Status of Invertebrate Fisheries off the Pacific Coast of Canada (1985/86)

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STATUS OF INVERTEBRATE FISHERIES OFF THE PACIFIC COAST OF CANADA (1985/86)

PROCEEDINGS FROM THE SHELLFISH STOCK ASSESSMENT SUBCOMMITTEE MEETING, SEPTEMBER 2 - 3, 1986

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ABSTRACT

Harbo, R. M. and G. S. Jamieson [Eds.]. 1987. Status of invertebrate fisheries off the Pacific Coast of Canada. Can. Tech. Rep. Fish. Aquat. Sci. 1576: 158 p.

Invertebrate species status reports are given for those species commercially fished in British Columbia in 1986. These reports were presented to resource managers and provided the biological advice used to establish 1987 shellfish fishing plans. Net, trap, diver and intertidal fisheries are included, as well as specific advice on size limits for pink and spiny scallops and on historical review of the use of size limits in the region's intertidal clam fisheries. This is the first annual report of the Shellfish Stock Assessment Subcommittee of the Pacific Stock Assessment Review Committee (PSARC) and as such, is the base document which will be updated in the provision of advice in future years.

RESUMÉ

Harbo, R. M. and G. S. Jamieson [Eds.]. 1987. Status of invertebrate fisheries off the Pacific Coast of Canada. Can. Tech. Rep. Fish. Aquat. Sci. 1576: 158 p.

On présente des rapports sur l'état des stocks d'invertébrés qui ont fait l'objet d'une exploitation commerciale en Columbie-Britannique en 1986. Les conseils biologiques apportés ont servi aux gestionnaires des ressources pour l'élaboration des plans de pêche des mollusques et crustacés de 1987. Sont compris les pêches au filet, à la trappe, en plongée autonome et dans les zones intertidales, des conseils précis sur la taille légale à la capture des pétoncles roses et épineux et un aperçu historique de l' utilisation de limites de longueur dans le cas de la pêche des clams dans la zone intertidale. Le présent document constitue le premier rapport annuel du Sous-comité d'évaluation des stocks de mollusques et crustacés, sous-comité tributaire du Comité d'examen des évaluations des stocks du Pacifique. À ce titre, il servira de document fondamental qui sera mis à jour pour la prestation future de conseils.

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INTRODUCTION

This advisory document presents advice and recommendations from meetings of the Shellfish Stock Assessment Subcommittee of the Pacific Stock Assessment Review Committee (PSARC) held September 2nd and 3rd, 1986.

Presentation were made by staff from the Shellfish Division, Biological Sciences Branch and from the North and South Coast divisions of the Fisheries Branch.

Recommendations from this subcommittee were reviewed by the Shellfish Working Group and formed the basis of fishing plans presented to industry at public meetings. The fishing plans for each species are published in an annual commercial fishing guide for shellfish and minor finfish species.

The development of management advice was organized by gear type (trap and net, diving, and intertidal) and then by species. Effort landings and value of invertebrate fisheries have increased significantly in the past 4 years. Landings for 1984 and 1985 are shown in Tables 1 and 2. The total landed value of invertebrate fisheries in 1985 exceeded $18 million.

Some fisheries have limited entry licences (abalone (26), geoduck and horse clam (55), and shrimp trawl (249)) but the majority are open to over 6,000 eligible licensed vessels.

Quotas are set for some species (abalone, geoduck, sea urchins, sea cucumbers, euphausiids), some are managed by active enforcement of size limits (intertidal clams, crabs, scallops) and some species require in-season management programs (prawns). Some species are considered to be underutilized and fisheries are carried out with few, if any, restrictions on an exploratory basis (inshore squid, octopus, goose barnacles, and mussels). Exploratory, experimental driftnet fishing for offshore flying squid has been closely monitored and regulated.

Table 1. Summary of 1984 and 1985 catch statistics (as reported on sales slips) for shellfish species not included in the Z licence.

Species/Licence required	1984 Landings (t)					1985 Landings (t)				
	North Coast	South Coast	Fraser Area	1984 Total	Value $\$10^{-3}$	North Coast	South Coast	Fraser Area	1985 Total	Value $\$10^{-3}$
Clams/PCFL[1]										
Razor	95	5.9	0	101	123	90.1			90	95
Butter	*	131	0	131	54		252.2		252	74
Littleneck	0.6	294	0	295	311		192.2		192	202
Manila	*	1,677	0	1,677	1,809		1913.5		1914	2,220
Mixed	9.0	400	0.1	409	454		477.9		478	553
(Total clams from above)	(105)	(2,509)	(0.1)	(2,615)	(2,758)	(90.1)	(2835.8)		(2926)	(3,144)
Geoduck clams/G[2]	575	2,908	0	3,482	2,937	1436.3	3933.8		5370	4786
Horse clams (subtidal)/G[2]	0	7	0	7	5		6.3		6.3	6
Abalone/E[2]	46	12	0	58	530	32.0	10.1		42	442
Shrimp trawl/S[2]	32	177	200	409	1,022	34.2	490	153.5	678	1,180
Crab/C[3]	296	518	341	1,155	4,558	274.2	538.3	352.6	1165	4,719

*less than 100 kg.

[1]Personal Commercial Fishing Licence when digging by hand. Mechanical diggers or other apparatus require a Z licence.

[2]These are limited entry licences.

[3]C licence or other that carries C privileges - A, B, G, K, L, S and T.

Table 2. Summary of 1984 and 1985 catch statistics (as reported on sales slips) for Z licence species.

Species	1984 Landings (t)					1985 Landings (t)				
	North Coast	South Coast	Fraser Area	1984 Total	Value $\$10^{-3}$	North Coast	South Coast	Fraser Area	1985 Total	Value $\$10^{-3}$
SHELLFISH										
Prawn	112	353	39	504[1]	2,304	99	368	47.1	514	2,461
Red sea urchin	0	1,828	5.7	1,834[1]	740		1768	47.3	1815	762
Sea cucumber	0	113	0	113[1]	26		344	1.5	346	91
Squid	41.7	13.6	15.0	70.3[1]	86	3.1	123	0.1	126	139
Octopus	14.3	16.0	*	30.4[1]	64	9	24.3	0.1	34	68
Euphausiids	0	93.6	0.3	93.9[1]	38		118.8	3.3	122	n/a
Scallops (weathervane, pink, and spiny)	3.6	23.0	0	26.6[1]	74	0.3	52.6	0.2	53	137
Mussels	—	—	--	--					n/a	n/a

n/a - not available.

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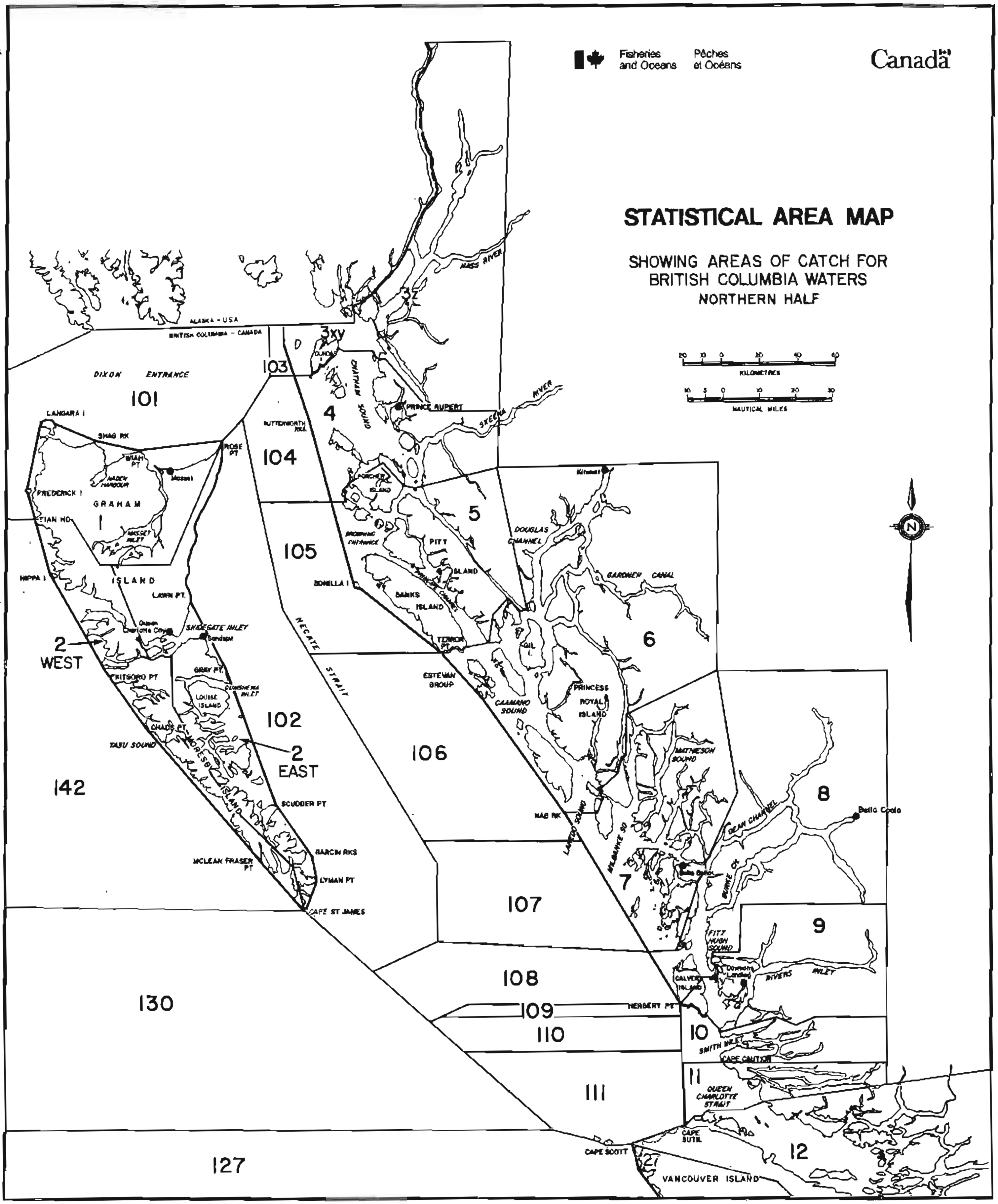

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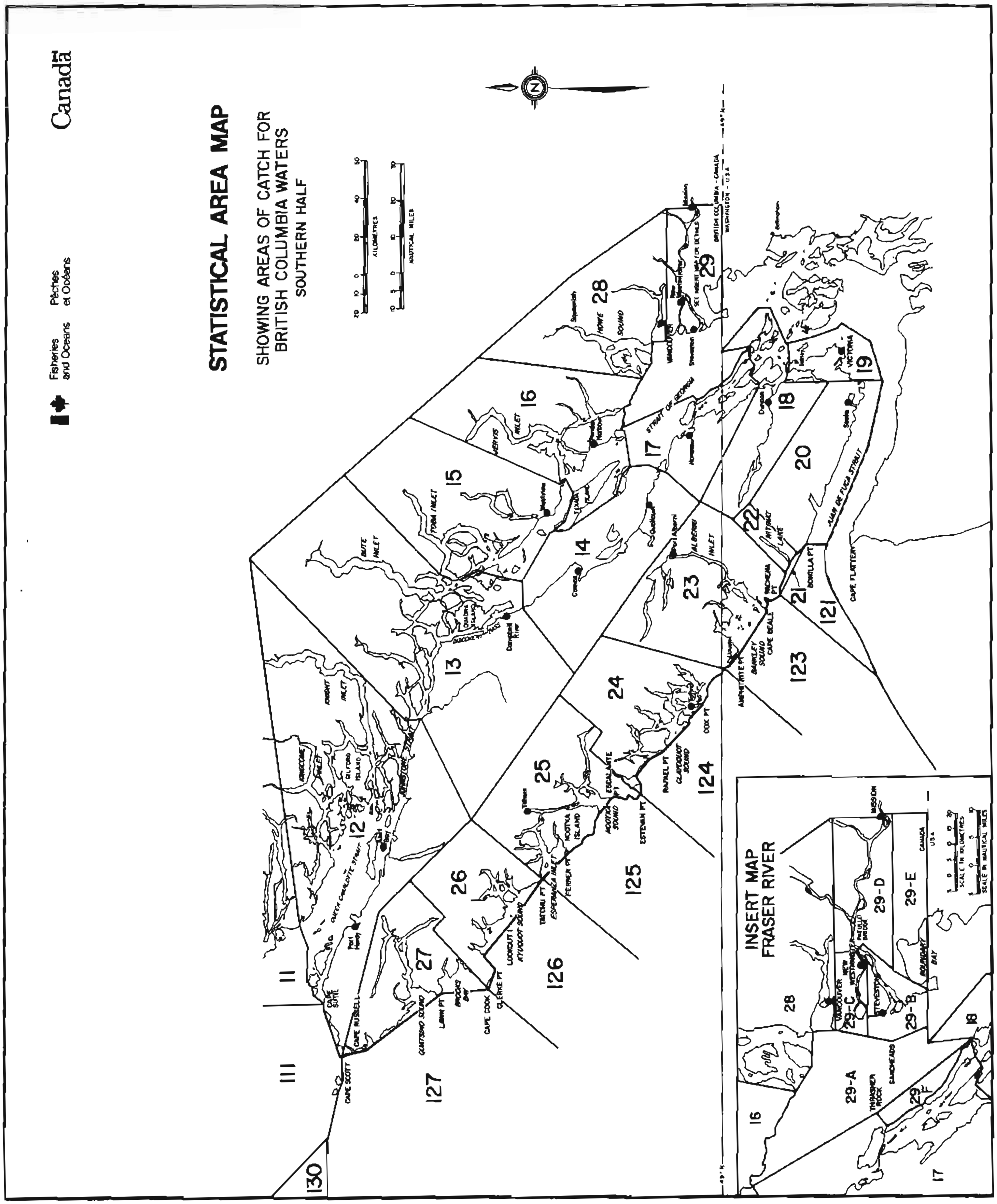
Fisheries and Oceans
Pêches et Océans
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STATISTICAL AREA MAP
SHOWING AREAS OF CATCH FOR
BRITISH COLUMBIA WATERS
SOUTHERN HALF
KILOMETRES
NAUTICAL MILES
INSERT MAP
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1. PLANKTON - EUPHAUSIIDS (trawl fishery)

N.A. Sloan and J. Fulton

INTRODUCTION

The euphausiid fishery started in 1970 with experimental harvesting in the Strait of Georgia area for the pet food trade. This night-time, small boat trawl fishery has remained inshore, although large offshore stocks of this small shrimp-like crustacean are available (Fulton and LeBrasseur 1984). Trawls with 6 to 7 mm (0.25 in) stretch mesh are towed at slow speed at depths above 20 m. Euphausiids concentrate in layers 5 to 20 m thick, and densities have been estimated up to 10,000 m^{-3} from Pisces submersible observations (Mackie and Mills 1983).

BIOLOGY

The dominant species of euphausiid in the Strait of Georgia, Euphausia pacifica, matures in one year and reproduces May through September. Although the life span is about 19 months for males and 22 months for females, there is apparently no breeding in the second year (Heath 1977). Eggs are fertilized externally from a spermatophore that males transfer to females during copulation. Females may carry spermatophores for several months before eggs, each about 0.4 mm in diameter, are released. Eggs float free in the plankton for 5 to 6 days before hatching into the nauplius, or first larval stage. There may be 10 - 23 larval stages over the next 4 weeks before the juvenile stage is reached. Maximum growth rates of about 0.1 mm per day occur during the summer. Growth rate, dependent on available food, slows in late summer and autumn and almost ceases during winter.

E. pacifica grazes in the surface waters at night on phytoplankton although it is known to be omnivorous (Mauchline and Fisher 1969). Diel vertical migrations of up to 200 m are performed by adults (Mackie and Mills 1983; Mackie 1985). Migration to the surface at night may be inhibited by bright moon light and the daytime depth of the downwards migration is thought to be controlled by a critical light level. Typically, adult E. pacifica live in dense swarms which are easily recognized on high frequency echo soundings. Daytime surface swarms sometimes have also been observed.

GEORGIA STRAIT STOCK ASSESSMENT

Stock estimates for 1981 for the Strait of Georgia (Table 1) were made from daytime oblique BONGO net hauls taken at 90 stations during 9 cruises between February 18 and June 14. Stations were established in a grid pattern north from latitude 49 to the south end of Texada Island. Standing stock was estimated to have increased during the sampling period from 2,400 t - 3,490 t (Fig. 1). Preliminary studies indicate that night time BONGO hauls at night catch 10 to 20 times more euphausiids than do day hauls, and so data have been multiplied by 20. Growth rate of *E. pacifica* over the study period was estimated at 1.5% day^{-1} (J. Fulton, unpub.).

Data are not available for the inlets off the Strait, where the fishery has taken place.

FISHERY MANAGEMENT

Landings (Table 2) have come mostly from inlets such as Howe Sound, Jervis Inlet and Saanich Inlet. Early landing data are adjusted to accommodate for the November to March season, i.e. 1975 landings are for 1975-76. In 1979 some landings were reported from the west coast of Vancouver Island. A November to March season was set initially to avoid by-catch of early life stages of other commercial species. The quota of 453 t for Georgia Strait has remained unchanged since 1976 and has never been met (Table 2). Licensing was by Scientific Permit through 1982 and now occurs under a Z licence (Table 2). In 1985, five licenses were issued and only two vessels reported landings. In 1985 to promote exploration, the seasonal closure was removed except for a June 1 to August 15 regulatory closure for all areas except 28 and 29 (closed December 1 to March 31). Fishing in spring and summer months has failed due to net clogging by jellyfish and phytoplankton.

Considering the undeveloped nature of the fishery, a relatively large amount of biological information is available for the most common euphausiid species, *Euphausia pacifica*. The distribution (Fulton 1982; Fulton et al. 1982; Fulton and Lebrasseur 1984) and population dynamics of stocks (Heath 1977) have been investigated.

CONCERNS

The possible salmon mariculture industry need for euphausiids as a feed additive may stimulate an increased priority for evaluation of euphausiids stock status. Of particular interest are euphausiid sources in nearshore areas close to fish net pen facilities. Key industry concerns are:

1. Further development of euphausiid harvesting technology;

2. Development of euphausiid storage technology;

3. Development of the incorporation of euphausiids in fish diets to improve flesh quality, and maturation of salmon brood stock.

If euphausiids became the sole source of protein in salmon feeds, the projected 20,000 t of cultured salmon per year by 1995 would require 140,000 t of euphausiids. If used as a supplement only for improving flesh quality for marketing and enhanced reproductive vigor, about 14,000 t would be required.

In light of increased demand for euphausiids, three fisheries related questions are prominent and beyond the scope of the private mariculture industry to answer:

1. What are the stock sizes and annual average production of euphausiids in the Strait of Georgia and inlet areas?

2. What are the roles of euphausiids in food webs supporting other fisheries such as salmon, herring and groundfish?

3. Could a year-round euphausiid harvesting season be developed without clogging of nets and by-catch of early life stages of commercial species in spring and summer?

RECOMMENDATIONS

MANAGEMENT

1. Quota should remain at the current levels with the exception of harvesting during co-operative research between the industry and DFO.

2. The seasonal (Dec. to March) closure in Area 28 and 29 should be abolished since there are no biological rationale for it.

3. The June to August regulatory closure for all Areas should be reviewed.

RESEARCH

1. Initial estimates of a 20-fold difference between day and night sample catches requires further verification.

2. Co-operation research between DFO and industry in stock location and harvest techniques should proceed.

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Table 1. Euphausiid stocks in the Strait of Georgia, 1981. Estimates are from oblique BONGO net hauls taken during daylight.

Cruise	Julian day[1]	Minimum stock (10^{-3}t)	Maximum stock[2] (10^{-3}t)
1	52	2.40	48.0
2	65	2.68	53.6
3	78	2.82	56.4
5	93	6.14	122.8
7	107	3.85	77.0
8	120	4.30	86.0
9	129	3.92	78.4
10	143	3.85	77.0
11	158	5.49	109.8

[1]Julian day = days of the year numbered 1 to 365.

[2]Maximum stock is estimated as 20 times the daytime catch. The two fold increase in standing stock on cruise 5 is attributed to immigration from the north.

Table 2. Euphausiid fisheries statistics. Data from D.F.O, Statistics Division, Fulton (1982) and Harbo and Hand (in press).

Year	Landings* t	Landed value ($10^{-3})	Price ($\$\cdot t^{-1}$)	Licences No.	Licences Type	No. of vessels reporting landings
1975	40	ND	ND	ND	SP	4
1976	69	ND	ND	6	SP	5
1977	104	ND	ND	ND	SP	6
1978	91	ND	ND	11	SP	7
1979	107	ND	ND	12	SP	12
1980	72	60	833	30	SP	ND
1981	19	6	308	15	SP	4
1982	0	0	0	ND	SP	0
1983	50	ND	ND	7	Z	2
1984	94	ND	ND	8	Z	4
1985	130	84	690	5	Z	2

* 1975 to 1977 from Fulton (1982); 1978 to 1985 from Harbo and Hand (in press).

SP = Scientific permit.

ND = No data.

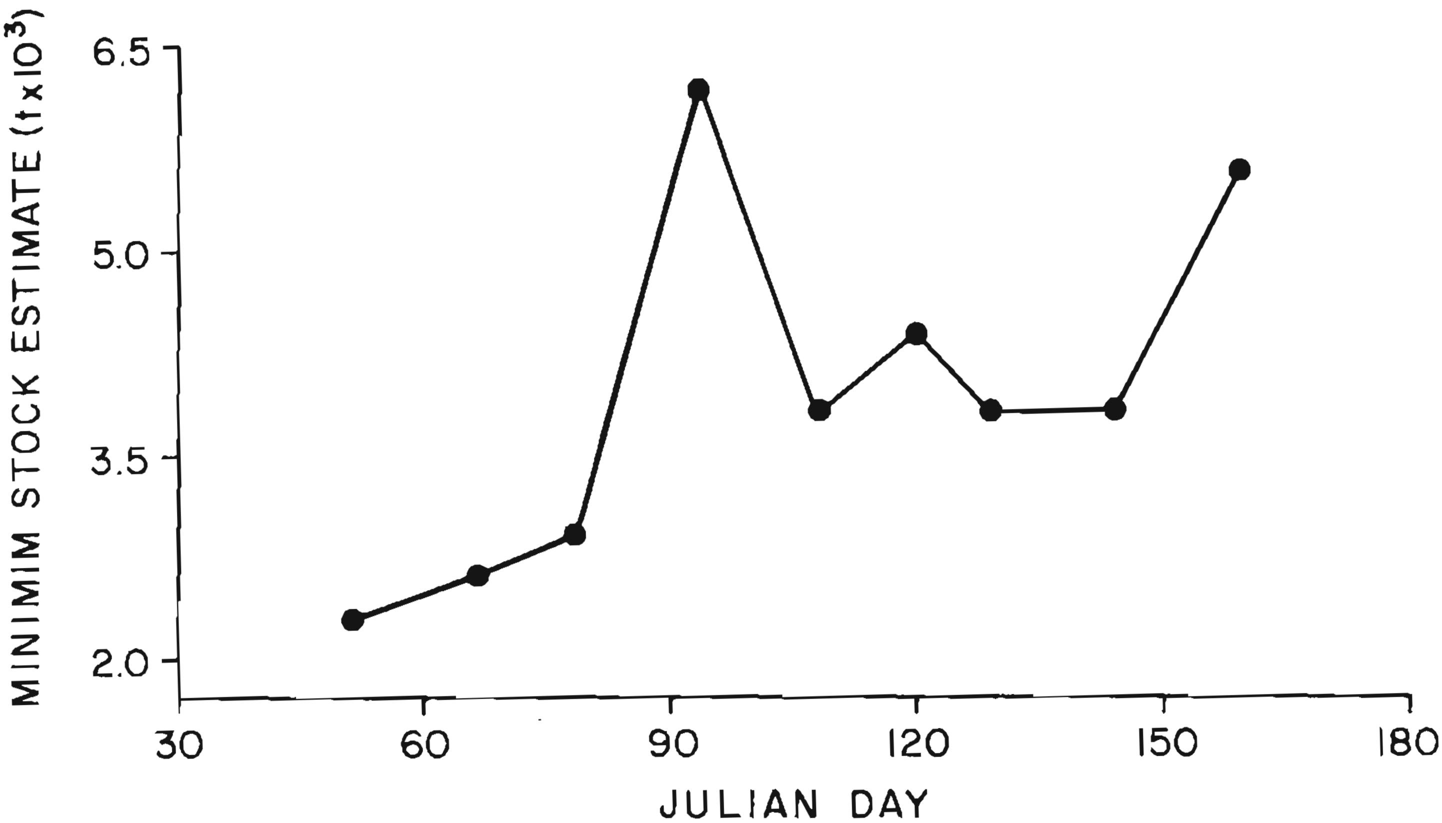

Fig. 1. Estimates of euphausiid standing stock in the Strait of Georgia between February and June, 1981.

2. INSHORE SQUID (seine fishery)

G. S. Jamieson and G. D. Heritage

INTRODUCTION

Jefferts (1986) has recently summarized cephalopod fisheries and their management in the North Pacific. The only existing significant cephalopod fisheries in the northeastern Pacific are for Loligo opalescens (opal squid) in California and Dosidicus gigas (jumbo squid) in the Gulf of California. In British Columbia, which is near the northern limit of the former species' distribution (southeastern Alaska), there has been only a sporadic inshore squid fishery for the opal squid.

Landings were 126 t in 1985, averaging \$1.65 kg^{-1} and the limited fishery (Table 1) has been concentrated on the west coast of Vancouver Island. The squid were sold primarily for bait in the black cod fishery. There is not a directed fishery for the red squid, Berryteuthis magister, in British Columbia but occasionally this deep-water, demersal species is landed as a by-catch in nearshore groundfish and shrimp trawling.

The California fishery for opal squid occurs from April-September and has ranged from about 9,000-18,000 t annually. The Oregon fishery increased from 51 t in 1982 to about 400 t in recent years, whereas the Washington fishery has been less than 50 t.

BIOLOGY

This species has a life span of 1-2 yr and schools by size, being most abundant in waters of 10-16 C. It migrates into shallow water (5-40 m) to spawn, usually on sheltered inshore sites of sand or mud, and it is largely these spawning concentrations that are fished, usually with purse seines. Spawnings in southern British Columbia may occur from December until September, but two major ones usually occur. There is often a winter spawning around March, but mating behaviour can occur over the preceeding few months, and a second one around July (Bernard 1980). There is a general pattern of winter spawnings in the Strait of Georgia and Queen Charlotte Strait and summer spawnings near Victoria and along the west coast of Vancouver Island, but how consistent this pattern is over the long term is uncertain.

The demersal eggs hatch in 1-3 mo and subsequent growth is very rapid. Sexual maturity is reached at about 10 cm mantle length. Spawned out individuals have little market value and opinions vary as to the desirability of egg-carrying females.

Opal squid also congregate during feeding and possibly during migratory movements, especially over La Perouse Bank on the west coast of Vancouver Island (Bernard 1980). Fishery potential at these times has not been investigated.

FISHERY MANAGEMENT

Squid fishing requires a Z licence which is available to any fisherman with a C-license or equivalent. In 1985, 26 vessels reported landings of squid: 126 t over 277 fishing days. There is not any biological management of the resource since nothing is known about stock abundance and spawning aggregations are unpredictable. The present practice is to keep the fishery closed and only open it on an area basis following indication by fishermen that they are interested in fishing squid at that time. This serves two functions: it prevents fishing from occurring in areas where they may be herring spawnings and juvenile salmon concentrations and it gives the fishery officer some idea as to where squid fishing is actually occurring and how many boats are involved.

RECOMMENDATIONS

At the current low levels of exploitation (Table 1), the existing management approach and lack of need for biological advice seems appropriate. Occurrance of spawning concentrations and overall abundance seem largely dependent on oceanographic factors, and it is possible that with events such as El Nino, there may be opportunity for significantly increased landings if fishermen are prepared and have established markets. During the last El Nino (1983), there was some evidence of a northern shift in overall species abundance throughout its range.

There might be some conflict with incidental catch of herring or salmon at certain locations or time of year, but since squid are predatory (Loukashin 1976), perhaps on young herring and salmon if available, squid exploitation may have some positive merit.

No research on inshore squid is planned for 1987/88 but a study on the food habits of squid in Barkely Sound and their impact on salmon abundance is tentatively planned for 1988/89.

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Table 1. Landings (tonnes) of squid by statistical area from sales slip and harvest log data.

Statistical area	1983	1984[1]	1985[1]
1	1.2	1.4	0.2
2W	7.0	1.6	0.4
4	*	-	-
5	*	0.8	-
6	40	2.2	-
7	2.1	131	0.6
8	0.2	22.7	1.9
11	-	0.9	-
12	45.2	0.2	-
13	-	-	0.2
14			0.2
17	-	0.4	0.1
18	0.5	1.6	0.2
19	5.4	6.9	16.1
20	2.8	-	*
21	-	-	*
23	3.7	0.7	86.8
24	-	2.9	19.4
25	-	-	0.1
27	2.5	-	0.2
28	-	*	-
29	*	*	0.1
30	0.3	15	-
TOTAL	111.3	70.3	126.3

*less than 100 kg.

[1]1984 and 1985 data corrected to include harvest log data (R. Harbo, per. comm.).

3. OFFSHORE SQUID (drift gillnet fishery)

G. S. Jamieson and G. D. Heritage

INTRODUCTION

Flying squid, Ommastrephes bartramii, is the main squid species exploited in offshore waters in the eastern North Pacific. Nail squid, Onychoteuthis borealijaponica, are also widely distributed throughout the region and may in the future generate more fishery interest. Nail squid occur at about 400 m depth during the day but rise to near the surface at night, where they can be jigged. They are reported as relatively common along the edge of the continental slope off the west coast of Vancouver Island (Bernard 1980). To date, there have been no landings of this species in British Columbia. A limited experimental fishery for this species in 1983 with the Japanese research vessel Tomi Maru #88 yielded little catch (Sloan 1984).

Besides Todarodes pacificus, an ommamstrephid squid endemic to the northwestern Pacific, the flying squid is the major squid species exploited in the Pacific with an estimated maximum sustained yield (MSY) of 80,000-100,000 t annually in the Japanese jig fishery, i.e. west of 170° E (Jefferts 1986). The sustainable level of production in the gillnet fishery (170° E to 145° W) is not known, but annual catches exceed that of the jig fishery. It is an upper water species widely established in subtropical oceanic waters in the northern Pacific, and is maximally abundant at the Subarctic Boundary in summer and fall. It is extensively fished by jig along the northern edge of the Kuroshio Current and accounts for more than half the squid fished in Japanese waters. However, only younger smaller squid are traditionally jigged and when the squid become large, jigging is may be less efficient. Jigging does not appear to be economically feasible in the northeastern Pacific (Mercer and Bucey 1983; Robinson and Jamieson 1984; Sloan 1984). At the present, the Fishery Agency of Japan limits gillnetting for squid to an area between 20° and 46°N, and between 145°W and 170°E (outside the 322 km economic fishing zone around the Hawaiian Islands). There is interest by Canadian fishermen in developing a new fishery for British Columbia on a currently underutilized resource.

Research surveys using commercial Japanese vessels have been conducted in Canadian waters in 1979, 1980, 1983, 1985 and in 1986. Results have been summarized by Bernard (1981) and Sloan (1984). Participation by Canadian vessels occurred in 1983 (Robinson and Jamieson 1984) and in 1986 (Jamieson and Heritage, in press).

BIOLOGY

Flying squid grow to a length of about 1 m, with a mantle length up to about 50 cm and a total weight of 4.5 kg (Bernard 1980). Little is known about the general biology of the species but it is probably similar to that of its close relative Todarodes pacificus, which has been more extensively studied. They probably spawn in semitropical waters at depth, with the larvae and juveniles migrating northwards as the warm waters extend north during the summer. They likely attain sexual maturity in one season, and after returning to more southern waters in the fall and winter, die after spawning . Growth is thus very rapid.

Flying squid have diel migrations from about 400 m to the surface at night, and seem to occur in rather loose, scattered schools of a few dozen individuals. While migrating, they probably only move 10-15 km a day, with movements probably most controlled by water temperature. Relatively little is known about their biology in the northeastern Pacific since the species has only been studied during a narrow segment of its life, i.e. in July through September while in Canadian waters.

FISHERY MANAGEMENT

Most flying squid fishing in Canadian waters that has been undertaken to date has involved commercial Japanese fishing vessels participating in research studies. Prior to 1985, surveys were exploratory in nature but since 1985 squid have been fished as they would be commercially so that the catch characteristics of a fishery could be better evaluated. Fishermen, Japanese or Canadian, are not allowed to retain salmonids but do keep albacore and some sharks. To date, greatest squid catches have been at the outer limit of the Canadian economic fishing zone, with some fishing occurring in international waters.

There are two concerns related to the development of a squid fishery. Firstly, do squid occur in commercial quantities and is a viable Canadian fishery possible, and secondly, can such a fishery occur without a bycatch (Table 1) of salmonids or other species at unacceptable levels. Since the fishery uses gillnets (121 mm mesh), 8 - 10 m deep and with nightly sets of up to 50 km of net, the potential catch of other species has been a cause of concern.

Squid appear to be regulary present in commercial quantities (Table 2). Concerns if the fishery develops are dependence on a foreign market and the need to establish an offshore fishing fleet in British Columbia. There are relatively few fishing vessels on the coast large enough to carry the fishing, processing and freezing equipment required and to stay at sea long enough to fill their holds. The relatively large 1983 salmon bycatch, (559 pieces caught by the Japanese vessel, Tomi Maru #88 in 3 nights fishing (Sloan 1984) appears to have been mostly the result of the exploratory nature of the fishery in that year.

Subsequent fishing by that vessel in 1983 caught only 360 pieces in 37 nights fishing. The Canadian vessel, Simstar, in 1983, fished squid commercially and caught an average of 5.5 salmon per 10 km of net fished. In 1985, the Tomi Maru #88 caught an average of 3.1 salmon per 10 km of net fished.

It appears that the relatively warm waters preferred by flying squid are not the preferred habitat of salmonids but further research is required to define the preferred habitats of squid and salmonids.

There is currently no long term management policy for commercial fishing of flying squid and fishing has to date been research oriented. The squid resource appears to extend outside the Canadian economic fishing zone. Within our economic fishing zone, vessels presently fishing flying squid can only do so with Ministerial approval. It is required that an observer be continuously on board to monitor the catch of all species.

RECOMMENDATIONS

1. Research on the characteristics of an offshore squid fishery should continue.

2. If a commercial fishery is established, an improved understanding of the nature of the stock being exploited in Canadian waters should be developed. Questions to be asked include: Is it part of the same population being exploited in the central Pacific or does it represent another stock? Where do populations spawn and what is the average stock biomass? What are the annual fluctuations in abundance?

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Table 1. Summary of 1985 catch by the Japanese vessel, Tomi Maru #88, by species, pieces, weight and percentage by piece (% estimated from total weight divided by average weight).

Species (common name)	Pieces	Weight (t)	Percentage (pieces)
Ommastrephes bartramii (Flying squid)	338,188	771	91.4
Prionace glauca (Blue shark)	8,249	67	2.2
Brama japonica (Pomfret)	13,145	31	3.6
Thunnus alalunga (Albacore)	3,769	23	1.0
Lamna ditropis (Salmon shark)	492	14	0.1
Trachurus symmetricus (Jack mackerel)	5,149	12	1.4
Luvarus imperialis (Louvar)	4	*	T
Seriola alandei (Yellowtail)	8	*	T
Mola mola (Ocean sunfish)	8	N/A	T
Thunnus thunnus (Bluefin tuna)	5	*	T
Alepisarus ferox (Longnose lancetfish)	1	*	T
Pentaceros richardsoni (Pelagic armourhead)	35	*	T
Dasyatis violacea (Pelagic stingray)	1	*	T
Oncorhynchus gorbuscha (Pink salmon)	16	*	T
O. keta (Chum salmon)	294	0.8	0.1
O. nerka (Sockeye salmon)	138	0.3	T
O. kisutch (Coho salmon)	35	*	T
Salmo gairdneri (Steelhead trout)	286	0.9	0.1
Phocoenoides dalli (Dall porpoise)	1	N/A	T
Callorhinus ursinus (Fur seal)	1	N/A	T
Lagenorhynchus obliquidens (Pacific white-sided dolphin)	1	N/A	T

* = less than 100 kg.

T = less than 0.1 % of total pieces.

N/A = not available.

Table 2. Comparison of CPUE* between Canadian (Simstar) and Japanese vessels that have fished off the British Columbia coast. CPUE 300 $kg \cdot km^{-1}$ is felt to indicate positive commercial potential. CPUE of the Tomi Maru #88 was low in 1980 and 1983 because of the exploratory design of the survey in those years.

Vessel	Date	CPUE* kg squid $\cdot km^{-1}$	Source
Tomi Maru No. 88	July to September 1985	311.5	Unpublished data
Simstar	July to August 1983	339.2	Robinson & Jamieson (1983)
Tomi Maru No. 88	July to August 1983	232.3	Sloan (1984)
Tenu Maru No. 37	July to August 1980	332.0	Bernard (1981)
Tomi Maru No. 88	August 1980	165.8	Bernard (1981)
Tomi Maru No. 88	August 1980	165.8	Bernard (1981)

$$* \text{ CPUE} = \frac{\text{total weight of squid caught (kg)}}{\text{total length of gillnet}}$$

4. SHRIMP INSHORE AND OFFSHORE FISHERIES (trawl)

J. A. Boutillier

INTRODUCTION

The shrimp trawl fishery targets primarily on three species of shrimp: Pandalus jordani (smooth pink); P. borealis (northern pink); and Pandalopsis dispar (sidestripe). Pandalus hypsinotus (humpback) and P. platyceros (prawn) are caught incidentally or in small, directed trawl fisheries in Area 1 for humpback and Areas 17, 23, and 28 for prawn.

BIOLOGY

The five species of shrimp caught in the British Columbia trawl fisheries all belong to the family Pandalidae. Butler (1980) and Butler and Boutillier (1983) give detailed and general accounts respectively of the biology of these animals. All these animals have the peculiar biological characteristic known as protandric hermaphrodism in that they change sex in mid-life. They function initially as males for a year or two before undergoing sexual transformation to become females for the final year or two of their lives. Although this is the general pattern for all these species, individuals of some of the species have been known to bypass the male phase.

Spawning occurs in late autumn or early winter. The females carry developing eggs on their swimmerets until they hatch in the spring. Upon hatching shrimp larvae swim freely about for up to three months before settling to the bottom.

FISHERY MANAGEMENT

The shrimp trawl fishery is a limited entry fishery which requires a valid "S" licence or special permit. In 1986 there were 247 "S" licence entitlements. Five scientific permits were issued to allow fishing in a portion of Barkley Sound.

The fishery in recent years has been carried on mainly by smaller beam trawl vessels, most of which also have "A" licences (Noakes and Jamieson 1986) and either gillnet or troll for salmon. The larger otter trawlers which were active in the mid-1970's have, to a large extent, been inactive since the collapse of the offshore fishery (Boutillier 1982). Only limited activity by a few of the larger otter trawlers has been evident in the last two years. There is interest by some of the small beam trawl fishermen to switch to otter trawls which are more efficient but have a higher incidental catch of fish. Shrimp trawlers are not permitted to land groundfish unless they have a "T" licence.

The trawl fishery in 1985-86 was a year-round fishery with a short local closure in areas 28 and 29 in response to overfishing concerns expressed by fishermen. The three main areas of shrimp trawling are off the west coast of Vancouver Island, in the Strait of Georgia, and in Chatham Sound.

1) WEST COAST OF VANCOUVER ISLAND (WCVI) FISHERY (Areas 23, offshore 123, 124, 125)

In 1985, 21 vessels reported landings of 192 t.

In this area, fishing has historically occurred from Area 23 in the south to Area 125 in the north.

Areas 23 and 123: Barkley Sound has a fishery which has both inshore (Area 23) and offshore (Area 123) components. Thompson and Margolis (in press) used a parasite as a natural tag and suggested the occurrence of separate stocks of shrimp in each of Trevor Channel, Imperial Eagle Channel and offshore. The Trevor Channel and Imperial Eagle Channel fisheries are mixed fisheries for smooth pink and sidestripe shrimp with an incidental catch of prawns. The offshore component of this area has a fishery for smooth pink shrimp. Biological data from this fishery comes from a biological monitoring program and mandatory logs from special permit boats. Voluntary logs have been solicited from S-tab vessels but the response has been poor.

Areas 124 and 125: Offshore Areas 124 and 125 also support fisheries for smooth pink shrimp. It is speculated that these offshore smooth pink shrimp might be the northern limit of a single commercial stock of P. jordani which extends from Morro Bay, California to mid-Vancouver Island (Anon. 1981). Over the entire offshore region of this stock, shrimp abundance fluctuates widely apparently due to factors independent of fishing. Biomass surveys of Area 124 (Tofino ground) and Area 125 (Nootka ground) have seen biomass estimates fluctuate by a factor of 324 and 19 fold, respectively (Table 1). Biological data from these fisheries comes from research surveys, biological monitoring, and voluntary logs.

The most recent survey of Areas 124 and 125 was completed in May 1985 (Boutillier and Harling 1985). This survey found that shrimp abundance in offshore areas was increasing. This was confirmed later by the increase in 1985 commercial landings from Barkley Sound, which was mainly taken from the offshore stock (Fig. 1-3). In 1986 there has been renewed activity by small otter trawlers in Area 124. There has also been some shift of small beam trawlers into the northern Tofino grounds. All offshore landings are being processed through registered processing plants.

2) STRAIT OF GEORGIA SHRIMP FISHERIES (Areas 14, 17, 28 and 29)

Area 14: Comox has a local small-boat beam trawl fishery for smooth pink shrimp which peaked in landings in 1965 at 131 t. In 1985, reported landings by 16 vessels were 32 t, 24% of the peak year, but well above the previous 10 year average of 10 t (Fig. 4). The shrimp from this fishery are processed in small local plants or sold over-the-dock.

Area 17: Stuart Channel has a small-boat beam trawl fishery composed of a local fleet and a transient fleet from Steveston and Vancouver. This is a mixed shrimp fishery with all five shrimp species landed. The two main target species are smooth pink and sidestripe shrimp. Peak production was 328 t in 1957. In 1985 reported landings by 31 vessels were 58 t, only 18% of the peak year but above the previous 10 year average of 33 t (Fig. 5). The landing from this fishery are processed in small plants or sold over-the-dock locally in Steveston.

Areas 28 and 29: English Bay, Sturgeon Bank, off Sechelt and Howe Sound all have small-boat beam trawl fisheries. As in Area 17, all five shrimp species are caught. However, the main target species for English Bay, Sturgeon Bank and off Sechelt are pink and sidestripe shrimp while the target species in Howe Sound is a mixture of pink and smooth pink shrimp. The English Bay fleet has mostly experienced fishermen, whereas the Steveston fleet has a larger proportion of new fishermen. These new fishermen have bought up previously inactive licences, resulting in increased effort in some areas. The Sechelt/Howe Sound fleet is relatively new with some influx from the Steveston fleet. Peak production was 443 t in 1957. In 1985, reported landings by 64 vessels were 152 t, 34% of the peak year but above the previous 10 year average of 137 t (Fig. 6). Historically, landings from this fishery have been processed through small local plants. In more recent years, there has been an increase in over-the-dock sales in Steveston.

Areas 4 and 5: Chatham Sound has mainly a small boat beam trawl fishery which targets on pink and sidestripe shrimp and has incidental catches of humpback shrimp. The fishery thrived in the 1960's with a peak recorded landing of 160 t in 1963. In the 1970's the fishery declined, collapsing completely in 1975 and 1976 because of marketing problems. In 1985 the report catch was 29 t by 22 vessels, only 18% of peak production but above the previous 10 year average of 12 t (Fig. 7).

MANAGEMENT ISSUES

There are four key issues facing management of shrimp trawl fisheries.

1) STOCK ASSESSMENT DATA:

The first and most critical factor is that there are not any biological data bases with which to conduct stock assessments. The sales slip data are inaccurate and does not collect appropriate measure of effort for conventional assessment procedures. Sales slips do not identify the catch by species which is a major problem in mixed shrimp fisheries. The voluntary logbook system is not being supported by industry and a recent attempt to solicit support from the Vancouver fleet has been unsuccessful. The fisheries as they stand now are not managed and, if anecdotal information is correct, some areas are probably being overfished.

A biological data base has been developed for smooth pink shrimp stocks in offshore waters off the west coast of Vancouver Island. This data is based on a series of research area-swept trawl surveys which commenced in 1973 and are now planned biannually for May in odd number years (a cruise has been proposed for 1987). After this cruise an in-depth assessment of this data base is planned to investigate:

1) better estimation procedures of year-class abundance;

2) abiotic and biotic mechanisms which affect recruitment;

3) management options and determine what, if any, are the biological implication of the various options.

The use of logbook and sales slip data have, in the past, proved to be inadequate for stock assessments of offshore fisheries, since they do not reflect the overall distribution of shrimp on the grounds. Shrimp are known at times to be concentrated in relatively small areas, while at other times, the same population can be spread over a large area in a more uniform distribution. These changing distributions have been addressed in the assessment of the banana prawn fishery (Lucas et al. 1979) with the inclusion of search time in the fishing effort calculation. This method was not useful in the WCVI offshore fishery because of a high degree of cooperation between fishermen, who inform each other on the location of shrimp concentrations, thus allowing a high CPUE to be maintained with little or no documented search time. For the offshore fishery, I feel that reliable population estimates will be obtained only through a continued series of research cruises. This type of database is difficult to logistically establish in the smaller inshore fisheries of the coast. If a biological database is to develop for these areas, it will have to be collected through the establishment of a mandatory logbook system in conjunction with a biological monitoring program. Since these more reliable data bases are not currently available, initial assessments of inshore fisheries have been attempted using a time-series analysis of the sales slip data (Noakes 1986).

A time-series analysis of the reported sales slip catches from Area 28 and 29 gave a naive forecast that the 1986 catch from these areas would be 158 t, slightly below the overall average of 171 t (see Appendix A for time-series calculations).

A time-series analysis of the reported sales slip catches from Areas 4 and 5 gave a naive forecast that the 1986 catch from these areas would be 29 t which is slightly below the overall average of 42 t (see Appendix B for time-series calculations).

Time-series analysis on the catch data for the other areas was attempted but fits were so poor that results are not presented.

2) INCREASED FISHING EFFORT:

Fishery officers and the fishing industry report a large resurgence of the use of "S" tabs in the inside fishing areas. Most of this increase seems to be in the Steveston fleet and is probably impacting on the areas exploited by this fleet; in particular the Sturgeon Bank, off Sechelt and Stuart Channel. This increase is not documented in sales slip data and it appears that most of the catch is landed as unreported dock sales. We now have a situation where there are concerns of overfishing by licenced vessels in some areas, while in other areas special permits are required to allow fishing on otherwise underexploited stocks.

There has been a documented need for a review and evaluation of the shrimp trawl licensing system for years. It may be possible to direct the new effort to underexploited stocks.

3) INCIDENTAL CATCHES:

The incidental catch and targeting on prawns (P. platyceros) by shrimp trawlers has two major problems associated with it. The first is a high incidental catch of juvenile prawns in certain areas, particularly Area 23, where these animals are well below the present recommended size limit for prawns. The second problem is the retention of prawns by trawlers when the area is closed to prawn trapping. Trawlers can and do target on prawns in some areas, such as Areas 17 and 29. In both cases it should be noted that the handling mortality of prawns caught in a trawl is probably 100%.

Resolution of the problem of incidental and targeted catches of prawns in the trawl fishery will probably require a number of actions to solve specific aspects of the problem. With respect to a high incidental catch of juvenile prawns, it may be necessary to close known juvenile rearing areas if these areas can be delineated. In regards to targeting on legal prawns while the area is closed to prawn trapping, it will be necessary to enforce non-retention of prawns in the catch. From the experience in Howe Sound it was found that fishermen could target on P. jordani and Pandalopsis dispar and reduce their incidental catches of prawns to almost zero. If boats are found targeting on prawns in closed areas, there may be no recourse but to shut down the entire area to all shrimp fishing while the area is closed for conservation of prawns. This may mean a closure of up to 10 months in areas like Howe Sound, but such closures should not be necessary if all fishermen act responsibly.

4) GEAR CONFLICTS:

There is a growing concern by industry that the use of otter trawls in traditional beam trawl areas somehow damages the grounds.

It would be difficult to document the nature or extent of damage that an otter trawl may have on the fishing grounds. It is known, however, that otter trawls are generally more efficient and have a higher incidental catch of juvenile fish than beam trawls. This may be particularly important in Area 17 which has traditionally been closed to trawling because of its identified importance as a nursery area for a number of species.

RECOMMENDATIONS

1. Develop an assessment data base for inshore fisheries through a mandatory logbook and biological sampling program.

2. Conduct an area-swept trawl survey on offshore smooth pink shrimp fishing grounds.

3. No changes in the current, management of shrimp trawl fisheries are recommended, since the available data bases are extremely limited.

4. Review the licensing and permit system with a view to redirecting any new effort into underexploited regions of the coast.

5. Enforce non-retention of prawns in trawl catches when the area is closed to commercial prawn trapping.

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Table 1. Estimated biomass (tonnes) and distribution (km^2) of smooth pink shrimp (_P. jordani_) off the west coast Vancouver Island, 1977-1985.

Year	Tofino Ground		Nootka Ground	
	Biomass (t)	Area (km^2)	Biomass (t)	Area (km^2)
1985	1782	648	566	329
1983	30	3	604	298
1982	813	165	171	89
1981	1528	336	1449	202
1980	479	163	418	137
1979	1162	247	935	192
1978	1743	254	804	151
1977	4627	748	2359	329
1976	9716	720	3302	175
1975	7176	659	1651	165
1973	9716	556	1016	89

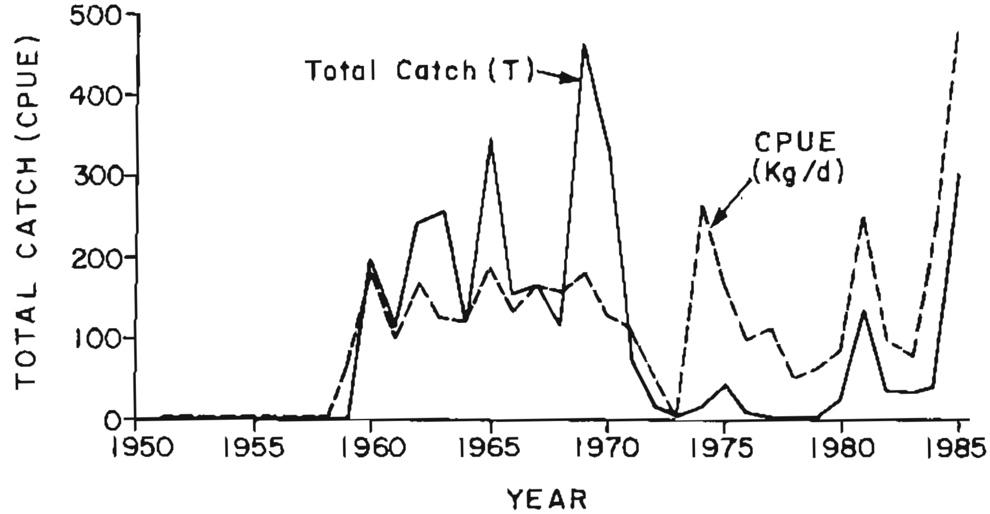

Fig. 1. Total catch and catch-per-day of shrimp taken in the trawl fishery from Statistical Areas 23 and 123

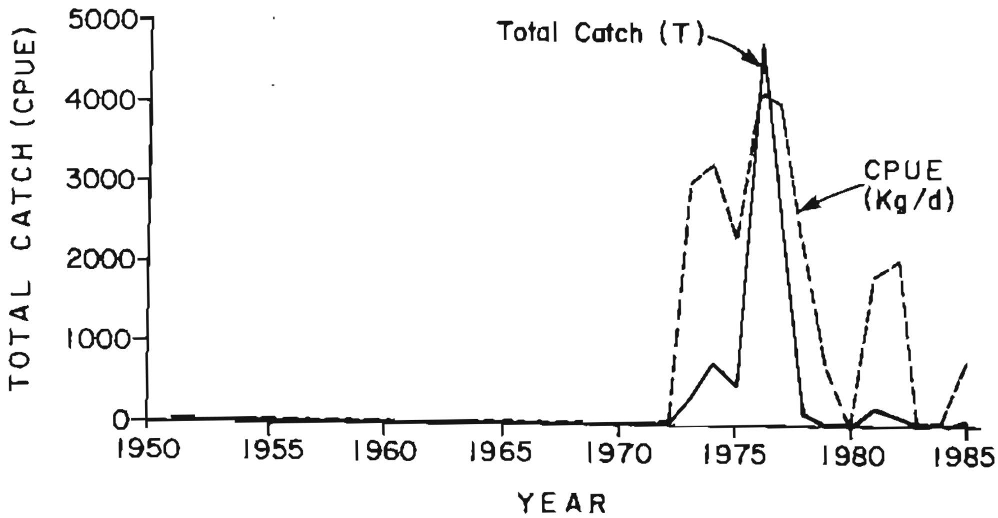

Fig. 2. Total catch and catch-per-day of shrimp taken in the trawl fishery from Statistical Area 124.

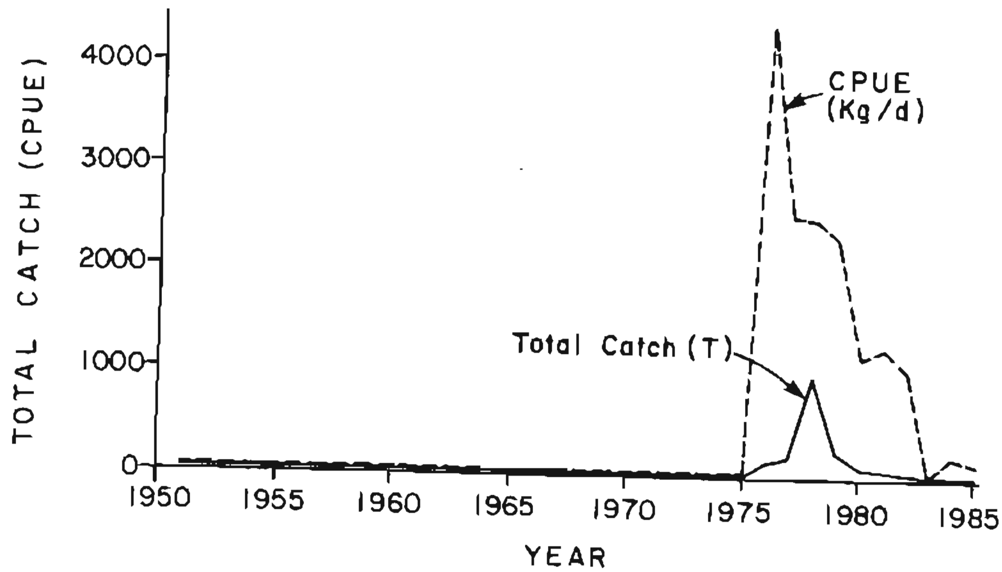

Fig. 3. Total catch and catch per day of shrimp taken in the trawl fishery from statistical area 125.

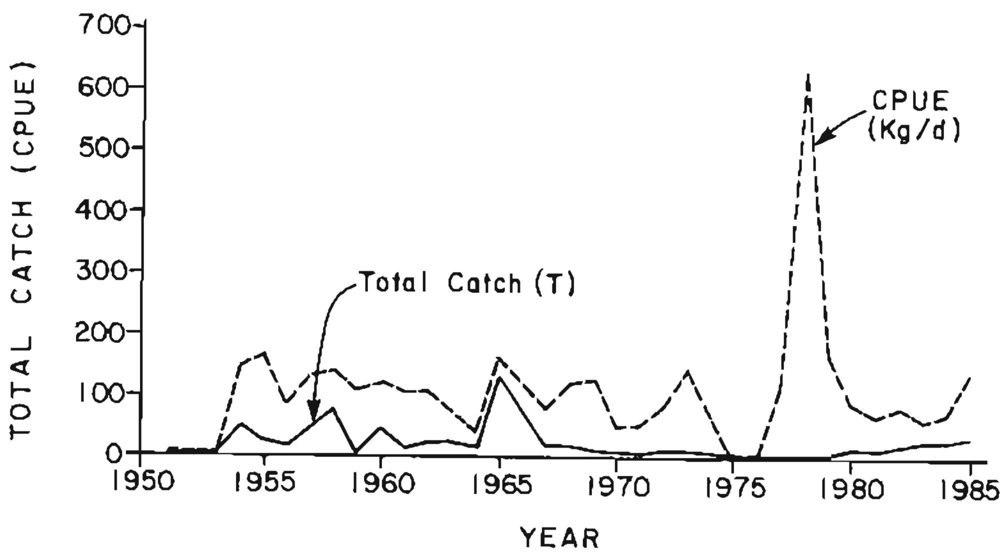

Fig. 4. Total catch and catch per day of shrimp taken in the trawl fishery from statistical area 14.

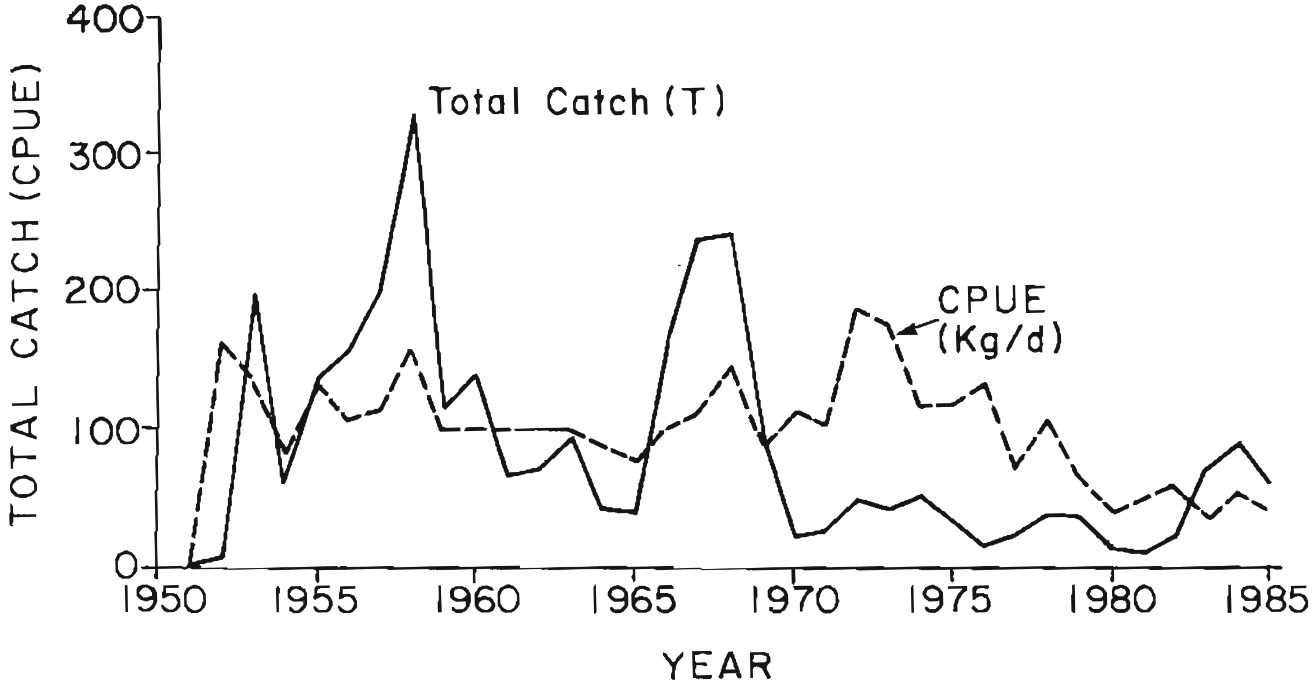

Fig. 5. Total catch and catch per day of shrimp taken in the trawl fishery from statistical area 17.

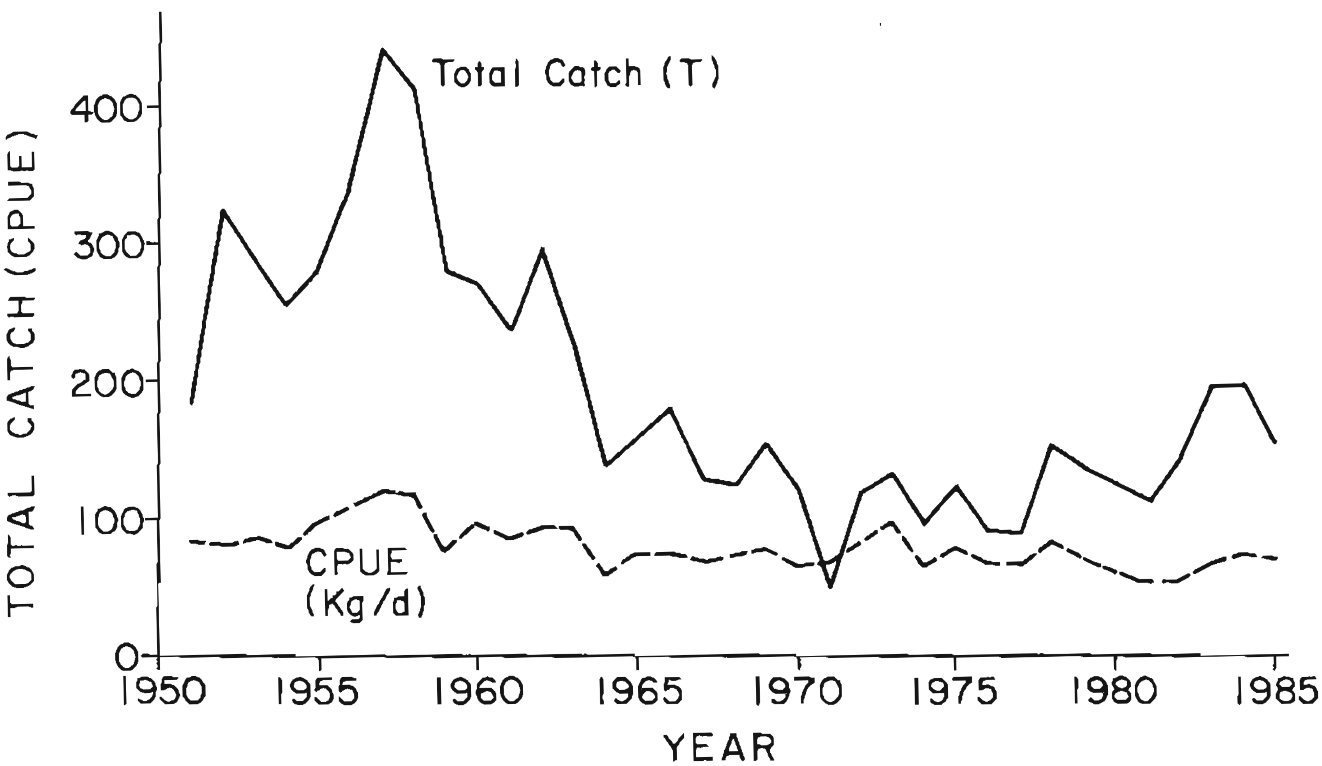

Fig. 6. Total catch and catch per day of shrimp taken in the trawl fishery from statistical area 28 and 29.

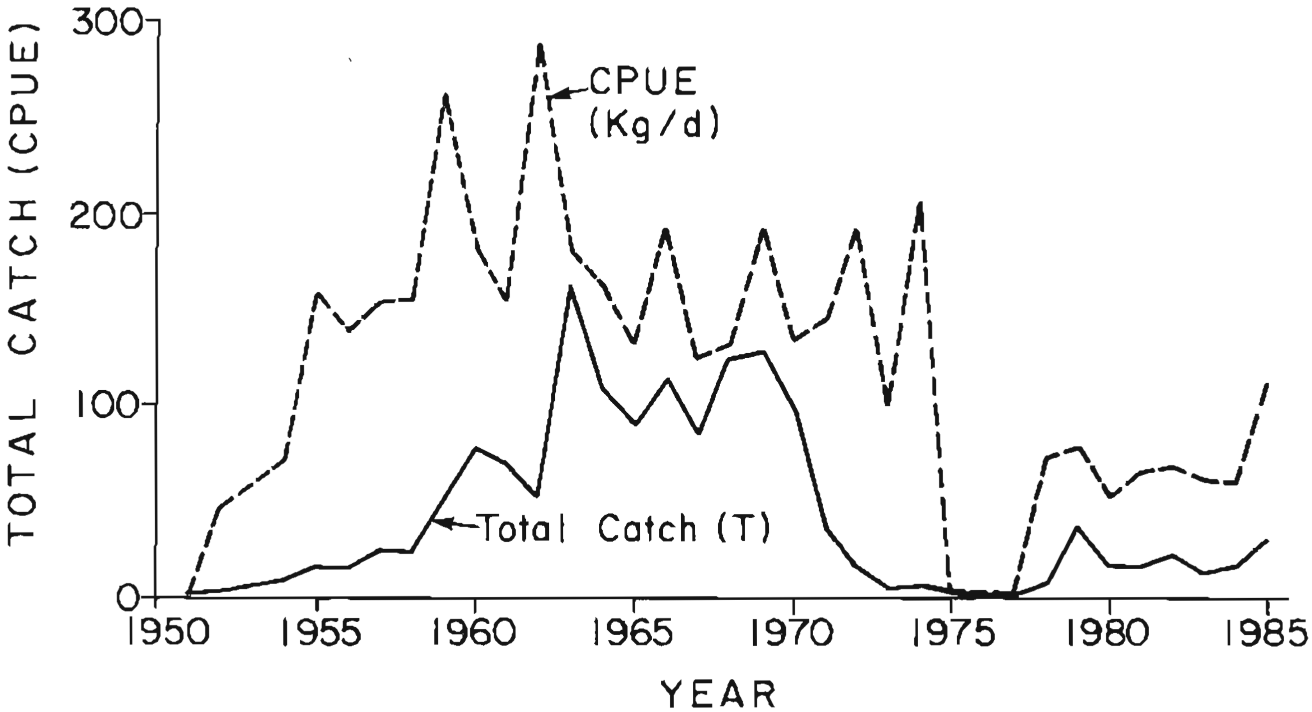

Fig. 7. Total catch and catch per day of shrimp taken in the trawl fishery from statistical areas 4 and 5.

APPENDIX A: TIME SERIES ANALYSIS OF COMMERCIAL LANDING STATISTICS FROM AREAS 28 AND 29 FOR 1951-1985.

SARIMA (1, 0, 0)(0, 0, 0) 0

LENGTH OF THE INPUT TIME SERIES = 35

MODIFIED SUM OF SQUARES ESTIMATION

SUM OF SQUARES	RESIDUAL VARIANCE	R-SQ
8.88448470D+04	1.43601224D+01	65.90%

AIC	BIC
2.80375457D+02	-1,42520751D+02

BOX-COX TRANSFORMATION PARAMETERS

LAMDA	SE(LAMDA)	CONS
0.5000	0.0000	0.000000D+00

DETERMINISTIC COMPONENT

SERIES MEAN	S.E.	TREND TERM	S.E.
2.498893D+01	3.089892D+00	5.180235D+00	2.672455D+00

ESTIMATED BETA PARAMETERS

BETA	SE(BETA)
0.7927	0.1030

------------------------------ RESIDUAL ANALYSIS ------------------------------

SKEWNESS		KURTOSIS	
G1	S.L.	G2	S.L.
0.0996	0.781918	0.1361	0.869809

TEST FOR HETEROSCEDASTICITY DEPENDING ON THE CURRENT LEVEL

CHI	SE(CHI)
-0.008242	0.046558

TEST FOR TRENDS IN THE VARIANCE OVER TIME

CHI	SE(CHI)
-0.029860	0.023669

APPENDIX A: (Cont'd)

RESIDUAL AND SQUARED-RESIDUAL AUTOCORRELATIONS

LAG	RA	SE	QA	RAA	QAA
1	0.01081	0.13399	0.00	-0.05608	0.12
2	-0.26718	0.14798	2.81	-0.11618	0.65
3	0.20014	0.15614	4.43	-0.11636	1.20
4	0.14676	0.16105	5.33	-0.07120	1.41
5	0.20661	0.16406	7.17	0.17861	2.79
6	0.14925	0.16593	8.16	-0.20629	4.69
7	-0.12479	0.16709	8.88	0.26882	8.03
8	-0.08532	0.16781	9.23	-0.09481	8.46
9	-0.05485	0.16827	9.38	-0.11993	9.18
10	0.18126	0.16855	11.09	-0.06258	9.38
11	-0.07160	0.16873	11.36	-0.18803	11.29
12	-0.08745	0.16884	11.79	0.11316	12.01
13	-0.07286	0.16891	12.10	0.18887	14.11
14	-0.12822	0.16896	13.12	0.17509	16.00
15	-0.08190	0.16898	13.55	0.15564	17.57
16	-0.01328	0.16900	13.57	-0.08554	18.07
17	0.08008	0.16901	14.03	-0.09139	18.67
18	-0.06504	0.16902	14.35	-0.10884	19.57
19	-0.36325	0.16902	25.03	0.35872	29.98
20	0.05945	0.16903	25.33	-0.01555	30.00

Q(20) = 25.33 ON 19 DF IS NOT SIGNIFICANT AT THE 5 PERCENT LEVEL

Q(20) = 30.00 ON 20 DF IS NOT SIGNIFICANT AT THE 5 PERCENT LEVEL

C_t = Catch @ time t

$C^1{}_t = 2[C_t{}^{.5} - 1]$

a_t = NID $(0, o^2)$

$o^2 = 14.36 \quad o = 3.789$

$(C^1{}_t - 24.989) = .7927\ (C^1{t-1} - 24.989) + a_t$

$C^1{}_t = 5.180 + .7929\ (C^1{t-1}) + a_t$

1985 catch = 152 t $\quad C^1{}_{1985} = 22.658$

Forecast for 1986

$C_t = 5.180 + .7929 \times 22.658 + a_t = 23.146 \pm 7.426$

C_t = 158 t

95% CI [78,265]

APPENDIX B: TIME SERIES ANALYSIS OF COMMERCIAL LANDING STATISTICS FROM AREAS 4 AND 5 FOR 1951-1985.

SARIMA (1, 0, 0)(0, 0, 0) 0

LENGTH OF THE INPUT TIME SERIES = 34

MODIFIED SUM OF SQUARES ESTIMATION

SUM OF SQUARES	RESIDUAL VARIANCE	R-SQ
8.09577929D+03	1.23864674D+01	73.51%

AIC	BIC
1.92073079D+02	-9.83260801D+01

BOX-COX TRANSFORMATION PARAMETERS

LAMDA	SE(LAMDA)	CONS
0.5000	0.0000	0.000000D+00

DETERMINISTIC COMPONENT

SERIES MEAN	S.E.	TREND TERM	S.E.
8.957626D+00	4.142616D+00	1.305126D+00	1.066899D+00

ESTIMATED BETA PARAMETERS

BETA	SE(BETA)
0.8543	0.0891

------------------------------ RESIDUAL ANALYSIS ------------------------------

SKEWNESS		KURTOSIS	
G1	S.L.	G2	S.L.
0.9031	0.023745	1.7596	0.035954

TEST FOR HETEROSCEDASTICITY DEPENDING ON THE CURRENT LEVEL

CHI	SE(CHI)
0.091449	0.040796

TEST FOR TRENDS IN THE VARIANCE OVER TIME

CHI	SE(CHI)
-0.002927	0.024722

APPENDIX B: (Cont'd)

RESIDUAL AND SQUARED-RESIDUAL AUTOCORRELATIONS

LAG	RA	SE	QA	RAA	QAA
1	-0.00052	0.14651	0.00	-0.05700	0.12
2	0.02798	0.15366	0.03	-0.15242	1.01
3	0.24013	0.15868	2.31	0.06127	1.16
4	-0.04643	0.16224	2.39	-0.00930	1.16
5	0.02662	0.16479	2.42	0.00425	1.16
6	0.10804	0.16663	2.93	-0.13425	1.95
7	-0.12916	0.16796	3.69	-0.11246	2.52
8	-0.17125	0.16892	5.07	0.22685	4.95
9	0.01120	0.16962	5.08	-0.01267	4.95
10	-0.03583	0.17013	5.14	-0.08769	5.35
11	-0.04240	0.17050	5.24	-0.08779	5.76
12	-0.24122	0.17077	8.48	0.02187	5.78
13	-0.03454	0.17097	8.55	-0.07677	6.13
14	-0.21015	0.17111	11.25	-0.08971	6.62
15	-0.06841	0.17122	11.55	-0.08331	7.07
16	0.13053	0.17129	12.71	0.16825	8.99
17	-0.18586	0.17135	15.20	0.02784	9.05
18	-0.03474	0.17139	15.29	-0.10468	9.88
19	0.17476	0.17142	17.78	-0.05428	10.12
20	-0.06195	0.17144	18.12	0.01608	10.15

Q(20) = 18.12 ON 19 DF IS NOT SIGNIFICANT AT THE 5 PERCENT LEVEL

Q(20) = 10.15 ON 20 DF IS NOT SIGNIFICANT AT THE 5 PERCENT LEVEL

C_t = Catch @ time t

$C^1_t = 2[C_t^{\circ.5} - 1]$

$a_t = NID\ (0,\ o^2)$

$o^2 = 1.239 \times 10^1$ $\quad$ $o = 3.520$

$(C^1_t - 8.958) = .8543\ (C^1_t{-1} - 8.958) + a_t$

$C^1_t = 1.305 + .8543\ (C^1_t{-1}) + a_t$

1985 catch = 29t $\quad$ $C^1_{1985} = 8.770$

Forecast for 1986

$C^1_t = 1.305 + .8543 \times 8.770 \pm 6.899$

$C^1_t = 8.797 \pm 6.899$

$C_{1986} = 29t$

95% CI [4, 78]

5. DUNGENESS CRAB

G. S. Jamieson

INTRODUCTION

Dungeness crab, Cancer magister, is the main crab species exploited in British Columbia, with landings in recent years averaging about 1200 t. Landed value was $4.6 million in 1984, making it the most valuable invertebrate species in British Columbia. There were 387 vessels with crab landings in 1984 (Noakes and Jamieson 1986). Dungeness crab range in distribution from the Aleutian Islands, Alaska, to Monterey Bay, California but although British Columbia is in the centre to the species' range, it has the lowest annual landing among adjacent American states (Jamieson 1985). This appears to be the result of environmental factors but the explanation for this is not obvious (Jamieson 1986b); it may result from the region's topography, oceanography or some biological parameters.

The Dungeness crab fishery in British Columbia consists of a number of geographically discrete subfisheries (Jamieson 1985), with the major ones (150 t in 1985) being in McIntyre Bay in Dixon Entrance, the Fraser River estuary, around Victoria and around Tofino on the west coast of Vancouver Island (Figs. 1, 2; Table 1). The annual pattern of landings in each subfishery has fluctuated independently, presumably because of unique fishing, biological and/or environmental reasons (Jamieson 1985, Noakes 1986) but also apparently because of variable fishing effort arising from the relative return available from crab in comparison to other potential species (Noakes and Jamieson 1986). As a result, it is not clear to what extent annual landings can be interpreted as reflecting year-class strength.

Early studies of Dungeness crab in Canada focussed on general life history (eg. Butler 1956, 1960, 1961, Mackay 1942, Weymouth 1916) and fishery characteristics (eg. Butler 1951; McMynn 1951) with research emphasis on legal male crabs.

In the past few years, study of Canadian Dungeness crab fisheries initially focused on Dixon Entrance (Booth et al. 1985) but for logistic reasons, emphasis later shifted to the Fraser River estuary (Breen 1985a,b) and the west coast of Vancouver Island (Jamieson, unpub. data) in response to requests by fishermen for study of crab. In the Fraser, studies had been initiated by management and habitat biologists to address concerns about the landing of soft-shell crab (L. Kalnin and K. Wilson, unpub. data) and the environmental consequences arising from the Roberts Bank coal terminal (B. Waddell, unpub. data), whereas studies by research biologists have focussed on overall crab population dynamics (Breen 1985a,b). The timing of the annual closure of crab fishing in the spring in the Fraser River estuary, initially intended to be based on the pattern of moulting that specific year, is now recognized as being an arbitrary closure period which generally includes the period of greatest soft-shell frequency (L. Kalmin and K. Wilson, unpub. data).

Studies off the west coast of Vancouver Island were initiated in response to soft-shell crab exploitation and a more general concern that two discrete subpopulations (inlets in Clayoquot Sound vs. Long Beach) existed, and inlet crabs were being particularly heavily exploited. Studies have subsequently tried to define the main factors influencing overall crab year-class strength in the area. This includes characterization of larval abundance and distribution, both inshore, and offshore, and the study of both juvenile and adult crab population dynamics in the vicinity of Tofino. Studies are still underway but early results indicate a general absence of larval crab settlement in both 1985 and 1986 as a result of environmental factors. Currently exploited year-classes of mature crabs will likely be depleted in late 1987 and landings are expected to be low in this subfishery for at least the following 2-3 years.

BIOLOGY

Male Dungeness crab have a maximum shell width of about 230 mm and weight of about 2 kg (Hart 1982). Females seldom exceed 190 mm in shell width. They are most abundant on sand but also occur on mud and gravel, from the intertidal to a depth of 180 m. Mating can only occur when the female crab moults, usually in late spring-early summer, but egg laying and fertilization are typically delayed until the fall. There is evidence that the sperm remain viable for at least 1 year, so that 2 or more batches of eggs may be successfully fertilized between matings (Hankin et al. 1985). Eggs hatch in late winter and along the outer coast, larvae appear to disperse rapidly to offshore waters. Few larvae have been found within 50 km of shore off Tofino in the last two years (unpub. data). Larvae hatched in enclosed waters (eg. Hecate Strait, Strait of Georgia) may not disperse offshore as plankton, but no comprehensive study of inshore larvae has been undertaken. Booth et al. (1985) studied larvae in Dixon Entrance but did not establish their occurrence in adjacent areas. The larval stage lasts about 90-120 days and it seems unlikely that larvae hatched in any given location will ultimately return to that location at settlement (Jamieson 1986).

Crabs recruit at 3-4 yr of age, whereas sexual maturity is attained at about 2-3 yr of age (Butler 1960).

FISHERY MANAGEMENT

Crabs are currently managed by a minimum size limit, gear restrictions and occasional closures during periods of soft shell. Few annual modification of regulations are usually made (Jamieson 1986a). The minimum legal size limit (165 mm, spine to spine, carapace width) applies to both males and females. This is in contrast to adjacent American state regulations, which prevent the harvest of females irrespective of shell size. However, this restriction in the U.S. is not based on any demonstrated biological evidence that ultimate yields are enhanced and their policies are currently under review.

In British Columbia there are general gear restrictions to prevent retention of sublegal-size crabs, and some regional closures to address economic concerns raised by fishermen from the area. Advice is periodically requested by fishermen and/or fishery officers from an area to evaluate the biological consequences of alternative management options.

The soft-shell crab issue in the Fraser River estuary is primarily an economic issue, not a biological one, in that it affects product quality, not the population dynamics of the species. There may be however, increased mortality in an intensive fishery and this might decrease potential long-term yield from a year class. Timing of the existing regulation is somewhat arbitrary (L. Kalnin and K. Wilson, unpub. data) and has been justified for socio-economic reasons. It has the support of most fishermen.

One concern, largely ignored to date, characteristic of all trap fisheries is the continued fishing of lost traps (i.e., ghost fishing) and the resulting loss of crabs (Breen 1985b). In the Fraser River estuary, the annual trap loss was estimated to be 11% and the resulting crab loss to ghost fishing might exceed 7% of the annual reported catch in the area (P. Breen, unpub. data). A self-distruct mechanism used on a trap to insure against its ghost fishing was suggested to be cost effective.

RECOMMENDATIONS

In general, the crab fishery is relatively stable with most management concerns relating to allocation of resource among fishermen and achieving the maximum dollar value from the resource. Because of their relatively large larval size, Dungeness crab lend themselves as a model to study overall population dynamics in invertebrates, and because of their offshore distribution and relative ease of sampling, they also appear to be an effective indicator species of oceanographic events which may have broad relevance to other commercial species, both finfish and invertebrates. It is planned to establish low-effort, routine monitoring programs to document larvel crab abundance and distribution on an on-going basis, while addressing more specific management concerns on request.

In 1987/88, the detailed study of crab around Tofino will be completed and effort in future years be partially redirected towards the Fraser River subfishery.

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Table 1. Definitions of geographical groupings used in this paper.

Designated names	Area code	Statistical areas
Queen Charlotte Islands	(QCI)	1,2
Chatham Sound	(CS)	3,4,5
Central Coast	(CC)	6-10,30
Johnstone Strait	(JS)	11-13
Georgia Strait	(GS)	14-18
Victoria	(V)	19-20
West Coast of Vancouver Island	(WVI)	21-27
Fraser River	(FR)	28,29

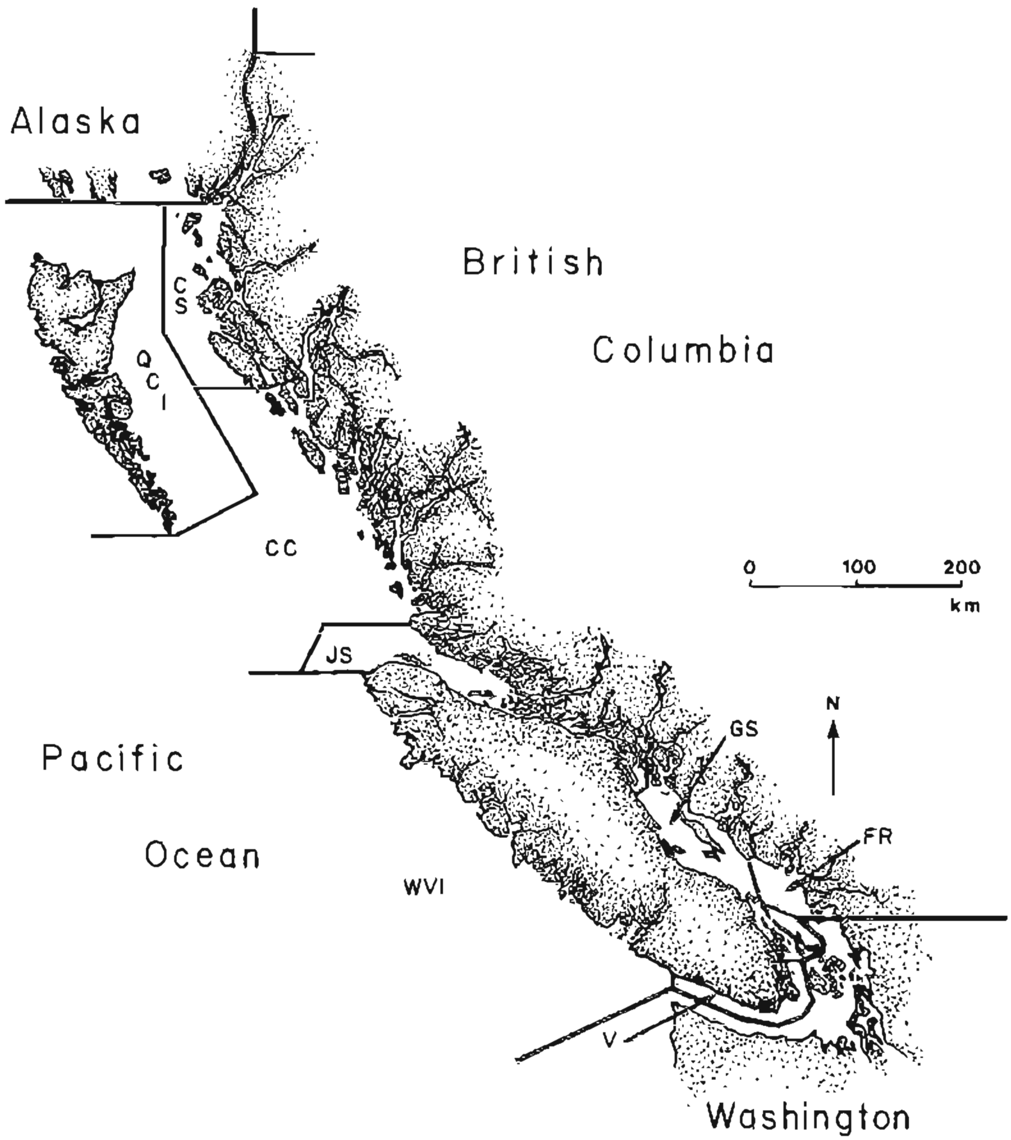

Fig. 1. The boundaries of the eight geographically distinct areas. Reference symbols are: QCI, Queen Charlotte Islands; CS, Chatham Sound; CC, Central Coast; JS, Johnstone Strait; WVI, west coast of Vancouver Island; GS, Georgia Strait; FR, Fraser River estuary; V, Victoria.

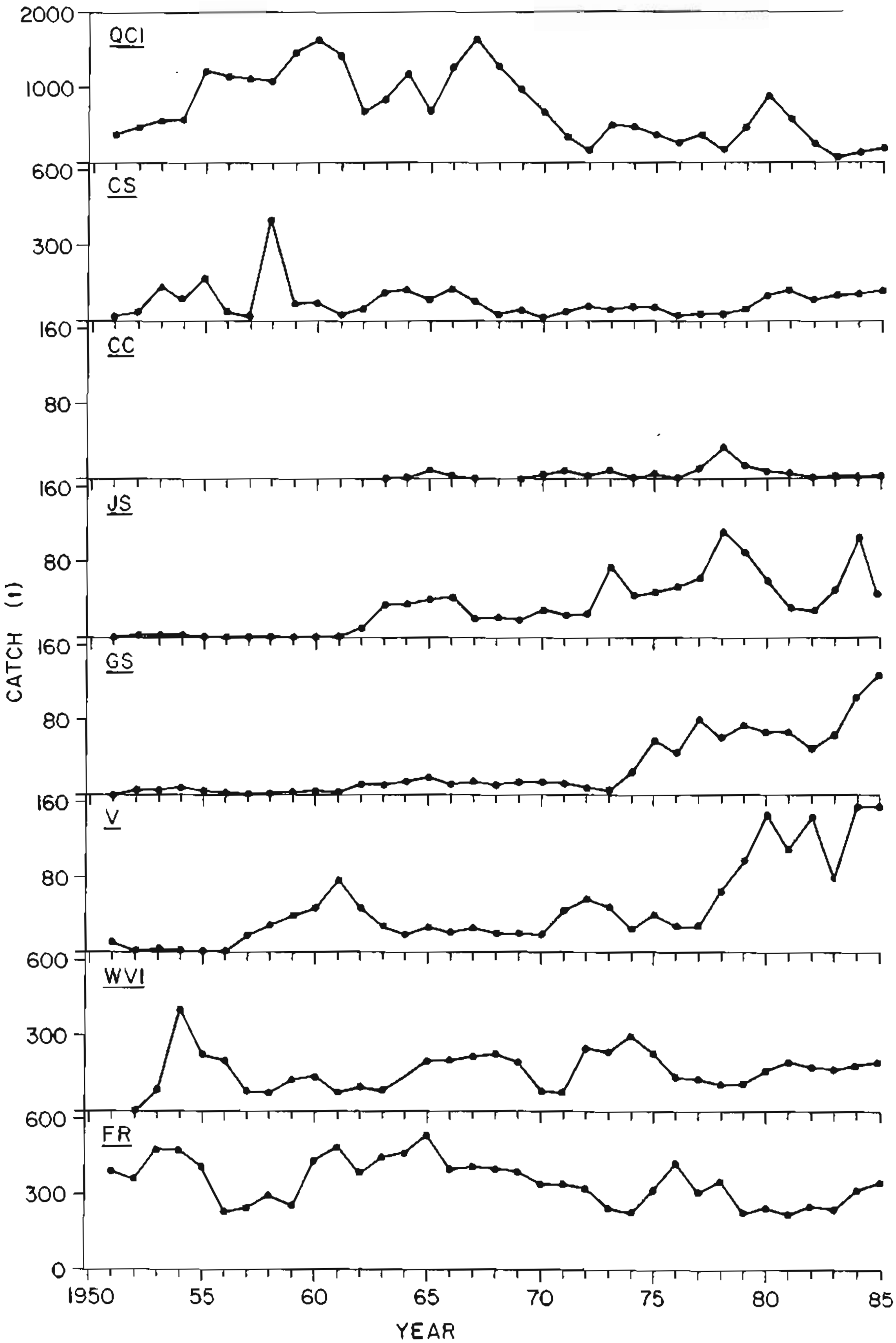

Fig. 2. Annual Dungeness crab landings in the eight fisheries identified in British Columbia. Reference symbols and geographic boundaries are described in Table 1 and Fig. 1, respectively.

6. KING, TANNER, RED ROCK AND GALATHEID CRABS

G. S. Jamieson

INTRODUCTION

Although Dungeness crab (Cancer magister) is the only crab species regularly exploited in quantity in British Columbia, there are occasional landings of king, tanner, red rock (C. productus) and galatheid (Munida quadrispina) crabs, sometimes as a bycatch in the Dungeness crab and prawn (Pandalus platyceros) fisheries and sometimes through limited, directed fishing. Such landings are summed with those of Dungeness crab in regional annual statistics and so their relative magnitude and value by species are unknown.

Two species of king crab, red (Paralithodes camtschatica) and golden (Lithodes aequispina), and one species of tanner crab (Chionoecetes bairdi) were commercially exploited in British Columbia in the early 1980's (Jamieson and Sloan 1985). To date, all three species have only been found in commercial quantities north of Cape Caution (Jamieson et al. 1986; Jamieson, unpub. data). Populations with commercial potential have been sporadic and widely distributed geographically, and probably result from the chance settlement of larvae in abundance. British Columbia is the southern limit of the ranges of distribution of these three species.

Under these circumstances, it is questionable whether populations of king and tanner crabs should be exploited with the intent of achieving any optimal level of long-term production. With red king crabs, for example, few male crabs in British Columbia reach in size the minimum legal size of 178 mm set in Alaska (Otto 1985). The explanation is unknown but it probably reflects the less optimal growing conditions one would expect on the fringe of a species' range. Regardless, though, it demonstrates that conventional management approaches, based on biological criteria established in other areas, are probably inappropriate, yet any potential Canadian fishery would not be of magnitude at this time to justify a significant research or management effort.

Recent studies of king and tanner crabs in British Columbia were largely the result of concern raised by some fishermen because of decreasing king crab catches in Alice Arm, coincident with the initiation of discharge of tailings from a mine into the inlet. Studies were conducted in an effort to establish the environmental impact resulting from the mine's operation (eg. Reid and Baumann 1984), to document crab population dynamics (Sloan 1984, 1985) and to determine if alternative crab stocks existed in the region to allow the recently established crab fishery to be sustained (Jamieson et al. 1986).

Red rock and galatheid crabs are widely distributed throughout British Columbia. The former species is largely exploited by the recreational fishery whereas the latter is mostly discarded bycatch in the prawn fishery. Because red rock crab are generally smaller than Dungeness crab and have a harder shell, they are not particularly desired by current commercial markets. Galatheid crabs are eaten by people in South America but because of a lack of market in North America, their probable use, if a fishery develops, will be as a dietary component in salmonid feeds (Burd 1986). Their red pigments are very effective in turning salmon flesh pink.

BIOLOGY

Golden king crab is a deepwater species, 77 - 730 m depth (Hart 1982), found primarily on the continental shelf and in some of the deeper channels in southeastern Alaska. The only commercially exploitable population known to exist in British Columbia is a population at the head of Observatory Inlet (Alice and Hastings Arms), apparently mostly confined there by shallow sills in the inlet (Jamieson and Sloan 1985; Jamieson et al. 1986). Little is known about early life history, but the adult population is known (Sloan 1984, 1985) to be heavily infested (about 40%) with a rhizocephalan parasite which causes atrophy of the reproductive organs. It is not clear whether decline in population abundance, reflected by declining commercial catch rates, was the result of fishing, parasitism or pollution from the mine tailings.

Red king crab is a shallower-water king crab species found in a number of locations in the north coast (Jamieson et al. 1986). All king crab landed in quantity outside of Observatory Inlet are of this species. Commercial concentrations are widely scattered and it seems unlikely that any are self-sustaining. Those populations that have been found appear to be relatively small and localized. In the Bering Sea, this species reaches sexual maturity at about 6 yr of age and recruits to the fishery at about age 8.

Tanner crabs are found usually on mud to a depth of about 200 m (Hart 1982) and because of their smaller size relative to king crabs, are more often fished as a bycatch during prawn fishing. However, as with king crabs, commercial concentrations appear to be small and widely scattered (Jamieson, unpub. data), although this species appears to have a wider range of distribution in British Columbia than do either king crab species. Like king crab, tanner crab disperse widely during their planktonic larval period, which lasts 70-90 days.

Red rock crabs prefer rocky bottoms from the intertidal to a depth of 79 m in British Columbia (Hart 1982). Like Dungeness crab they appear to have an extensive larval dispersal phase but subsequent recruitment patterns have not been well documented. They probably recruit at about 3-4 yr of age.

Galatheid crab grow up to 67 mm carapace length and are found between 22-1463 m depth. Their biology and commercial potential have recently been studied by Burd (1983, 1986, respectively). The species tends to occur at a slightly greater depth than prawns and surveys indicate that this species is abundant in many prawn fishing areas in B.C. Crabs from the north coast appear to be about 30% larger than those from the south coast (Burd 1986).

FISHERY MANAGEMENT

Fishermen are required to have C licence privileges to exploit red rock and king crabs but because tanner and galathid crabs are not specifically identified in licensing schedules, commercial fishing of these latter species can only occur with a special permit.

There is a minimum size limit of 115 mm CW (carapace width, spine to spine) for red rock crab, but there are no such limits for the other crab species discussed in this report. When king crab were exploited in quantity by one fishermen in the early 1980's, he arbitrarily set himself a size limit of 165 mm. Jewett et al. (1985) recommended a minimum size limit of 181 mm CW for golden king crab in Observatory Inlet. Implications of establishing 165 or 181 mm minimum size limits for king crab in British Columbia were discussed by Jamieson and Sloan (1985) who noted that because relatively few crab exceed this latter size, imposition of this size limit would effectively prevent any commercial landings. They also stated that rhizocephalan parasitized crabs should not be relocated and that all sizes of both sexes of such crabs should be harvestable since they can no longer contribute reproductively to the population.

There is a regulation prohibiting the retention of female king crabs.

RECOMMENDATIONS

It seems unlikely there will be any significant commercial fishing of king or tanner crabs in the near future from known locations of commercial potential because of low population abundance. Red rock crabs are common, but not abundant, and have poor market demand. Galatheid crabs have a potential market if the salmon aquaculture continues to develop significantly but it is difficult at this time to predict market demand or the economics of fishing them. Recommendations are:

(1) tanner and galatheid crabs should be specified in regulation as to licence requirements so that fishery monitoring can be more easily effected.

(2) at this time, no minimum size limits for king, tanner and galatheid crabs are recommended as the biological data required to establish optimum sizes for such species in British Columbia are largely unavailable, and the lack of any current fisheries for these species in British Columbia gives the acquisition of such data a low priority.

(3) crab species should be given individual codes for recording catch statistics. Currently all landings of crabs, regardless of the species, are given the same code.

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7. OCTOPUS (trap, trawl and diver fisheries)

G. S. Jamieson

INTRODUCTION

Three species of octopus occur in British Columbia but the giant Pacific octopus, Octopus dofleini, is the only species with any commercial potential. The octopus fishery in Canada is relatively small with landings ranging from 18 to 71 t in recent years (Table 1), mostly as bycatch in shrimp and groundfish trawling. Periodically, fishermen will initiate a directed trap fishery for octopus but to date, such efforts have never lasted long nor produced a significant landings. Divers use diluted bleach to flush octopus out of dens and bags to capture the octopus (R. Harbo, pers. comm.). In contrast, in Hokkaido, Japan, the fishery for O. dofleini alternated with flatfish during the 1960's as the most valuable fishery resource. Landings were freqeuntly 20,000 t, and in recent years, landings in Japan for all species combined have been about 35,000 t (Fish. Stat. Japan 1984, Min. Agric. Forestry, and Fish, Japan).

In a directed fishery, fishermen typically use unbaited traps (Mottet 1975). As larger octopus are most frequently found in dens during the day, it has been suggested that the abundance of octopus in an area is related to the availability of lairs, and this is the basis behind the use of such gear. A study of the potential for an octopus fishery was conducted off Tofino on the west coast of Vancouver Island (Hartwick et al. 1982). The most effective trap was a large, cedar box trap (Puget Sound design), fished in deep water (80-100 m) during the winter. Most octopus caught were males. However, information provided by this study has not resulted in establishment of a fishery, presumably because such fishing is not as economically attractive as fishing for other species.

BIOLOGY

The range of O. dofleini extends from northern California to Japan. Sexes are separate and while spawning appears to occur throughout the year, it appears to be most prevalent during the fall (Hartwick 1983). Female octopus brood their eggs for 5-6 mo in their dens and since they do not feed during this time, consequently die from starvation shortly after, or occasionally even before, the eggs hatch. Females likely only mate once whereas males can probably mate a number of times. The life span of both sexes is 3-5 yr. Larvae are planktonic for about 2 mo before they settle to the sea bottom. Little is known about juvenile ecology or distribution (Hartwick et al. 1984), but growth rate is relatively rapid with little difference between the sexes

(Robinson 1983). They reach a weight of about 1 kg in a year and about 12 kg after 18 mo. Males in British Columbia mature at about this weight but continue to grow to about 25 kg. Females reach sexual maturity at about 20 kg.

Octopus start entering traps at about 1 yr of age, and it is the life history of these larger individuals that is best understood. In Japan, octopus weighing over 1 kg make two seasonal onshore-offshore migrations a year, and there is some evidence that this is the case with immature octopus in Canada as well (Hartwick et al. 1982, 1984). In general, the populations are in deep water from February through April and from August through October, and in shallower water from July through September and November through January. During migrations, octopus may swim at the surface or at mid-water depths as well as crawl along the bottom.

Octopus may stay anywhere from 2 weeks to 6 months in a limited area, occupying several dens during that period (Hartwick et al. 1983).

FISHERY MANAGEMENT

A Z licence is required to fish octopus either from shore or from a vessel by diving. Gear restrictions are designed to minimize wounding of the animal. The use of copper sulphate is prohibited and all chemicals are banned in the intertidal zone. The fishery is closed year-round (by schedule) but following the expression of interest by fishermen, it can be opened by local fishery officers. This procedure allows fishery officers to monitor effort and landings.

RECOMMENDATIONS

In British Columbia, octopus appear to be an underutilized resource of uncertain economic value relative to other exploitable species. Problems appear to be no significant local food markets and a lack of experience fishing this species. Since they are not currently exploited, their abundance presumably reflects the existing carrying capacity of the habitat. How this relates to ultimate potential fishery yield is uncertain but in Japan at least, the management strategy of increasing the number of refuges on the bottom has increased yield. However, in the absence of any extensive fishing, it is recommended that the situation be routinely monitored but that no significant management or biological research effort be devoted to octopus at this time.

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Table 1. Landings (tonnes) of octopus by statistical area from D.F.O. sales slip and harvest log data (unpublished).

Statistical area	1983	1984	1985
1	0.2	0.4	0.4
2E	1.9	3.7	1.2
2W	*	0.2	-
3	1.0	0.5	1.1
4	3.4	2.6	2.0
5	5.1	4.2	1.9
6	1.1	2.0	1.2
7	0.2	-	0.6
8	0.7	0.6	0.7
9	*	*	*
10	0.3	0.1	-
11	0.3	0.6	0.5
12	2.5	0.7	1.7
13	2.5	3.3	3.1
14	*	0.1	0.8
15	*	*	0.2
16	1.1	*	*
17	0.9	0.3	1.0
18	0.7	1.9	3.7
19	6.7	6.4	7.6
20	3.2	2.1	4.8
21	0.2	*	0.1
22	-	-	-
23	1.2	0.2	0.7
24	3.6	0.2	0.4
25	-	*	*
26	-	*	*
27	0.2	*	*
28	*	-	0.1
29	*	*	0.1
Total	37	30.3	34

* less than 100 kg.

8. PRAWN (trap fishery)

J.A. Boutillier

INTRODUCTION

The shrimp trap fishery in B.C. began in the early 1900s. The fishery mainly targeted on prawns (Pandalus platyceros) with incidental catches of humpback (P. hypsinotus) and pink shrimp (P. borealis).

Prawns occur along the west coast of North America from Unalaska to San Diego and in Asian waters from the Sea of Japan to Korea Strait. They occur at depths from the intertidal zone to 487 m (Butler 1970).

Of the six commercial pandalid shrimp species in B.C. waters, prawns are the largest, with a maximum reported size of 254 mm total length (Butler 1970).

BIOLOGY

Larval prawns generally hatch in March or April at depths of 70-90 m. By summer, late larvae and postlarvae are found at depths 54 m (Butler 1980). They generally metamorphose and remain in shallow water areas for up to a year after hatching. Prawns first mature as males at 16 to 18 mo, and will remain as functional males usually for a additional year. When prawns are about 2.5 yr old they undergo sex reversal and become functional females. They breed in the fall and use their first four pairs of swimming legs to carry their eggs until hatching, generally 5-6 months later. Butler (1970) reports egg counts per female of 1393-3162.

Prawns are benthic in habitat and feed on amphipods, polycheates, and detritus (Butler 1970). The major predators of prawns have not been reported. Octopus, sea stars and several gadid fishfhave been observed to eat prawns in traps.

FISHERY MANAGEMENT

Traditionally, the prawn fishery was limited to south coast areas (Butler 1980) with the first substantial landings from the north coast occurring in 1979 (Bernard 1982), subsequent to a series of exploratory prawn trap surveys in the region (Butler et al. 1975, Boutillier and Cooke 1976, Cooper and Boutillier 1979).

Participation in this fishery requires a Z-licence for shrimp trap fishing. As of June 1986, 451 licences had been issued. In 1985, 471 licences were issued of which 241 vessels reporting fishing (J. Fulton, pers. comm.). This is a five-fold increase over the number of vessel reported fishing in this same fishery in 1976. The best estimated catch for 1985 was 511 t, a seven-fold increase over the 71 t reported in 1976 (see Table 1). It is estimated that there were 109,000 traps in use in 1985.

Comparisons of the logbook and saleslip databases have shown that up to 25% of the catch has gone unreported in the published sales slip catch statistics prior to 1985 (J. Fulton and R. Harbo, pers. comm.).

IN-SEASON MANAGEMENT

Prior to 1979, there was not a management program in place for prawns (Jamieson 1986). With the rapid expansion of the fishery in 1979, a management system was developed which allowed for a minimum escapement of the spawning cohort of prawns within a management area. An index is obtained by monitoring the age by length frequency analysis and sex composition of the commercial catch per trap. This establishes an index of spawners which is then compared to a criterion of minimum spawner escapement established from study areas in Knight and Kingcome Inlets which were monitored from 1973 to 1982 (Table 2). If the spawner index in the commercial area falls below the monthly criteria, the area is closed until the egg-bearing period is over, usually the following April. In 1983, the prawn fishery came under the Z-licence category and, as a condition of the licence, participating fishermen are required to keep a detailed log of their catch and effort. In 1985, a minimum size limit (30 mm carapace length) was gazetted for prawns, based on studies by Boutillier (1984, 1985).

BIOLOGICAL SAMPLING

Approximately 50 vessels are boarded each season by management biologists to sample the catch. Samples are taken for CPUE ($kg \cdot trap^{-1}$) and a spawner index (Table 2).

The data received from the biological sampling of different areas is not standardized according to the trap type, bait, soak time and other variables. New biological sampling procedures are being developed which will be utilized by all fisheries staff gathering biological information.

WINTER CLOSURES - SOUTH COAST

In 1984 and 1985, a winter closure on prawn was implemented by managers for all south coast areas over the period January to March inclusive. The closure was in response to low spawner indices and an inability to adequately monitor these fisheries as this time of year. The south coast closure to prawn fishing caused shifts in effort into more remote northern areas where it was difficult to monitor the fishery.

MINIMUM SIZE LIMIT AND TRAP ESCAPE STUDIES

A minimum size limit, 30 mm carapace length, came into effect in 1985. The regulation has since been varied so that it is not in effect because of a number of difficulties with enforcement. To simplify enforcement it was recommended at industry meetings in early 1986 that trap modifications be developed which insured escapement of sublegal prawns (Boutillier and Sloan 1986, in press).

RESEARCH PROGRAMS

PRAWN STUDY AREAS

Studies were initiated in 1985 using experimental areas for prawn fishing. There are 2 study areas located in the south coast: 1) Salmon and Sechelt inlets and 2) Alberni Inlet; one study area, Howe Sound, in the Fraser River Division and 3 areas in the north coast; 1) Work Channel, 2) Gardner Canal and 3) River and Moses inlets. The purpose of these areas is to build, using logbooks and regular standardized sampling practices, a data set which allows estimation of impacts of the fishery on various population parameters such as total, natural, and fishing mortalities; growth rates of the total population and of individuals within a year-class; and the relationship of density to growth, survival, catchability, and availability. From this information we hope to develop and evaluate various alternate management scenarios utilizing the data base from the commercial monitoring program and a series of pre- and post-commercial fishery surveys.

GEAR STANDARDIZATION

The fleet currently uses a variety of fishing methods (i.e. traps, baits, depths, soak-times) which affect their effective fishing effort. This unstandardized effort makes it difficult to use logbooks for stock assessment and affects the interpretation of the results from spawner index monitoring.

A series of experiments have been carried out to evaluate important variables in the definition of effective fishing effort (Boutillier 1986; Boutillier, in press; and Boutillier and Sloan, in press). The results of these studies will all be drawn together to develop an effort standardization algorithm.

SALES SLIP AND LOGBOOK DATA

At present the logbook and sales slip databases are used to complement and correct each other. Both these databases depend on data received from the industry and therefore are not independent checks on the reliability of either system. There are two additional independent sources of information on fishing activity which should provide excellent checks on the logbook and saleslip data bases: the catch sampling program, and a fishing activity log which could be kept by patrol vessels and fishery officers. The biological monitoring program is partially used until in a standard format is developed. The patrol log is being developed for 1987.

INFESTATIONS BY PARASITES

Populations of central and north coast prawns are infected with a parasitic barnacle, *Sylon* sp.. A central coast population under investigation has a 20% infestation rate. This parasite may castrate its host and eventually kill it. Infected prawns are also less desirable a product which receives a lower price. These parasites do not appear in prawn populations in the south and with transportation of live and fresh product their spread to the southcoast may be a real risk. The industry has been sent an information bulletin on the parasite and a questionaire requesting information on the distribution of the parasite on prawns and other shrimp.

RECOMMENDATIONS

1. The spawner escapement managment program should continue in 1987.

2. Prawn study areas should remain in effect and be monitored.

3. Further research is proposed to develop an effort standardization algorithm to apply to logbook data and data collected by management biologists while sampling commercial catches.

4. A patrol log is being developed for 1987 to record fishing activity as a check against logbook and sales slip data.

5. Studies should continue to identify and document the implication of the infection of the Sylon parasite on its host.

6. Further investigation is planned to evaluate trap modifications for the escapement of small prawns.

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Table 1. The total number of vessels reporting landings and the total reported catch (t) of prawns by trap in the B.C. fishery 1976-1985.

Year	Number of vessels	Total catch (t)
1976	48	71
1977	108	153
1978	152	211
1979	307	310
1980	261	361
1981	212	320
1982	218	264
1983*	276	420
1984*	305	503
1985*	241	511

*Estimates of the number of vessels and total catch is from unpublished data corrected from sales slips and logbooks combined. Mandatory logbook data was not collected prior to May 1983. With the introduction of the logs, it was shown that at least 25% of the total landings were previously unreported.

Table 2. Monthly spawner index determination used for in-season management of prawns.

Month	Monthly Index # per Pardiac trap soaked for 24 hr using herring bait	Sex classes** to be included in index determination
April	3.8	some* 1's, all 2's and all 3's
May	3.5	* 1's, all 2's and all 3's
June	3.2	* 1's, all 2's and all 3's
July	2.9	* 1's, all 2's and all 3's
Aug	2.6	all 2's and all 3's
Sept	2.4	most 2's should be gone, all 3's and all 4's
Oct	2.1	all 3's and all 4's
Nov	1.9	most 3's will be gone and all 4's
Dec	1.6	all 4's
Jan	1.4	all 4's and all 5's
Feb	1.2	all 4's and all 5's
March	1.0	all 4's and all 5's

*Only the small portion of 3 year old males which have not changed sex will be included in the spawner index calculation. This portion falls off dramatically over the summer as the animals undergo a sex change. The only way of determining this proportion of males is through mode length frequency analysis.

** Sex 1 = male.

Sex 2 = transition.

Sex 3 = non-ovigerous female.

Sex 4 = ovigerous female.

Sex 5 = female after hatching.

9. ABALONE

N.A. Sloan and S. Farlinger

INTRODUCTION

The northern abalone (Haliotis kamtschatkana) fishery in British Columbia is well documented with a detailed historical review by Fedorenko and Sprout (1982) and management reviews by Breen (1980, 1986) Sprout (1983), Bates (1984, 1985), Farlinger and Bates (1985) and Jamieson (1986). Harvesting began in the early 1900's but landing records have only been kept since 1952. In the first 20 years (1952-1971), annual landings averaged 7.7 t with only the years 1964 and 1970 exceeding a value of $10,000. Table 1 lists landings, licensing and value data since 1972. The landed value has increased by an order of magnitude since 1972.

BIOLOGY

Northern abalone are patchily distributed along most rocky B.C. shores adjacent to open water. They are not generally found in inlets and only small populations are found in the Strait of Georgia. They occur from the lower intertidal zone to 100 m depth. Abalone are not very mobile and tend to stay in the same area all their lives.

Spawning usually occurs April through June when males and females aggregate to synchronously broadcast their gametes for external fertilization. Fecundity is poorly described, but there is an unpublished observation that a 135 mm long female can produce 2.3 million eggs. The planktonic larval phase is about two weeks, as with other Haliotis spp. (Mottet 1978), and metamorphosed larvae likely settle on encrusting red coralline algae where they remain as grazers of epibiota until they are large enough to begin capturing drift algae. As they grow, young northern abalone gradually become less cryptic and occupy more exposed rock surfaces. Mortality of young northern abalone is speculated to be high as there are numerous predators such as sea stars, crabs, octopus and browsing fishes.

Growth is slow and it takes at least 6 years to reach the legal size of 100 mm shell length (Breen 1986), at which time they weigh between 116 to 164 g, according to locality (Breen and Adkins 1982). Growth rate is highly site-specific, depending completely on the amount and type of food available locally. Moreover, size can also be influenced by local wave energy which stunts individuals on the most exposed shores (Breen 1980). Northern abalone cannot be reliably aged, but they probably live at least 15 years (Fournier and Breen 1983). Natural mortality of adults is thought to be low in areas devoid of sea otters, which is most of the B.C. coast. Unharvested populations are characterized by accumulations of large, older individuals which led to a false perception of high recruitment in the early years of the diving fishery in the mid-1970's.

FISHERY MANAGEMENT

The abalone fishery has been characterized by a variety of management regulations (Jamieson 1986). Until the marked stock decline in the late 1970's, the abalone fishery was largely unregulated except for minimum size limits. It became a limited entry fishery in 1977 with a quota first imposed in 1979; a size limit modified to 100 mm in 1980 (Fedorenko and Sprout 1982; Breen 1986). The quota, evenly shared among the 26 licences, was 47.2 t in 1986. A serious problem of poaching occurs, in part due to high prices. Many of the closures on the west coast of Vancouver Island are not consistent with quota management objectives or the rationale for other closures, to protect native food fish and sportfish resources.

Some fishermen have questioned the value of a size limit of 100 mm shell length, suggesting an increase. Breen (1986) suggests that a minimum size was not considered by managers in the early 1980's to be a "major management tool".

Port sampling in Prince Rupert in 1985 revealed that mean landed abalone size was 112 mm (Farlinger and Bates 1985). Early indications from 1986 sampling are that average abalone size in the catch is increasing. This may, however, reflect poor recent recruitment and the general absence of smaller-size animals rather than selection of larger abalone by fishermen. Farlinger and Bates (1986) report that commercial fishing locations in the central coast had an increase in average total density of abalone between 1983 and 1985 from 1.43 abalone$\cdot m^{-2}$ to 1.57 abalone$\cdot m^{-2}$. Accordingly, we recommend no change in the 1986 quota or 47.2 t for 1987.

North coast management biologists have attempted estimating stock size using Stock Reduction Analysis (SRA) as described in Breen (1986). SRA allows estimation of initial population biomass from the proportion by which a stock has decreased (P), catches, and assumptions of values for mortality (M), recruitment and growth. Estimates of M and P came from Breen (1986) and survey data (Farlinger and Bates 1986). Accurate catch data came from logs. These data have been used to estimate initial biomass for Areas 1, 2E, 6 and 20 but solutions using SRA have not yet proven to be sufficiently accurate to justify management action.

RECOMMENDATIONS

MANAGEMENT

1. The quota for 1987 should not be reduced, because of an indication of stock stabilization in the recent central coast survey (Farlinger and Bates 1986). Moreover, anecdotal observations from recreational divers and fishery officers suggest an increasing availability of abalone.

2. A resurvey of the Queen Charlotte Islands (Area 2E) is recommended for 1987 to establish the possibility of abalone stock improvements. The established sampling protocol (Boutillier et al. 1984, 1985) should be used.

RESEARCH

1. The benefits of an increased size limit could be evaluated to determine the increase of reproductive contribution of the population newly sheltered.

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Table 1. Abalone fisheries statistics. Data from Fisheries Branch, Statistics Division, Farlinger and Bates (1985) and Breen (1986).

Year	Landings* (t)	Landed Value ($\$10^{-3}$)	Price ($\$\cdot t^{-1}$)	Licences No.	Licences Type	Quota** (t)
1972	60	59	983	Open	C	None
1973	68	94	1,382	Open	C	None
1974	26	43	1,654	Open	C	None
1975	59	132	2,237	Open	C	None
1976	274	860	3,139	Open	C	None
1977	428	1,733	4,049	29	C	None
1978	433	1,864	4,305	27	E	None
1979	186	1,062	5,710	26	E	226.8
1980	97	601	6,196	26	E	113.4
1981	85	795	9,353	26	E	94.3
1982	82	457	8,463	26	E	94.3
1983	56	464	8,286	26	E	70.6
1984	58	530	9,138	26	E	58.9
1985	44	442	10,524	26	E	47.2

* Landings were first recorded in 1952; we have adjusted 1982 landings to include an additional 28 t from logbook data.

** 1986 quota = 47.2 t

10. GEODUCK CLAM

R.M. Harbo and J. Fulton

INTRODUCTION

The geoduck, Panope abrupta (Conrad, 1849) (Panope generosa) is the largest clam in British Columbia. Mean weight of harvested animals is 1 kg with some exceeding 2 kg (Harbo et al. 1983). They are found from the +0.3 m tide level to depths of 111 m (Jamison et al. 1984).

Geoducks are processed for their neck or siphon meat, which is primarily exported to Japan for sushi. Body meat is processed for chowders or other products.

Geoduck clams are harvested commercially by divers using hand-held high pressure water jets which displace the substrate surrounding individual clams. The fishery is managed by annual quotas to maintain a sustainable yield. Licence limitation constrains the fleet to 55 G licence vessels. Most geoduck fishermen derive the majority of their income from geoducks, but they also often participate in other diving fisheries, particularly for sea urchins and sea cucumbers.

The fishery has been documented in detail by Cox (1979), Harbo and Peacock (1983) and Harbo et al. (1986) and generally evaluated by Jamieson (1986). The commercial fishery in British Columbia has landed approximately 24,000 t (60 million lb.) over the period 1976 to 1986 inclusive. Annual landings have increased significantly in the north coast since 1984. Landed values and value per tonne are given in Table 2. CPUE data from log-books shows a general trend of increased catches (Figs. 1 and 2).

LIFE HISTORY AND BIOLOGY

Geoducks are a long-lived species with low annual recruitment. Age structure, recruitment and growth patterns of various populations are described in Breen and Shields (1983), Harbo et al. (1983) and Goodwin and Shaul (1984). Few geoducks less than 12 years of age are taken in the fishery (Harbo et al. 1983). Mean geoduck age varies from 28 years at Tofino to 61 years at Spider Anchorage; the oldest individual found was 146 years old.

Geoducks mature at between 4 and 7 years of age and may be capable of reproducing for over a century (Anderson 1971; Goodwin 1976; Sloan and Robinson 1984). Since the size and age of geoducks harvested is well above the size of maturity, most individuals should have an opportunity to breed prior to reaching a harvestable age.

FISHERY MANAGEMENT

Quotas were introduced in 1979 after effort and landings had greatly increased. Licence limitation was implemented in 1981.

Breen (1982) recommended that quotas be kept within 0.75 to 2% of the virgin biomass in order to maintain a sustainable yield and a population 50% of the original biomass. Initial biomass estimates were derived from surveys (Cox and Charman 1979; Cox unpublished data) and expectations of similar stocks in other areas (Harbo et al. 1986). Statistical area quotas were increased in 1984 based on data on fishing areas obtained from log books. Currently quotas are based on the number and area (ha) of fishing grounds, density ($t \cdot ha^{-1}$) and other factors such as historical pattern of fishing and fishery development. Based on areas exploited to 1985 (16,254 ha), "commercial densities" ranging from 9 to 18 $t \cdot ha^{-1}$ and exploitation rates of 0.75 to 2%, regional annual quota options range from 1,097 to 5,851 t.
Landings in 1985 were 5,370 t.

Various management options for geoducks have been considered, such as a single coast-wide quota, exploratory fishing zones without quotas, and a staggering of openings to maintain a year round supply of product to service live markets (Harbo et al. 1986). Annual fishing plans are currently developed with consultation from the fishermen, the Underwater Harvesters Association, and processors. Sloan (1985) reviewed the history and problems of geoduck stock assessment and recommended some methods and estimated costs. Harbo et al. (1986) discussed geoduck abundance and distribution.

There are a number of small park and research area closures included in the conditions of the licence, and seasonal closures in some areas to protect herring spawn.

In 1984, 2 north coast vessels were licenced (P licence) to partially process geoducks. Due to the lack of processing facilities in the north this was increased to 5 P licences in 1986.

The annual regional fishing plan is complex with numerous area quotas and seasonal openings to maintain a year round fishery.

RECOMMENDATIONS

MANAGEMENT

1. Quotas for 1987 should not differ greatly from 1986 unless new fishing grounds are identified in late season fishing.

2. Industry should be requested to propose a south coast fishing plan to maintain a year round supply for live markets in 1987.

RESEARCH

1. To optomize exploitation, a major commitment is required to investigate survey techniques, establish population biomass and determinerecruitment rates. Much of this work should be done in cooperation with commercial diving fishermen. At least three relatively large (eg. 20 ha) study areas should be surveyed, "fished out", resurveyed and fished again if necessary, and then monitored for recruitment over the long term.

2. An assessment of post recruitment should be carried out on heavily harvested grounds identified by logbooks.

3. An assessment of grading procedures by processors is required. Industry grade standards may have to be set in the future.

4. An assessment of deep (> 20 m, the normal limit for diving) water populations is required to determine total stock size. The PISCES IV submersible or remote sensing units might be used to establish general biomass proportion by depth.

5. Hatchery techniques should be evaluated and trial seeding of juvenile geoducks should be considered. This is regarded as a low priority at this time in Canada since it is currently being studied in Washington.

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Table 1. Summary of geoduck landings tonnes by area from 1976 to 1985, as reported on sales slips.

	North coast										South coast: Mainland and east coast Vancouver Island										South coast: West coast Vancouver Island						Annual landings
Year	2E	2W	3X	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	23	24	25	26	27	(t)
1976														9.5			8.2		26								44
1977													14	9.2	77		137	1.7				6.0					245
1978													8.4	261	321	3.4	24	19	136	0.5	2.7	1.8	236	2.0			1016
1979												24	160	276	263	148	209	2.9	159			153	950	87	22	9.4	2463
1980	31			3.6					28	5.3			97	210	17	298	221	34	91	5.1		288	841	321	303		2794
1981	11				84	6.1	370	18		20			41	180	29	70	155	44	28	7.6		187	819	473	156	5.7	2704
1982							227					83	14	144	33	103	17	1.0	14	14		174	1218	366	726		3134
1983							202	299				16	29	340	29	42	13	2.0	9.8			84	1066	215	287	0.9	2636
1984	3.6		3.4		213.7	7.9	108.9	182.6	53.8		8.3	301.7	149.7	284.8	53.7	129.2	128.3	0.5	117.8			218.9	627.8	422.1	443.2	2.0	34.82
1985	341	213			291	59.6	494	37.2			13.2	490	81.4	180	42.4	29.8	137	4.1	77.7	0.4		227	730	599	272	1050	5370
1976 to 1985	387	213	3.4	3.6	589	73.6	1402	537	81.8	25.3	21.5	915	595	1895	865	823	1050	109	660	27.6	2.7	1340	6488	2505	2209	1068	23,888

North coast total = 3316

Mainland & east coast Vancouver Island = 6933 t

West coast Vancouver Island = 13,640 t

South coast totals = 20,573 t

Coastwide landings = 23,888

Table 2. Landings and landed values of geoduck clams, 1977 to 1985 as reported on sales slips.

Year	Total landings (lb.)	Total landings (tonnes)	Total value (10^{-3})	Mean price[1] ($·lb.$^{-1}$)	Mean price[1] ($·kg^{-1})	Price range[2] ($·lb.$^{-1}$)	Price range[2] ($·kg^{-1})
1976		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	2,462	1,669	0.31	0.68	0.13 - 0.40	0.29 - 0.88
1980	6,160,903	2,795	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	0.22 - 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	11,839,270	5,370	4,599	0.40	0.89	0.00 - 1.00	0.00 - 2.20

[1]Price paid to commercial fishermen.
[2]Price ranges taken from Market Reports/sales slips.

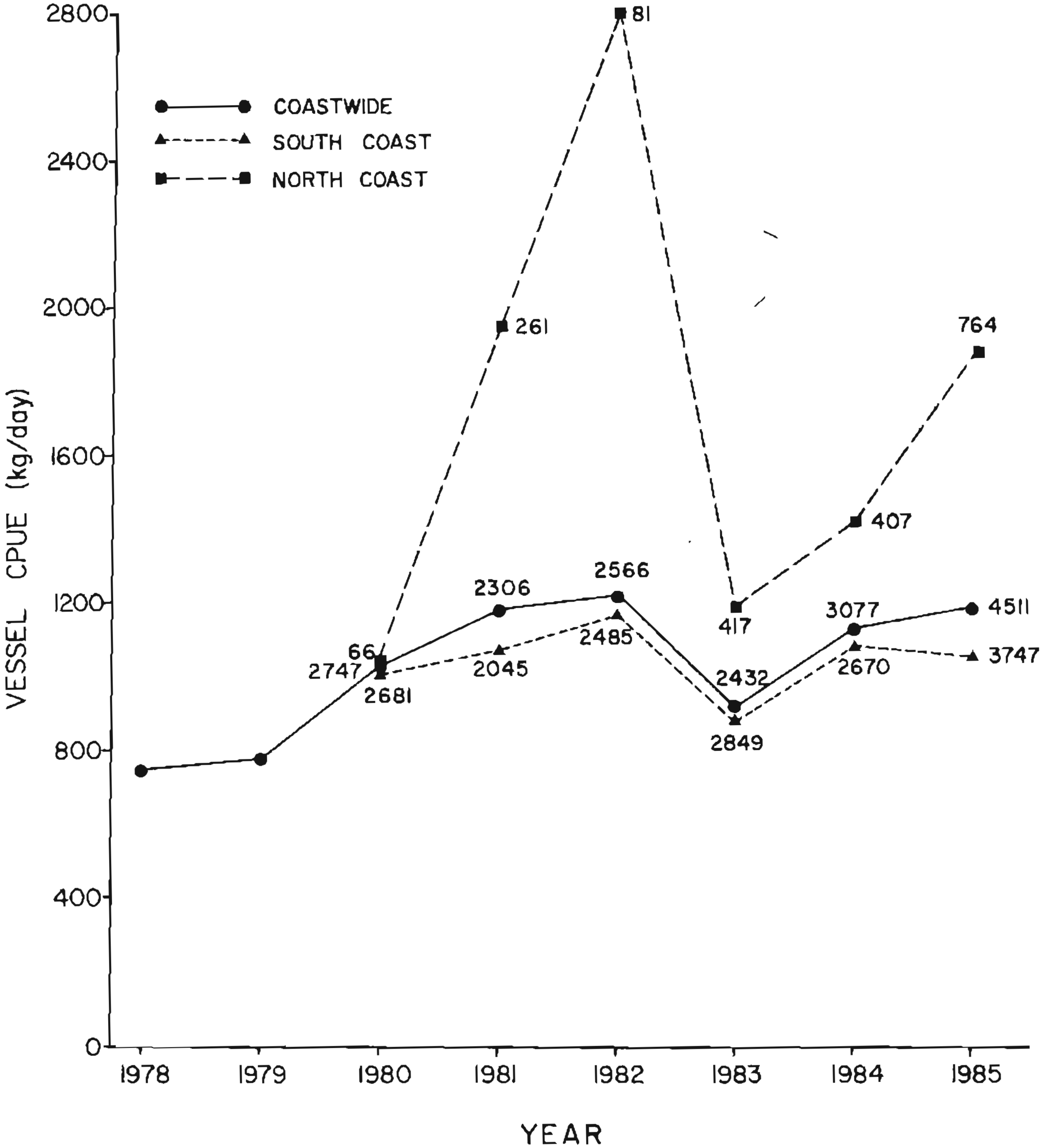

Fig. 1. Vessel catch-per-unit-effort (kg/day) as reported on sales slips, 1978-1985. Numbers refer to vessel days fished.

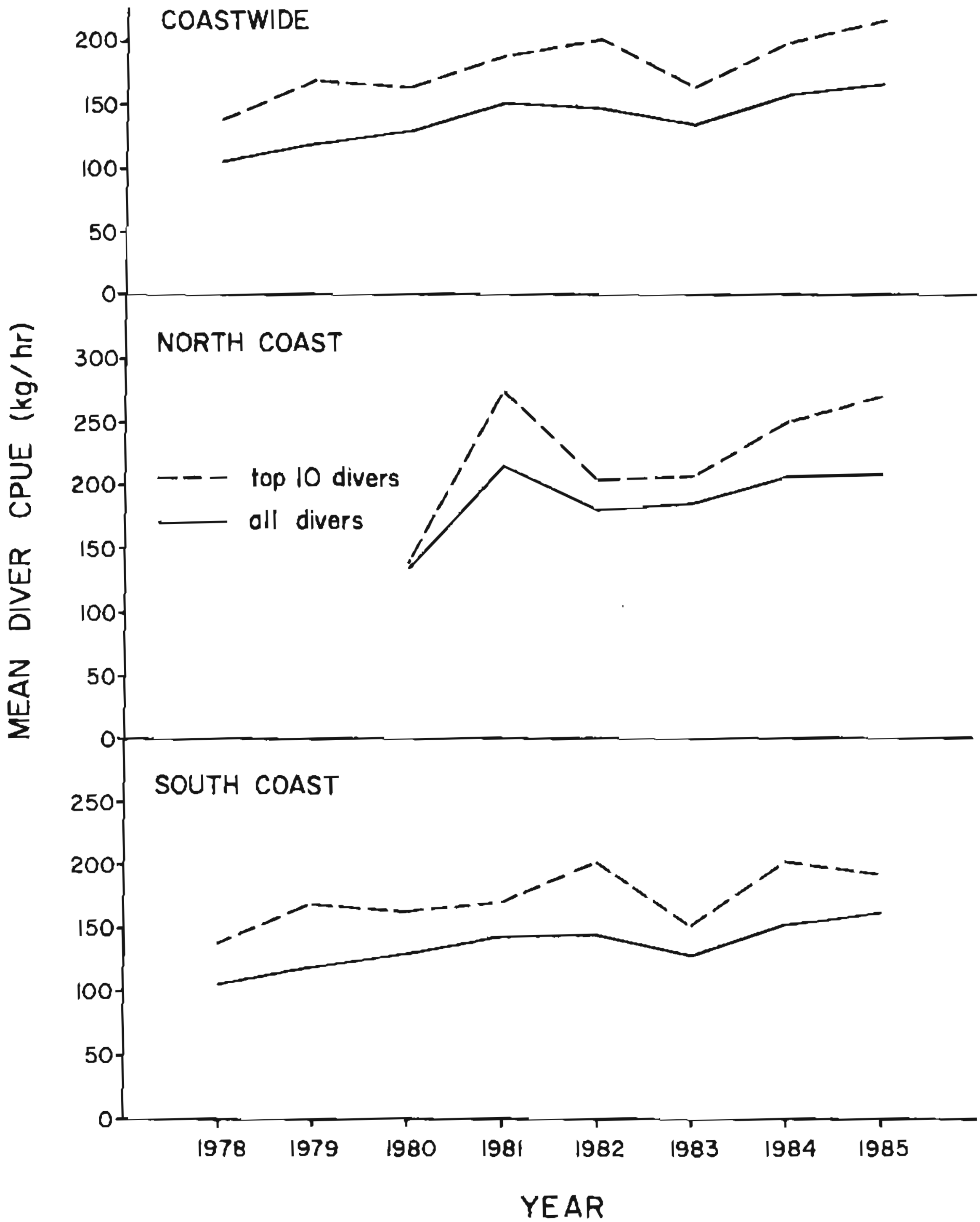

Fig. 2. Mean diver catch-per-unit-effort as reported on harvest logs, 1978-1985.

11. HORSE CLAMS

N. Bourne and R.M. Harbo

INTRODUCTION

Two species of horse clams, Tresus capax and T. nuttallii, occur commonly in British Columbia. Neither species has been used to any extent in commercial fisheries to date but they have harvest potential.

BIOLOGY

Horse clams are large clams that can attain a shell length of 200 mm The shells of both species are thick but quite brittle and the exterior surface is usually covered with periosticum. T. nuttallii has the umbones displaced well to the anterior end with an extended, upswept, posterior region that gapes widely. T. capax is similar in size but has nearly equilateral valves and the umbones located centrally. The two species may be found together intertidally but generally the habitat of the two species differ. T. nuttallii is usually found in sandy substrate while T. capax is found along with butter clams in gravel-shell-mud substrates. Both species occur from California to Alaska, T. nuttallii from 28° to 58°N and T. capax from 37° to 60°N (Quayle 1960; Bernard 1983). Both species bury deeply in the substrate to depths of 0.6 m and occur in the lower third of the intertidal beach to subtidal depths of 30 to 50 m. T. capax is more common intertidally in British Columbia (Bourne and Smith 1972b).

Sexes are separate in both species. T. capax spawns from late winter to early spring while T. nuttallii spawns in summer (Quayle and Bourne 1982; Bourne and Smith 1972b). Growth rates have been calculated for T. capax for several localities (Bourne and Smith 1972b).

In the Strait of Georgia they attain a shell length of about 100 mm in five years (Bourne and Smith 1972b). T. capax matures sexually at about 70 mm, ie. three to four years old in the Strait of Georgia (Bourne and Smith 1972b).

Studies have produced information on distribution, growth, recruitment, abundance, length-weight relationships, size of species harvested, catch per unit of effort and life cycles (Quayle and Bourne 1972; Bourne and Smith 1972a, 1972b). Like other species of clams, horse clams are susceptable to pollution and PSP (paralytic shellfish poisoning), but since the commercial fishery is small these factors are not of large concern at present.

FISHERY MANAGEMENT

There has never been a prolonged fishery for either species. There are problems processing both species, for although 25% to 30% of the total weight is edible meat, the siphon, which forms about 60% of the tissue weight, requires special attention. It has a skin that must be removed by blanching, and because the siphon is muscular, it is usually minced. Canneries occasionally mix horse clams with butter clams to whiten the product pack.

T. capax is dug occasionally with butter clams. Because fork digging usually breaks the shell, clams often lose internally contained water, allowing the meat to dry. Such clams are then of little market value. Occasionally *T. capax* was dug with small hydraulic harvesters (requiring a special license) and only the siphon used, the remainder of the clam being left on the beach. Landings of horse clams from the intertidal have not been specifically recorded in official statistics; they were probably included in the category "mixed clams".

More recently, small landings of *T. capax* and *T. nuttallii* have been made from subtidal populations by geoduck divers after geoduck quotas were met (Table 1). Harvest was limited in 1981 to fishermen who held a G licence (55 in 1985).

Since divers used geoduck harvesting gear, they were able to harvest horse clams without breaking the shells. These were taken to processors and sent live to markets, mostly in the Orient. Landings peaked at 321 t in 1982, but markets have not been consistent and landings have declined since then.

Preliminary information has been gathered on the fishery. Two commercial catches from divers, one from Comox Bar in the Strait of Georgia and the other from Stubbs Island on the west coast of Vancouver Island, were sampled in 1983 to determine age at length and weight (Tables 2 and 3). Ages of clams in the sample ranged from 8 to 17 yr for *T. capax* and from 4 to 15 yr for *T. nuttallii*. Average individual weight of *T. capax* (n=113) was 0.89 kg and of *T. nuttallii* (n=169) 0.75 kg.

Catch per unit effort ranges from 0.1 to 1.0 $t \cdot vessel\ day^{-1}$ (Table 1). One fisherman in 1982 had a CPUE of 96 $kg \cdot diver\ hr^{-1}$.

RECOMMENDATIONS

The fishery should be monitored, but otherwise it has low priority at this time. Extensive populations of horse clams exist in coastal water of British Columbia that could support a commercial fishery. Whether a fishery for either or both species attains its potential will depend on development of economically viable harvesting and processing methods and finding suitable markets for the product. At present this does not appear to be a high priority of industry and it is doubtful if horse clam landings will increase significantly in the immediate future.

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Table 1. Landings of horse clams (tonnes) landed value, the number of vessels and CPUE, 1979 to 1985.

Year	Landings (t)	Landed value ($ 10^{-3})	# of vessels	CPUE t·vessel day^{-1}	CPUE kg·diver hr^{-1}	CPUE kg·diver day^{-1}
1979	37	--	--	--	--	--
1980	128	79	28	0.6	--	--
1981	51	38	12	1.0	--	--
1982	321	235	40	0.5	96	225
1983	21	12	8	0.7	--	--
1984	6.7	5.5	5	0.2	--	--
1985	6.3	5.9	7	0.1	--	--

[1]CPUE - t·vessel day^{-1} based on sales slip reports.

[2]CPUE - kg·diver $hr.^{-1}$ and kg.diver day^{-1} based on harvest log data.

Table 2. Mean shell length (mm) at age for *Tresus capax* and *T. nuttallii* populations collected at Comox Bar and Stubbs Island, Tofino (1983).

	Comox Bar						Stubbs Island					
	T. capax			*T. nuttallii*			*T. capax*			*T. nuttallii*		
Age	N	$\overline{L}$	SD	N	$\overline{L}$	SD	N	$\overline{L}$	SD	N	$\overline{L}$	SD
4										2	148.5	3.5
5										3	150.6	12.6
6				3	155.0	17.1	1	147.0		4	157.7	10.0
7				4	158.0	12.1	1	144.0		8	158.6	5.7
8	4	139.0	5.3	6	157.5	9.5				12	164.0	11.9
9	10	151.3	7.0	13	154.7	11.8	1	169.0		22	162.6	9.5
10	11	153.6	8.9	19	155.9	10.7	2	141.0		15	165.0	5.8
11	13	151.3	9.2	11	155.5	13.6				13	171.9	10.3
12	22	154.7	6.4	12	158.8	9.6	1	157.0		4	167.5	14.5
13	18	163.9	10.3	7	169.6	13.9				3	157.6	10.1
14	13	157.4	11.0	2	157.0	5.6				1	153.0	
15	15	159.2	12.2	5	168.2	16.3						
16	4	156.4	14.7									
17	2	173.0										

$\overline{L}$ - mean shell length (mm)

N - number of samples

SD - standard deviation

Table 3. Summary of mean ages, lengths and whole weights (undrained) of horse clams collected at Comox Bar and Stubbs Island, Tofino (1983).

Site	Species	n	$\bar{X}$ Age (SD) (yr)		$\bar{X}$ Length (SD) (mm)		$\bar{X}$ Weight (SD) (g)	
Comox Bar	*T. capax*	113	12.4	(2.3)	156.2	(10.8)	892.3	(209.0)
(Area 14)	*T. nuttallii*	82	10.5	(2.2)	158.2	(12.2)	760.1	(194.0)
Stubbs Is.	*T. capax*	6	9.0	(2.2)	149.8	(11.3)	652.7	(117.9)
(Area 24)	*T. nuttallii*	87	9.1	(2.0)	163.2	(10.4)	752.9	(134.9)

$\bar{X}$ = mean

SD = standard deviation.

N = number of samples

12. RED SEA URCHINS

R. M. Harbo and N. A. Sloan

INTRODUCTION

The fishery for red sea urchins, Strongylocentrotus franciscanus, began in 1970 and has grown rapidly since 1979 to become the second most valuable diving fishery. The fishery has expanded into new areas and landings in 1985 were 1815 t for a landed value of $763,000 (Table 1). The fishery remained strong, with landings of 473 t over the January 1 to February 15, 1986 opening (compared to 359 t over the same period in 1985).

The red sea urchin, S. franciscanus, is a large, abundant sea urchin harvested in shallow waters to a depth of 15 m. The red sea urchin may be bright red to maroon to almost black in colour and grows a test diameter of 150 mm with long thin spines to 50 mm.

The smaller green and purple sea urchins are common but not as abundant as the red sea urchins. The purple sea urchin, S. purpuratus, rarely exceeds 100 mm and is typically bright purple (occasionally pale green/greenish tinged with purple). Its spines are less than 25 mm, long, thick and blunt. Purple urchins are found in areas of moderate to strong wave action, in exposed and open coast habitats. Green sea urchins, Strongylocentrotus droebachiensis grow to 90 mm test diameter, have pale, thin spines to 30 mm and long, dark tube feet. They are common but not as abundant as the red sea urchin.

Sloan (1986) reviewed the history, management and biology of sea urchin fisheries in the N.E. Pacific, Harbo and Hand (in press) discuss in detail recent sea urchin management practices in B.C., and Kato and Schroeter (1985) give a detailed account of the fisheries and biology of the red sea urchin in California.

BIOLOGY

Red sea urchins are estimated to be 4-5 yr old at the minimum legal size of 100 mm test diameter and 9-10 yr at maximum size of 150 mm. Settlement likely occurs annually in B.C. waters but varies greatly in magnitude between locations (Sloan et al., in press). Settlement density at specific sites has been as high as 50% of the adult population, but overall, observed recruitment rates in B.C. (Adkins et al. 1981; Sloan et al. in press) have been less than those reported for California (Kato and Schroeter 1985).

Spawning peaks between June and September, with broadcasting of sperm and eggs for external fertilization (Bernard 1977). Juveniles to 40 mm in diameter are found under the tests of adult urchins and live in the protection of the spine canopy (Tegner and Dayton 1977; Sloan et al. 1987). The ecology of sea urchins has been discussed by Breen (1980) and Sloan (1986).

FISHERY MANAGEMENT

Sea urchins are processed for their "roe" (gonads of both sexes) which represents 11 to 26% of total drained weight, according to season (Kramer and Nordin 1975). Processors report recoveries based on whole wet weight of 7 to 9%. Vessels require a Z licence; no vessels have yet attempted partial processing at sea under a P licence. Fishermen submit mandatory harvest logs detailing harvest sites, catch and effort.

The fishery in B.C. is currently limited to the south coast, and is managed by a minimum size limit (100 mm), a number of area specific quotas and a restricted season (October 15 to February 15).

The minimum size limit has been discussed by Breen (1982, 1984). Because higher prices are generally paid for smaller roe there is pressure from industry to lower or eliminate the size limit.

The implementation of quotas in 1981 was stimulated by surveys (Adkins et al. 1981) and studies (Breen et al. 1976; Breen and Adkins 1978) which indicated slow recovery of populations of sea urchins after intensive harvesting. Additional quotas or "catch ceilings" were implemented (without further surveys) by managers in 1985 and 1986 (Table 2) as the fishery grew rapidly and expanded into new areas (Harbo and Hand, in press).

Highest market demand is over the fall and winter period, and so the harvest season for the south coast was restricted in 1985 to the period October 15 to February 15 to ensure sufficient product was available during the period of highest product quality. Without seasonal restriction, quotas were filled early in the year, resulting in closures for the balance of the year. This practice of a restricted season to permit a late fall fishery is supported by the processors and harvesters.

The north coast has been open except for a regulatory closure, June 1 to August 30, but the high costs of transportation relative to current prices paid has limited expansion of the fishery there to date. The limited season restricts fishing time and consequently has limited expansion of the fishery into new areas. Annual landings have not been greatly reduced (Table 1), although in 1984, 467 t were landed over the period March to September (Harbo and Hand, in press).

Landed and export values (Table 1) have almost doubled over the period 1978 to 1986. The fishery was initially dominated by geoduck fishermen, but in recent years other fishermen have participated; in 1985, 21 of 46 vessels with urchin landings had geoduck (G) licences, accounting for 58% of the catch.

Average daily landing for vessels was 1.7t·per day^{-1} in 1985, an increase from previous years (Table 1). Diver catch per unit effort increased in 1985 with divers harvesting an average of 13 pieces·min^{-1} or approximately 360 kg·hr^{-1} (Table 1).

RECOMMENDATIONS

MANAGEMENT

No major changes from the 1986 fishing plan are recommended for 1987, even though area quotas and openings are many (Table 2). It is anticipated that the fishery will develop further on the west coast of Vancouver Island and into the north coast region. Additional area quotas might have to be introduced in-season depending on the fishing locations and intensity. The 100 mm size limit should be enforced and monitored closely.

RESEARCH CONCERNS

Analysis of harvest log data is needed to examine landings and catch per unit effort data in areas with several years of exploitation. Area 19 is of particular concern since little recruitment has been observed in this area since 1980 (Adkins et al. 1981; Harbo, unpub. data). Some fishermen have reported depleted stocks in Areas 14 and 19.

Before the question of lowering the size limit can be addressed, further work is required to determine the reproductive contribution of various size classes, particularly the largest urchins.

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Table 1. Red sea urchin landings and catch per unit effort, as calculated from sales slips and harvest log data - 1978 to 1985.

Year	Type and number of licences issued	Number of vessels[1] with landings	Fishing days[2]	Landings[3] (t)	X CUPE[1] (t· vessel day^{-1})	X CPUE (kg· diver hr^{-1})	Landed value ($10^{-3})	Landed value ($·t^{-1})	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[3]	Z 64	36	825	982	1.2[1.3]	311	348	354	15,850
1984[3]	Z 85	47	1,150	1,834	1.6[1.5]	281	740	403	19,530
1985[3]	Z 86	46	1,086	1,816	1.7[1.4]	360	762	419	N/A

[1]From sales slips and harvest logs.

[2]From sales slips; CPUE [] from harvest log data.

[3]1983, 1984 and 1985 landings and value higher than published previously because of inclusion of harvest log data.

1983 - 712t on sales slips, an additional 270t reported on harvest logs.
1984 - 1764t on sales slips, an additional 70t reported on harvest logs.
1985 - 1653t on sales slips, an additional 163 t reported on harvest logs.

N/A - Not available.

Table 2. Red Sea Urchin Management Plan: 1986 Opening and quotas.

Area	Open Period	Quota (lb./ t)
1) SOUTH COAST		
INSIDE WATERS - EAST COAST VANCOUVER ISLAND AND MAINLAND COAST (AREAS 11 TO 19)		
11	Jan 1 to Feb 15 and Oct 15 to Dec 31	Exploratory*
12	Jan 1 to Feb 15 Oct 15 to Dec 31	250,000 lb./ 113 t 250,000 lb./ 113 t
13A (West) portion of 13-3; subareas 13-2, 13-6 to 13-11 and 13-37 to 13-43 inclusive	Jan 1 to Feb 15	400,000 lb./ 181 t
13B (East) Subareas 13-1, 13-12 to 13-26 inclusive	Oct 15 to Dec 31	300,000 lb./ 136 t
14	Jan 1 to Feb 15 Oct 15 to Dec 31	150,000 lb./ 68 t 150,000 lb./ 68 t
15	Oct 15 to Dec 31 only	100,000 lb./ 45 t
16	Oct 15 to Dec 31 only	100,000 lb./ 45 t
17*	Dec 8 to Dec 31	50,000 lb./ 23 t
18*	Dec 8 to Dec 31	100,000 lb./ 45 t
19*	Dec 8 to Dec 31	150,000 lb./ 68 t
WEST COAST VANCOUVER ISLAND (AREAS 20-27)		
20	Oct 15 to Dec 31	75,000 lb./ 34 t
23 (includes Ucluelet) offshore 123-3 and 123-5	Oct 15 to Dec 31	150,000 lb./ 68 t
24 Subarea 24-8 and Offshore 124-3	Jan 1 to Feb 15	150,000 lb./ 68 t
subarea 24-6	Oct 15 to Dec 31	100,000 lb./ 45 t
subarea 24-2	when other subareas close	100,000 lb./ 45 t
25 offshore 125-1 and 25-7	Oct 15 to Dec 31	150,000 lb./ 68 t
25-6 and 25-15	when other subareas close	150,000 lb./ 68 t
125-3 and 25-13	when other subareas close	150,000 lb./ 68 t
26	Oct 15 to Dec 31	Exploratory*
27 inside (27-7 to 27-14)	Oct 15 to Dec 31	100,000 lb./ 45 t
27 outside (27-1 to 27-6)		Exploratory*
2) FRASER RIVER DIVISION (AREAS 28, 29)		
28, 29		Exploratory*
3) NORTH COAST (AREAS 1 -10)		
1 - 10		No quota set

*Exploratory - landings will be monitored. A quota may be set in-season or subareas may be closed.

13. SEA CUCUMBER

N. A. Sloan and R. M. Harbo

INTRODUCTION

Landings of California sea cucumbers (Parastichopus californicus) have been recorded since 1980 (Table 1), but although increasing, are erratic due to market conditions (Sloan 1986). The product is the five muscle bands on the inside of the body wall, which represents 12 to 15% of the landed weight. The body wall itself is currently being evaluated as a dried product. The history, management and biology of harvested Parastichopus in B.C. and the northeastern Pacific has been reviewed (Harbo and Hand in press; Sloan 1986, respectively).

BIOLOGY

The life history of this deposit-feeding species (Cameron and Fankboner 1984) has been partially described and is very season related (Cameron 1985). Between September to December virtually all sea cucumbers undergo resorption of their internal organs (Fankboner and Cameron 1985). Spawning occurs mostly from May to September (Cameron and Fankboner 1986). Aspects of the population dynamics of P. californicus such as recruitment, growth rates, longevity and mortality remain largely unknown.

FISHERY MANAGEMENT

In British Columbia, only divers can harvest sea cucumbers and most landings are recorded from the Strait of Georgia. There has been occasional interest expressed in trawling for sea cucumbers. Harbo and Hand (in press) review management in B.C., which allows the fishery to continue on a limited scale in the south coast while management options are being evaluated. Recently, only areas 13 to 20, and 24, have been open. Area 12 was opened in September, 1986. Also, there is a seasonal closure (June 1 to August 31) which is varied annually according to intensity of harvesting. In 1986, the north coast was opened in June, with a quota of 500 t set to restrict landings until stocks become better known. The Z licence (Table 1) requires submission of log book data on harvesting sites, catch and effort, and this is the main information source on the fishery.

Recent trends in the fishery have been towards a more dedicated fleet; in 1984, nine of twelve vessels landing sea cucumbers had geoduck licenses, but in 1985 only four of twenty-two were geoduck boats. The incidental catch of sea cucumbers with geoducks makes CPUE data difficult to interpret. CPUE data reflects actual fishing time only, and does not include time spent searching for harvestable populations. In 1986, some fishermen complained that it may take 2 to 3 days of test diving before commercial densities were found. Landings range from 318 to 372 kg·hour $diver^{-1}$ and 940 to 1620 kg·day $vessel^{-1}$ (Table 2). In 1984 and 1986, a vessel with a P-licence processed sea cucumbers at sea.

We feel that only a small proportion of the stock is being harvested. Monitoring by DFO divers indicated that many sea cucumbers are left behind, and only dense populations are currently being exploited (B. Adkins, pers. comm.). In addition, population distribution extends below safe diving depths.

This fishery is expected to continue growing as more of the coast is opened. Because of low product recovery rate, low price (about $0.15 per piece) and unstable markets, it is unlikely, however, that this will become a major invertebrate fishery for some time.

RECOMMENDATIONS

MANAGEMENT

Initial restrictions were based on concerns about alleged low recruitment, slow growth and low natural mortality, all of which would render a population particularly vulnerable to overfishing. Although recruitment may be low, it has been observed annually on bivalve culture strings suspended from rafts. Moreover, immigration from areas too deep to dive (> 19 m) likely occurs as well.

1) South Coast (Areas 11 to 27) - all areas should be opened to increase incidental landings by geoduck vessels and to permit expansion of a directed fishery. Catch and effort should be continuously monitored through log books and specific area quotas should be implemented if harvesting is perceived as too intensive. Quota size will be arbitarily determined until sufficient data can be obtained for a comprehensive stock assessment. The analysis of log book data over the next few years may reveal the appropriate harvest levels for specific areas. The June 1 to August 31 regulatory closure should continue to be reviewed, and perhaps invoked, in season.

2) North Coast (Areas 1 to 10) - the 500 t quota should continue for 1987.

3) Fraser River (Areas 28 and 29) - leave open and monitor fishing actively through log book returns. A research area closure in Indian Arm should remain in effect.

RESEARCH CONCERNS

If the fishery continues to expand, the alleged low recruitment of this species should be investigated in detail. Prime concerns should be the location of nursery areas and the growth rates of juveniles, i.e. period prior to recruitment to the fishery.

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Table 1. Sea cucumber fisheries statistics. Data from Statistics Division, Fisheries Branch and Harbo and Hand (in press).

Year	Landings (t)	Landed value ($ 10^{-3})	Price ($\$ \cdot ^{-1}$)	Licences		No. of vessels reporting landings
				No.	Type	
1980	20	5.5	277	ND	C	9
1981	27	7.4	277	ND	C	11
1982	5	ND	ND	ND	SP	ND
1983	527	114	216	43	Z	19
1984	113	26	230	29	Z	12
1985	346	90	265	40	Z	21

ND = no data.

SP = scientific permit

* Landings are usually reported as pieces and later converted by 0.635 kg (1.4 lb.) per piece (whole, wet, not drained).

Table 2. Sea cucumber catch per unit effort as calculated from sales slip and harvest log data - 1980 to 1985 (Harbo and Hand, in press).

	Total harvest					Directed effort for sea cucumbers*		
Year	No. of vessels	Fishing days	Vessel CPUE ($kg \cdot day^{-1}$)	Diver CPUE ($kg \cdot hr^{-1}$)	Avg day length (hr)	No. of vessels	Fishing days	Vessel CPUE ($kg \cdot hr^{-1}$)
1980	9	59	356	ND	ND	ND	ND	ND
1981	11	ND	ND	ND	ND	ND	ND	ND
1982	ND	ND	ND	ND	ND	ND	ND	ND
1983	19	356	1,480	372	3.4	19	316	1,621
1984	12	249	455	318	3.6	9	114	941
1985	21	271	1,275	342	2.9	N/A	N/A	N/A

ND = no data.

N/A = data not available.

* = This excludes landings of sea cucumbers incidental to geoduck fishing, as determined from log book data.

14. SCALLOPS

N. Bourne

INTRODUCTION

Thirteen species of scallops have been found in British Columbia waters (Bernard 1983) but only four are large or occur in sufficient abundance to elicit enquiries about possible commercial fisheries. Present commercial fisheries are small.

BIOLOGY

The four scallop species with some commercial potential are: weathervane, Patinopecten caurinus; rock, Crassodoma gigantea (=Hinnites giganteus); pink, Chalmys rubida and spiny, C. hastata.

WEATHERVANE SCALLOPS

Weathervane scallops are large and can attain a shell height of 23 cm. The upper left valve is reddish to yellow-brown in color with prominent ridges radiating from the umbone to the ventral margin. The lower valve is white to light brown with similar ridges. Distribution is from California to Alaska, latitude 36-59°N (Quayle 1960; Bernard 1983). In British Columbia distribution is discontinuous; a small population occurs in the Gulf Islands area and another in Dixon Entrance (Bourne 1969). Scattered individuals are found in other areas along the coast in depths from 20 to 200 m, mostly on sand or mud bottom.

Sexes are separate, the male gonad is white and the female red in color. In the Gulf Islands area of the Strait of Georgia, spawning occurs from mid-April to mid-June. Growth is fairly rapid and animals 12 cm in diameter are about four years old.

ROCK SCALLOPS

Rock scallops are large and massive and can attain a shell height of 25 cm. The valves are quite irregular in shape, the outer surface is sculptured with strong radiating ribs and brown-green-grey in color. Frequently the valves are pitted with holes of boring animals (often a sponge) and encrusted with animal and plant growth. In the early stages rock scallops are free swimming like other scallops but when about 25-35 mm shell height they attach to a rock and remain there for life. Distribution is from California to the Aleutian Islands, latitude 25-60°N (Quayle 1960a; Bernard 1983). Rock scallops occur throughout British Columbia but are not particularly abundant in any one place. They are found mostly on rocky shores and are essentially subtidal, occurring at the lowest intertidal level to depths of 80 m.

Sexes are separate. In southern British Columbia, spawning probably occurs in June-September. Initial growth is fairly rapid and they can attain a shell height of 10 cm in three years. Growth slows after they attach themselves to rocks and the shells become massive. Large individuals have been aged at 27 years.

PINK AND SPINY SCALLOPS

Pink and spiny scallops are small and rarely attain a shell height larger than 80 mm. The color of the upper valve can be quite variable, from white through yellow to brown and red, often with bands of white in the color. The bottom valve is usually white with some pale color. Frequently the upper valve is encrusted with sponge. Pink scallops have numerous fine ridges radiating from the umbone to the ventral margin of the shell. Spiny scallops have several prominent and numerous small ridges radiating from the umbone to the ventral margin which are studded with short spines. Distribution of spiny scallops is from 33 to 66°N latitude and of pinks from 33 to 58°N (Bernard 1983). Both species occur throughout British Columbia although distribution is discontinuous. They can occur in small dense beds. Spiny scallops are usually found on firmer bottom, gravel or rock, in areas of strong current. Pink scallops tend to occur in areas of softer bottom. Pink scallops occur in somewhat deeper water than spiny scallops, 5 to 200 m compared to 5 to 150 m (Bernard 1983).

Sexes are separate in both species. Pink scallops probably spawn in winter, January to March, while spiny scallops probably spawn in late summer and early fall. Growth is slow and animals of 75 mm shell height are about four years old.

FISHERY MANAGEMENT

Commercial fisheries exist or have existed for all four species. Commercial scallop fishermen must have a personal fishing licence and the boat a Z licence.

WEATHERVANE SCALLOPS

Harvest of weathervane scallops is regulated by a size limit (120 mm shell height) and by total width of the drag used (maximum of 2 m).

Attempts to harvest weathervane scallops commercially in the Gulf Islands and Dixon Entrance areas have failed because populations were too small. In most instances catches were insufficient to pay for trip expenses. In 1984, 1.4 t was landed with drags in the north coast (Farlinger and Bates 1985). There is a small fishery for this species in Alaska and a brief fishery existed off Oregon in 1981 and 1982.

ROCK SCALLOPS

Attempts have been made to harvest rock scallops commercially but these failed because populations are scattered and sparse. No commercial fishing is permitted for rock scallops and harvest in the recreational fishery is regulated by daily bag limits. This species is firmly cemented to rocks and must be harvested by divers who chisel them off. Even with the high prices paid for scallops, it was not economic to do this.

PINK AND SPINY SCALLOPS

A commercial fishery for pink and spiny scallops began in southern British Columbia in 1982. Commercial harvest of pink and spiny scallops is regulated by a size limit (a minimum of 60 mm shell height implemented in 1985) and by total width of drag that can be used (a maximum of 2 m). To date the fishery has been mostly for spiny scallops and annual reported landings have been under 55 t whole weight. In most North American scallop fisheries only the large adductor muscle is used but in this fishery the entire animal is marketed. Spiny scallops are mostly harvested by divers, while pink scallops are mostly harvested with drags. To date the fishery has been confined to the south coast.

RESEARCH PROGRAMS

WEATHERVANE SCALLOPS

Information on population size and structure, growth rate, recruitment rate, distribution, time of spawning, length-weight relationships and life history is available for weatnervane scallops. Extensive surveys were undertaken along the coast in the early 1960s to determine if populations existed that could support a commercial fishery, but results were disappointing (Quayle 1960, 1961). Attempts to collect natural spat of weathervane scallops for aquaculture purposes have been unsuccessful.

ROCK SCALLOPS, PINK AND SPINY SCALLOPS

Research on rock, pink, and spiny scallops has been relatively less, focusing on growth, time of spawning, length-weight relationships and larval development.

Scallop Culture

There is considerable interest in scallop culture in British Columbia due partly to strong markets and high prices for scallops and partly to the success the Japanese have achieved (Ventilla 1982). Extensive research is currently underway to study the feasibility of scallop culture in British Columbia. Research has focused on producing large numbers of juvenile scallops that can be used in grow-out work. Pink and spiny scallop spat can be collected naturally but these two species are probably too small and slow-growing for economic culture. Natural sets of rock scallop spat are occasionally caught on oyster rafts. Whether sufficient natural sets of rock scallops can be obtained consistently for large scale culture is unknown.

Culture studies are on-going, investigating the potential of the four native species and two exotics, Japanese scallops, *Patinopecten yessoensis*, and sea scallops, *Placopecten magellanicus* (Thompson et al. 1985). Most research is presently on the Japanese scallop and the native rock scallop.

Although scallops are subtidal they can be affected by pollution and PSP (paralytic shellfish poisoning). The adductor muscle is not affected by either pollution or PSP, except in rock scallops where PSP has been reported in the muscle of some California specimens. Since both pink and spiny scallops are marketed and consumed whole, they are affected by both pollution and PSP. Subareas of Area 19 have been closed to harvest because of pollution. Scallops become toxic by ingesting either *Protogonyaulax* (= *Gonyaulax*) sp. or its spores and when this occurs, local fishing is closed.

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15. SIZE LIMITS FOR PINK AND SPINY SCALLOPS

N. Bourne and R. Harbo

INTRODUCTION

Two small species of scallops are commercially landed in British Columbia: pink, Chlamys rubida, and spiny, C. hastata. Both species rarely attain a shell height over 80 mm and occur in small beds scattered along the coast of British Columbia. Distribution and size of beds, and size and structure of populations on them are not known. Spiny scallops, which comprise most of the catch, are found most frequently on firm bottom, rock or gravel, at depths to 150 m. Pink scallops occur more frequently on softer bottom sand and mud, at depths to 200 m (Bernard 1983).

With scallops, the large adductor muscle (meat) or the adductor muscle attached to the gonad, is eaten. Pink and spiny scallops are marketed whole in the shell, fresh or frozen. Processing is simple, involving only removal of fouling organisms that adhere to the shells.

FISHERY MANAGEMENT

A commercial fishery began in 1982, but landings have remained low, reaching 53.2 t in 1985 with a landed value of about $175,000 (Table 1). Logbook data and other information from fishermen indicates landings were higher than shown in official statistics since some landings went unreported. The fishery is located in the southern part of the Province: Juan de Fuca Strait, the Gulf Islands, and Baynes Sound.

Fishing is by two methods, towing small home made drags (less than 2 m wide) from small boats or by diving. At present, most of the catch is taken by divers. In 1985, twelve boats reported landings but only one used a drag on a part-time basis. Most of the catch in the diving fishery is spiny scallops since these scallops generally occur at shallow depths on rocky reefs. Pink scallops are caught most frequently in the drag fishery off Victoria.

REGULATIONS

When the fishery began in 1982, there was only limited information on growth, life cycle, length-weight relationships and distribution of either pink or spiny scallops. There was no information on size of beds, population size, and structure or recruitment rate.

Management by sustained yield is desirable but it isn't feasible to establish total biomass on even a portion of the beds that are scattered widely along the coast. Regulation by size limits is a practical alternative. The fishery is small and probably will remain so. Resources to investigate the biology of either species and undertake surveillance of the fishery are limited. There may be significant differences in parameters such as growth, mortality, and recruitment, even between populations on beds that are in close proximity.

A restriction was placed on size of drags that could be used; drags cannot measure more than 2 m in width.

Rationale for a scallop size limit was the same as that used to establish size limits in intertidal clams, i.e. to permit animals to spawn at least once before they attained the legal harvestable size. Based on limited data available, it was recommended that the minimum size be 60 mm shell height for both species (Bourne 1984).

RE-EXAMINATION OF THE SIZE LIMIT

There have been complaints by fishermen and processors that the current minimum size limit, 60 mm shell height, is too large and much of the catch has to be returned to the water. It is causing economic difficulties and industry would like the size limit reduced to 55 mm shell height. Industry has stated current markets will not accept scallops smaller than this size, but markets can change.

Results of samples taken from catches from two tows, Brotchie Ledge off Victoria, in 1982, are shown in Table 2. (This area has since been closed because of sewage pollution). Size frequency distribution of pink and spiny scallops in the tows shows 65% of the catch was greater than 50 mm shell height, 40% was greater than 55 mm, but only 20% was greater than 60 mm shell height. In 1982, there was no size limit and drag fishermen were landing over 200 kg per day.

Limited biological sampling suggests that while spiny scallops are often over 60 mm shell height, with some animals attaining shell heights of 80 mm, few pink scallops in any populations are over 60 mm and only rarely do pink scallops exceed 70 mm shell height. It suggests a separate size regulation for each species.

ADDITIONAL SAMPLING

Further sampling has been done that could influence a decision on the size limit for pink and spiny scallops. Monthly samples of spiny scallops were obtained from a single location in Barkley Sound in 1985/86, to measure changes in gonadal index (ratio of weight of gonad to weight of total soft parts) to accurately determine time of spawning. Samples included a wide range of sizes to enable determination of size at sexual maturity. No work was done on pink scallops because consistent samples could not be obtained. A source of supply has been found in 1986 and monthly samples are being collected.

A limited survey was undertaken from June to August 1986 to determine the size frequency distribution of pink and spiny scallops landed in commercial catches. Eight samples of pink and spiny scallops that were landed by divers were measured at processing plants in Vancouver and on Vancouver Island. Approximately 200 scallops were sampled from each catch by randomly taking individual scallops from a sack or plastic bucket. Samples were sorted by species and shell heights measured to the nearest mm with calipers.

RESULTS AND DISCUSSION

COMMERCIAL CATCH SAMPLING

Results of sampling commercial catches from the dive fishery in 1986 showed that 88 to 100% were spiny scallops (Table 3). Most spiny scallops were greater than 60 mm in height, with about 10% between 55-60 mm in height. Two samples had 30 to 40% in this latter size range, and one sample had 39% less than 55 mm. Numbers of pink scallops in samples were limited, but while most of the catch was between 55 and 60 mm shell height and few exceeded 60 mm.

With the landed catches of both scallops combined (i.e. not sorted by species), undersize scallops at the 60 mm limit ranged from 9 to 19% in six samples and in two samples were 37.5 and 72% undersize. The mean for unsorted landings was 24.6% (2.16 SD). At a limit of 55 mm, in seven of the eight samples, they were less than 10% undersize; one sample had 36% undersize. The mean for unsorted landings 55 mm was 8.2% (11.5 SD).

The sampling of commercial catches suggests that if the size limit of 60 mm is maintained, fishermen should sort out the pink scallops and a separate size limit for pinks should be considered. If the limit could be reduced to 55 mm, it could apply to both species without significant landings of undersize scallops.

BIOLOGICAL STUDIES

Spiny scallops from Barkley Sound were sexually mature at a shell height of 25 to 30 mm and all spiny scallops over 35 mm had mature gonads (unpub. data). Results to date indicate pink scallops mature at a similar size.

Preliminary investigation of gonadal index indicates that spiny scallops spawn in late summer and early fall but pink scallops spawn in mid to late winter. Unlike some species of scallops, e.g. weathervane scallops, gonads of pink and spiny scallops do not appear to completely empty, sexes can be identified by gonadal color throughout the year, males with white gonads and females with red gonads. Rather than massive spawning, spawning may extend over a period of 8-10 weeks.

Growth rates have been calculated for both pink and spiny scallops. These growth rates were determined by measuring the straight line distance from the hinge to the ventral margin of annual rings with calipers to the nearest mm. Specimens were sent to Dr. A. V. Silina of the Laboratory of Paleoecology, Institute of Marine Biology, Academy of Sciences of the USSR in Vladivostock for verification of the location of annual rings. Animals used were collected randomly from commercial samples and the exact lcoation and depth from which they were taken is not known. Further growth studies are required to determine if there is variation in growth between animals collected at different depths and geographic locations.

Pink scallops spawn in late winter at approximately the same time as the annual growth ring is laid down on the shell. Hence when the first ring is laid down pink scallops are about one year old, two years old when the second ring is deposited, three years old when the third ring is deposited and so on. . Spiny scallops spawn in late summer or early fall and when the first ring is depositing in January-February they are about one half year old. They are about 1.5 years old when the second ring is deposited, 2.5 years old at the third ring, and so on.

Growth rates of pink and spiny scallops are shown in Fig. 1, the lines have been fitted by eye. The growth curve for spiny scallops was adjusted by assuming the mid distance between the first and second rings corresponded to an age of one year, mid distance between the second and third years was two years, and so on as discussed above.

Assuming growth rates shown in Fig. 1 are generally applicable to pink and spiny scallops throughout southern British Columbia waters, then growth to age three is similar. After the third year growth of pink scallops slows significantly and at 60 mm they are about five year old. Growth of spiny scallops does not slow as much after three years and at age five they are about 73 mm shell height.

Both pink and spiny scallops would mature sexually when they are about two years old a shell height of 25 to 30 mm for spiny scallops, and 35 mm for pink scallops. At a shell height of 60 mm, the current minimum legal size, pink scallops could have spawned four times and spiny scallops twice. At a shell height of 55 mm, pink scallops would be about four years old and could have spawned three times, while spiny scallops would be about three years old and could have spawned twice.

Studies on pink and spiny scallops are continuing.

CONCLUSIONS

Sampling of commercial dive catches shows that most scallop landings (88-100%) are of spiny scallops. A reduction of the size limit from 60 mm shell height to 55 mm could result in a significant increase in landings and a decrease in enforcement problems of undersize scallops.

A reduction of the size limit in the pink and spiny scallop fishery from 60 to 55 mm shell height would still permit spiny scallops to spawn twice and pink scallops to spawn three times before they attained a harvestable size.

It may be necessary to consider separate size regulations for pink and spiny scallops.

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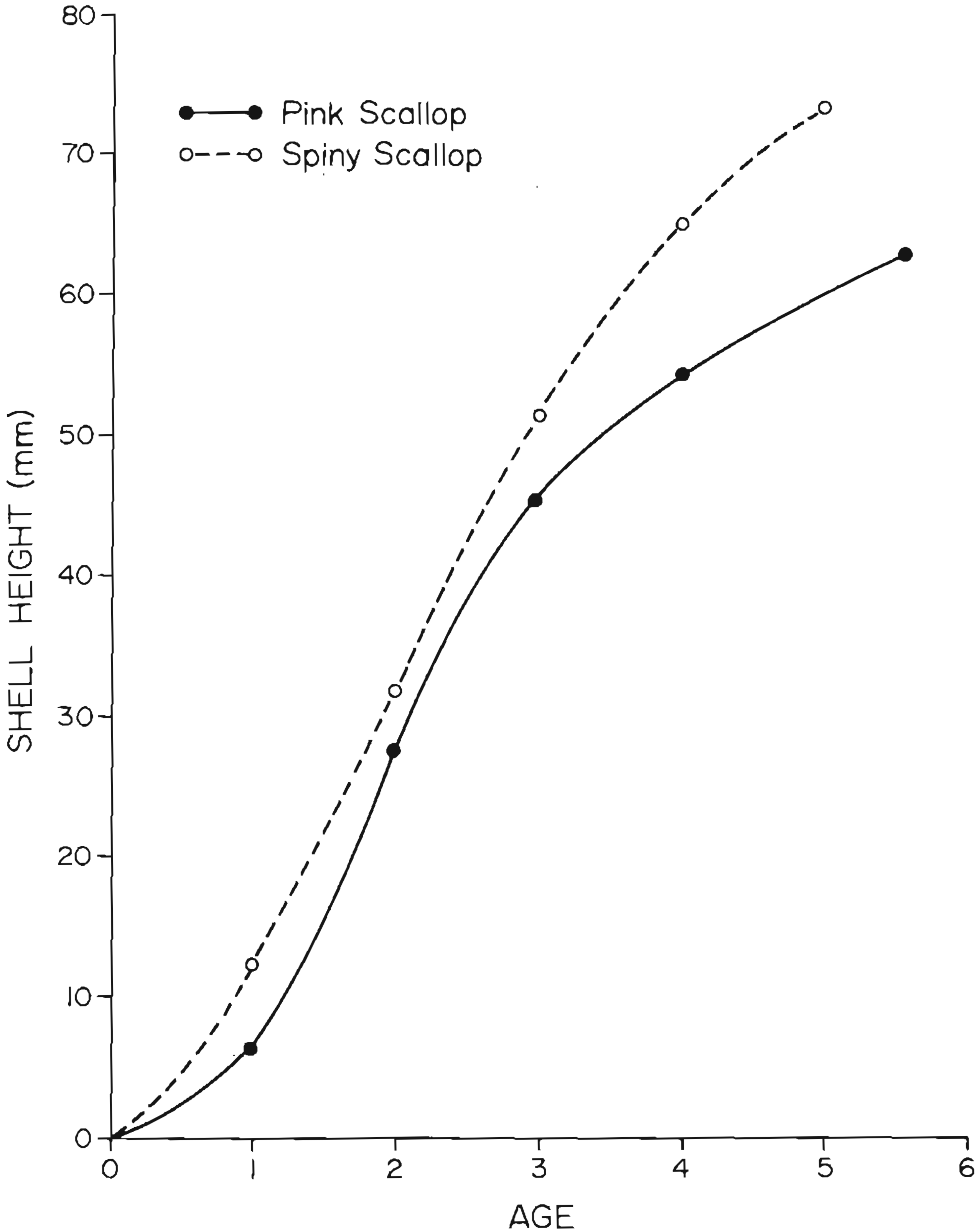

Fig. 1. Growth rate of pink and spiny scallops collected from British Columbia.

Table 1. Landings (tonnes whole weight) and value of pink and spiny scallops in British Columbia commercial fishery, 1982 to 1985 (as reported on sales slips and harvest logs)

Year	Number of vessels	Landings (tonnes)	Landed value ($\$10^{-3}$)
1982	8	8.3	$19
1983	6	11.0	$24
1984	13	16.4	$74
1985	13	53.2	$175 (est.)

Table 2. Catch samples of pink and spiny scallops* from a commercial drag, Area 19, May, 1984. Percent marketable (by number) at sizes greater than 50, 55 and 60 mm.

Tow No.	Duration (min)	Depth (m)	Whole weight if scallops (kg)	Percent Shell height (mm)		
				50	$\geq$ 55	$\geq$ 60
1	10	29	7.23	65.0	40	20
2	13	29	11.08	65.4	40.4	20.4

*The catch was not sorted by species.

Table 3. Summary of data from market samples of pink and spiny scallops harvested by divers (Vict = Victoria; Van = Vancouver).

	Date sampled DA-MO-YR (location)	Harvest location area	Number	Sample composition % of scallops		Percentage Undersize					
						$n \leq 60$			$n \leq 55$		
				Pink	Spiny	Total	Pink	Spiny	Total	Pink	Spiny
#1	05-06-86 (Van)	29	230	12	88	17	89	7	5	32	1
#2	18-06-85 (Vict)	17	160	6	94	12	90	7	2	30	1
#3	18-06-86 (Vict)	17	143	2	98	14		12	6	67	4
#4	19-06-86 (Vict)	14	200	0	100	26	-	26	9		9
#5	09-07-86 (Union Bay)	17	200	0	100	9	-	9	2		2
#6	09-07-86 (Van)	N/A	130	0	100	19	-	19	1		1
#7	14-08-86 (Van)	14	200	0	100	37.5	-	37.5	4.5		4.5
#8	28-08-86 (Van)	18	144	9.7	90.3	72	100	69	36	4.4	30
						$\overline{X}$ = 24.6 (21.6 SD)			$\overline{X}$ = 8.2 (11.5 SD)		

N/A = data not available. $\overline{X}$ = mean SD = standard deviation.

*Total Undersize = % total number of both species combined <60mm; <55mm.

Pink Undersize = % number pink scallops <60mm; <55mm.

Spiny Undersize = % number spiny scallops <60mm; <55mm.

16. A REVIEW OF MANAGEMENT OPTIONS AND THE RATIONALE FOR SIZE LIMITS IN BRITISH COLUMBIA'S COMMERCIAL FISHERIES FOR INTERTIDAL CLAMS

N. Bourne

INTRODUCTION

Intertidal clam resources are an integral part of the economy of many coastal communities and it is essential that they be managed properly and effectively. They have always been important to native people along the coast and before the turn of the century a commercial fishery began that has continued to the present (Quayle and Bourne 1972; Bourne 1986). Landings from the commercial fishery have fluctuated widely over the years from a low of about 450 t to a peak of 3,500 t (Quayle and Bourne 1972) (Fig. 1, Introduction). The resource is also important and widely used in the recreational fishery.

Over 400 species of bivalves have been recorded from British Columbia waters (Bernard 1983) but only a few are used in either the commercial or recreational fisheries. The species of intertidal clams considered here comprise the major part of the commercial harvest: butter, *Saxidomus giganteus*; littleneck, *Protothaca staminea*; manila, *Tapes philippinarum*; and razor, *Siliqua patula*.

REVIEW OF CLAM REGULATIONS

COMMERCIAL FISHERIES

There have been several management methods, used singly or in combination to control the commercial harvest of intertidal clams. They include size limits, seasonal restrictions, export restrictions, quotas, gear restrictions (mechancial harvesters), pollution and PSP (paralytic shellfish poison) closures, and area or beach closures.

Size Limits

The method most commonly used to manage intertidal clam populations in British Columbia is a size limit. These limits were introduced in the province in the early 1930s (Quayle and Bourne 1972) after biological investigations by early shellfish scientists (Fraser 1930; Fraser and Smith 1928a; and 1928b; Smith 1933; Weymouth and McMillan 1931).

Initial size limits established in the 1930s were 1.5 in. (38 mm) shell length for butter and littleneck clams and 3 in. (90 mm) for razor clams. Manila clams were not established in British Columbia at that time. In 1938 the size limit for butter clams was raised from 1.5 to 2 in. (38 to 63 mm) shell length (Quayle and Bourne 1972). Fishing for manila clams began in the early 1940s and the same size limit applied to littlenecks was applied to them. These size limits were applied to both commercial and recreational fisheries and have remained in effect in the commercial fishery until the present time, but were rescinded in the recreational fishery in 1971 and 1972 because many people were having difficulties in correctly identifying the species.

Seasonal Restrictions

Although there were some biological rationale for seasonal restrictions, the major reasons were economic factors. The seasonal closures in regulation have changed numerous times, but have been relatively consistent by Fisheries Public Notice. A Fishery Officer can vary any close time in regulation by posting a Fisheries Public Notice.

In the 1960's, clams (butter, littleneck, manila) and mussels were closed in regulation October 1 to October 31, then June 1 to October 31 and finally May 1 to October 31. Razor clams were closed initially July 1 to October 31, but the season was later adjusted to the period June 15 to August 31, corresponding to the spawning period.

The main species affected when seasonal restrictions were in place was butter clams, which were canned. During late spring and summer, companies were busy with the salmon fishery and had no time to handle or process clams. During spring and summer, clams feed heavily on phytoplankton and the gut and digestive gland become filled with green pigment (green feed). During the canning process the gut walls burst and when the can is opened, the product is of unacceptable quality. The seasonal limit also suited management staff since fishery officers were busy with the salmon fishery.

Seasonal restrictions on harvesting butter, littleneck and manila clams were eliminated in 1966 and 1967 for the Strait of Georgia (but have persisted for razor clams in the north coast). This permitted the industry to make use of daylight tides. Markets for steamer clams, being developed in the United States, which required a year around supply and this could only be accomplished by rescinding seasonal regulations. The industry itself continued to impose seasonal restrictions on butter clams destined for canning. However, some butter clams are still harvested throughout the year since some processors freeze the shucked meats to avoid the seasonal quality problem of "green feed".

Due to the considered high risk, PSP seasonal closures remained in effect on the west coast of Vancouver Island and there is a total closure for the north coast.

In 1978, a close time of 2300 to 2400 hours was entered into the Pacific Shellfish Regulations (Section 13(6)). This gave a closed time that could be varied by a Fishery Officer posting a Fisheries Public Notice. In 1983, the Pacific Shellfish Regulations were amended, and a schedule of close times (Schedule IV) was introduced. Under this schedule, harvesting of all clams was closed January 1 to December 31, in all subareas, and by all gear types. This schedule is currently in effect, so that any clam fishery requires a Fishery Officer to vary this closure, to open for a specified time, area and gear type.

Export Restrictions

Restrictions exist on the export of live clams to insure as much Canadian processing as possible. Live butter clams had to be exported in wooden boxes, with not more than 80 lb. (36 kg) of clams per box. This restriction also applied to export of littleneck and manilas but was changed to permit export of both littlenecks and manilas in sacks, with no more then 100 lb. (45 kg) per sack. Current regulations state that not more than 40 kg of clams other than littleneck and manila, and not more than 45 kg of littlenecks and manilas, can be shipped in containers, and that containers must be clean and undamaged (Pacific Shellfish Regulations).

Quotas

Management by quotas has been attempted in a few areas. Experimental digging of butter clams was undertaken at Seal Island (northern tip of Denman Island in the Strait of Georgia) beginning in 1939 to attempt to achieve maximum production from a particularly strong year class (Quayle and Bourne 1972). Annual quotas were established for various sections of the beach but the project was terminated in the late 1960s due to the problems of monitoring landings.

Conflicts between commercial and recreational harvesters led to annual quotas in 1978 for steamer clams on Savary Island in the northern part of the Strait of Georgia (Bourne and Adkins 1985). Quotas were for allocating the resource between two competing groups rather than for biological purposes.

Gear Restrictions - Mechanical Harvester

There are currently restrictions on methods of harvest, with only hand digging permitted. Application for a Z licence must be made to use any type of mechanical harvester. Attempts have been made to harvest intertidal clams with mechanical harvesters but they have either been unsuccessful or have caused extensive damage to beaches (Adkins et al. 1983).

Biological Factors - PSP and Pollution

Commercial harvest is restricted because of PSP (paralytic shellfish poisoning) and pollution. Outbreaks of PSP were sporadic until 1963 when a serious outbreak closed the north coast and much of the west coast of

Vancouver Island, and these areas have remained closed until the present. Digging steamer clams is permitted under a monitoring program by Fish Inspection, DFO and considerable quantities of these two species currently come from the west coast of Vancouver Island. Methods were developed to process mildly toxic butter clams but this adds to cost and has not been generally accepted. Many areas, particularly in the Strait of Georgia, have been closed because of pollution. Although clams from these areas could be depurated, it is costly and not generally done.

Area and Beach Closures

The Pacific Rim National Park is closed by regulation to commercial harvesting of intertidal bivalves.

Periodically, there are other closures, by local fishery officers, based on conservation concerns. Area 23 was closed between 1981 and 1983 (and again in 1986) based on the concerns of local fishery officers about over-fishing. Several beaches have also been closed in Area 24, in recent years (B. Adkins, per. comm.). These closures were implemented after several incidences of harvesting of sublegal clams. There was also concern about mortality of sublegal clams in an intensive fishery where the beach may be dug over several times.

RECREATIONAL CLAM FISHERY

There are few regulations in the recreational fishery for intertidal clams. Originally regulations in the recreational fishery were the same as those in the commercial fishery, and included size limits and a season.

In the late 1960's the seasonal restriction was removed, and in 1971 the regulations allowed sports fishermen to have razor clams or butter clams of any size; the size limits for littleneck and manilas were locally still in effect. Due to the confusion of sports fishermen in identifying the different species, the regulation was further amended in 1972, so that for personal use, a person engaged in sportfishing may dig for, take or have in his possession, any clams of any size.

A daily bag imit was introduced, in 1974, at 24 clams per person per day, but was increased in 1978, to 75 clams per person per day. South of Cape Caution, the combined daily limit is 75, of which no more than 12 may be razor clams and no more than 25 may be butter clams. South of Cape Caution the 75 clams can be of any species.

Special bag limits (1974) apply within the borders of the Pacific Rim National Park. For sports fishermen there is a daily bag limit of 24 clams; within the aggregate 6 can be razor clams, 3 may be goeducks, 12 may be horse or 12 may be butter clams.

The British Columbia Sport Fishing Regulations were established in 1982 and regulations that applied to sport fishing for shellfish were removed from the Pacific Shellfish Regulations.

RATIONALE FOR SIZE LIMITS IN CLAM FISHERIES

Size limits are introduced for one or more of three reasons:

1. To provide an opportunity for clams to spawn at least once before they are harvested.

2. For economic considerations; such as when the industry does not want to process clams under a certain size because it is not profitable to do so.

3. To maximize yield per recruit.

The most common reason for introduction of a size limit in clam fisheries is to ensure animals spawn at least once before they reach a harvestable size, and thus insure perpetuation of the species, even if the animals above the size limit are exploited to the maximum extent. Minimum legal size is based on biological data which can be obtained fairly readily: size at maturity and growth rate.

If size limits are adhered to in the fishery, sublegal size clamsinadvertantly dug up can rebury into the substrate and be harvested at a later date when they grow to legal size. Size limits do not guarantee consistent annual recruitment on beaches. In fact, consistent settlement is not a general occurrence and large fluctuations in local clam populations often occur.

The size limit is generally set at a size attained two years after than the size at which clams become sexually mature since they may not spawn the first season after becoming sexually mature. After maturity is attained, fully developed reproductive cells may be present in many clam species at all times but spawning is generally confined to a particular season.

Economic considerations are important but in general, the size at which the market wants clams is larger than the biological size limit, recommended to permit breeding at least once before harvest. Size limits preferred or accepted by industry, however, may be smaller than those advocated by yield per recruit models.

Size limit recommedations from yield per recruit studies are the soundest biologically since they take into account to growth and survival rates and can be adjusted to allow for successful reproduction to occur.

RATIONALE FOR CLAM SIZE LIMITS IN BRITISH COLUMBIA

Management by size limits is currently considered to be the most practical way to manage the commercial fishery for intertidal clam resources along the coast of British Columbia. Size limits can be enforced at several locations: on the beach, or in the possession of buyers or processors. Enforcement on the beaches is important to ensure that small clams are left where they will rebury and so be available to the fishery at a later date.

In British Columbia, the rationale for establishing size limits for intertidal clams was to provide an opportunity for clams to spawn at least once before they could be harvested legally.

In bivalves, attainment of sexual maturity depends on size rather than age and this size at maturity has been determined for the four intertidal commercial clam species: butter clams, 40 mm shell length (Neave 1944; Quayle and Bourne 1972); littlenecks, 22-35 mm (Quayle 1943); manilas, 20 mm (Holland and Chew 1974) and razor clams, 61-66 mm (Weymouth and McMillan 1931; Nickerson 1975). Growth rate varies with latitude (Quayle and Bourne 1972; Bourne 1982), between positions on the beach (Bourne and Quayle 1970) and on beaches within a small area (Quayle and Bourne 1972). Table 1 summarizes the size (shell length) and age of species at maturity and at the minimum legal size. Under optimum conditions, butter clams attain the present legal size of 63 mm shell length in 5 years (Quayle and Bourne 1972), littlenecks 38 mm in 3.5 years (Quayle and Bourne 1972); manila clams 38 mm in 3 years (Bourne 1982), and razor clams 90 mm in 3.5 years at Masset (Bourne and Quayle 1970). Under these conditions there is sufficient opportunity for clams to spawn at least once before they attain legal size and enter the commercial fishery.

Size limits were rescinded in the recreational fishery for two reasons. Many recreational diggers couldn't distinguish between clam species, which created enforcement problems, and it was considered to be easier to enforce a daily bag limit. It was assumed the amount of clams removed in the recreational fishery would be small in comparison to that removed in the commercial fishery and that the recreational fishery would not significantly deplete breeding populations.

Management of intertidal clams by size limits appears to have few, if any, negative consequences. There have been fluctuations in landings but these have been largely due to socio-economic, rather than biological reasons. There is occasional pressure from industry to harvest smaller clams than allowed by the size limit but these have been resisted since they could lead to depletion of brood stock population.

Because size limits have been in effect since the 1930s, yield per recruit analyses have not been done for intertidal clam populations in British Columbia, although information on many of the required parameters is now available. Yield per recruit studies might only be applicable to local areas where they were carried out and might not give results that could be applied on a coast wide basis. Stock recruitment relationships have not been examined for British Columbia intertidal clams.

CLAM REGULATIONS IN OTHER AREAS

Clam resources in California are limited and at present there is no commercial fishery. The resource is allocated to the recreational fishery and regulated by bag limits.

Clam resources are limited in Oregon but there is a small commercial fishery. The only size limit is for razor clams. Originally it was set at 4.5 in. (11.4 cm) shell length based on yield per recruit analyses (Hirschhorn 1962) but it was later lowered to 3.75 in. (9.5 cm) at the request of industry. In the mid-1970s Oregon considered size limits on cockles, butter and littleneck clams but no action has been taken. The current arrangement allows diggers to sort out small clams and return them to beaches provided they are not broken (D. Demory, pers. comm.).

There is a large commercial clam fishery in Washington but there are not any size limits. However, the situation with respect to ownership of the intertidal area differs to that in British Columbia. In Washington, commercial harvesting of intertidal clams is restricted to privately owned or leased areas. State-owned intertidal areas are allocated to the recreational fishery and this is regulated by a daily bag limit. The assumption by State officials is that in the commercial fishery, areas will be managed effectively by the lease holders and only larger clams will be harvested. In addition, there is some seeding of clams from hatcheries onto the leases.

Alaska has considerable clam resources but with the exception of razor clams, the entire state is closed to clam harvesting because of PSP. The considerable distance from major markets also makes clam harvesting uneconomical. Razor clams are harvested in some areas where PSP can be closely monitored (Nickerson 1975; Schink et al. 1983). The commercial fishery is regulated by type of gear that can be used and a minimum size limit of 4.5 in (114.3 mm). The market for razor clams has fluctuated; they are sold both for human consumption and for bait in the Dungeness crab fishery. A daily bag limit is in place for the recreational fishery.

RECOMMENDATIONS

MANAGEMENT

Several options are available to manage the commercial fishery which can be applied singly or in combination. Currently the type of harvesting gear is restricted and there are biological closures, but the main management method for the commercial fishery is minimum size limits on clams harvested. These limits were set after early biological investigations insured the animals can spawn at least once before they enter the fishery.

Due to the nature of the fishery, which occurs on hundreds of beaches scattered along the coast, the most practical way to manage the commercial intertidal clam fishery in British Columbia remains the continued enforcement of size limits. Rigorous adherence to these size limits should insure that adequate breeding population remains.

RESEARCH

Yield per recruit analysis should be done for all four intertidal species to determine if present size limits are optimal or if they should be raised or lowered. Fecundity of different size clams of all four species should also be determined. It should be noted that a small change in the size limit would likely to resisted by enforcement personnel and the industry.

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Table 1. Size (shell length) and age at maturity and at minimum legal size for intertidal clams.

Species	Size at maturity (mm)	Age* at maturity (yr)	Minimum legal size (mm)	Age* at minimum legal size (yr)	Maximum size (mm)	Age* at maximum size (yr)
Littleneck clams	22-35	1.5 to 2.5	38	3.5	75	14 (generally less than 8)
Manila clams	20-25	1 to 2	38	3	75	14 (generally less than 8)
Butter clams	40	3	63	5	130	20 (generally less than 12)
Razor clams	61-66	1 to 2	90	3.5	180	15 (generally less than 9)

*Age at optimum conditions.

17. INTERTIDAL CLAM RESOURCES - MANILA, LITTLENECK, BUTTER AND RAZOR CLAMS.

N. Bourne

INTRODUCTION

Intertidal clam fisheries have been documented by Quayle and Bourne (1972) and Bourne (1986).

The demand for fresh clams, "steamers", has greatly increased in recent years. Manila clams, Tapes philipinarum (= Venerupis japonica) and littleneck clams, Protothaca staminea, together often called "stemer clams", are now the most important bivalves in the intertidal clam fisheries. Figure 1 shows the shift in dominance in the landings from butter clams, Saxidomus giganteus in the 1950s and 1960s to manila, littleneck and mixed (manila and littleneck combined) clams in the 1980s.

The decline in butter clam landings has been due to economic reasons. Butter clams have been traditionally canned and used to make chowders but Canadian processors cannot currently compete in this market. Another major cause for decreased butter clam landings is paralytic shellfish poisoning (PSP), discussed in detail later.

Razor clams, Siliqua patula support only a small commercial fishery in the north coast. Currently, most of these clams are used as bait in Dungeness crab fisheries. In earlier years razor clams were canned, but in the late 1960s it was no longer economical to do so. Attempts were made to sell frozen blocks of shucked clams but this also failed.

BIOLOGY

MANILA CLAMS

Manila clams, sometimes called Japanese littlenecks, are medium-sized clams that are similar in appearance to native littleneck clams, but the valves are longer than high so the clam has a distinct oblong shape. Valves are heavy with radiating ribs and less prominent concentric ridges. External colour varies from greyish-white, through yellowish-buff to brown, often with geometric patterns of black and white in the young. The interior surface is deep purple at the posterior end and the tip of the siphon is split (Quayle and Bourne 1972).

Manila clams are native to Japan between latitudes 25 to 45°N. They were accidently introduced into B.C. waters with Japanese oyster, Crassostrea *gigas*, seed and were first recorded in Ladysmith Harbour in 1936, (Quayle 1938; Quayle and Bourne 1972). The species spread rapidly throughout the Strait of Georgia and along the west coast of Vancouver Island but did not spread north of Seymour Narrows and Yuculta Rapids, presumably because of cold water barriers. In the past ten to fiteen years manila clams have spread northward into the central coastal area, presumably from spawnings in the Quatsino Sound area. They now occur to latitude 52°30'N (Bourne 1982).

In British Columbia, manila clams occur from about the 1 m intertidal level to well above the half tide level on protected mud-gravel-sand beaches. They burrow to 6 cm in the substrate and are somtimes have extensive mortality in abnormally cold winters (Bower et al. 1985). Subtidal populations are unknown in British Columbia. This species does not apparently compete for space with littleneck or butter clams (Bourne 1982).

Sexes are separate and spawning occurs in late spring to early fall in the southern part of the province. Maturity is a matter of size rather than age and occurs at a length of about 20-25 mm (Holland and Chew 1974). Manila clams have a high fecundity and successful breeding appears to occur in most years. Growth rate varies from year to year, from area to area and even between beaches that are in close proximity. The legal size in the commercial fishery, 38 mm shell length, is attained in three years under optimum conditions in the southern part of the Province but takes 5-6 years in the central coastal area (Bourne 1982). Stunting is sometimes observed in manila clams, particularly in populations high in the intertidal zone. At 38 mm shell length, manila clams weigh about 17 g.

LITTLENECK CLAMS

Littleneck clams are medium-sized clams that can attain a shell length of 75 mm. The shells are heavy, solid and oval to round in shape. External valve surfaces have radiating ribs with less prominent concentric ridges. The colour of the external surfaces may vary from white to chocolate brown; often angular patterns are present. Littleneck clams occur from lower California to Alaska (latitude 23-60°N) and can withstand wide ranges of temperature and salinity (Quayle 1960a; Bernard 1983). Although found with butter clams, they usually occur in a more gravelly, firmer type of substrate and at a slightly higher intertidal level. They burrow to a maximum depth of about 15 cm and occur from slightly above the mid-intertidal beach zone to subtidal depths of 12 m.

Sexes are separate and spawning in the southern part of the province occurs from late spring to the end of summer (Quayle and Bourne 1972). Maturity is a matter of size rather than age and occurs at a length of 22-35 mm (Quayle 1943). Successful settlement at a specific site does not usually occur in consecutive years. The typical situation is one or two strong year classes followed by several years with low recruitment (Quayle and Bourne 1972). Growth rate can vary greatly from year to year, area to area, and between different locations on the same beach. The legal size in the commercial fishery, 38 mm shell length, is attained in 3.5 years under optimum conditions in the southern part of the province, but takes up to 6 years in the northern part. At this size, littleneck clams weigh about 17 g.

BUTTER CLAMS

Butter clams are relatively large clams that may attain a shell length of 130 mm. The shells are heavy and solid, square to round in shape. External valve surfaces have prominent concentric ridges with winter checks and are grey-white to white in colour. Butter clams occur from northern California to Alaska (latitude 37-60°N) and are able to withstand wide ranges of temperature and salinity (Quayle 1960a; Bernard 1983). They inhabit a wide variety of substrates but most commonly a mixture of mud, broken shell and small gravel. They burrow to depths of 30 cm in the substrate and occur from the lower third of the intertidal beach to subtidal depths of 10 m.

Sexes are separate and spawning in the southern part of the province occurs in May (Quayle and Bourne 1972). Maturity is a matter of size rather than age and occurs at a length of about 40 mm. Successful settlement does not occur regularly; usually one or two strong year classes are followed by several years with low recruitment. Growth rate can vary from year to year, from area to area and between different locations on the same beach. The legal size in the commercial fishery, 63 mm shell length, is attained in 5 yr under optimum conditions in the southern part of the province, in 6.5 to 8.5 yr in the Queen Charlotte Strait area and in up to 9 yr in the Prince Rupert area. At 63 mm shell length, butter clams weigh about 60 g (Quayle and Bourne 1972).

RAZOR CLAMS

Razor clams, <u>Siliqua patula</u>, are local in occurence and distinctive in appearance among clams along the British Columbia coast. The valves of razor clams are thin and brittle, long and rather narrow in shape, and may measure up to 180 mm in length. The shell is covered with an olive-green to dark brown shiny covering (periosticum) that may be worn away at the umbone region of older animals. Razor clams are found from lower California to the Aleutian Islands, i.e. latitude 37-60°N (Quayle 1960a; Bernard 1983) and only occur on surf-swept ocean beaches from the mid-intertidal level to about 10 m water depth.

Razor clams have a powerful foot and can bury rapidly to depths of 0.6 m within a minute. Concentrations of razor clams are local in occurrence in British Columbia. There are populations on the west coast of Vancouver Island between Pachena Point and Clayoquot Sound, on the west coast of Calvert Island and on beaches east of Masset in the Queen Charlotte Island. The largest population is near Masset and it is the only one that has supported a continuing commercial fishery (Quayle and Bourne 1972). Extensive subtidal stocks of razor clams are believed to occur off the Masset Beaches and this was confirmed to some degree when mechanical harvesters were operating there.

Sexes are separate and spawning occurs in August on the west coast of Vancouver Island and from mid-June to mid-August at Masset (Bourne and Quayle 1970; Bourne 1979a). Recruitment studies at Masset indicated successful breeding does not occur every year (Bourne 1979a). Growth rate varies latitudinally in the Province, from beach to beach at Masset and between different locations on the same beach (Bourne 1969; Bourne and Quayle 1970). Fastest growth occurs in the lowest section of the intertidal beach. The minimum legal size of 90 mm shell length in the commercial fishery is attained in about 2.5 years on the west coast of Vancouver Island and in about 3.5 years under optimum conditions at Masset (Bourne and Quayle 1970).

FISHERY MANAGEMENT

Anyone digging intertidal clams commercially must have a Personal Commercial Fishing Licence (PCFL). Because of the health risk of eating bivalves contaminated by pollution or paralytic shellfish poison (PSP), all bivalves harvested must be be delivered to a registered shellfish plant. These plants are monitored regularly by Fish Inspection Officers and clam samples are routinely tested.

Only hand digging is currently permitted in the harvest of intertidal clams. Applications to use mechanical harvesters must be made to the Department of Fisheries and Oceans. Attempts have been made to dig littleneck clams mechanically but they have either been unsuccessful or have caused extensive damage to beaches (Adkins et al. 1983).

In the recreational fishery harvest of clams is regulated only by daily bag limits.

There are several management controls in place but the primary management in the commercial fishery regulation is the size limit. No person shall dig for, take, have in possession, buy or sell any manila or littleneck clams that measure less than 38 mm shell length, butter clams less than 63 mm and razor clams less than 90 mm. Enforcement of these size limits takes place on the beaches, at buying stations, processing plants and on occasion at the border where clams are trucked to the USA.

Until 1966, there was a seasonal closure for clams in the Strait of Georgia and inside waters, from May 1 to October 31. This seasonal closure remains in affect on the west coast of Vancouver Island, where there are also some beach closures for conservation reasons. All of Area 23 has been closed for some years due to concerns by Fishery officers of overfishing. Harvest of razor clams at Masset was once closed by regulation from June 15 to August 31 and this seasonal restriction has continued by Fisheries Public Notice.

Export regulations require that live littleneck and manila clams be packaged in new or clean undamaged containers, containing not more than 45 kg of clams in the shell.

MANILA CLAM FISHERY

Manila clams spread rapidly throughout the Strait of Georgia after introduction and began to be harvested in the commercial fishery in 1941 (Quayle and Bourne 1972). Clam landings were not reported by species until 1951 and there is little information on amounts taken in the commercial fishery from 1941-1951.

Annual landings were about 80 t in 1951, increasing to 205 t in 1955 and then declined slightly (Fig. 1). From 1951 to 1970, manila clam landings averaged 95 t (sd = 65) which amounted to less than 10% of the annual clam catch. In the mid-1970s diggers switched from harvesting butter clams to digging steamer clams (manila and littleneck) because of market demand. At first the market preferred littleneck clams but towards the end of the 1970s this changed and the market began to prefer manila clams. Since then landings of manila clams have increased steadily and during 1984 and 1985 annual landings were 1,677 and 1,910 t respectively (Fig. 1). This dramatic increase in landings was in part due to the poor current economic situation in coastal areas. There is widespread unemployment and as a result more people are digging clams.

Virtually all commercial manila clam landings are from the south coast fishery district. Minor landings used to occur in the Fraser River estuary before it was closed because of pollution. Although manila clams have spread to the central coast, it is apparently not economic to harvest them there because of limited abundance and high transportation costs. The costs of sampling and monitoring clams for PSP are also a deterrent. In the south coast, the main digging area has been statistical area 17 but substantial landings now come from areas 13, 14, 15, 16, 24 and 25.

As in other clam fisheries there is little sophistication in harvesting manila clams. Most diggers use short handled rakes or bent forks that are pulled through the substrate and farm the clams out. Manila clams are usually sacked and taken to buyers or processors for fresh sale.

The intertidal beach is part of the crown foreshore and digging is permitted to anyone in this area provided it has not been closed because of pollution or PSP and fishery regulations are observed.

LITTLENECK CLAM FISHERY

The commercial clam fishery began before the turn of the century but landings were not assigned by species until 1951. Most landings (80-90%) prior to 1951 were butter clams, the remainder being littleneck clams (Quayle and Bourne 1972). A record of littleneck landings was kept at the Pacific Biological Station from 1941-1951; landings rose from 90 t in 1941-42 to a peak of 380 t in 1949-50. Catch per man per tide was 59 kg in 1941, 58 kg in 1942, 70 kg in 1943, 58 kg in 1944 and 83 kg in 1945 (Quayle and Bourne 1972).

From 1951 to 1970, annual landing of littlenecks averaged 87 t (sd = 65) and since 1971, landings have averaged 277 t (sd = 119) (Fig. 1). Prior to 1970, littlenecks represented less than 10% of total clam landings. Fluctuations in landings were due to the same reasons that caused fluctuations in landings of butter clams (Quayle and Bourne 1972).

In 1971-72, landings of littlenecks increased due to greater market demand. Since 1972, highest market demand has shifted to manila clams, and diggers now target on this latter species.

Most landings of littleneck clams are from the south coast fishery district. Minor landings were made around the Fraser River before it was closed because of pollution. Only minor landings occur in the north coast but littlenecks are a common species there and are consumed locally. Littleneck clams are sold live and must be sent to markets quickly after digging; at present it is not economically feasible to ship littlenecks from the north to major markets. It was not until 1970 that littlenecks were landed from statistical area 12, a major butter clam producing area, but with inproved road access area 12 is now a major harvesting region for this species. Initially, most landings were from areas 13, 15, 17 and 18, but now most come from areas 12 and 17.

Littleneck clams are frequently dug along with butter clams and methods and equipment are similar in the two fisheries. On beaches with extensive populations of littlenecks but few butter clams, diggers may use long-tined rakes that are pulled through the soil, and the littlenecks turned out. They are frequently dug along with manila clams by raking with short tined rakes.

When there were seasonal restrictions on harvesting, littleneck clams were sometimed held in sink floats during the closed season before being sent to market. At present there is no closed season (other than PSP closures) and they are immediately put in sacks, taken to processors and sent to market.

BUTTER CLAM FISHERY

Fishing equipment is simple and inexpensive: some type of transportation to clam beaches, a lantern (since digging in fall and winter is at night), a fork and a basket. The standard, time-honoured method of digging butter clams is with an ordinary long-handled, 4-tined garden fork. An indication of clam abundance can be obtained from observing the number of siphon holes after the tide recedes. Diggers usually arrive at the beach about two hours before low tide and continue digging for about the same time after low water. During this time they can dig between 20-35 m^2 of substrate. Clams are usually put into sacks for transport to buyers or processors.

Until 1966 there was a seasonal closure from May 1 to October 31. However, if butter clams are being canned, a seasonal demand is applied by processors. Because clams actively feed on phytoplankton (green feed) during the summer, this colors the digestive gland green and since it often breaks on canning; canning such clams can discolor the product and reduce its aesthetic quality.

Although attempts have been made to harvest butter clams mechanically they have either not proven to be successful or have caused damage to the beach (Adkins et al. 1983).

Until 1963, butter clam landings were divided fairly evenly between the south and north coast districts. In 1963 the northern area and much of the west coast of Vancouver Island was closed to clam harvesting because of an outbreak of PSP (Quayle 1969). Most of these areas have remained closed to clam harvesting because of chronic low levels of PSP, particularly in butter clams. Although methods have been developed to process butter clams from these areas (Quayle 1967), it appears that it is not economically feasible to do so. In recent years butter clam landings have been entirely from the south coast district, mostly areas 12 and 17.

RAZOR CLAM FISHERY

Razor clams have been dug commercially on the west coast of Vancouver Island but the fishery has always been small. The catch was generally consumed locally or used for bait in the Dungeness crab fishery. Much of this razor clam population lies within Pacific Rim National Park and is now closed to commercial harvesting. Limited harvest of razor clams continues in this area in the recreational fishery.

The main razor clam fishery in British Columbia has always been in the Queen Charlotte Islands on beaches east of Masset. The fishery began there in 1923 and landings increased rapidly to a peak of 725 t in 1925, but declined rather sharply after that (Quayle and Bourne 1972). Landings in recent years have been generally under 100 t (Fig. 1). Low landings in recent years have been due mostly to a lack of diggers and low prices.

Razor clams are dug individually, not randomly as is the case with other intertidal clams. When disturbed, razor clams frequently produce a "show" on the surface of the sand. The number of shows produced depends on several factors including weather, state of the tide, and amount of surf. Shows are usually more numerous on hot, dry days than on cold, wet ones. Diggers try to make clams produce shows by stomping on the beach.

Razor clams are dug with a thin bladed shovel called a "clam gun". A small wedge of sand is removed seaward of a show to expose the siphon, which is grasped quickly and the clam removed. If the clam is not caught on the first attempt, commercial diggers move to another show since the clam quickly burrows beyond reach. The number of clams dug depends greatly on the skill of the digger and partly on whether clams are showing well, but an experienced digger can consistently dig 90-140 kg of clams per four hour tide. Attempts were made to harvest razor clams at Masset with mechanical harvesters but they were not successful.

There is a seasonal closure, June 15 to August 31 during the time of spawning.

Razor clams are exploited extensively in the recreational fishery in the state of Washington (Schink et al. 1983) and the resource is allocated almost entirely to this fishery. Recreational harvest on the west coast of Vancouver Island and at Masset has not been documented. With increasing tourist traffic to the Queen Charlotte Islands, harvest of razor clams in the recreational fishery could increase significantly in the future.

Masset beaches were held as leases by the cannery at one time but now all razor clam beaches are part of the crown foreshore and digging is permitted to anyone, provided fishery regulations are observed.

ENVIRONMENTAL FACTORS

Two environmental factors affect clam production, pollution and paralytic shellfish poison (PSP) (Quayle 1969).

Pollution may be from industrial or domestic sources. Industrial pollution often causes poor growth or clam mortality. Sewage contamination causes high bacteria counts in both the water and in clams and makes them unfit for human consumption. Specified areas on the coast are closed due to sewage pollution. Clams can be depurated holding them in depuration plants, but this has not found acceptance in the industry, presumably because of high associated costs. Transplanting clams to non-poluted areas has not been approved by Fisheries.

The problem with PSP is a difficult one and at times seriously affects production. A surveillance system is in place to protect the public from eating toxic clams harvested in the commercial fishery. Manila and littleneck clams do not accumulate as much toxin as butter clams and purge themselves of it much more quickly, about six weeks after blooms subside. Although much of the west coast of Vancouver island is closed to clam harvesting because of PSP, a seasonal testing system (November 1 to April 30) has been instituted that allows harvest of steamer clams from these areas. This system could be extended to the central coast area if the industry decided it was economically feasible to harvest manila clams from there.

Methods have been devised to process mildly toxic butter clams but there is little interest in it at present because of the economics of canning clams, (Quayle 1967).

Improvements in the PSP assay method which would permit more frequent and extensive monitoring would benefit the industry and permit wider use of all clam resources.

CURRENT ISSUES

MANILA CLAMS

Considerable research has been done on manila clams, much of it in conjunction with other clam studies and data is available on growth, recruitment, production, distribution, length-weight relationships, predator and life history.

Numerous surveys has been undertaken of clam beaches throughout the Province but as with other intertidal clams, the broad application of limited samples is questionable because of the large number of beaches and the great variability in clam populations on them, even between beaches that are in close proximity. An estimate of the sustainable yield of manila clams in the early 1970s suggested that 225 t could be harvested annually from the south coast (Quayle and Bourne 1972). However, recent annual landings have greatly surpassed this level.

Currently, there is considerable interest in culturing manila clams in British Columbia. Breeding areas where large quantities of seed (juveniles) can be gathered naturally are unknown in British Columbia and although seed can be purchased from hatcheries, this can be costly. A major problem in clam culture is heavy mortality (up to 95%) after seed is planted in the substrate (Anderson et al. 1982; Bourne in press). A solution is to cover the substrate with netting after the clam seed is planted, but this adds to the cost. Profitable clam culture may require 10 - 15 mm seed for outplanting. This would reduce the time required for clams to grow to a harvestable size and increase juvenile survival. Such culture has been initiated on the west coast of Vancouver Island and early results are promising (Bourne in press).

Manila clam culture is technologically possible in British Columbia and may also be economically feasible at the present time. With continuing strong demand and high prices for manila clams, and with improved hatchery and grow-out technology, manila clam culture may become more economically attractive in the near future. Before manila clam culture can become a reality a leasing system must be instituted to guarantee the grower legal right to his culture area.

LITTLENECK CLAMS

Considerable research work has been done on littleneck clams, much of it in conjunction with butter clam research. Studies have produced information on growth, recruitment, production, length-weight relationships, distribution and life history.

Numerous surveys have been undertaken of clam beaches throughout the province but as with butter clams the value of such surveys is limited because of the large number of beaches and great variation in clam populations on them, even between beaches that are in close proximity. An estimate of sustained yield of littlenecks indicated 225 t could be harvested annually from both the north and south coast districts (Quayle and Bourne 1972), but this may be a conservative estimate.

Extensive surveys of the subtidal area indicate there are no significant subtidal populations of littlenecks in British Columbia (Quayle 1960b, 1961).

An attempt was made to culture littleneck clams but lack of seed (juveniles) and high mortality does not appear to make this profitable currently (Bourne in press).

BUTTER CLAMS

Studies on butter clams document growth, mortality, recruitment, production, optimum digging frequency, distribution, length-weight relationships and life history. Much of the work has been done at Seal Island, an important butter clam producing area at the northern end of Denman Island in the Strait of Georgia.

Numerous surveys have been undertaken on clam beaches throughout the Province but the value of such surveys is limited because of the large number of beaches and the great variation in clam populations even in areas of close proximity. An estimate of sustained yield of butter clams indicated 1,400 t could be harvested annually from both the north and south coast districts (Quayle and Bourne 1972).

Extensive surveys have also been undertaken to determine if subtidal populations of clams exist that could support commercial harvesting. No significant subtidal populations were found (Quayle 1960b, 1961).

Attempts have been made to culture butter clams but lack of seed (juveniles), slow growth and high mortalities do not make this a feasible proposition currently (Bourne in press).

RAZOR CLAMS

Research has been done on razor clams, both on the west coast of Vancouver Island and on Masset beaches. Studies have produced information on growth, recruitment, population abundance and size frequency distribution, catch per unit effort, estimates of sustained yield, length-weight relationships and life history.

Studies of catch per unit effort (man per tide) at Masset in the 1940s showed the population was relatively small, probably because of reduced recruitment. The population apparently recovered since catch per unit effort returned to higher levels in the early 1950s (Quayle and Bourne 1972). Studies in the late 1960s indicated an annual sustained yield of 225 t was feasible from the intertidal population, but this was never realized in the fishery (Bourne 1969). Major recruitment probably occurs from populations of juveniles in the offshore area that move into the intertidal area (Bourne 1979; N. Rickard, per. comm.).

RECOMMENDATIONS

MANAGEMENT

1. Landings of manila and littleneck clams are expected to remain high or increase due to the strong demand for steamer clams. Stocks of littleneck clams are not being exploited in the north coast. The current management practices should be continued, with rigorous enforcement of the size limit and seasonal closures on the west coast of Vancouver Island. The minimum size limit is adequate to insure spawning at least once before clams enter the fishery.

2. Current beach closures in Area 24 and the closure of Area 23 should be reviewed annually.

3. Landings of butter clams will probably not increase significantly in the near future because of current poor demand for them. The situation could change if new markets for butter clams develop. The minimum size limit is adequate to insure spawning at least once before butter clams enter the fishery.

4. If the razor clam fishery expands at Masset, then the effectiveness of managing the resource by size limits should be re-examined and consideration given to managing by annual quotas. Razor clams are often damaged when digging, particularly by inexperienced diggers (Schink et al. 1983). There is no point in returning damaged undersized razor clams to beaches since they will die. Access to beaches is limited and so catches can be monitored either as diggers leave the beach or at processing plants.

The need for the seasonal closure, June 1 to August 31 should be reviewed.

RESEARCH

MANILLA AND LITTLENECK CLAMS

Due to the increasing market demand for manila and littleneck clams, there are concerns for overharvesting and excessive mortalities of sublegal clams because of frequent redigging of the substrate. Consideration should be given to develop research programs:

1. Develop adequate, standard methods for assessment of stocks on heavily harvested beaches.

2. Establish study areas to monitor recruitment, growth, biomass, natural mortality and fishing mortality to provide information for yield models.

3. Assess catch of clams in the recreational fishery.

4. Determine if catch and effort data can be obtained from selected commercial harvesters to provide catch per unit effort data.

5. Undertake yield per recruit analyses to determine if the current size limits provide optimum yields.

BUTTERCLAMS

No research is proposed due to the current low levels of exploitation.

RAZOR CLAMS

Due to the current low levels of exploitation, research on razor clams is a low priority. If demand increases, the above studies might be required in this speciesa as well as those detailed below:

1. Assess intertidal populations on Masset beaches and determine if they have changed significantly since the last survey in 1969. Investigate the potential of subtidal stocks.

2. Assess if catch and effort data can be obtained from selected commercial harvesters to provide catch per unit effort data.

3. Assess if major recruitment of juveniles measuring 2 cm shell length or larger occurs from the subtidal area.

4. Investigate feasibility of managing this fishery by yearly quota.

5. Assess the extent of the recreational harvest of razor clams both at Masset and on beaches on the west coast of Vancouver Island.

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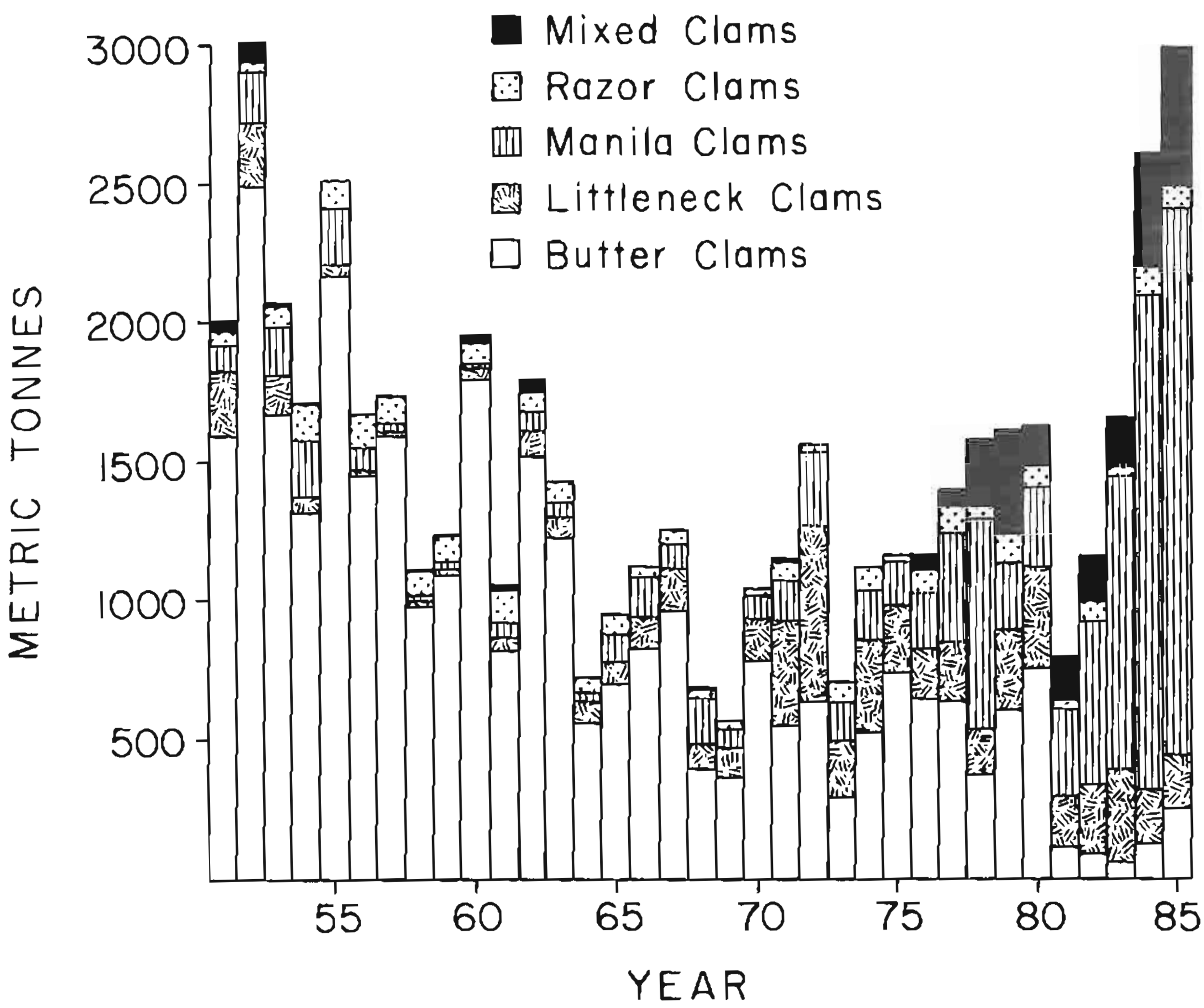

Fig. 1. Landings of intertidal clams by species in the British Columbia commercial fishery, 1951-1985.

18. MUSSELS

G. S. Jamieson and S. Swarbrick

INTRODUCTION

Athough there are 11 species of mussels in British Columbia, only two species are commercially fished: the blue mussel, Mytilus edulis, and the California, or sea mussel, M. californicanus. Product is obtained both by hand-gathering both species of mussels growing wild in the interidal zone and by the culture of blue mussels, usually through suspension in the water column. The farming of mussels has been practised in Europe for many years and more recently, in the Philipines, New Zealand and eastern North America, notably Maine, Nova Scotia and Prince Edward Island. Mussels presently sold live in the Pacific northwest are largely from Maine, U.S.A. Their success has led to considerable local interest in mussel culture over the past few years, and there are presently a few companies actively attempting to culture mussels in quantity for regional commercial markets. To date, most regional production has come from Washington, USA.

The market seems to prefer a smaller mussel than the abundant, relatively large, California mussel, and the blue mussel is seldom abundant enough in B.C. and of a size sufficient to support a wild stock fishery. Most local production is through culture of blue mussels rather than wild harvest, and the culture technique most employed is suspended culture, using either longlines or rafts. Production in British Columbia has been minor to date (Table 1), with a projected harvest in 1986 of 30 t, mostly from a grower in Barkley Sound (Area 23). The projected harvest in 1987 is about 78 t from mussel farms.

In 1985, an estimated 190 t of mussels was imported live into British Columbia, whereas total mussel production in Canada in 1984 was 940 t (Anon. 1985). Total market demand in Canada in 1984 was 2,200 t, with American imports accounting for 65%. Locally produced mussels wholesale at about $\$2.2 \cdot kg^{-1}$ whereas imported mussels wholesale at about $\$3.3 \cdot kg^{-1}$ due to higher shipping costs.

The main management issue is probably that common to most bivalve culture, namely reconciling aquaculture site requirements with traditional wild harvest practices. There seems to be little problem with species abundance, and in fact mussels are a major fouling problem with any object suspended in the water column.

BIOLOGY

Blue mussels are the species of most interest in British Columbia. This circumpolar species is widely distributed in the northern hemisphere and regionally, inhabits the intertidal zone down to a depth of 45 m. It is most common between the 1.5 to 3.7 m tide levels. They grow to about 70 mm shell length and are conventionally harvested at a size 50 mm. Sexes are separate and the larvae pelagic, with final settlement at about a size of 1 to 1.5 mm. Sexual maturation can occur within the first year and although spawning can occur at any time of year, peak breeding at least in the Strait of Georgia, occurs during the spring and summer.

Growth rate can vary greatly between sites, but mussels continuously suspended in the water column can reach a size of 50 mm in less than 1 year. This may require 2 to 3 yr for intertidal mussels.

One problem to industry development has been an unexplained, relatively high mortality of mussels in late summer-early fall, particularly in the Strait of Georgia (Heritage 1983). Studies are presently underway investigating the characteristics of this mortality and trying to find a methodology to minimize its effects. There is no evidence that it is the result of a contagious disease (S. Bower, unpub. data).

FISHERY MANAGEMENT

Culturists are required to have both provincial and federal licences, whereas the only restriction on wild harvest is a ban on mechanical harvesting tools. The north coast (i.e. north of Cape Caution) and west coast of Vancouver Island are closed year round to wild harvest due to PSP hazards, but can be opened with the provision of test samples and monitoring. A Z licence is required for the commercial harvest of wild mussels.

One potential problem is that because mussels are purchased alive, there is the danger that imported mussels may carry disease and be unintentially released into the wild. Because they are imported for human consumption, imports are not required to be certified as free of disease or parasites which don't affect humans but which might affect wild stocks. Instances of release of Atlantic mussels into Pacific waters are known to have occurred and it seems only a matter of time before a problem will arise.

RECOMMENDATIONS

It is anticipated that interest in mussel culture will expand greatly over the next few years and that a considerable increase in production will occur. Conflict with wild harvest fishermen may occur as optimal growout areas are contested over. Since cultured mussels can be expected to be well-managed by the grower, there would seem to be little need for fisheries management by government within a commercial operation, although an integrated research/extension service is likely to be required to ensure that maximum harvests can be routinely produced.

Problems relating to accidental disease introduction from imported mussels need to be addressed, although it is beyond the mandate of the Department of Fisheries and Oceans to deal with this problem alone.

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Table 1. Recent and projected mussel landings (tonnes) in British Columbia, as reported on sales slips.

Year	Landings (t)
1982	0.5
1983	*
1984	1.2
1985	3.4
1986 (projected)[1]	30
1987 (projected)[1]	78

[1]Projected landings are from interviews with mussel culturists.

*less than 100 kg

19. GOOSENECK BARNACLES

G. S. Jamieson

INTRODUCTION

Gooseneck barnacles, Pollicipes polymerus, are presently an underutilized resource of uncertain economic fishery potential. Relatively little is known about their biology in British Columbia, although a report summarizing some work done in the late 1970s is presently in preparation (F. Bernard, pers. comm.). In southern Europe, a related species, P. pollicipes, is extensively exploited and commands a high market price because of limited availability. This has stimulated fishery interest for gooseneck barnacles in other parts of the world in an attempt to meet this market demand.

The history of exploitation in British Columbia is relatively recent (R. Harbo, unpub. data) and to date, no viable fishery has been established. In 1978, 19.2 t was harvested from the waters around Tofino. There are no records of landings in 1979.

In 1979, T. Proverbs (unpub. data) prepared a report evaluating problems associated with exporting gooseneck barnacles and the nature of the Spanish market. His conclusions were that in British Columbia, duration of harvesting season would be unpredictable, many populations were inaccessible, harvesting would be labour intensive, and there would be quality and shipping problems associated with a Canadian product which would have to be overcome. On the positive side, our local stock is extensive, a strong demand for acceptable product exists in Spain and the price is high. To date, Proverb's conclusions seem substantiated and a significant fishery has yet to be established.

A small shipment of barnacles (30 kg) was exported to Spain in 1980 but otherwise there was no commercial interest in this species until 1984, when two unsuccessful attempts to establish a fishery occurred.

In 1985, two new proposals were initiated, although only one resulted in any product being landed. NOPSA Ltd. planned to harvest and immediately freeze the barnacles and to this end, received federal funding to both evaluate harvest strategies and monitor the biological aspects related to harvesting. Initial landings were less than expected and product characteristics were a problem (W. Austin, unpub. data). In most barnacle clumps, many of the barnacles are either too large or too long and slender for the traditional Spanish market, with only about 20% of the barnacles collected actually marketable. Landings by NOPSA were about 1.2 t in 1985. In 1986, emphasis has now shifted back to marketing a live product, as holding and shipping techniques have been refined.

Attempts to initiate a sustainable fishery for this species have not been very successful too date. The Spanish market seems to prefer a product shorter and of greater diameter than is easily obtainable in British Columbia. Many Canadian specimens are too large or too long and slender, necessitating extensive culling. Initial concerns relating to the potential for over-exploitation do not seem to present a problem, as the scattered distribution of colonies, often on unsuitable substrates, has made the exploitation of gooseneck barnacles very patchy. Only about 8% of the stock may be exploitable (W. Austin, unpub. data).

BIOLOGY

The geographical range of P. polymerus extends from Sakhalin Is., USSR, to Baja California, Mexico, and in British Columbia, it is a dominant orgamism in the middle and upper intertidal zone. It grows to 10 cm in length and is the largest gooseneck barnacle species. It is the muscular peduncle (= neck) that is eaten, after being boiled and stripped of its flexible, outer sheath. Being a crustacean, the resultant piece of white meat has a similar texture and taste to that of crab or lobster.

The species is usally found in colonies, tightly clumped and 20 to 40 cm in diameter, with the largest, oldest individuals in the centre. They occur in areas of strong wave surge and if cluster shape is significantly disrupted, the entire colony is likely to be destroyed through wave action. They feed on zooplankton rather than phytoplankton and seem to be less susceptable to paralytic shellfish poisoning than bivalves. However, studies in California (Sharpe 1981) have shown that occasionally they may be slightly toxic and that caution should be exercised. Once removed from a specific location, it may be many years before a gooseneck barnacle colony is reestablished, in part because of strong competetion for space by mussels and other barnacle species (F. Bernard, pers. comm.).

Sexual maturity is reached after 1 yr but P. polymerus is relatively slow-growing (Lewis and Chia 1981) in contrast to the related genus Lepas. Bernard (unpub. data) estimates Von Bertalanffy growth parameters of $k = 0.35$, $l = 31.6$ (capitulum length) and $t_0 = -0.584$; this suggests that optimal age of first exploitation is about 6 yr although W. Austin (pers. comm.) suggests that a marketable product is achieved in 3 yr. This period, together with the need for active water movement, may render impossible any feasible culture of this species (Goldberg 1974).

RECOMMENDATIONS

The present approach of requiring that interested fishermen obtain a Z licence and document their fishing activities seems acceptable. Unless the fishery were to suddenly expand significantly, little management or biological concern is required.

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Appendix 1. List of common and scientific names of commercially exploited species of shellfish.

Phylum - Class[1] Common name	Scientific name
(A) PHYLUM MOLLUSCA	
CLASS GASTROPODA	
abalone (northern, pinto)	Haliotis kamtschatkana
CLASS BIVALVIA	
geoduck (king clam)	Panope abrupta (= P. generosa)
horse clam (gaper clam)	Tresus capax
	Tresus nuttallii
manila clam	Tapes philippinarum
littleneck (native) clam	Protothaca staminea
butter clam	Saxidomus giganteus
razor clam	Siliqua patula
blue (bay) mussel	Mytilus edulis
California (sea) mussel	Mytilus californianus
weathervane (Pacific) scallop	Patinopecten caurinus
pink (smooth, swimming) scallop	Chlamys rubida
spiny (pink, swimming) scallop	Chlamys hastata
CLASS CEPHALAPODA	
opal (market) squid	Loligo opalescens
red squid	Berryteuthis magister
* nail squid	Onychoteuthis borealijaponica
flying squid	Ommastrephes bartramii
(B) PHYLUM CRUSTACEA	
CLASS MALACOSTRACEA	
euphausiids (krill)	Euphausia pacifica
prawn (spot shrimp)	Pandalus platyceros
smooth pink shrimp	Pandalus jordani
northern (spiny) pink shrimp	Pandalus borealis
sidestripe shrimp	Pandalopsis dispar
coonstripe shrimp	Pandalus danae
humpback shrimp	Pandalus hypsinotus
Dungeness crab	Cancer magister
red rock crab	Cancer productus
red (Alaska) king crab	Paralithodes camtschatica
golden (brown) king crab	Lithodes aequispina
tanner crab	Chionoecetes bairdi
* galatheid crab (squat lobster)	Munida quadraspina
CLASS CIRRIPEDIA	
gooseneck barnacles	Policipes polymerus
(C) PHYLUM ECHINODERMATA	
CLASS ECHINOIDEA	
red sea urchin	Strongylocentrotus franciscanus
green sea urchin	Strongylocentrotus droebachiensis
CLASS HOLOTHURIODEA	
California sea cucumber	Parastichopus californicus

*Of potential interest.

[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.

Appendix 2. Gear and licence category for licensed species in British Columbia.

Species	Gear	Licence category
Abalone	diving	E
Anchovy	seine	Z (vessel)
Black Cod (see Sablefish)		
Butter Clam	mechanical digger apparatus of dredge*	A (vessel)
Butter Clam	hand picking	PCFL (without vessel)
Cockles	mechanical digger apparatus of dredge*	Z (vessel)
Cockles	hand picking	PCFL (without vessel)
Capecod	pelagic trawl	Z (vessel)
Dogfish (see Groundfish)		
Dungeness Crab	trap or ring net	C
Eulachon	gillnet, set net	C
Eulachon	gillnet, set net	Z (without vessel)
Euphausiid	pelagic trawl	Z (vessel)
Flounder (see Groundfish)		
Flounder	hook and line	C
Geoduck	diving	G
Goose Barnacle	hand picking	Z (without vessel)
Graceful Crab	trap or ring net	C
Groundfish	trawl	T
Hake (see groundfish)		
Herring Spawn on Kelp		J
Horse Clam	diving	G (vessel)
Horse Clam	mechanical digger apparatus of dredge*	Z (vessel)
Horse Clam	hand picking	PCFL (without vessel)
King Crab	trap or ring net	C
Limpet	hand picking	Z (without vessel)
Lingcod (see Groundfish)		
Lingcod	hook and line	C
Little Neck Clam	mechanical digger appartus or derdge*	Z (vessel)
Little Neck Clam	hand picking	PCFL (without vessel)
Manila Clam	mechanical digger apparatus or dredge*	Z (vessel)
Manila Clam	hand picking	PCFL (without vessel)
Mussel	hand picking	Z (without vessel)
Octopus	trap or diving	Z (vessel)
Octopus	hand picking, diving	Z (without vessel)
Oyster		Province of BC permit wild leases
Pacific Cod (see Groundfish)		
Pacific Cod	hook and line	C
Pacific Ocean Perch (see Groundfish)		
Packing		D
Pile Perch	hook and line or drag seine	Z (vessel)
Pink Scallop	dredge or diving	z (vessel)
Pollock (see Groundfish)		
Prawn (see Shrimp)		
Processor		P

* operating from vessel or floating platform.

Appendix 2 (cont'd)

Species	Gear	Licence category
Razor Clam	mechanical digger apparatus or dredge*	Z (vessel)
Razor Clam	hand picking	PCFL (without vessel)
Red Rock Crab	trap or ring net	C
Red Sea Urchin	diving	Z (vessel)
Rockfish (see Groundfish)		
Rockfish	hook and line	Z (vessel)
Roe Herring	gillnet	H
Roe Herring	seine	H
Roe Herring (Native)	gillnet, seine	H
Sablefish (see Groundfish)		
Sablefish	longline, trap	K
Salmon	gillnet, troll	A
Salmon	seine	AS
Salmon	gillnet, troll	B
Salmon (N.N.F.C.)	gillnet, troll	N
Sea Cucumber	diving	Z (vessel)
Shrimp	trap	C
Shrimp	trawl	S
Skate (see Groundfish)		
Skate	hook and line	C
Smelt	gillnet, set net	C (vessel)
Smelt	gillnet, set net	Z (without vessel)
Soft Shell Clam	mechanical digger apparatus or derdge	Z (vessel)
Soft Shell Clam	hand picking	PCFL (without vessel)
Sole (see Groundfish)		
Sole	hook and line	C
Spiny Dogfish	hook and line	C
Spiny Scallop	dredge or diving	Z (vessel)
Squid Species	seine or hook and line	Z (vessel)
Steelhead Trout (see Salmon)		
Sturgeon (see Groundfish)		
Sturgeon	troll, gillnet	C
Surf Perch	hook and line or drag seine	Z (vessel)
Top snail	hand picking	Z (without vessel)
Tuna	hook and line, seine, floating longline or gillnet	C
Turbot	hook and line	C
Weathervane Scallop	dredge	Z (vessel)
Whelk	hand picking	Z (without vessel)
Winkles	hand picking	Z (without vessel)

Scientific Permits

Tanner Crab
Mackeral
Green Sea Urchins

*Operating from vessel or floating platform.