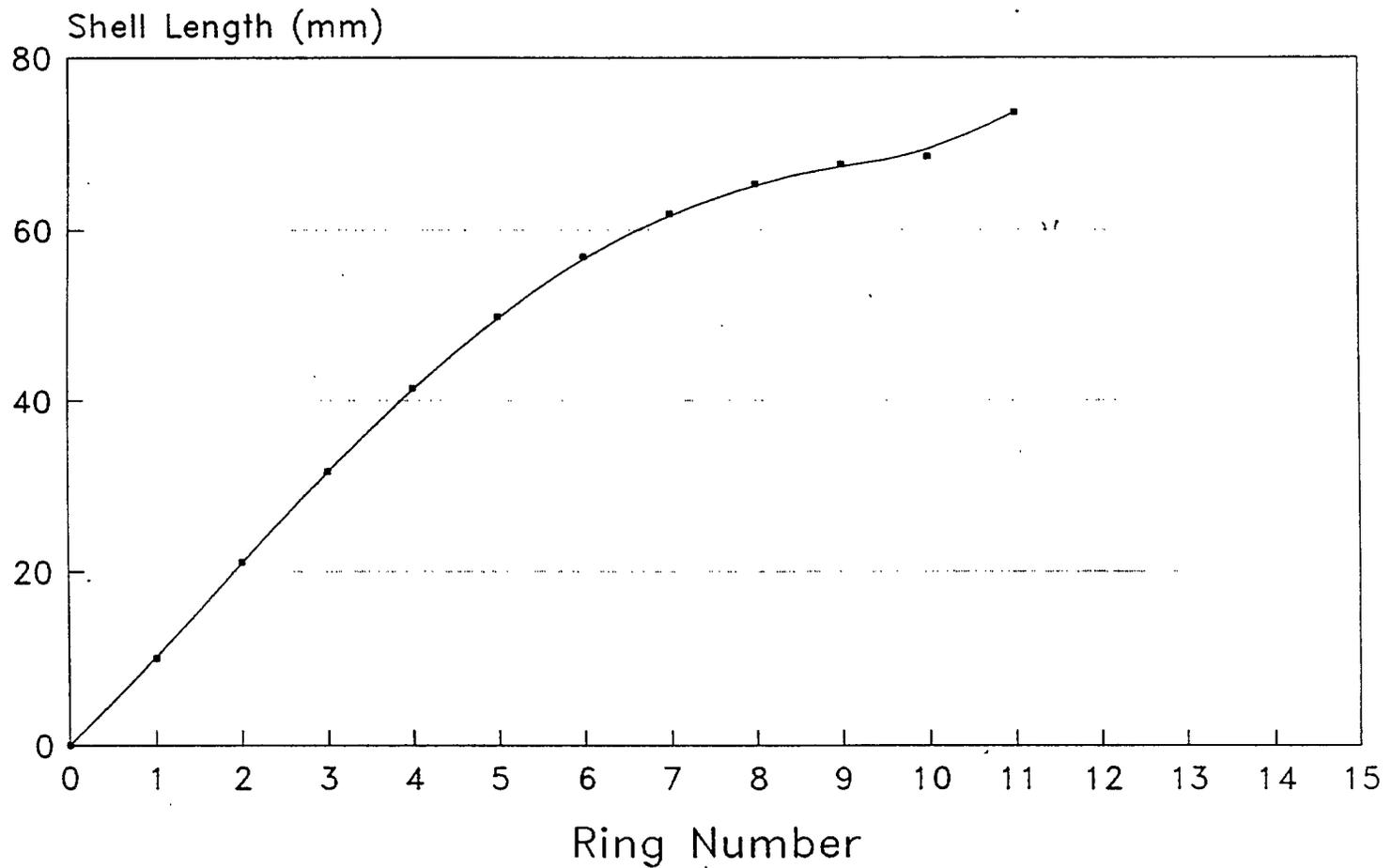


Fig. 8

RESCUE BAY LITTLENECK CLAMS

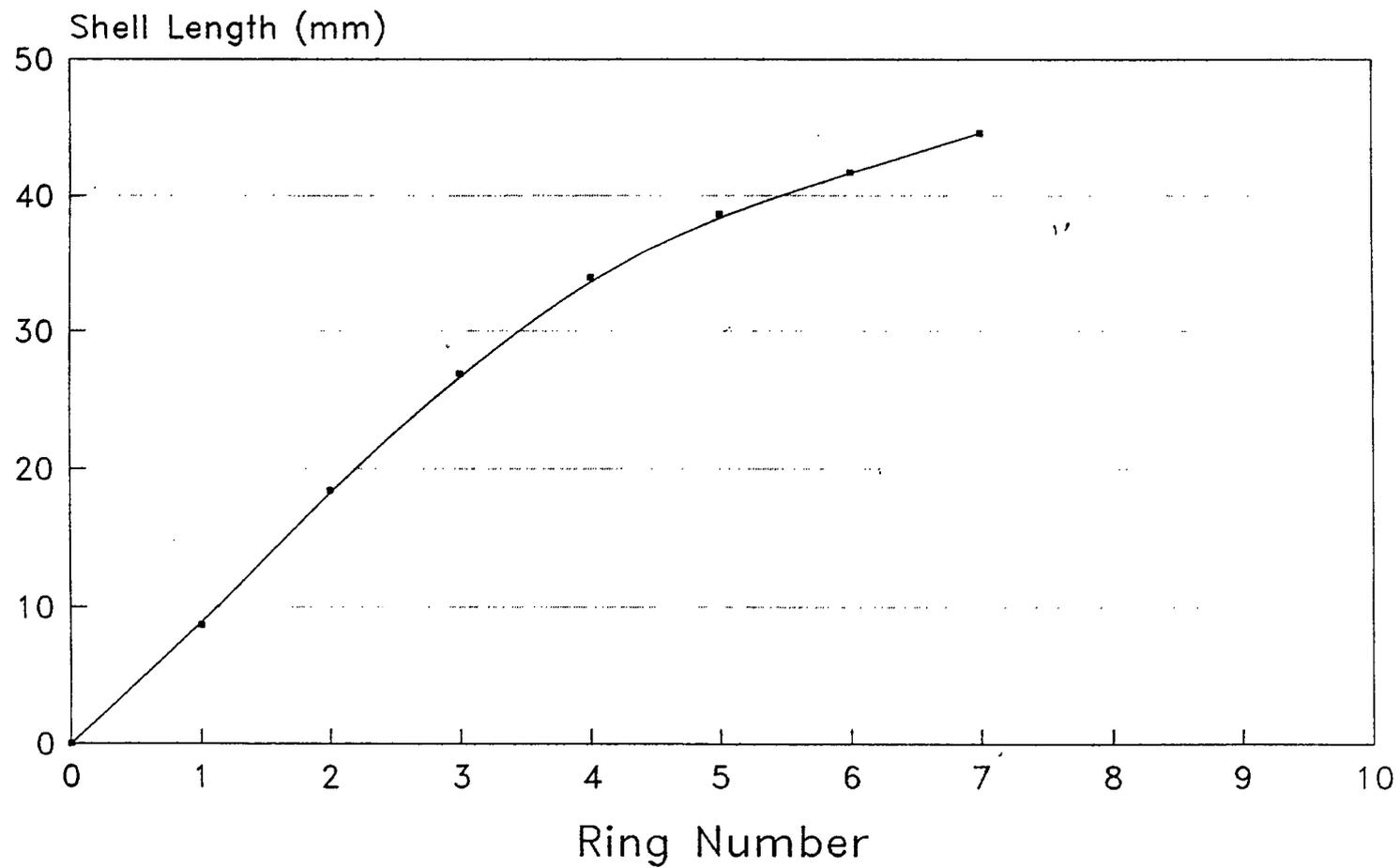


Fig. 9

RESCUE BAY MANILA CLAMS

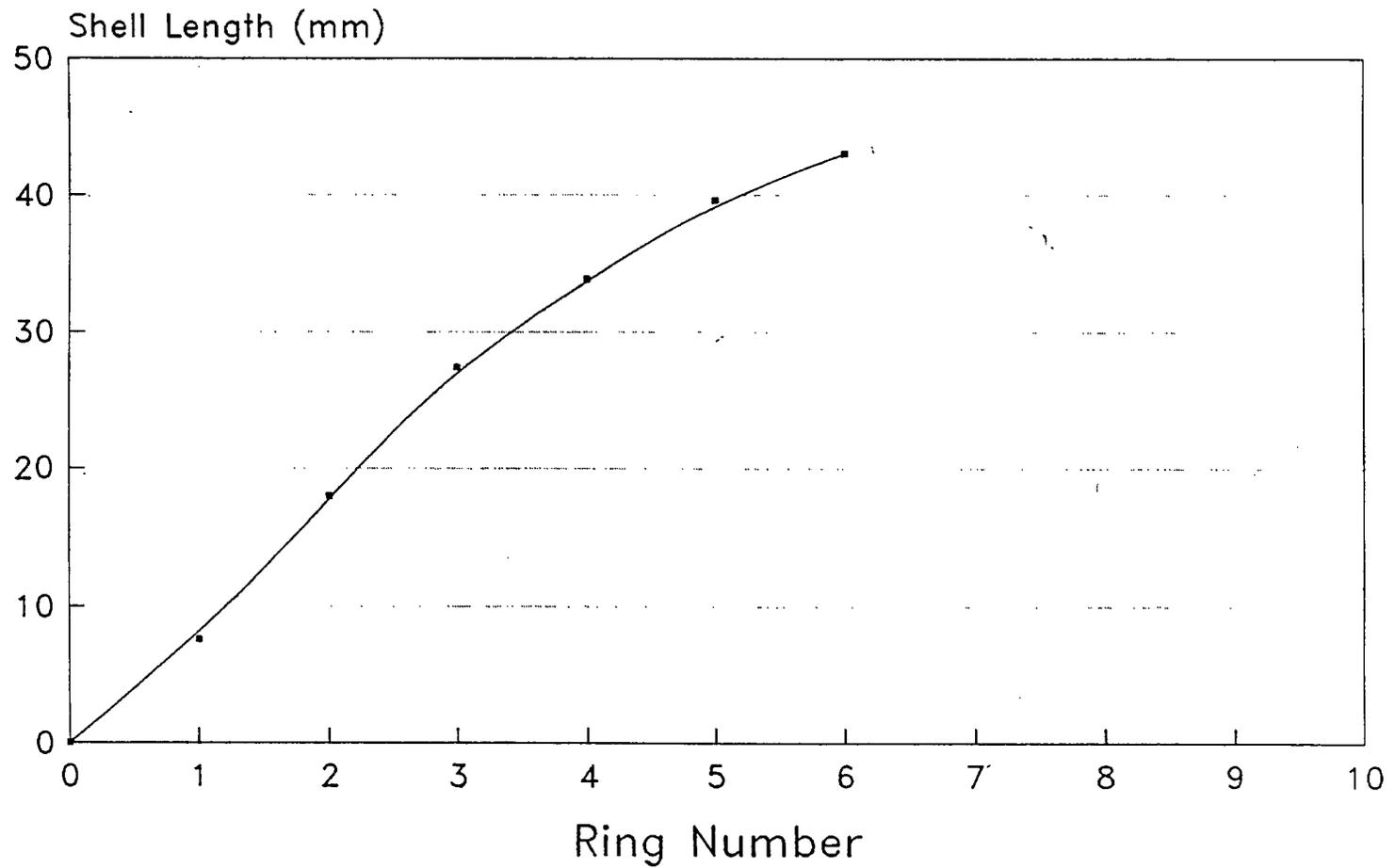


Fig. 10

SALMON BAY MANILA CLAMS

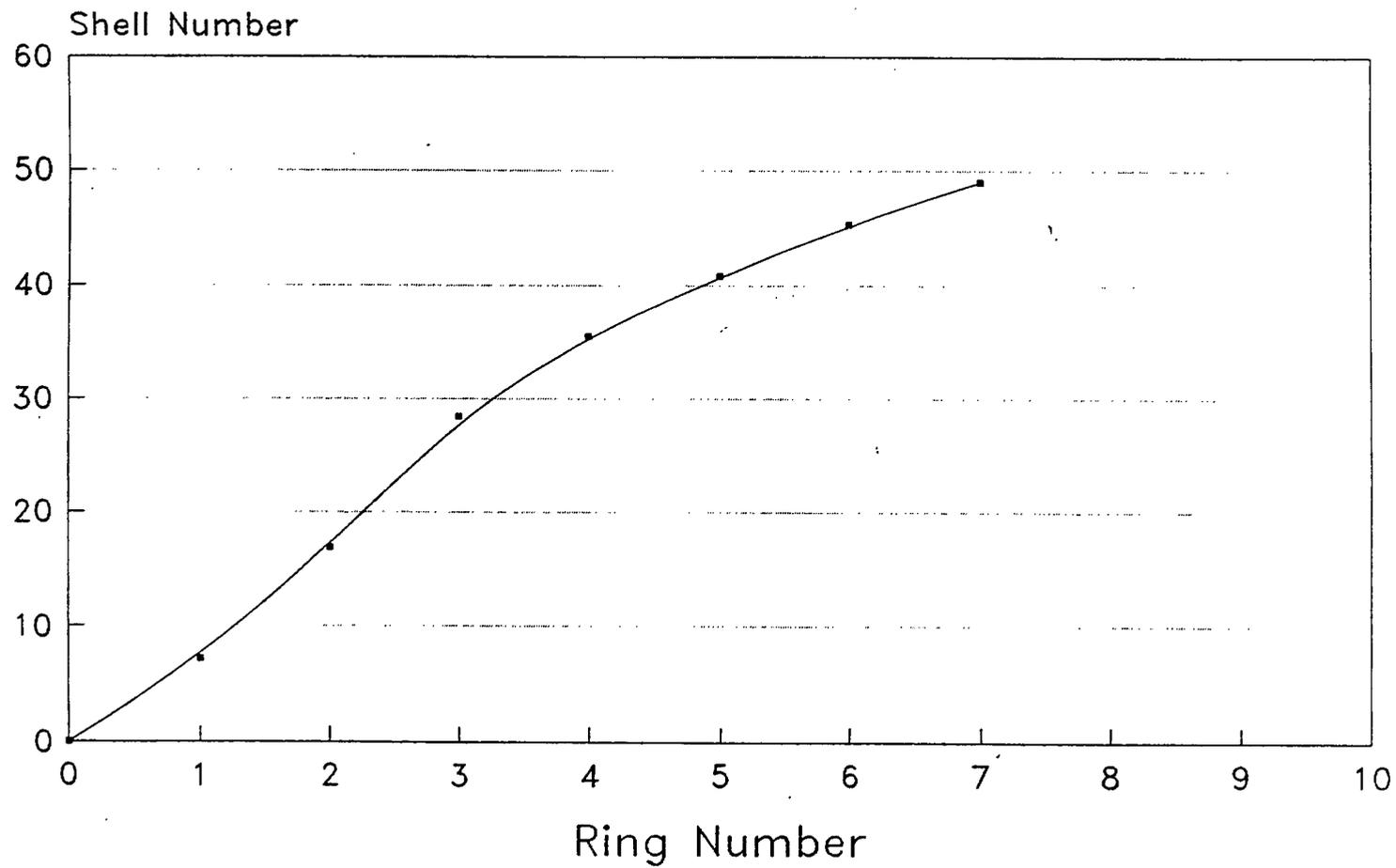


Fig. 11

ST. JOHN HARBOUR MANILA CLAMS

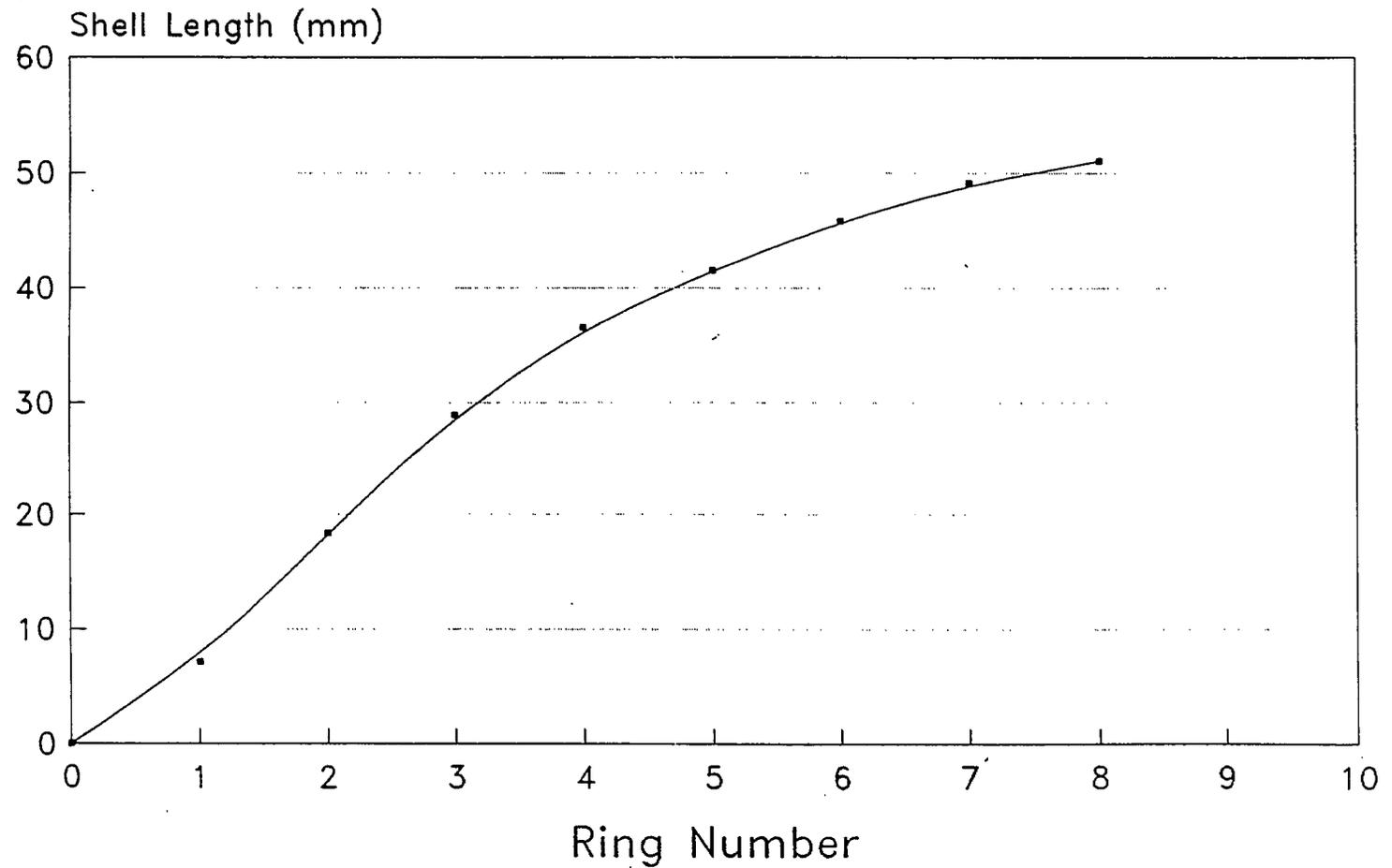


Fig. 12

DEARTH ISLAND MANILA CLAMS

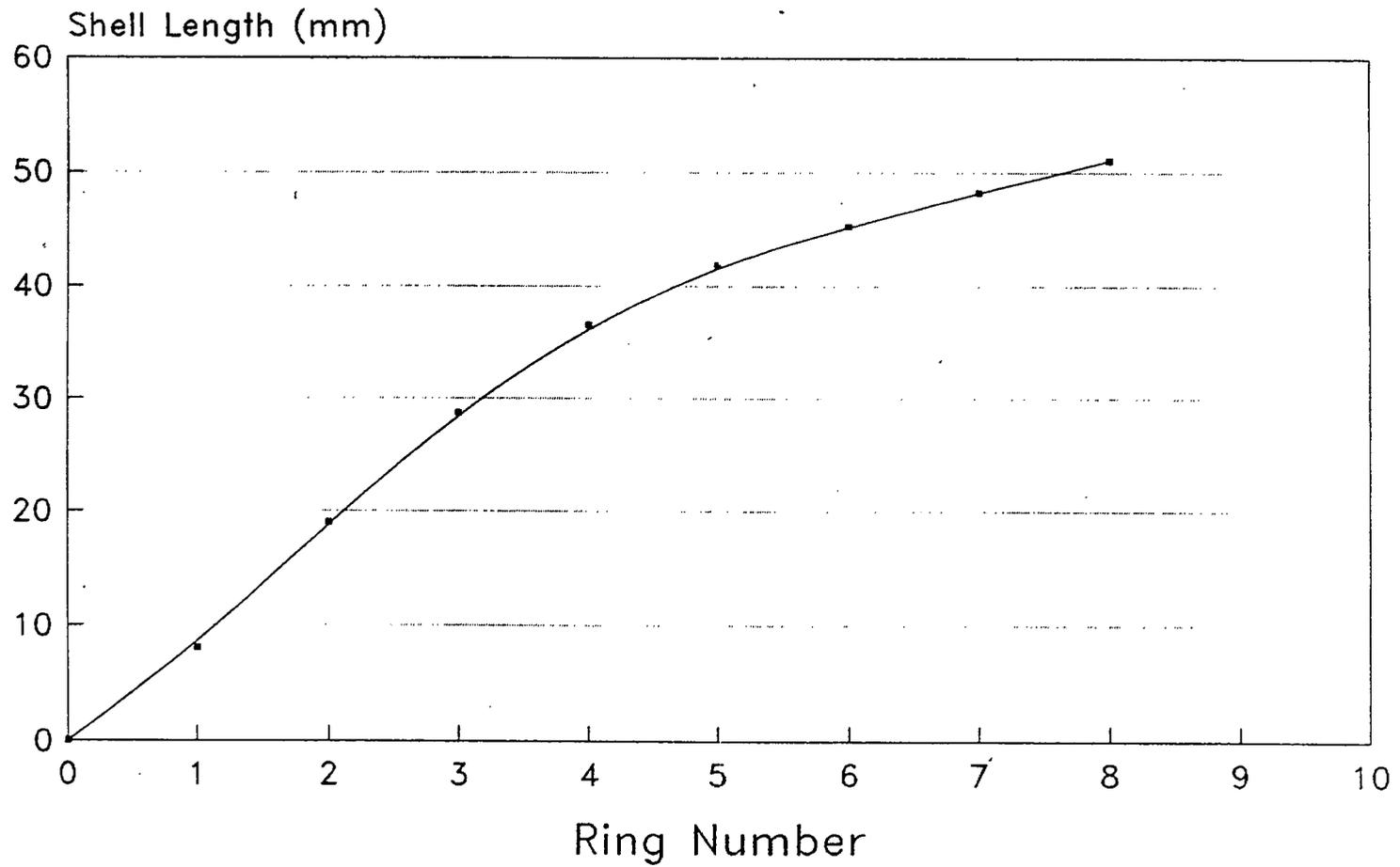


Fig. 13

JOASSA CHANNEL BUTTER CLAMS

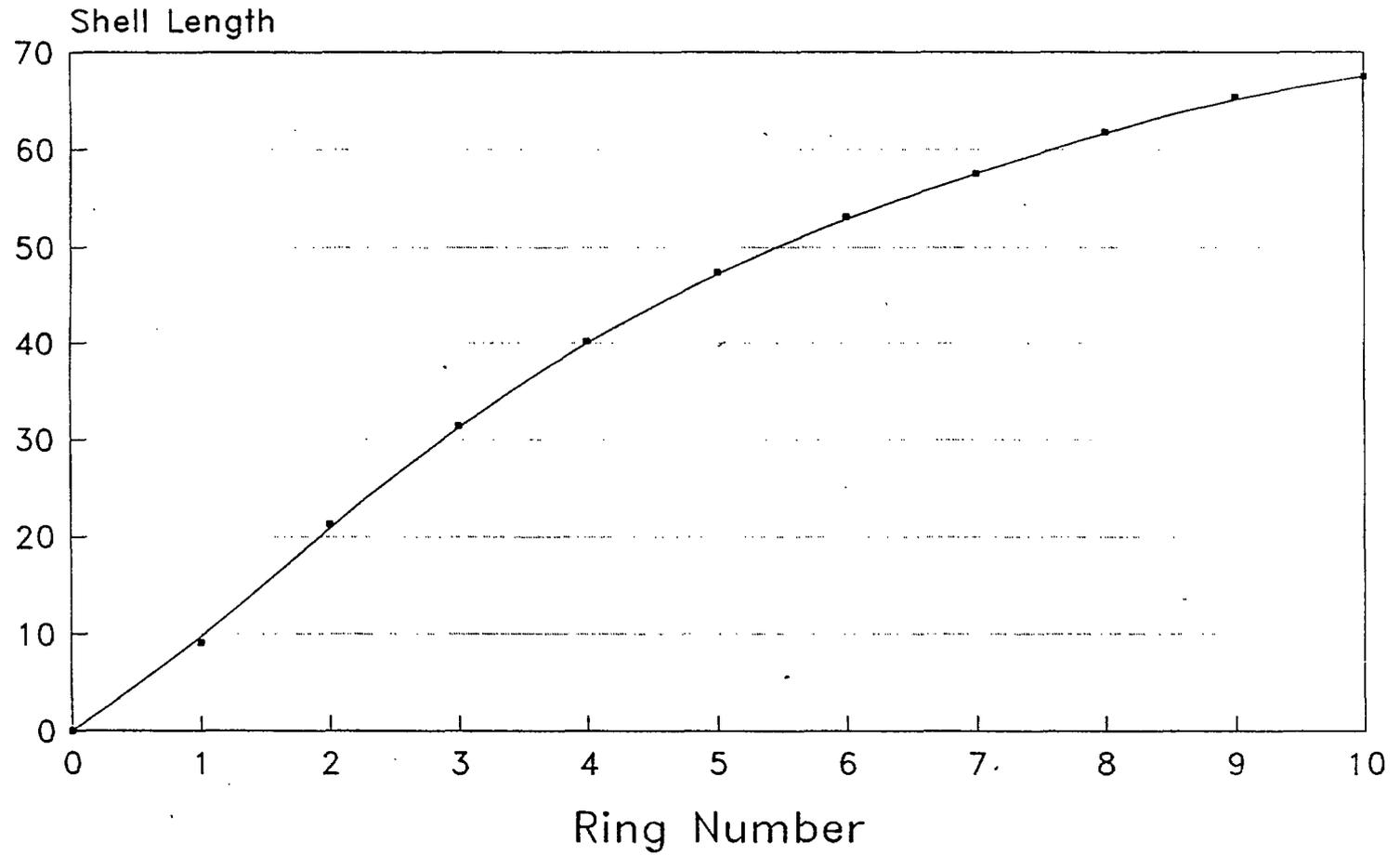


Fig. 14

JOASSA CHANNEL LITTLENECK CLAMS

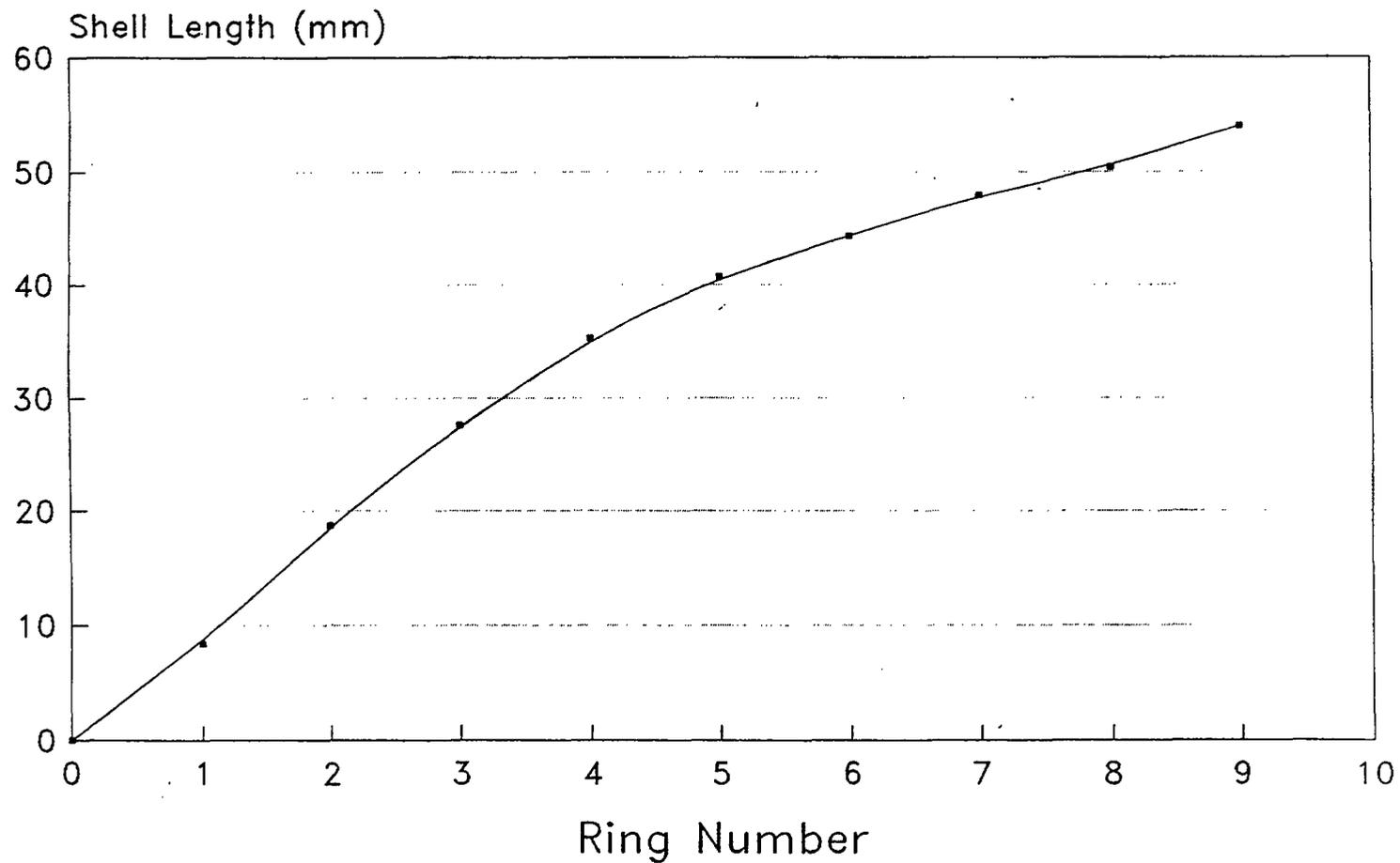


Fig. 15

JOASSA CHANNEL LITTLENECK CLAMS

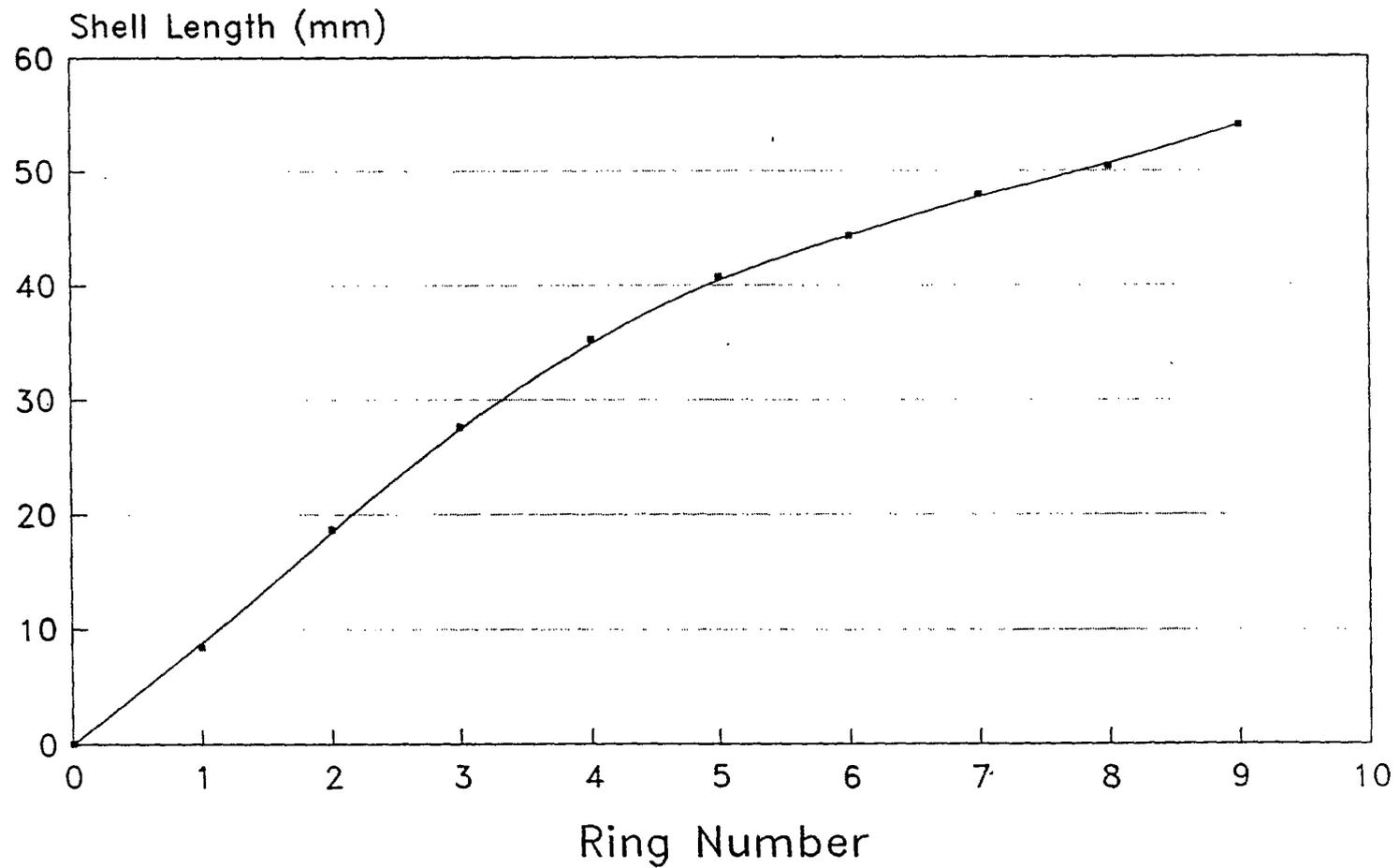


Fig. 15

JOASSA CHANNEL MANILA CLAMS

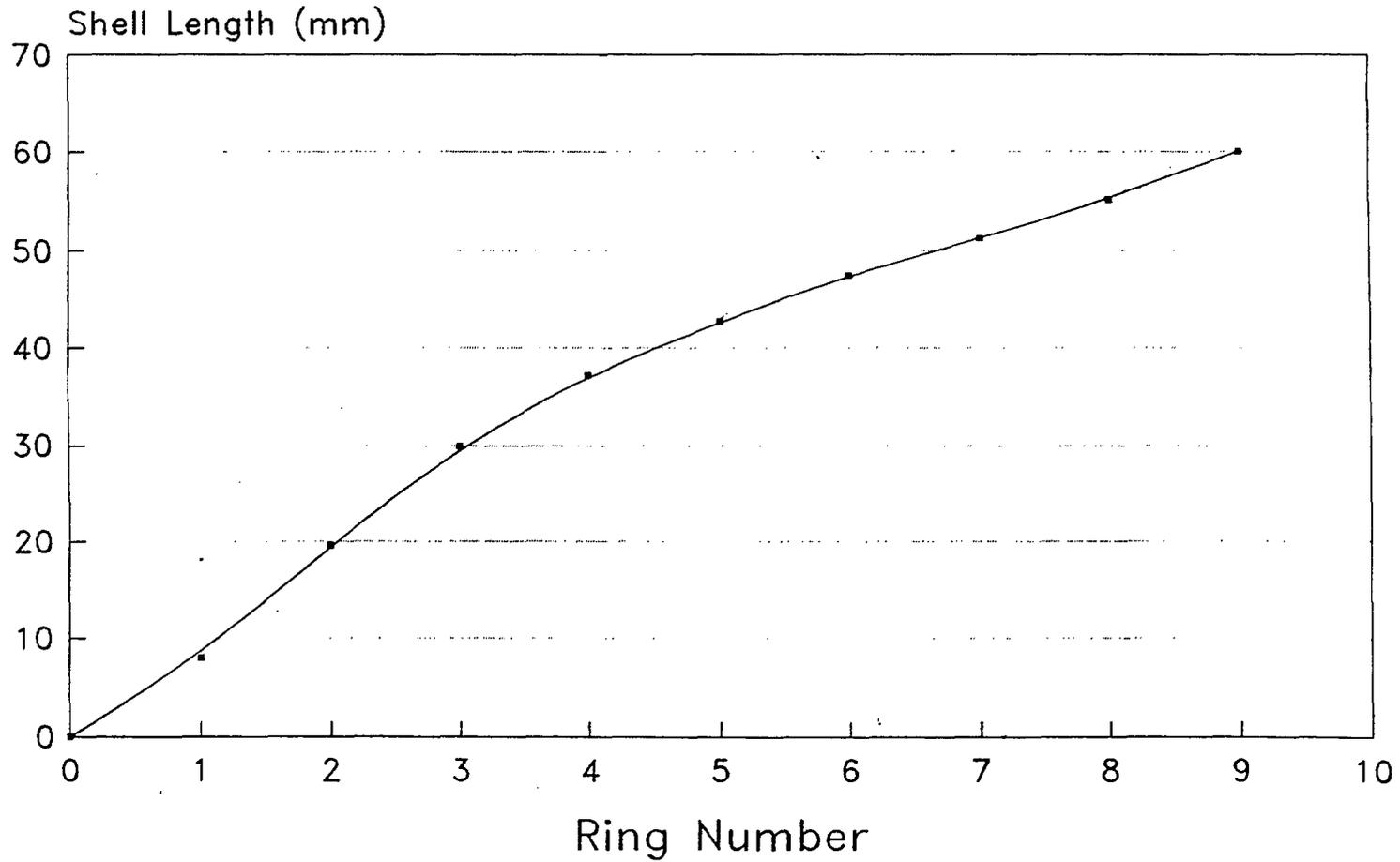


Fig. 16

FANNIE AND LIZZIE COVES BUTTER CLAMS

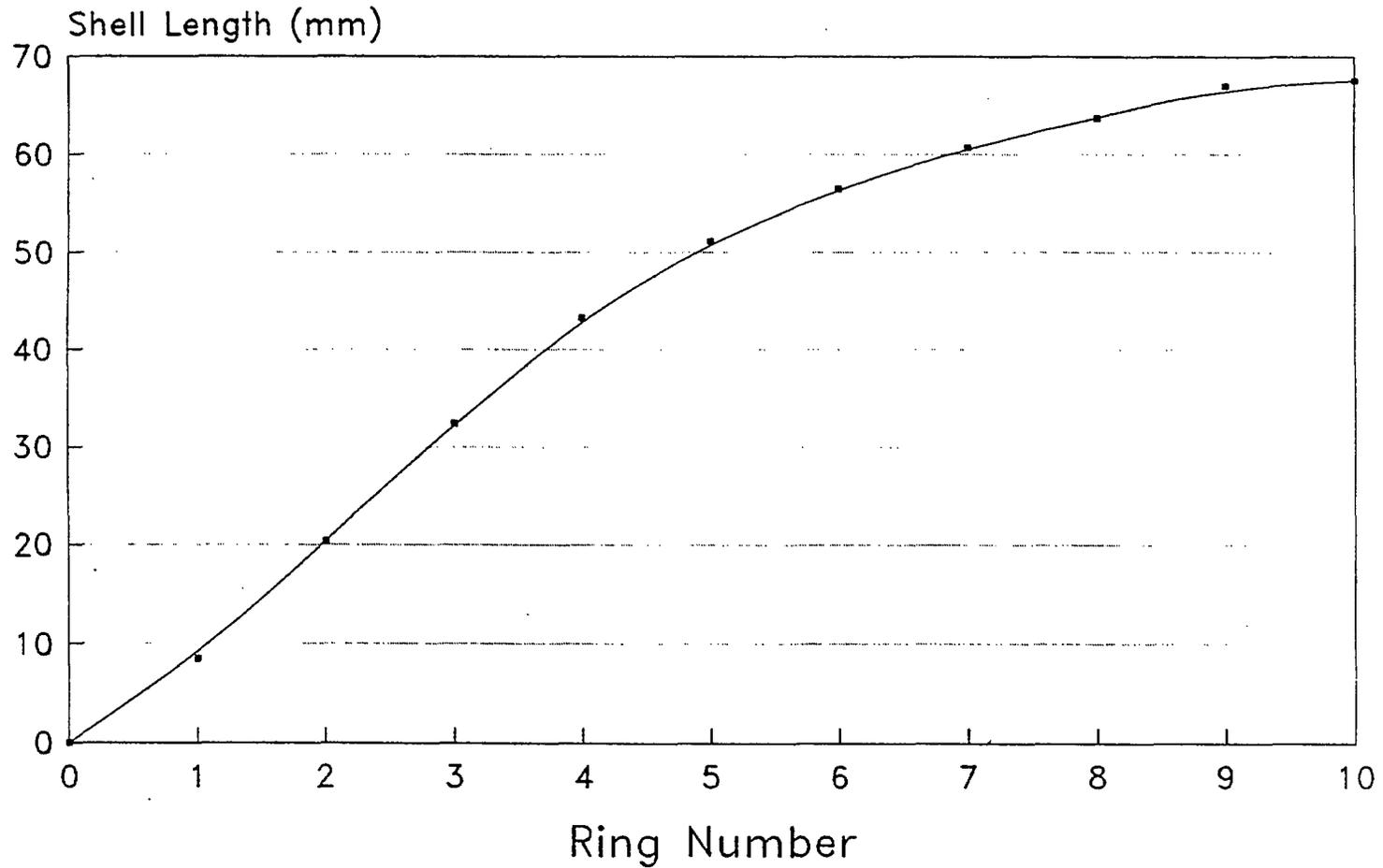


Fig. 17

FANNIE AND LIZZIE COVES LITTLENECK CLAMS

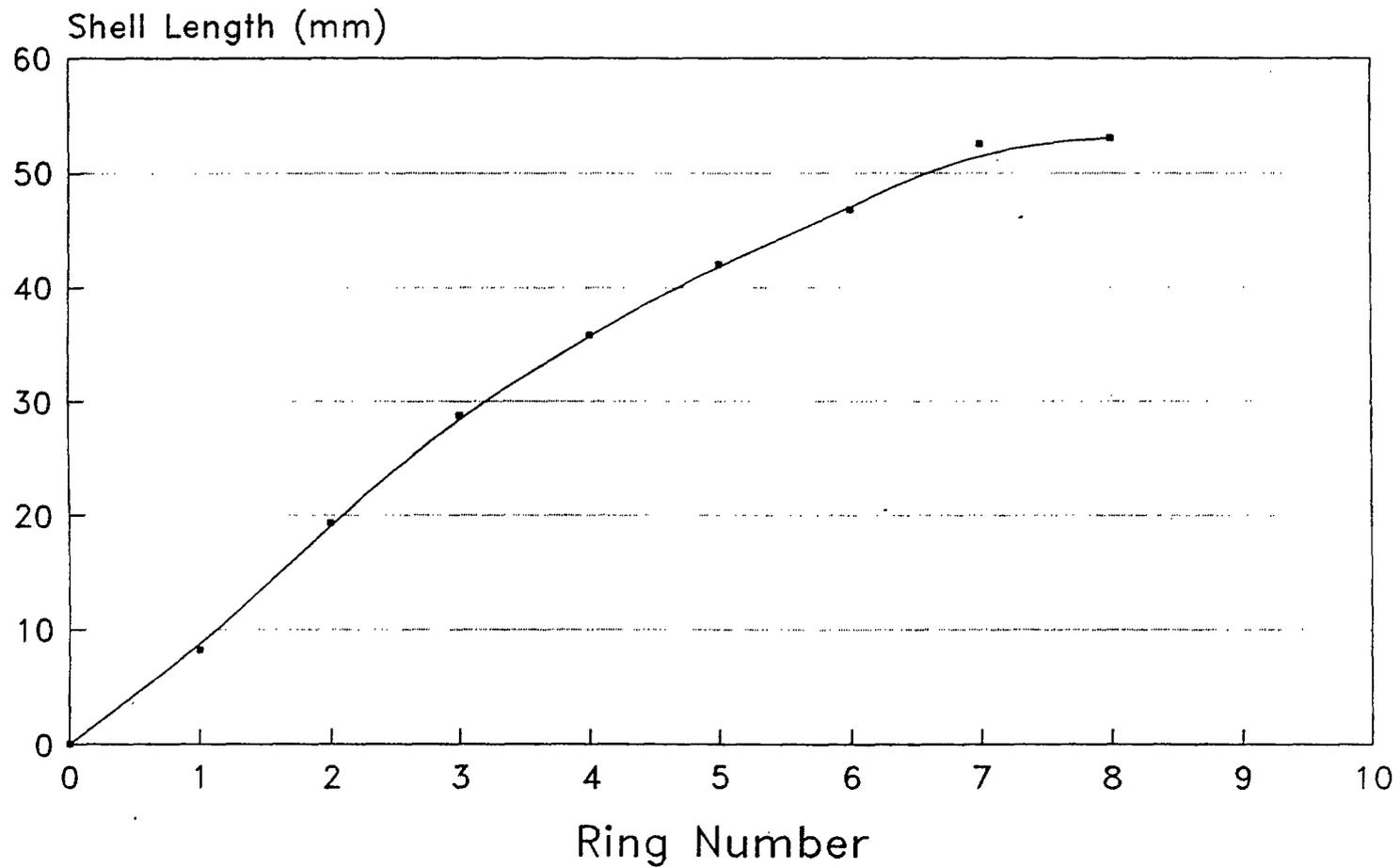


Fig. 18

FANNIE AND LIZZIE COVES MANILA CLAMS

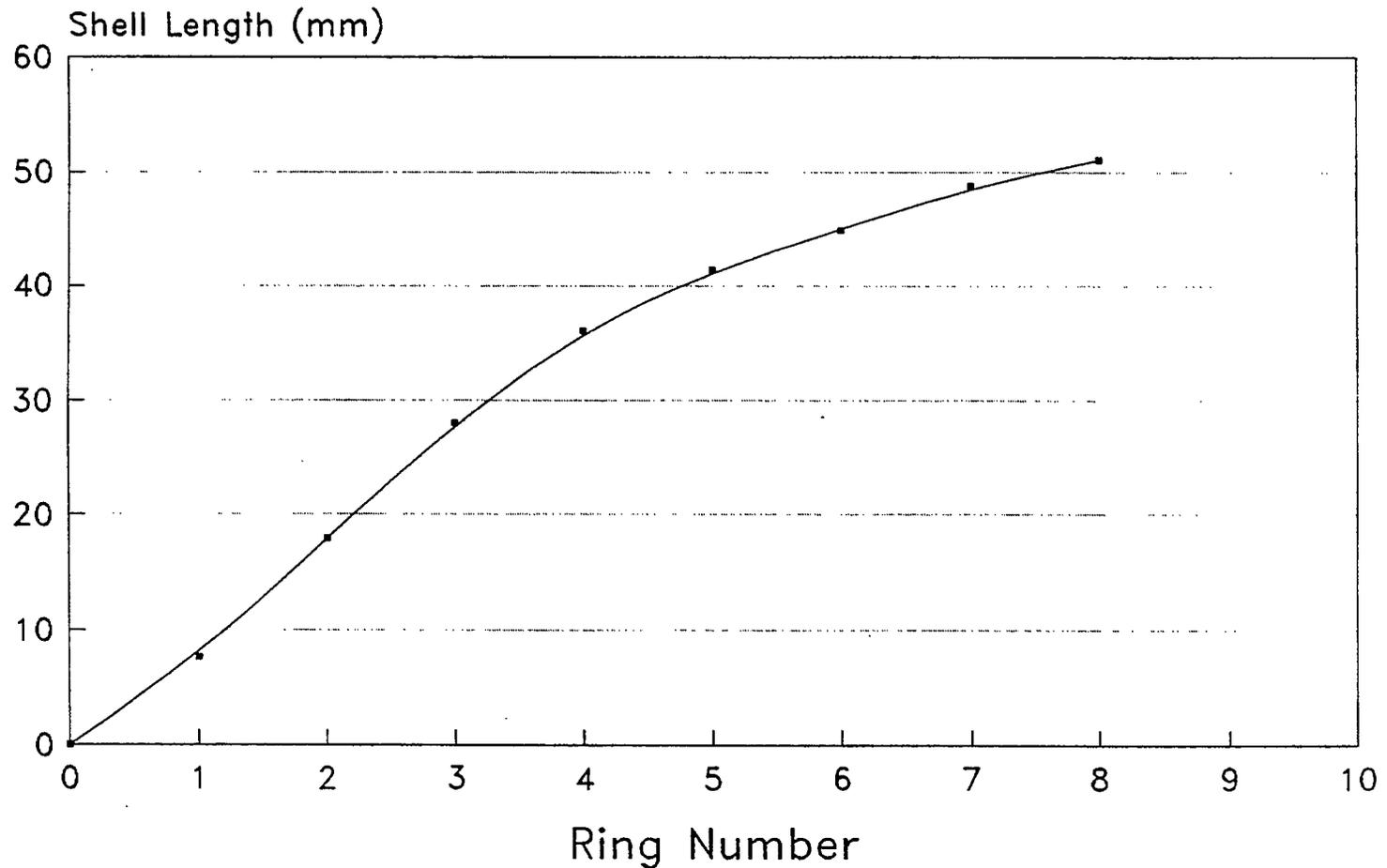


Fig. 19

SANS PEUR PASSAGE BUTTER CLAMS

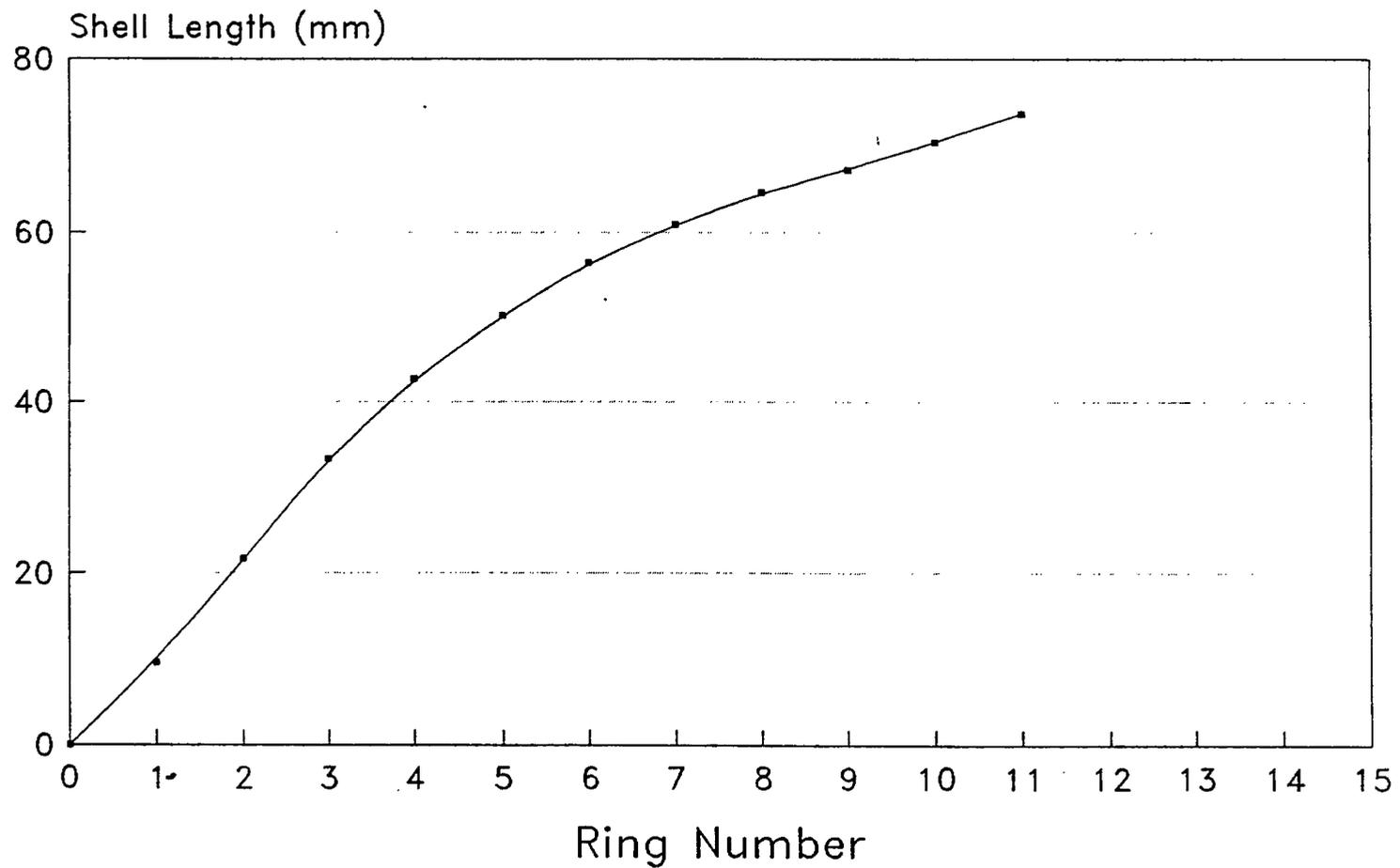


Fig. 20

SANS PEUR PASSAGE LITTLENECK CLAMS

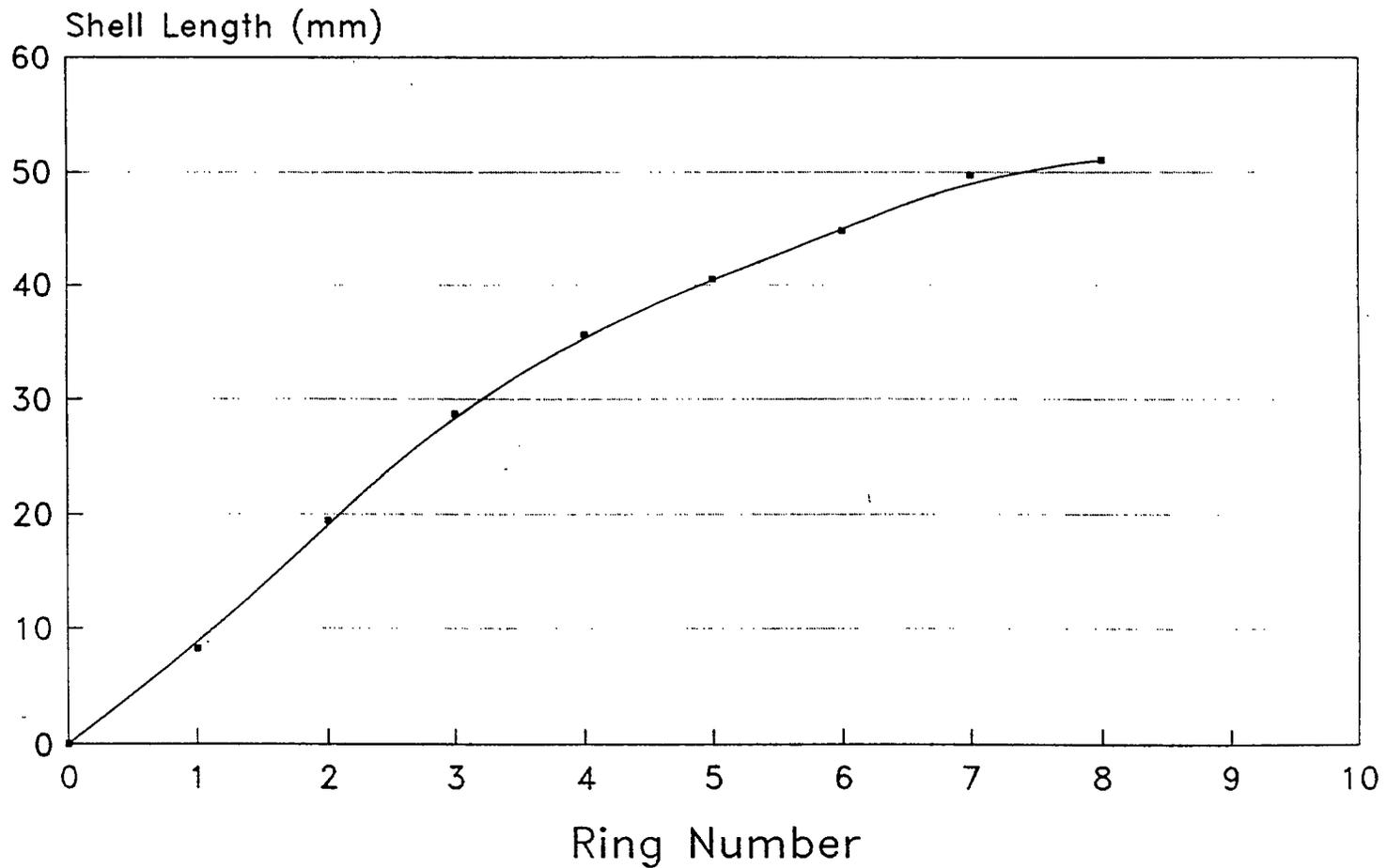


Fig. 21

SANS PEUR PASSAGE MANILA CLAMS

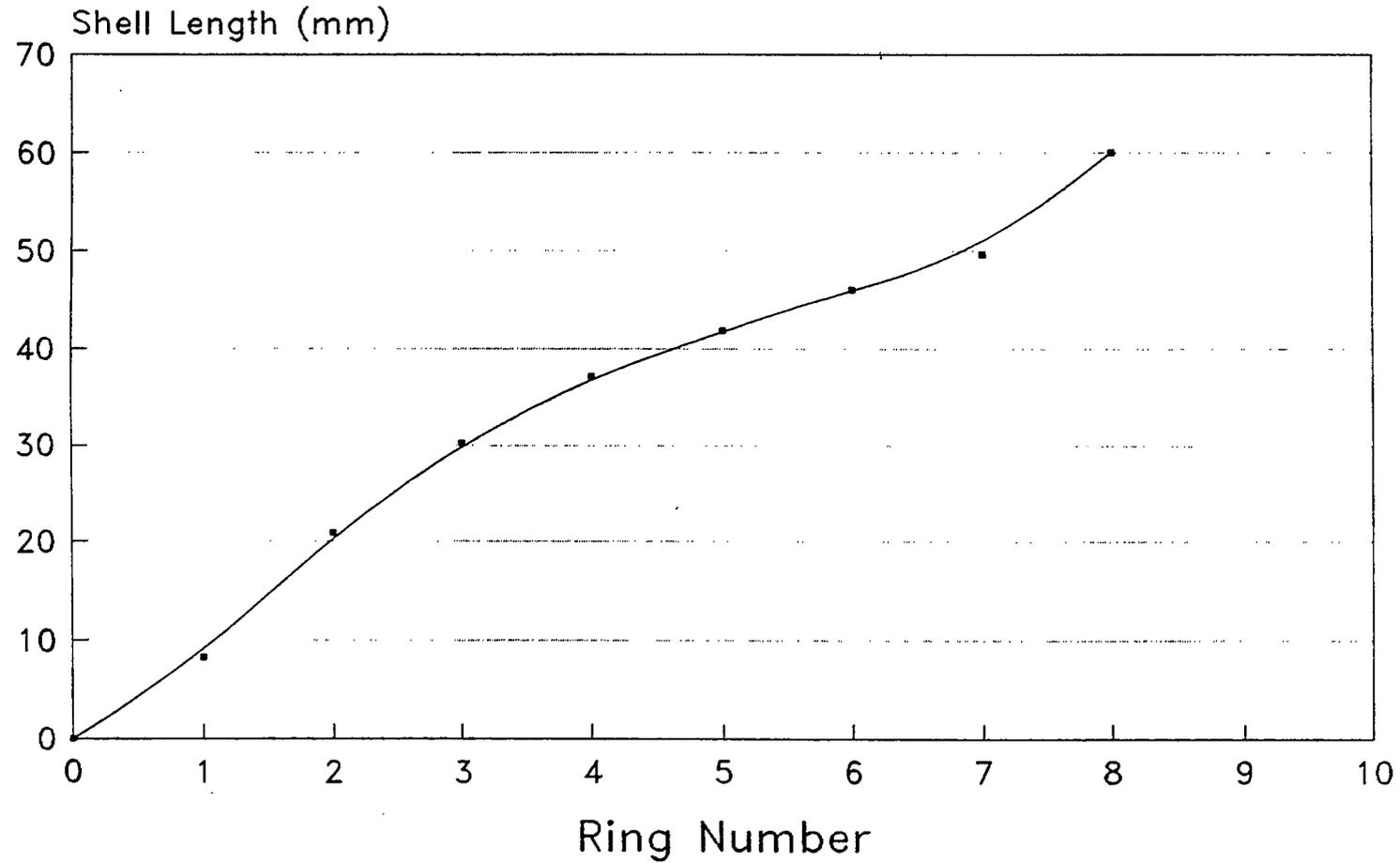


Fig. 22

RAYMOND PASSAGE MANILA CLAMS

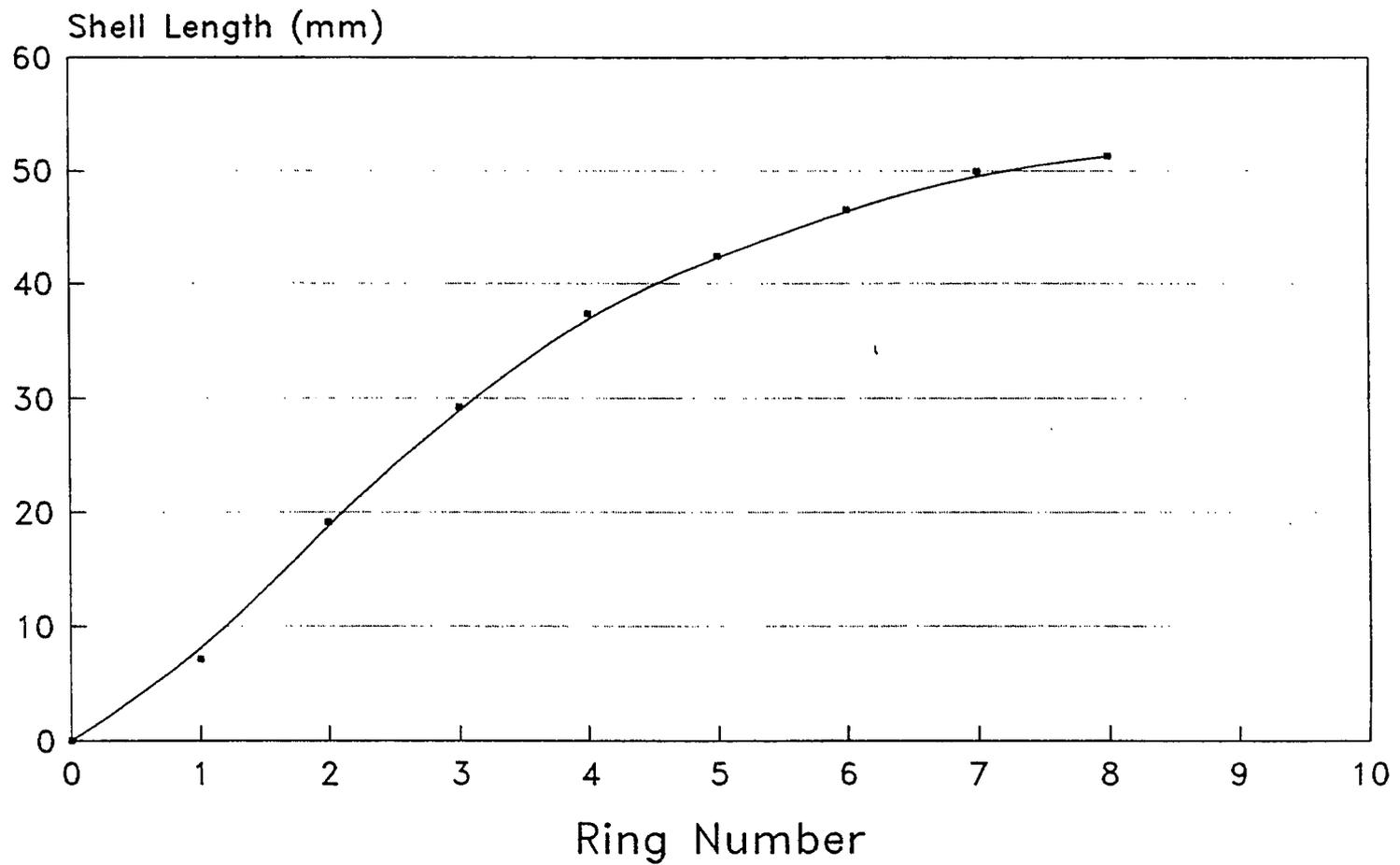


Fig. 23

TABLES

1. Areas surveyed during an intertidal clam survey, June 20-27, 1990.
2. Density by legal and sublegal sizes of butter, littleneck and manila clams in plots dug on beaches in the north coast district, June 20-27, 1990.
3. Density by legal and sublegal sizes of manila clams from plots dug on beaches in the north coast district, June 20-27, 1990.
4. Density of manila clams from random plots dug on beaches in the north coast district, June 20-27, 1990.

Table 1. Areas surveyed during intertidal clam survey - 1990

Beach Location	Statistical Area	Date
Wilcox Group-Kitkatla Inlet	5	June 20, 1990
Weinberg Inlet-Campania Islands	6	June 21, 1990
Kitasu Bay-Meyers Passage	6	June 22, 1990
Mathieson Channel-St. John Harbour	7	June 23, 1990
Dearth Island-Joassa Channel	7	June 24, 1990
Lama Passage-Hunter Channel	7	June 25, 1990
Seaforth Channel-Raymond Passage	7	June 26, 1990
Gunboat Passage	7	June 27, 1990

DENSITIES PER SQUARE METRE

<u>SITE</u>	<u>BUTTERCLAMS</u>		<u>LITTLENECKS</u>		<u>MANILAS</u>	
	LEGAL	SUBLEGAL	LEGAL	SUBLEGAL	LEGAL	SUBLEGAL
KITKATLA						
plot 1	30	15	16	—	—	—
plot 2	7	3	20	—	—	—
plot 3	45	7	3	6	—	—
plot 4	15	15	17	19	—	—
plot 5	60	4	156	116	—	—
plot 6	4	76	92	296	—	—
KITASU BAY						
plot 1	168	42	24	12	—	—
plot 2	—	9	47	45	1	—

Table 2

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DENSITIES PER SQUARE METRE

<u>SITE</u>	<u>BUTTERCLAMS</u>		<u>LITTLENECKS</u>		<u>MANILAS</u>	
	LEGAL	SUBLEGAL	LEGAL	SUBLEGAL	LEGAL	SUBLEGAL
CAMPANIA ISLANDS						
plot 1	36	7	11	1	—	—
plot 2	2	1	—	—	—	—
plot 3	14	2	—	2	—	—
plot 4	37	30	4	5	—	—
plot 5	46	30	10	2	—	—
plot 6	21	7	10	15	—	—
RESCUE BAY						
plot 1	—	16	68	436	4	16
plot 2	36	2	118	73	5	3

Table 2 cont.

DENSITIES PER SQUARE METRE

<u>SITE</u>	<u>BUTTERCLAMS</u>		<u>LITTLENECKS</u>		<u>MANILAS</u>	
	LEGAL	SUBLEGAL	LEGAL	SUBLEGAL	LEGAL	SUBLEGAL
JOASSA CHANNEL						
plot 1	48	48	120	4	-	-
plot 2	76	52	76	52	-	-
plot 3	136	292	88	24	-	-
plot 4	132	272	220	100	-	-
DEARTH ISLAND						
plot 1	52	68	10	2	46	-
plot 2	12	16	12	-	-	2

Table 2 cont.

DENSITIES PER SQUARE METRE

HUNTER PASSAGE

<u>SITE</u>	<u>BUTTERCLAMS</u>		<u>LITTLENECKS</u>		<u>MANILAS</u>	
	LEGAL	SUBLEGAL	LEGAL	SUBLEGAL	LEGAL	SUBLEGAL
LIZZIE COVE						
plot 1	4	36	—	24	—	—
plot 2	60	4	12	—	—	—
plot 3	40	36	8	32	—	—
plot 4	32	48	12	12	—	—
FANNIE COVE						
plot 1	44	28	4	4	—	—
plot 2	8	28	12	12	—	—
SANS PEUR PASSAGE						
plot 1	4	4	40	12	—	—
plot 2	204	24	48	8	—	—
plot 3	40	44	224	88	—	—

Table 2 cont.

DENSITIES PER SQUARE METRE

SEAFORTH CHANNEL

<u>SITE</u>	<u>BUTTERCLAMS</u>		<u>LITTLENECKS</u>		<u>MANILAS</u>	
	LEGAL	SUBLEGAL	LEGAL	SUBLEGAL	LEGAL	SUBLEGAL
NORMAN MORRISON BAY						
plot 1	—	32	16	112	100	—
plot 2	12	40	12	84	44	24
NORMAN MORRISON PASSAGE						
plot 1	20	24	20	4	—	—
plot 2	—	68	28	—	—	—
ORMIDALE HARBOUR						
plot 1	4	84	4	128	372	20
plot 2	—	60	20	96	36	—

Table 2 cont.

Table 3. MANILA CLAMS PER SQUARE METER

<u>Location</u>		<u>Legal</u>	<u>Sublegal</u>
Salmon Bay		22	36
St. John Harbour		64	6
Joassa Channel	Site 1	92	10
	Site 2	131	6
	Site 3	47	10
Hunter Channel	Site 1	14	3
	Site 2	32	3
	Sites 4-6	38	5
Seaforth Channel			
Norman Morrison Bay			
	Site 1	56	168
	Site 3	102	58
	Site 4	170	34
Ardmillan Bay		120	119

Table 4. MANILA CLAM POPULATIONS

		<u>Plots</u>	<u>Area*</u>	<u>Number per sq meter</u>
Kitkatla		10		0
Campania Islands		10		0
Kitasu Bay				
	Site 1	10	1	0
	Site 2	5	1	0
	Site 3	10	1	0
Meyers Passage				
	Site 1	10	1	0
	Site 2	10	1	0
	Site 3	5	1	0
Mathieson Channel				
Rescue Bay	Site 1	8	0.5	8,10,0,2,0,8,6,10
	Site 2	7	0.5	8,2,4,6,0,4,4
	Site 3	6	0.5	0
	Site 4	4	0.5	0
	Site 5	2	0.5	2,2

* square meters

Table 4. cont. MANILA CLAM POPULATIONS

	<u>Plots</u>	<u>Area*</u>	<u>Number per sq meter</u>
St. John Harbour			
Site 1	3	0.25	12,0,4
Site 2	3	0.25	72,80,236
Sites 3-8	4	0.25	0
Dearth Island			
Site 1	3	0.25	28,12,56
Site 2	4	0.25	4,24,24,0
Joassa Channel			
Site 1	4	0.25	32,156,132,136
Site 2	4	0.25	248,176,52,204
Site 3	4	0.25	84,44,52,52
Lama Passage/Hunter Channel			
Site 1	3	0.25	21,3,15
Site 2	3	0.25	15,39,24
Site 4	3	0.25	8,4,20
Site 5	4	0.25	12,16,44,36
Site 6	3	0.25	124,76,56

* Square Meters

Table 4. cont. MANILA CLAM POPULATIONS

	<u>Plots</u>	<u>Area*</u>	<u>Number per sq. meter</u>
Seaforth Channel/Raymond Passage			
Site 1	2	0.25	184,272
Site 3	2	0.25	192,276
Sites 4-6	-	-	commercial digging
Site 7	3	0.25	156,300,228
Gunboat Passage			
Site 1	6	0.25	0
Site 2	few		10 total
Site 3	5		few
Site 4	4	0.25	24,32,16,20
Site 5	3	0.25	16,36,80
Site 6	3	0.25	16,16,8
Site 7	4	0.25	64,44,88,96

* Square Meters

Table 4. cont. MANILA CLAM POPULATIONS

	<u>Plots</u>	<u>Area*</u>	<u>Number per sq meter</u>
Seaforth Channel/Raymond Passage			
Site 1	2	0.25	184,272
Site 3	2	0.25	192,276
Sites 4-6	—	—	commercial digging
Site 7	3	0.25	156,300,228
Gunboat Passage			
Site 1	6	0.25	0
Site 2	few		10 total
Site 3	5		few
Site 4	4	0.25	24,32,16,20
Site 5	3	0.25	16,36,80
Site 6	3	0.25	16,16,8
Site 7	4	0.25	64,44,88,96

* Square Meters

10. Development of a Clam Farming Policy
for the Pacific Region of DFO

by

N. Bourne and F. Dickson

SUMMARY

There has been a significant change in the harvest of intertidal clams in the past twenty years. Until the mid 1970's the main species harvested was the butter clam, Saxidomus giganteus. Since then steamer clams, littleneck, Protothaca staminea and manila, Tapes philippinarum, have been the main species harvested and since the mid 1980's manila clams have comprised over 75% of intertidal clam landings. The increase in manila clam landings was the result of strong markets and an abundance of labour. As a result many beaches in the south coast district have been dug several times in a year and there has been a tendency to harvest manila clams in restricted areas. Landings of manila clams have decreased in the last two years because accumulated stock has been removed and now the industry must rely mainly on incoming single year classes.

The decline in abundance and landings of manila clams has prompted people in industry to consider the possibility of clam farming to augment harvest of the wild resource. This attitude is due not only to strong markets but also to the success of clam farming operations in other places, particularly the State of Washington. Many west coast bivalve hatcheries are now producing juvenile manila clams so seed is readily available.

Present DFO policy only permits clam farming operations in areas where there is no history of commercial, recreational or native clam harvest. This policy will have to be changed if clam farming is to be encouraged in British Columbia.

The advantages and disadvantages of culture over wild harvest are well known. The main problem for regulatory agencies will be to insure that people are actually farming an area and not simply treating it as a private clam beach. Six criteria are presented that can be used either singly or in combination to assure that clam farming is actually being undertaken.

Short and long term clam farming policies are suggested for DFO. The short term policy would last for a period of 5-10 years and would permit clam farming on all existing oyster leases, on intertidal areas fronting Indian reserves and in the north coast district. Results of clam farming would be monitored closely in the short term period to determine the viability of such

operations. If clam farming was successful, then the long term policy could be introduced in which beaches would be taken out of the common property resource (up to 25% in any area) and assigned to people for clam farming operations.

EXECUTIVE SUMMARY

A commercial fishery for intertidal clams has existed since before the turn of the century. Four species have comprised most (over 95%) of the landings:- razor, butter, littleneck and manila. Originally most of the landings were butter clams but in the past fifteen years there has been a shift from harvesting this species to harvesting steamer clams, littleneck and manila clams, particularly the latter species. In the last five years manila clams have comprised over 65% of annual intertidal clam landings. Landings have fluctuated over the years for several reasons, mostly socio-economic. In the past few years there has been a sharp increase in landings that are a result of particularly strong markets for manila clams and the fishery has targeted on harvesting this species. This increase in landings coincided with other factors including, a depressed economy with high levels of unemployment and an influx of southeast Asians who had few applicable work skills but who were excellent clam diggers and willing to work anywhere. The result was a great increase in fishing pressure on intertidal clam beaches in the southern part of the Province which has caused many problems for DFO managers.

Accumulated stocks of legal-sized steamer clams have been removed on many beaches and landings are declining. The industry now argues that in order to maintain current levels or increase manila clam production they must begin to culture clams.

The past policy of DFO Pacific Region has been unsympathetic to clam culture since it would require alienation of the common property intertidal foreshore. The policy has been to restrict clam culture to areas where there is no history of commercial, recreational or native food clam fisheries. However, with the recent pressure on stocks, DFO has agreed to re-evaluate its position on clam culture.

The main advantage of clam culture over wild harvest is that maximum production could be maintained for an area. Eventually a major portion of commercial clam production might come from culture operations which would alleviate management problems in the wild harvest for DFO. With culture, a continuous production schedule could be established by industry which would assure markets and lead to higher profits. Although major clam production would come from farmed areas, sufficient areas would remain for a continuing wild harvest and for the recreational and native food fisheries.

There are some disadvantages to clam farming, the main one being that DFO would lose management control over farmed areas.

In general the advantages outweigh the disadvantages.

The major concern that DFO has with any clam culture operation is to insure that the lease holder is not using the area as a private clam digging beach but that he/she is actually farming clams. DFO must define what standards it will use to assess clam farming. Six criteria are suggested which may be used alone or in combination:- maintain maximum production for a lease, maintain an active seeding program, beach improvement, predator control, increasing recruitment and controlled digging. Criteria used might be site specific.

To encourage development of clam culture in British Columbia a short term and long term scenario is discussed.

The short term scenario would be for a period of five to ten years. Clam culture would be encouraged on existing oyster leases and on intertidal areas fronting Indian reserves. These areas have already been alienated from the common property resource. Results of clam culture in these areas would be carefully monitored during the short term period to provide data on the viability of clam culture in British Columbia.

If clam culture proved to be economically viable in the short term period then a long term policy could be instituted. In it, intertidal areas would have to be taken out of the common property resource and assigned to clam farmers. This could be accomplished by assigning a certain percentage of areas (e.g. up to 25% in a statistical area) for clam culture. Sufficient areas would be left for a reduced wild harvest and for the recreational and native food fisheries.

Considerable research and development work is required to assist DFO to realistically assess the viability of clam farming in British Columbia and a method for doing this is suggested.

INTRODUCTION

The clam industry in British Columbia can be divided into two main fisheries; those for intertidal and subtidal stocks. Intertidal fisheries are primarily for four species:- razor, Siliqua patula; butter, Saxidomus giganteus; littleneck, Protothaca staminea; and manila, Tapes philippinarum. The subtidal fishery is primarily for geoducks, Panope abrupta, although there are minor landings of two species of horse clams, Tresus capax and T. nuttallii.

Total landings and values of these fisheries are small when compared to total fishery landings for the Province. In 1988, the total landed weight of all species of intertidal clams was 4,386 t with a value of \$7.593 million and for subtidal fisheries, 4,881 t with a value of \$10.062 million (Tables 1 and 2). Although the fisheries are small they are important to coastal communities and provide much needed employment to many people. In addition intertidal clams are widely used in the recreational and native

food fisheries. It is estimated that 30,000-40,000 people dig clams recreationally during a year. The extent of landings in the recreational and native food fisheries is unknown. Clam resources must be managed properly to protect stocks and maximize yields for the commercial and recreational fisheries.

At present there is a strong belief in the industry that it would be advantageous to culture or farm clams for commercial production rather than rely entirely on harvest of wild stocks. This belief is due to several reasons; many people in the industry have experience farming oysters intertidally and have suitable sites for clams, declining stocks of some species of clams, strong markets and high prices, the inability of wild stocks to supply markets on a year round basis, and the apparent success of clam farming in some parts of the world, particularly in the State of Washington.

It is an appropriate time for DFO to examine its position on clam farming in British Columbia and determine if a change in present policy towards clam farming is warranted.

HISTORY OF THE CLAM FISHERY

A convenient place to begin an examination of the potential for clam farming in British Columbia is to briefly review the present clam fishery.

The clam fishery in British Columbia began before the turn of the century (Quayle and Bourne 1972). Until the mid 1970's the main species harvested was the butter clam which was canned and used in chowders. Digging occurred during winter months and was mainly by native people. Many of the harvesters were salmon fishermen who dug clams in the off season, particularly if the previous salmon season had been poor. There was a summer closure which was instituted primarily by industry; they were busy canning salmon during the summer and butter clams were unsuitable for canning from about April - October. Until 1963, about half the landings were from the north coast and half from the south coast. After 1963 the north coast was closed to harvesting clams because of chronic low levels of PSP (paralytic shellfish poisoning). Although procedures were devised to permit digging in some parts of the north coast, little digging for butter clams occurred there after 1963. Fluctuations in annual landings were due mostly to socio-economic reasons.

There is a small fishery for razor clams on the beaches east of Masset in the Queen Charlotte Islands which began in 1924. Originally the product was canned but since the early 1970's razor clams have been used primarily for bait in the crab fishery. Fluctuations in annual landings have been due again mainly to socio-economic reasons.

Until the 1940's there were small landings of littleneck clams, mostly in the southern part of the Province, close to markets in Vancouver and Victoria because the clams were marketed fresh. Poor transportation facilities prevented extensive marketing in the United States. In the 1940's, manila clams began to enter the commercial fishery. The manila clam is an exotic, having been accidentally introduced from Japan along with Pacific oyster, Crassostrea gigas, seed. It was first found in Ladysmith Harbour in 1936 (Bourne 1979) and since then has spread throughout the southern part of the Province and as far north as the Bella Bella area (Bourne 1982). Until 1970 fisheries for littleneck and manila clams were carried out from November 1 to April 30. Since then harvest has been throughout the year.

A significant shift in the intertidal clam fishery began in the mid 1970's. Butter clam landings began to decline because of the high cost of processing. Landings continued to decline and in 1988 were only 83 t. Market demand began to shift from butter clams to fresh steamer clams, littleneck and manila clams. Many of these markets were in the United States and because of improved transportation links they could be readily supplied from British Columbia. At first market demand was for littleneck clams, but since 1980 it has been for manila clams and recently manila clams have comprised over 90% of intertidal clam landings (Table 1). This increase in landings was generated mainly because of strong markets for steamer clams in the United States.

Other events occurred that contributed to increased landings. High unemployment was prevalent in the late 1970's and early 1980's so people were available to dig clams. There was a significant influx of people from southeast Asia who were looking for work, who were excellent clam diggers and who were willing to travel anywhere to dig clams. Little capital is required to become a clam digger so anyone could enter the fishery. Because of high prices some harvesters invested in vessels so they could travel to remote beaches which had received little previous digging pressure. Increased prices for clams meant that harvesters could earn good wages digging intertidal clams. In fact for these immigrant clam harvesters, this fishery became their full time employment and industry no longer had to rely solely on local harvesters. Further, the intertidal clam fishery is an open fishery so that anyone can become a commercial clam digger.

. The result was a goldrush attitude on the part of industry and a great increase in effort. Landings of manila clams began to increase sharply in 1983 and continued as accumulated stock was harvested through to about 1988. In 1988 and 1989 the accumulated stock of legal-sized manila clams had largely disappeared and diggers began to harvest clams in previously untouched areas; e.g. beaches with much rock, oyster leases. They also harvested in many areas that are closed because of sewage pollution. The fishery will now have to depend mainly on the strength of single incoming year classes for most of the production and this could lead to fluctuations in annual landings.

This situation led many in the industry, particularly people with experience in intertidal oyster culture, to consider clam farming as a better method to sustain high levels of production rather than managing wild stocks of intertidal clams.

MANAGEMENT

Many methods are used to manage clam resources in the world and several have been tried in British Columbia (Bourne 1986).

The physiography of the British Columbia coast creates major difficulties in managing intertidal clam resources. The total coastline is about 27,000 km and there are probably an equal number of intertidal beaches. Most beaches are small and many are isolated. There can be great variation in clam populations on beaches separated by a few km.

Because of the myriad of beaches, large distances, isolation and variations in clam populations on beaches, the main management policy for intertidal clams in British Columbia is a size limit, 63 mm (2.5 inches) shell length for butter clams, 38 mm (1.5 inches) for littleneck and manila clams and 90 mm (3.5 inches) for razor clams. Size limits have been set so that the clams can spawn at least once before they reach commercial size (Bourne 1987). A major disadvantage in managing clam harvest by size limit is there is no control over effort and the number of times a beach can be dug in a single year. Because accumulated stock of manila clams has been largely harvested, diggers now frequently return to beaches and redig them; some beaches have been dug as many as five and six times in a single year which is undoubtedly very damaging to the beaches and prerecruit clams.

In an attempt to control effort, a clam harvester license and area digging were introduced in 1989. The coast was divided into six areas and diggers can only harvest intertidal clams in one area. The time permitted for harvesting has been reduced and rotational openings have been introduced. However, these management practices do not control the number of times a single beach can be dug in a year. DFO has insufficient management and enforcement staff to manage this fishery on a beach by beach basis.

HISTORY OF CLAM FARMING

References to clam culture date back to 2,000 B.C. in eastern civilizations (Iverson 1968) and appear in Japanese literature as early as the eighth century.

Since the turn of the century clam culture has been attempted in many parts of the world. Extensive culture of manila clams and other species was investigated in Japan beginning in the 1920's (Cahn 1951; Arakawa 1987). Extensive clam culture is practised in China and southeast Asia (Davy and Graham 1982).

In these clam culture operations, seed (juveniles) is gathered from areas of abundance and spread at lower densities in better growing areas. This method of culture can only be practised in areas where abundant juvenile clams occur and where inexpensive labour is available, since gathering large quantities of juvenile clams in the natural environment is labour intensive. In some areas, particularly in southeast Asia, such clam farming is practised at the artisanal level.

Similar clam culture work was attempted in North America, mostly on the Atlantic coast (Bourne 1989). Again juveniles were gathered from areas of abundance and spread in better growing areas. These culture attempts failed because of the high cost of gathering seed, slow growth rates and high mortalities.

This type of clam culture is probably not suitable for British Columbia. No areas are known where there is an overabundance of clam seed that could be gathered economically and spread in better growing areas. Also, there is the danger that a "robbing Peter to pay Paul" scenario could develop.

With the advent of bivalve hatcheries in the 1960's, a reliable and cheaper supply of seed became available and clam farming took on a new dimension. Culture of manila clams is now being carried out successfully in several countries including France and is being attempted in Spain. Active clam culture, mostly quahaugs, Mercenaria mercenaria, occurs on the east coast of the U.S. with varying degrees of success. Clam culture, mostly manila clams, is being attempted on the west coast of the U.S. and in British Columbia, again with varying degrees of success.

Extensive clam culture could develop in British Columbia in the next decade. The goal would be to have all commercial intertidal clam production from farmed areas.

SPECIES

Attempts have been made to culture several species of clams on the west coast of North America. In British Columbia, experimental culture of butter, littleneck and manila clams has occurred (Bourne 1989). Manila and razor clams and geoducks have been or are cultured in the State of Washington.

The only clam species that appears to offer potential for culture in the next decade in British Columbia is the manila clam. Markets for this species are strong, it is reasonably fast growing (3 years to attain the commercial size of 38 mm under optimum conditions in the southern part of British Columbia), it can be cultured at high densities and seed can be purchased from hatcheries. Culture of other clam species presents too many difficulties at the present time.

REASONS FOR PRESENT INTEREST IN CLAM CULTURE

The present interest in clam culture in British Columbia is due to several reasons.

Present intertidal clam harvest is in a chaotic state that has been brought on to a large measure by the goldrush attitude of industry. Accumulated stocks of manila clams have been harvested and landings will probably decline as the fishery tends to rely on single incoming year classes. Because of high prices, more people will tend to harvest clams in closed areas and DFO can only monitor this with increased surveillance or imposition of severe restrictions on harvest.

Effort is much too high. Because so many people have become reliant on the clam fishery for full time income and accumulated stock has been harvested, diggers are redigging beaches, as many as five and six times per year which is damaging to the beach and prerecruits. Quayle (1952) examined yield of butter clams when beaches were dug twice per year, once per year, every second year, every third year and at the end of seven years and found there was little difference in production between the first four treatments but the last was considerably poorer than the other four. When the economics of digging is considered it might be best to dig an area for butter clams every three years. The optimum digging frequency for manila clams is unknown but it is probably no more than once a year and may be every other year.

Another reason for interest in clam culture is that the Pearse report (Pearse 1982) stated that DFO should encourage clam farming with the goal of eventually having all commercial clam harvest from farmed areas.

The general advantages of culture over wild harvest have also contributed to interest in clam culture; production per unit area could be greatly increased, a better quality product could be produced and harvest could be scheduled for a year round operation which would help to assure good markets.

A major reason for the interest in clam farming in British Columbia is the apparent success of manila clam culture in the state of Washington, but this should be carefully examined. Biologically, the Puget Sound area is different to the Strait of Georgia where optimum conditions for manila clam culture exist in British Columbia. Higher clam densities and faster growth rates* are reported for manila clams in Puget Sound than in the Strait of Georgia. Further manila clam farming in Puget Sound could be termed pseudo farming rather than true farming. In previous years considerable gravelling of beaches occurred in Puget Sound to create good substrate for growing native oysters, Ostrea lurida. Little culture of native oysters occurs now because of the economics of culture. However, ideal habitat was created for manila clams and much of the clam farming now occurs in areas formerly used for native oyster culture. Although seeding occurs

there are no data to indicate what portion of production in culture operations is from seeding and what is from natural sets. Estimates of yields from planted seed range from 5-30% of total production but the figure is probably closer to 5%. Increased clam production from these areas is probably not the result of a heavy seeding program but from the fortuitous creation of an ideal manila clam habitat and good husbandry of natural sets of juveniles.

It should be pointed out that manila clam culture operations in some parts of Puget Sound do rely solely on seeding. Survival and production of juveniles is reportedly high but the economic viability of the operation has not been assessed.

Experimental work in British Columbia showed manila clam culture is feasible (Bourne 1989), the question is whether it is economically viable. To a large extent clam farming is viewed as a panacea by the British Columbia industry. Clam farming, like oyster culture, requires a considerable commitment of funds and work if it is going to succeed.

ADVANTAGES AND DISADVANTAGES OF CLAM FARMING

The general advantages of culture over harvest of wild stocks has been stated on numerous occasions and need not be repeated here. However, it is appropriate to consider some specific advantages and disadvantages of clam culture over wild harvest in British Columbia.

ADVANTAGES

The main advantage of culture is the maximum yields should be obtained for a given area. There are only limited data estimating maximum yields of manila clams on British Columbia beaches. Maximum yields will depend on the type of culture and geographic location. In the state of Washington annual yields of 54 t per hectare (10 lbs/square yd) have been reported and these might be attainable under some local conditions in British Columbia. Certainly consistent yields of 27 t per hectare (5 lbs/square yd) should be attainable on many British Columbia beaches.

It should be feasible to culture manila clams over a much wider portion of the beach, e.g. lower in the intertidal zone. Growth would probably be faster lower on the beach provided adequate predator control occurred. An increase in production should result from use of more of the beach for culture.

The chaotic nature of the present fishery would be avoided. Digging would be controlled and continuous redigging of beaches avoided.

Harvest would be scheduled to meet market demand so an orderly production would occur. There should be economic benefits to local communities who would supply clam harvesters for leased operations compared to the transitory behaviour of many wild clam harvesters.

DFO would have little involvement in clam farming operations which would leave time for better management of areas where wild and recreational clam harvest would continue. Eventually there could be a reduction in conflicts between the commercial and recreational clam fisheries because the major portion of commercial production would come from farmed areas leaving more areas available for the recreational fishery.

Problems such as poaching on leases would not involve DFO but would be a responsibility of the lease holder.

DISADVANTAGES

The main disadvantage with clam culture is that some areas eventually would be taken out of the public fishery. Clams have long been considered as a common property resource. This will undoubtedly cause problems, particularly from recreational harvesters. However, as pointed out above this may not be a major problem because eventually most commercial production will come from farmed areas.

Some mechanism will have to be established to insure that production goals are maintained and that production is from leased areas and not from areas where wild harvest continues.

DFO will have little control of shellfish in leased areas, as this is a Provincial responsibility.

There may be a slight reduction in the number of clam diggers. Diggers will still be required to harvest clams in cultured areas. Since clam densities in cultured areas should be higher than in wild harvest areas, diggers should be able to earn more in cultured areas than in wild harvest areas.

In general the advantages outweigh the disadvantages. Production of clams should increase because of farming operations, marketing should proceed in an orderly fashion, industry would manage their own areas and although there may be a slight reduction in the number of diggers, those remaining would probably earn more.

CRITERIA FOR CLAM FARMING

A primary consideration for DFO and MAF (Ministry of Agriculture and Fisheries) the Provincial administrative agency, will be to establish a definition of clam farming and to formulate criteria to insure that farming operations are carried out on leased areas.

Intertidal and subtidal areas in Canada belong to the government (crown land) and there is a strong feeling in the west that anyone can walk on any beach in the marine environment and harvest his/her share of clams. If intertidal areas are taken out

of the crown land category and assigned to a particular individual then the public will demand assurance that the area is being actively cultivated and production maintained at higher yields than occur in a wild fishery.

Several criteria have been proposed to define clam farming but none is all encompassing. The following criteria are the ones most frequently suggested. Maintain maximum production for a lease. The area under consideration for leasing would be surveyed, preferably by government biologists, and a decision made in conjunction with the owner on the maximum level of production that should be maintained for the area. The method used to maintain maximum production levels would be left to the grower. Some allowances would have to be made in production schedules in the event that catastrophic events occurred that did not permit attainment of production quotas, e.g. winter kill during extremely cold winters.

A problem with this criteria is that it could require considerable time by government biologists to conduct surveys. Further, very little actual farming might be necessary on some leases to achieve maximum levels of production. This is somewhat similar to the present situation in Puget Sound. However, it is a simple method of maintaining high levels of production in some areas. It could be used in polyculture operations since seeding might be required for one species but not the other.

Maintain an active seeding program. This criteria is easily administered. A grower would be required to plant a minimum amount of clam seed in a given area. The frequency of seeding would depend on the culture scenario. It requires about three years for manila clams to reach the legal size of 38 mm shell length under optimum condition in British Columbia. If a grower intended to harvest only single year classes then he would plant seed in one location every three years. If he intended to harvest all area every year, as happens at present with natural sets, then he would plant less seed every year. Administrators could review invoices to insure active seeding was carried out.

There are serious problems with this criteria. Natural sets could be sufficient to provide maximum yields for some area so planting hatchery seed would be wasteful. Clam seed is expensive. Further the larger the seed the more it costs, at present manila clam seed is approximately \$1.00 per thousand per mm. It is much better to plant the largest possible seed since survival is better than when small seed is planted and the time taken to reach a harvestable size is reduced. If 1 cm seed was planted in the early spring it is possible that it could be harvested 2-2.5 years later, compared with 3-3.5 years for 1 mm seed. However, there is a significant difference in cost between 1 mm and 10 mm seed. The cost of seeding one hectare at a density of 200 seed clams per square meter (which is much below optimum densities for most areas) is \$2,000.00 when 1 mm seed is used and \$20,000.00 when 10 mm seed

is used. Most growers would buy the minimum amount of the cheapest (smallest) seed and scatter it on the lease to meet seeding requirements but in reality would rely on natural sets to meet production quotas. The seeding requirement would do little more than satisfy administrators.

Beach improvement. Much of the manila clam production from cultivated areas in Puget Sound is the result of creating an ideal substrate for manila clams by putting down layers of gravel. As pointed out previously the gravel was put down originally to create good substrate for growing native oysters. The size of the gravel is important. Layers of gravel (up to 20 cm in total thickness) could be placed on leases where the substrate is unsuitable for manila clams, thus creating a good habitat for manila clams. A grower could then rely on natural sets or seed the area to obtain maximum production.

This method of culture would only be used to produce good clam substrate where none or marginal substrate exists. A disadvantage is that gravelling beaches is expensive but it would only have to be done once. However, by going to this expense a grower would demonstrate his/her intention of farming clams and a seeding requirement may or may not be needed. Another disadvantage is that gravelling may not be permitted on some beaches for habitat considerations.

Predator control. There are numerous predators of small clams, i.e. clams under 5 mm shell length (Anderson et al 1982). Predators include several species of crabs and small fish. By spreading vexar netting on the beach predators can be controlled and production increased. It may be necessary to spread netting on beaches that are seeded to protect them from predation. Netting is expensive to put down and it must be maintained regularly so that breaks do not occur which would allow predators into culture areas.

An advantage of this culture method is that it can be readily monitored for diligent use purposes.

Increasing recruitment. Recruitment from natural sets can be increased by putting down artificial barriers on beaches to create eddies and trap setting larvae. Increased setting would presumably lead to higher numbers of juvenile clams and increased production. Several methods can be used to create artificial barriers. It has been shown that spreading vexar netting creates artificial eddies which increase settlement of manila clams (Anderson et al 1982).

Controlled digging. A major reason for declining clam production on some beaches is probably repeated digging. Redigging beaches five and six times in a year undoubtedly damages the beach as a clam environment and kills prerecruit clams. If beaches were dug once a year or perhaps every other year (this should be determined) it could lead to maximum yields for a given area

provided good natural sets were obtained. This method could be used in polyculture, culture of Pacific oysters, Crassostrea gigas, and manila clams. However, the grower should be allowed to harvest the clams when it is convenient to him so that no damage is caused to oyster farming operations.

There are advantages and disadvantages using all these criteria. It may be necessary to use a combination of more than one of them to ultimately establish criteria for clam farming. However, it would appear that the main criteria to use to realistically assess clam farming is to insure maintenance of maximum levels of production from a leased area. The grower will decide how he/she will attain this production. This will provide administrative problems, particularly at the beginning, but a monitoring system could be developed.

PRESENT STATUS OF CLAM FARMING IN BRITISH COLUMBIA

As mentioned previously there have been attempts to culture manila clams commercially in British Columbia. At the present time the Province has granted 24 leases for clam culture or joint clam/oyster culture. Culture methods have included spreading vexar netting on the beach and seeding. In 1987 landings of 25 t were reported from eight of the leases but it is not known what percentage of the production was from seeding operations and what portion resulted from good husbandry of natural sets.

DFO CONCERNS

The main concern for DFO will be to insure that lease holders are actually farming an area and not simply using it as a private clam digging beach. Criteria will have to be developed between DFO and MAF (Ministry of Agriculture and Fisheries) to formulate a lease management plan and diligent use policy that clearly state what is required to qualify for clam farming. Adequate surveillance will be needed and administrative procedures will have to be in place to insure production levels are met by growers and that reported clam production is from farmed areas and not in part from areas where wild harvest occurs.

Another concern will be whether all molluscan shellfish species on the lease belong to the lease holder. The lease holder may only farm manila clams but may also harvest littleneck and butter clams, although these species are not being farmed.

DFO OPTIONS

The Pearse Report (Pearse 1982) states that DFO should encourage clam farming in British Columbia and options should be developed to achieve this goal.

Present DFO policy states that clam farming will only be permitted in areas where there is no history of important commercial, native or recreational clam harvest. This policy is

unsatisfactory since it confines clam farming mostly to unsuitable areas. If clam farming is to succeed it must be carried out under optimum environmental conditions which will necessitate a change in present DFO policy.

If DFO opened up all intertidal areas for clam farming there would be a gold rush attitude as people claimed areas for clam farming, which they might or might not farm. This would be unacceptable to DFO and to the public.

It must be stressed that clam farming is not a panacea to solve the problems of the clam industry. Clam farming will require a real commitment from industry if it is to succeed. The example of the oyster industry, which is the main invertebrate species cultured in British Columbia, is not impressive. Much of the intertidal area leased for oyster production has not been farmed properly and maximum production levels have not been maintained on most leases. A legitimate question is whether it will be any different for clam culture. In formulating a clam farming policy it will be advisable to begin small and start slowly. When manila clam farming is proven to be economically viable then a policy can be introduced to expand growing areas.

There are two options which DFO could consider to commence encouraging clam farming in British Columbia, a short term and a long term option.

SHORT TERM OPTION

The short term option would cover a period of five to ten years and during this period DFO would give full support to undertaking clam farming operations on existing oyster leases and on lands fronting native Indian property.

Oyster leases are areas which have already been removed from the public fishery status. Clam farming could be practised in these areas and results monitored closely to determine the method(s) employed to farm manila clams and to assess whether production was increased to maximum yields. If clam farming proved to be successful on existing oyster leases then farming operations could be expanded.

A lease holder should be allowed to manage all shellfish resource on a lease as he/she deems necessary. The present policy of controlled clam harvest on leases is unsatisfactory since it restricts harvesting times to periods dictated by the wild fishery. Lease holders should be allowed to harvest all molluscan shellfish on their leases at times when it is most convenient and desirable to do so. The only DFO regulations that should apply to harvest of clams on leased areas is the size limit and closures because of PSP and pollution.

Polyculture of manila clams and Pacific oysters should be encouraged. These two species appear well suited for joint culture since they can be grown at approximately the same intertidal tidal level and have about the same growout period. In any polyculture operation a grower would have to be able to harvest both crops at his/her convenience to insure minimum damage to either crop and to meet marketing schedules.

Lease holders should be encouraged to utilize more of the beach, particularly the lower portion of the beach where growth rates of both manila clams and oysters are faster. This will probably involve development of new technology to protect juvenile clams from heavy predation.

A second short term option would be to encourage clam farming by Indian bands on all areas fronting their lands. Some of these beaches have excellent manila clam habitat and would support clam farming operations. Conditions outlined above for culture on oyster leases would apply here as well.

A third option would be to encourage clam culture in the central coast area. This would necessitate water quality surveys and a monitoring program for PSP. Growth would probably be slower in this area but it would be one way to begin clam harvesting in the central coast.

LONG TERM OPTION

If clam culture proved to be successful and economically viable in the five to ten year short term period, then DFO would have to consider granting new areas for clam culture, areas presently not used for oyster culture. However, immediate attention should be given to developing a policy to deal with applications for new areas as they are received, i.e. those received within the next ten years.

A suggestion has been made that DFO consider confining clam farming operations to a particular geographic location; e.g. the Baynes Sound area. Much of this area is already under lease so granting additional clam farming leases would not cause serious problems. Further the area has good habitat for manila clams. However, this would be grossly unfair to people in other parts of the Province. There is considerable interest in clam farming among people in other parts of the Province and these people should have a chance to try clam farming.

A suggested option would be to grant a certain percentage of beaches in a given area (perhaps a statistical subarea) for clam farming, e.g. 10-25% of beaches in any area could be set aside for culture purposes. These would be beaches with suitable habitat for clam farming and probably would have some history of previous clam harvest. Sufficient beaches would still be left to support a limited wild harvest and for the recreational fishery.

Leases for new clam (shellfish) culture areas could be granted on a first come first served basis, a lottery system, or to people who are resident in the area. The latter is probably the most equitable system to develop since it would provide more benefit to local individuals and communities. Such a scenario would insure an orderly development of clam farming in British Columbia.

OTHER CONSIDERATIONS

In both the short term and long term options considerable beach area would be left for the wild and recreational fisheries. In the long term option a maximum of 25% of existing clam beaches would be used for culture purposes, 75% would be left for the wild and recreational fisheries. Since major production would be from farmed areas the digging pressure on natural areas would probably be reduced. DFO could develop management harvest plans for the wild and recreational fisheries.

DEMONSTRATION FACILITY

Considerable additional information is required before a comprehensive DFO policy can be developed for clam farming in British Columbia. Research is required to determine if seeding is necessary to maintain maximum yields of clams for any given area. If seeding is required then the amount needed, frequency of seeding operations, and optimum size of seed should be determined. Harvesting frequency in farmed areas should be assessed. Methods to control predation to permit culture in lower parts of the beach should be developed. Maximum production levels for leases should also be determined.

Much of this information could be obtained if a Demonstration Farm was available for experimental culture. The farm should be located in one of the major clam producing areas and it should be a joint Federal-Provincial project. Information obtained from experimental projects could be used to demonstrate improved culture techniques to industry and to formulate a DFO clam farming policy.

Present DFO resources are inadequate to maintain and operate such a Demonstration Farm. Consideration should be given to levying a royalty or landings tax on all intertidal clams harvested in the Province, the tax could be 2-10 cents per kg. Proceeds from this tax would be used to operate and undertake research work on clam farming at the Demonstration Farm.

SUMMARY

The Pearse report (1982) recommended that DFO promote clam culture in British Columbia and it would appear that since some species in the wild resource are probably now fully exploited it is a appropriate time to begin. DFO must take a lead role in promoting clam culture and not appear to be simply tolerating it. The task won't be easy and many problems will have to be solved before a suitable system is established for clam culture in the

Province. It must be stressed that clam culture is not a panacea and won't answer all the problems involved in the clam industry. However, it does provide an opportunity to increase clam production in an orderly fashion in the Province. The time is propitious for DFO to seize this opportunity to establish a firm and rational policy for clam culture in British Columbia.

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Table 1. Landings of shellfish in kg in British Columbia, 1981-1988

SHELLFISH LANDED CATCH (t) - 1981-88		1981	1982	1983	1984	1985	1986	1987	1988

INTERTIDAL CLAMS									
Razor		30	68	31	101	90	142	142	155
Butter		120	103	77	131	252	159	69	83
Manila		317	597	1049	1677	1914	1894	3608	3839
Nat. Ln.		179	241	325	295	192	285	373	288
Mixed		161	155	280	409	478	369	87	27

TOTAL INTERTIDAL C		807	1164	1762	2613	2926	2849	4279	4386
GEODUCK		2704	3135	2636	3483	5370	5006	5734	4553
HORSE CLAM		57	321	21	7	6	96	355	328
SHRIMP		581	415	411	408	678	768	2644	2211
PRAWN		358	274	331	381	514	550	620	708
CRAB		1317	1002	960	1155	1165	1321	1631	1406
ABALONE		85	54	56	58	42	52	49	48
OCTOPUS				37	25	34	53	130	205
SEA URCHIN				982	1764	1815	2067	2223	2349
SEA CUCUMBER					95	346	786	1722	1930
SCALLOP			8	11	18	53	68	66	66

TOTAL KG		5909	6373	7207	10007	12949	13616	19453	18190

Table 2. Value of landings of shellfish in \$000 in British Columbia, 1981-1988

SHELLFISH VALUE OF LANDED CATCH - 1981-88								
	1981	1982	1983	1984	1985	1986	1987	1988

INTERTIDAL CLAMS								
RAZOR	24	55	24	123	95	127	126	137
BUTTER	42	36	33	55	138	75	40	40
MANILA	323	611	1043	1813	2278	2762	6003	7023
NAT. LN	195	263	329	311	202	327	474	357
MIXED	175	169	293	455	575	510	132	36

TOTAL INTERTIDAL C	759	1134	1722	2757	3288	3801	6775	7593
GEODUCK	2434	2814	1818	2937	4777	4294	6184	9762
HORSE CLAMS	42	235	12	5	6	63	309	300
SHRIMP	912	652	1095	1022	1180	1240	4609	2802
PRAWN	2019	1545	2154	2464	3379	3734	4326	5724
CRAB	3556	2703	3320	4558	4719	5661	6452	5555
ABALONE	721	457	464	530	442	734	973	1076
OCTOPUS			80	56	82	136	381	629
SEA URCHIN			358	712	763	1011	1276	1634
SEA CUCUMBER				22	94	236	768	961
SCALLOP		17	45	56	139	212	244	285

TOTAL VALUE	10443	9557	11068	15119	18869	21122	32297	36321

11. Climatic Change and the Intertidal:
Physical and Biological Influences on
Species Composition, Abundance and
Recruitment Patterns

by

D. Noakes and G. Jamieson

SUMMARY

This paper provides initial data on the possible impacts climatic change may have on the growth, recruitment, and survival of intertidal invertebrate species. Plausible relationships were investigated between mean annual air and sea surface temperatures and 1) annual indices of geoduck growth in Ladysmith Harbour, B.C. 2) the magnitude of oyster spawning in Ladysmith harbour, and 3) winter mortalities in manila clams in the Georgia Strait.

Trends in geoduck growth appear to be linked with low frequency shifts in mean annual temperature. A general warming period of about 0.5°C around 1920 was coincident with a 9% increase in annual growth. For the range of temperatures examined, there is a positive relationship between temperature and growth.

Oyster spawning success was linked to mean sea surface temperature. Significant spawning events were coincident with relatively high mean sea surface temperatures during the period June 1 to August 31. The time series of mean sea surface temperature during this summer period exhibited strong shifts in variance over time. The reason(s) for this behaviour is (are) unknown. Mean summer sea surface temperatures have increased steadily since 1980.

Hourly dry-bulb air temperatures and calculated tidal heights for the period 1960 to 1989 were used to determine winter exposure factors (degree hours) for manila clams in the southern portion of the Strait of Georgia. The maximum exposure factor was -73.2°C h recorded in 1968. Exposures greater than -40°C h , which appears sufficient to induce significant mortalities, were recorded in 10 of the 30 years examined.

These investigations indicate that anticipated climate change will have a significant impact on the growth, recruitment, and survival of intertidal invertebrate species. Further research to document and quantify connections between the various biotic and abiotic factors is planned. In particular, the relationship between temperature and both growth and mortality will be investigated because of the increased interest in clam culture.

INTRODUCTION

There is a growing body of evidence to support the phenomenon commonly referred to as global warming (see for example Freeland 1990; Hansen and Lebedeff 1988; Jacoby and D'Arrigo 1989). If predictions are true, we can expect to see significant increases in sea surface temperatures and sea surface levels along the coast of British Columbia (Peltier and Tushingham 1989). Some experts have speculated that these changes will have profound impacts on the distribution and abundance of marine life. These predictions are based on a general understanding of the links between physical and biological processes. Their accuracy depends upon the realism of the forecasted climate changes and the confidence we place on our understanding of the various processes involved.

With the exception of the shrimp trawl fishery, invertebrate fisheries in British Columbia are concentrated in coastal inlets and along the foreshore (Jamieson and Francis 1986). Shallow bays support crab populations while prawns tend to inhabit deeper fjord type inlets. Some species such as geoducks, sea cucumbers, and sea urchins are collected in dive fisheries that typically operate in waters much less than 50 m. Mollusks and other invertebrates found in the intertidal zone also support significant commercial and recreational fisheries. Because of our extensive coastline and differences between areas, it is difficult to adequately monitor changes for all species. Intertidal zones are generally more amenable to long term sampling and monitoring studies given limited resources. Also, research on the vast array of sea life available in this region may provide useful insight into the possible processes acting in other areas or zones of interest.

The intertidal zone is unique for a number of reasons. First, because of tidal action the organisms in this zone are affected by both oceanographic and atmospheric conditions. The degree to which these two factors influence creatures in the intertidal zone depends to a large extent on their location in this zone. Those organism in the upper reaches of the beach will be exposed to the atmosphere for significant portions of their life. They will be exposed to far greater temperature extremes than animals that are submersed in salt water for most of their lives. These factors will impact various aspects of the life cycle: most notably growth, recruitment and survival. It is therefore important to consider both oceanographic and meteorological factors when attempting to quantify changes in this ecosystem.

The second unique aspect of this zone is the types of life one might expect to find in this area (Table 1). Many species, such as small crabs and fish, will move in and out with the tide. However, adult stages of the commercially important species such as clams, mussels and oysters (Quayle and Bourne 1972) lack such mobility. These animals can not merely move to more favourable environmental conditions. They must either adapt to living in sub-optimal conditions or perish.

Lastly, this is the interface between our marine and terrestrial environments and there are and will be significant changes in climate and community structures over relatively short geographic distances. Most of us enjoy going to the beach and this remains our most common interface with our marine environment. Over time we have developed certain expectations or notions about this area. Changes here are likely to be noticed sooner than changes in other areas of our marine environment not because they will be more significant but because we are more aware or familiar with this part of the marine ecosystem.

RESPONSE TO CHANGE

Environmental change will, of course, result in changes in a number of areas. Species composition is very much related to habitat and changing sea levels will result in some shifts in species mix. The species found in the intertidal zone are, however, remarkably tolerant and can adapt to sub-optimal conditions (Table 2). For example, introduced species such as manila clams adapted quite well to the environmental conditions found on this coast and spread at a remarkable rate (Bourne 1982). One would therefore expect changes in relative abundance and not the disappearance or introduction of different species.

Factors affecting growth are likely to be similar to other species. Animals are liable to respond to both absolute and relative fluctuations in temperature and food mixture and availability. Filter feeders, such as clams and other mollusks, depend on phytoplankton and changes in primary productivity will have significant affects on this community. Changes in growth may correspond to shifts in temperature or salinity. It is likely, however, that such relationships are symptomatic rather than causative. That is, temperature fluctuations result in direct changes in food type and availability. These changes are then filtered through to the next level of production, the mollusks. The links between environmental conditions and food production and distribution at this scale are poorly understood. Thus, although there may be an obvious conceptual connection between environmental factors and growth, development of useful predictive tools will be sometime in the future.

Considerable effort has been expended investigating possible links between environmental conditions and the recruitment of fish stocks (see for example Sinclair et al. 1988). Success has at best been limited. Like so many other fisheries, recruitment of commercially important invertebrate species is thought to be sporadic with exceptional year-classes resulting from favourable environmental conditions. Temperature is thought to have a significant impact on the initiation of spawning (Nickerson 1975) but other oceanographic conditions appear to play an important role in the settlement and development of new recruits. Exactly how the various processes are linked is unknown.

Besides man, the two main causes of mortality are predation and temperature extremes. Predator abundance will be established through an intricate balance in the marine ecosystem and may increase or decrease in both absolute and relative terms. Perhaps as important as predators will be the effect of temperature extremes. Some of the species found in the intertidal zone can withstand freezing temperatures (Table 2). Changes in absolute temperature extremes or the rate of temperature change could affect certain biological processes including survival.

In general, we do not fully understand some of the biotic and abiotic processes which determine the biological responses to climatic change. We can, however, use what we know to speculative on plausible outcomes given reasonable scenarios. In the following sections, we present evidence to suggest general trends in growth, recruitment and mortality expected from climatic change. Recommendation on key areas of further research and monitoring are discussed.

MATERIALS AND METHODS

Studies dealing with species found in the intertidal zone (and other species and zones) have been of limited scope and duration. In many instances, the link between the biological processes of interest and the environment is poorly understood or established only within a limited range. In the following sections, we present case studies relating growth, recruitment, and mortality to environmental variation. Based on these examples, we speculate on plausible links with other species.

GROWTH

A number of studies have considered size-at-age, growth, and maturity of marine bivalves (see for example Harbo et al. 1983; Ohba 1959; Weymouth and McMillin 1930, Yamamoto and Iwata 1956). A few have consider the relationship between temperature, growth and reproduction (see for example Mann 1979). The link between temperature and growth is, however, somewhat indirect in that temperature changes cause fluctuations in primary production (the food) which in term result in increased or decreased growth. Temperature changes may directly affect growth if accompanied by shifts in metabolic rates.

Annual growth data for geoduck clams located in Ladysmith Harbour, B.C. were considered in this study (Noakes and Campbell, 19xx). Although they may be found in the intertidal zone, geoducks are primarily sub-tidal. They are, however, filter feeders as are most other bivalves. Because of this common physiology and their proximity to the intertidal zone, we assume that environmentally induced changes in geoduck growth will be representative of other bivalve species found in the intertidal zone.

Acetate peels were made from cross-sections of the right shell portion of each clam. The number and distances between the annuli in shell cross-sections were used to determine age and growth. Von Bertalanffy growth curves, fitted for each clam, were used to calculate the expected growth in each year. Relative growth was then calculated by dividing the observed annual growth by the expected annual growth for each individual. Indices from individual clams were then averaged to determine the relative growth in each year back to 1907 (Figure 1a).

These growth indices were compared to annual air temperatures recorded at the Gonzales Station, Victoria, B.C. (Figure 1b). Air temperatures were used in this study because existing sea surface temperatures from this area only began in the mid-1930's. Also, we found that annual air temperatures were highly correlated with sea surface temperatures ($r = 0.77$). Thus the use of air temperatures instead of sea surface temperatures should not significantly influence, at least qualitatively the general relationship between growth and temperature change.

RECRUITMENT

There have been few serious attempts to link stock and recruitment for invertebrate species. The common belief is that recruitment is basically a random event with occasional large recruitments occurring when environmental conditions are favourable. There is some evidence to suggest that temperature influences at least the initiation of spawning in some bivalves (Nickerson 1975). In general, the links between environmental conditions and recruitment are poorly understood.

The best information we have on recruitment of bivalves in B.C. is for Pacific oysters. Quayle (1988) monitored spawning intensity near Ladysmith from the early 1930's to 1981. Spatfall was recorded as the average number of spat settling on discarded oyster shells. Spawning was considered to be significant if more than 10 spat were deposited per shell (Table 3).

Nickerson (1975) used degree days since January 1st to determine when razor clams would spawn. In this spirit, we looked at the average temperature for the period June 1 to August 31 to determine if there was a relationship between temperature and spawning intensity (Figure 2). Daily sea surface temperatures at Entrance Island, B.C. were used in this analysis.

MORTALITY

Information concerning mass mortalities of clams in the intertidal zone is for the most part anecdotal. There has been no effort to routinely monitor beaches to determine if or to what extent severe environmental conditions caused significant mortalities. The most common event seems to be mortalities due to

extremely cold periods in the winter. Notable mortalities within the Strait of Georgia occurred in 1968, 1985, and 1989 (Bower et al. 1986; Neil Bourne and Susan Bower, pers com.). There may have been other mass mortalities. However, these other instances were either undetected or unreported.

Calculated hourly tidal heights at Point Atkinson, B.C. were used to determine periods when the low tide mark fell below a specified elevation above the zero datum (2 m in this study). Hourly dry bulb air temperatures measured at the Victoria Airport were then used to determine minimum exposure factors. Exposure factors were calculated as the air temperature times the duration the beach was exposed to air. For instance, if the beach was exposed for 3 hours at an average temperature of -10°C , the exposure factor was calculated as -30°C h . The same exposure would be calculated for a beach exposed for 6 hours at -5°C . The absolute minimum exposure was calculated for each year to determine if a pattern existed between the notable mass mortalities and periods of extreme exposure. It is also plausible that mortality occurs only after repeated exposure to extreme cold. Consequently, in addition to estimating the absolute minimum each year, the number of days the exposure fell below a given threshold (-30°C h) was also determined.

RESULTS

GROWTH

The estimated geoduck growth indices have an expected value of 1. Thus values greater than 1 represent periods of above average growth while indices less than 1 correspond to intervals of below average growth. The time series of growth indices (Figure 1a) indicates three distinct growth regimes. The first portion of the series, 1907 to about 1920, fluctuated around 1. This represents a period of average growth. Above average growth appeared to have occurred from 1920 to about 1960, with most values during this period being somewhat greater than 1. Since the early 1960's, there has been a sharp decrease in growth rate which has persisted until the series ends in 1980. This decrease was substantial, representing nearly a 30% decrease in annual growth compared to the previous 40 years of data (Noakes and Campbell 19xx). This decline coincided with the initiation of log booming and storage in Ladysmith Harbour (Anon. 1976).

The above average geoduck growth around 1920 corresponds to a general increase in air temperature (Figure 1b). A rise of about 0.5°C in mean annual air temperature resulted in an 8% increase in geoduck growth (Noakes and Campbell 19xx). A cold period during the mid to late 1940's resulted in decreased growth during this period. After 1960, the relationship is less apparent due to the overwhelming impact of logging practices.

RECRUITMENT

Mean sea surface temperatures between June 1st and August 31st at Entrance Island ranged from 14.6°C in 1939 to 18.6°C in 1958 (Figure 2). A striking feature of this data is the apparent shifts in variance over time. Variance appeared to be quite high from 1936 to 1943 and from 1958 to 1967. Since 1980, temperature has increased in almost a linear fashion while at the same time exhibiting very little variability. There is no obvious reason for this observed behaviour.

Relatively high mean sea surface temperatures between June 1st and August 31st coincided with significant oyster spawnings in 1936, 1942, 1958, 1961, and 1967 (Table 3). The largest spawning occurred in 1958 when the average temperature reached 18.6°C. Temperatures in 1956 and 1971 were 15.8°C and 15.7°C, respectively, and do not fit the pattern observed for the other significant spawning events. The magnitude of these two spawnings was, however, smaller than those mentioned previously.

MORTALITY

Minimum cumulative exposures ranged from -5.1°C h in 1976 to -73.2°C h in 1968 with a mean of -29.4°C h (Figure 3). Although exposures were severe in the three years of significant clam mortalities (1968, 1985 and 1989), exposures in 1963, 1964, 1969 and 1972 were as severe as those recorded in the mildest of the three years 1985 (-45.6°C h). The most prolonged cold spells occurred in 1972, 1983 and 1989 when 6, 5 and 4 days, respectively, had exposure factors less than -30°C h. In 1983, this cold spell occurred over 5 consecutive days while in 1972 and 1989 the cold spells were punctuated by 1 or more days when exposure factors were higher than the threshold of -30°C h.

Discussion

Geoduck growth and temperature appear to be related in a positive sense. An increase in annual temperature approximately 0.5°C around 1920 was coincident with an 8 percent increase in growth for geoduck clams in Ladysmith Harbour. The precise nature of the relationship is unclear at this time but it does not appear to be linear. Since geoduck physiology is similar to that of other bivalve species found in the intertidal zone, we speculate that changes in growth for these other species will be similar to those found in this study. If sea surface temperatures rise by 1 or 2°C, it is possible that bivalve production could be increased by 10 or 20 percent due to increased growth.

There also appears to be a positive relationship between temperature and recruitment of Pacific oysters. Significant oyster spawnings were recorded when average sea surface temperatures between June 1st and August 31st were at or above 17.4°C. There is some evidence to suggest that temperature influences spawning activities in other species of bivalves (Bourne 1982; Nickerson

1975). If true, then elevated temperatures during the spring and summer months could result in increased recruitment of juvenile bivalves. This may or may not result in increased production. Food and habitat availability, increased predation and disease, and other deleterious effects of warming may negate any gains associated with increased spawning success.

It is certainly plausible that cold temperatures may lead to mass mortalities of certain clam species (Bower et al. 1986). This is particularly true of manila clams which inhabit the higher reaches of the beach. Some of the global warming scenarios have suggested that although mean temperatures will increase, there may also be an increase in the frequency of extreme events. If so, then more frequent severe cold spells could lead to more frequent mortalities of clams and other bivalves in the upper portions of the intertidal zone.

There are obviously important gaps in our understanding of the biology of many invertebrate species and how environmental conditions influence behaviour and population dynamics. Understanding recruitment and its relationship to stock size and the environment will require significant resources over an extended period of time. Given the relative size of these fisheries, such an investment may be unwarranted. A more reasonable approach would be to accept the assumption of average recruitment in most years and attempt to determine which environmental factors produce significant year-classes.

Determining links between environmental change, growth and mortality may be more tractable. Unlike recruitment which influences a single age-class, changes in the environment will be reflected in the growth rates of individuals of all ages in the population. Geoduck growth and temperature seem to be related in a positive sense and we speculate that same may be true for many other bivalve species. Also, unlike recruitment where several years may elapse before animals recruit to the fishery, growth effects are evident within a year. Time lags associated with mass mortalities are also short allowing researchers to sharpen and test their hypotheses more quickly. Tide and weather predictions are often timely enough to allow samples to be taken before and after extreme events.

The findings presented in this study have implications to both the wild stock fisheries (recreational and commercial) and aquaculture sectors of the shellfish industry. Elevated sea temperatures could lead to increased growth and recruitment for species found in intertidal and sub-tidal zones. Both would increase the value of the commercial fishery and inflate profit margins for existing or future mollusc culture operations. Coupled with these changes, however, is the possibility of more frequent and more intense extreme climatic events. Severe cold or hot spells could increase mortality rates for species in the upper

reaches of the beach. Manila clams inhabit these areas and are currently the focus of both commercial fishing and aquaculture operations. A general warming trend and an increase in extreme events has the potential to create volatility in this sector both in terms of supply and price.

Recommendations

1. Plausible links between environmental variation (primarily temperature) and bivalve growth should be investigated. This is especially important given the increasing interest in mollusc culture in British Columbia.
2. If extreme climatic events (particularly extreme cold) are forecasted to occur during a low tide cycle, samples should be taken before and after these events to determine if or to what extent mortalities have occurred.

Acknowledgements

We thank Howard Freeland for supplying the calculated hourly tidal heights and some of the sea surface temperature data employed in this study. Hourly air temperature data were obtained from Atmospheric Environment Services, Toronto. Dr. Frank Bernard (deceased) collected and processed the geoduck shells used in this study. Geoduck age and growth determinations were done by Susan Stradsine.

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Table 1. Major intertidal species that are exploited commercially in British Columbia.

Common Name	Latin Name	1988 Landed Value (\$ X 10 ³)
Manila clam	<u>Tapes philippinarum</u>	7,000
Littleneck clam	<u>Protothaca staminea</u>	357
Butter clam	<u>Saxidomis giganteus</u>	40
Pacific oyster	<u>Crassostrea gigas</u>	3,500
Blue mussel	<u>Mytilus edulis</u>	4
Gooseneck barnacle	<u>Pollicipes polymerus</u>	392
Sea asparagus	<u>Salicornia virginica</u>	75

Table 2. Habitat preference, geographic range, and temperature and salinity tolerances for the major intertidal species that are exploited commercially in British Columbia. Intertidal range given as meters above datum.

Species	Intertidal and geographic range	Temperature and salinity tolerances
Manila clam	0.0 - 3.0m; 38N - 60N	0 - 23°C; 11 - 32 ppt
Littleneck clam	0.0 - 2.0m; 23N - 60N	0 - 27°C; 20 - 32 ppt
Butter clam	0.0 - 1.5m; 37N - 60N	-1 - 26°C; 20 - 32 ppt
Pacific oyster	0.0 - 3.0m; 38N - 60N	-4 - 32°C; 11 - 32 ppt
Blue mussel	0.0 - 3.0m; 23N - 71N	-4 - 30°C; 10 - 32 ppt
Gooseneck barnacle	2.1 - 2.9m; 30N - 57N	?
Sea asparagus	3.5m +; ?	?

Table 3. Significant oyster spawnings in Ladysmith,
British Columbia, 1936 - 1980.

Year	Magnitude of spatfall
1936	2 sets, 100 per shell
1942	50 per shell
1956	10 - 25 per shell
1958	up to 500 per shell
1961	30 - 46 per shell
1967	50 per shell
1971	30 per shell

Not monitored after 1981.

Source: Quayle 1988.

Figure Captions

- Figure 1: a) Standardized geoduck growth in Ladysmith Harbour, B.C. and b) mean annual air temperature at the Gonzales Station, Victoria, B.C. for the period 1907 - 1980, inclusive. A standardized growth of 1 indicates average growth. Values above or below 1 signify relatively good or poor growth, respectively. The lowest curve line in panel b represents average trends in air temperature over time.
- Figure 2: Mean sea surface temperature at Entrance Island, B.C. for the period June 1 to August 31, inclusive. Annotated years indicate significant oyster spawnings as identified by Quayle (1988).
- Figure 3: Minimum annual exposure, in degree hours, of clams in the mid-intertidal region (2 m above datum). Exposures were calculated as hourly air temperatures ($^{\circ}\text{C}$) times the duration (hours) of exposure to air. The estimates represent the minimum value observed during each calendar year. The most extreme event during the period 1960 to 1989 was -73.2°C h in 1968.
- Figure 4: Duration and frequency of minimum exposure rates. Only exposure rates less than -30 degree hours were considered. The harshest year was 1968 (-73.2°C h) while 1972 had the most number of days (6) with exposures less than or equal to -30°C h .

Figure 1a and 1b

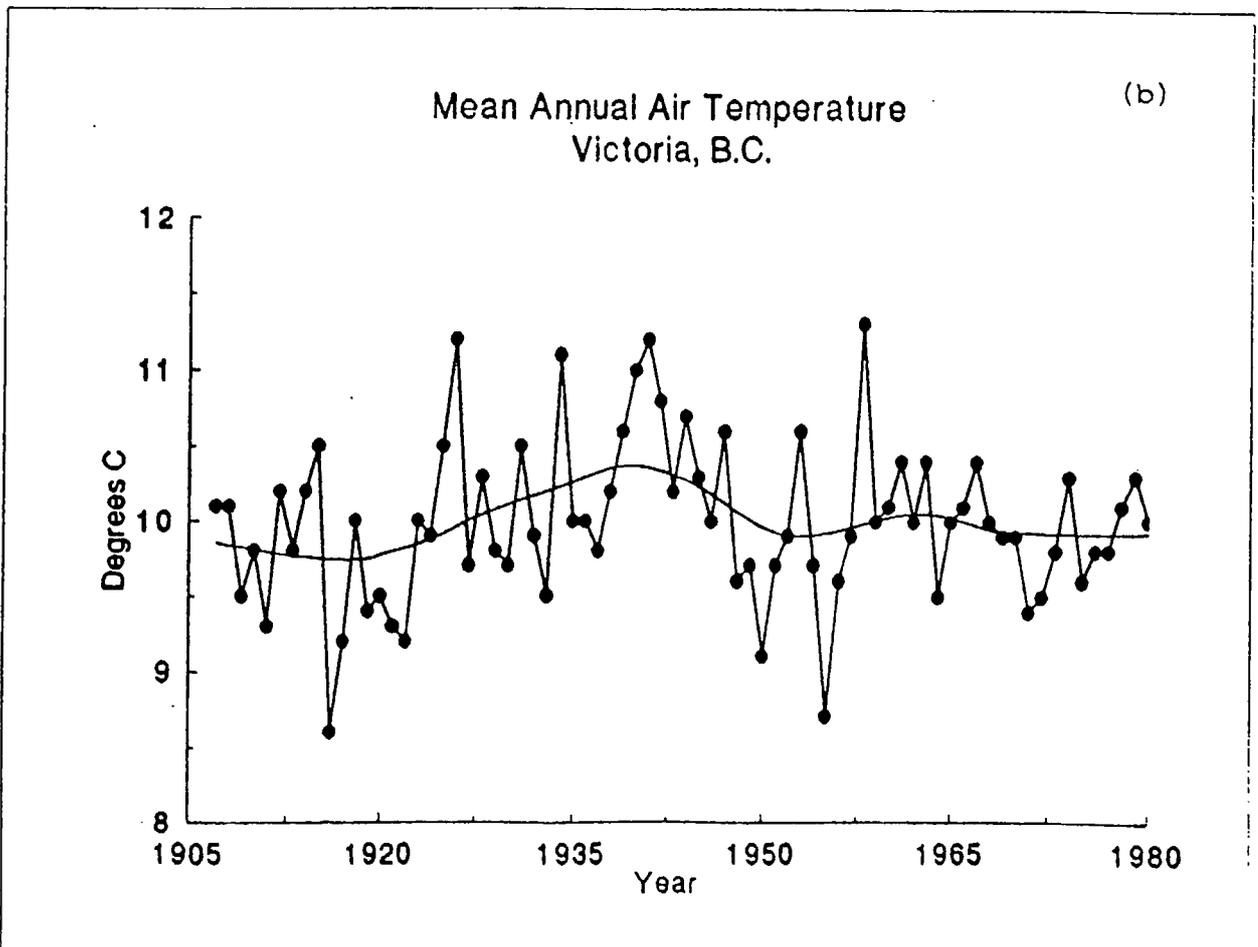
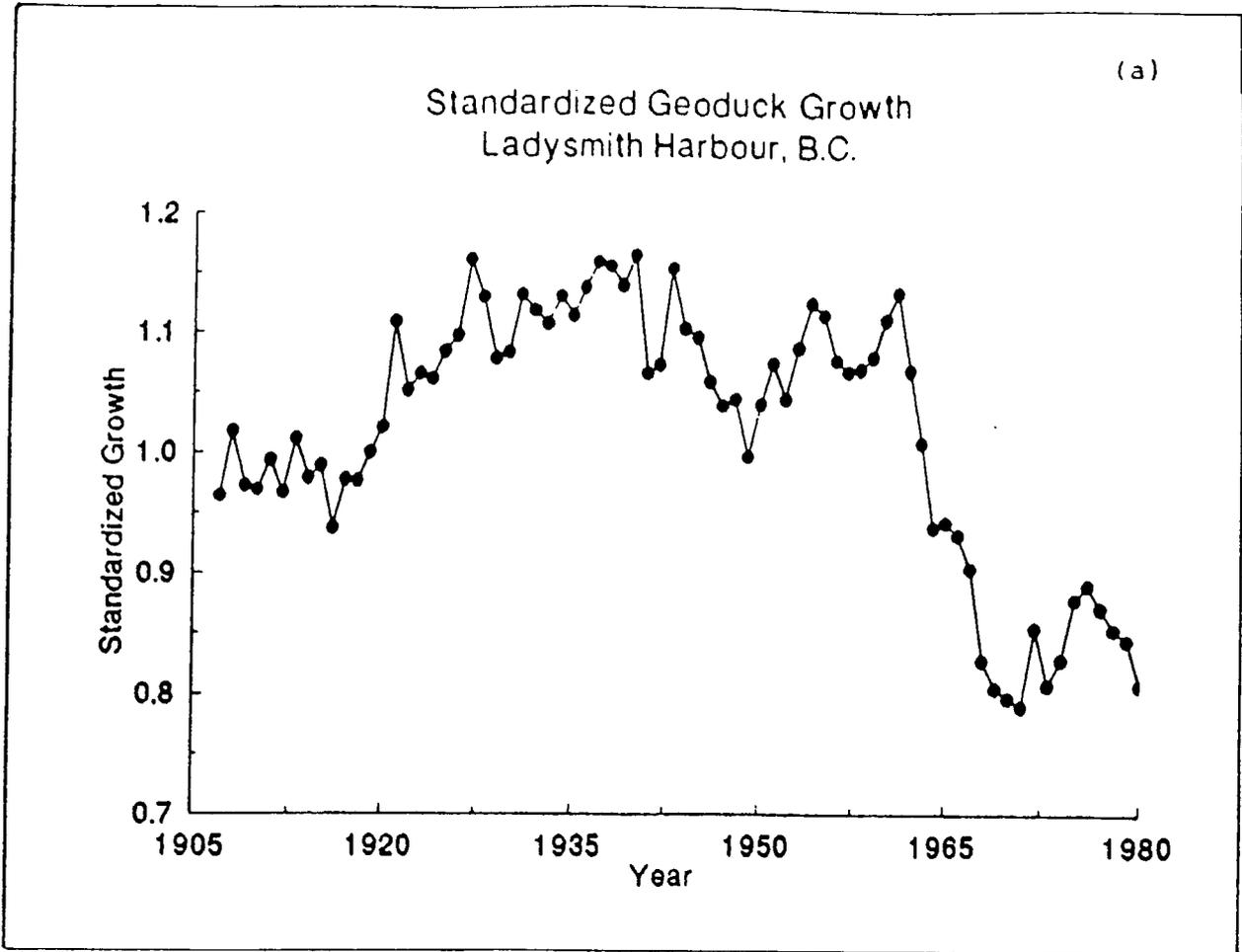


Figure 2.

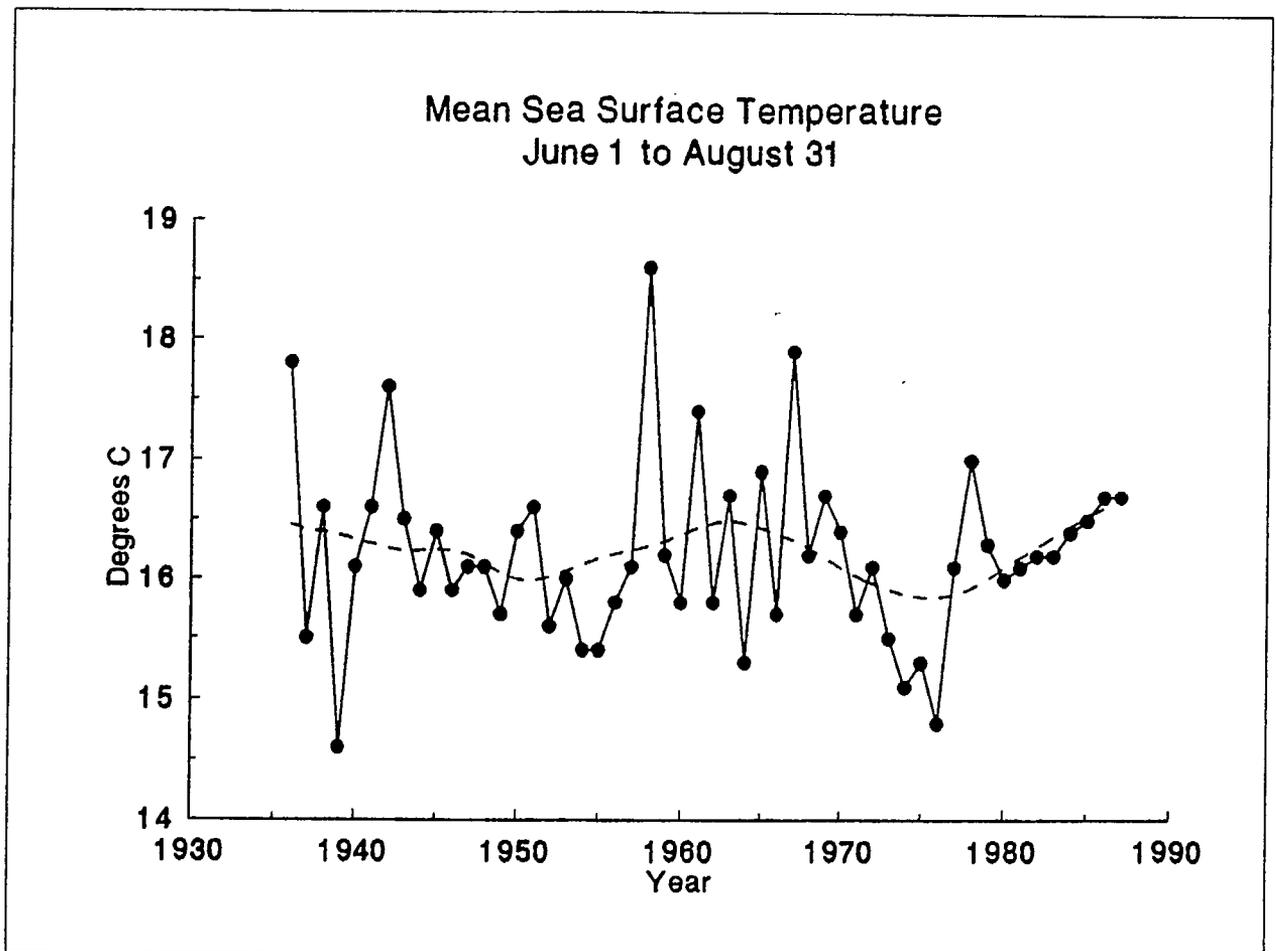


Figure 3.

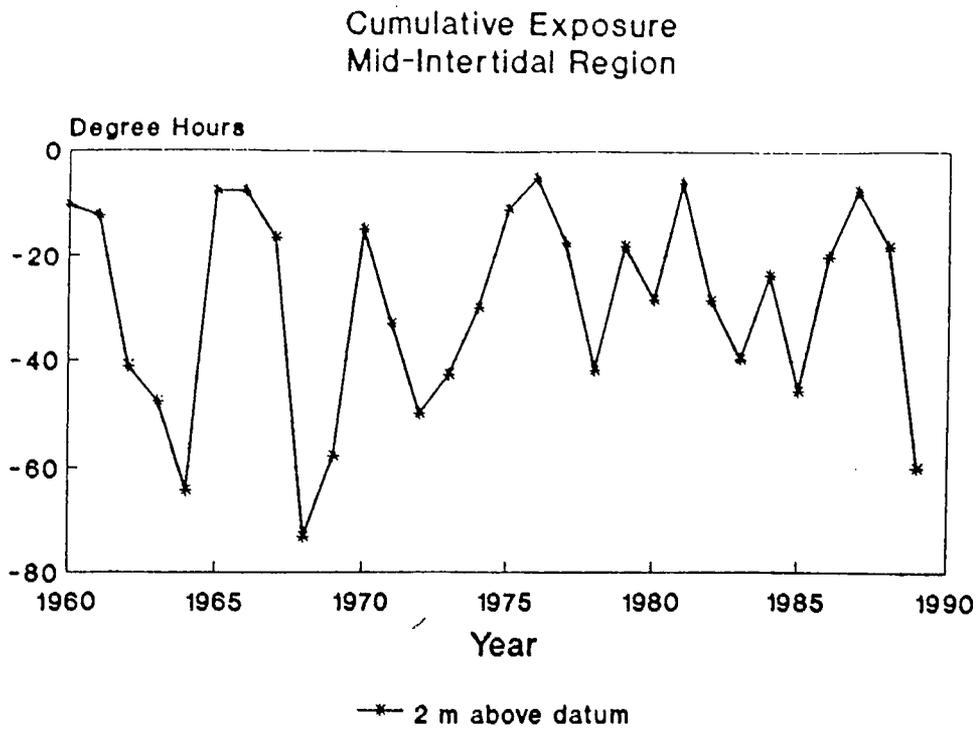
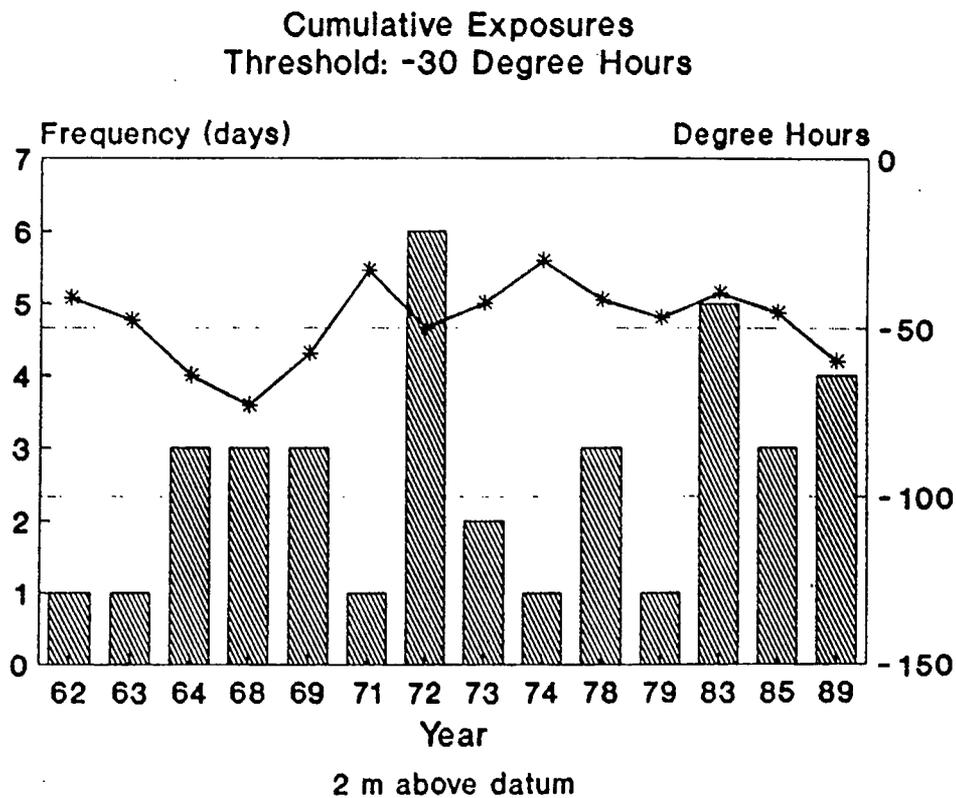


Figure 4.



11. FISHERY UPDATES

1. Shrimp By Trawl Fishery

by

K. Lynn Yamanaka

Shrimp fishing by trawl gear became a limited entry fishery in 1978. There are presently 249 vessels eligible for 'S' tabs, however in 1989 only 165 of these vessels reported landings by either sales slip or log book records.

The total 1989 B.C. shrimp catch reported from sales slips corrected by log book records (PBS database - John Fulton 30 July 1990) is 2427.43 t (Figure 1). Shrimp catch by trawl gear for 1989, is shown by statistical area in figure 2. The greatest catch was taken from area 124 (Tofino) for the Offshore, area 29 (Vancouver) for the Fraser River, area 17 for the South Coast, and area 4 (Chatham Sound) for the North Coast. Effort in hours of shrimp fishing is shown by statistical area in figure 3. Catch in kilograms per unit of fishing effort is shown by statistical area in figure 4. Catch per unit of effort was greatest in area 124 for the Offshore, area 28 for the Fraser River, area 15 for the South Coast, and area 2 for the North Coast.

The preliminary total 1989 B.C. shrimp catch reported by DFO Statistics Unit from sales slips to 19 May 1990 is 1719.294 t. Percentage of total catch and prices by month are shown for B.C. in figure 5, Fraser River in figure 6, North Coast in figure 7, and the South Coast in figure 8. Fraser River shrimp catch (106.954 t) is distributed throughout the year with little activity in the months of July, August, and December. Prices remained fairly constant (average \$2.26/kg) with a low in June (\$1.75/kg) and high in December (\$3.22/kg). The North Coast catch (24.057 t) fluctuates widely through the year with no activity reported for January, July, and August. Average prices are high due to 'treated' sidestripe shrimp prices as high as \$8.82/kg. The South Coast catch (1588.283 t) is distributed mainly from May to October with little activity from November to April. Prices remained fairly constant (average \$1.07/kg) through the year with the higher prices paid from January (\$1.91/kg) to March.

figure 1

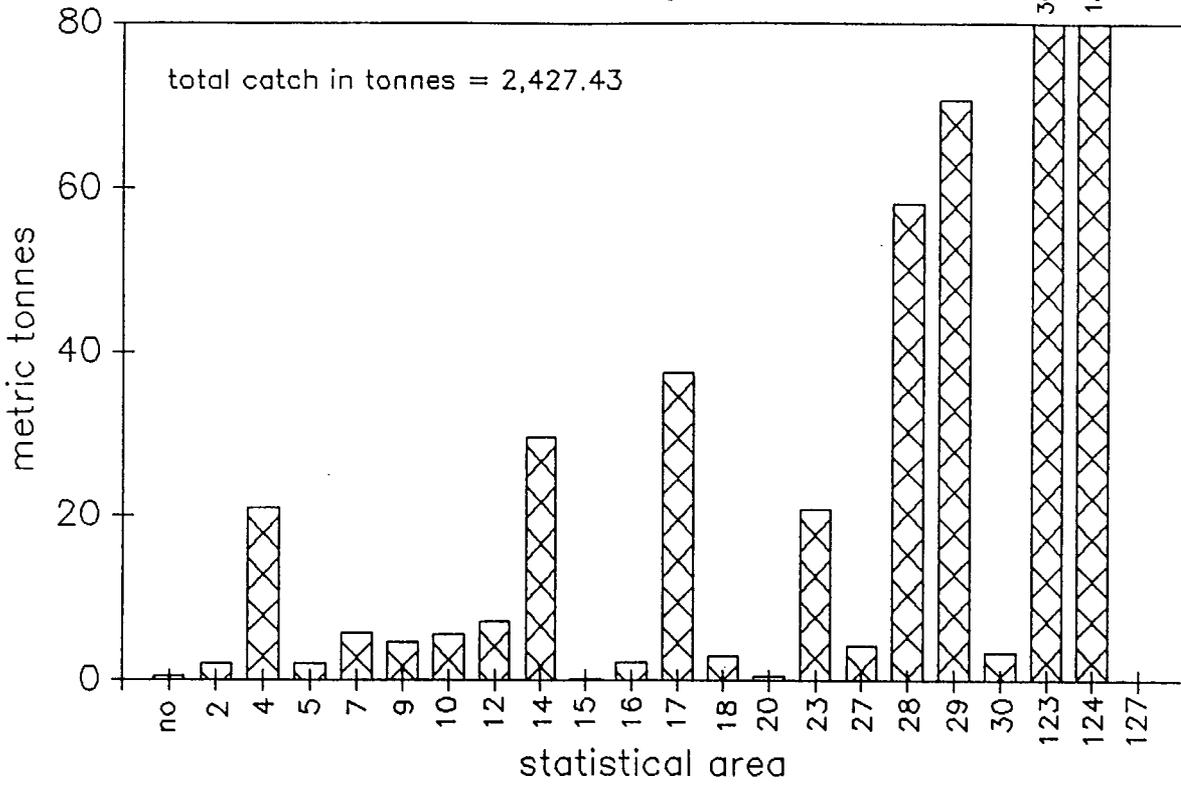
1989 SHRIMP CATCH corrected from sales slips *

STAT AREA	CATCH MT	EFFORT hours	CPUE kg/hr	DAYS FISHING
no	0.529	52	20	9.42
2	2.207	37	112	6.72
4	20.855	895	46	162.76
5	1.979	114	34	20.67
7	5.783	120	96	21.82
9	4.636	216	42	39.27
10	5.547	272	40	49.38
12	7.163	675	21	122.66
14	29.583	1409	41	257.54
15	0.255	8	61	1.52
16	2.147	194	22.1	35.20
17	37.498	2568	29.2	466.94
18	2.948	207	28.4	37.63
20	0.550	29	37	5.27
23	20.695	876	47	159.23
27	4.202	289	29	29.00
28	58.233	2218	52	403.20
29	70.780	5091	27	925.70
30	3.413	61	112	11.02
123	303.088	3148	192	572.42
124	1845.380	7691	480	1398.35
127	0.096	14	13	2.62
TOTAL	2427.43	26190	185	4761.91

* PBS database - John Fulton

figure 2

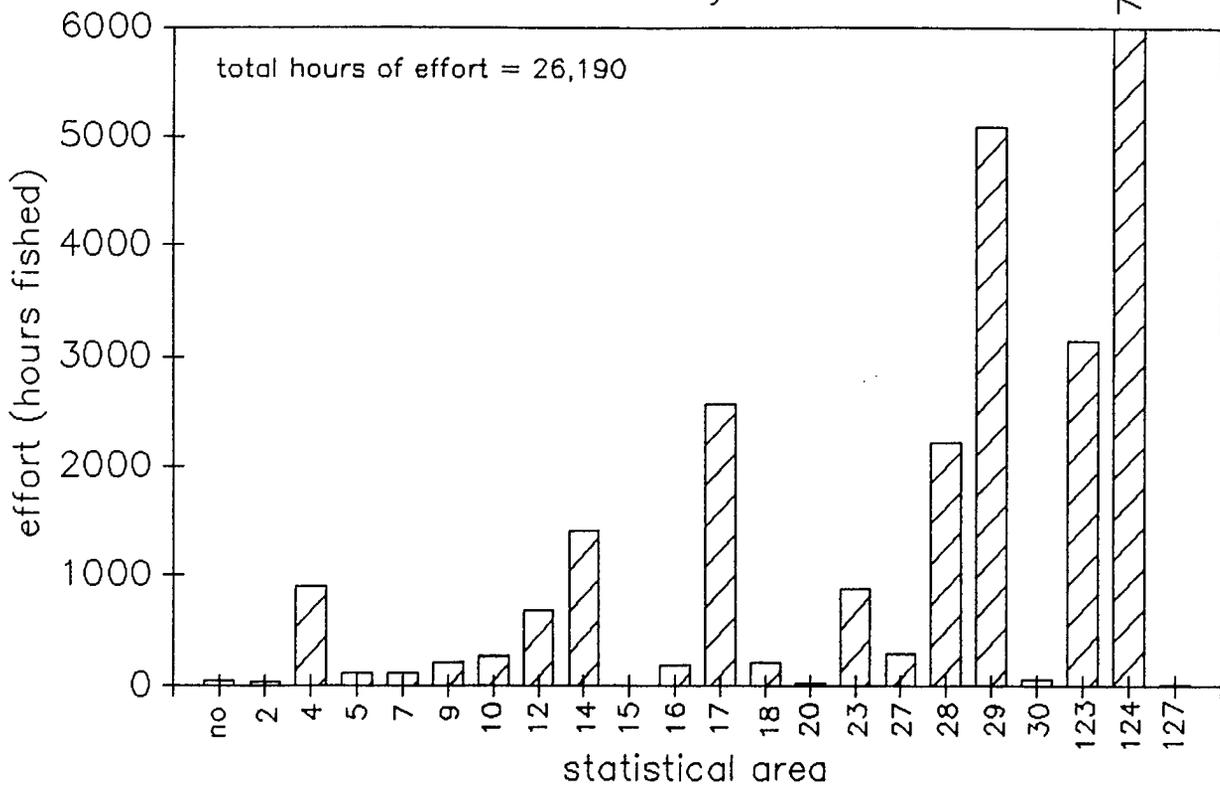
SHRIMP BY TRAWL 1989 *
catch by area



* data from log records and sales slips

figure 3

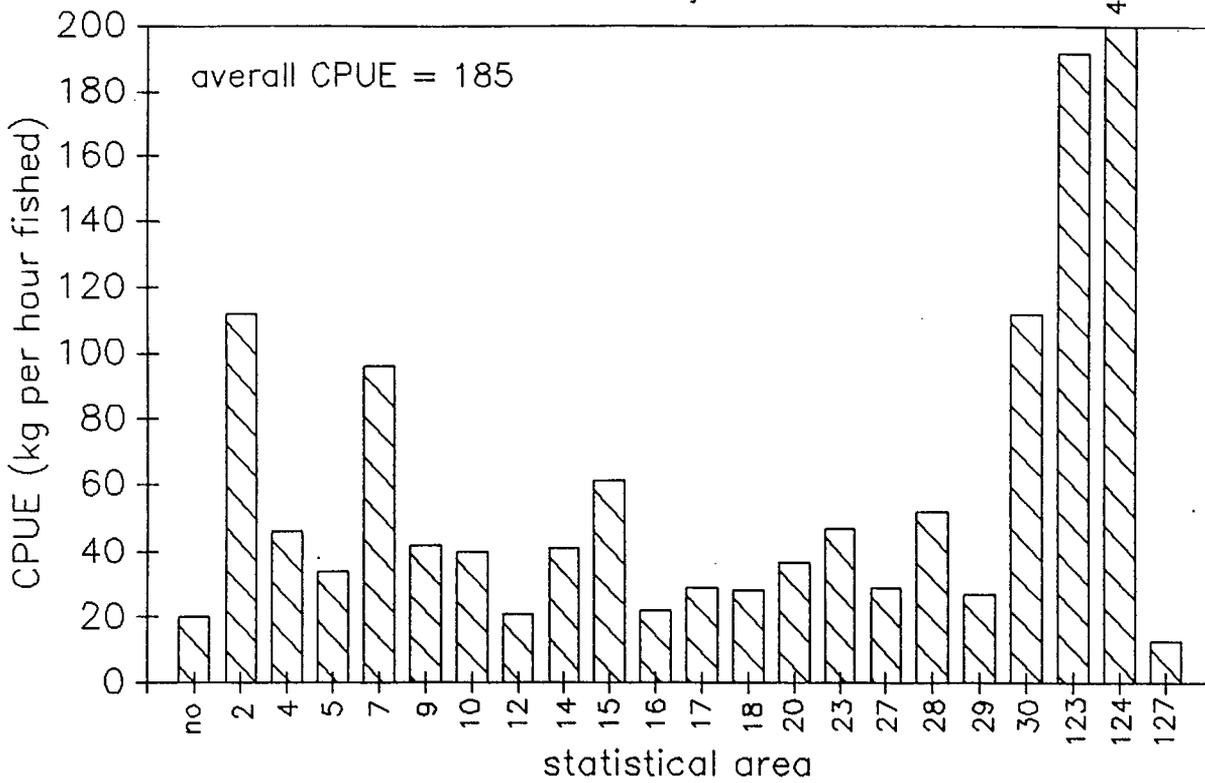
SHRIMP BY TRAWL 1989 *
effort by area



* data from log records and sales slips

figure 4

SHRIMP BY TRAWL 1989 *
 CPUE by area

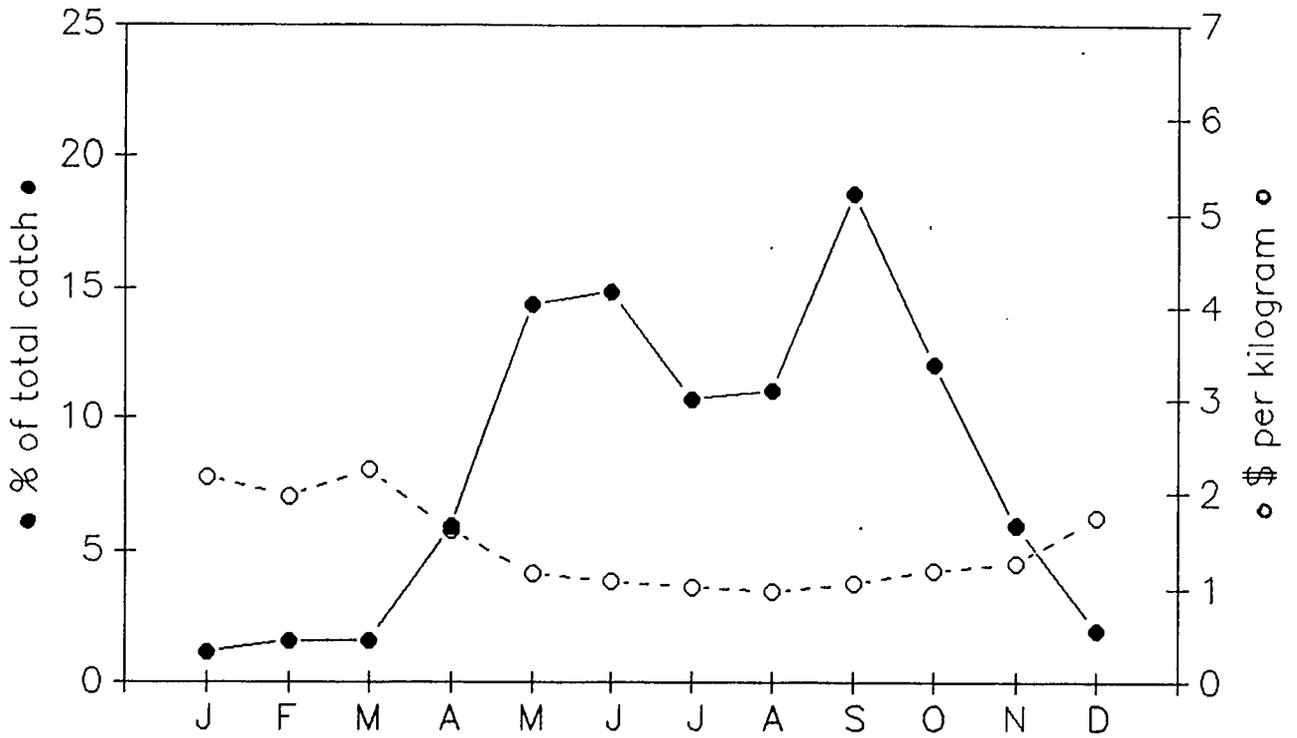


* data from log records and sales slips

figure 5

1989 TOTAL % B.C. SHRIMP CATCH AND PRICES BY MONTH *

TOTAL B.C. SHRIMP CATCH = 1,719.294 MT

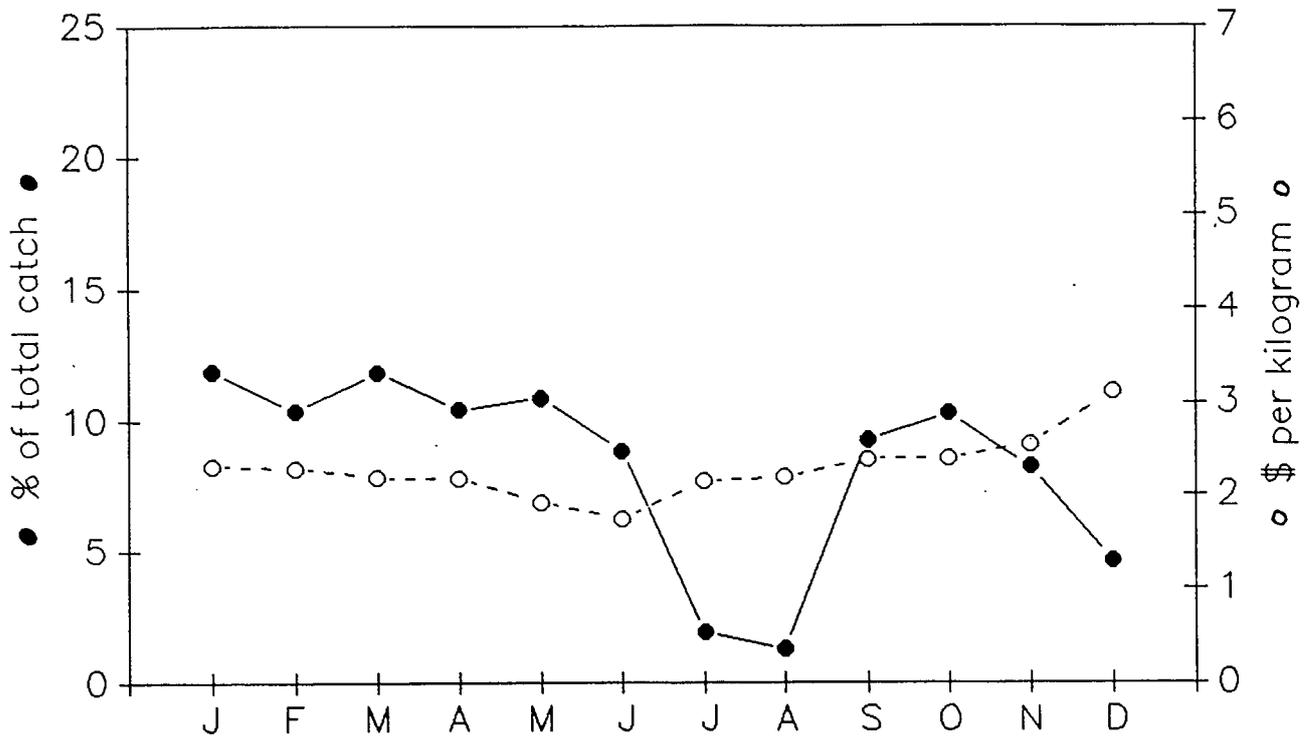


* preliminary 1989 data DFO Statistics Unit from sales slips to 19 May 1990

figure 6

1989 TOTAL % FRASER DISTRICT 1 SHRIMP CATCH AND PRICES BY MONTH *

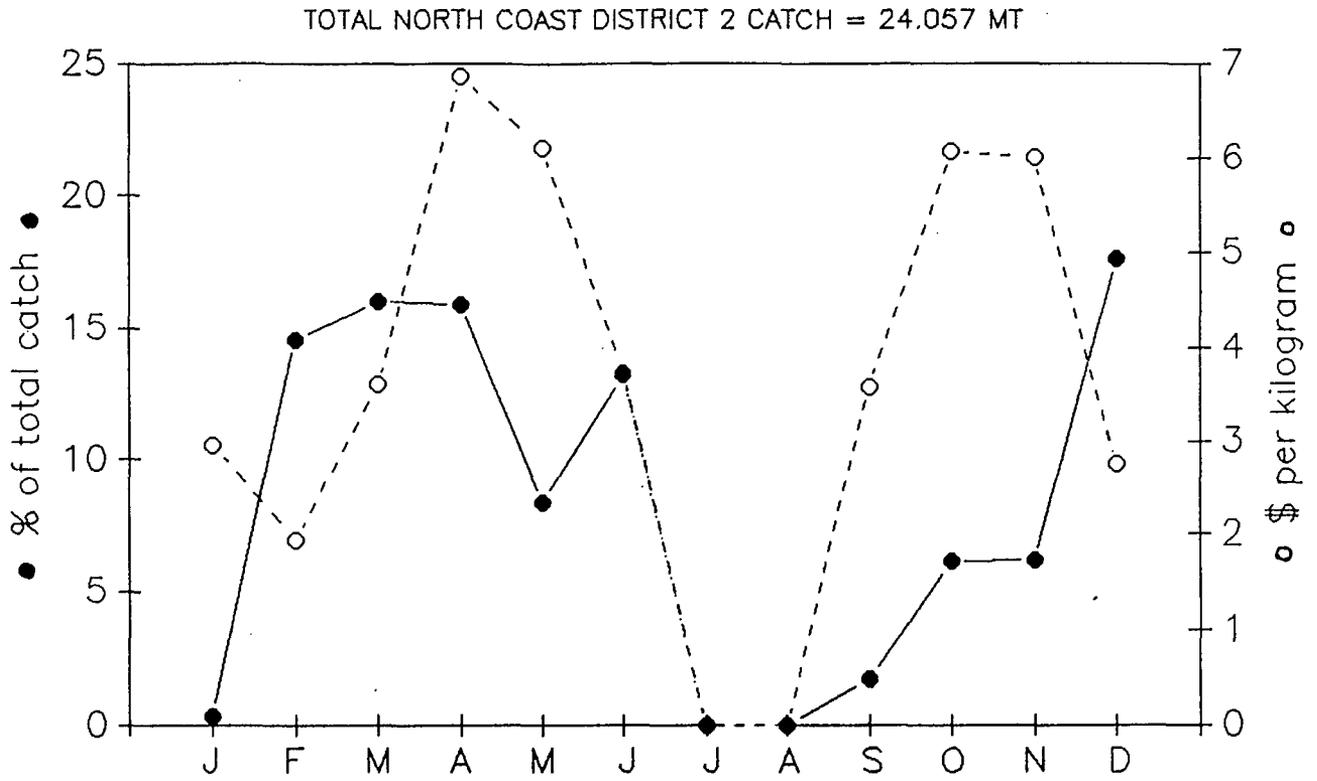
TOTAL FRASER DISTRICT 1 CATCH = 106.954 MT



* preliminary 1989 data DFO statistics Unit from sales slips to 19 May 1990

figure 7

1989 TOTAL % NORTH COAST DISTRICT 2 CATCH AND PRICES BY MONTH *

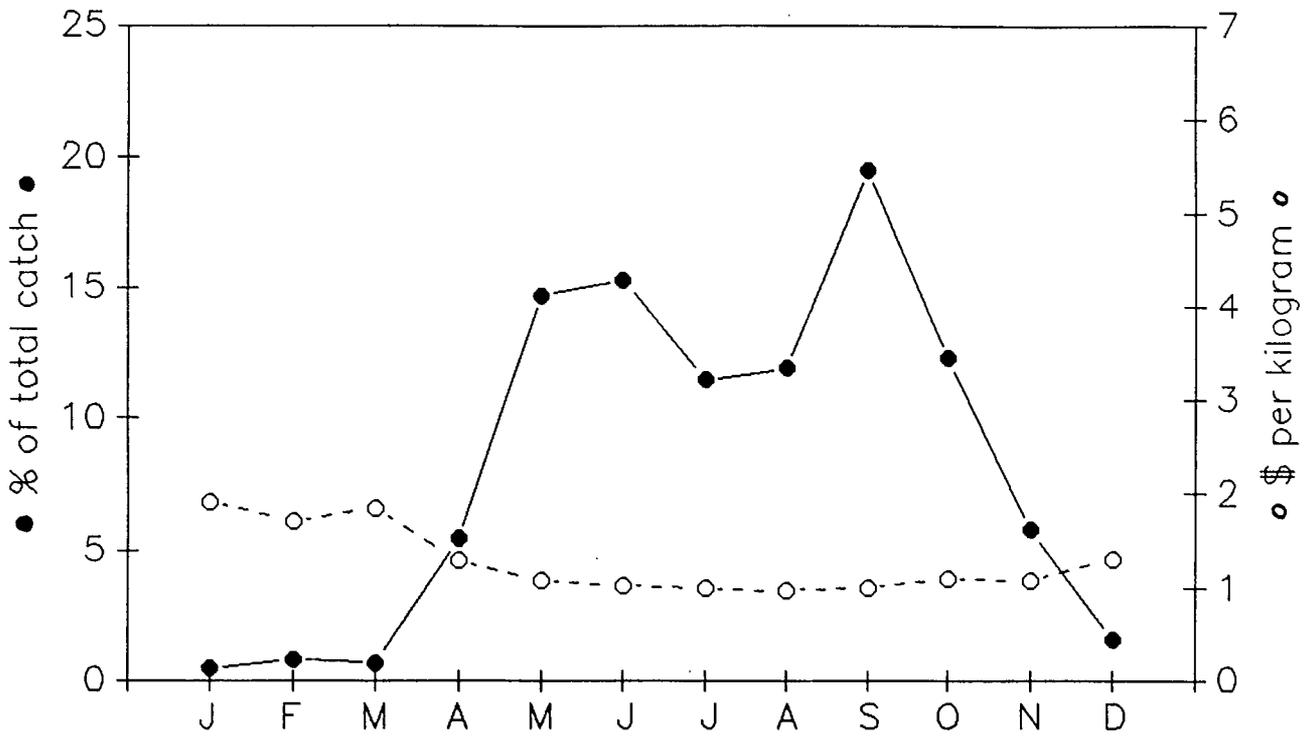


* preliminary 1989 data DFO Statistics Unit from sales slips to 19 May 1990

figure 8

1989 TOTAL % SOUTH COAST DISTRICT 3 CATCH AND PRICES BY MONTH *

TOTAL SOUTH COAST DISTRICT 3 CATCH = 1588.283 MT



* preliminary 1989 data DFO Statistics Unit from sales slips to 19 May 1990

2. Plankton Fishery

by

J. Fulton

INTRODUCTION

Total catch for 1989 was 380 tonnes with a landed value of \$223,000 up slightly from 1988 (Table 1, Fig 1). The fishery has remained concentrated in Areas 15 and 16 although some small test fisheries were prosecuted in six other statistical areas. Forty-nine licences were issued and fifteen vessels reported catches in 1989.

FISHERY MANAGEMENT

The 1990 regulations set a quota of 215 t in Strait of Georgia; 40 t in Howe Sound; 35 t in Jervis inlet; 20 t in Toba inlet; 30 t in Homfray-Price-Lewus channels; 75 t in Bute inlet; 10 t in Loughborough inlet and 75 t in Knight inlet. There is a closure June 1 to August 15, by regulation, that can be varied.

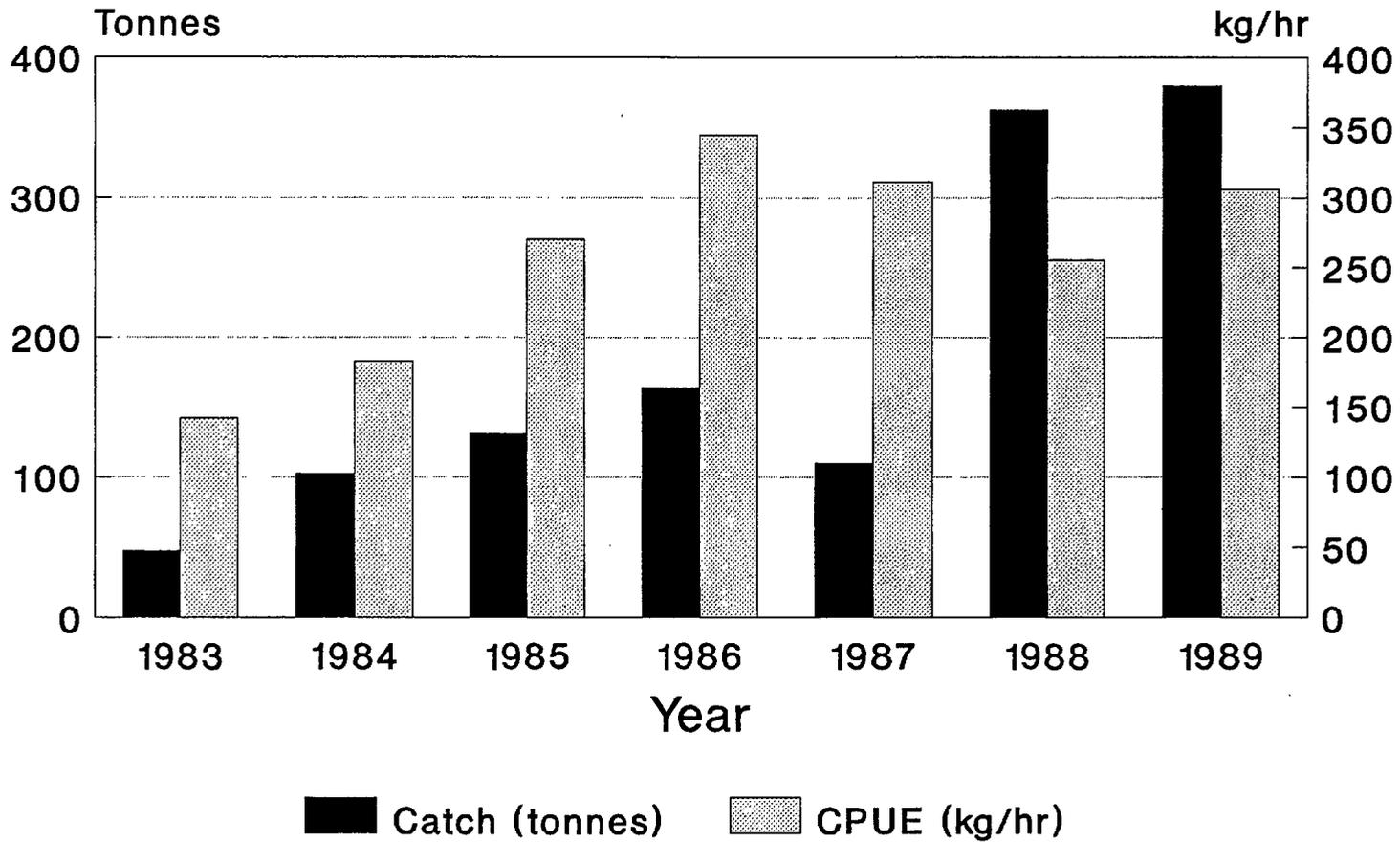
CONCERNS

See working paper I90-4 "Euphausiid fishery review regarding potential expansion concerns."

Table 1. The Euphausiid Fishery 1983-1989

Year	Number of Vessels	Catch Tonnes	Effort Hours	CPUE Kg/hr	Stat areas Fished
1983	2	47	333	142	13, 15, 16
1984	2	103	563	183	16
1985	2	131	486	270	16, 28
1986	2	164	475	345	16
1987	3	110	354	331	16
1988	5	363	1427	255	15, 16
1989	12	380	1070	306	12, 13, 15, 16, 17, 23, 28, 29

EUPHAUSIID CATCH & CPUE



209

logbook data

3. Squid Fishery

by

R. Harbo and K. Hobbs

Table 1 updates landings on opal squid, Loligo opalescens. Reported landings in 1989 were 70 tonnes, with Area 23 accounting for 60 t. Only 8.8 t were reported from the north coast, all from Area 7 in Feb. 1989 (Table 2).

This fishery is for bait purposes in the crab and sablefish fisheries. There is an increasing trend to use hake as bait in the sablefish fishery, so the demand for squid may drop.

Some landings are likely not reported as sales are private, to other fishermen, or for personal use as bait.

Table 2 gives landings by month for 1989. The highest monthly reports were for May-June and in September.

CURRENT ISSUES

This is currently an underutilized species. There is some interest in assessing Loligo as a predator of salmonid smolts.

The large California squid fishery produces a low priced food product. B.C. fishermen cannot currently fish and market their squid to compete in this market.

Table 1. Annual Squid (*Loligo* sp.) landings (tonnes) by Management Area, 1984 to 1989.

Year	No. Licences Fished	Total Landings (t)	Value \$10 ⁻³	Fishing Days	Management Area															
					North					South										
					1	2	4	7	8	9	12	13	14	17	18	19	20	23	24	27
1984 ³	26	69	25																	
1985	24	111	120	274	0.2	0.4		0.6	1.9		0.2		0.2	0.1	0.2	16		72	19	0.2
1986	18	89	127	288	2.0	0.9	0.1	7.3	2.3						0.2			61	16	0.1
1987	8	86	132 ²	123	0.3						0.2							0.1	67	18
1988	8	88	113 ²	98	0.2	0.1			1.2	1.9										85
1989 ¹	8	70	94 ²	94				8.8				0.5				0.1				60

¹ preliminary data from sales slips and harvest logs combined.

² estimated value.

³ area breakdown not available.

Table 2. Summary of squid landings by Management Area for 1989¹, as reported on sales slips and harvest logs.

Month	North Coast	South Coast			Total Landings
	7	13	19	23	
Jan					
Feb	8.8			4.5	13.3
Mar				4.1	4.1
Apr				0.5	0.5
May				11.8	11.8
June				19.5	19.5
July				5.0	5.0
Aug				2.9	2.9
Sept				12.2	12.2
Oct					
Nov					
Dec		0.5	0.1		0.6
Area Totals	8.8	0.5	0.1	60	70

¹ preliminary data for 1989.

4. Prawn Trap Fishery

by

B. Adkins and J. Fulton

1989 FISHERY

The total reported landings for the 1989 prawn trap fishery were 745 tonnes, an increase of 4.3% over the 1988 landings. The number of vessels reporting landings on harvest logs increased by 17% between 1988 and 1989; 305 vessels reported landings in 1989 compared to 262 vessels in 1988. The estimated total number of trap hauls increased by 27% between 1988 and 1989. Prawn (Z-H) licences were issued to 901 vessels in 1989 compared to 677 licences in 1988. Only 34% of the vessels licensed in 1989 reported prawn landings. Table 1 presents annual prawn landings and catch per unit effort data for 1982 through 1989. Table 2 shows annual landings by district, 1976 through 1989. Reported landings decreased in the north coast by 19%, from 233 t in 1988 to 189 t in 1989. Reported landings increased in the south coast to 555 t, the highest recorded landings to date.

MANAGEMENT CLOSURES - 1989

A coast wide closure was in effect up to April 1, 1989. This was only the second year a coast wide closure occurred in the commercial prawn fishery; prior to 1988 annual winter closures were in effect only in south coast areas.

SOUTH COAST

Prawn monitoring in the study areas was reported by Boutillier. In the south coast biologists carried out prawn monitoring surveys in six areas during the first quarter, six areas during the second quarter and three areas during the third quarter. The following area closures resulted:

Area 12: lower Knights Inlet, Clio Channel, Tribune Channel and Thompson and Bond Sounds, subareas 12-26, 12-27 and 12-35 to 12-37 inclusive, closed to commercial prawn fishing May 22, 1989 to April 1, 1990 as a result of a low spawner index. All remaining subareas closed November 20, 1989 also the result of a low spawner index.

Area 16: all subareas excluding the west side of Texada Island, subareas 16-19 to 16-22 inclusive closed December 3, 1989 to April 1, 1990 as a result of a low spawner index.

Area 19: as in 1988 there was a very short delayed fishery in Saanich Inlet due to limited stocks, sport fishing concerns and a traditional intensive commercial prawn fishery. This fishery opened September 11 and was closed October 5 due to a low spawner index.

NORTH COAST

All north coast areas (Areas 1 to 10) closed to commercial prawn fishing December 14, 1989 as a result of continued high effort and a low catch per unit effort and low spawner index determined from limited sampling in the central coast area (Areas 7 and 8). This closure was concurrent with the south coast closure, December 31 to April 1, 1990, to prevent an escalation of the north coast fishery following the south coast area closures detailed in the 1989 prawn fishery management plan.

There was a delayed opening of the fishery in areas 2E and 2W. These areas were open to commercial prawn fishing for the month of September only. Attempts to sample experimental areas in the north coast were unsuccessful.

POLLUTION CLOSURES 1989 - 1990

In addition to the 1988 prawn closures announced for portions of Howe Sound (a portion of subarea 28-1 and subareas 28-3, 28-4 and 28-5) and Porpoise Harbour and in the vicinity of Coast Island (subarea 4-12) as a result of dioxin and furan pollution, a portion of Muchalat Inlet (subarea 25-1) was also closed to commercial prawn fishing November 23, 1989.

Additional data on prawns sampled in Howe Sound was released in April 1990. Levels of contaminants were low from two samples in the open area and one sample from the closed area. The closure remained in effect pending results of further samples.

FISHERY MANAGEMENT 1990

Limited entry for the prawn trap fishery was announced by the minister on November 9, 1989. The licence eligibility criteria were reported landings of at least 1000 pounds in any two of the 1986, 1987 or 1988 fishing seasons. Landings in 1989 were not considered for licence eligibility. Approximately 120 fishermen qualified for a prawn (Z-H) licence in 1990 based on the eligibility criteria and approximately an additional 90 licences were granted through appeals to the Pacific Licence Appeal Board. In addition to licence limitation further measures of effort control will be considered in 1991.

To address concerns that shrimp trawlers were targeting on prawns an incidental prawn trip limit of 1% or five pounds was imposed on all "S" licensed fishermen in 1990. As this was not announced until January 1990 three shrimp fishermen (one north coast and two south coast) whose historical landings had largely

been prawns were given permits to allow for the retention of prawns in selected areas for a two year period ending December 31, 1991. Limited samples taken aboard one of these vessels showed a high rate of capture of undersized prawns (greater than 70% of the sampled catch) and significant mortality of this year class prior to being returned to the water. These permits are to be reviewed prior to reissuing in 1991.

Standard marking of gear was initiated in 1990. Effective April 1990 both ends of prawn ground lines must be marked by 50 inch circumference red or orange buoys. Both the vessel name and CFV number must be affixed to the buoy with characters not less than 75 mm in height.

In the north coast, effective April 1, 1990, prawn fishermen were required to provide 24 hour notification prior to entering a management area for fishing.

STUDY AREA OPENINGS - 1990

NORTH COAST

Openings and closures as detailed in the 1990 Prawn Management Plan.

SOUTH COAST

The Howe Sound and Salmon-Sechelt Inlet fisheries were discussed at an industry meeting March 28, 1990.

Two openings were set for Howe Sound; the first commenced 08:00 July 16 and the second opening was set for December. Howe Sound closed to commercial prawn fishing August 3 to provide adequate stock for the December opening.

The Salmon-Sechelt Inlet opening was delayed to September 4, 1990 to provide an increased yield per recruit and an opportunity for all local fishermen to participate in this fishery. A limit of 200 traps per vessel with a maximum of 50 traps per ground line was set for this fishery. This was to test the feasibility and effectiveness of trap limitation as an effort limiting measure in the commercial prawn fishery. It was estimated that the stocks in these inlets would support approximately 50,000 trap pulls at which point a closure would be announced.

Saanich Inlet (subareas 19-07 to 19-12) was defined as a new study area in 1990. The 1990 fishing plan for this area was discussed at an industry meeting on June 6, 1990. A trap limitation similar to that set for Salmon and Sechelt Inlets will be imposed on this fishery. A closure will be announced when the spawner index falls below a minimum monthly index. A pre- and post-season test fishery will be conducted during August to estimate pre- and post-season spawner abundance and year class strengths.

Alberni Inlet opened July 1, 1990 and will close when the spawner index falls below a minimum monthly level.

SURVEYS AND CLOSURES TO DATE (AUGUST, 1990).

Commercial prawn surveys were carried out in several areas to date. Two in area 12, two in area 16, three in area 17 and one in area 14. The following closures were effected as a result of low spawner indexes in some of these areas:

Area 16, all subareas with the exception of subareas 16-19 to 16-22 on the west side of Texada Island, was closed 23:59 August 15 until April 1, 1991. The spawner index estimated from samples taken in this area during early August was 2.90 spawners per trap ($1.94 < N < 3.86$) $P = 0.25$ compared to the minimum monthly index of 4.40 spawners per trap. *

Area 17 (subareas 17-03, -04, -10, -17 and 29-05) closed 23:59 June 23 to April 1, 1991. The spawner index estimated from samples taken in this area during June was 5.07 spawners per trap ($3.26 < N < 6.87$) $P = 0.25$ compared to the minimum monthly spawner index of 5.40 spawners per trap for June. Samples of commercial prawn catches taken from other subareas in Area 17 indicate that further closures may be necessary in this area.

Trawl caught prawns sampled on board an "S" licence vessel under permit to retain prawns in Area 17 showed significantly higher catch rates of sub-legal prawns compared to trap caught prawns in the same area. Greater than 70% of the trawl caught prawns were sub-legal size compared to 36 to 60% for trap caught prawns.

Table 1. Annual landings and catch per unit effort of prawns by trap 1982 -1989.

Year	No. of Licences ¹	No. of Vessels ²	Estimated Landings tonnes	No. of traps hauled ³	Standardized	
					CPUE lb/trap ⁴	CPUE lb/trap ⁵
1982	--	218	264	--	--	
1983	567	276	420	1,618,321	0.572	
1984	693	305	503	2,136,053	0.519	
1985	544	241	511	1,968,580	0.572	
1986	551	205	545	2,029,020	0.592	0.765
1987	698	216	616	2,495,705	0.544	0.703
1988	677	262	714	2,825,235	0.557	0.704
1989	901	305	745	3,665,482	0.448	0.610

¹ licences issued

² vessels that reported landings

³ calculated from total landings (sales slips+harvest logs)/cpue

⁴ cpue = catch per unit effort as determined from log records. (cpue is not standardized according to trap type)

⁵ cpue standardized to trap type.

Table 2. Landings (tonnes) of prawns (by trap) by year for North and South Coast Areas of British Columbia, 1976 to 1988, as reported on sales slips and harvest logs.

Year	South Coast			South Coast Total	Coastwide ¹ Total
	North Coast (Areas 1 to 10)	E.C.V.I. (Areas 11-19, 28, 29)	W.C.V.I. (Areas 20-27)		
1976					71
1977					153
1978					211
1979					310
1980					361
1981					320
1982					264
1983					420
1984					503
1985					511
1986	126	391	25	416	545
1987	159	399	58	457	616
1988	233	411	70	481	714
1989	189	455	101	556	745
Totals 1986 to 1989	707	1,656	254	1,910	5,742

¹ Coastwide totals only from Harbo and Jameson, 1987. Area breakdown not available.

Table 3. Trap Types in Use in 1989

Trap Type	Number of Hauls
Web Traps	2,606,213
Solid Sided Traps	557,807
Wire Traps	543,297
Coonstripe Traps	6,868
Total	3,714,203

5. Dungeness Crab (and Tanner Crab) Fishery

by

G. Jamieson

STOCK STATUS OF DUNGENESS CRAB IN 1990

Landings in 1989 were 19% less than in 1988, which in turn was well below that of 1987. A reduction in catch was evident in most crab subfisheries in British Columbia (Fig. 1, 2). The relatively low landing at Tofino continues to be a result of poor larval settlement in recent years, but the dynamics of settlement and juvenile survival in Georgia Strait and Dixon Entrance remain to be determined. The 1989 settlement off Tofino was the highest observed since studies began in 1985 and so landings are predicted to increase there in 1-2 years. This fishery continues to be closely monitored.

Evidence that outer coast and Strait of Georgia crabs represent two distinct stocks continues to accumulate. A mechanism to explain how this separation is maintained was proposed last year, but unfortunately this could not be verified in 1989 because of our inability to find sufficient densities of crab megalopae during our 1 week offshore cruise in 1989. Megalopae were found to be scarce within 70 km offshore and we then had insufficient time to go further offshore to locate them. We had hoped to document conclusively the diurnal depth distribution of outer coast megalopae, but while this could not be done, we did firmly establish that Strait megalopae descend to >150 m during the day. Stock separation is hypothesized to hinge on the diurnal vertical depth of occurrence of megalopae. The implication of distinct stocks is that because the magnitude of larval settlement seems to fluctuate significantly on an annual basis, and this is a major, if not the most significant, determiner of year class size, each stock may then fluctuate in abundance independently of the other. Also, because of the unique growth and dispersal patterns of each population, or stock, juvenile dynamics and age at recruitment are also different. Understanding and documenting the nature of these differences continues to be the focus of on-going crab research for the next few years.

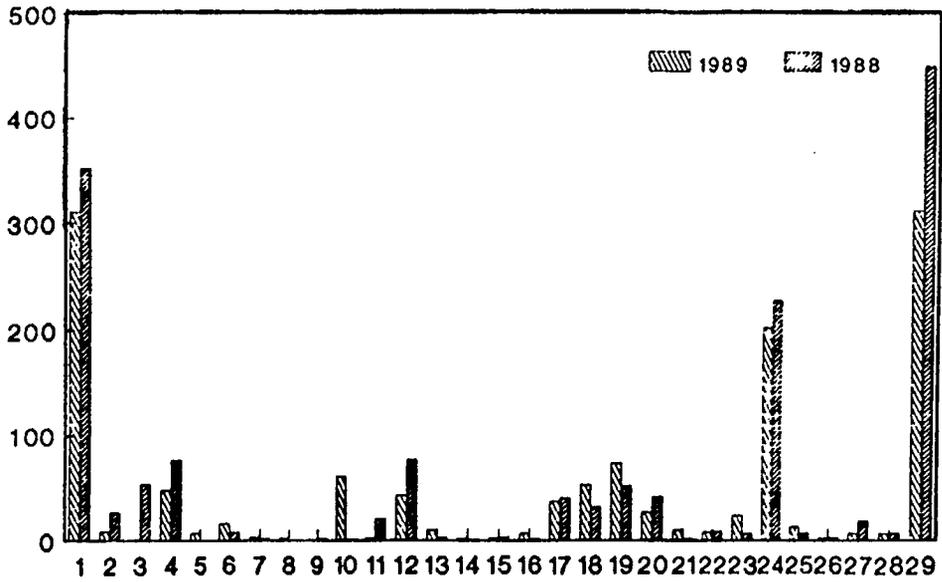
STOCK STATUS OF TANNER CRAB

A modest fishery continues to occur off the west coast of Vancouver Island, with landings (1988: 0.45 t; 1989: 35.5 t) still not reflective of actual crab abundance. A surplus of snow/tanner crab world-wide resulted in reduced prices in the latter part of 1989, and consequently fishing temporarily became uneconomic in British Columbia. An investigative cruise was conducted in April, 1990, but results have yet to be analyzed. No new data is

available since the last PSARC meeting, and so no change in management advice is recommended at this time. Fishermen should still be permitted to fish this species in a conservative manner, with the collection of biological data as a requirement.

Figure 1

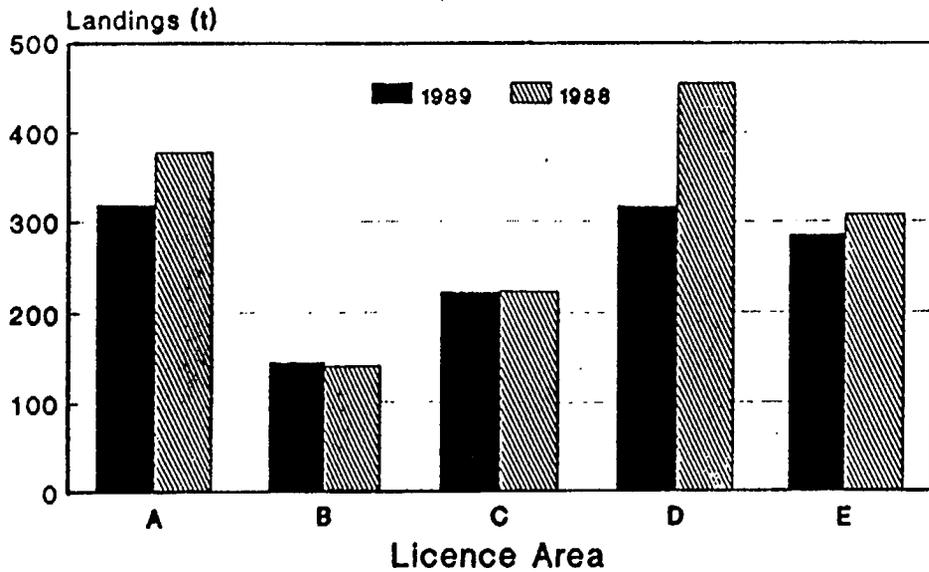
Dungeness crab landings 1989



1989 total = 1223 t; 1988 total = 1503 t

Figure 2

Dungeness Crab Landings by Licence Area



A = OCI; B = NCM; C = GS & JS;
D = FR; E = WCVI

6. Geoduck Fishery

by

R. Harbo, K. Hobbs and G. Thomas

The dive fishery for geoducks had the highest value for shellfish in 1989, and the greatest weight of landings. It is a limited entry fishery with 55 G licences, issued to harvest geoducks and horse clams by diving. Harvest is limited to depths greater than 10 feet at chart datum.

The geoduck fishery began a two year trial period (1989-1990) with individual vessel quotas (I.Q.'s) or enterprise allocations. I.Q.'s were 1/55 of the coast quota, 160,000 lb. for each of the 55 vessels in 1989 and 1990. In addition, vessels had to select one of three areas to fish in 1989; 22 quotas were assigned to the north coast, 12 to the inside waters of Vancouver Island and the mainland and 21 on the west coast of Vancouver Island.

Another new management initiative in 1989 was a three year area rotational fishery. This reduced the number of landing ports to monitor catches and made fishing more efficient for the harvesters. In previous years, many vessels would fish all over the coast both north and south. The rotation will leave some areas and beds undisturbed for many years and it is hoped that this may have positive benefits for recruitment. Many juvenile geoducks are dug up incidentally with the larger clams and are unable to rebury.

A detailed manuscript report on the fishery, 1985 to 1989 is in preparation. A PSARC Working Paper(I-90-7) has been prepared reviewing quota management in the fishery.

LANDINGS AND EFFORT

Total landings of geoducks in 1989 were 4087 tonnes, the lowest since 1984. The landed value, however, was a high at approximately \$13 million. Tables 1 and 2 update landings and value for the fishery. The mean price of geoducks almost doubled to \$0.97/lb. (\$2.15/kg) in 1988 (Table 1), and increased again in 1989 to \$1.45/lb. (\$3.19/kg).

Since the start of the fishery in 1976, 75% of the cumulative landings have come from the south coast (26% from inside waters, 49% west coast of Vancouver Island) and 25% from the north coast (Table 2).

Table 3 is a summary of geoduck landings by area for the south coast, 1976 to 1989. Table 4 shows north coast landings, 1980 to 1989.

Tables 5 and 6 show monthly landings by area in the south and north coast divisions, for 1989.

Diving effort and CPUE is summarized in Tables 7, 8, and 9. Figure 1 shows CPUE by vessel, (kg/day), 1978 to 1989. The daily landings by vessels decreased a minor amount in 1989 for the north and increased slightly for the south coast.

Table 11 shows harvest by depth intervals. Problems arose in 1988 log records from divers reporting maximum and minimum depths for dives (a new log format), rather than the average depths reported in the past.

FISHERY MANAGEMENT-1989/90

Management practices changed significantly in 1989, with a two year trial of individual quotas, area licensing and a three year rotational fishery between areas.

A steering committee and three area committees (north coast; west coast of Vancouver Island; inside waters of Vancouver Island and the mainland) were formed to review the progress of the fishery.

In January and April, 1989 the steering committee met and agreed that;

1. Weights from validations would be used to record landings against the assigned quotas.
2. When scales were not available at the point of delivery, a net weight of 55 lb. /cage would be used (this was increased to 60 lb. /cage in 1990).
3. A standard deduction of 4.5 lb. /cage would be used (This was later increased to 5 lb. /cage, on May 1/89).
4. Round weights would be taken at the point of delivery and there would be no adjustments for water content. Data was collected on water loss over the time of travel from the landing ports to the processing plants.
5. Data on conversion rates for P-licence vessels in the north would be collected, but the standard conversions would be used in 1989: neck and body x 2.326
neck meat x 4
body meat x 6.7
6. Final logbook data must be completed and submitted within one month of completion of the quota.
8. When only 10% of the quota is left the observer will be in daily contact with the local fishery officer to determine closure and opening times and dates.

NORTH COAST FISHERY MANAGEMENT

The north coast fishery and strategies developed to manage the fishery have evolved characteristics unique from that of the south coast because of the lack of shore based processing and the remote nature of the fishing locations.

In 1989 and 1990, 22 quotas of 160,000 lb. (72.6 t) each were assigned to the north coast totalling 3,520,000 lb. (1596 t). As part of the program, landings were monitored by contracted observers at three designated landing ports. As well, on-grounds monitoring and surveillance was provided by a chartered patrolman for the first four months of the fishery.

The 1989 quota for the north coast, approximately 1600 t, was 40% of the coast total and slightly less than the quota fished in 1988. Sixty percent of the north quota was calculated based on bed size and biological parameters and the remaining quota was exploratory. Area rotation was also implemented for the first time in 1989, so that the fishery was restricted to seven areas with quotas within the central coast district (Areas 6 to 10). The opening was delayed to March 1, both seasons, so that on-grounds surveillance could be provided by patrol vessels dedicated to the coincident herring fishery.

Operators choose to fish northern areas because of the relatively high catch rates (Fig. 1) and have adapted to the isolated conditions by fishing in small fleets, serviced regularly by packers. Most of the product has been packed to Port Hardy, then shipped by truck to processors in Vancouver.

1989 NORTH COAST FISHERY-LANDINGS AND EFFORT

A total of 1602 t of geoducks were landed in the north coast in 1989, valued at \$5.5 million (Tables 2 and 4). Overages were restricted because of intensive monitoring of each landing achieved through the I.Q. program and, as a result, total landings were reduced by 20% from the previous year. The reduction in landings was compensated by the large increase in price.

Since 1985, some fishermen have received "P" licences, to process at sea to maximize product quality and reduce packing costs. In 1989, only 71 t (4% of the north total) were processed on the grounds, a major reduction from 450 t processed in each of the two previous years. The reduction in processing probably resulted from the high price paid for the whole geoduck in 1989. In 1990, processing activity has increased in response to a decrease in the average price.

The fishery extended for a 10 month period, March to December, 1989, though 85% of the landings were made in the first three months (Table 6). In 1990, the fishery was slow paced initially because of the uncertainties in market price, but accelerated in

May and June and will likely conclude by September. The period of supply is not sustained in the north coast because of the high operating costs (packing, leasing plants) and because the product is not suitable for live market sale. Experiments are under way in 1990 to mark geoducks from the north coast and other PSP closed areas, so that there is confidence that the clams will not be shipped live to markets.

Table 10 summarizes the number of beds harvested annually in the north coast areas. Some exploration did occur in 1989 as cumulative beds fished increased by 9%. It appears that most expansion occurred within areas previously harvested as there was a 0.2% increase in total documented harvest area between 1988 and 1989 (PSARC Working Paper I90-7, Table 15).

The 22 available licences in the north coast were fished by 20 vessels in 1989. The trend toward licence consolidation continued in 1990, with 18 vessels fishing the available 22 quotas.

A summary of annual effort in diver hours is provided in Table 7. Diver hours increased annually in the north to 1988 then declined by 25% in 1989.

Annual CPUE in kg/diver hour for the north coast is summarized in Table 8. Diver CPUE (kg/hr.) increased in 1989 in the north coast, but vessel CPUE appears to have decreased slightly from the previous year. CPUE remains significantly higher than the south coast (Fig.1, Table 9).

SOUTH COAST FISHERY -1989

INSIDE WATERS-1989

There were 12 quotas allocated for inside waters, Areas 11, 12 and 13 and 9 vessels fished.

The opening was delayed to February 6, 1989 and limited to Area 12 to allow for contracted observers to be trained and in place at Port Hardy.

Landings and effort were spread out to maintain a supply year round for live markets (Table 5). This was one of the major objectives of the program.

AREA 11

On July 24, 1989 the Area 11 quota was combined with the Area 12-b Mainland quota for a total of 150,000 lb. Fishermen could not find stock in Area 11.

AREA 12 (12A AND 12B-MAINLAND EXPLORATORY)

Area 12 opened February 6, 1989 to October 18, 1989 for a quota of 1,320,000 lb., with landing ports designated at Port Hardy and Port McNeill.

There were some problems in supply of clams to the live market due to PSP closures on both coasts of Vancouver Island. PSP closure in Area 12 lifted July 1. In September, the areas of harvest for live market clams were limited to portions of subareas 12-11 and 12-16. On September 28 all harvest from Area 12 and portions of Area 13, subareas 13-13 to 13-15 had to be processed until November 11.

AREA 13

Area 13 opened May 18, 1989 for a quota of 450,000 lb. with the landing port at Heriot Bay, Quadra Island. There were some PSP closures in Area 13, from September 28 all harvest from Area 12 and portions of Area 13, subareas 13-13 to 13-15 had to be processed until November 11. Area 13 closed December 31.

WEST COAST OF VANCOUVER ISLAND-1989

There were 21 quotas allocated for the west coast of Vancouver Island. It was decided not to rotate fishing in Tofino-Clayoquot Sound, due to the dependence of the local community on the fishery. There is a processing plant located in Tofino and some licence holders and divers live in the community.

Other areas open in 1989 were Area 23, and portions of Area 27.

Due to PSP closures, there was concern that quotas would not be taken. Fishermen were advised that 1989 quotas could be carried over to 1990.

AREA 23

Area 23 had a quota in 1989 of 1,200,000 lb. and had two designated landing ports, Bamfield and Toquart Bay. The area was opened February 6 with Bamfield having an observer. Toquart Bay did not have an observer until May 26.

Area 23 was closed July 15 to concentrate effort in the exposed area of Tofino; Area 27 was also closed at the same time.

Area 23 reopened August 15, but the area was closed again over the period August 24 to November 7, 1989 due to the high levels of PSP.

AREA 24

Area 24 was subdivided into five smaller areas with quotas to spread out the fishing effort in 1989. Fishermen were not able to find geoducks in the 24-C exposed area, and in-season changes were made to open inlets and Russell Channel.

AREA 24-A (INSIDE)

Area 24-A opened February 6 to February 15, the traditional closure time due to herring spawning in the area. Area 24-A reopened April 16 and remained open to May 3. A small amount of quota was left in 24-A and there was an opening, December 11 for 6134 lb.

AREA 24-B (OUTSIDE)

Area 24-B opened February 16 and the quota was taken by March 20. All of Area 24 was closed March 20-April 15 until Area 24-A reopened April 16.

AREA 24-C (EXPOSED)

The management plan assigned 300,000 lb. for the exposed area. Fishermen advised in April-May that there was not adequate stock in the area and that other portions of areas would have to be opened. In consultation with the fishermen, the opening was redescribed:

- (i) 24-1 and 124-3 Hesquiat Harbour, exploratory fishery-100,000 lb.
- (ii) 24-2 Sidney Inlet (excluding Hot Springs Cove)-100,000 lb.

and

- (iii) the exposed portions of 24-8 and 124-3 -100,000 lb.

HESQUIAT HARBOUR

Only one vessel reported landings from Hesquiat Harbour, 3485 lb. taken in June, 1989.

SIDNEY INLET

This inlet was assigned 100,000 lb. quota as part of the 300,000 lb. originally assigned to the exposed area 24-C. There were 102,093 lb. taken.

EXPOSED 24-8 AND 124-3

The harvesters were only able to harvest 19,589 lb. of the 100,000 lb. quota. Areas 23 and 27 were closed July 15 to August 15 to concentrate effort until the quotas were taken for the exposed portions of Tofino. Harvesters were not able to find clams and August 1, 1989 other opportunities were given in the inlets (24-D) and in Russell Channel (24-E).

AREA 24-D (INLETS)

The inlets, subareas 24-5, 24-10 and 24-14 (Herbert Inlet, Fortune and upper Millar Channel) were opened August 1.

On November 8, 1989 further portions of the inlet area 24D were opened. Fortune Channel, 24-10 was opened November 9 to November 14, 1989.

AREA 24-E (RUSSELL CHANNEL)

A new area was opened August 1, 1989, 24E, an area inside a line from Yates Point to Shot Island to Tibbs Inlet to the most westerly portion of Siwash Cove, thence along the shoreline of Flores Island to Kutcouc Point, thence in a straight line to the most westerly point of Whitesand Cove. The Whitesand Cove closure remained in effect. Live marketing was not allowed from 24-6, August 24 and 27-2 on September 12.

Area 24 was closed September 1 to the harvest of all geoducks due to the high PSP levels. Geoducks for processing could not be taken. The areas were not reopened until November 7, 1989, but all product had to be processed.

AREA 27 (INSIDE)

Portions of Area 27, Quatsino Sound 27-2, Winter Harbour 27-3 and inlet subareas 27-7 to 27-11 opened, May 1, 1989, for a quota of 760,000 lb. (344.7 t).

On September 23, the harvest of geoducks was restricted in Area 27 to processing only. On November 7 live marketing was permitted in 27-2 and 27-3. On November 18 all product from Area 27 had to be processed until the area was closed December 12, 1989.

SOUTH COAST EFFORT DATA

Diver hours decreased in the south coast as a result of reduced landings. The landings and quotas were closely monitored by contracted observers and the landings were actually less than the overall quota. Diver CPUE (kg/hr.) increased in 1989 as shown in Table 9. In 1989, CPUE was much greater in Area 12, one of the highest recorded values. CPUE was highest in Area 24, on the west coast of Vancouver Island. The CPUE data has not been standardized for season, diver experience or other factors.

CURRENT ISSUES

The quotas are subject to review for the 1991 fishery. Table 12 gives the initial proposed three year plan of quotas. Some revised options for the north coast are presented in Table 12 and are discussed in detail in the quota review paper.

Fishermen advise that quotas for the inside areas of Vancouver and the mainland may be too high and require monitoring and assessment. Some fishermen have expressed concern about the state of the stocks in inside waters.

Fishermen have not been able to achieve the quotas set in 1989 and 1990 for Area 11, Area 24-exposed; Area 24 inlets and most recently in the north Area 5. Fishermen also advised reductions for Areas 9 and 10.

Clams from PSP closed areas may have to be marked in 1991.

Table 1. Landings and landed values of geoduck clams 1976 to 1989 as reported on sales slips.

Year	Total Landings		Total Value \$10 ³	Mean Price ¹		Price Range ²	
	lb.	tonnes		\$/lb.	\$/kg	\$/lb.	\$/kg
1976	97,002	44	N/A	N/A	N/A	N/A	
1977	540,898	245	89	0.17	0.36	N/A	
1978	2,239,950	1,016	569	0.25	0.56	0.15 - 0.35	0.33 - 0.77
1979	5,429,886	2,463	1,669	0.31	0.68	0.13 - 0.40	0.29 - 0.88
1980	6,160,903	2,806	2,299	0.37	0.82	0.30 - 0.48	0.66 - 1.06
1981	5,961,405	2,704	2,162	0.36	0.80	0.32 - 0.70	0.71 - 1.54
1982	6,910,800	3,135	2,814	0.40	0.89	0.22 - 0.46	0.44 - 1.01
1983	5,810,913	2,636	1,804	0.31	0.68	0.00 - 0.60	0.00 - 1.32
1984	7,678,465	3,483	2,937	0.38	0.84	0.00 - 0.95	0.00 - 2.09
1985	11,838,624	5,370	4,599	0.40	0.89	0.00 - 1.00	0.00 - 2.20
1986	11,035,396	5,005	4,296 (est)	0.39	0.86	0.00 - 0.85	0.00 - 1.87
1987	12,762,403	5,784	6,241 (est)	0.49	1.08	0.00 - 1.05	0.00 - 2.31
1988	10,068,830	4,567	9,807	0.97	2.15	0.03 - 1.88	0.07 - 4.14
1989 ³	9,011,013	4,087	12,967	1.45	3.19	0.25 - 1.75	0.55 - 3.85

¹Price paid to commercial fishermen.

²Price ranges taken from Market Reports/sales slips
lb. x.4536 converted to kg.

³1989 landings are preliminary and include harvest log reports.

Table 2. Cumulative landings (tonnes) of geoduck, by year for North and South Coast Areas of British Columbia, 1976 to 1989, as reported on sales slips.

Year	South Coast				Coastwide Total
	North Coast (Areas 1 to 10)	E. Coast Vancouver Island (Areas 11-19, 28, 29)	W. Coast Vancouver Island (Areas 20-27)	South Coast Total	
1976		44		44	44
1977		239	6	245	245
1978		773	243	1016	1016
1979		1242	1221	2463	2463
1980	68	980	1758	2738	2806
1981	509	547	1648	2195	2704
1982	227	409	2498	2907	3134
1983	501	481	1653	2134	2635
1984	575	1175	1734	2909	3484
1985	1436	1055	2878	3934	5370
1986	1692	1119	2194	3313	5005
1987	2206	1439	2139	3578	5784
1988	2026	995	1546	2541	4567
1989 ¹	1602	933	1552	2485	4087
Totals 1976 to 1989	10842	11430	21071	32501	43343

¹ preliminary landings for 1989 from sales slips and harvest logs.

SOUTH COAST MANAGEMENT AREAS

Year	East Coast Vancouver Island											West Coast Vancouver Island							Annual Landings
	11	12	13	14	15	16	17	18	19	28	29	20	21	23	24	25	26	27	
1976				10			8		26										44
1977			14	9	77		137	2						6					245
1978			8	261	321	3	24	19	136			1	3	2	236	2			1016
1979		24	160	276	263	148	209	3	159					153	950	87	22	9	2463
1980			97	215	17	301	225	34	91			5		288	841	321	303		2738
1981			41	180	29	70	155	44	28			8		187	819	473	156	6	2195
1982		83	14	144	33	103	17	1	14			14		174	1218	366	726		2907
1983		16	29	340	29	42	13	2	10					84	1066	215	287	1	2134
1984	8	302	150	285	54	129	128	1	118					219	628	442	443	2	2909
1985	13	490	81	172	42	38	137	4	78			0		227	730	599	272	1050	3934
1986	21	212	148	200	137	117	136	13	124		11	96		231	803	450	226	388	3313
1987		275	112	286	98	159	256	103	50		100	40		247	661	552	398	241	3578
1988	62	290	51	191	59	95	110	2	116	1	17	49		192	633	187	206	279	2541
1989	11	713	209					1	1					568	611			373	2485
1976 to 1989 ¹	115	2405	1114	2569	1159	1205	1555	228	950	1	128	213	3	2578	9196	3694	3039	2349	32501

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¹ preliminary landings for 1989.

Table 4. Summary of geoduck landings (tonnes) by North Coast Management Area, 1980 to 1989 as reported on sales slips.

NORTH COAST MANAGEMENT AREA												Annual Landings
Year	1	2E	2W	3	4	5	6	7	8	9	10	
1980		31			4					28	5	68
1981		11				84	6	370	18		20	509
1982								227				227
1983								202	299			501
1984		4		3		214	8	109	183	54		575
1985		341	213			291	60	494	37			1436
1986	7	254	325	120	125	323	24	392	2	103	17	1692
1987	136	391	179	134	95	337	484	231	91	11	117	2206
1988	119	462	45	77	150	191	423	309	250			2026
1989 ¹							109	1316	12		165	1602
1976 to 1989	262	1494	762	334	374	1440	1114	3650	893	196	324	10842

¹ preliminary data from sales slips and harvest logs combined

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Table 5. Summary of geoduck landings by South Coast Management Area (tonnes) in 1989 (preliminary), as reported on sales slips and harvest logs.

SOUTH COAST MANAGEMENT AREAS									
Month	East Coast V. I.					West Coast V. I.			Monthly Totals
	11	12	13	18	19	23	24	27	
Jan					1				1
Feb		96				4	216		317
Mar		88				70	173		331
Apr		123				220	84	15	442
May	11	61	60			109	3	63	307
June		51	49			97	14	46	257
July		84	21			16	29	33	182
Aug		41	11			2	68	12	135
Sept		43	26	1			4	60	133
Oct		86						58	144
Nov		37	16			18	0	58	129
Dec		1	27			31	21	27	107
Area Totals	11	713	209	1	1	568	611	373	2485

Table 6. Summary of geoduck landings (tonnes) by North Coast Management Area in 1989¹, as reported on sales slips and harvest logs.

NORTHCOAST MANAGEMENT AREAS						Monthly Totals
Month	6	7	8	9	10	
Jan						
Feb						
Mar	10	237				247
Apr	57	593				650
May	43	240	6			289
June		65	6			71
July		73				73
Aug		21			44	64
Sept		33				33
Oct		51			121	172
Nov						
Dec		3				3
Area Totals	109	1316	12		165	1602

¹ preliminary landings for 1989.

Table 7. Total number of diving hours annually for geoduck clams, from harvest log data.

Year	South Coast	North Coast	Total Hours	Total Weight*	CPUE kg•hr
1983	12,194	1742	13,936	1999 (76%)	143
1984	17,218	2045	19,263	3272 (94%)	110
1985	18,362	5019	23,381	4467 (83%)	191
1986	18,496	6562	25,058	4332 (87%)	153
1987	19,088	7249	26,337	5071 (88%)	168
1988	13,989	7870	21,859	4553 (91%)	162
1989	12,354	5853	18,207	3890 (95%)	194

* as reported by harvest logs (% indicated log returns compared to total landings reported on sales slips).

Table 8. Annual geoduck CPUE (kg/diver hr) for Management Areas, 1-10, 1980-1989, from harvest logs.

AREA	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989
1	-	-	-	-	-	-	272	153	113	-
2	125	-	-	-	-	215	278	378	-	-
2E	-	-	-	-	-	-	192	240	207	-
2W	-	-	-	-	-	-	209	224	193	-
3	-	-	-	-	-	-	218	207	203	-
4	153	-	-	-	-	-	216	208	166	-
5	-	211	-	-	247	207	187	196	176	-
6	-	-	-	165	-	253	190	221	234	238
7	-	253	183	180	200	208	198	188	218	229
8	-	-	185	220	208	206	151	164	185	262
9	145	147	-	-	110	-	185	186	-	-
10	-	-	-	-	-	-	161	179	-	165
All Areas	133	229	183	189	215	239	197	208	197	224

Table 9. Annual geoduck CPUE (kg/diver hour) for Management Areas 11 to 29, 1980 to 1989, from harvest log data.

Area	Year										
	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	
11							198		110	109	
12				96	166	155	177	185	170	207	
13	134	142	89	124	144	135	132	137	119	130	
14	107	95	115	111	141	127	114	131	114		
15	71	119	123	112	173	142	131	144	140		
16	130	136	133	125	115		128	145	136		
17	110	138	172	121	142	119	112	143	149		
18	76	160	108		113		194	129			
19 ¹	120	96	71	85	155		82	141	134		
29							138		83		
20							130	105	80		
23	135	160	143	89	138	185	160	166	150	176	
24	119	154	140	138	144	153	141	153	154	191	
25	200	161	192	150	166	188	164	185	186		
26	195	211	169	136	172	142	151	165	146		
27		262		98		186	169	178	165	154	
South Coast											
Average ²									155	146	180
Coastwide											
Average											
	129	159	153	143	110	191	153	168	162	194	

¹ some years may contain diving school landings which may lower the average CPUE.

² CPUE for south coast areas only is unavailable for some years.

Table 10. Cumulative number of geoduck beds harvested 1980-1989, for areas 1-10.

AREA	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989
1	-	-	-	-	-	-	-	2	2	2
2E	3	3	3	3	4	21	28	37	55	55
2W	-	-	-	-	-	6	14	14	21	21
3	-	-	-	-	-	-	6	7	8	8
4	1	1	1	1	1	1	6	8	12	12
5	-	3	3	3	6	6	6	6	8	8
6	-	-	-	2	2	3	5	19	26	29
7	-	9	13	17	17	20	24	26	28	41
8	-	1	2	2	2	2	4	4	13	14
9	1	1	1	1	1	1	2	3	3	3
10	-	-	-	-	-	-	3	6	6	6
Annual Total	5	18	23	29	33	60	98	132	182	199

Table 11. Seasonal harvest by depth interval and percentage of the annual total, 1978 to 1989.

Depth Interval	Percentage of annual harvest at depth intervals											
	(ft)	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988
10 - 20	0.1	1.2	0.7	1.3	1.7	0.4	1.5	0.7	2.1	0.9	0.8	0
21 - 30	50.6	20.6	18.0	12.2	16.3	8.9	21.8	9.01	1.1	5.6	6.8	11.2
31 - 40	32.1	67.7	69.1	69.5	63.6	79.0	53.8	55.9	54.0	50.5	15.8	40.4
41 - 50	16.2	10.2	11.9	11.9	18.2	10.4	20.9	28.8	30.3	36.3	50.1	29.3
51 - 60	0.3	0.2	0.3	0.6	0.9	0.1	1.9	1.1	2.4	5.9	13.4	15.5
61 - 70	0	0	0.1	0.1	0	0	tr	0.1	tr	0.7	1.6	3.5
71 - 80										0.1	0.1	0.04

Table 12. Proposed three year rotational fishery for geoducks, 1989 to 1991.

Year	Statistical Area	Description	Quota (lb-10-3)	Total (lb-10-3)
1989 Year 1				
	Inside waters:	11 All subareas	150	
		12 All subareas	1,320	
		13 All subareas	450	1,920
	West Coast:	23 All subareas	1,200	
		24 Inside/outside	1,100	
		24 Exposed	300	
		27 Inside	760	3,360
	North Coast:	6 Laredo/Kitasu	330	
		6/7 Price Is.	480	
		7 Upper	375	
		7 Thompson Bay to Hunter Channel	450	
		7 Spider Anchorage	1,500	
		8 All except 8-2	85	
		9 & 10 All subareas	300	3,520
		TOTAL 1989		8,800
1990 Year 2				
	Inside waters:	14 All subareas	1,320	
		16 All subareas	600	1,920
	West Coast:	24 Inside Outside	1,100	
		24 Inlets	150	
		26 All Subareas	1,350	
		27 Outside	760	3,360
	North Coast:	3 All Subareas	210	
		4 All subareas	720	
		5 All subareas	1,000	
		6 Upper and Aristazabel Is.	1,590	3,520
		TOTAL 1990		8,800
1991 Year 3				
	Inside waters:	15 Allsubareas	570	
		17 Including 29-4, 29-5	600	
		18 All subareas	150	
		19 All subareas	600	1,920
	West Coast:	20 All subareas	150	
		24 Inside/outside	1,100	
		24 Exposed	310	
		25 All subareas	1,650	3,360

Table 12. (Cont'd)

Year	Statistical Area	Description	Initial Quota (lb-10-3)	Revised Options (1990)*
1991 Year 3				
	North Coast:	1 All subareas	150	85x3 = 255
		2E Skidegate In.	300	55x3 = 165
		2E Cumshewa/Laskeek	750	280x3 = 840
		2E Juan Perez	600	200x3 = 600
		2E Lower	750	350x3 = 1,050
		2W Louscoone In.	300	100x3 = 300
		2W Flamingo/Kano	220	55x3 = 165
		2W Upper	450	150x3 = 450
		TOTAL 1991	3,520	3,825

* From Table 15 of Working Paper 90-7

Geoduck vessel CPUE from sales slip data 1978 - 1989

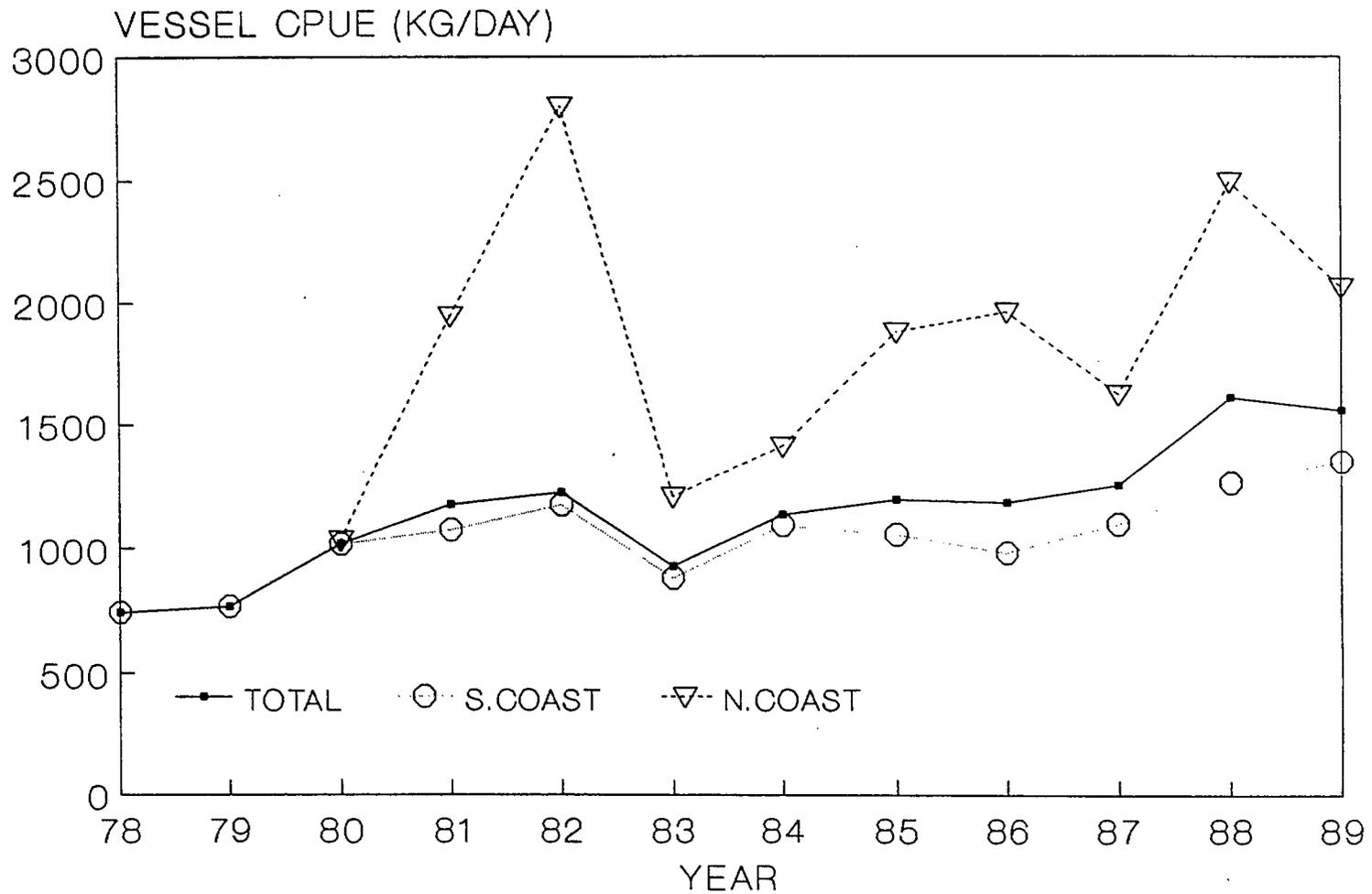


Figure 1.

7. Horseclam Fishery

by

R. Harbo and K. Hobbs

The horse clam fishery decreased significantly in 1989 to 115 tonnes (Table 1) for a landed value of \$144,000. The average value in 1989 was \$1.25/kg (\$0.57/lb.). Only five companies purchased horse clams in 1989.

The decline in landings was a result of changes to the management plan. In late 1989 and 1990, fishing for horse clams was limited to those areas open for geoduck. A three year rotational fishery between areas was set in the geoduck fishery in 1989.

In 1989, 16 vessels of the 55 G licensed vessels fished horse clams, reporting 118 fishing days. Diver CPUE decreased again in 1989 (Table 1), but this index has not been reliable due to the nature of the fishery. Horse clams are often taken incidentally, while fishing for geoducks.

Table 2 gives a summary of horse clam landings by area, 1979 to 1989, as reported on sales slips. There may be additional landings reported on logs. On the inside of Vancouver Island the majority of the landings have come from Areas 14 and 17. On the west coast of Vancouver Island, Area 24 is the only area with significant landings. Area 25 is considered to have large beds of horse clams as yet unfished due to low prices. This area will be open in 1991.

Landings by area and month for 1989 are shown in Table 3. Some landings were recorded in areas 14, 16, 17 and 19, early in the year before the policy on horse clam closures was set.

On the west coast of Vancouver Island, Area 24, Clayoquot Sound has supported most of the fishery. A closure was set in 1988 for an area heavily harvested at Dunlap Island in Tofino. This area has a significant population of horse clams but was closed until a management plan is developed and to encourage further exploration of the area. The closure continued in 1989 and 1990.

Only minor landings of horse clams were reported from the north coast, 0.2 t in 1987 (Table 3) and 0.8 t in 1988 (Table 4).

FISHERY MANAGEMENT-1990

Prior to 1988 there were no restrictions placed on this fishery, other than the requirement to have a G licence. The harvest of horse clams was restricted to divers fishing from G licensed vessels (55) in 1989. With the introduction of an

intertidal clam Z licence in May 1989, intertidal harvesters were limited to manila, littleneck and butter clams. There has been no significant harvest of horse clams by hand digging.

By condition of the G licence, the harvest of horse clams must be carried out at depths at least 10 feet below chart datum. Fishermen must contact the local fishery officer to open subareas or portions of subareas. Locations that support herring spawn are not opened to horse clam harvesting until an evaluation of the impact of harvesting can be carried out. The horse clams are often found in eelgrass beds where herring spawn.

In 1989 and 1990 it was decided to limit the areas of horse clam fishing to those management areas that were opened that season for geoducks. Initially, no quotas were set. Vessels were also restricted to the same geographical area chosen for geoducks (Areas 6 to 10 in the north coast, Areas 23, 24 and 27 south coast: west coast Vancouver Island; Areas 11, 12, 13 south coast inside waters of Vancouver Island). Vessels could only fish for horse clams in the north coast during open times for geoducks.

An exploratory quota was set, in June 1990, for two fishing areas in Area 24, with a summer and fall opening. A voluntary compliance boundary of fishing greater than 20 feet below chart datum was set due to concerns for shallow vegetation that support herring spawn. A three year rotational fishery was proposed in portions of Clayoquot Sound.

A portion of 24-7, Yellow Bank and a portion of 24-6, Epper Passage opened to the harvest of horse clams at depths greater than 20 feet below chart datum, June 25 for an exploratory quota of 125,000 lb. A further 125,000 lb. allocation is proposed for the fall in the same areas.

Measurements were taken in July 1990, of horse clams from Yellow Bank and Epper Passage in Clayoquot Sound, Area 24. The shells were retained for ageing but have not been processed to date.

RECOMMENDATIONS

1. A conservative approach should be taken with the development of the horse clam fishery. Quotas should be considered to limit landings until more biological information is collected and evaluated.
2. Area 24: A three year rotational fishery is recommended. It is proposed that in 1991, the subareas of Morfee-Dunlap islands be opened, with other exploratory opportunities in the area of Whaler and Shag islets. An exploratory quota should be set and biological samples taken.

In 1992, the subareas of Lemmens Inlet and portions of Van Nevel Channel should be opened.

3. Exploratory quotas, based on historical landings and available harvest and biological data, should be considered for all areas open in 1991.

Table 1. Landings of horse clams (tonnes), landed value, the number of vessels fishing and CPUE, 1979-1989.

Year	Landings (t)	Landed Value (\$10 ⁻³)	# of Vessels	CPUE ¹		
				tonnes· vessel day ⁻¹	kg· diver hr ⁻¹	kg· diver day ⁻¹
1979	37	--	--	--	--	--
1980	128	79	28	0.6	65	232
1981	51	38	12	1.0	--	--
1982	321	235	40	0.5	87	225
1983	21	12	8	0.7	ND	ND
1984	6.7	5.5	5	0.2	--	--
1985	6.3	5.9	7	0.1	--	--
1986	96	63	15	0.5	170	630
1987	355	359	27	0.8	152	621
1988	325	300	33	0.8	119	588
1989 ²	115	144	16	1.0	220	559

¹ CPUE- t·vessel day⁻¹ based on sales slip reports
 CPUE- kg·diver hr⁻¹ and kg·diver day based on harvest log data.
 ND - no data.

² 1989 preliminary data.

Table 2. Summary of horse clam landings (tonnes) by Management Areas, 1979-1989, as reported on sales slips.

Year	MANAGEMENT AREAS																			Total Landings
	North Coast			Mainland and East Coast Vancouver Island									West Coast Vancouver Island							
	2E	5	7	12	13	14	15	16	17	18	19	29	20	23	24	25	26	27		
1979					*	27	0.3	6.5	0.2							4.3				38
1980				0.1	0.5	22	46	50	9		*			0.4		*	*			128
1981				5.2	*	7.3	1.4	1.7	4.2		2.3			1.2	27	0.7				51
1982				3.1	0.3	163	0.3	2.6	15					2.3	123	3.4	6.6			320
1983						0.2		*						0.2	4.5	*	16			21
1984					3.9	2.3														6.2
1985						6.0		*	0.1											6.1
1986					23	67	0.9	0.2	2	3				*	0.2	0.2				96
1987	0.2			24	0.5	132	42	5.9	146	0.3	*	3.4	0.1	0.1	1.1					355
1988	0.7	0.1			14	58	0.3	9.2	77	4.9	1.5	5.3		7.3	140	0.9	4.2	1.2		325
1989 ¹			0.1	22	1.6	0.2		0.2	7.9		0.1			4.8	78				0.1	115
Area Totals	0.9	0.1	0.1	54	44	485	91	76	261	8.2	3.9	8.7	0.1	16	375	9.5	27	1.3		1,463

Mainland and East Vancouver Island = 1033
 South Coast Total = 14626

North Coast Total = 1.1

West Coast Vancouver Island = 429
 Coast Wide Total = 1463

* Landings less than 100 kg
¹ Preliminary landings for 1989.

Table 3. Horse clam landings (tonnes) by Management Area in 1989¹ as reported on sales slips and harvest logs.

MANAGEMENT AREAS											
	North Coast	East Coast V.I.						West Coast V.I.			Monthly Landings
Month	7	12	13	14	16	17	19	23	24	27	
Jan		0.7					0.1				0.8
Feb		*							4.4		4.5
Mar		1.1									1.1
Apr		19.9		0.2	0.2	7.9		3.9	44.6		76.7
May	0.1							0.1	17.7	0.1	18.0
June								0.8			0.8
July				0.0					7.6		7.6
Aug									3.8		3.8
Sept											
Oct											
Nov											
Dec			1.6								1.6
Area											
Totals	0.1	22	1.6	0.2	0.2	7.9	0.1	4.8	78	0.1	115

¹ preliminary landings for 1989.

8. Red Urchin Fishery

by

R. Harbo, K. Hobbs and G. Thomas

Tables 1 and 2 update landings, effort and value in the red sea urchin fishery. The number of licences issued and number of vessels participating in the fishery increased in 1989, and with the growth of the north coast fishery, the landings reached a high of 2645 t with a landed value of \$615K in 1989.

SOUTH COAST

Landings have stabilized in the south coast (Table 3) due to limited seasons, September to March, openings of four days per week, Sunday to Wednesday in some areas, and quotas set for conservation. There is a minimum size limit (100 mm) only in the south coast.

Landings increased in the south coast in 1989 to 1734 t, still less than the landings in years, 1984-1987.

Summer exploratory fisheries in 1989 landed 110 t in Area 12, 7.1 t in Area 25 and 60 t in Area 27 for a total of 177 t.

There were problems of poor quality on the west coast of Vancouver Island and not all quotas were taken in 1989 and 1990.

NORTH COAST

The north coast fishery has grown from 12 t in 1986 to 910 t in 1989 (Tables 2 and 4). Landings in 1990, to August, already exceed the total in 1989. In 1989, the north coast landings accounted for 34% of coast wide landings and were valued at \$560 K.

In order to control a rapidly expanding fishery, an experimental management scheme based on minimum (100 mm) and maximum (140 mm) size limits and area rotation was adopted. The maximum size limit of 140 mm, implemented in 1988, maintains a refuge of large individuals which provide protection for juveniles and some reproductive potential.

The rotational fishery was initiated in 1990 and allows recruits in closed areas to grow past the maximum size, thus sustaining large individuals in the population. It is proposed to maintain the fishery in the areas currently open for at least two years before moving to new areas. This method of management was chosen over setting arbitrary quotas.

A summary of annual landings by Area for the north is given in Table 4. A large portion of these landings have originated from the central coast, primarily in Area 7, but areas fished are expanding annually (Table 4). There were substantial landings (217 t) made for the first time in 1989 in Area 2E in the Queen Charlotte Islands.

Table 6 details the landings in 1989 by area and month. Approximately 73% of the landings were taken in February, March and April, 1989, following closures in the south coast. The period of fishery is also expanding each year. In 1989, 30 of the 39 vessels that fished in the north coast also fished in the south.

In 1989, the number of vessels increased to 39, reporting 406 vessel fishing days.

1989 FISHERY - SOUTH COAST

There were five periods of openings in the south coast in 1989, and 26 quotas totalling 1644 t (3,625,000 lb.).

A summer fishery, June 1 to August 15, allowed the harvest of red urchins in areas that cannot be fished in the winter due to weather problems. Quotas were taken in subareas 12-10 to 12-13 and 12-15 (200,000 lb.); subareas 27-1 to 27-6 (100,000 lb.). Some vessels attempted to fish Area 11 and subareas 125-1, 25-6, 25-7 and 25-15 but the landings were minor.

District and subdistrict offices monitored landings from vessel hails in 1989.

The Port Hardy quota of 75,000 lb. (subarea 12-16) was not achieved in 1989 due to low stocks and only 71,000 lb. were taken.

1990 FISHERY

The 1990 management plan did not change much from the previous year. Again there were five periods of openings and the number of quotas increased to 28, totalling 1667 t (3,675,000 lb.), an increase of 50,000 lb. over 1989.

CURRENT ISSUES

Industry continues to request a smaller minimum size limit in British Columbia.

Licence limitation has been announced for 1991, with the following eligibility criteria:

- 34,020 kg (75,000 lb.) cumulative landing requirement over the three year period 1987, 1988 and 1989 or;
- 20 days recorded harvest in any year from 1987, 1988, or 1989, or;
- 2268 kg (5,000 lb.) landed in any year in the north coast Areas 1 to 10, from 1987, 1988 or 1989.

Product quality remains a concern in the north coast fishery. Roe yields were low from unfished populations encountered in the early fishery, but yields should improve as new recruits become available. The reduction in the population is also believed to increase available food to individuals and improve roe quality. Operators have dumped some product on the grounds because of improper handling during warm periods in the summer.

An analysis of the price paid for urchins for each month is required to evaluate seasonal market demand. The export values of roe needs to be updated (Table 1).

Table 1. Red sea urchin landings and catch per unit effort, as calculated from sales slips and harvest log data - 1978 to 1989.

	Type and Number of Licences issued	Number of ¹ vessels with landings	Fishing Days	Landings (t)	X CPUE ¹ (t·vessel day ⁻¹)	X CPUE ² (kg·diver hr ⁻¹)	Landed Value (\$10 ⁻³)	Whole Landed Value (\$·t ⁻¹)	Roe Export Value (\$·t ⁻¹)
1978	C	4	54	75	1.4	--	16	213	
1979	C	29	298	317	1.1	--	76	240	
1980	C	18	331	333	1.0	--	84	252	
1981	C	18	127	116	0.9	--	34	293	11,090
1982	C	21	195	160	0.8	--	56	350	17,710
1983	Z 64	36	825	982	1.2 [1.3] ²	311	348	354	15,850
1984	Z 85	47	1,150	1,834	1.6 [1.5]	281	740	403	19,530
1985	Z 86	46	1,086	1,815	1.7 [1.4]	360	762	419	N/A
1986	Z 103	67	1,534	2,067	1.4 [1.6]	363	895	455	N/A
1987 ³	Z 184	97	N/A	2,061	N.A [0.6]	325	1,123 ⁴	545 ⁴	N/A
1988	Z 184	84	1,249	2,115	1.7 [1.3]	296	1,241	587	N/A
1989 ⁵	Z 240	109	1,511	2,645	1.8 [1.6]	360	1,628 ⁴	615 ⁴	N/A

¹ from sales slips and harvest logs

² CPUE [] from harvest log data

³ sales slip data for 1987 combined red and green sea urchin landings

⁴ value estimated from sales slip data

⁵ preliminary data for 1989

Table 2. Cumulative landings (tonnes) of red sea urchin, by year, for North and South Coast Areas of British Columbia, 1971 to 1989, as reported on sales slips.

Year	NORTH COAST (Areas 1 to 10)	SOUTH COAST			Coastwide Total
		E. Coast Vancouver Is (Area 11-19, 28, 29)	W. Coast Vancouver Is (Areas 20-27)	South Coast Total	
1971-73 ¹		110	254	364	364
1974-77 ¹		69	1.3	70	70
1978		46	29	75	75
1979		313	5.2	318	318
1980		331	1.8	333	333
1981		98	17	115	115
1982		154	5	159	159
1983		840	146	986	986
1984		1,635	195	1,830	1,830
1985		1,326	489	1,815	1,815
1986	12	1,483	572	2,055	2,067
1987	294	1,431	394	1,825	2,119
1988	437	1,218	460	1,678	2,115
1989	910	1,363	372	1,734	2,645
Totals 1971 to 1989	1,653	10,372	2,941	13,357	15,011

¹data for each year cannot be published separately.

Table 3. Annual red sea urchin landings (tonnes) by South Coast Management Area, 1971 to 1989, as reported on sales slips.

SOUTH COAST MANAGEMENT AREAS																			
Year	Mainland and East Vancouver Island											West Coast Vancouver Island							South Coast Total (t)
	11	12	13	14	15	16	17	18	19	28	29	20	21	23	24	25	26	27	
1971 ¹ to 1973 ¹									110						254				364
1974 to 1977		1.4		*	*	1.4			66			*		1.3					70
1978			*						46			29							75
1979			*	78			57	133	45			1.8	0.9	2.5					318
1980			-	18			162	54	97			1.8							333
1981 ²			20	4	*		5.3	47	22						17				115
1982		2.5		46			0.8	11	94						5				159
1983 ³	7.8	99	264	260	*	*	59	38	112			24		22	38		62		986
1984	0.3	478	791	185			33	67	76		5.0	69		17	105		3.9		1,830
1985		354	492	167	106	5.9	29	48	77		47	30		96	158	145	15	45	1,815
1986	27	548	376	178	56	4.4	57	129	105		2.0	40		154	285		2.5	91	2,055
1987	6.9	420	491	193	30		71	71	123	17	7.8	17		63	199	95	8.3	12	1,825
1988	2.6	534	480	78	21	2.3		22	78			74		13	250	66		58	1,678
1989 ⁴		571	523	122	6.7		9.0	70	60		1.6	15			220	39		98	1,734
Totals	45	3008	3444	1329	220	14	483	690	1111	17	63	302	0.9	369	1531	345	92	303	13,366

*Less than 500 kg

¹Data for each year cannot be published separately. There must be three or more processing companies reporting landings before the data may be released.

²Quotas for Area 17 (23 t), 18 (45 t) and 19 (68 t) were initiated in 1981.

³Mandatory logbook under Z licence come into effect in 1983.

⁴Preliminary landings for 1989

Table 4. Summary of red sea urchin landings (tonnes) by North Coast Management Areas, 1986 to 1989 as reported on sales slips.

NORTH COAST MANAGEMENT AREA												
Year	1	2E	2W	3	4	5	6	7	8	9	10	Annual Landings
1986											12	12
1987					23			179	91			293
1988					73	11	7.3	314	32			437
1989	0.2	217		1.6	112	1.3	165	205	65		143	910
1986 to 1989	0.2	217		1.6	208	12	172	698	189		155	1,653

Table 5. Preliminary red sea urchin landings (tonnes), 1989, South Coast Management Areas, as reported on sales slips and harvest logs combined.

SOUTH COAST MANAGEMENT AREAS																		
Month	Mainland and East Vancouver Island											West Coast Vancouver Island						Monthly Totals
	11	12	13	14	15	16	17	18	19	28	29	20	23	24	25	26	27	
Jan		212	206	65														483
Feb		3.7																3.7
Mar																		0
Apr																		0
May		20																20
June		90													5.4		14	109
July															1.7		46	48
Aug																		0
Sept																		0
Oct		7.8												50	32			89
Nov		130	317	55														502
Dec		107		1.9	6.7		9.0	70	60		1.6	15		170			38	480
Area Totals		571	523	122	6.7		9.0	70	60		1.6	15		220	39		98	1,734

Table 6. Summary of red sea urchins landings (tonnes) by area and month, 1989 as reported on sales slips and harvest logs combined.

NORTH COAST MANAGEMENT AREA											Total Monthly Landings
Month	1	2E	3	4	5	6	7	8	9	10	
Jan											0
Feb							48	54		113	215
Mar				52	1.3	83	76				213
Apr		110		54		24	43	1.5			233
May		56				3.5	33				93
June	0.2	34		0.1							34
July		17									17
Aug											0
Sept				0.1			5.8	9.3		15	30
Oct			1.6	5.0		15				15	37
Nov											0
Dec						39					39
Area Totals	0.2	217	1.6	112	1.3	165	205	65		143	910

Table 7. Summary of management actions in the red sea urchin fishery in British Columbia, 1970-1990.

Year	Management action	Quotas
1970-1978	A vessel C licence was required. A minimum size limit of four inches across shell or test (1973). An annual regulatory closure (1973), June 1 to August 31.	
1980	Metric minimum size limit, 100 mm.	
1981	Surveys undertaken and quotas set at 5% of estimated standing stock.	
1983	Introduction of a Z licence for red sea urchins. Logbooks mandatory.	
1985	Additional area quotas set for inside waters and the west coast of Vancouver Island. Season was reduced to periods of market demand-January.1-Feb.15; Sept. 15-Dec. 31.	
1986	First fishery in the north coast. Fall season reduced in south, Oct.-Dec.31.	
1987	North coast open year round, min. size limit (100 mm), no area quotas.	
1988	Min.(100 mm) and max.(140mm) size limits for the north coast fishery, open year round. Fishery limited to four day/week during open times in the south coast, Sunday to Wednesday inclusive. More detailed diver logbook.	
1989	Summer fishery in south coast, June 1-August 15.	
1990	Rotational fishery initiated in the north coast. Summer fishery in the south coast, June 1-August 30, on the west coast of Vancouver Island. Annual quota for south coast: 1667 t (3,675,000 lb.)	
1991	Licence limitation, based on landings 34,020 kg (75,000 lb.) cumulative over the period 1987, 1988, 1989, or; 2268 kg (5,000 lb.) landed from the north coast, Areas 1 to 10, from 1987, 1988 or 1989, or; 20 days recorded harvest in any year from 1987, 1988 or 1989.	

9. Green Urchin Fishery

by

R. Harbo and K.Hobbs

Effort has steadily increased in the green sea urchin fishery. Table 1 shows the annual landings by area, 1987-1989. Approximately 75 % of the catch in 1989 came from Areas 12 (47.5%) and 13 (26.3%). There were 12 tonnes taken in Area 27 in 1989, the highest recorded landing for the west coast of Vancouver Island.

Table 2 summarizes effort and CPUE. There have not been any biological studies, field surveys or stock assessment. The number of vessels almost doubled, the days fishing doubled but the total catch increased only by 28%. This may be due to incidental landings of greens with reds (small amounts, but assigned fishing days on sales slips) or it may reflect a decline in the stock. Diver CPUE, however, increased to 143 kg/hr. in 1989.

Landings in 1989, were 570 tonnes; 114 t (20%) landed early in the year, January 1 to February 29, and 457 t (80%) in the fall fishery, October 1 to December 31. Table 3 summarizes landings by month and area for 1989.

Preliminary landings in the early opening in 1990, January 1 to February 28, were 390 t, a considerable increase from 114 t landed over the same period in 1989. There were 145 vessels licensed in early 1990, compared to 140 issued to the same date in 1989. The fishery is scheduled to reopen, October 1 to December 31/90.

There has only been minor landings of greens in the north, 2% of the 1989 landings, coming primarily from Area 4 (Table 1). Transportation costs have limited development of the fishery in the north, since most of the product is exported live (whole). Fifteen companies purchased green sea urchins in 1989. At least one company processed the urchins and sent trays of roe.

FISHERY MANAGEMENT-1989/90

A Z licence for green sea urchins has been required since October, 1988. A condition of the licence was a minimum size limit of 55 mm test diameter. Compliance has been generally good, although some charges were laid. Generally, the market prefers urchins larger than 55 mm. Table 4 summarizes management actions in the green sea urchin, 1987-1990.

Cage weights are approximately 30 lb./cage, some pack the cages only 3/4 full to prevent crushing.

The season has been restricted annually to the period, January 1 to February 28 and October 1 to December 31, periods of strong market demand for sea urchin roe.

Subareas 12-1 and 13-29 to 13-40, north of Campbell River, closed January 31, 1989 due to heavy harvesting and increasing incidence of undersize urchins being taken. The area was reopened in October, 1989 and January, 1990.

An area south of Campbell River, subareas 13-1, 13-2 and 13-3 closed January 8, 1988 to October, 1988, but has been opened seasonally since the introduction of the size limit.

The average prices paid in 1989 for greens (sp. code 02) increased to \$1.67/kg or \$0.76/lb., considerably higher than the average price for reds (sp. code 69) \$0.61/kg or \$0.28/lb.

CURRENT ISSUES

In August, 1990, licence limitation was introduced for green sea urchins, effective in 1991. The eligibility criteria will be a cumulative landing requirement of 9,072 kg (20,000 lb.) over the two year period 1988 and 1989. It is estimated that 33 vessels will qualify initially. Other vessels may receive licences following the appeal process. Special consideration will be given to native Indian Bands that have trained divers, fished or invested in the fishery.

There needs to be an evaluation of the status of the stock.

It is recommended again that green sea urchins from Howe Sound be tested for dioxins and furans.

Export data should be reviewed.

Table 1. Annual green sea urchin landings (tonnes) by Management Area. 1987-1989.

Year	North Coast				East Coast Vancouver Island											West Coast Vancouver Island						Total (t)	
	1	2E	4	10	11	12	13 ¹	14	15	16	17	18	19 ¹	28	29	20	23	24	25	26	27		
1987 (log data)						1.8	58			2.5		4.2	37	17									121
1988		0.4		0.4	2.8	51	169	18	8.5	1.2	12	60	79	20	11	1.4	3.1	4.7	0.2	4.3			447
1989 ²	1.9		10			271	150	1.3		0.8	36	42	27	6.7	1.1	1.0	1.1	6.4			12		570
1987 to 1989	1.9	0.4	10	0.4	2.8	324	377	19	8.5	4.5	48	107	143	44	12	2.4	4.2	11	0.2	4.3	12		1138

¹ approximately 33% of landings are from Area 13, 16% from Area 19

² preliminary landings for 1989

Table 2. Green sea urchin landings (tonnes) and catch per unit effort data, as calculated from sales slips and harvest log data, 1987 - 1989 (preliminary).

Year	No. of vessels with landings	Total fishing days	Landings (t)	x cpue		Landed value \$10 ⁻³
				t vessel day ⁻¹	kg diver hr ⁻¹	
1987 (July - Dec. 31)	19 ¹	N/A	121 ²	-	151	147
1988	68	690	447	0.6	122	567
1989 ³	113	1358	570	0.4	143	990
1990 ⁴	-	-	390	-	-	-

¹ from logbooks

² from sales slips

³ preliminary data for 1989

⁴ preliminary data from processor hauls (Jan 1 - Feb 28)

Table 1. Annual green sea urchin landings (tonnes) by Management Area. 1987-1989.

Year	North Coast				East Coast Vancouver Island										West Coast Vancouver Island						Total (t)		
	1	2E	4	10	11	12	13 ¹	14	15	16	17	18	19 ¹	28	29	20	23	24	25	26		27	
1987 (log data)						1.8	58			2.5		4.2	37	17									121
1988		0.4		0.4	2.8	51	169	18	8.5	1.2	12	60	79	20	11	1.4	3.1	4.7	0.2	4.3			447
1989 ²	1.9		10			271	150	1.3		0.8	36	42	27	6.7	1.1	1.0	1.1	6.4			12		570
1987 to 1989	1.9	0.4	10	0.4	2.8	324	377	19	8.5	4.5	48	107	143	44	12	2.4	4.2	11	0.2	4.3	12		1138

¹ approximately 33% of landings are from Area 13, 16% from Area 19

² preliminary landings for 1989

Table 4. Summary of management actions in the green sea urchin fishery.

=====
 Year Management actions

- 1987** Scientific permits were issued, July 22 to December 31 to fishing vessels, for harvest by diving. The program was to identify stock abundance and distribution. Logbooks were issued with permits.
 Permits were limited to the inside waters of Vancouver Island, Areas 12 to 19, 28 and 29. Some minor area closures, parks or study areas, were in effect as for most dive fisheries.
 A minimum size limit of 40 mm was set as condition of the permit.
 Green sea urchins did not have a species code for statistics, so they were coded only as "sea urchins" and are mixed with the landings for red urchins. The landings may be separated by price, reds at <\$0.35/lb. and greens at >\$0.35/lb. As a result, landings have been estimated from logbook returns and hails from processors.
 Effort was restricted by limiting the season to the months of traditional market demand for sea urchins, October-December and January-February.
- 1988** Permits issued for the period, January 16-February 28.
 Green sea urchin landings were assigned a new statistical species code.
 A conservation closure was set, January 1-February 28, 1988 in subareas 13-1 to 13-3 due to the intensive fishery in a small area.
 A Z-licence (species specific) was required for green sea urchins in October 1 at the reopening of the fishery.
 A minimum size limit of 55 mm test diameter was set as a condition of licence.
 The season was limited again, January 1-February 28; October 1-December 31, 1988.
- 1989** The Z-licence, minimum size limit, and seasonal restrictions continued.
 A conservation closure as set for subareas 12-1, and 13-29 to 13-40, north of Campbell River, January 31-February 28, 1989 due to heavy fishing pressure and incidence of undersize urchins.
- 1990** The Z-licence, minimum size limit and seasonal restrictions continued.
- 1991** Licence limitation for 1991 was announced with the eligibility criteria of landings of 9,072 kg (20,000 lb.) over the two year period 1988 and 1989. At least 33 vessels will qualify before appeals are held.
-

10. Sea Cucumber Fishery

by

R. Harbo, K. Hobbs and G. Thomas

Tables 1 and 2 update landings, and effort for sea cucumbers. This fishery began in 1980 and has grown steadily since that time. In 1989, 1101 t were reported for a landed value of approximately \$1 million (Table 1). Landings in 1989 were reduced due to reductions in the south coast quota in 1989, from 1000 t to 300 t. The majority of landings have been taken from inside waters of Vancouver Island (Table 2).

In the past two years there has been increased utilization of the skin as well as the traditional muscle strip products.

Quotas in 1989 and 1990 remained the same for the coast (Table 3).

Data for the 1990 fishery is incomplete (Tables 1,2,4 and 5). Only 501 t of the 800 t quota has been reported on sales slips. Only 260 t has been reported for the north coast (500 t quota) and 241 t for the south (300 t quota) as shown in Table 2.

FISHERY MANAGEMENT

Table 3 gives the openings, quotas, landings, and closures for areas in 1989 and 1990. Some areas in the Strait of Georgia were closed in 1989 until further assessment, and remained closed in 1990.

SOUTH COAST

In 1989, due to an apparent decline in catch and effort in several inside areas, the quotas were reduced with some area closures (Table 3). The 1989 and 1990 quotas for Inside Waters were reduced to 150 t (from 500 t in 1988) resulting in early closures, January 29, 1989 and January 12, 1990 (Table 3). Areas 14 to 17, 28 and 29 were closed in 1989 and 1990.

The West Coast quota was also reduced to 150 t in 1989 and 1990, but no areas were closed. Most of the west coast landings have been taken from Area 24, and consideration should be given to splitting the quota by areas. The west coast closed on February 15, 1989 and January 15, 1990 (Table 3).

NORTH COAST

The fishery is characterized by high catch rates and short seasons, making catch monitoring difficult. Management efforts are further confounded by remote locations of the fisheries and processing plants, and the lack of on-the-grounds surveillance. Catches are tallied in-season by direct communication with processing plants and by hails from processing vessels. Vessel activity is monitored by a requirement to provide prior notice of fishing.

The fishery first expanded to the north coast during the latter portion of 1987, after the quota for the south had been landed. The fishery continued in early 1988, with a new annual 500 t quota for the north coast.

The 1988 quota remained at 500 t, judged to be a conservative level of harvest.

In 1989, the quota of 500 t was subdivided into the three districts, 160 t in the Queen Charlotte District, and 170 t in both the Central Coast and Prince Rupert Districts (Table 3). This pattern continued in 1990 (Table 4).

Vessel activity was monitored by requiring vessel operators to provide prior notice of fishing. As well, in 1989 and 1990, P-licence holders were required to provide bi-weekly hails from the fishing grounds.

Vessels have been issued P-licences to process sea cucumbers in the north coast to improve quality, maximize utilization of the product and due to limited shore based processing (in earlier years). Three P-licences were issued in 1987 and 1988, and in 1989 six were issued. However, only one vessel processed in 1987, no records were received for any processing in 1988, and only three vessels processed in 1989.

In 1990, 6 P licences for sea cucumbers were issued, and 2 vessels reported landings. Vessels landed 27 t of sea cucumbers from Area 3 for the first time (Table 5).

AREA LANDINGS

SOUTH COAST

Table 2 summarizes the landings from 1981 to 1989, for the north and south coasts. The two quotas for south coast areas, 150 t for the east coast of Vancouver Island and 150 t for the west coast of Vancouver Island were exceeded by 75% and 97%.

Table 4 shows catches by area each year for the south coast and Table 5 for the north coast. Tables 6 and 7 show landings by month in 1989.

In 1989 and 1990, Areas 14 to 17, 28 and 29 were closed due to concerns of over harvesting.

Preliminary landings and effort for 1990 are given in Tables 1 and 2. The fishery was expected to be short, but industry requested an early January opening.

In Washington State, the fishery is set over the period, May 1 to October 1, a time when they regard quality (recovery of muscle strips) as significantly better. In B.C., quality differs from area to area and processors have not found that quality changes significantly over the season.

In 1990, vessels were required to hail their weekly catches to the District offices. In-season landings were also monitored by a weekly telephone survey to processors, but these hails were not sufficiently timely or accurate to control catch.

NORTH COAST

In 1989, a total of 545 t of sea cucumber valued at \$494K was landed from the north coast (Tables 1 and 2). The 1989 landings were less than those in 1988, but were still (9% over quota. Because quotas were reduced in the south coast in 1989, the north coast landings now account for 50% of the total landings. Four processing vessels landed 48 t , approximately 9% of the north coast landings.

In 1988, the quota was landed in the four month period, January 1 to April 24. The quota was landed over the same four month period in 1989, but the area specific quotas (Table 3) served to rotate the fishery between the three north coast districts.

Table 5 contains annual north coast landings by area. In the first two years of the fishery the majority of the landings originated from the central coast, but landings were dispersed in 1989 and 1990 as the quota was subdivided. Area 7 has the highest total recorded landings on the B.C. coast, primarily because of local access to processing facilities.

Table 7 contains north coast landings by area and month in 1989. In both 1989 and 1990, fishing commenced in early January and progressed sequentially through the three north coast districts- central coast, Prince Rupert, then the Queen Charlotte Islands. The pace of the fishery increased dramatically in 1990, with the period of fishing reduced from four months in 1989 to 2.5 months in 1990 (Table 3). In 1990, the 170 t quota in the central coast was harvested in only eight days by 36 vessels.

The number of vessels with north coast landings has increased from 12 in 1987 to 29 in 1989. Total effort in fishing days declined from 574 days in 1988 to 420 days in 1989, probably because fishing was restricted due to earlier closures and closer monitoring of the quotas.

EFFORT AND CPUE

Table 1 lists catch and CPUE for the coast, and shows diver CPUE for the south and north coasts.

Of the 91 vessels fishing coast wide in 1989, 29 operated in the north coast. Members of native bands in Klemtu and Bella Bella participated in the fishery. Income from the fishery and employment provided by local processing have contributed to local communities.

In 1989, as in past years, diver production was higher in the north coast (Table 1).

There has also been increased participation by native bands in the south coast, on the west coast of Vancouver Island and in the Alert Bay area.

FISHERY CONCERNS

Under the current management plan, landings are difficult to monitor and quota overages are common. Further management controls are required to rationalize this fishery.

Fishermen continue to appeal for larger quotas in the north coast. A conservative ceiling is retained because of apparent stock decline in the south coast fishing areas. Abundance surveys, as carried out in Alaska, would provide some basis for modifying quotas in the future.

Licence limitation for sea cucumbers will come into effect in 1991. The qualifying criteria are:

- 22,680 kg (50,000 lb.0 cumulative landing requirement over the three year period 1987 to 1989 inclusive, or;
- 20 days recorded harvest in any year from 1987, 1988, or 1989.

Area licensing should be considered for 1991 to slow production and prevent landings from exceeding the quota.

Table 1. Sea cucumber catch per unit effort, as determined from sales slips and harvest log data 1980-1990.

Year	No. of vessels w/landings	Total fishing days	Total landings (t)	Landed value (10 ⁻³)	\bar{x} CPUE ¹ (t·vessel day ⁻¹)	\bar{x} CPUE ² (kg·diver hr ⁻¹)		Av Diver day ² length (hr.)	
						Total	(North) (South)		
1980	9	59	20		0.4	ND		ND	
1981	11	ND	27		ND	ND		ND	
1982	ND	ND	ND		ND	ND		ND	
1983	19	356	527		1.5	372		3.4	
1984	12	249	113	22	0.5	318		3.6	
1985	21	271	346	94	1.3	342		2.9	
1986	34	733	786	236	1.1	289		3.1	
1987	56	1906	1722	768	0.9	347	(433)	(327)	4.5
1988	79	1512	1922	984	1.3	281	(294)	(276)	2.7
1989 ³	91	1022	1101	998	1.1	285	(307)	(267)	2.1
1990 ⁴	93	781	501	637	0.6	NA	NA	NA	NA

ND - no data

NA - data not available

¹ - data from sales slips

² - data from harvest logs

³ - 1989 data preliminary to August 1989 sales slips and harvest logs combined

⁴ - 1990 data from incomplete sales slips.

Table 2. Cumulative landings (tonnes) of sea cucumbers by year for North and South Coast Areas of British Columbia, 1981 to 1990, as reported on sales slips.

Year	NORTH COAST (Areas 1 to 10)	SOUTH COAST			Coastwide Total
		E. Coast Vancouver Is. (Areas 11-19, 28, 29)	W. Coast Vancouver Is. (Areas 20-27)	South Coast Total	
1981		40	6	46	46
1982		NO RECORDED LANDINGS			
1983		472	55	527	527
1984		113		113	113
1985		320	27	347	347
1986		777	8.7	786	786
1987	421	859	441	1,300	1,721
1988	580	620	722	1,342	1,922
1989 ¹	545	261	295	556	1,101
1990 ²	260	104	137	241	501
Totals 1981 to 1990	1,806	3,566	1,692	5,257	7,063

¹ 1989 preliminary.

² 1990 data from incomplete sales slips.

Table 3. Sea cucumber quotas and closures for 1989 and 1990. All quota areas opened January 1.

South Coast (300 tonnes total; 472,500 pieces)

- (a) 150 tonnes (236,250 pieces) - Areas 20-27, - West Coast Vancouver Island.
Closed: February 15/89 ; January 15/90.
- (b) 150 tonnes, Areas 11 to 13, (18 and 19) - Inside waters. (Areas 14 to 17 closed.)
Closed: January 29/89 ; January 12/90.

North Coast - (500 tonnes total; 787,500 pieces)

- (a) 160 tonnes (252,000 pieces) - Areas 1, 2E and 2W - Queen Charlotte Island District.
Closed: April 14/89 ; February 17/90.
 - (b) 170 tonnes (267,750 pieces) - Areas 3 to 5 - Prince Rupert District.
Closed: March 3/89 ; January 23/90.
 - (c) 170 tonnes - Area 6 to 10 - Central Coast District.
Closed: January 16/89 ; January 8/90.
-

* for statistical purposes 1 piece = 1.4 lb. or 0.635 kg.

Table 4. Annual South Coast sea cucumber landings (tonnes), 1980 to 1990, as reported on sales slips.

Year	South Coast Total	Mainland and East Coast Vancouver Island											Sub Total	West Coast Vancouver Island						Sub Total		
		11	12	13	14	15	16	17	18	19	28	29		20	23	24	25	26	27			
1980/81	48			8	8		*	15	16	1.0			41	6		*	*					7
1982														No landings recorded								
1983	527			239	6		44	13	18	152			472	*	1	1	6	47				55
1984	113			2.3	4.8			61	15	30			113									
1985	346		25	144	25		15	14	45	50		1.6	319			27						27
1986	786		0.2	45	85	39	84	179	183	162			777	1.8	4.1			2.8				9
1987	1300		135	236	22	77	178	1.7	68	91	50		859	*	36	136	169	89	11			441
1988	1342	59	71	143	10	16	15	2.6	226	85	1.3		620	12	10	444	80	62	114			722
1989 ¹	555		62	127					32	40			261	45	37	152	29			30		295
1990 ²	241		75	15				2.0	6.0	6.0			104	3.0		97	29			7.0		137
Area Totals		59	368	951	152	132	336	288	609	617	51	1.6		68	89	857	313	202	162			
Mainland and East Vancouver Island = 3566												West Coast Vancouver Island = 1691						South Coast Total = 5257				

¹ Preliminary 1989 totals.

² Incomplete 1990 landings from sales slips to June/90.

* Less than 100 kg

Table 5. Annual North Coast sea cucumber landings (tonnes) as reported on sales slips.

Year	Management Area										Annual Totals	
	1	2E	2W	3	4	5	6	7	8	9		10
1987		19			3.2	5	4.2	376	14			421
1988		1.4			18	0.2	120	423	17			580
1989 ¹		149			74	96	70	156				545
1990 ²		23		27	26	54	33	98				260
Area Totals		192		27	121	155	227	1053	31			1705

¹ Preliminary harvest log and sales slip information.

² 1990 data from incomplete sales slips.

Table 6. Preliminary sea cucumber landings (tonnes) in 1989, by area and month, for South Coast Management Areas as reported on sales slips.

SOUTH COAST MANAGEMENT AREAS																			
Mainland and East Vancouver Island											West Coast Vancouver Island							Monthly Totals	% Totals
Month	11	12	13	14	15	16	17	18	19	28	20	23	24	25	26	27			
Jan		62	127					32	40		23		60	2		2	348	(63)	
Feb											23	37	92	27	1	28	207	(37)	
FISHERY CLOSED																			
Area Totals		62	127					32	40		45	37	152	29	1	30	555		
Mainland and East Vancouver Island: 261					West Coast Vancouver Island: 294					South Coast total: 555									

Table 7. Preliminary summary of sea cucumber landings (t) in North Coast Management Areas, by area and month, 1989 as reported on sales slips.

Month	North Coast Management Area										Monthly Totals	
	1	2E	2W	3	4	5	6	7	8	9		10
Jan		1			29	30	70	156				287
Feb					44	24						68
Mar		70				43						112
Apr		78										78
May												
June				FISHERY CLOSED								
Area Totals		149			74	96	70	156				545

11. Octopus Fishery (Diving, Hook and Line, Trap and Trawl) -1989

by

R. Harbo and K. Hobbs

The octopus fishery has shown rapid growth in recent years due to the directed effort by divers and the retention of octopus landed in other fisheries. Tables 1 and 2 show the increase in total reported landings, from 23 t in 1984 to 209 t in 1988, and a level in the catch at 205 t in 1989 (175 t south, 29 t north).

Much of the octopus landed has been utilized as halibut bait. In 1989, there has been an increased interest in octopus as a food product. There may be a great potential for growth in the fishery in the next few years. The average price for octopus in 1989 was \$3.19/kg (\$1.45/lb.). The average price for the higher quality, diver caught octopus was \$3.48/kg or \$1.58/lb. The price was \$1.85/kg or \$0.84/lb. for trawl caught octopus. Trap caught octopus was \$3.02/kg or \$1.37/lb.

The majority of landings are currently taken by directed effort by divers (Table 3) in the south coast. Area 19 accounts for 30% of the south coast landings and Area 13 for 13%. Minor landings are taken as incidental catch in trap (prawn) and trawl (groundfish/shrimp) fisheries. In 1989, trawl vessels were required to obtain a Z-octopus licence to retain octopus for bait or for sale.

SOUTH COAST

There was a minor increase in landings from the south coast, 175 t in 1989, up from 169 t in 1988.

The majority of landings are from the south coast areas (Table 1), Port Hardy to Campbell River (Areas 12-13), the Gulf Islands (Areas 14,16,17,18), Victoria to Sooke (Areas 19-20). Landings by month in 1989 are shown in Table 4. Landings are still relatively minor on the west coast of Vancouver Island, primarily from Barkley Sound (Area 23), Clayoquot Sound (Area 24), and Area 25 in 1989 (Table 1).

There were a some changes in 1989 to the management plans of octopus:

1. The Z-octopus licence, issued to fishermen without a vessel, was discontinued in 1989.

2. A seasonal closure was implemented at Wilby Shoals, Campbell River, subarea 13-1, January 1 to February 29, 1989 and November 1, 1989 to February 28, 1990. This closure was at the request of diving fishermen who wanted to protect spawning octopus.

Small closures for the commercial harvest of octopus continued in 1990 in study areas and areas designated as underwater parks or reserves.

There has been some concern expressed by individual fishermen and fishery officers that the current levels of harvest cannot be maintained in easily accessible areas.

NORTH COAST

North coast landings are shown in Table 2. Most of these landings are incidental to the trawl and trap fisheries. There was a slight decline in landings in the north to 29 t in 1989 from a high of 41 t in 1988.

DIVER CPUE TRENDS

Divers landed approximately 80% of the total catch in 1989 (Table 3). Divers are required to complete and submit accurate records of their harvest. There were logbook records for 1059 diver days reported for 34 divers in 1989.

Table 4 presents a monthly summary of landings by Area in 1989. Effort and landings decreased over the summer months of June-July-August.

There was little change in effort and CPUE between 1988 and 1989. Diver catch per unit effort (CPUE) is given in Table 6. There were sales slip records for 25 vessels landing octopus by divers in 1989, compared to 23 vessels in 1988.

Table 1. Annual landings (tonnes) of octopus in the South Coast and Fraser River division, 1984 to 1989 - all gear types.

Year	Coastwide Total (t)	South Coast (t)	SOUTH COAST MANAGEMENT AREAS																		
			11	12	13 ¹	14	15	16	17	18	19 ¹	20	21	23	24	25	26	27	28	29	30
1984	23	13	0.4	0.3	2.1	0.1	*	*	0.1	1.7	5.6	2.0	*	0.1	0.1	*	*	*			
1985	34	24	0.3	1.5	3.0	1.0	*	*	0.8	3.5	7.5	4.6	0.2	0.7	0.2	*	*	*	0.1	0.1	
1986	53	45	0.7	4.1	4.2	0.5	0.5	0.9	6.7	5.1	11	6.3	0.6	1.0	1.8	0.3	0.7	0.6	*	0.3	
1987	130	102	0.8	18	14	1.0	0.3	0.9	7.2	9.4	29	8.9	0.1	4.4	6.3	*	0.2	*	*	1.6	
1988	209	169	1.2	41	21	1.7	1.5	0.1	8.0	12	50	7.6	0.1	3.1	10	0.3	0.1	10	0.4	1.0	
1989 ²	205	175	1.6	35	19	4.8	1.1	1.3	12	34	36	7.2		5.8	11	4.6	0.8	0.2	0.1	0.8	1.5
Area Totals 1984 to 1989	648	525	5.0	100	63	9.1	3.4	3.2	35	66	139	37	1.0	15	29	5.2	1.8	11	0.6	3.8	1.5

¹ Areas 18 and 19 account for 32% of South Coast landings.
 Areas 11 to 13 account for 26% of South Coast landings.
 Landings on the West Coast of Vancouver Island still relatively minor.

² 1989 preliminary landings.

*

Less than 100 kg.

Table 2. Annual landings (tonnes) of octopus in the North Coast, 1984 to 1989 - all gear types.

Year	Coastwide total (t)	North coast (t)	North Coast Areas										
			1	2E	2W	3	4	5	6	7	8	9	10
1984	23	10	0.4	1.9	0.1	0.3	1.9	4.0	1.4		0.2		
1985	34	8.5	0.3	0.9		1.0	2.0	2.0	1.0	0.5	0.5	0.3	
1986	53	7.6	0.2	2.2	*	*	1.6	1.1	0.3	*	1.7		0.5
1987	130	2.7	0.2	2.8	0.3	0.4	4.0	12	1.9	1.3	3.6	0.2	0.6
1988	209	41	3.8	5.7		0.6	4.5	13	2.9	2.0	6.9	0.4	0.8
1989	205	29	0.8	3.5		0.3	4.6	12	1.2	2.8	1.6	0.8	1.0
Area totals 1984-1989	648	123	5.7	17	0.4	2.6	19	44	8.7	6.6	15	1.7	2.9

less than 100 kg.

Table 3. Landings of octopus by gear types, 1984 to 1989, as reported on sales slips.

Year	Total landings (t)	Gear type			
		Hook and Line (t)	Trawl (t)	Dive ¹ (t)	Trap (t)
1984	25	1.2	6.7	13	4.0
1985	34	2.9	4.2	20	6.7
1986	53	2.8	5.5	40	4.7
1987	130	1.5	21	95	12
1988	209	3.2	28	161	17
1989	205	3.4	21	165	16

¹ dive - 72% in 1987; 75% in 1988, 80% in 1989

Table 4. Monthly summary of octopus landings by South Coast Management area (tonnes) in 1989¹, as reported on sales slips

SOUTH COAST MANAGEMENT AREAS																			
Month	East Coast Vancouver Island											West Coast Vancouver Island							Monthly Totals
	11	12	13	14	15	16	17	18	19	28	29	20	23	24	25	26	27	30	
Jan		4.6	1.6	0.3	0.3		0.7	1.3	2.0		*	0.5	0.2	0.6	*		*		12.2
Feb		4.5	3.0	0.4			0.3	1.1	2.8			0.4	0.2	0.3					13.1
Mar		2.8	3.1			0.2	0.8	0.9	3.5			0.3	0.1	0.2					11.8
Apr	*	1.6	2.0	*	*	0.2	0.4	0.9	3.5			0.9	0.3	0.1	*			0.6	10.4
May	0.2	0.9	0.4	0.5		*	1.3	2.2	3.0		0.1	1.3	0.3	0.4	*			0.8	11.6
June	0.2	0.4	0.4	0.3		*	1.6	0.5	1.5		*	0.5	2.8	1.4	0.1				9.7
July	0.1		*	0.2		*	1.1		1.7			0.2	0.4	0.8	0.2	0.3	0.1		5.3
Aug	0.0	1.6	0.6	0.2	*		0.6	1.3	1.1		0.1	0.3	0.4	2.3	1.2	0.2			9.8
Sept	0.3		1.3	0.3	*	*	1.5	3.2	4.6		*	1.0	1.1	0.6	1.5			*	15.6
Oct	0.2	4.9	2.5	0.6	0.1	0.2	0.9	3.2	7.5	*	0.5	0.1		3.4	1.5	0.1	*		25.7
Nov	0.2	5.3	2.3	0.8	0.4	0.4	1.2	2.2	2.8	*	*	0.9				0.1			16.6
Dec	0.4	8.6	2.1	1.1	0.2	0.2	1.8	17.3	2.0			0.7		0.6		0.1			35.0
Area																			
Totals	1.6	35.2	19.3	4.8	1.0	1.3	12.1	33.9	35.9	0.1	0.8	7.2	5.8	10.8	4.6	0.8	0.2	1.5	176.9

*landings less than 100 kg.

¹preliminary landings for 1989.

Table 5. Monthly summary of octopus landings by North Coast Management Area (tonnes) in 1989¹ as reported on sales slips.

Month	NORTHCOAST MANAGEMENT AREAS										Monthly Total	
	1	2E	2W	3	4	5	6	7	8	9		10
Jan		0.3			0.3	0.8		0.1				1.5
Feb		0.5			0.6	1.2		0.2	*		*	2.6
Mar		0.6			0.2	0.7		0.4				1.9
Apr	0.3	0.2			0.4	0.9	*	*	0.1	*	0.1	2.1
May	*	0.7			0.7	0.6		0.2	0.1	*	0.1	2.5
June		*			0.1	0.3	0.1	0.6	0.1		0.1	1.4
July					0.3		0.1	0.2	0.1	0.7	*	1.4
Aug					*		*	0.1	0.4	0.1		0.6
Sept		0.3			0.1	0.4	*	0.2	0.3			1.2
Oct		0.4		*	0.5	2.4	0.5	0.2	0.1		*	4.2
Nov	0.3	0.3		*	0.9	1.0		0.1			0.2	2.8
Dec	0.1	0.3		0.2	0.4	3.4	0.4	0.4	0.4		0.4	6.0
Area												
Totals	0.8	3.5		0.2	4.6	11.7	1.2	2.8	1.6	0.8	1.0	28.1

* less than 100 kg.

¹ preliminary landings for 1989.

Table 6. Diver catch per unit effort in the octopus fishery (from logbook data).

Year	No. of vessel days	CPUE kg.hr
1984	136	33.7
1985	211	45.8
1986	379	35.3
1987	531	68.3
1988	954	74.3
1989	958	79.9

12. Scallop Fishery

by

R. Harbo and K. Hobbs

ROCK SCALLOPS

There have been concerns expressed regarding depletion of rock scallops in the Strait of Georgia (Bourne and Harbo 1989, 1990) by sport divers. No stock assessment or management actions have been taken. There is a regulation prohibiting the commercial harvest of rock scallops.

The daily limits for sport fishing are 6 rock scallops per day, south of Cape Caution. North of Cape Caution is closed due to risk of Paralytic shellfish Poison (PSP).

PINK AND SPINY SCALLOPS

Table 1 presents the landings of scallops over the past 8 years. The fishery began in 1982, with a regulation change that allowed the harvest by diving. The catch by divers decreased for the first time in 1989, but the total catch increased to high of 77 t due to landings of 37 t from five vessels using drags (reported on logs).

Most landings (52%) of spiny, Chlamys hastata, and pink C. rubida, were taken by divers in 1989*. The landings increased slightly to a high of 77 t, with 14 vessels reporting catches (Table 1). The landings were mostly from Areas 20, 17 and 18 as shown in Table 2.

There were not any landings in 1988 in the north coast. There have been minor landings of weathervane scallops, Patinopecten caurinus in the past.

The increase in landings is attributed to product taken by small trawls, primarily in Area 20. Most of the catch was reported to be C. hastata but no catch sampling was undertaken.

No surveys of populations or catches were undertaken in 1989. The size limit was reduced to 55mm shell height in 1989. Illustrations of how to measure scallops (shell height) were included in the management plan and commercial fishing guide.

PARALYTIC SHELLFISH POISON IN SCALLOPS

Scallops are not known to accumulate toxins on the east coast of Canada. Some data for Pacific coast scallops are presented in Table 3.

The rock scallop, Crassadoma gigantea (Bernard 1986), has been found to accumulate high levels of PSP, as shown in Table 3.

The spiny scallop has consistently tested positive, with high levels of PSP (Table 3).

Monitoring of drag catches should be carried out.

*sales slip reports by gear and area are required.

Table 1. Landings (tonnes, whole weight) and value of pink and spiny scallops in British Columbia commercial fishery, 1982-1989 as reported in sales slips.

Year	Number of Vessels	Landings (t)	Landed Value ¹ (\$10 ⁻³)	Dredge Vessel CPUE (t·vessel day ⁻¹)	Diver ² CPUE (kg·diver hr ⁻¹)
1982	8	8	\$ 19		-
1983	6	11	24		-
1984	13	16	74		-
1985	13	53	291		-
1986	15	68	212		61
1987	10	61	250		54
1988	15	67 ³	286	0.08	118
1989 ⁴	14	77 ⁵	321	0.14	66

¹ estimated landed value

² diver CPUE calculated from harvest log data on 36 t total landings (1986), 48 t (1988), 30 t (1989)

³ diver landings were 57 t, dredge landings were 10 t.

⁴ preliminary landings for 1989.

⁵ diver landings were 40 t, dredge landings were 37 t.

Table 2. Preliminary scallop landings (tonnes) by month and Management Area for 1989 as reported on sales slips.

SOUTHCOAST MANAGEMENT AREAS													
Month	East Coast Vancouver Island							West Coast Vancouver Island				Total Landings	
	13	14	17	18	19	28	29	20	23	25	27		
Jan			0.5	1.0	0.3			3.5					5.3
Feb			0.3	1.3	0.1			3.6					5.4
Mar	0.1		0.6	1.9		0.1		4.9					7.7
Apr			0.8	1.8			*	8.4					11.1
May			0.8	1.5				8.6	0.1				11.1
June			0.9	1.8				6.7					9.4
July			1.8	1.6				3.0				*	6.4
Aug			2.6	2.0									4.7
Sept			1.7	1.5			0.2	0.4					3.8
Oct			2.8	0.9			0.4						4.0
Nov			1.1	1.5									2.6
Dec		*	1.8	3.0						0.1			4.9
Area Totals	0.1	*	16	20	0.5	0.1	0.6	39	0.1	0.1	*		77

* less than 100 kg.

13. Intertidal Clam Fishery

by

F. Dickson and K. Hobbs

SPECIES HARVESTED

The intertidal clam fishery harvests four species primarily, the manila clam, native littleneck, butter clam and razor clam. The manila clam has been the most important clam in the past ten years of landings (Fig 1). Butter clams are currently underutilized.

LANDINGS AND VALUE

Landings in the intertidal clam fishery increased steadily over the past ten years up to 1988 (Fig 1). In 1989 there was a decline in landings as the fishery has now fully harvested accumulated stocks and must rely on annual recruitment to beaches. The most valuable species is the manila clam (Fig 2). Up to the late 1970's, butter clams were the most valuable species.

In 1989 (preliminary) manila clam landings were 2728 tonnes (approx. 6.0 million lb.) for a landed value of \$5.9 million (\$0.98/lb.). This is a decrease over 1988 of 29% by weight but only 14.3% in value as the price per pound increased in 1989. The 1989 littleneck production nearly doubled over that of 1988 as clam harvesters looked to these clams to supplement declining available manilas. Total clam production was 4,387 t valued at \$7.6 m.

CLAM HARVESTERS AND PROCESSORS

A new clam licence was introduced in May, 1989. Prior to this time the Department could only estimate the number of commercial clam harvesters to be 3,000 to 4,000 of the 20,000 Personal Commercial Fishing Licences issued in 1988. In 1989, a total of 1870 licences were issued (Table 1).

It is estimated that there are 37,000 sports fishermen who harvest shellfish (all species). There is no estimate of the number of recreational clam diggers. There is a record of 31 companies buying clams in 1989. The Department does not have an estimate of native indian harvesters.

CLAM BEACHES

An inventory of clam beaches in the south coast is being updated and it assesses beach use by Indian food fishermen, commercial and recreational fishermen (Fig 3). This information has been entered into a data base that includes digitized charts

with clam beaches, water quality survey stations, oyster leases and applications. The data base is being developed by Environment Canada. The clam atlas is an important reference tool for field staff responding to applications for clam culture or other foreshore uses.

CLAM LANDINGS BY MANAGEMENT AREAS

(Fig. 4) presents data for intertidal clam landings by fisheries management areas. The new clam licence is an area licence, and the coast was divided into six areas, one area in the north for razor clams and five areas in the south with approximately equal landings of manila clams (Fig. 5).

CLAM MANAGEMENT

There are several management practices used singly or in combination to manage the clam fishery. They include the clam licence including area restrictions introduced in May 1989. Harvesters must choose one of six areas on the coast (Fig. 6) for the year.

The primary conservation method in the commercial fishery is a minimum size limit that allows clams to spawn at least once before they are taken in the fishery. To attempt to maintain a year round supply of clams, openings are staggered for the various areas. Limiting the number of days of fishing per week extended the fishery in heavily exploited areas such as Savary Island and Baynes Sound.

Currently, there are restrictions on the use of hydraulic or mechanical fishing gear. Harvesting in the intertidal zone is strictly by hand tools.

There are a number of beach closures as a result of pollution. There are a growing number of closures of beaches or subareas due to conservation when the beach has been repeatedly dug or when there are problems of sublegal clams being taken. PSP closures are in effect permanently in the north coast and periodically in the south. Harvest of clams from closed polluted beaches is a growing enforcement problem.

There were 13 recreational reserves in the Strait of Georgia closed to commercial fishing in 1989. These are detailed as a condition of the clam licence. In 1990, an additional three beaches on Gabriola Island have been closed to commercial fishing by public notice.

A clam harvest log was issued in 1989 to assist in the compilation of clam statistics, however, it was poorly completed and discontinued for the 1990 fishery. Instead, a new clam fish slip has been introduced to better capture individual licensed fisherman information.

The sports fishery is managed by bag limits only. A shellfish sports licence has been considered. Minimum size limits for clams taken in the sports fishery will not be implemented until the effort is considered to pose conservation problems.

CLAM CULTURE

There is growing interest in manila clam culture due to production limitations from the wild fishery and its inability to provide a consistent year round market supply. A letter of understanding on clam culture between the Department of Fisheries and Oceans and the Ministry of Agriculture and Fisheries is in final approval stages and has been reviewed by the federal-provincial Aquaculture Industry Advisory Committee. While the economics of clam culture are yet to be proven, it is initially being encouraged on existing shellfish tenures, particularly oyster tenures, and on beaches fronting Indian Reserves. As of June, 1990, 24 clam culture or joint oyster/clam culture licences have been issued by the Province.

1990 INTERTIDAL CLAM FISHERY

Due to conservation concerns, Savary Island, Area 15-2, Mary Basin in Area 25, and Area 26 have been kept closed to commercial harvest in 1990. Fisheries in Georgia Strait have been restricted to three or four days per week. Both of the spring fisheries closed much sooner than planned due to early depletion of legal sized clams available for harvest as well as problems with illegal harvest from contamination closed areas. 1990 landings appear to be much lower than those of 1989 for the same time period and there has been a heavier harvest of littleneck clams.

Table 1. 1989 COMMERCIAL CLAM LICENCES

Area	Description	No. Licences Issued
A	North Coast	10
B	Johnstone Strait	224
C	Sunshine Coast	400
D	Upper Strait of Georgia	421
E	Lower Strait of Georgia	374
F	West Coast of Vancouver Island	441
Total		1870

ANNUAL CLAM LANDINGS 1979-1989 TOTAL FOR B.C.

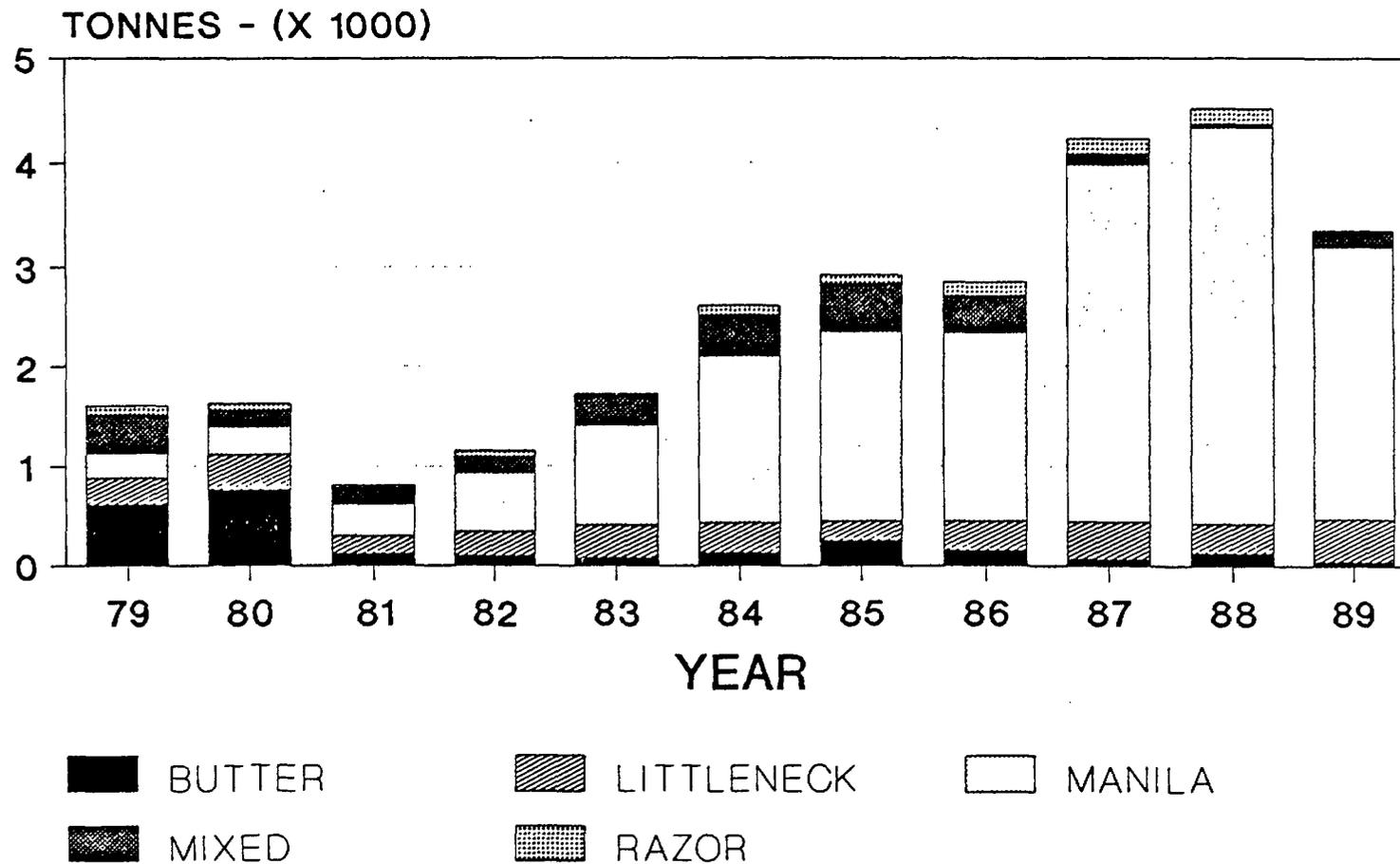


Figure 1.

LANDED VALUES OF INTERTIDAL CLAMS 1984-1989

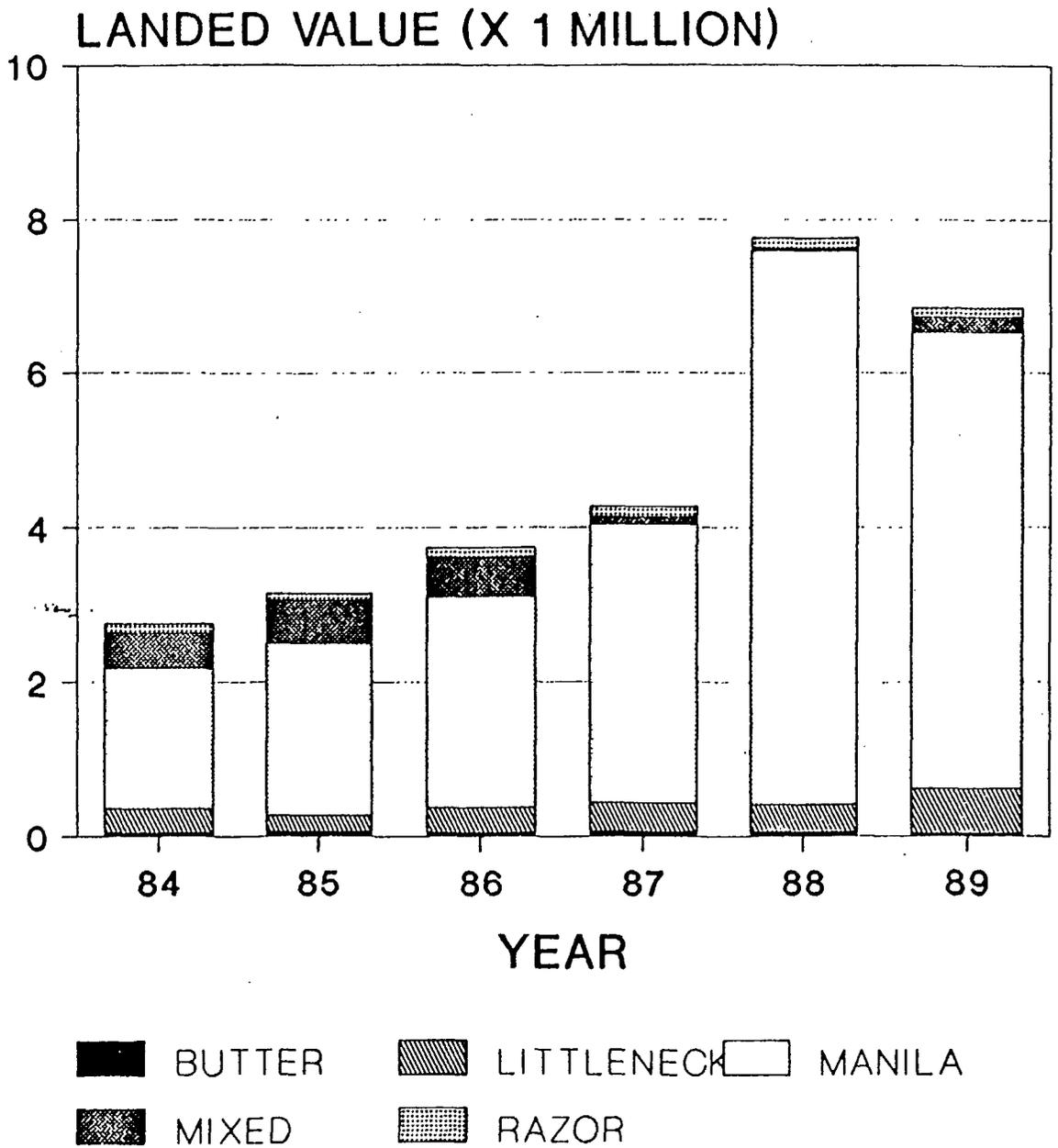


Figure 2.

CLAM BEACH INVENTORY

<u>AREA</u>	<u># OF BEACHES</u>		
	<u>COMM</u>	<u>IFF</u>	<u>REC</u>
Mainland and East Coast Vancouver Is. (12 to 20):	472	167	482
	Estimated area: 6892 HA		
West Coast Vancouver IS. (23 to 27):	192	49	154
	Estimated area: 1218 HA		
South Coast Totals:	664	216	636
	Total estimated area: 8110 HA		

Figure 3.

MANILA, LITTLENECK & MIXED CLAM LANDINGS BY AREA, 1984-1989

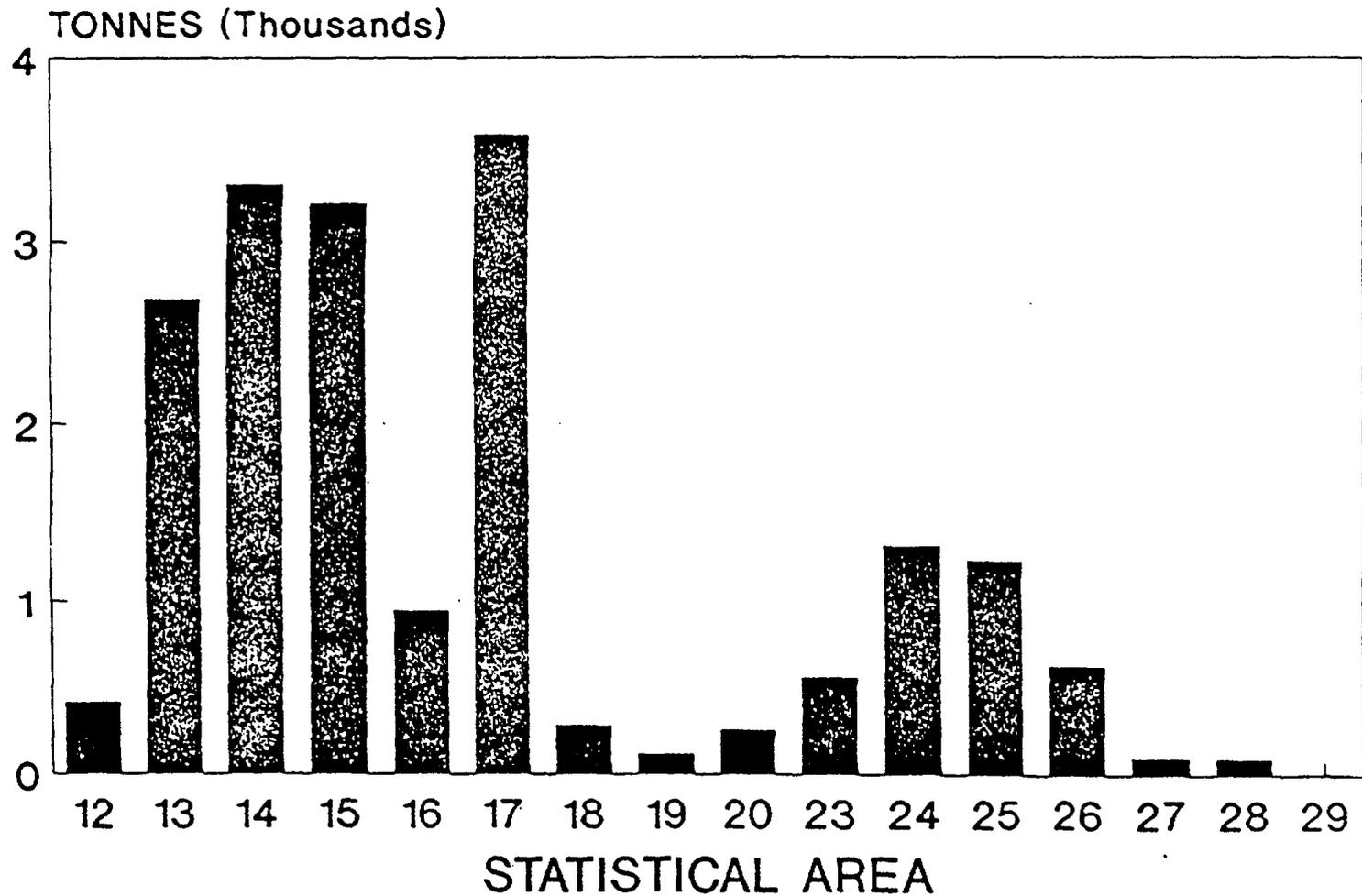


Figure 4.

Commercial Clam Harvesting Areas

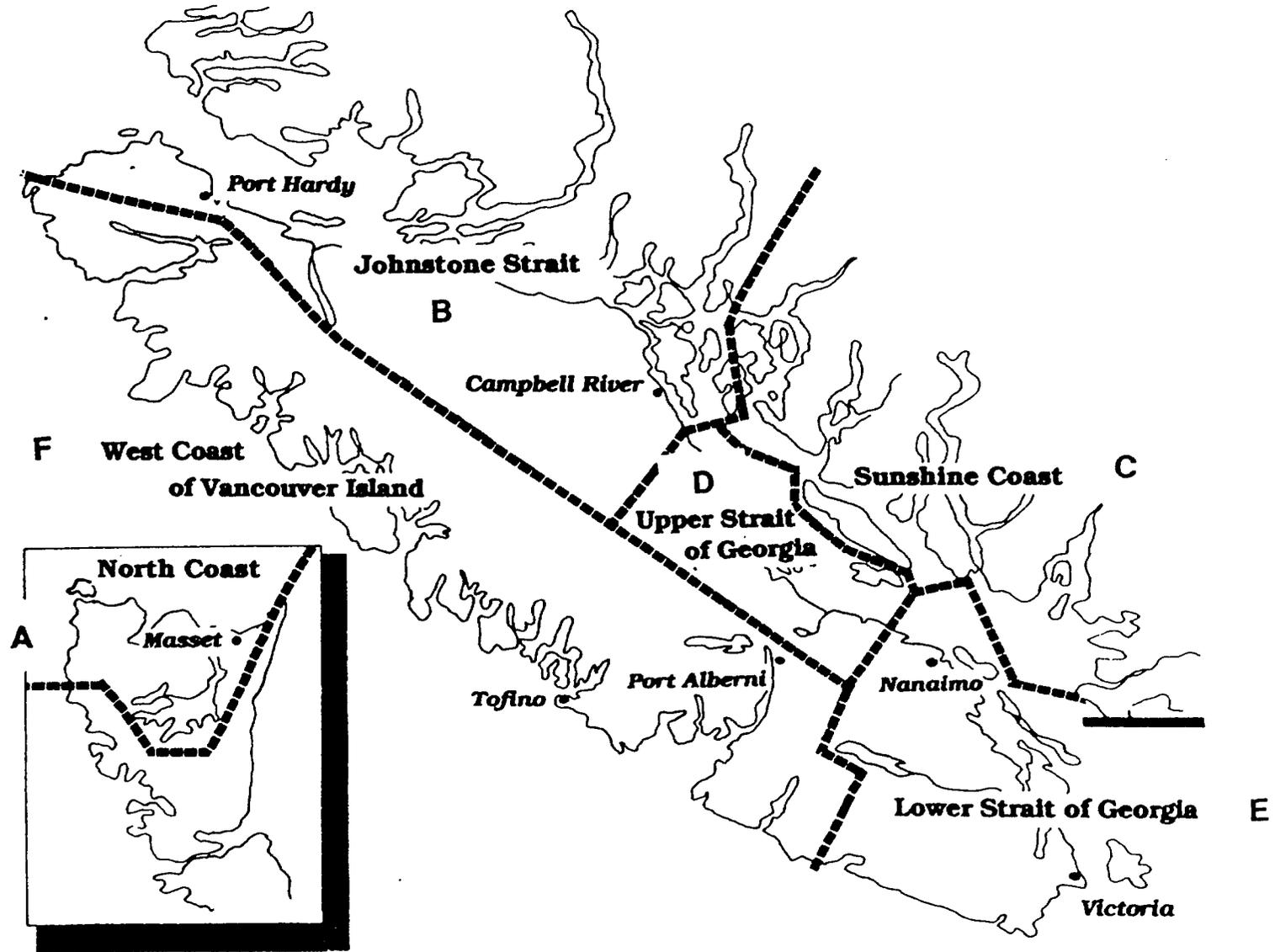


Figure 5

14. Oyster Fishery

by

N. Bourne

Management of oyster resources in British Columbia is a responsibility of the Provincial government. Leases are granted by the Lands Branch of the Ministry of Forests and Lands and management of the resource is carried out by the Agriculture and Commercial Fisheries Branch of the Ministry of Agriculture and Fisheries.

The British Columbia oyster industry remains primarily an intertidal bottom culture operation. In 1989 there were 241 intertidal bottom sites comprising 909 hectares (Table 1). Interest in off bottom culture continued in 1989 with 152 sites comprising 736.5 hectares. Only minor interest exists in near bottom culture. The total number of growers was 270 in 1989. It is expected that any further significant increase in oyster culture will occur in off bottom rather than intertidal bottom culture because of the lack of suitable intertidal bottom sites.

At present oyster production data for 1989 are preliminary but indications are that total landings will be about 4,000 metric tonnes, a 9% increase over the previous year and the highest since 1973 (Table 2). This continues the trend of recent years of increasing annual production. There was a significant increase in the number of single oysters harvested in 1989 (80% over the previous year). The value of oysters also increased substantially (45% over the previous year) to a record level of \$5.2 million.

The industry continued to rely primarily on remote setting of mature (eyed) larvae for their seed source. Most of the larvae were supplied from hatcheries in the United States. A few growers obtained their seed supply from an excellent wild set in Nesook Inlet in Nootka Sound. An excellent set was reported in Pendrell Sound but it was not used by anyone in the industry.

Conflicts between oyster growers and clam harvesters were reduced in 1989 and 1990. This resulted from better delineation of oyster lease boundaries and the fact that growers were more familiar with clam harvesting schedules.

Interest continues in the culture of other oyster species, particularly the European flat oyster, *Ostrea edulis*. Arrangements were made to breed stocks of this species from Scotland and Nova Scotia under quarantine conditions at the Pacific Biological Station in 1990 to determine if these stocks are faster growing than the stock now in British Columbia which originated from California hatcheries.

Considerable interest also exists amongst oyster growers to use part of their intertidal bottom areas for manila clam, Tapes philippinarum, culture. Some growers undertook an active manila clam seeding program in 1990. It is expected that the major portion of leased intertidal bottom areas will continue to be used for oyster culture.

There is continuing strong interest in oyster culture in British Columbia and it is expected that landings and value will continue to increase in 1990.

Table 1. Type, number and area of Pacific oyster, Crassostrea gigas, growing sites in British Columbia in 1989.

<u>Culture type</u>	<u>Number of Sites</u>	<u>Total Hectares</u>
Bottom	241	909.220
Near Bottom	3	13.310
Off Bottom	152	736.480
Bottom and Off Bottom	22	96.960
Bottom and Near Bottom	2	12.940
Total	420	1,768.91

Total Number of Registered Growers 270

Table 2. Production of Pacific oysters, Crassostrea gigas, in British Columbia in metric tonnes (MT) whole weight, dozens (single oysters) and total value in millions of dollars, 1981 - 1989

	1981	1982	1983	1984	1985	1986	1989
M. tonnes	1,415	2,366	2,977	3,542	3,420	2,394	4,000
Dozen	41,352	63,764	101,067	146,067	240,000	374,368	400,000
Value	1.03	1.23	1.55	2.00	2.60	2.35	2.80

* Data for 1989 are preliminary

15. Gooseneck Barnacle Fishery

by

R. Harbo, B. Adkins and K. Hobbs

Table 1 updates landings in the gooseneck barnacle fishery. There was little monitoring of the fishery in 1988 or 1989. The total reported landings declined in 1989 to 35 tonnes, from a high of 49 tonnes reported in 1988.

There were landings in 1989, in the north coast, 0.7 t in Area 7 and 1.2 t from Area 8, and small amounts from Area 2 (Table 1). The difficulties in transportation to ship this product live to Spain or other destinations has limited development of the fishery in the north.

Table 2 presents landings by month for 1989.

The reported value of goose barnacles increased to \$11.51/kg (\$5.11/lb.) from \$9.08/kg in 1988. The number of companies buying increased to 3 from 11, and only 130 licences were issued compared to 467 licences issued in 1988. There has been a minor increase in domestic sales, but most of the product is exported live to Spain.

The number of fishing days reported dropped by 46% in 1989. CPUE data is not yet available.

The reported CPUE on sales slips declined to 32 kg/day in 1988 from 40 kg/day in 1987. Sales slip data is still incomplete for 1989, but harvest log data was 34 kg/day. Considering the high value of the product and the nature of the fishery, it is likely that much of the landings are not reported.

During winter months there is often an under supply of barnacles resulting from night tides and poor weather conditions. The price paid to harvesters may reach as high as \$9.00/lb. The high price often attracts new harvesters into the fishery in the spring and the price drops to approximately \$5.50/lb. In the summer the price may drop as low as \$4.00/lb.

During the period, April to September, one buyer purchased 4000 to 5000 lb./week.

During most of the year buyers tend to purchase product from a regular crew of pickers. In most cases sale is confirmed prior to the product being harvested. Most of the crews are comprised of experienced pickers, harvesting for four or more years.

Reduction in fishing times in the clam fisheries in 1989 and 1990 has resulted in an increased number of barnacle pickers. Many of these harvesters were first-time or inexperienced and were unable to sell their product. As a result there were complaints in 1990 about product left rotting in sacks on docks or on the beaches.

CURRENT ISSUES

Consultations are ongoing with the provincial government regarding fisheries that take place in the vicinity of provincial parks and ecological reserves. There has been some concern expressed that harvesting of gooseneck barnacles should not be carried out on the foreshore of bird colonies, protected by park or reserve status. One such area is Cleland Island on the west coast of Vancouver Island. There is interest among the fishermen in forming an association to provide advice on the management of the fishery.

Study sites initiated in 1985, should be revisited and recruitment assessed .

Table 1. Annual goose barnacle landings (tonnes) by Management Area 1985 to 1989, as reported on sales slips.

Year	No. of Companies	No. Licences Issued	Total Landings t	Value \$10 ³	Fishing Days	Management Area													
						North Coast					South Coast								
						2	5	7	8	10	11	12	20	21	23	24	25	26	27
1985	N/A	9	1.2																
1986	N/A	25	2	4.7	N/A						1.2		0.2	0.2					
1987	9	221	32	211	798	-	*	-	-	-	0.2	*	*	11	18	0.5	1.3	0.1	
1988	11	467	49	436	1513	0.2		0.1	0.1	0.7	0.4	0.5	0.2		6.6	19	3.0	17	0.9
1989 ¹	3	130	35	397	689 ²	*		0.7	1.2		0.1	0.1			4.9	11	0.1	17	

* less than 100 kg

¹ preliminary landings for 1989.

² incomplete total from logbook reports.

Table 2. Monthly summary of goose barnacle landings (tonnes) by Management Area in 1989¹, as reported on sales slips and harvest logs.

Month	North Coast			South Coast						Total Landings	
	2W	7	8	11	12	23	24	25	26		
Jan	*		0.1				0.1			0.3	0.5
Feb		0.2	0.3			1.1	0.9			1.2	3.7
Mar		0.2				0.2	1.1			0.5	2.0
Apr			0.2			0.6	1.1			1.8	3.7
May		0.1	*			0.8	0.3	0.1		2.9	4.4
June		0.2	*	0.1	0.1	0.2	0.1			2.3	3.0
July			*			0.5	1.0			2.0	3.5
Aug			0.2			0.2	1.6			1.8	3.8
Sept			0.2			0.3	1.5			1.4	3.3
Oct			0.1			0.1	1.1			0.9	2.2
Nov						0.1	0.7			0.4	1.2
Dec			*			0.7	1.1			1.5	3.3
Area Totals	*	0.7	1.2	0.1	0.1	4.9	11	0.1	17	35	

¹ preliminary landings for 1989.

* landings less than 100 kg.

APPENDIX 1: 1989 Shellfish Licensing

Species	Gear Type	Licence Category	Number Licences to be Issued	Number Licences Issued
A: Limited Entry Licence				
Abalone	Dive	E	26	26
Geoduck	Dive	G	55	55
Horseclam	Dive	G	55	55
Shrimp Trawl	Trawl	S	249	248
B: Unlimited Licences With Vessel				
Crab	Trap	C	Unlimited	1085
Euphausiid(zooplankton)	Trawl	Z-F	Unlimited	45
Copepod	Trawl	Z-G	Unlimited	0
Green Sea Urchin	Dive	Z-A	Unlimited	191
Octopus	Dive, Trap, and Trawl	Z-J	Unlimited	257
Pink or Spiny Scallop	Dive, Drag	Z-I	Unlimited	43
Red Sea Urchin	Dive	Z-C	Unlimited	240
Sea Cucumber	Dive	Z-D	Unlimited	245
Shrimp	Trap	Z-H	Unlimited	901
Squid Species	Net, H&L	Z-E	Unlimited	72
Weathervane Scallop	Drag	Z-B	Unlimited	7
Without Vessel				
Clam	Hand Pick	Z-2	Unlimited	1870
Gooseneck Barnacle	Hand Pick	Z-6	Unlimited	130
Mussel	Hand Pick	Z-1	Unlimited	20
Winkles	Hand Pick	Z-3	Unlimited	0
Top Snail	Hand Pick	Z-4	Unlimited	0
Limpet	Hand Pick	Z-5	Unlimited	0
Octopus	Hand Pick	Z-7	Unlimited	0

Appendix 2: List of common and scientific names of commercially exploited species of shellfish.

<u>Phylum - Class 1</u>		
	<u>Common name</u>	<u>Scientific name</u>
(A)	PHYLUM MOLLUSCA	
	CLASS GASTROPODA	
	abalone (northern, pinto)	<u>Haliotis kamschatkana</u>
	CLASS BIVALVIA	
	geoduck (king clam)	<u>Panope abrupta</u> (= <u>P. generosa</u>)
	horse clam (gaper clam)	<u>Tresus capax</u>
		<u>Tresus nuttallii</u>
	manila clam	<u>Tapes philippinarum</u>
	littleneck (native) clam	<u>Protothaca staminea</u>
	butter clam	<u>Saxidomus giganteus</u>
	razor clam	<u>Siliqua patula</u>
	blue (bay) mussel	<u>Mytilus edulis</u>
	California (sea) mussel	<u>Mytilus californianus</u>
	pink (smooth, swimming) scallop	<u>Chlamys rubida</u>
	spiny (pink, swimming) scallop	<u>Chlamys hastata</u>
(B)	PHYLUM CRUSTACEA	
	CLASS MALACOSTRACEA	
	euphausiids (krill)	<u>Euphausia pacifica</u>
	prawn (spot shrimp)	<u>Pandalus platyceros</u>
	smooth pink shrimp	<u>Pandalus jordani</u>
	northern (spiny) pink shrimp	<u>Pandalus borealis</u>
	sidestripe shrimp	<u>Pandalopsis dispar</u>
	coonstripe shrimp	<u>Pandalus danae</u>
	humpback shrimp	<u>Pandalus hypsinotus</u>
	Dungeness crab	<u>Cancer magister</u>
	red rock crab	<u>Cancer productus</u>
	red (Alaska) king crab	<u>Paralithodes camtschatica</u>
	golden (brown) king crab	<u>Lithodes aequispina</u>
	tanner crab	<u>Chionoecetes bairdi</u>
	CLASS CIRRIPEDIA	
	gooseneck barnacles	<u>Policipes polymerus</u>
(C)	PHYLUM ECHINODERMATA	
	CLASS ECHINOIDEA	
	red sea urchin	<u>Strongylocentrotus franciscanus</u>
	green sea urchin	<u>Strongylocentrotus droebachiensis</u>
	CLASS HOLOTHURIOIDEA	
	California sea cucumber	<u>Parastichopus californicus</u>

1 Phyla and class names according to J.D. George and J.J. George 1979 Marine Life. An illustrated encyclopedia of invertebrates in the sea - Douglas & McIntyre Ltd., Van. B.C.

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