Abalone Biology, Fishery Regulations, Commercial Catch (1952-1980), and Current State of Resource in British Columbia

A. Y. Fedorenko and P. E. Sprout

Department of Fisheries and Oceans
Prince Rupert, B.C.
V8J 1G8

June 1982

Canadian Manuscript Report of Fisheries and Aquatic Sciences No. 1658

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

Canadian Manuscript Report of
Fisheries and Aquatic Sciences 1658

June 1982

ABALONE BIOLOGY, FISHERY REGULATIONS, COMMERCIAL CATCH (1952-1980), AND CURRENT STATE OF RESOURCE IN BRITISH COLUMBIA

by

A.Y. Fedorenko and P.E. Sprout

Department of Fisheries and Oceans
Prince Rupert, B.C.
V8J 1G8

Cat. No. Fs 97-4/ 1658 ISSN 0706-6473

Correct citation for this publication:

Fedorenko, A.Y. and P.E. Sprout. 1982. Abalone biology, fishery regulations, commercial catch (1952-1980), and current state of resource in British Columbia. Can. MS Rep. Fish. Aquat. Sci.1658: vii + 74 p.

CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF APPENDICES

ABSTRACT

Fedorenko, A.Y. and P.E. Sprout. 1982. Abalone biology, fishery regulations, commercial catch (1952-1980), and current state of resource in British Columbia. Can. MS Rep. Fish. Aquat. Sci. 1658: vii + 74 p.

Landings of northern abalone (Haliotis kamtschatkana) in British Columbia have expanded greatly since 1976, with 1,474 m.t. harvested during 1976 to 1980. By late 1970's, the abundance of legal-sized abalone has declined by 60 - 85%. This report reviews the biology of northern abalone, world-wide production and trading of abalone, and its aquaculture; examines the development of commercial abalone fishery in B.C.; reviews management strategies in B.C., especially from 1976 to 1980; summarizes the annual landings by Statistical Area during 1952-1980, emphasizing catch trends and fishing effort in the last five years; examines biological studies in fishery management of abalone; and makes recommendations for a more viable abalone fishery in B.C.

Key words: northern abalone, fishery, management regulations, biology, overharvesting.

RÉSUMÉ

Fedorenko, A.Y. and P.E. Sprout. 1982. Abalone biology, fishery regulations, commercial catch (1952-1980), and current state of resource in British Columbia. Can. MS Rep. Fish. Aquat. Sci. 1658: vii + 74 p.

Les débarquements d'ormeaux (Haliotis kamtschatkana) en Colombie-Britannique ont beaucoup augmenté depuis 1976: 1 474 tm ont été récoltées de 1976 à 1980. À la fin des années soixante-dix, l'abondance des ormeaux de taille légale avait diminué de 60 à 85 %. Le présent rapport passe en revue la biologie de l'ormeau, la production et le commerce mondiaux ainsi que l'aquiculture; fait une rétrospective du développement de la pêche commerciale en C.-B.; examine les stratégies de gestion en C.-B., surtout de 1976 à 1980; donne un résumé des débarquements annuels par zone statistique de 1952 à 1980, dans lequel l'accent est mis sur les tendances des prises et l'effort de pêche pendant les cinq dernières années; évalue les études biologiques pour la gestion de la pêche de l'ormeau; et fait des recommandations pour une pêche de l'ormeau plus viable en C.-B.

Mots-clés: ormeau, pêche, règlement de gestion, biologie, surexploitation.

INTRODUCTION

The northern abalone, Haliotis kamtschatkana, is the only abalone species found in British Columbia. It is widely distributed throughout the B.C. coast and supports recreational, commercial and Indian food fisheries. The abalone fishery started in B.C. at the turn of the century when canneries in Jedway, Bella Bella and Alert Bay turned out a limited amount of production (Quayle 1962). In the 1950's, the fishermen often operated alone on dayboats and generally landed their catch fresh (Breen 1980, a&b). Prior to 1976, landings were comparatively low and highly variable from year to year, ranging from 181 kg (400 lb) in 1959 to 67,000 kg (148,000 lb) in 1973 (Table 1).

In the mid-1970's, a strong Japanese market developed for abalone and, in response, the abalone fishery in B.C. expanded rapidly in both scale and efficiency. The small operators of the formerly insignificant fishery fleet where joined by new operators with larger boats equipped with freezing and compressing systems, and capable of making prolonged trips and hiring additional divers. A major shift in landings also occurred during this period, from the south to the north coast of B.C., as the operators with larger boats headed for the Queen Charlotte Island abalone beds, then shipped their catch out of Prince Rupert to Japan. By 1976, British Columbia became the major supplier of abalone on the west coast of North America. The United States fishery was severely depleted by this time, due primarily to heavy commercial fishing and increased recreational demands (Cicin - Sain et al. 1977). In 1977, B.C. landings reached 481 m.t. (1,061,250 lb), with a value of nearly $2 million, rendering the abalone the second most valuable shellfish fishery in B.C. after shrimp (Breen 1980 a).

Due to the greatly increased abalone landings, the established commercial abalone fishermen, Indian bands and sport fishermen voiced a strong concern about their share in the resource. Pressure from these groups and the threat of severe overfishing of the slow growing abalone resource prompted the Department of Fisheries and Oceans (DFO) in British Columbia to implement in 1977 major regulations to control the abalone fishery.

Table 1. Total annual landings and value[a] of abalone in B.C., 1952-1980[b].

Year	Landings (kg)	Landings (lb)	Price/lb ($)	Total value ($)
1952	5,398	11,900	.08	1,000
1953	10,342	22,800	.13	3,000
1954	6,849	15,100	.07	1,000
1955	3,538	7,800	-	-[c]
1956	499	1,100	-	-
1957	953	2,100	-	-
1958	5,307	11,700	.09	1,000
1959	181	400	-	N.R.
1960	1,542	3,400	-	N.R.
1961	9,389	20,700	.10	2,000
1962	17,463	38,500	.16	6,000
1963	5,715	12,600	.12	1,500
1964	57,062	125,800	.16	20,000
1965	3,084	6,800	.15	1,000
1966	726	1,600	-	-
1967	862	1,900	-	-
1968	91	200	-	-
1969	635	1,400	-	-
1970	16,239	35,800	.42	15,000
1971	6,441	14,200	.36	5,000
1972	59,602	131,400	.45	59,000
1973	67,131	148,000	.63	95,000
1974	26,308	58,000	.74	43,000
1975	56,699	125,000	1.06	132,000
1976	273,061	602,000	1.43	860,000
1977	481,373	1,061,250	1.84	1,953,000
1978	404,212	891,138	1.95	1,738,000
1979	208,169	458,937	2.59	1,189,000
1980	107,619	237,260	2.81	667,000
Total	1,836,490	4,048,785	-	6,792,500

[a] Price paid to fishermen.

[b] From: sales slip records for 1952-1977; log-book records for 1978-1980.

[c] No record; less than $500.

The present report reviews the life history of abalone and its importance to British Columbia and the world fishery; outlines the management strategies in B.C. up to 1980; reviews the state of B.C. abalone fishery up to the present regarding total catch, catch per area, and effort per vessel and day; discusses research findings and concerns as well as aquaculture possibilities; and presents recommendations for improved management of the above stocks. This report is the first in a series of publications by the DFO aimed at providing an annual summary of the abalone fishery, based on harvest logs submitted by licence holders. Due to the confidentiality of harvest logs, only general fishing areas, rather than specific sites, will be discussed.

SOURCE OF DATA

Data on abalone landings by year and by area were extracted from the B.C. Catch Statistics annual reports for years 1952-1976 (earlier data were not summarized). These data were derived from the sales slips received by the Department of Fisheries and Oceans. The 1977-1980 data were derived from the fishermen's harvest logs and are considered to be much more accurate than the published data from sales slips. For this reason, some discrepancy is expected between the catch data from this report and from the Fisheries Statistics, B.C., which relies only on the sales slip system.

Fishing effort (CPUE) was calculated as kg of abalone landed per diver day, as reported in fishermen's harvest logs since 1977. Catch per diver hour could not be determined with confidence because only the 1980 harvest logs contained relatively complete records of daily diver hours. Although difficult to interpret, the fishing effort per Statistical Area and year has been included in this report for purposes of general interpretation and for comparison with future data.

The landings are expressed in kilograms (kg), metric tonnes (1 m.t. = 1,000 kg) or occasionally in pounds (lb) for comparative purposes.

REVIEW OF ABALONE (Haliotis kamtschatkana) BIOLOGY

DISTRIBUTION

Of the approximately 94 known species of abalone found throughout the world, only one species, the northern abalone (Haliotis kamtschatkana) is found in British Columbia (Breen 1980 b). This species, commonly known as the pinto abalone in California, has a coastal distribution from San Diego, California, to Alaska (Mottet 1978), and is usually found on exposed rocky substrates, often with beds of kelp nearby (Miller 1974). In B.C. and Alaska, the greatest concentrations of large-sized abalone are found from zero tide to 5m depth, but in California they are usually found in deeper waters (Cox 1962; Breen 1980 b). The individuals are clumped rather than randomly distributed (Quayle 1962), and their density is partly related to the type of habitat (Breen and Adkins 1979).

REPRODUCTION

Sexes in abalone species are mostly separate. In B.C. significant spawning by abalone does not occur until about age three, or a length of some 50 mm (Quayle 1971), and the number of eggs is smaller in younger compared to older females (Breen 1980 b). In Alaska, northern abalone reach sexual maturity at an approximate length of 65 mm (Parker, 1973 in Paul et al. 1977). Gonad maturation is apparently controlled by such factors as day length, food availability and water temperature, with abalone response to a given factor probably being species specific (Mottet 1978). During spawning from April to August (Quayle 1971; Poore 1973; Paul et al. 1977; Breen and Adkins 1980) masses of sperm and eggs (up to three million per female) are shed simultaneously into sea-water for fertilization (Breen 1980 b).

The abalone eggs hatch within a day and the free-swimming larvae drift for two to 11 days (depending on species and rearing conditions) before sinking and settling on a substrate (Mottet 1978). Larval settlement is triggered by a chemical produced by encrusting red alga Lithothamnion spp. and related genera (Morse et al. 1979). The light sensitive, young abalone, after metamorphosing to the benthic stage, seek habitats in cracks and undersides of rocks (Cox 1962).

FOOD

Abalone are selective plant feeders (Cox 1962). They consume microscopic diatoms and drifting algae when young, and shift to larger macrophyte fragments, such as kelp, when older (Breen 1980, a&b). When offered a variety of kelp, the northern abalone select Macrocystis (Breen 1980 a). Paul et al. (1977) found that the Alaskan northern abalone preferred feeding on diatoms, especially Chaetoceros spp. and Navicula spp., to feeding on macroalgae.

AGE AND SIZE

The northern abalone, like some other abalone species, cannot be aged from growth rings (Leighton and Boollootian 1963; Sainsbury 1977; Breen 1980 a). Quayle (1971) measured sizes of tagged abalone and found that the growth rates were almost identical in northern and southern B.C., which he attributed primarily to similar water temperatures. However, Breen (1980 a) found that growth rates of abalone in northern B.C. varied greatly among areas sampled and appeared to be related directly to food supply (see below).

The B.C. abalone may reach a length of 20 mm in the first year, 35 mm in the second year, and 50-60 mm in the third year (Quayle 1971). The mean growth increment from Quayle's (1971) tag returns of abalone 60-140 mm long was 6.5 mm per year, so that an abalone of near maximum size (140 mm) may be 15 years old (Fig. 1). However, most abalone measure less than 10 cm in length (Cox 1960). In good habitat, northern abalone may reach the minimum legal size of 100 mm in six to eight years (Fig. 1).

Some abalone populations have stunted growth and never reach the recorded maximum size. Such "surf" abalone, as they are called by fishermen are often found in exposed locations or in Pterygophora kelp beds and are distinguished by shells that are relatively small, thick and heavily encrusted with organisms, and eroded apparently from age (Breen 1980 a).

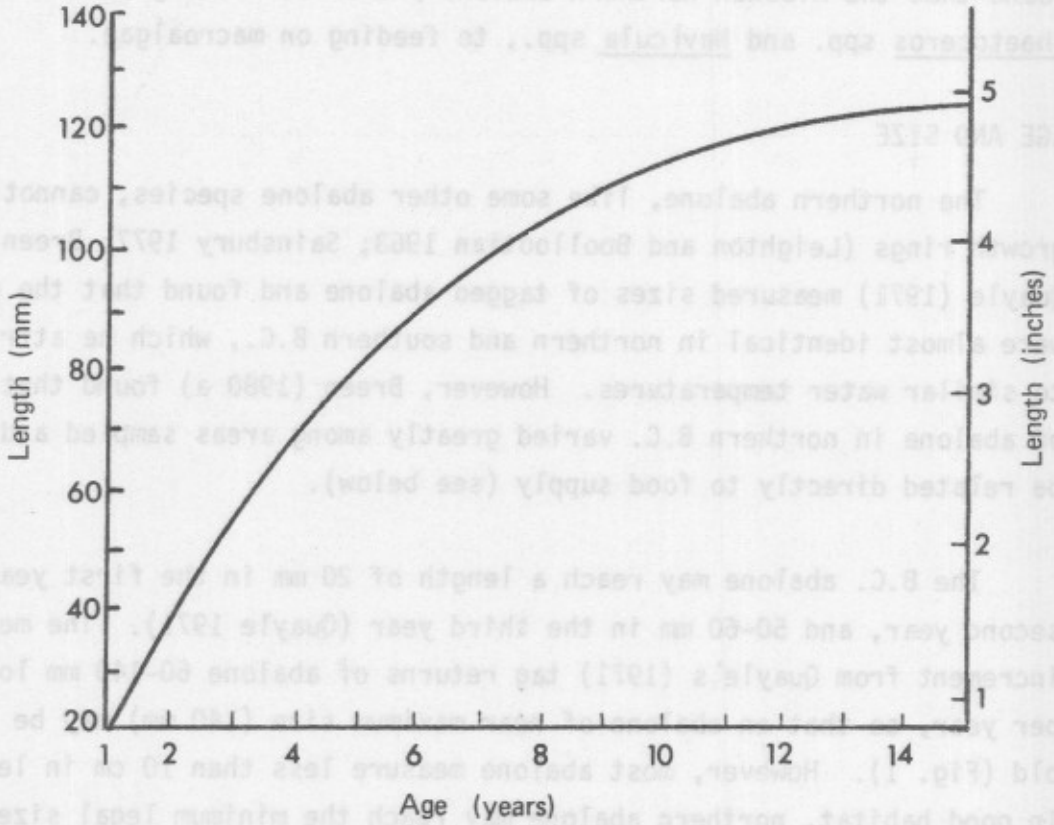

Fig. 1. Suggested growth curve for abalone *(H. kamtschatkana)*. (from: Quayle, 1971).

Researchers found that abalone populations differ in final size depending on the dominant kelp species present in the area (Breen and Adkins 1979; Breen 1980 a & b). Growth rate and final size of adults were found to be related directly to food supply, with large abalone in low densities observed under giant kelp beds (Macrocystis spp.), and smaller-sized abalone in higher densities observed under tree kelp canopies (Pterygophora spp.) and in sea-urchin barrens (Breen and Adkins 1979; Breen 1980 a & b). Of the two kelp types above, Macrocystis is a better and more abundant food source. But food supply does not govern abalone abundance; rather the poorly understood combined effects of larval settlement and mortality rates determine the population density (Breen 1980 a&b).

MORTALITY FACTORS

Adult abalone have few predators. Probably the two major ones are octopi (Octopus spp.) and sunflower starfish (Pycnopodia helianthoides), while the boring sponge (Cliona celata) may increase predation by weakening the shells of old abalone (Breen 1980 a). Sea otters can be very destructive to abalone as was observed in California (Burge et al. 1975), but they are not a problem in B.C. (F. Dickson, D.F.O, pers. comm.). Other predators include several fish and starfish species, crabs and whelks (Mottet 1978). The predators of small abalone are more numerous but poorly known and may include many species of fish, crabs, starfish, whelks and polychaete worms (Mottet 1978; Breen 1980 a).

Severe storms may result in heavy mortalities of abalone whereby they may be dislodged, then crushed by rolling boulders, or transported to unsuitable habitats where they may die (Cox 1962). Also, an influx of freshwater or of sand may lead to rapid death of abalone through osmoregulatory imbalance or suffocation respectively (Bonnot 1930; Cox 1962).

Natural mortality rates of abalone (i.e. deaths from all causes except fishing) are poorly known. Breen (1980 a) estimated that the annual finite natural mortality rate of abalone in B.C. in the absence of fishing is around 21%; in fished populations the total annual mortality rate is 40% (P. Breen, pers. comm.). Of concern is the fishing mortality of sub-legal abalone which may have their foot cut while being pryied from a substrate, or of sub-legals brought up to the surface and then thrown back overboard (Breen 1980 a). Due to

excessive bleeding and in the presence of predators, mortality of an injured abalone may approach 50-100% (Burge et al. 1975; Cicin - Sain et al. 1977).

INTERACTIONS WITH SEA-URCHINS

A complex relationship exists between abalone and sea-urchins, as was observed in California, Australia and Hawaii (Cox 1962; Shepherd 1973; Burge et al. 1975; Cicin - Sain et al. 1977). Breen and Adkins (1979) suggest that similar interactions between abalone and sea-urchins may exist in B.C., adding that there is indication in California and Australia that areas heavily fished for abalone may never recover fully due to invasion of the habitat by sea-urchins. However, P. Breen (pers. comm.) cautions that the overall relationship between abalone and sea-urchins, especially in unfished areas, appears to be more complex than is presently believed and requires further study.

WORLD-WIDE ABALONE USE, PRODUCTION AND TRADING

Abalone is a relatively scarce commodity with only about 23,000 metric tonnes (50 million pounds) harvested world-wide per year in the last decade (Anon. 1976). Abalone is valued for its edible muscular foot which comprises approximately 40% of its body weight (Livingstone 1952; Quayle 1962). It is a popular seafood throughout the Orient, in Mediterranean countries, and in the United States, especially California (Anon. 1976). Abalone are shipped live, frozen, or processed and frozen into steaks, and also canned in brine; in Asia, abalone are eaten raw, sauteed, boiled, steamed and roasted; in Japan, they are eaten raw or are dried, salted, pickled in bean paste, boiled in water, or canned in soup, while abalone viscera are used for salted refreshments; in North America, abalone are served as pounded, sauteed steaks, with trimmings often used for chowder soups; abalone shells are widely used for handicrafts (Cox 1962; Anon. 1976; Mottet 1978).

CANADA

Harvesting, processing and export

British Columbia is the only abalone producing region in Canada. According to an industry representative, the B.C. product is apparently preferred by the world

buyers due to the size, colour and texture of the B.C. abalone (F. Dickson, DFO, pers. comm.). Prices paid for abalone to B.C. fishermen rose from $0.42 per pound in 1970 to $2.81 per pound in 1980, bringing the total landed value of abalone in B.C. to nearly $2 million in 1977 and in 1978 (Table 1).

Prior to the development of scuba gear during World War II, commercial abalone harvesting in North America (U.S.) was done with the use of hard hat divers (Cox 1962). In addition, shore picking at low tides by native Indians and recreational skin diving fishery continue to be practiced on a limited scale. To-day, commercial divers in B.C. generally use the standard scuba gear (Fig. 2) and blunt diving knives or abalone harvesting tools. Abalone that are not firmly attached to rocks may be removed by striking them sharply on the side with a knife, flipping them up in the water and scooping them into a bag. Some divers have marks on their knives or tools indicating the legal size, and some experienced divers may use the distance between their thumb and finger to gauge abalone size (F. Dickson, pers. comm.).

The cost of abalone production is very low compared to most other seafood products, since the processing usually involves only freezing. This generalization, however, excludes the very high initial costs to the fishermen for equipment, and subsequent annual costs for maintenance of freezer boats and accessories, as well as hiring of support crew and divers. At sea, the vessels with freezer units glaze their catch by first allowing the abalone to drain for a short period; the catch is then weighed and frozen; subsequently, the frozen abalone are removed and dipped briefly in saltwater. This procedure provides a protective coating or glaze that can add up to 10% to the total weight of abalone. Weight of glaze is included in the landing data, and prices offered by companies are usually set for the glazed product. However, some companies will deduct a small amount from the glazed weight to compensate for the weight of glaze. On shore, the processing companies hold the abalone in cold storage until export time, although a very small quantity may also be smoked. In 1978, costs to the land processors were approximately 11¢ per kg (5¢ per lb) (Proverbs MS 1979). In 1980, the processors paid $2.81/lb for the product and received from buyers an average of $3.16/lb (Fisheries Statistics, B.C. 1980).

Fig. 2. An abalone diver.

Since 1975, five to 10 companies (five in 1980) were involved in processing abalone in B.C., but a large portion of catch was usually handled by only two or three firms located in the northern regions. In addition, a considerable number of fishermen are now marketing their own product and storing the catch in independent cold storages until a competitive price is offered (Proverbs MS 1979). Despite the increased number of processing firms in B.C., few companies use different processing methods such as smoking, canning or live export. Recently, the latter method became more popular and at least two operators are now exporting live abalone.

The B.C. abalone are exported either by the processing companies or by the trading and wholesale firms. On a world scale, Canada is a minor producer and exporter of abalone, generally contributing less than 1% to the U.S. abalone imports in the last decade (Append. 3), and less than 10% to the Japanese imports since 1973 (Append. 2). Japan is the major buyer of B.C. abalone (nearly 400 m.t. exported to Japan in 1977 and 1978, Append. 2), but smaller amounts are also exported to Hong Kong and the United States, particularly to Seattle, New York, Los Angeles and Honolulu (Append. 3) (Proverbs MS 1979). Finally, a small percentage of B.C. abalone is consumed domestically, and some is shipped east to Toronto.

OTHER COUNTRIES

The world landings of abalone, as reported by the Food and Agriculture Organization (FAO) of the United Nations averaged from 12,000 m.t. to 17,000 m.t. annually in the last decade, declining somewhat since the early 1970's (Table 2). The FAO data, however, are incomplete as they do not include the substantial landings made in Australia (5,000-8,000 m.t. per year) (Table 3), nor apparently the production of abalone through aquaculture. Of the three major abalone categories distinguished by the FAO, the largest contribution to the 1970-1979 world landings was made by the "Abalones" (7,000-10,000 m.t. per year); the second largest contribution by the Japanese "Giant abalones" (5,000-6,500 m.t. per year); and the third largest by the South African "Perlemoen abalones" (~ 1,000 m.t. per year). (Append. 1).

Table 2. World abalone landings (m.t.) by country and species, 1970-1979[a].

Country	Species[b]	Year 1970	1971	1972	1973	1974	1975	1976	1977	1978	1979
Japan	Giant abalones (Haliotis gigantea)	6,500	5,700	5,800	5,800	4,971	5,416	5,655	5,203	5,377	4,866
Mexico	Abalones (Haliotis spp.)	6,700	6,400	5,400	4,700	6,062	6,407	6,447	6,043	4,550	3,723
United States	Abalones	1,300	1,300	1,400	1,500	1,177	1,020	806	1,036	1,165	1,326
South Africa	Perlemoen abalone (Haliotis midae)	1,900	1,200	900	900	970	1,078	1,037	736	799	735
	Abalones	-	-	-	0[c]	0	0	0	0	0	0
Rep. Korea	Abalones	400	600	1,000	2,400	518	568	622	606	496	661
New Zealand	Abalones	600	1,500	700	800	439	505	562	768	581	479
Canada	Abalones	00[d]	00	100	100	26	57	273	428	433	186
Philippines	Abalones	-[e]	-	-	-	-	-	28	9	188	223
Total		17,400	16,700	15,300	16,200	14,163	15,051	15,430	14,829	13,589	12,199

[a] 1970-1975 data from F.A.O. (1975); 1976-1979 data from F.A.O. (1979); FAO did not include Australian abalone catch (Table 3).

[b] Scientific name given in parentheses.

[c] More than zero but less than 0.5 m.t.

[d] More than zero but less than 50 m.t.

[e] Nil.

Table 3. Australian abalone landings and exports, 1970/71 - 1978/79[a].

Year	Landings[b] (m.t.)	Exports[c] (m.t.)	% Exported
1970/71	7,869	3,246	41.3
1971/72	7,957	3,575	44.9
1972/73	6,418	3,179	49.5
1973/74	6,032	3,046	50.5
1974/75	5,735	2,537	44.2
1975/76	7,850	2,683	34.2
1976/77	6,320	2,764	43.7
1977/78	5,099	2,820	55.3
1978/79	6,197	2,948	47.6

[a]From: Australian Fisheries (Feb., Oct., 1972; March, Nov., 1973; June, Sept., 1974; Sept., Oct., 1975; Aug., Oct., 1976; June, Nov., 1977; April, 1978; March, Oct., 1979; July 1980).

[b]Live weight.

[c]Frozen and canned.

Table 4. Chilean loco landings, 1970-1979[a].

Year	Landings (m.t.)	Year	Landings (m.t.)
1970	3,800	1975	5,928
1971	5,000	1976	10,012
1972	6,700	1977	14,161
1973	5,400	1978	12,252
1974	5,928	1979	16,571

[a]See Table 2 , footnote "a".

The largest world producers of abalone are Japan, Mexico and Australia (~ 5,000-7,000 m.t. per country per year); United States and South Africa each harvest annually approximately 1,000 m.t. of abalone; and Republic of Korea, New Zealand, Canada and Philippines are among the significant but lesser producers (Tables 2&3). In addition, Chile harvests annually from 4,000 m.t. up to 17,000 m.t. (in 1979) of loco (Table 4). Loco is a marine snail (Concholepas concholepas) of the family Muricidae, which the Japanese import as a cheap substitute for abalone (Stanistreet 1978).

The major world importer of abalone is Japan. During 1973-1979, over 10 countries (chiefly Australia, Canada and Chile (Chilean loco)) supplied Japan with approximately 1,500-5,000 m.t. of abalone products per year (Append. 2). The United States is another major importer of abalone, with approximately 1,000-2,000 m.t. received annually during 1966-1980 (Append. 3). Of the over 30 countries trading with the United States at some time during that period, Mexico generally contributed over 70% to the total U.S. import, with Australia and Chile (the latter presumably supplying Chilean loco) being the only other significant suppliers (Append. 3). Other importing countries include Hong Kong, Malaysia and Singapore but the data are incomplete.

The world's largest exporters of abalone are Australia and Mexico, with many other countries exporting smaller amounts (Proverbs MS 1979). Australia exported annually approximately 2,500-3,500 m.t. of abalone during 1970-1979, which translates to over 40% of Australia's total abalone production (Table 3). The major consumer of Australian abalone is Japan (1,200-1,800 m.t. exported to Japan annually during 1973-1979), with Hong Kong, United States, Malaysia and Singapore among the lesser but significant markets (Proverbs MS 1979). Mexico exports annually 1,000-2,000 m.t. to the United States, probably its chief buyer (Append. 3) (Proverbs MS 1979).

At present, the maximum potential world market for abalone is difficult to access. However, with fish and shellfish resources diminishing around the world, and given an expanded and economically profitable culturing of abalone in the near future, a wider market is expected, particularly in the United States (Anon 1976).

ABALONE AQUACULTURE

Records of abalone culturing date back to 1881 when Japan pioneered the practice. Intensive cultivation began there in the 1940's and to-day Japan is the world leader in abalone farming. California and Mexico, prompted by severe depletion of their stocks, entered this field in the 1970's. Discoveries of new aquacultural methods in the last 10 years boosted greatly the overall production success.

Abalone is suitable for domestication for several reasons: it is a primary feeder converting inexpensive macroalgae into animal protein; it has a simple life cycle that can be replicated in a laboratory; tends to be gregarious in nature which encourages high stocking rates; is resistant to diseases; and does not tend to accummulate toxic wastes or heavy metals due to its negligible content of fatty tissues (Anon. 1976; Mottet 1978). The abalone is also a gourmet food item with a high market value.

The available methods of artificially enhancing and/or rehabilitating abalone stocks include: outplanting of hatchery produced seed into depleted areas; transplanting adult brood stock into areas where there is none; modifying the bottom substrate to increase juvenile settlement and survival; planting of kelp to increase food supply; and controlling the abundance of predators (Burge et al. 1975); as well as transplanting stunted populations into areas more favourable for growth, as is done in Japan (Mottet 1978).

The techniques for artificial spawning and culturing of abalone juveniles are well established for various species in Australia, Japan and California (Ino 1968; Sanders 1971; Bardach et al. 1972; Rutherford 1976; Shepherd 1976; Mottet 1978). Some of the recent breakthroughs in the methodology include the discovery that the addition of hydrogen peroxide to seawater induces spawning in gravid male and female abalone (Morse et al. 1976), and the discovery by Japanese researchers that intense ultra-violet irradiation of seawater, combined with temperature stress, induces an epidemic spawning in both sexes resulting in a high fertilization rate of 92-97% (previous success rate was around 20%) (Kikuchi and Uki 1974 a&b; Klopfenstein D. and I. 1976).

The major drawback to intensive and economically profitable culturing of abalone is the high cost of seed production in hatcheries, slow growth rate and lack of adequate methods for rearing to a marketable size (Anon. 1976). In particular, an accurate knowledge of specific food preferences (natural and/or artificial) and of appropriate feeding methods in captivity are required. To date, larger abalone are reared either in tanks or ponds on shore, or out on sea bottom in natural but often hostile environments (Ino 1968; Anon 1976; Shepherd 1976).

Japan

There are presently over 10 research institutions/hatcheries in Japan, producing annually several billion seed abalone (Mottet, 1978). The juveniles, grown to 1.5-2.0 cm in length, are either released directly into denuded or previously unproductive areas as a conservation measure, or are sold to fishermen's cooperatives for stocking by hand of natural reefs for later capture at marketable size (Tamura 1960; Bardach et al. 1972). The fishermen also transplant wild seedlings from highly productive to depleted areas, and improve selected nursery areas by dropping stones to serve as abalone substrate (Ino 1968). The Japanese fishermen are organized into cooperatives with exclusive rights over sea-use in specified zones. This allows for and encourages the above collective management of the resource.

In addition, a considerable number of artificial reefs were constructed in Japan to serve as abalone habitats; these are seeded with artificially propogated or with relocated natural seed abalone (Sanders 1971). In a very successful 1975 experiment, some 100,000 abalone spat were planted on man-made iron reefs, then submerged to depths of from 5 to 7 m (Anon. 1977). Resulting harvest yielded approximately 25 abalone/m^2, compared to the previously recorded mean yield for the same region of 0.3-0.5 abalone/m^2. The abalone so produced were similar in size to natural abalone (14cm, 405g).

California

Compared to Japan, California is still relatively experimental in its abalone aquaculture. The emphasis in California is open-ocean production in underwater containers to protect abalone from predators and from wave action, while maintaining a natural environment (Mottet 1978).

At present, California has in operation several commercial enterprises with hatcheries and a state experimental station (Klopfenstein, D. and I. 1976):

1) The California Marine Association (Calma) operates the Morro Bay hatchery, producing and selling red abalone seed for stocking by local county governments. Other developments include rearing for market of abalone in shoreside ponds, producing 2-3-year olds for canning, and growing abalone commercially in special shelters below an oil platform in the Santa Barbara Channel.

2) The Ad-Lab at Port Hueneme is a private firm which grows seed for the Ventura County natural enhancement program.

3) The Moneterey Abalone Farm at Monterey is doing nutritional studies to optimize growth.

4) The Abalone Hatchery at Santa Barbara is growing seed abalone to be planted by commercial divers in areas of poor seed production. This is a non-profit organization sponsored by divers and the processing industry and related to the Santa Barbara Foundation.

5) Pacific Ocean Farms of Carmel is rearing seed for stocking artificial shelters made of highway culvert pipes, 1.2m in diameter. A diver will provide kelp for food and remove fouling organisms. It is estimated that one hectare covered with these shelters could produce 1,180 tons of abalone per year (525 tons per acre). The company intends to use an open coastal lease.

6) The California State Marine Culture Laboratory at Granite Canyon near Carmel mass-produces seed abalone. This laboratory has also developed methods to relocate and plant healthy juveniles, and has developed inexpensive artificial habitats (Mottet 1978).

British Columbia

The scientific research and commercial ventures concerning abalone propogation in B.C. are at a very elementary stage of development. In 1978, the Department of Fisheries and Oceans granted two abalone aquaculture licences to be renewed annually. Some of the goals of these operations were to develop a polyculture of seaweed and abalone, to experiment with abalone spawning and development of seed stock, to spawn up to one million seed, and to determine food preferences, growth rates, maintenance requirements and optimal pond design for B.C. abalone in a specific environment. Presently, B.C. has four licenced operations in various stages of development. The major goals of these operations are to produce and develop seed stock and to rear abalone to marketable size.

Other

In Mexico, a hatchery has been built to provide abalone seed for the west side of the Baja Peninsula, and in England a company on the Channel Islands is developing an abalone propagation program (Mottet 1978).

ABALONE RESEARCH

In British Columbia, research on abalone for managing the fishery is carried out by the Pacific Biological Station at Nanaimo. Research topics include abalone growth, mortality, recruitment and production rates, as well as the impact of commercial fishery on stock size to determine sustainable yield. Some of the major findings in B.C. and elsewhere are presented below. Abalone surveys are also conducted by the Field Services Branch of the Department of Fisheries and Oceans, usually to examine areas with potential conflicts between user groups. Areas closed to commercial fishery are also surveyed. Results of one study are reported by Breen, Adkins and Sprout (in press).

BRITISH COLUMBIA FISHERY REGULATIONS

REGULATIONS PRIOR TO 1976

Prior to 1976, the abalone fishery was relatively undeveloped and few fishing regulations existed. The season was open year round except for a closure every third year during 1911-1947. Minimum legal size of abalone decreased from 102 mm (4") during 1908-1913 to 89 mm (3.5") during 1914-1937, to 64 mm (2.5") during 1938-1977. After 1968, an abalone fisherman required only a personal fishing licence and a "C" licence for his boat. The size of commercial fleet was unrestricted and from 1975 to 1976, some 60 vessels had participated according to sales slip records.

1976 REGULATIONS

The 1976-1980 commercial fishery regulations are summarized in Table 5. In 1976, the regulations were largely as in the preceeding years but the fishery was closed in November when the landings reached a very high total of 273 m.t. (602,000 lb). Since 1976, major amendments were made to the Pacific Shellfish Regulations in order to reduce future abalone landings.

1977 REGULATIONS

The following controls were made effective in 1977:

1. Limited entry

   Licences were issued only to persons who operated vessels which:

   (i) landed in excess of $2,000 of abalone in 1976 or earlier, and

   (ii) made more than 50% of their fishing income from abalone.

Not more than one licence was issued per individual and not more than one vessel could be used per licence. A licence appeals board was set up to review each licence application; following appeals, 29 individuals were licenced to fish abalone, each paying a $200 licence fee. The ownership of a vessel was not required to qualify for a licence, but once obtained, the abalone licence

Table 5. Summary of major commercial fishery regulations for abalone, 1976-1980.

Year	Length of season: No. months	Length of season: Interval	No. vessels licenced	Legal size of abalone	Quota	Effort per boat	Log data to submit
Prior to 1976	12	All year	No licencing (21 in 1975)	64 mm	None	Unlimited	No
1976	10½	Jan.1-Nov.14	No licencing (43)	64 mm	None	Unlimited	No
1977[a]	8	Apr.1-Nov.27	29	100 mm	None	Max. 3 divers	Yes
1978	3	Mar.1-May 31	27[b]	100 mm	None	Max. 3 divers	Yes
1979[c]	~ ½	Apr.15-May 3[d]	26	100 mm	226,800 kg (500,000 lb)	Max. 3 divers; (4,500 kg (10,000 lb) vessel quota	Yes
	~ 6½	May 8-Nov.30[e]					
1980	7½	Apr.15-Nov.30	26[f]	100 mm	113,400 kg (250,000 lb)	4,500 kg (10,000 lb) vessel quota Divers unlimited	Yes

[a]Also: large area closures; immediate replacement of sub-legal abalone; $200.00 personal licence fee; minimal landing requirement of 2,270 kg (5,000 lb) for licence renewal; and licence non-transferability.

[b]One of these vessels did not fish.

[c]Revoked minimum landing requirement for licence renewal.

[d]Open fishery.

[e]Quota fishery.

[f]One vessel was burned at start of season.

holder had to place his licence upon the vessel in which he had to own the majority interest, and the abalone licence was not transferable. However, the abalone licence holder could transfer his licence to another vessel, but only when he was the major owner of the new vessel. In an effort to reduce licence speculation and to ensure that only bona fide fishermen participated in the fishery, a 2.3 m.t. (5000 lb) minimal landing was required for renewal of the abalone licence.

2. Limited length of season

The 1977 abalone fishery season was reduced to eight months (April 1 - November 27).

3. Limited effort per boat

Abalone licence holders were limited to a maximum of three divers.

4. Minimum legal size of abalone

The legal size of abalone was changed from a width to a length in order to facilitate measurement, and the minimum length was increased from 90 mm (or a width of 64 mm (2.5")) to a length of 100 mm (~ 4"), as the previous size limit did not afford adequate protection to abalone stocks. According to Quayle's (1971) abalone growth curve, the new size regulation increased the age of harvestable abalone from about six years to 7-12 years.

5. Catch inventory

The abalone licence holders were required to submit each month daily harvest log sheets with detailed catch and effort data (diver days and hours) and with maps showing exact locations of harvest. The mandatory log system was aimed at improving the accuracy of data base to be used for management.

6. Harvesting techniques

In order to reduce the sub-legal abalone mortality from poor harvesting practices, all size measurements were to be made underwater immediately upon removal of abalone from substrate, and all sub-legals were to be returned immediately to their original rock.

7. Area closures

Additional large areas were closed to commercial fishery, especially on the north coast where local residents and native Indian Bands were concerned about the loss of their recreational and Indian food fisheries due to heavy commercial harvesting.

1978 REGULATIONS

The 1977 regulations continued into 1978 but the season was further reduced to only three months (March 1 - May 31) since the 1977 controls failed to limit abalone landings. Some additional area closures were also implemented. In 1977, only 21 out of 29 licenced vessels reported landings equal to or higher than the minimum 2.3 m.t. (5000 lb) required for licence renewal. Following appeals, 27 licences were issued for the 1978 abalone fishing season; no new licences were issued.

1979 REGULATIONS

Despite the many new restrictive regulations, landings in 1978 remained high as the efficiency of the commercial fleet continued to increase. Additional radical measures were required to halt the severe exploitation of remaining abalone stocks. In 1979, a quota of 227 m.t. (500,000 lb) was imposed on the abalone fishery. This quota was based on the best estimate of annual abalone production of 113 m.t. (250,000 lb) (Breen 1980 a), and on an assumption that some unfished stocks with large-sized individuals still remained. The fishery was divided into two seasons: a short open fishery (April 15 - May 3), and a longer quota fishery (May 8 - November 30), for a total season length of 7.5 months. A catch of 113-136 m.t. (250,000 - 300,000 lb) was anticipated for the open fishery, with

the remaining allowable catch to be divided equally among the 26 licence holders (one vessel did not fish in 1978 and lost its licence). This guaranteed a minimum of 4.5 m.t. (10,000 lb) per licenced vessel. The abalone vessels were required to have their landings inspected by Fishery Officers after each trip prior to unloading, in order to update the total catch. The 2.3 m.t. (5,000 lb) minimum landing requirement for licence renewal was revoked.

The 1979 management policy attempted to accommodate operators of small vessels which lacked freezing facilities, and to provide for fresh local markets, both of which would have been seriously impaired by a short, open fishery. These regulations also supported the Minister's policy of providing some protection to the operators of small vessels, many of whom pioneered the fishery.

1980 REGULATIONS

The 1980 regulations were aimed at further restricting the total abalone landings while protecting the small operators. In 1980, the fishing quota on abalone was reduced to 113 m.t. (250,000 lb), following more precise biological findings regarding the annual sustainable yield. This quota was assigned equally among vessels, assuring 4.5 m.t. (10,000 lb) per licence holder. The season was open from April 15 to November 30.

The limited entry of 26 vessels and the $200.00 licence fee were continued for this fishery, and the licence holder had to be also the registered owner of the designated vessel; personal abalone licences continued to be non-transferable. A minimum abalone catch was unnecessary to be eligible for licence renewal in 1981 and there was no restriction on the number of divers, but each had to have a valid personal commercial fishing licence. Prior to fishing, each abalone licence holder had to check in with the appropriate District Office, and all abalone vessels had to be inspected by a Fishery Officer after each trip prior to unloading. As in previous years, log sheets accompanied by maps showing exact harvest locations, had to be filled daily and made available on demand, and sales slips had to be submitted for all abalone harvested.

RECREATIONAL FISHERY REGULATIONS, 1980

As in previous years, the recreational fishery on abalone was open throughout the year along the entire B.C. coast, except for the waters within 1.6 km of the Mitlenatch Island Park in the Strait of Georgia (Fig. 3b). This was an increase from 0.8 km zone set in 1973. As in the commercial fishery, the minimum legal size was 100 mm (~ 4"). Since 1973, a daily bag limit was set of 12 abalone in the waters south of Cape Caution (just north of Vancouver Island, Fig. 3a) and of 24 abalone north of Cape Caution, as well as a two-day possession limit (prior to 1973, no catch limit existed). The larger bag limit allowed for the northern regions reflected the relatively larger abalone stocks and fewer sport fishermen in the northern compared to southern areas.

NATIVE FOOD FISHERY REGULATIONS

As in the recreational fishery, the native food fishery was open all year and along the entire B.C. coast. The legal size of 100 mm (~ 4") was the same as in other fisheries. By regulation, an Indian was required to obtain a permit from the local Fisheries Office to harvest abalone for food purposes. Unlike the recreational fishery, there were no restrictions on the amount of abalone which could be harvested under the conditions of this permit.

COMMERCIAL ABALONE AREA CLOSURES

Commercial abalone closures have been implemented in a number of areas along the B.C. coast, with major regulations introduced in 1977. Generally, closures have been set in order to conserve overharvested or low productivity areas, and to preserve traditional native food fishing areas and important recreational sites. Areas closed, reasons for closures and implementation dates are given in Table 6. Boundaries of closed areas are specified in Append. 4.

Table 6. Area closures for commercial abalone fishery, B.C., 1980[a].

Area[b]	Date closure implemented	Comments
Area 1 - Masset Inlet, Masset Sound, and McIntyre Bay	1977	- recreational harvest - native harvest
Area 1 - Virago Sound	1978	- low stock levels - recreational harvest - native harvest
Area 2E - Juan Perez Sound	1973	- traditional native harvest - recreational harvest, in conjunction with Hotspring Island
Area 2E - Cumshewa Inlet	1977	- low levels of old individuals; few juveniles and sub-legals; possibility of "recruitment" overfishing
Area 2E - Skincuttle Inlet and Carpenter Bay	1979	- low stock levels
Area 2W - Rennell Sound	1977	- recreational harvest; one of two areas in Area 2W that is accessible by road from east coast
Area 2W - Skidegate Channel	1977	- traditional native harvest - recreational harvest; same as for Rennell Sound
Area 2W - Tasu Sound	1977	- recreational harvest - surveys in this area by Dept. Fisheries and Oceans in June, 1981, have indicated very low abundance of legal-sized abalone; this area has been closed to recreational harvesting since 1980

Table 6. (Cont'd).

Area[b]	Date closure implemented	Comments
Areas 4 and 5 - parts of Porcher Island, north end of Banks Island	1977	- native harvest (Kitkatla Band) - recreational harvest
Areas 4 and 5 - Stephens Island, Banks Island closure extended southward	1980	- native harvest (Kitkatla Band) - recreational harvest
Area 6 - Campania Island, Gil Island, Laredo Channel	1977	- native harvest (Klemtu, Bella Bella Bands) - recreational harvest - concern by Fishery Officers that recreational divers are overfishing the resource - closure was modified in 1981 and will be evaluated at end of season
Area 7 - inside Price Island, Swindle Island, Princess Royal Island, Don Peninsula	1977	- native harvest (Klemtu, Bella Bella Bands)
Area 8 - North end of Calvert Island	1977	- low stock abundance (Fishery Officer estimates)
Areas 9 and 10 - Rivers and Smith Inlets	1978	- low stock abundance
Areas 12 - 19 - Lower Johnstone Strait, Strait of Georgia, Strait of Juan de Fuca	1971	- low stock abundance - recreational harvest thought to meet or exceed what stocks can sustain already
Areas 21 - southwest coast of Vancouver Island	1978	- concern by Fishery Officers for low stock abundance
Areas 23 and 24- Barkley Sound and Clayoquot Sound	1978	- these areas were fished very heavily during 1970-1973; stocks have not recovered sufficiently to permit re-opening
Area 26 - Kyuquot Sound	1980	- conservation; concern by Fishery Officers for low stock abundance.

[a]For area boundaries see Appendix 4.

[b]See Figs. 3a and b for area location.

COMMERCIAL CATCH

ANNUAL LANDINGS AND THEIR DISTRIBUTION BETWEEN NORTH AND SOUTH B.C., 1952-1980

During 1952 to 1980, the B.C. commercial fishery has landed a total of 1,836 metric tonnes (m.t.) (4,048,800 lb) of abalone valued at 6.8 million dollars (Table 1). Contributions to this total by specific time periods were as follows:

1952-1960	2%
1961-1970	6%
1971-1975	12%
1976-1980	80%

In 1977 and 1978 alone, 48% of the historical total was harvested.

Of the overall total, the northern B.C. (Statistical Areas 1-10, Fig. 3a) yielded 83% and the southern B.C. (Statistical Areas 11-27, Fig. 3b) only 17% (Fig. 4,Table 7). Yet, prior to 1973, the major portion of annual landings of abalone was taken from the south (especially Statistical Area 12), except during 1959 to 1965 when landings from the north (Areas 1-6) predominated (Fig.4, Table 8). In 1973 and 1974, both the north and south coasts produced similar quantities of abalone, but from 1975 to 1980, the north coast yielded 78% to 98% of the annual B.C. landings (Fig. 4, Table 8).

DISTRIBUTION OF LANDINGS BY STATISTICAL AREA, 1952-1980

The bulk (71%) of the total historical (1952-1980) abalone harvest has originated from only three areas, and most of it in the last five years (Fig.4, Table 7):

Area (Fig.2a)	% Of total historical harvest
2E (east side of Queen Charlotte Islands)	29.4%
5 (off Banks Island)	19.7%
6 (in Caamano Sound - Estevan Group and Aristazabal Island)	22.0%

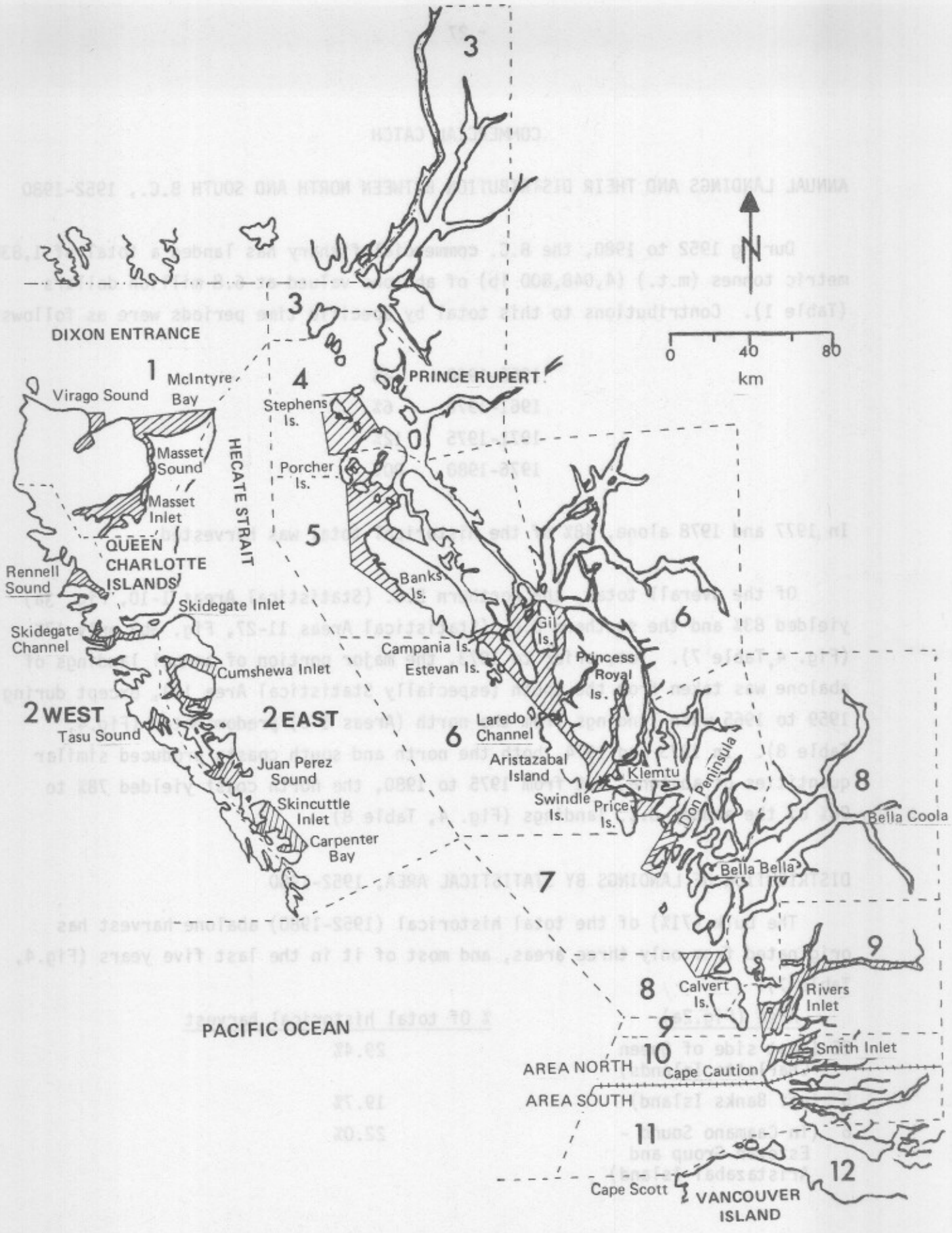

Fig. 3 a. Location of Statistical Areas in northern B.C. and 1980 area closures (hatched).

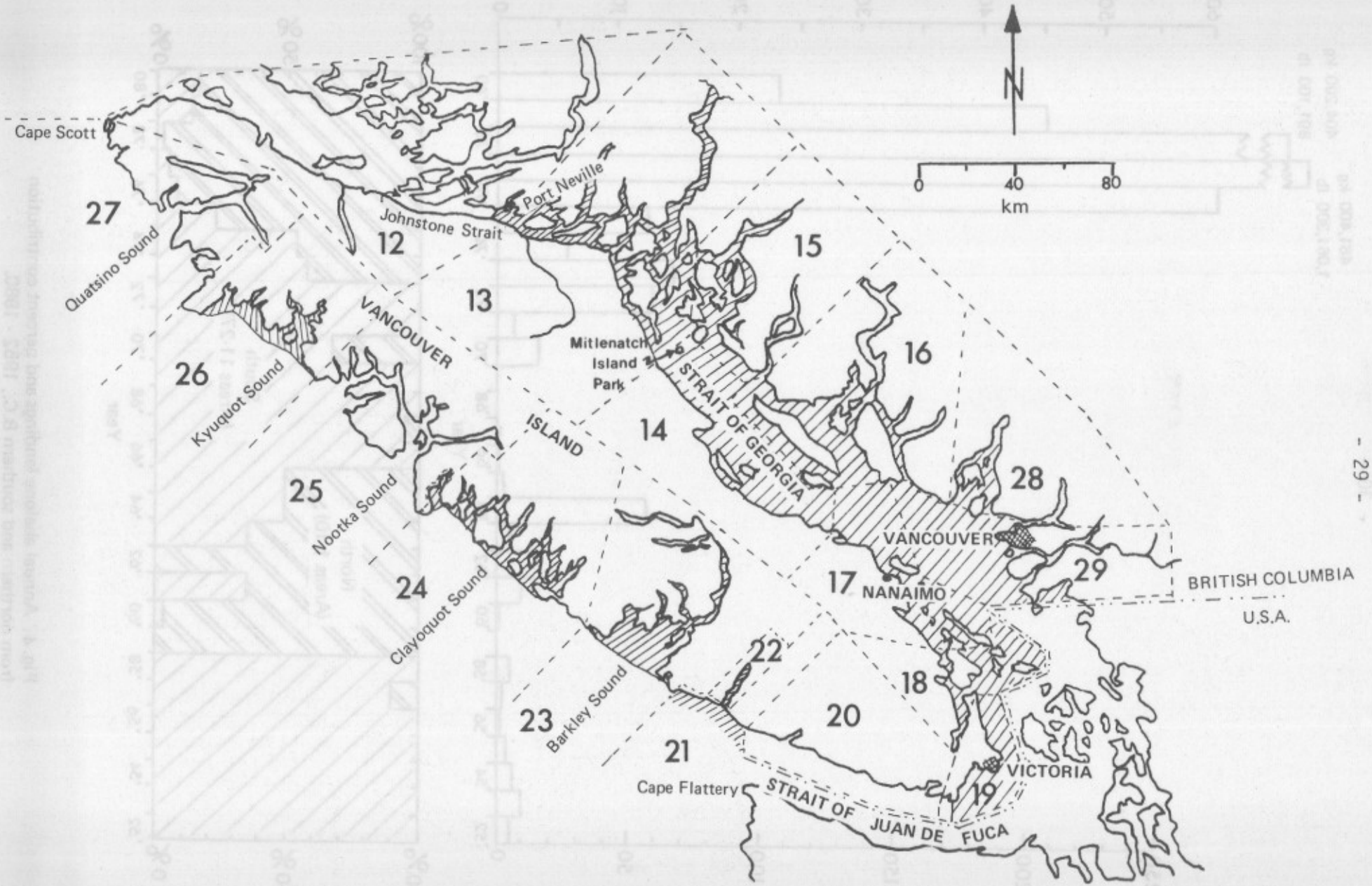

Fig. 3b. Location of Statistical Areas in southern B.C. and 1980 area closures (hatched).

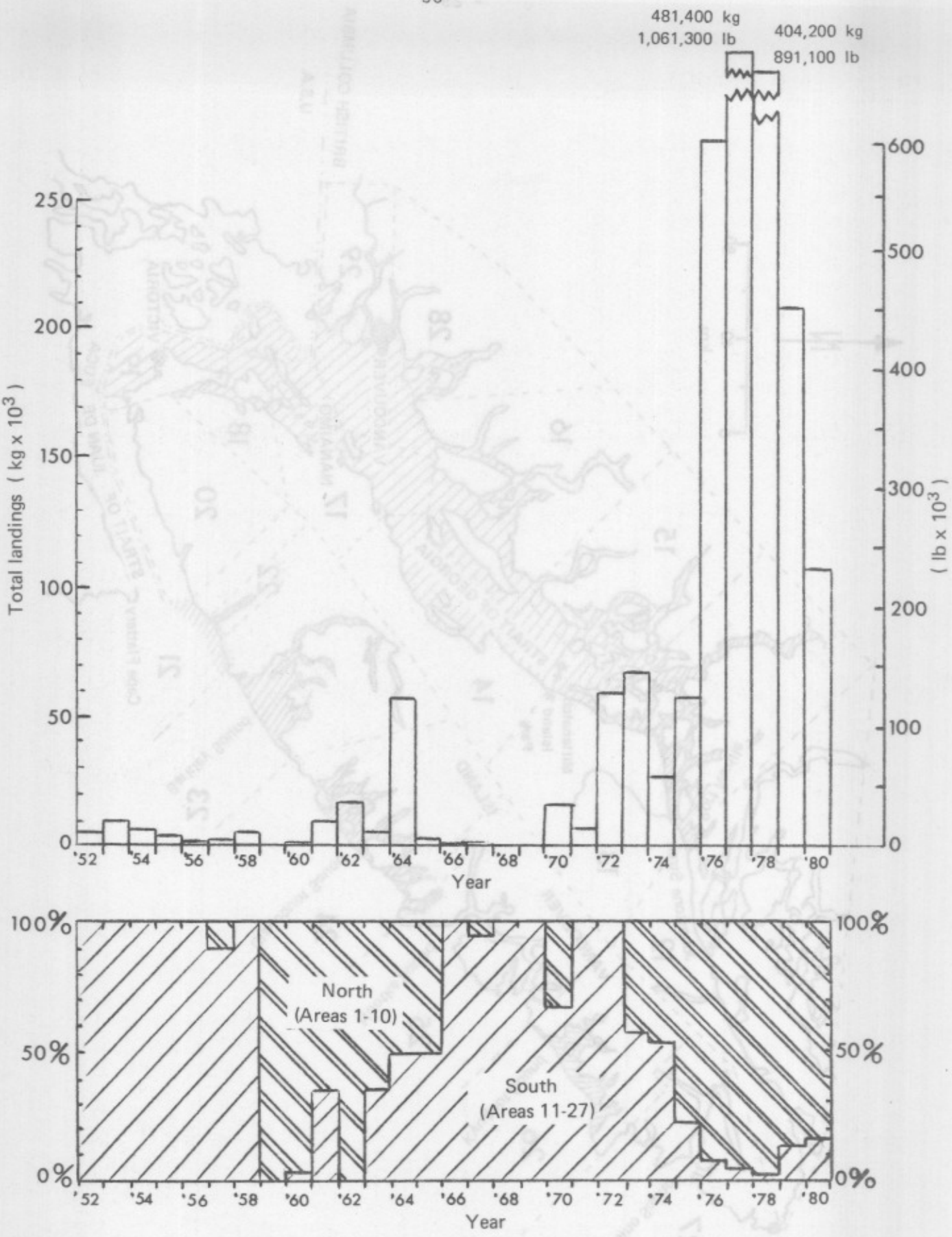

Fig. 4. Annual abalone landings and percent contribution from northern and southern B.C., 1952 - 1980.

Table 7. Total 1952-1980 abalone landings by Statistical Area, and % contribution by Area for specific time periods.

Statistical Area	1952-1980 landings (kg)	% of Total harvest				
		1952-1960	1961-1970	1971-1975	1976-1980	1952-1980
North						
1	75,427	-[a]	6.1	-	4.7	4.1
2W	48,311	-	4.0	0.8	2.9	2.6
2E	539,016	-	19.0	3.6	34.6	29.4
3	12,582	-	-	-	0.9	0.7
4	30,558	-	6.5	2.9	1.2	1.7
5	362,170	4.8	5.3	14.9	21.9	19.7
6	403,678	-	11.0	10.7	25.0	22.0
7	54,722	-	5.1	6.5	2.4	3.0
8	245	-	-	-	0	0
9	1,206	-	-	-	0.1	0.1
Total North (%)	-	4.8%	57.0%	39.4%	93.7%	83.2%
(kg)	1,527,915	1,769[b]	63,231	85,274	1,377,732	-
South						
11	7,047	-	-	-	0.5	0.4
12	122,965	94.5	28.7	5.6	3.1	6.7
13	680	0.1	0.5	-	-	< .05
15	862	-	0.8	-	-	< .05
17	3,402	0.3	-	1.5	-	0.2
18	6,577	-	1.4	2.3	-	0.4
19	8,176	-	1.0	1.1	0.3	0.5
20	33,268	-	1.6	8.0	1.0	1.8
21	<500	-	-	-	-	< .05
22	952	-	0.6	0.1	-	.05
23	67,086	-	7.4	26.6	0.1	3.7
24	26,805	-	1.1	10.7	0.2	1.5
25	16,246	-	-	2.6	0.7	0.9
26	6,215	-	-	1.7	0.2	0.3
27	8,199	-	-	0.4	0.5	0.4
Total South (%)	-	94.9%	43.1%	60.6%	6.6%	16.8%
(kg)	308,480	32,840	48,035	130,905	96,700	-
North + South (%)	-	100%	100%	100%	100%	100%
(kg)	1,836,490	34,609	111,266	216,181	1,474,434	-

[a] No landings reported; assume 0% contribution.

[b] Includes 91 kg from unspecified northern Area.

Table 8. Annual abalone landings and % of annual total for northern B.C. (Areas 1-10) and southern B.C. (Area 11-27), 1952-1980[a].

Year	Northern B.C.			Southern B.C.		
	(kg)	(lb)	%	(kg)	(lb)	%
1952	-[b]	-	0	5,398	11,900	100
1953	-	-	0	10,342	22,800	100
1954	-	-	0	6,849	15,100	100
1955	-	-	0	3,538	7,800	100
1956	-	-	0	499	1,100	100
1957	91	200	10	862	1,900	90
1958	-	-	0	5,307	11,700	100
1959	181	400	100	-	-	0
1960	1,497	3,300	97	45	100	3
1961	6,078	13,400	65	3,311	7,300	35
1962	17,418	38,400	99.7	45	100	0.3
1963	3,719	8,200	65	1,996	4,400	35
1964	29,030	64,000	51	28,032	61,800	49
1965	1,588	3,500	51	1,497	3,300	49
1966	-	-	0	726	1,600	100
1967	45	100	5	816	1,800	95
1968	-	-	0	91	200	100
1969	-	-	0	635	1,400	100
1970	5,352	11,800	33	10,886	24,000	67
1971	-	-	0	6,441	14,200	100
1972	-	-	0	59,602	131,400	100
1973	28,576	63,000	43	38,555	85,000	57
1974	12,247	27,000	47	14,061	31,000	53
1975	44,452	98,000	78	12,247	27,000	22
1976	249,928	551,000	92	23,133	51,000	8
1977	461,111	1,016,580	96	20,262	44,670	4
1978	395,008	870,848	98	9,203	20,290	2
1979	181,215	399,513	87	26,954	59,424	13
1980	90,472	199,458	84	17,147	37,802	16

[a] For source see Table 1, footnote 'b'.

[b] No landings reported.

Next in historical importance are Area 7 (off Bella Bella) and Area 23 (in Barkley Sound), each contributing about 3% to the overall total (Table 7). During 1952-1960, Area 12 (in Johnstone Strait) contributed 95% to the nine year harvest of 34.6 m.t., and Area 5 most of the remaining 5% (Table 7). During the next 10 years (1961-1970) when 111.3 m.t. have been landed, over half the total originated from Area 2E (19%), Area 6 (11%) and Area 12 (29%), while Areas 1, 5, 7 and 23 each contributed over 5% to the total. During 1971-1975, when 216.2 m.t. have been landed, 64% originated from Area 5 (15%), Area 6 (11%), Area 23 (27%), and Area 24 (in Clayoquot Sound) (11%). Areas 7 and 12 each contributed around 5%. Finally, during the last five years of peak abalone harvest (1976-1980), when 1,474 m.t. were landed, the majority of harvest or 82% came from Area 2E (35%), Area 5 (22%), and Area 6 (25%) (Table 7).

Annual abalone landings since 1952 are presented by Statistical Area in Append. 5a-d and 6), and by specific time period per Area in Table 9, and are discussed below.

Queen Charlotte Islands - Areas 1, 2E and 2W

Area 1 on the north coast of Queen Charlotte Islands, was never an important commercial producer, as indicated by the catch data. The considerable harvest of 45.5 m.t. made there in 1977 was due largely to an extensive scouting undertaken that year by major harvesters (F. Dickson, pers. comm.). Much of the above abalone harvest was made in the Virago Sound which was closed to fishing in 1978.

Area 2W on the west coast of the Queen Charlotte Islands, was also a minor producer of abalone, although in recent years (1977-1979) it yielded 10-15 m.t. of abalone per year. Closures of Rennell Sound, Skidegate Channel and Tasu Sound in 1977 (Table 6), reduced the commercial harvest from this area.

Area 2E on the east coast of the Queen Charlotte Islands, was a major producer of abalone in the last five years, contributing during that time 95% (510 m.t.) to the total B.C. catch. In 1977 alone, this area yielded 259 m.t., much of it from the highly productive Cumshewa Inlet (Breen and the Adkins 1979). This inlet was closed to commercial fishing in 1977 (Table 6).

Table 9. Summary of abalone landings by Statistical Area for specific time periods, 1952-1980.

Period	Statistical Area 1		2W		2E		3		4		5		6		7	
	kg	%	kg	%	kg	%	kg	%	kg	%	kg	%	kg	%	kg	%
1952-'60	0	0	0	0	0	0	0	0	0	0	1,678	0.5	0	0	0	0
1961-'70	6,759	9.0	4,400	9.1	21,137	3.9	0	0	7,212	23.6	5,896	1.6	12,202	3.0	5,625	10.3
1971-'75	0	0	1,814	3.8	7,711	1.4	0	0	6,350	20.8	32,205	8.9	23,133	5.7	14,061	25.7
1976-'80	68,668	91.0	42,097	87.1	510,168	94.6	12,582	100	16,996	55.6	322,391	89.0	368,343	91.2	35,036	64.0
Total	75,427	100	48,311	100	539,016	100	12,582	100	30,558	100	362,170	100	403,678	100	54,722	100

	8		9		11		12		13		15		17		18	
	kg	%	kg	%	kg	%	kg	%	kg	%	kg	%	kg	%	kg	%
1952-'60	0	0	0	0	0	0	32,704	26.6	45	6.6	0	0	91	2.7	0	0
1961-'70	0	0	0	0	0	0	31,978	26.0	590	86.8	862	100	0	0	1,588	24.1
1971-'75	0	0	~0	0	0	0	12,020	9.8	45	6.8	0	0	3,311	97.3	4,989	75.9
1976-'80	245	100	1,206	100	7,047	100	46,263	37.6	0	0	0	0	~0	0	0	0
Total	245	100	1,206	100	7,047	100	122,965	100	680	100	862	100	3,402	100	6,577	100

	19		20		21		22		23		24		25		26		27	
	kg	%	kg	%	kg	%	kg	%	kg	%	kg	%	kg	%	kg	%	kg	%
1952-'60	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1961-'70	1,134	13.9	1,769	5.3	0	0	680	71.4	8,210	12.2	1,224	4.6	0	0	0	0	0	0
1971-'75	2,314	28.3	17,191	51.7	~0	0	272	28.6	57,515	85.7	23,133	86.3	5,534	34.1	3,674	59.1	907	11.1
1976-'80	4,728	57.8	14,308	43.0	~0	0	0	0	1,361	2.0	2,448	9.1	10,712	65.9	2,541	40.9	7,292	88.9
Total	8,176	100	33,268	100	<500	0	952	100	67,086	100	26,805	100	16,246	100	6,215	100	8,199	100

North Coast - Areas 3, 4 and 5

Area 3 was never an important producer of abalone. Area 4, off the Prince Rupert coastline, was also a minor producer with a mean annual harvest generally below 5 m.t. However, Area 5, off Banks Island, was an important source of abalone in the last decade, with approximately 90 m.t. landed there annually during 1976 to 1978. The closure in Area 5 was extended in 1980 (Table 6).

Central Coast - Areas 6, 7, 8, 9 and 10

Area 6, like Area 5, contributed significantly to the B.C. abalone commercial harvest since 1976, with a maximum landing of 160 m.t. reported in 1978. Area 7, off the Bella Bella coastline, was always a low commercial producer of abalone, while Areas 8, 9 and 10 were negligible producers.

South coast - Areas 11-19

Of the above areas, only Area 12 was a significant producer of commercial abalone in B.C. During 1952-1960, Area 12 yielded 94.5% (32.7 m.t.) of the total B.C. abalone catch; during 1976-1980 it yielded 46.2 m.t. Most of the Areas 13 to 19 have been closed to commercial fishery since 1971.

South coast - Areas 20-27

Area 20 in the Strait of Juan de Fuca, contributed less than 10 m.t. annually in its most productive years during 1973 to 1978. Miller (1974) suggested that Areas 19 and 20 probably also supported recreational fisheries of 45-225 kg per year; recent reports by Fishery Officers suggest that much higher recreational catches are being made in those areas. Areas 21 and 22, off the southwestern tip of Vancouver Island, had negligible commercial abalone landings. Area 23 in Barkley Sound and Area 24 in Clayoquot Sound were important producers of abalone in the early 1970's, with a maximum of 40 m.t. harvested in Barkley Sound in 1972. Areas 25-27 were never important abalone producers, each generally yielding well below 5 m.t. annually.

DISTRIBUTION OF LANDINGS BY VESSEL, 1977-1980

The large range in seasonal landings per vessel, characteristic of the 1977 and 1978 open fisheries, contrasts sharply with the narrow ranges observed in the 1979 and 1980 reduced quota fisheries (Fig. 5, Table 10). During 1977 and 1978, each vessel landed between 700 and 84,600 kg, and a minority of the fleet harvested most of the annual catch; in 1977, 10 out of 22 vessels landed 87% of the catch; in 1978, seven out of 25 vessels landed 68% of the catch. Likewise, during the brief, open fishery in 1979, landings per vessel ranged from 700 - 16,000 kg and five out of 21 vessels landed 68% of that year's open season harvest.

With the introduction of a quota fishery, landings per vessel became relatively uniform. In the 1979 quota fishery, 23 out of the 24 participating vessels reported a catch of approximately 4.5 m.t. (allowed quota per vessel) or less (but one vessel overfished) (Table 10). Also in the 1980 quota fishery, catch per vessel did not vary substantially due to the imposed 4.5 m.t. quota per vessel (Table 10).

FISHING EFFORT BY STATISTICAL AREA AND BY VESSEL, 1977-1980

Catch per unit effort (CPUE) was measured as catch per diver day and as total diver days per fishing season. Abalone fishing effort by vessel is shown in Fig. 5 and Table 11. Fishing effort by Statistical Area is shown in Fig. 6, Table 11, and Append. 7. The total annual number of diver days declined from a high of 2,389 days in 1977 to a low of 811 days in 1980 (Table 11). The mean annual CPUE for the entire B.C. coast also declined steadily from a high of 202 kg/diver day in 1977 to a low of 133 kg/diver day in 1980 (Table 11). However, the annual ranges of CPUE per vessel and per Statistical Area remained wide. Also, among the high yielding Areas, only Area 5 showed a steady decline in CPUE with time; the other Areas generally showed either little change or fluctuated from year to year (Fig. 6).

Table 10. Distribution of abalone landings by vessel, 1977-1980.

Catch ($\times 10^3$ kg)	1977			1978			1979									1980		
							NO QUOTA			QUOTA			TOTAL					
	No. vessels	% Of vessels	% Of total catch	No. vessels	% Of vessels	% Of total catch	No. vessels	% Of vessels	% Of total catch	No. vessels	% Of vessels	% Of total catch	No. vessels	% Of vessels	% Of total catch	No. vessels	% Of vessels	% Of total catch
0-2	1	4.5	0.1	----------			5	23.8	5.7	1	4.2	1.0	----------			1	4.0	1.4
2-4	5	22.7	3.4	7	28.0	5.5	4	19.0	10.4	8	33.3	28.3	4	16.0	6.2	6	24.0	19.1
4-6	1	4.5	1.2	3	12.0	3.9	4	19.0	16.2	14	58.3	64.6	5	20.0	11.4	17	68.0	71.8
6-8	3	13.6	4.3	2	8.0	3.6	3	14.3	19.2	1	4.2	6.1	5	20.0	16.4	----------		
8-10	2	9.1	3.7	2	8.0	4.7	3	14.3	24.3	----------			3	12.0	13.3	1[a]	4.0	7.7
10-12	1	4.5	2.3	1	4.0	2.6	2	9.6	24.2	----------			2	8.0	10.7	----------		
12-14	1	4.5	2.5	1	4.0	3.1	----------			----------			4	16.0	25.1	----------		
14-16	1	4.5	3.2	----------			----------			----------			1	4.0	7.0	----------		
16-20	1	4.5	4.1	2	8.0	9.0	----------			----------			----------			----------		
20-40	1	4.5	8.3	5	20.0	42.4	----------			----------			1	4.0	9.9	----------		
40+	5	22.7	66.8	2	8.0	25.3	----------			----------			----------			----------		
Total	22	100%	100%	25	100%	100%	21	100%	100%	24	100%	100%	25	100%	100%	25	100%	100%

[a]Carried additional licence from a burned vessel.

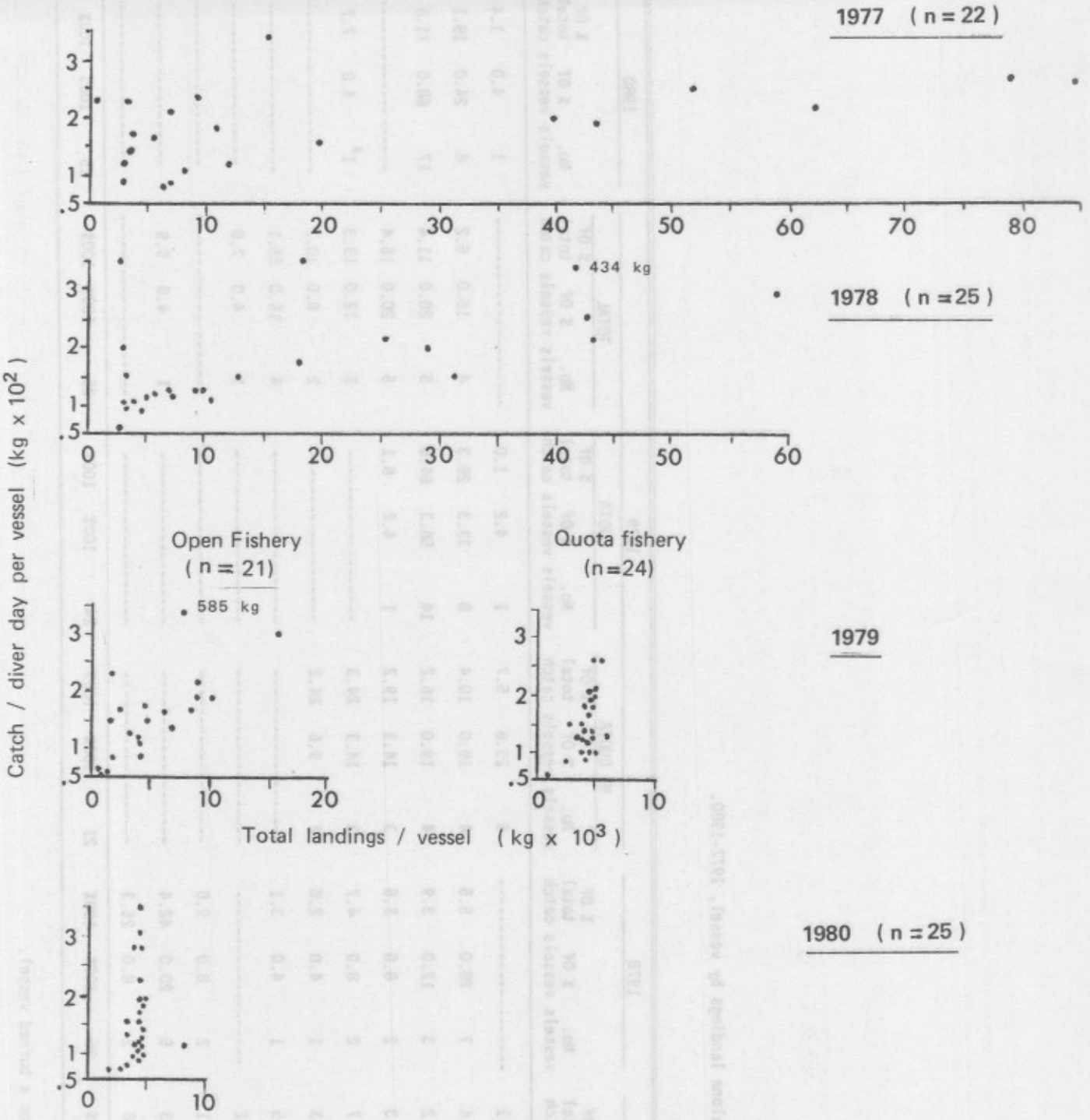

Fig. 5. Fishing effort (catch/diver day) and total landings per vessel, 1977 - 1980.
(n gives number of vessels.)

Table 11. Mean annual abalone catch per vessel and fishing effort (No. diver days and catch/diver day), 1977-1980.

Year	No. vessels fishing	Total catch (kg)	Mean catch per vessel[a] (kg)	No. diver days			Catch/diver day (kg)		
				Total	Mean per vessel[b]	Range per vessel	Overall mean[c]	Range per Statistical Area	Range per vessel
1977	22	481,373	21,881	2,389	109	3-327	202	45-285	72-340
1978	25	404,212	16,168	2,162	86	8-204	187	51-218	49-354
1979 open	21	108,664	5,174	653	31	8-54	166	-	49-585
quota	24	99,505	4,146	695	29	16-48	143	-	62-282
total	25	208,169	8,327	1,348	54	-	154	70-197	-
1980	25[d]	107,619	4,305	810.5	32	13-73	133	50-261	70-349

[a]Total catch ÷ Total vessels.

[b]Total diver days ÷ Total vessels.

[c]Total catch ÷ Total diver days.

[d]One additional livenced vessel burned.

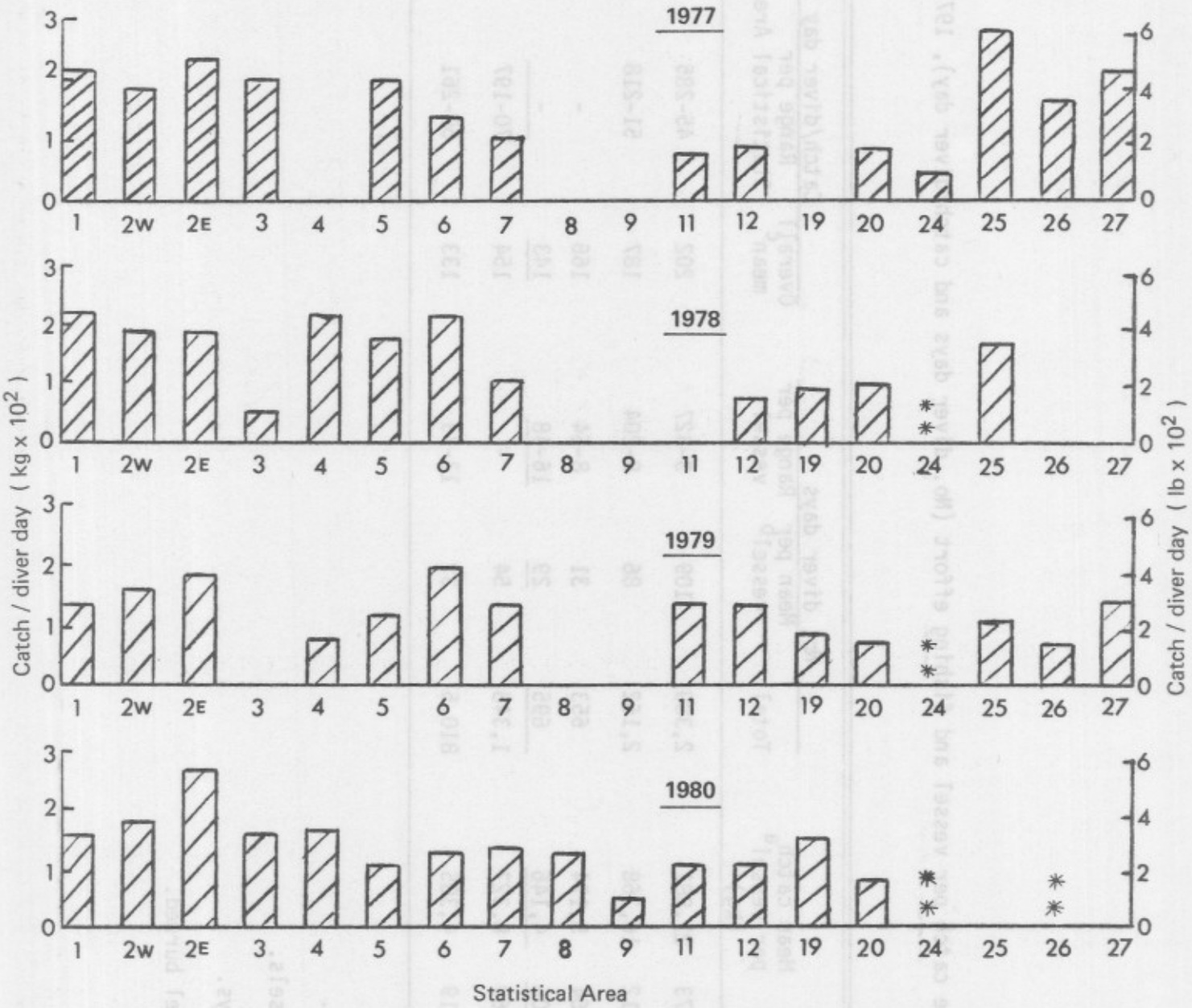

Fig. 6. Annual abalone fishing effort by Statistical Area, 1977 - 1980. (**indicates total Area closure).

During the open fishery from 1977 to early 1979, CPUE was generally highest for vessels with the greatest seasonal landings (Fig. 5). However, several vessels with a low seasonal catch also reported some very high CPUE values during this period (Fig. 5). Such vessels fished for only short periods. Individual vessels in 1977 fished from 3 to 327 days each (Table 11). During the quota fishery in 1979 and 1980, the range of CPUE per vessel remained high (62-349 kg/diver day) (Fig. 5, Table 11) while the range of diver days per vessel declined considerably (13-73 days in 1980) (Table 11).

COMPARISON OF OPEN AND QUOTA FISHERIES, 1979

In 1979, 52% of that year's catch were landed by 21 vessels during the 0.5 months of the open fishery; the remaining 48% of catch were landed by 24 vessels during the 6.5 months of the quota fishery (Table 10). Comparing the two seasons, each vessel operating in the open fishery had on the average a larger catch (5.2 m.t. vs 4.1 m.t.), more diver days (31 vs 29), and a greater CPUE (166 kg/diver day vs 143 kg/diver day) (Table 11).

DISCUSSION

DISTRIBUTION OF ANNUAL LANDINGS BY AREA

Despite the limited entry, shorter open season and other restrictive measures introduced since 1976, abalone landings rose sharply in 1977 and remained high in 1978. With the introduction of a quota fishery in 1979, the annual landings dropped to just below the allowable quota of 227 m.t. (500,000 lb) for 1979, and 113 m.t. (250,000 lb) for 1980.

The major reason for a shift in abalone harvest from the south to the north of B.C. during the mid-1970's, was the introduction of larger, more mobile fishing vessels with freezer capacity. These vessels could travel to more remote areas, cover a larger area under more adverse weather conditions, and harvest more abalone without spoilage. Also, the operators could hire additional scuba divers due to the continuing increases in the price of abalone.

The historical, 1952-1980, distribution of catch by Statistical Area shows that most of the annual landings generally came from only one to three Areas (Append. 5 & 6). In particular, the following areas were fished most intensively during 1976 to 1980:

Year	Area	Landings (m.t.)	% of B.C. total
1976	2E, 5, 6	237.7	87%
1977	1, 2E, 5, 6	431.8	90%
1978	2E, 5, 6	350.0	86%
1979	5, 6	129.1	62%
1980	6	49.2	46%

The decline in landings, observed in the above northern areas in the late 1970's, is due to a number of factors. Since the 1976 to 1978 fisheries were based largely on stocks of older, basically unfished abalone, once harvested these areas were expected to have a reduced future harvestable stock due to slow growth rates and sporadic recruitment of abalone. Secondly, the imposition of a quota fishery in 1979 and in 1980 restricted the abalone harvests in the more remote northern areas, and changed the fishing pattern and intensity (see below). As the quota was further reduced in 1980, it probably became quite costly for the operators to head for the Queen Charlotte Islands, and more accessible location were sought for harvesting abalone. Finally, much of the recent decline in abalone harvest in northern regions may be attributed to the closure of several prime fishing locations, such as the Cumshewa Inlet (Area 2E) in 1977 and the Banks Island (Area 5) in 1980.

DISTRIBUTION OF LANDINGS BY VESSEL

Prior to 1979, the largest and most efficient vessels profited the most, as the majority of abalone were harvested by a minority of the fleet. The more successful operators probably worked longer days, had a larger support crew, had more divers with a higher catch efficiency, and may also have scouted the fishing areas prior to their opening.

The imposition of a boat quota system in 1979 and 1980, had a considerable equalizing effect on the catch redistribution among vessels. This measure has also altered the fishing pattern from a competitive to a more relaxed one, with vessels generally operating closer to port because of convenience and reduced travelling expenses. In addition, a few freezer vessels have recently switched to landing fresh abalone and therefore are staying closer to port.

FISHING EFFORT

The fishing rate (CPUE) on abalone in B.C. (133-202 kg/diver day, 1977-1980 data), is comparable with the CPUE in California (187 kg/10 hr diver day) (Gotshall et al. 1976). At this stage in the B.C. fishery, the fishing rate does not appear to be a good indicator of abalone stock size; i.e. CPUE may remain stable while stocks are declining. For example, fishing rates were similar in 1977 and 1978 (202 kg and 187 kg respectively) despite the considerable removal of stocks during that period. However, the above fishing rates were expected to be relatively high and stable, since much of the 1977 and 1978 harvest was made in previously unfished, northern areas (Breen 1980 a; Breen and Adkins 1979).

A factor, other than stock abundance, which may affect CPUE has been suggested by Beinssen (1976). He observed that as the abalone densities in the Australian fishery became reduced, less time was spent in actively handling abalone and more time on searching for them. He therefore suggested that in that fishery the "fishing power" (defined as the effective area covered per unit operation) will increase as the stock density is reduced, and the fishing fleet will remove abalone from a progressively greater area in the same diving period. Thus, catches may remain high in spite of reduced abalone densities. Newman (1967) in South Africa and Harrison (1969) in Tasmania also found that constant fishing rates need not indicate a stable abalone fishery.

The CPUE also depends on divers' experience in finding and harvesting abalone, and this no doubt has increased steadily (Breen 1980 a). The importance of CPUE as an indicator of abalone stock size is further weakened by the partially incomplete and inaccurate data from the fishermen's logs and the non-uniformity

of fishing procedures among vessels. The significance of CPUE is also reduced by the introduction, since 1976, of new fishery regulations, particularly the shorter season and the quota fishery which tend to encourage a respective increase and decrease in CPUE. In addition, the catch per diver day used here, is a far less accurate measure of effort compared to catch per diver hour, because of the undefined day length. For example, in 1980, a diver day varied from one to nine hours. The total effect is to conceal any real decline in abalone abundance as indicated by CPUE. This probably occurred in Area 2E which has maintained a relatively high and stable CPUE during 1977-1980 (185-261 kg/diver day, Fig. 6), despite the heavy harvesting of abalone during that period. The apparent general decline from 1977 to 1980 in the mean CPUE for the entire B.C. coast (202 kg in 1977 to 133 kg in 1980) may be due in part to the introduction of the quota fishery in 1979 and 1980 which may have resulted in a more relaxed attitude and less intensive fishing. Another reason for this decline may be the imposition of additional area closures which restricted the operators to less productive fishing locations. Finally, a lowered CPUE may indicate a real decline in abalone stock abundance along the B.C. coast. For example, the CPUE in Area 5, which was fished heavily since 1976, has been steadily declining (Fig. 5), although the more recent decline may be due in part to the closure in 1980 of some of the more productive regions in Area 5 (Table 6). It may be concluded therefore that if a steady decline in CPUE is observed in a specific area, after taking into consideration the changes in management policies, such as area closures and reduced quotas, a serious overharvesting of localized stocks may be suspected.

The fishing rate per vessel (CPUE), traced through 1977 to 1980 for 17 individual licence holders who operated continuously during this period, showed a continuous decline with time in only four cases, a steady increase with time in seven cases, and considerable fluctuation from year to year for the remaining vessels. As stated earlier, the most successful operators tended to have some of the highest fishing rates, although their CPUE did not necessarily increase with time. This emphasizes the great variability from year to year in fishing rates among the individual operators and supports the above statement that catch rates need not reflect the abundance of abalone stocks.

Comparing the open and quota fisheries in 1979, an increase in fishing effort(i.e. total diver days per unit time period and catch per diver day), occurred during the short open season. This indicates that a time pressure element in a fishery can lead to increased fishing effort by a portion of the fleet.

IMPACT OF ABALONE FISHERY ON STOCK ABUNDANCE AND DENSITY

The intensity of abalone fishery since 1976 was evaluated by examining changes in catch per unit effort, by measuring abalone densities at several sites before and after fishing, by determining the ratio of legal to sub-legal abalone abundance in fished and unfished sites, and by comparing the postulated historical density levels of legal sized abalone with the 1978 values. (Breen and Adkins 1979; Breen, 1980 a).

Abalone length data collected during 1964 and 1978, indicate that the abundance of legal sized abalone declined by 60% on the north coast and by 85% on the south coast, and declined by as much as 90% in Cumshewa Inlet on the Queen Charlotte Islands (Breen 1980 a). In northern areas surveyed in 1978, the density of legal sized abalone declined by 80% (from a postulated historical abundance of 2.5 abalone/m^2 to 0.52 abalone/m^2) (Breen 1980 a). The above author estimated the historical abundance largely by using information from operators during the early fishery and from surveys of apparently unharvested areas.

The present biological information indicates that the abalone fishery in B.C. has been removing accumulations of old animals, and that the importance of annual production to the pre-1979 fishery was probably minimal because of apparent low growth and recruitment rates of abalone (Quayle 1971; Breen 1980 a). This means that the earlier high annual landings were far above the sustainable annual abalone yield.

RECRUITMENT AND LEGAL SIZE AT HARVESTING

Abalone abundance and size frequency distributions have been studied in various areas of the B.C. coast (Thompson 1914; Quayle 1971; Adkins and Stefanson 1977; Adkins 1978; Breen et al. 1978 a & b; Breen and Adkins 1979; Breen 1980a). In many of the above populations surveyed prior to the intensive 1976-1980 fishery, the size structure was dominated by the old individuals (Breen and Adkins 1979). This suggested to the above authors a low and possibly erratic recruitment rate with low adult mortality that allowed older individuals to accumulate. The erratic recruitment rate is evidenced by the fact that abalone have a highly uncertain larval survival (Mottet 1978). Since the breeding individuals in an abalone population are generally larger than the minimum legal size of 100 mm (Breen 1980 a), an intensive abalone fishery may remove much of the breeding population. Smaller sub-legal abalone will also reproduce (Quayle 1971), but they are less fecund and less abundant than the larger individuals, and their contribution to the total larval production is relatively low (Breen 1980 a).

The possible failure of stock recovery after severe harvesting or "recruitment" overfishing is now recognized as a real hazard in an intensive commercial fishery (Harrison 1969; Sainsbury 1977). Recruitment overfishing was apparently one of the major causes for a severe decline of abalone stocks in California, despite appropriate and enforced size limit measures (Cicin - Sain et al. 1977). In B.C., poor recruitment of abalone, as a result of greatly reduced stock levels, was observed in the heavily harvested areas on the west coast of Vancouver Island, such as Barkley Sound (Breen 1980 a), and in the Queen Charlotte Sound (Breen et al. 1978 b).

The critical size of a population (the point where the instantaneous rates of growth and natural mortality are equal and a year-class reaches its maximum biomass) is important in determining the maximum yield from a population (Ricker 1975). Breen (1980 a) estimated that the critical size of abalone in B.C. is between 92 and 99 mm, or just below the present minimum legal size of 100 mm ($\sim$ 4"). In view of the danger of recruitment overfishing, it appears that the present legal size should be maintained in order to safeguard abalone stock recruitment.

ABALONE PRODUCTION AND YIELD

The presently available data for predicting the annual sustainable yield of abalone in B.C. are incomplete. Breen (1980 a) calculated abalone growth, mortality and stock recruitment rates, and estimated that the annual production of legal-sized abalone in commercial beds was only 6.5% of the existing biomass in unharvested stocks. He based this estimate on a calculated maximum sustainable yield of 30 g/m^2/year. Breen (1980 a) estimated that the theoretical annual sustainable yield for the entire B.C. coast was 115-150 m.t. (~250,000 - 340,000 lb); from this, the 1980 fishery quota of 113 m.t. (250,000 lb) was derived. However, more recent studies indicate that the annual sustainable yield may be less than 90 m.t. (200,000 lb) (P. Breen, pers. comm.). Future estimates should reevaluate the assumptions that the commercial fishery causes little sub-legal mortality and that no major habitat changes occur due to fishing (Breen 1980 a).

WEAKNESSES IN FISHERY REGULATIONS IN B.C.

A major weakness in the fishery regulations in B.C. is the potential for overharvesting of specific areas. In addition, patrolling of B.C. abalone fishery on the grounds is limited and, in most cases, non-existent due to extensive area size, long fishing season, and limited budget and manpower available to the Department of Fisheries and Oceans. In addition, abalone fishermen often work in remote areas which patrol vessels do not visit routinely. This is particularly the case during the salmon fishing season when patrol vessels have other responsibilities. As a result, records of area-specific and of total commercial landings have been unreliable, particularly prior to the 1977 log-book reporting. Since 1977, the Department of Fisheries and Oceans has been collecting information on abalone abundance and distribution indirectly, using the fishermen's harvest logs with catch, effort and catch location data. These records are relatively complete, compared to earlier years when the total number of fishing vessels and of divers could only be estimated, and when much of the catch went unreported due to dock-side sales for restaurant trade and sales to brokers rather than to fish processing companies (F. Dickson, pers. comm.), as well as abalone spoilage prior to shipping. In addition, the sales slip system was incomplete with slips being

lost or withheld. Also, as with salmon, some of the abalone catches have been attributed to the area landed rather than to the area of catch. In addition, recreational scuba divers have been known to make a considerable but undetermined abalone harvest and sell it at the docks or to the restaurant trade (F. Dickson, pers. comm.). Based on the above, it is suspected that the commercial abalone landings were underestimated by up to 20% prior to 1977. More recent records probably underestimate the catch by some 10%. Finally, there is lack of information on the Indian food fishery.

Incidents of poor harvesting techniques have been reported. Abalone shipments from Areas 6 and 7 had on occassion arrived to Vancouver with up to 60% of the load spoiled (DFO, 1974 memo). There have been abuses also from recreational scuba divers, including disregard for size limits and exceeding bag limits. Unfortunately, no record is available of the sport fishing catch of abalone.

EFFECTIVENESS OF MAJOR FISHERY REGULATIONS

1. Licencing

A limited entry in itself will not control the fishing pressure, and may involve difficult social and political decisions.

2. Length of season and area closures

These measures are generally ineffective in reducing fishing pressure since the operators may work longer and harder hours during open season and in open areas. For example, a similarly large catch was taken in B.C. in 1978 as in 1977, but in less than half the time. Also, the value of the resource may be reduced with a shorter fishing season because abalone are landed in a short time but not necessarily the best time for marketing. In addition, a shorter season is detrimental to the local fresh abalone market and to the small operator. However, a restricted season length and/or area closures allow for a less costly and more effective enforcement of the fishery.

3. Rotating fishing grounds

For this measure to be effective, the open areas must not be overharvested in order to encourage stock recovery. However, this measure may be undesirable under a quota system since it would be uneconomical to travel long distances to harvest small amounts of abalone. Also, such a system may discriminate against the small, less mobile operators that supply local markets.

4. Bag limits

This can be an effective measure for reducing fishing pressure but it can discriminate against the experienced, full-time divers (Mottet 1978). Bag limits are best applied to control the sport fishery.

5. Minimum legal size of abalone

This measure in itself is not effective for maintaining a viable breeding population, unless the size limit is sufficiently high. Previous fisheries, such as those in California, show that even with size limits, recruitment overfishing can occur and result in stock depletion.

6. Effort limitation

This method in itself does not provide an effective means of controlling catches. Limiting the operators to three divers per vessel is difficult to enforce in the abalone fishery, and it does not effectively limit catches as operators will spend additional time to make up for any loss in manpower.

7. Quotas

(i) Area: Management by area quota has advantages over other methods in that catch limitations are set and the fishery is open only until the quota is harvested, so that the chance of greatly exceeding the allowable catch is remote. This approach results in a very intensive fishery where the catch is landed in a short period of time and the majority of landings are made by a minority of operators.

(ii) Vessel: The vessel quota system allows for a longer fishery that can be spread over the entire year, thereby enabling the operators to harvest and market abalone at more optimal times. This system, however, results in increased enforcement costs since enforcement must be conducted throughout the year as opposed to a short time period.

RECOMMENDATIONS

1. Maintain present regulations and continue adjusting the available landing quota using improved estimates of the sustainable yield. In particular, continue with the compulsory declaration of landings by the operator of each vessel, and impose strict penalties if landings declared under the licences exceed the quotas. Also continue with licence conditions demanding that operators submit information on catch location and fishing effort, contact the local Fishery Office prior to fishing, and allow a Fishery Officer to inspect the catch during unloading.

2. Match abalone stock size with harvest capacity by assigning, on a trial basis, a limited number of fishermen to harvest those areas where stocks can support modest catches but where there is concern for overharvesting by the entire fleet. This procedure maybe particularly suitable in areas such as the Cumshewa Inlet where stocks are comprised of old individuals and where concern for overharvesting exists, should the entire fleet fish in that area.
   If the above system proves to be successful, expand it by determining the total allowable catch of abalone by specific geographic areas and assigning licenced quotas with these areas. This could eliminate competition among operators for the same resource, and encourage each to protect and manage the resources of his specified area.

3. Monitor closely in the next few years the catch and CPUE per Statistical Area. Aside from area closures, those areas showing a large and continuous decline in either of above parameters should be assessed without delay for stock overharvesting and, if necessary, should be closed to commercial fishery

in order to avoid severe stock depletion and possible recruitment failure.

4. Educate commercial fishermen at public meetings and through lectures on the significance of sub-legal abalone mortality and encourage fishermen to use simple, blunt-edged prying tools to harvest abalone. Stress to commercial fishermen the need for accurate and reliable information on abalone harvest since these data are vital for evaluating B.C. abalone productivity and for setting up the appropriate management policies.

5. Introduce random "surprise spot-checks" from aircraft or patrol vessels at fishing sites in order to enforce the required legal size of abalone at harvest and the underwater measurement of abalone at capture site.

6. Operators who fail to present accurate and complete harvest records should be advised of the necessity to do so. If further failure to comply with these conditions occurs, charges should be considered.

7. Increase enforcement on non-commercial fishermen, especially regarding commercial sales by unlicenced divers.

8. With the increased work-load for Fisheries Officers on waterfront to check all abalone landings, it may be necessary to adopt an honour system in declaring landings, where only spot-checks are made by Fishery Officers during unloading.

9. Determine the feasibility of enhancing abalone stocks by transplanting on an experimental basis stunted sub-legal sized abalone ("surf abalone") to more optimal habitats, and closely monitor resulting growth and mortality.

10. Develop a comprehensive mariculture and transplant policy which establishes conditions for qualifying licences and preferred geographic locations, determines Federal-Provincial jurisdiction and responsibilities, assesses impacts on current fishery, and develops appropriate Federal regulations.

SUMMARY

1. Abalone biology is reviewed briefly, including their distribution, reproduction, food, age, size and mortality factors.

2. Major world producers of abalone are Japan, Mexico, and Australia; major world exporters are Mexico and Australia; major importers are Japan and United States. B.C. abalone are exported largely to Japan, with small amounts also sold to Hong Kong and United States.

3. Significant aquaculture of abalone is practiced in Japan, California and Mexico. Abalone culturing in B.C. is still at an experimental stage.

4. Starting in 1976, a series of large annual abalone harvests have been made in B.C. in response to a strong Japanese market.

5. In an attempt to control the abalone landings, conserve the stock, protect the small operators, and improve catch and effort inventory, the following major fishery regulations have been made since 1976:
   (i) Limited vessel entry introduced in 1977 and continued thereafter.
   (ii) Increased minimal legal size of abalone to 100 mm (~ 4") introduced in 1977 and continued thereafter.
   (iii) Restricted fishing effort to three divers per boat, effective 1977-1979.
   (iv) Limited season length, ranging from three to 7½ months, introduced in 1978.
   (v) Additional extensive area closures to commercial fishery made in 1977, and more closures made thereafter.
   (vi) Detailed fishermen's harvest logs introduced in 1977 and continued thereafter.
   (vii) Personal licence fee of $200.00 and licence non-transferability.

The above measures were followed by management actions designed to gradually reduce the total catch to annual sustainable yield:

(viii) A two-season fishery (open and quota seasons) of 227 m.t. (500,000 lb) total allowed catch implemented in 1979. In quota season each licenced vessel was allowed to catch 4.5 m.t. (10,000 lb).

(ix) A single season quota fishery of 113 m.t. (250,000 lb) total allowed catch implemented in 1980, in which each licenced vessel was allowed to catch 4.5 m.t. (10,000 lb).

6. Of the total abalone harvest made in B.C. during 1952-1980, 80% or 1,474 m.t. (3.3×10^6 lb) were landed during 1976-1980. A major shift in abalone landings occurred from south to north B.C. during the mid-70's, with northern B.C. (Areas 1-10) contributing 94% to the total 1976-1980 abalone harvest; major contributors were Area 2E (35%), Area 5 (22%) and Area 6 (25%).

7. Prior to 1979 and 1980 quota fisheries, seasonal catch per vessel depended largely on the operator's fishing effort and experience and varied greatly, with a minority of fleet (generally the larger freezer vessels) harvesting the bulk of annual landings. Also, the CPUE/vessel was typically highest for vessels with the highest seasonal catch. In the quota system, seasonal catch per vessel became relatively uniform, but CPUE/vessel remained highly variable.

8. Mean CPUE for the entire B.C. coast has declined from 1977 to 1980 (202 kg to 133 kg/diver day). In particular, Area 5 has shown a steady decline in total landings and CPUE, indicating stock overharvesting. Total annual number of diver days has declined from 2389 days in 1977 to 811 days in 1980. At present, CPUE is a poor indicator of abalone stock size in B.C. For example, the 1977 and 1978 CPUE were similar despite a real decline in abalone stock abundance as measured in various studies.

9. Since the 1960's, the abundance of legal-sized abalone declined by 60% on the north coast and by 85% on the south coast. In some northern areas, density of legal-sized abalone declined by up to 80% (1978 data).

10. Abalone populations have erratic annual recruitment and low adult mortality that result in accumulations of older individuals. Intensive harvesting of older abalone may lead to recruitment failure and severe depletion of the resource.

11. The annual sustainable yield of abalone was initially estimated at 115-150 m.t.(~250,000 - 340,000 lb), but more recent studies indicate that this estimate is too high and could be less than 90 m.t. (200,000 lb).

12. The current quota system is successful in limiting the total annual catch to a desired level and providing some protection to smaller operators.

13. Major weaknesses in the present fishery regulations include the potential for overharvesting of specific areas; low or insufficient enforcement of commercial and sport fisheries, and poor enforcement in those areas where "poaching" of abalone is known to occur; inconsistent monitoring of commercial catches when landed; incomplete records of total commercial landings and of CPUE; and lack of catch information on the recreational and Indian food fisheries.

14. Several recommendations are made regarding abalone management, enforcement and enhancement measures.

ACKNOWLEDGEMENTS

The authors are grateful to Frances Dickson and Laurie Gordon for critically reviewing the manuscript, and to Paul Breen for his acute and helpful criticisms of the drafts. We also thank Jim Roussy for helping with data analysis and Mrs. F. Alladina for typing the manuscript.

REFERENCES

Adkins, B.E. 1978. An examination of some commercially harvested abalone populations in the Moresby Island area. Fish. Mar. Serv. MS Rep. 1455: 19 p.

Adkins, B.E., and A.P. Stefanson. 1977. An examination of harvested and unharvested abalone populations in the Moresby Island area. Fish. Mar. Serv. MS Rep. 1435: 23 p.

Anon. 1976. "Abalone farming in California. An idea whose time has come?" Commerc. Fish. Farmer and Aquaculture News 2(6): 6-9.

Anon. 1977. "Japan's abalone history changing". Mar. Fish. Rev. 39(7): 28-29.

Bardach, J.E., J.H. Ryther, and W.O. McLarney. 1972. Aquaculture: The farming and husbandry of freshwater and marine organisms. Wiley - Interscience. New York. 868 p.

Beinssen, K. 1976. The fishing power of divers in the abalone fishery of Victoria, Australia. Rapp. P.V. Réun. Cons. int. Explor. Mer. 175: 20-22: 288. Population assessment of shellfish stocks. Ed. H.J. Thomas, Publ. Dec., 1979.

Bonnot, P. 1930. Abalones in California. Cal. Fish and Game 16 (1): 15-23.

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

Breen, P.A. 1980 b. The northern abalone, muscled mollusc. Diver (6): 26-28.

Breen, P.A., and B.E. Adkins. 1979. A survey of abalone populations on the east coast of the Queen Charlotte Islands, August 1978. Fish. Mar. Serv. MS Rep. 1490: 124 p.

Breen, P.A., and B.E. Adkins. 1980. Spawning in the British Columbia population of northern abalone, Haliotis kamtschatkana. Veliger 23(2): 177-179.

Breen, P.A., B.E. Adkins, and G.D. Heritage. 1978 a. Observation of abalone and subtidal communities made during a survey of the Queen Charlotte Strait and upper Johnstone Strait areas, July 13-20, 1977. Fish. Mar. Serv. Tech. Rep. 789: 91 p.

Breen, P.A., A.P. Stefanson, and B.E. Adkins. 1978 b. North coast abalone surveys in harvested areas, spring 1978. Fish. Mar. Serv. MS Rep. 1480: 61 p.

REFERENCES (Cont'd)

Burge, R., S. Schultz, and M. Odemar. 1975. Draft report on recent abalone research in California with recommendations for management. Mimeo report to California Fish and Game Commission, California Dept. Fish and Game: 62 p.

Cicin - Sain, B., J.E. Moore, and A.J. Wyner, 1977. Management approaches for marine fisheries: the case of California abalone. Inst. Mar. Res., Univ. Calif. 223 p.

Cox, K.W. 1960. Review of the abalone in California. Cal. Fish and Game, Fish. Bull. No. 118: 133p.

Cox, K.W. 1962. California abalones, family Holistidae. Resources Agency of California, Dept. Fish and Game, Fish. Bull. 118: 133 p.

FAO. 1975 Yearbook of Fisheries Statistics. United Nations, Food and Agricultural Organization, Catches and Landings. Rome, 40: 417.

FAO. 1979. Yearbook of Fisheries Statistics. United Nations, Food and Agricultural Organization, Catches and Landings. Rome, 48.

Gotshall, D.W., L.L. Laurent, and F.E. Wendell. 1976. Diablo Canyon Power Plant Site ecological study Annual Report, 1974-75. Calif. Dept. Fish and Game, Mar. Res. Admin. Rep. 76-8: 112 p.

Harrison, A.J. 1969. The Australian abalone industry. Aust. Fish. 28(9): 3-13.

Ino, T. 1968. The abalone science and its propagation in Japan. Fish Res. Board Can. Transl. Ser. 1078: 209 p.

Kikuchi, S., and Uki, N. 1974 a. Technical study on artificial spawning of abalone, Genus Haliotis, I. Relation between water temperature and advancing sexual maturity of Haliotis discus hannai Ino. Bull. Tohoku Reg. Fish. Lab. 33: 69-78.

Kikuchi, S., and Uki, N. 1974 b. Technical study on artificial spawning of abalone, Genus Haliotis, II. Effect of irradiated seawater with ultra violet rays in inducing to spawn. Ibid,: 79-86.

Klopfenstein, Don and Inez. 1976. U.S. abalone hatcheries adopt a Japanese technique. Fish Farming Internat. 3(3): 46-48.

Leighton, D.L., and R.A. Boolootian. 1963. Diet and growth in the black abalone, Haliotis cracherodii. Ecol. 44(2): 227-238.

Livingston R. Jr. 1952. Preliminary investigation of the southeastern Alaska abalone (Haliotis kamtschatkana). Commerc. Fish. Rev. 14 (9): 8-18.

Miller, D.C. MS 1974. Abalone and sea urchin survey, 1974. Federal Provincial Cost Shared Project. B.C. Dept. Rec. and Con. Env. Can. 53 p.

REFERENCES (cont'd)

Morse, D.E., H. Duncan, N. Hooker, and A. Morse. 1976. Hydrogen peroxide induces spawning in molluscs, with activation of prostaglandin endoperoxide synthetase. Science 196: 298-300.

Morse, D.E., N. Hooker, H. Duncan, and L. Jensen. 1979. Gamma-aminobutyric acid, a neurotransmitter, induces planktonic abalone larvae to settle and begin metamorphosis. Science 204: 407-410.

Mottet, M.G. 1978. A review of the fishery biology of abalones. Wash. Dept. Fish. Tech. Rep. 37: 81 p.

Newman, G.G. 1967. Abalone research in South Africa. Fish. Bull. South Africa 4: 28-34.

Paul, A.J., J.M. Paul, D.W. Hood, and R.A. Nevé. 1977. Observations on food preferences, daily ration requirements and growth of Haliotis kamtschatkana Jonas in captivity. Veliger 19 (3): 303-309.

Parker, J.W. 1973. The abalone in Alaska. Alaska Dept. Fish and Game Wildlife, Notebook Series: 2 p.

Poore, G.C.B. 1973. Ecology of New Zealand abalones, Haliotis species (Mollusca: Gastropoda): 4. Reproduction. N.Z.J. Mar. Freshwater Res. 7(1&2): 67-84.

Proverbs, T.B. MS 1979. A status report on the British Columbia and international abalone industries. Economics and Statistical Services, DFO, unpublished MS: 38 p.

Quayle, D.B. 1962. Abalones in British Columbia. Fish. Res. Board Can., Pacific Prog. Rep. 114: 9-12.

Quayle, D.B. 1971. Growth, morphometry and breeding in the British Columbia abalone (Haliotis kamtschatkana Jonas), Fish. Res. Board Can., Tech. Rep. 279: 84 p.

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

Rutherford, D. 1976. California farm rears prized red abalone. Fish Farming Internat. 3(4): 9 p.

Sainsbury, K.J. 1977. Population dynamics and fishery management of the abalone, Haliotis iris. Ph.D Thesis, Univ. Canterbury, Christchurch, N.Z. 183 p.

Sanders, M.J. 1971. Australian studies Japanese fish culture techniques. Austr. Fish. 30(10): 3-9.

REFERENCES (Cont'd)

Shepherd, S.A. 1973. Competition between sea urchins and abalone. Austr. Fish. 32(6): 4-7.

Shepherd, S.A. 1976. Breeding, larval development and culture of abalone. Austr. Fish. 35(4): 7-10.

Stanistreet, K. 1978. Abalone sales prospects may not be on the mend. Austr. Fish. 37(4): 29-30.

Tamura, T. 1960. Marine aquaculture. Eng. trans. 1907 by M. Watanabe, Nat. Sci. Found., Wash., D.C.

Thompson, W.F. 1914. Report on the abalone of British Columbia (Haliotis giganteus Chemnitz). Report of the British Columbia Commissioner of Fisheries. 1913: 126-130.

Appendix 1. World abalone landings (m.t.) by species, 1970-1979[a].

Species[b]	Year									
	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979
Giant abalone (Haliotis gigantea)	6,500	5,700	5,800	5,800	4,971	5,416	5,655	5,203	5,377	4,866
Perlemoen abalone (Haliotis midae)	1,900	1,200	900	900	970	1,078	1,037	736	799	735
Abalone (Haliotis spp.)	9,000	9,800	8,600	9,500	8,222	8,557	8,738	8,890	7,413	6,598
Total	17,400	16,700	15,300	16,200	14,163	15,051	15,430	14,829	13,589	12,199

[a]See Table 2, footnote 'a'.

[b]Scientific name given in parenthesis.

Appendix 2. Japanese abalone imports (m.t.) by country, 1973-1979[a].

Country	Year 1973	1974	1975	1976	1977	1978	1979
Australia	807.3	586.0	558.2	714.4	515.2	1,205.5	1,201.4
Canada	86.8	38.0	70.7	310.2	386.7	385.2	147.4
Chile	-[b]	-	118.8	513.0	2,368.7	1,170.2	2,931.4
Hong Kong	-	-	1.4	-	-	22.5	-
N. Korea	1.5	-	5.0	-	2.2	-	0.3
Rep. Korea	85.8	82.0	124.1	94.4	45.8	5.9	0.6
Philippines	4.8	-	1.6	-	23.6	13.7	30.3
South Africa	-	-	0.5	-	-	-	-
United States	174.1	-	10.6	-	5.2	45.4	126.2
Other	-	35.0	-	15.5	-	0.2	5.1
Total unprocessed[c]	1,160.3	741.0	890.9	1,647.5	3,347.4	2,848.6	4,442.7
Total processed[d]	1,002.3	678.0	623.4	708.4	757.1	708.0	727.0
Overall total	2,162.6	1,419.0	1,514.3	2,355.9	4,104.5	3,556.6	5,169.7

[a]From: Japan Marine Products Importers Association. Japanese Imports of Marine products, 1973-1979.

[b]None recorded.

[c]Live, fresh, chilled or frozen abalone; sum of above countries.

[d]Abalone in airtight countainers, not broken by country. Australia supplies over 80% of all canned abalone imports to Japan (Proverbs 1979, unpublished MS).

Appendix 3. U.S. abalone imports (m.t.) by country, 1964-1980[a].

Country	Year							
	1964	1965	1966	1967	1968	1969	1970	1971
Australia	3.0[b]	29.1	65.3	179.6	362.9	217.9	152.1	487.2
Austria	-	-	-	-	7.5	-	-	-
Bahamas	-	-	-	-	-	-	-	-
Belgium	-	-	-	-	-	-	-	-
Canada	13.0	0.5	2.1	-	-	-	29.2	17.7
Chile	-	-	-	-	-	-	-	-
China, Rep.	-	-	-	-	-	-	-	-
Denmark	-	-	-	-	-	-	-	-
Germany W.	-	-	-	-	-	-	-	-
Greenland	-	-	2.7	-	-	-	-	-
Haiti	-	-	-	-	-	-	-	-
Hong Kong	0.1	-	-	-	0.1	0.1	-	0.5
Iceland	-	-	-	-	-	0.4	-	-
India	-	-	-	-	-	-	-	-
Japan	61.0	25.7	34.8	21.1	40.8	23.5	17.3	13.2
Korea, Rep.	0.4	2.3	-	-	1.5	-	-	-
Mexico	2,809.1	2,612.7	2,132.7	1,686.4	1,979.7	1,997.5	2,155.4	1,708.8
Netherlands	-	-	-	-	-	-	-	-
New Zealand	3.5	3.0	-	0.3	4.2	20.1	9.6	-
Nicaragua	-	-	-	-	-	-	-	-
Pakistan	-	-	-	-	-	-	-	-
Peru	-	-	-	-	-	-	-	-
Philippines	-	-	-	-	-	-	-	-
Singapore	-	-	-	-	-	-	-	-
South Africa	5.6	2.1	6.5	3.0	15.4	2.1	-	-
Africa (Other)	-	-	-	-	-	1.1	-	-
South Vietnam	-	-	-	-	-	-	-	-
Taiwan	-	-	-	-	-	0.3	-	-
Thailand	-	-	-	-	5.9	-	-	-
Other	-	-	-	-	-	-	-	-
Total	2,895.7	2,675.4	2,244.1	1,890.3	2,418.2	2,264.5	2,363.6	2,227.4

Appendix 3. (Cont'd.)

Country	Year 1972	1973	1974	1975	1976	1977	1978	1979	1980
Australia	-	289.0	235.1	181.5	85.0	190.4	197.0	132.4	286.0
Austria	-	-	-	-	-	-	-	-	-
Bahamas	-	-	2.6	-	-	-	-	-	-
Belgium	-	-	24.1	-	-	-	-	-	-
Canada	-	4.0	7.7	2.6	19.1	-	15.1	44.4	15.9
Chile	-	-	-	105.4	113.8	175.9	96.0	167.7	149.0
China, Rep.	-	0.2	0.3	0.3	-	-	-	-	7.4
Denmark	-	1.0	0.3	-	-	-	-	-	-
Germany W.	-	-	5.4	-	-	-	-	-	-
Greenland	-	-	-	-	-	-	-	-	-
Haiti	-	-	1.3	-	-	-	-	-	-
Hong Kong	-	0.1	0.1	2.3	-	-	-	-	4.7
Iceland	-	-	-	0.1	-	-	-	-	-
India	-	-	-	3.2	-	-	-	-	-
Japan	-	4.0	0.9	2.6	1.7	-	2.2	-	2.2
Korea, Rep.	-	-	-	0.3	-	-	-	-	-
Mexico	-	756.0	1,311.9	1,663.4	1,942.6	1,794.6	1,359.5	1,436.8	838.8
Netherlands	-	-	37.9	96.3	-	-	-	-	-
New Zealand	-	-	-	-	-	-	-	-	-
Nicaragua	-	-	0.4	-	-	-	-	-	-
Pakistan	-	-	-	-	-	-	-	-	-
Peru	-	-	-	-	-	44.6	102.6	136.8	42.1
Philippines	-	-	0.4	0.9	-	-	-	-	-
Singapore	-	-	-	1.8	-	-	-	-	-
South Africa	-	-	12.4	-	-	-	-	-	-
Africa (Other)	-	-	-	-	-	-	-	-	-
South Vietnam	-	-	-	-5.2	-	-	-	-	-
Taiwan	-	-	-	-	-	-	-	-	-
Thailand	-	-	-	-	-	-	-	-	-
Other	-	-	0.5	-	0.7	24.1	10.5	24.1	13.2
Total	-	1,054.3	1,641.3	2,065.9	2,162.9	2,229.6	1,782.8	1,942.1	1,355.2

[a]From: U.S. Department of Commerce. U.S. General Imports: Schedule A Commodity by Country. Washington, 1964-1980.

[b]None recorded.

Appendix 4. Commercial abalone area closures, 1980.

THE FOLLOWING AREAS ARE CLOSED BY REGULATION IN THE "PACIFIC SHELLFISH REGULATIONS"[a] OR BY PUBLIC NOTICE[b]

Areas 1, 2E and 2W

Regulations - 1) the waters of Juan Perez Sound and adjacent waters inside a straight line from Werner Point on Moresby Island to Ramsay Point on Ramsay Island, thence along the northerly shoreline of Ramsay Island to Andrew Point, thence in a straight line to Tuft Island, thence in a straight line to Fuller Point on Lyell Island, thence along the southerly shoreline of Lyell Island to Richardson Point, thence a straight line to Darwin Point on Moresby Island and thence south along the shoreline of Moresby Island to the point of commencement (Werner Point).

Regulations - 2) the waters of Rennell Sound inside a straight line from Cone Head to Clonard Point.

Regulations - 3) the waters of Skidegate Channel and adjacent areas (Dawson Inlet, Dawson Harbour, Trounce Inlet), inside a straight line from Ells Point on Graham Island to Teenakun Point on Chaatl Island, thence easterly along the north shoreline of Chaatl Island to Exact Point, thence in a straight line to Demariscous Point on Moresby Island, thence easterly along the north shoreline of Moresby Island to McLellan Point (East Narrows), thence a straight line true north to Graham Island, thence along the south shoreline of Graham Island to the point of commencement (Ellis Point).

Appendix 4. (Cont'd)

Regulations -	*4)*	*the waters of Tasu Sound and adjacent areas inside a straight line from Davidson Point to Tasu Head.*
Regulations -	*5)*	*the waters of Masset Inlet, Masset Sound and McIntyre Bay inside a straight line from Wiah Point to Skonun Point.*
Public Notice	*6)*	*the waters of Cumshewa Inlet inside a line from Cumshewa Head to Skedans Point, and including waters of Carmichael Passage and Selwyn Inlet bounded on the south by a line from Selwyn Point Light on Moresby Island to a boundary sign opposite on Talunkwan Island, and on the east by a line from Nelson Point to Louise Island to Heming Head on Talunkwan Island.*
Public Notice	*7)*	*the waters of Virago Sound inside a straight line true north from Inskip Point to point of interception with a straight line from Cape Naden to Cape Edensaw hence westerly along the line between Cape Naden and Cape Edensaw to Cape Naden.*
Public Notice	*8)*	*the waters of Skincuttle Inlet and Carpenter Bay inside a line from Scudder Point on Burnaby Island to Benjamin Point on Moresby Island and in the north by a line running true east from Dolomite Point on Moresby Island to a point on Burnaby Island.*

Area 4

Regulations -	*1)*	*all waters inside a line commencing at Hunt Point on Porcher Island, thence in a straight line to the most easterly point of Lucy Island, thence in a straight line to Triple Island, thence in a straight line to Butterworth Rocks, thence in a straight line to Seal Rocks, thence in a straight line to Welcome Point on Porcher Island, thence along the northwesterly shore of Porcher Island to Hunt Point on Porcher Island.*

Appendix 4 (Cont'd).

Area 5

Regulations - 1) & Public Notice

those waters inside a line commencing at a white fishing boundary sign on Cape George on Porcher Island and following a southern shore of Porcher Island to Sparrowhawk Point, thence in a s raight line in a direction approximately 155 degrees true to the northwest corner of McCauley Island, thence following the northwest shore of McCauley Island to the light on Keswar Point, thence in a straight line in a direction approximately due south to an orange fishing boundary sign to the southeast of the entrance to Keyarko Cove on Banks Island, thence following the easterly and northerly shores of Banks Island to the light at the entrance to Larsen Harbour, thence in a straight line true south to Banks Island, thence following the westerly shoreline of Banks Island to Kelp Point, thence in a straight line true west to the surf-line, thence following the surfline northerly to Bonilla Island light, thence following the surf-line northerly to a point bearing Cape George true east, thence in a straight line true east to Cape George.

Area 6

Regulations - 1) inside a line commencing at Blackfly Point on Gil Island thence following the westerly side of Gil Island to Fawcett Point, thence in a straight line to Dogan Point on Campania Island, thence following the easterly shore of Campania Island to the southerly extremity of Campania Island, thence in a straight line to Oswald Point on Rennison Island to the eastern extremity of Rennison Island, thence in a straight line to Ulrich Point on Aristazabal Island, thence along the easterly shore of Aristazabal Island to Lombard Point, thence in a straight line projected easterly to a white fishing boundary sign placed on the northwesterly shore of Price Island, thence along the westerly and northerly shores of Price Island to a white fishing boundary sign marking the boundary between Salmon Purse Seine Area Six and

Appendix 4 (Cont'd).

Area 6 (cont'd)

Salmon Purse Seine Area Seven, thence along the Salmon Purse Seine Six--Salmon Purse Seine Area Seven boundary to Split Head on Swindle Island, thence in a straight line to Errigal Point on Princess Royal Island, thence along the southerly shore of Princess Royal to Hartnell Point, thence in a straight line to the most southerly extremity of Hastings Island, thence along the easterly shore of Hastings Island to Hilbert Point, thence in a straight line across Laredo Inlet to Waser Point on Princess Royal Island, thence following sinuosities of the westerly shore of Princess Royal Island to Nelly Point, thence in a straight line to Maple Point on Gil Island, thence along the northerly shore of Gil Island to Blackfly Point, the point of origin.

Area 7

Regulations - 1) bounded on the north by a straight line true east from Jorkins Point on Swindle Island to Dowager Island opposite, and bounded on the south by a line true west from Keith Point on Dowager Island to Price Island opposite.

Regulations - 2) bounded on the west from Promise Point on Cecilia Island along the westerly shore of Cecilia Island to Rankin Point, thence by a straight line to Providence Rock near Cape Mark; and bounded on the south by a straight line to the most northerly point on Limit Island, thence by a straight line to the most northerly point on Limit Island, thence by a straight line to Fingal Point on Princess Alice Island; and bounded on the east by a straight line to Bush Point on Don Peninsula; and bounded on the north from Bush Point on Don Peninsula along the southwesterly shore of Don Peninsula to Schubert Point, thence by a straight line to Promise Point on Cecilia Island opposite.

Appendix 4 (Cont'd).

		Area 8
Regulations -	*1)*	*bounded on the north from Bayly Point on Nalu Island along the southeasterly shore to the most southerly point of Stirling Island, thence by a line true west to the surfline; bounded on the east by a straight line from Bayly Point on Nalu Island to Kelpie Point on Hecate Island, thence along the easterly shore of Hecate Island to Experiment Point, thence by a straight line to Wedgborough Point on Calvert Island; bounded on the south from Wedgborough Point on Calvert Island along the northerly shore of Calvert Island to a point due south of Surf Island, thence by a straight line to Surf Island, thence by a line true west to the surfline.*
		Areas 9 and 10
Regulations -	*1)*	*in the waters of Salmon Purse Seine Areas Nine and Ten as described in the aforementioned regulations.*
		Southern B. C.
Regulations -	*1)*	*"all waters of Johnstone Strait, Straist of Georgia, Strait of Juan de Fuca, or any bay, inlet or other tidal water tributary thereto in the area bounded on the north by a line drawn from Neville Point to the westerly entrance to Port Neville Inlet to Hickey Point Light on Vancouver Island and bounded on the south by a line drawn from Williams Head through Race Rocks due south magnetic to the International Boundary."*
Public Notice	*2)*	*all of Salmon Purse Seine Areas 21, 22, 23, 24 and 26.*

[a] "Regulations" are denoted in official, permanent Shellfish Regulations.

[b] "Public Notice" is issued and posted by a Fishery Officer, and may not be denoted in Shellfish Regulations.

Appendix 5a. Annual abalone landings (kg) by Statistical Area 1-10, northern B.C., 1952-1980.[a]

Year	Statistical Area									
	1	2W	2E	3	4	5	6	7	8	9
1952	-[b]	-	-	-	-	-	-	-	-	-
1953	-	-	-	-	-	-	-	-	-	-
1954	-	-	-	-	-	-	-	-	-	-
1955	-	-	-	-	-	-	-	-	-	-
1956	-	-	-	-	-	-	-	-	-	-
1957	-	-	-	-	(+ 91 kg from unknown Area)			-	-	-
1958	-	-	-	-	-	-	-	-	-	-
1959	-	-	-	-	-	181	-	-	-	-
1960	-	-	-	-	-	1,497	-	-	-	-
1961	227	-	-	-	2,132	363	3,357	-	-	-
1962	862	1,860	6,486	-	3,901	4,309	-	-	-	-
1963	998	-	408	-	1,134	1,179	-	-	-	-
1964	4,672	2,540	12,655	-	-	-	8,845	318	-	-
1965	-	-	1,588	-	-	-	-	-	-	-
1966	-	-	-	-	-	-	-	-	-	-
1967	-	-	-	-	45	-	-	-	-	-
1968	-	-	-	-	-	-	-	-	-	-
1969	-	-	-	-	-	-	-	-	-	-
1970	-	-	-	-	-	45	-	5,307	-	-
1971	-	-	-	-	-	-	-	-	-	-
1972	-	-	-	-	-	-	-	-	-	-
1973	-	1,814	5,443	-	4,082	16,783	454	-	-	-
1974	-	-	-	-	-	5,897	6,350	-	-	-
1975	-	-	2,268	-	2,268	9,525	16,329	14,061	-	<228
1976	4,536	-	112,037	-	4,989	88,450	37,194	1,814	-	907
1977	45,476	13,563	259,463	10,185	-	93,796	33,027	5,601	-	-
1978	12,847	14,602	101,257	254	6,388	88,358	160,380	10,922	-	-
1979	2,613	10,208	24,874	-	2,927	40,478	88,582	11,533	-	-
1980	3,196	3,724	12,537	2,143	2,692	11,309	49,160	5,166	245	299

[a] From sales slip records (1952-1977); from log-book records (1978-1980).

[b] No landings recorded.

Appendix 5b. Annual abalone landings (lb) by Statistical Area 1-10, northern B.C., 1952-1980.[a]

Year	Statistical Area									
	1	2W	2E	3	4	5	6	7	8	9
1952	-[b]	-	-	-	-	-	-	-	-	-
1953	-	-	-	-	-	-	-	-	-	-
1954	-	-	-	-	-	-	-	-	-	-
1955	-	-	-	-	-	-	-	-	-	-
1956	-	-	-	-	-	-	-	-	-	-
1957	-	-	-	-	(+ 200 lb from unknown Area)			-	-	-
1958	-	-	-	-	-	-	-	-	-	-
1959	-	-	-	-	-	400	-	-	-	-
1960	-	-	-	-	-	3,300	-	-	-	-
1961	500	-	-	-	4,700	800	7,400	-	-	-
1962	1,900	4,100	14,300	-	8,600	9,500	-	-	-	-
1963	2,200	-	900	-	2,500	2,600	-	-	-	-
1964	10,300	5,600	27,900	-	-	-	19,500	700	-	-
1965	-	-	3,500	-	-	-	-	-	-	-
1966	-	-	-	-	-	-	-	-	-	-
1967	-	-	-	-	100	-	-	-	-	-
1968	-	-	-	-	-	-	-	-	-	-
1969	-	-	-	-	-	-	-	-	-	-
1970	-	-	-	-	-	100	-	11,700	-	-
1971	-	-	-	-	-	-	-	-	-	-
1972	-	-	-	-	-	-	-	-	-	-
1973	-	4,000	12,000	-	9,000	37,000	1,000	-	-	-
1974	-	-	-	-	-	13,000	14,000	-	-	-
1975	-	-	5,000	-	5,000	21,000	36,000	31,000	-	< 500
1976	10,000	-	247,000	-	11,000	195,000	82,000	4,000	-	2,000
1977	100,258	29,901	572,020	22,455	-	206,786	72,812	12,348	-	-
1978	28,324	32,192	223,235	559	14,083	194,796	353,579	24,080	-	-
1979	5,761	22,504	54,837	-	6,454	89,238	195,292	25,427	-	-
1980	7,045	8,210	27,640	4,725	5,935	24,933	108,380	11,390	540	660

[a,b] As for Append. 5a.

Appendic 5c. Annual abalone landings (kg) by Statistical Area 11-27, southern, B.C., 1952-1980.[a]

Year	Statistical Area														
	11	12	13	15	17	18	19	20	21	22	23	24	25	26	27
1952	-[b]	5,398	-	-	-	-	-	-	-	-	-	-	-	-	-
1953	-	10,342	-	-	-	-	-	-	-	-	-	-	-	-	-
1954	-	6,849	-	-	-	-	-	-	-	-	-	-	-	-	-
1955	-	3,538	-	-	-	-	-	-	-	-	-	-	-	-	-
1956	-	499	-	-	-	-	-	-	-	-	-	-	-	-	-
1957	-	862	-	-	-	-	-	-	-	-	-	-	-	-	-
1958	-	5,216	-	-	91	-	-	-	-	-	-	-	-	-	-
1959	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1960	-	-	45	-	-	-	-	-	-	-	-	-	-	-	-
1961	-	-	-	-	-	-	-	-	-	-	3,311	-	-	-	-
1962	-	45	-	-	-	-	-	-	-	-	< 227	-	-	-	-
1963	-	1,996	-	-	-	-	-	-	-	-	-	-	-	-	-
1964	-	26,580	590	862	-	-	-	-	-	-	-	-	-	-	-
1965	-	1,497	-	-	-	-	-	-	-	-	-	-	-	-	-
1966	-	726	-	-	-	-	-	-	-	-	-	-	-	-	-
1967	-	816	-	-	-	-	-	-	-	-	-	-	-	-	-
1968	-	91	-	-	-	-	-	-	-	-	-	-	-	-	-
1969	-	227	-	-	-	-	-	-	-	-	-	408	-	-	-
1970	-	-	-	-	-	1,588	1,134	1,769	-	680	4,899	816	-	-	-
1971	-	<227	-	-	-	-	-	-	-	272	6,169	-	-	-	-
1972	-	6,577	45	-	3,311	3,175	953	408	-	-	40,007	-	5,080	45	-
1973	-	-	-	-	-	1,814	1,361	5,897	-	< 227	8,618	20,865	-	-	-
1974	-	2,268	-	-	-	-	< 227	7,257	< 227	-	1,814	2,268	454	-	-
1975	-	3,175	-	-	-	-	-	3,629	-	-	907	-	< 227	3,629	907
1976	-	5,443	-	-	< 227	-	1,361	9,525	< 227	-	1,361	2,268	< 227	-	3,175
1977	861	8,545	-	-	-	-	-	1,430	-	-	-	180	4,554	2,332	2,361
1978	-	459	-	-	-	-	912	2,115	-	-	-	-	5,718	-	-
1979	5,548	17,312	-	-	-	-	1,408	281	-	-	-	-	440	209	1,756
1980	638	14,504	-	-	-	-	1,047	957	-	-	-	-	-	-	-

[a,b] As for Append. 5a.

Appendix 5d. Annual abalone landings (lb) by Statistical Area 11-27, southern, B.C., 1952-1980.[a]

Year	Statistical Area														
	11	12	13	15	17	18	19	20	21	22	23	24	25	26	27
1952	-[b]	11,900	-	-	-	-	-	-	-	-	-	-	-	-	-
1953	-	22,800	-	-	-	-	-	-	-	-	-	-	-	-	-
1954	-	15,100	-	-	-	-	-	-	-	-	-	-	-	-	-
1955	-	7,800	-	-	-	-	-	-	-	-	-	-	-	-	-
1956	-	1,100	-	-	-	-	-	-	-	-	-	-	-	-	-
1957	-	1,900	-	-	-	-	-	-	-	-	-	-	-	-	-
1958	-	11,500	-	-	200	-	-	-	-	-	-	-	-	-	-
1959	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1960	-	-	100	-	-	-	-	-	-	-	-	-	-	-	-
1961	-	-	-	-	-	-	-	-	-	-	7,300	-	-	-	-
1962	-	100	-	-	-	-	-	-	-	-	< 500	-	-	-	-
1963	-	4,400	-	-	-	-	-	-	-	-	-	-	-	-	-
1964	-	58,600	1,300	1,900	-	-	-	-	-	-	-	-	-	-	-
1965	-	3,300	-	-	-	-	-	-	-	-	-	-	-	-	-
1966	-	1,600	-	-	-	-	-	-	-	-	-	-	-	-	-
1967	-	1,800	-	-	-	-	-	-	-	-	-	-	-	-	-
1968	-	200	-	-	-	-	-	-	-	-	-	-	-	-	-
1969	-	500	-	-	-	-	-	-	-	-	-	900	-	-	-
1970	-	-	-	-	-	3,500	2,500	3,900	-	1,500	10,800	1,800	-	-	-
1971	-	< 500	-	-	-	-	-	-	-	600	13,600	-	-	-	-
1972	-	14,500	100	-	7,300	7,000	2,100	900	-	-	88,200	-	11,200	100	-
1973	-	-	-	-	-	4,000	3,000	13,000	-	< 500	19,000	46,000	-	-	-
1974	-	5,000	-	-	-	-	< 500	16,000	< 500	-	4,000	5,000	1,000	-	-
1975	-	7,000	-	-	-	-	-	8,000	-	-	2,000	-	< 500	8,000	2,000
1976	-	12,000	-	-	< 500	-	3,000	21,000	< 500	-	3,000	5,000	< 500	-	7,000
1977	1,899	18,838	-	-	-	-	-	3,152	-	-	-	396	10,039	5,141	5,205
1978	-	1,011	-	-	-	-	2,011	4,663	-	-	-	-	12,605	-	-
1979	12,231	38,166	-	-	-	-	3,104	620	-	-	-	-	971	460	3,872
1980	1,406	31,977	-	-	-	-	2,309	2,110	-	-	-	-	-	-	-

[a,b] As for Append. 5a.

Appendix 6. Percent contribution to annual abalone landings by Statistical Area 1-27, B.C., 1952-1980.

	Year														
Area	'52	'53	'54	'55	'56	'57	'58	'59	'60	'61	'62	'63	'64	'65	'66
1	0	0	0	0	0	0	0	0	0	2.4	4.9	17.5	8.2	0	0
2W	0	0	0	0	0	0	0	0	0	0	10.6	0	4.5	0	0
2E	0	0	0	0	0	0	0	0	0	0	37.1	7.1	22.2	51.5	0
3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0	0	0	22.7	22.3	19.8	0	0	0
5	0	0	0	0	0	0	0	100	97.1	3.9	24.7	20.6	0	0	0
6	0	0	0	0	0	0	0	0	0	35.7	0	0	15.5	0	0
7	0	0	0	0	0	0	0	0	0	0	0	0	0.6	0	0
8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
12	100	100	100	100	100	90.5	98.3	0	0	0	0.3	34.9	46.6	48.5	100
13	0	0	0	0	0	0	0	0	2.9	0	0	0	1.0	0	0
15	0	0	0	0	0	0	0	0	0	0	0	0	1.5	0	0
17	0	0	0	0	0	0	1.7	0	0	0	0	0	0	0	0
18	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
19	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
21	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
22	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
23	0	0	0	0	0	0	0	0	0	35.3	0	0	0	0	0
24	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
26	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
27	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	100	100	100	100	100	100[a]	100	100	100	100	100	100	100	100	100

[a] Includes 9.5% from unknown northern Area.

Appendix 6. (Cont'd.)

Area	Year '67	'68	'69	'70	'71	'72	'73	'74	'75	'76	'77	'78	'79	'80
1	0	0	0	0	0	0	0	0	0	1.7	9.4	3.2	1.3	3.0
2W	0	0	0	0	0	0	2.7	0	0	0	2.8	3.6	4.9	3.5
2E	0	0	0	0	0	0	8.1	0	4.0	41.0	53.9	25.1	11.9	11.6
3	0	0	0	0	0	0	0	0	0	0	2.1	0.1	0	2.0
4	5.3	0	0	0	0	0	6.1	0	4.0	1.8	0	1.6	1.4	2.5
5	0	0	0	0.3	0	0	25.0	22.4	16.8	32.4	19.5	21.9	19.4	10.5
6	0	0	0	0	0	0	0.7	24.1	28.8	13.6	6.8	39.7	42.6	45.7
7	0	0	0	32.7	0	0	0	0	24.8	0.7	1.2	2.7	5.5	4.8
8	0	0	0	0	0	0	0	0	0	0	0	0	0	0.2
9	0	0	0	0	0	0	0	0	0	0.3	0	0	0	0.3
10	0	0	0	0	0	0	0	0	0	0	0	0	0	0
11	0	0	0	0	0	0	0	0	0	0	0.2	0	2.7	0.6
12	94.7	100	35.7	0	0	11.0	0	8.6	5.6	2.0	1.8	0.1	8.3	13.5
13	0	0	0	0	0	0.1	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0	0	0	0	0	0	0
17	0	0	0	0	0	5.6	0	0	0	0	0	0	0	0
18	0	0	0	9.8	0	5.3	2.7	0	0	0	0	0	0	0
19	0	0	0	7.0	0	1.6	2.0	0	0	0.5	0	0.2	0.7	1.0
20	0	0	0	10.9	0	0.7	8.8	27.6	6.4	3.5	0.3	0.5	0.1	0.9
21	0	0	0	0	0	0	0	0	0	0	0	0	0	0
22	0	0	0	4.2	4.2	0	0	0	0	0	0	0	0	0
23	0	0	0	30.2	95.7	67.1	12.8	6.9	1.6	0.5	0	0	0	0
24	0	0	64.3	5.0	0	0	31.1	8.6	0	0.8	0	0	0	0
25	0	0	0	0	0	8.5	0	1.7	0	0	0.9	1.4	0.2	0
26	0	0	0	0	0	0.1	0	0	6.4	0	0.5	0	0.1	0
27	0	0	0	0	0	0	0	0	1.6	1.2	0.5	0	0.8	0
Total	100	100	100	100	100	100	100	100	100	100	100	100	100	100

Appendix 7. Abalone fishing effort by Statistical Area, B.C., 1977-1980.

Statistical Area	1977			1978			1979			1980		
	Total diver days	CPUE/diver day kg	CPUE/diver day lb	Total diver days	CPUE/diver day kg	CPUE/diver day lb	Total diver days	CPUE/diver day kg	CPUE/diver day lb	Total diver days	CPUE/diver day kg	CPUE/diver day lb
1	211	215.5	475.2	59	217.8	480.1	20	130.7	288.1	21	152.2	335.5
2W	75	180.8	398.7	80	182.5	402.4	63	162.0	357.2	21	177.4	391.0
2E	1,111	233.6	514.9	547	185.1	408.1	134	185.6	409.2	48	261.2	575.8
3	51	199.6	440.0	5	50.7	111.8	-	-	-	14	153.1	337.5
4	-	-	-	30	212.9	469.4	40	73.2	161.4	16	168.2	370.9
5	470	199.6	440.0	506	174.6	385.0	347	116.6	257.2	104	108.7	239.7
6	251	131.6	290.0	761	210.7	464.6	449	197.3	434.9	381	129.0	284.5
7	51	109.8	242.1	101	108.1	238.4	86	134.1	295.7	32+[a]	133.7	294.7
8	-	-	-	-	-	-	-	-	-	2	122.5	270.0
9	-	-	-	-	-	-	-	-	-	6	49.9	110.0
11	11	78.3	172.6	-	-	-	42	132.1	291.2	6	106.3	234.3
12	95	89.9	198.3	6	76.4	168.5	126	137.4	302.9	130+[a]	106.8	235.5
19	-	-	-	10	91.2	201.1	17	82.8	182.6	7	149.6	329.9
20	16	89.4	197.0	23	91.9	202.7	4	70.3	155.0	12	79.7	175.8
24	4	44.9	99.0	-	-	-	-	-	-	-	-	-
25	16	284.6	627.4	34	168.1	370.7	4	110.1	242.8	-	-	-
26	14	166.6	367.2	-	-	-	3	69.6	153.3	-	-	-
27	11	214.6	473.2	-	-	-	13	135.1	297.8	-	-	-
Total	2,387	-	-	2,162	-	-	1,348	-	-	800+10.5	-	-
Mean[b]	-	201.7	444.6	-	187.0	412.2	-	154.4	340.5	-	132.8[b]	292.7[b]

[a] 1,389 kg of unknown fishing effort; CPUE based on remaining catch.

[b] Total catch/Area (Append. 5a-d.) ÷ Total diver days.