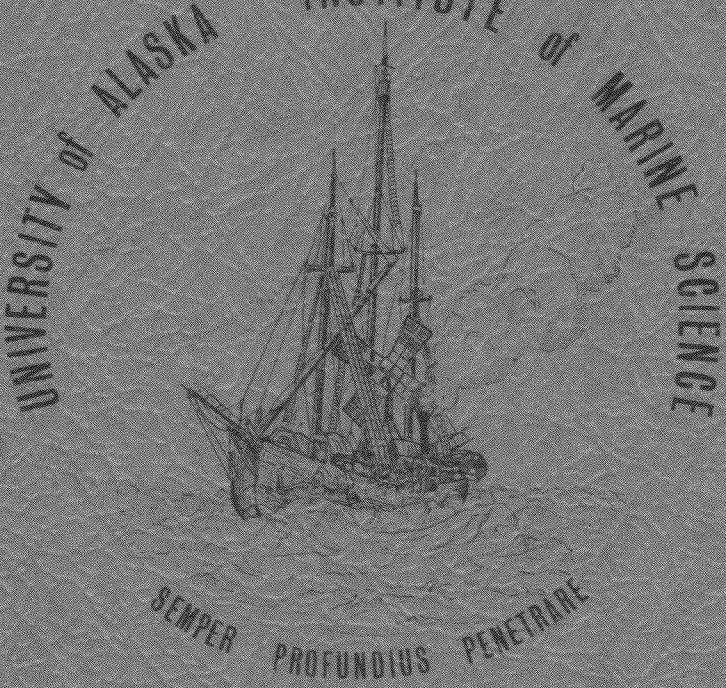
CLAM, MUSSEL, AND OYSTER RESOURCES OF ALASKA

A. J. Paul and Howard M. Feder



IMS Report No. 76-4
Sea Grant Report No. 76-6
April 1976

D. W. Hood
Director

Institute of Marine Science
University of Alaska
Fairbanks, Alaska 99701

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by

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PREFACE

This report is a compilation of data gathered in the course of a University of Alaska Sea Grant project, *The Biology of Economically Important Bivalves and Other Molluscs*. This project concentrated on the study of hard shell clams and was designed to complement on-going Alaska Department of Fish and Game razor clam research. The primary purpose of this report is to provide the public with existing biological information on the clam, mussel, and oyster resources of the state. It is intended to be supplementary to a previous report *The Alaska Clam Fishery: A survey and analysis of economic potential*, IMS Report No. R75-3, Sea Grant No. 75-5. (Orth, et al., 1975).

ACKNOWLEDGEMENTS

The authors wish to thank Sam Stoker (Institute of Marine Science, University of Alaska) and Rae Baxter (Alaska Department of Fish and Game) for reviewing this report and providing additional information from their own research. The following Alaska Department of Fish and Game biologists also provided helpful information: Rodney Kaiser (Kodiak), David Nelson (Soldotna), Richard Nickerson (Cordova), and John Westlund (Ketchikan). Judy M. Paul and Carol Bennie aided in editing and typing. The crew of the *R/V Acona* aided in many of the collections.

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SUMMARY

The total clam resource in Alaska is unknown, but must be considered to be quite large. Growth information is available for intertidal razor, butter, littleneck, pinkneck, and soft-shell clams in southcentral Alaska. Similar information for these species from other areas of the state is not available. Currently, stock assessment, recruitment, and toxin monitoring programs are restricted to razor clams. These programs must be extended to all other species of clams of potential commercial value before they can be harvested for human consumption.

Observations on the stability of razor clam populations in the Clam Gulch area in Cook Inlet and the recovery of littleneck and soft-shell clams after the 1964 earthquake in Prince William Sound indicate that it may be possible to manage these species on a sustained yield basis. Butter clams in southeastern Alaska and British Columbia exhibit variable recruitment, therefore, it is possible that sustained yields of this clam cannot be maintained in all areas. The failure of butter clams to return to their pre-earthquake abundance levels in Prince William Sound supports this theory. Further work on spawning and recruitment success are necessary to determine if butter clams can be harvested on a sustained yield basis.

Little is known about the biology of the subtidal clams, *Mya priapus*, *Spisula polynyma*, and *Tellina lutea*. However, these clams apparently grow slowly and require periods of ten to fifteen years to reach a harvestable size. Information concerning the abundances, distribution, and reproductive biology of these animals will have to be gathered before their fishery potential can be assessed.

In Alaska, the blue mussel represents an unexploited intertidal fishery with great potential. Alaskan mussel beds are presently capable of yielding millions of pounds of palatable flesh. However, current consumer prejudices inhibit the exploitation of this resource.

The economics dealing with potential Alaskan clam fisheries have been thoroughly discussed by Orth, et al., (1975). Currently, the Pacific razor clam is the only species that is commercially harvested in Alaska and the majority of the catch is sold for crab bait. At present, Alaskan clam prices are high and not competitive. This is primarily due to high labor costs involved with hand digging. The high price for clam products could be reduced by the introduction of mechanical harvesting; however, a hydraulic dredge capable of properly harvesting razor clams has not been designed. Hydraulic dredges that could be used for the harvesting of butter clams, littleneck clams, soft-shell clams and pinkneck clams exist and are used on the east coast of the U. S., in Washington and British Columbia. At properly reduced prices, Alaskan clam products could compete with those of British Columbia and the state of Washington for the Pacific coast market. The economic feasibility of such a fishery depends on the development of reliable markets and the ability to produce clam products at competitive prices.

Before a clam fishery can become a reality in Alaska, the problem of Paralytic Shellfish Poison (PSP) must be resolved by the development of an effective beach-monitoring system in conjunction with a rapid assay for the presence of toxin in fresh or canned clam meats. Currently, only the

razor clam beaches in the Cordova, Polly Creek, and Swikshak areas are monitored for PSP.

Alaskan clams represent a large untapped fishery resource. If declines in other important Alaskan fisheries occur, then harvesting clams could help maintain the production of fishery products within the state.

INTRODUCTION

In 1968, the U. S. Bureau of Commercial Fisheries, Department of Interior, estimated the potential annual harvest of clams for Alaska (Fig. 1) to be about 50 million pounds or 22,680,000 kg (U. S. Department of Interior, Bureau of Commercial Fisheries, 1968). At present, the annual harvest is only 200,000 pounds or 90,720 kg (Orth, et al., 1975). Clam harvests in Alaska have traditionally been supported by three intertidal species, the razor clam (*Siliqua patula*), the butter clam (*Saxidomus gigantea*), and the cockle (*Clinocardium nuttallii*). The razor clam has been the most important of the three species, representing more than 95 percent of the catch since the 1950's.

There are two other species of intertidal clams that are abundant, but unexploited; the littleneck clam and the soft-shell clam. The littleneck clam (*Protothaca staminea*) is commonly found in association with butter clams, but has been commercially harvested only to a limited extent in Alaska (Rae Baxter, Alaska Department of Fish and Game, personal communication). This clam is of commercial importance in British Columbia and Washington. The soft-shell clam (*Mya arenaria*) is another unharvested intertidal clam commonly found in Alaska (Feder and Paul, 1973; Rae Baxter, Alaska Dept. of Fish and Game, personal communication, 1976). This clam is the mainstay of the clam fisheries of Maine and northeastern Canada (Dow and Wallace, 1961; Hanks 1963).

Unknown quantities of horse clam (*Tresus capax*) and the pinkneck or surf clam (*Spisula polynyma*) occur intertidally. The blue mussel (*Mytilus edulis*) is abundant in Alaska but unharvested.

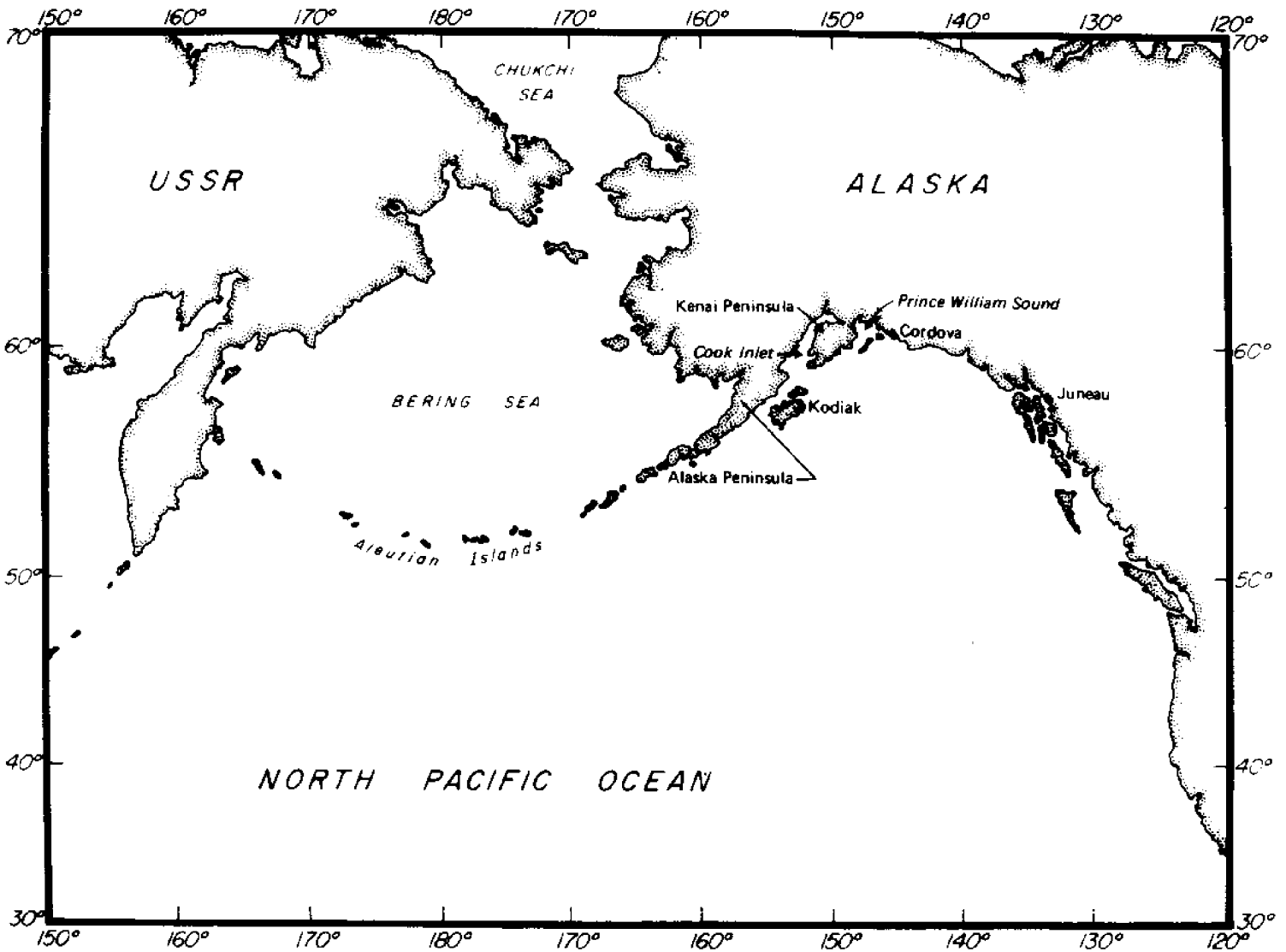

Figure 1. Map of Alaska showing the major areas discussed in this report.

At least two species of clams with commercial potential occur subtidally in Alaskan waters. Good subtidal catches of pinkneck clams (*Spisula polynyma*) have been reported in Icy Straits, southeastern Alaska (Kessler and Hitz, 1971), and examinations of walrus stomachs indicate the existence of large numbers of *Mya priapus* and *Spisula poynyma* in the Bering Sea (Rae Baxter, Alaska Dept. of Fish and Game; Sam Stoker, University of Alaska, personal communications, 1976; Feder, unpublished). Dense aggregations of butterfly tellin (*Tellina lutea*) are also commonly found intertidally and subtidally in the Bering Sea (Feder, unpublished). No abundance estimations exist for these clams.

FACTORS AFFECTING CLAM DENSITIES

The three major biological factors that effect the potential clam harvest of an area are reproduction, recruitment success, and growth. The reproductive success of a species is affected primarily by food availability and water temperature. Clams spawn large numbers of eggs and sperm into the water. Free swimming larvae hatch from the fertilized eggs, and are carried about by currents. Eventually the larvae settle to the bottom and begin their sedentary existence. There are beaches in Alaska that could provide good clam habitat; however, the prevailing currents bypass them and thus, the larval clams are precluded from settling there. In the cold waters of Alaska, clams grow slowly and live to be relatively old (Weymouth, et al., 1931; Baxter, 1965; Paul and Feder, 1973; Paul, et al., 1976b & c; Feder, et al., 1976). Growth rates directly affect the amount of time required before an area can be reharvested.

Predation is an additional factor that affects the abundance and distribution of bivalves in an area. Sea stars (Paul and Feder, 1975), bottom-feeding fishes, predatory snails, crabs (Bourne and Lee, 1974), and marine mammals (Stoker, 1973; Cole, 1975) feed on clams. Human utilization, likewise, affects the abundance of clams in an area. In addition to the mortality caused by the removal of the clams for consumption, small clams may be buried or broken by the digging activity.

GOVERNMENTAL REGULATIONS

There are state and federal regulations which affect the harvesting of clams in Alaska. Clam products that are destined for interstate shipment must come from beaches certified free of Paralytic Shellfish Poison, harmful bacteria and/or viruses (Orth, et al., 1975). In Alaska, most of the clam beaches are relatively free from contamination by human sewage, therefore, bacterial and viral contamination is minimal. Paralytic Shellfish Poison (PSP) results from the ingestion by clams of certain microscopic organisms known as dinoflagellates. This toxin does not affect the clam, but may cause humans who consume toxic clam products to become ill. In Alaska, there exist both PSP-free and contaminated clam beds. Laboratory assay methods must be used to determine PSP toxicity. Certification of clam beaches and clam products is done through the National Shellfish Sanitation Program (NSSP) and the State Department of Health and Social Services (Orth, et al., 1975).

The state of Alaska also has regulations concerning harvesting techniques. Presently clams may be harvested only with hand tools (shovels, hoes,

rakes, and clam guns) throughout most of Alaska. In 1970, hydraulic diggers were authorized in areas west of the Kenai Peninsula. However, to date, a hydraulic dredge suitable for Alaskan razor clams has not been developed. Such a dredge must efficiently harvest larger clams without destroying young clams and the habitat.

DEMAND FOR CLAM PRODUCTS

The demand for clam products in the U. S. and especially the Pacific Northwest increases annually (Glude, 1974). However, in the past there have been large unexploited stocks of clams in the U. S. and increases in demand could be supplied without large increases in the real price of clams (Orth, et al., 1975). In the past, subtidal harvests of surf clams (*Spisula solidissima*) and soft-shell clams (*Mya arenaria*) from the New Jersey and Chesapeake Bay areas supplied the bulk of U. S. clam products (Dow and Wallace, 1961). Currently the east coast surf clam fishery is in a state of decline (Geiser, 1976), and the National Marine Fisheries Service is exploring the production potential of Bering Sea stocks of *Spisula polynyma*.

The ability of Alaskan clam products to compete with established American clam fisheries and foreign sources depends primarily on the ability of harvesters to introduce efficient mechanical harvesting machines (Orth, et al., 1975). The most accessible markets for Alaskan clam products include the crab bait market and west coast consumers who have a preference for west coast clam species (Glude, 1974; Orth, et al., 1975).

RAZOR CLAM (*SILIQUA PATULA*)

Commercial quantities of Pacific razor clams occur on beaches near Cordova, southwest of Cook Inlet, along the west side of Cook Inlet, and in the Swikshak area of the Alaska Peninsula. The clams inhabit open beaches consisting of fine or coarse sand with some glacial silt and/or gravel (Amos, 1966). Razor clams are generally not found in enclosed bodies of water. Commercial harvests of razor clams are regulated by the Alaska Department of Fish and Game.

In Alaska, razor clams must be 4.5 inches (11.4 cm) in length before they can be harvested legally. Razor clams require four to nine years to reach harvestable size in most areas of Alaska (see Table 1). Razors are sexually mature at approximately 4 inches (10.1 cm) shell length (Weymouth, et al., 1925). Spawning in Cook Inlet occurs during July and August when the water temperatures reach 56° F or 13° C (Nosho, 1972).

Currently there is no quantitative literature concerning the abundance of Pacific razor clams for the state of Alaska. However, Richard Nickerson, Alaska Department of Fish and Game biologist, reports the potential of the statewide Alaskan razor clam fishery to be that of a multi-million dollar industry (Rearden, 1974; Nickerson, 1975). Qualitative population assessments are available for razor clams from beaches in the Kodiak area (see Table 2), but quantitative data are unavailable for this area. Before large scale harvesting of Alaskan razor clams can begin, an efficient mechanical harvesting device that will not destroy young clams must be designed (see Rearden, 1974, for discussion). Table 3 summarizes recent

Table 1.

Growth rates of razor clams from four areas in Alaska. The measurement reported is shell length in centimeters (2.54 cm = 1 inch). Legal size = 11.4 cm or 4 1/2 inches, and is underscored for each area.

AGE (YEARS)	CONTROLLER BAY+	KARL BAR+	SWIKSHAK+	HALLO BAY+	HARTNEY BAY*
1	0.34	0.38	0.38	0.34	0.66
2	2.12	2.43	2.73	2.25	1.65
3	4.18	5.49	6.41	5.42	3.54
4	6.52	8.57	9.28	8.60	6.15
5	8.45	10.92	<u>11.49</u>	10.96	8.68
6	9.71	<u>12.66</u>	12.74	<u>12.37</u>	10.58
7	10.51	13.78	13.70	13.17	<u>12.37</u>
8	11.25	14.52	14.19	13.65	
9	<u>11.90</u>	15.03	14.63	14.06	
10	12.60	15.43	14.94	14.44	
11	13.00	15.63	15.25	14.75	
12	13.28	15.95	15.61	15.08	
13	13.51	16.05	16.12	15.38	
14		15.90	15.96	15.50	
15		15.95	16.72	15.80	
16		16.15		15.61	
17		16.25		15.74	
18		16.40		16.31	

\+ Data from Weymouth, McMillin and Rich (1931).

* Data from Nickerson (1975).

Table 2.

A qualitative assessment of razor clams abundance in the Kodiak region*

AREA	ESTIMATE MILES OF BEACH	CLAM ABUNDANCE	UTILIZED COMMERCIALLY
Buskin	1	Poor	No
Middle Bay	1/2	Good	No
Narrow Cape	5	Poor	No
Portage	1/2	Fair	No
Saltery	1/2	Poor	No
Ocean Beach	3	Fair	No
Rolling Bay	1	Fair	No
Tugidak	10	Fair	No
Alitak	10	Fair	Yes
Bumble Bay	2	Fair	Yes
Halibut	5	Good	Yes
Carmel	2	Fair	No
Duck Bay	1/2	Fair	No
N. Swikshak	25	Excellent	Yes
S. Swikshak	20	Excellent	Yes
Kukak Bay	10	Excellent	Yes
Dakavak Bay	3	Good	Yes
Kashvik Bay	2	Excellent	Yes
Alinchak Bay	4	Good	Yes
Imuya Bay	2	Excellent	No
Chiginagak Bay	2	Good	Yes
Yantarni Bay	10	Excellent	Yes
Aniakchak	5	Excellent	Yes
Chignik Bay	1	Good	No

* From the Kodiak office, Alaska Department of Fish and Game.

Table 3.

Alaska razor clam landings, value of landings, and prices (1960-1974) from Orth, et al., 1975. (Assumes 35% meat recovery).

YEAR	LANDINGS (POUNDS OF MEAT)	AVERAGE PRICE (CENTS PER POUND)	VALUE IN DOLLARS
1960	473,000	37	175,000
1961	326,000	37	121,000
1962	241,000	33	79,000
1963	144,000	36	52,000
1964	35,000	55	19,000
1965	31,000	71	41,000
1966	15,000	59	9,000
1967	41,000	72	30,000
1968	28,000	71	20,000
1969	30,000	84	25,000
1970	56,000	71	40,000
1971	85,000	83	70,000
1972	75,000	91	69,000
1973	81,000	110	89,000
1974	79,845	124	99,779

statewide razor clam landings and their dollar value; Table 4 illustrates the catch for the Kodiak, Cook Inlet, Cordova, and Aleutian areas. (Also, see Fig. 2).

Currently, most of the Alaskan razor clams harvested commercially are sold to Dungeness crab (*Cancer magister*) fishermen in Alaska, Washington, and Oregon. Razor clams are excellent crab bait, and many fishermen prefer them to other baits. Razor clam products for human consumption are sold fresh, frozen, or canned.

An additional edible species of razor clam, *Siliqua alta*, is encountered from Cook Inlet to the Arctic Ocean (Abbott, 1974). It is similar in appearance to the Pacific razor clam but chalky-white inside, more truncate at both ends, and the meat is much darker in color. No quantitative information is available concerning the abundance of this species in Alaskan waters. However, it probably does not occur in commercial densities in the Cook Inlet area (Dave Nelson, Alaska Department of Fish and Game, personal communication, 1976), and in the Bering Sea it is too small to be considered for harvest (Rae Baxter, Alaska Department of Fish and Game, personal communication, 1976).

An active sport fishery for razor clams exists on the east side of the Kenai Peninsula. Daily bag limits are 60 clams per person. In 1972, 437,500 razor clams were harvested by 15,400 sport diggers. Over half of these clams were harvested from one area - Clam Gulch. During the period of 1965-1975, no decrease in the average size of clams from Clam Gulch has been observed (Alaska Department of Fish and Game, 1973), indicating that

Table 4.

Comparative Alaska Razor Clam Harvest by Area
(thousand pounds shell weight)

1965 - 1972

	CORDOVA	COOK INLET	KODIAK	ALEUTIANS EAST UNALASKA	TOTAL
1965	87.7	0	0	0	87.7
1966	28.6	0	15.5	0	44.1
1967	114.9	0	2.2	0	117.1
1968	72.9	0	6.4	0	79.3
1969	26.8	0	12.1	47.4	86.3
1970	27.9	0	132.3	0.1	160.2
1971	38.0	14.8	190.4	0	243.1
1972	30.0	31.4	158.8	0	213.8
1973			153.2		153.2
1974			175.9		175.9

Source: Alaska Department of Fish and Game, Statistical Leaflets.

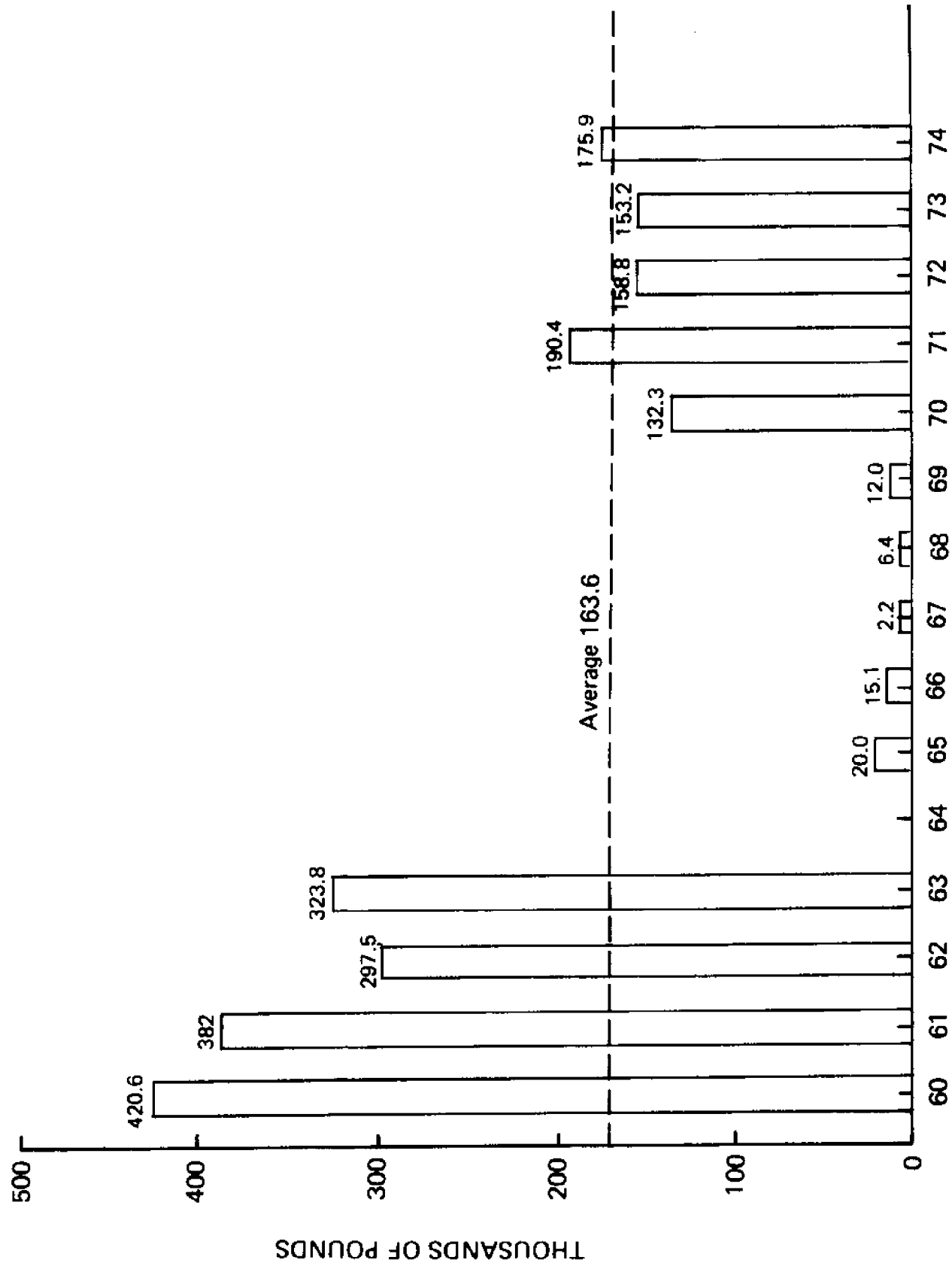

Figure 2. Annual Commercial Harvest of Razor Clams for the Kodiak Area, 1960-1974. (average based on years of harvest only)

harvest pressure is not presently too extreme. Based on the observations made on the sports fishery, it appears that razor clams can be managed for sustained yield. The Alaska Department of Fish and Game is currently involved in razor clam research. The work is being conducted through the Cordova, Kodiak, and Soldotna offices.

BUTTER CLAM (*SAXIDOMUS GIGANTEA*)

Commercial quantities of butter clams are found on beaches throughout southeast Alaska (Paul, et al., 1976c). Isolated beaches with dense populations of butter clams also occur in Icy Bay, Yakutat Bay, Prince William Sound, Cook Inlet, and along the Alaska Peninsula. Butter clams are generally found from the minus 2 foot (0.61 m) tide level to depths of 30 feet or 9.14 m (Amos, 1966). They are encountered on well-protected beaches in mixed sand or mud and gravel substrates.

Butter clams are generally harvested at about 2.5 inches (6.4 cm) in length, and they generally require a minimum of eight to ten years to reach this size (see Table 5). Individuals may live 20 years or more (Baxter, 1965; Quayle and Bourne, 1972).

Butter clams are sexually mature at approximately 1.5 inches (3.8 cm) shell length (Quayle and Bourne, 1972) and usually spawn at 68° F or 20°C (Nosho, 1972). During cold years, butter clams may not spawn in all parts of Alaska; therefore, annual recruitment is variable (Nosho, 1972; Paul, et al., 1976c). In British Columbia, butter clam beds exist in which only one major spawning has occurred in a 20 year period (Quayle and Bourne, 1972).

Table 5.

Growth rates of butter clams in the northeastern Pacific. The measurements reported are shell lengths in centimeters (2.54 cm = 1 inch). Butter clams are harvested at 6.4 cm (2.5 inches); harvestable sizes in each region are underlined below.

AGE	PRINCE RUPERT* (B.C. CANADA)	PORPOISE ISLAND+ (S.E. AK.)	KASITSNA BAY- (S. CENTRAL AK.)	KING COVE- (S.W. AK.)
1	0.54	0.51	0.41	0.58
2	1.67	1.12	0.80	1.08
3	2.69	1.54	1.47	1.76
4	3.73	2.25	2.31	2.56
5	4.61	3.03	3.20	3.57
6	5.46	3.82	4.19	4.25
7	6.20	4.59	5.12	5.42
8	6.77	5.41	6.13	6.18
9	7.31	6.26	7.23	6.84
10	7.81	7.13	8.19	7.40
11	8.45	7.74	9.01	7.51
12		8.25	9.73	7.90
13		8.69	10.56	

* From Fraser and Smith, 1928.

\+ Paul, et al., 1976c.

\- Unpublished data.

The butter clam formerly supported a small fishery in southeast Alaska. The meats were generally canned. Commercial harvesting began in 1930 with an initial catch of 25,000 pounds (11,340 kg) and continued until 1942 with no appreciable expansion (Nosho, 1972). Wartime demand gave the industry impetus to increase production and by 1946 five southeastern Alaska canneries were producing a pack valued at $170,000 (Orth, et al., 1975). The clam fishery was of special importance to resident Alaskans because it was a winter operation offering employment and income during an otherwise slack season (Orth, et al., 1975). However, the presence of a toxin, Paralytic Shellfish Poison, in the canned product led to the decline and ultimate collapse of the butter clam industry in southeast and southcentral Alaska. From 1960 to the present, less than 2,000 pounds (907 kg) of butter clams have been processed in Alaska (Nosho, 1972). A small butter clam fishery in the Kasitsna Bay area of Cook Inlet has been in existence since the 1950's (Smelcer, 1974).

Butter clams have been traditionally harvested with hand tools, but may also be harvested with hydraulic pumps (Bourne, 1967) and possibly with escalator clam dredges similar to those used on the east coast of the United States.

There are no abundance estimations for butter clams in the state of Alaska. However, based on the large number of beaches on which they occur, the commercial potential of this clam must be considered extensive. Alaskan sports fishermen actively seek this animal in southeastern, southcentral, and southwestern Alaska.

Little long-term information is available on the stability of butter clam populations in the state, and no information is available concerning the effect of fishing pressure on butter clam populations. The 1964 earthquake destroyed most of the butter clam beds in Prince William Sound and to date the clams have failed to return to their former level of abundance (Feder and Paul, unpublished). In southeastern Alaska and British Columbia, Canada, butter clam recruitment appears to be variable (Quayle and Bourne, 1972; Paul, et al., 1976c). Therefore, it is possible that areas disturbed by commercial harvesting may require long periods (20 years or more) to regain harvestable populations of butter clams.

Butter and littleneck clams (*Protothaca staminea*) are eaten by sea otters. Adult sea otters consume approximately 10 pounds (4.5 kg) of shellfish daily (Cole, 1975). The authors have observed beaches in Prince William Sound where virtually all the sexually mature butter clams have been eaten by sea otters (unpublished).

BASKET COCKLE (*CLINOCARDIUM NUTTALLII*)

Basket cockles, or heart cockles, are found throughout Alaska, and may be encountered in dense aggregations on tide flats of sand, mixed sand and mud, mixed gravel and mud, and in eelgrass beds. They are found in the lower tidal zones, usually on or near the surface of the substrate. Alaskan cockles are harvested between 2 and 4 inches (5 to 10 cm) shell length, and require approximately five to fifteen years to reach this size (Fig. 3) (Weymouth and Thompson, 1931; Rae Baxter, Alaska Department of Fish and Game, personal communication, 1976).

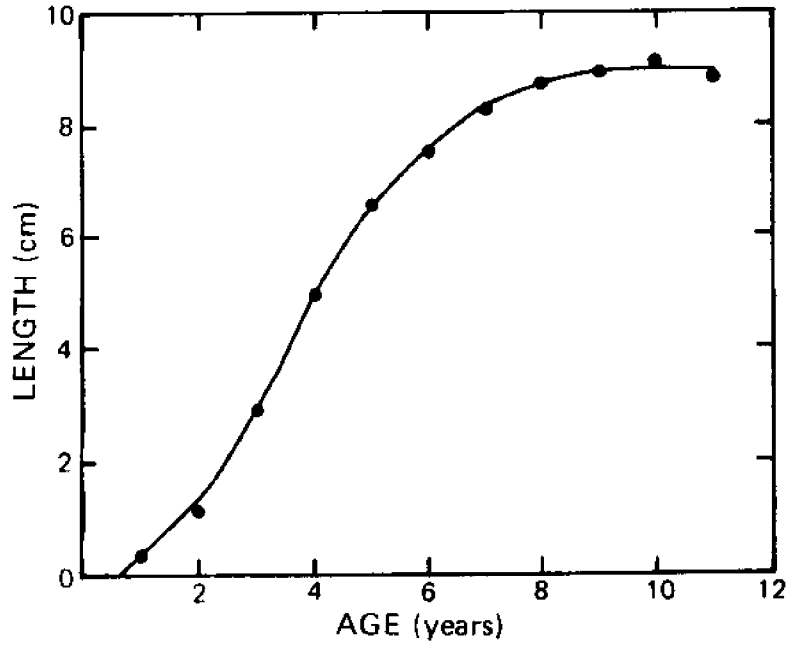

Figure 3. Growth of *Clinocardium nuttallii* at Snug Harbor, Alaska. (Weymouth and Thompson, 1931)

In the past, Alaska was the chief commercial source for cockle meats, with major harvest in the Cordova and Kodiak regions (Nosho, 1972). The canning process utilized during the 1940's and 1950's required an extensive amount of labor and the recovery rate of meat was relatively low (Rae Baxter, Alaska Department of Fish and Game, personal communication, 1976). Because of these problems and restrictions due to Paralytic Shellfish Poisoning, there have been no recent landings.

There is no current assessment of the commercial potential of cockles in Alaska. Table 6 summarizes the cockle landings and their dollar value.

LITTLENECK CLAM (*PROTOTHACA STAMINEA*)

Littleneck clams are found throughout southeastern and southcentral Alaska, often in dense aggregations. On one beach in Galena Bay, Prince William Sound, with a length of 900 feet (272 m) the population of littleneck clams was estimated to be 1,159,515 individuals (Feder and Paul, 1973). The density of these animals was 19 harvestable size clams per 10 inches^2 or 0.25 m^2 (Feder and Paul, 1973).

Populations of littlenecks like these are encountered in southeastern Alaska, Prince William Sound, southern Kenai Peninsula, and Cook Inlet. Littleneck clams are generally found on well-protected beaches in mixed gravel and mud substrates, and are often found in association with butter clams (*Saxidomus gigantea*). They are usually within 2.5 inches

Table 6.

Southcentral Alaskan Cockle Landings in Pounds and Value.[1]

YEAR	POUNDS	VALUE IN DOLLARS	YEAR	POUNDS	VALUE IN DOLLARS
1944	8,580	270	1953	20,000	1.616
1945	10,918	420	1954	67,778	5,422
1946	7,368	442	1956	81,678	6,534
1947	4,696	282	1957	640	45
1949	8,316	499	1960	81,079	10,054
1950	73,200	4,392	1961	40,000*	
1951	32,073	2,566	1962[1]	1,429	260
1952	8,830	662			

* Rae Baxter, Alaska Department of Fish and Game, personal communication.

1 There have been no reported cockle landings from 1963 to 1974 (Smelcer, 1974).

(6 cm) of the sediment surface (Paul and Feder, 1973), but may occur to depths of 7 inches (18 cm). Intertidally they occur between plus 3 and minus 3 (0.9 m) with dense concentrations generally at mean low water or 0.0 feet (0.0 m) (Amos, 1966; Paul and Feder, 1973).

Littleneck clams are harvested at about 1.25 inches (3.0 to 3.2 cm) in length (Quayle and Bourne, 1972; Paul and Feder, 1973). In Prince William Sound the growth of these clams is slow, and it requires about eight years for them to reach this size (Paul and Feder, 1973). In the Juneau region of southeastern Alaska and in northern British Columbia, littleneck clams require six and three years of growth respectively before they are of harvestable size (Fig. 4).

Sexual maturity in littleneck clams is achieved at 0.75 to 1.37 inches or 2.2 to 3.5 cm (Quayle, 1943). In southcentral Alaska spawning has been observed in mid-July with water temperatures of 46° F (8° C) (Paul, unpublished); however, littlenecks with ripe gonads can be found throughout much of the year (Feder and Paul, unpublished). In British Columbia spawning usually begins in April (Quayle, 1943).

Littleneck clams, like butter clams, exhibit variable recruitment in Alaska (Paul and Feder, 1973; Paul, et al., 1976b), but they appear to exhibit greater settlement success than the butter clams (Paul and Feder, 1973; Paul, et al., 1976b). No information is available on the effect of commercial harvests on recruitment success of Alaskan littleneck clams. However, the heavy mortality of littleneck clams that occurred in Prince

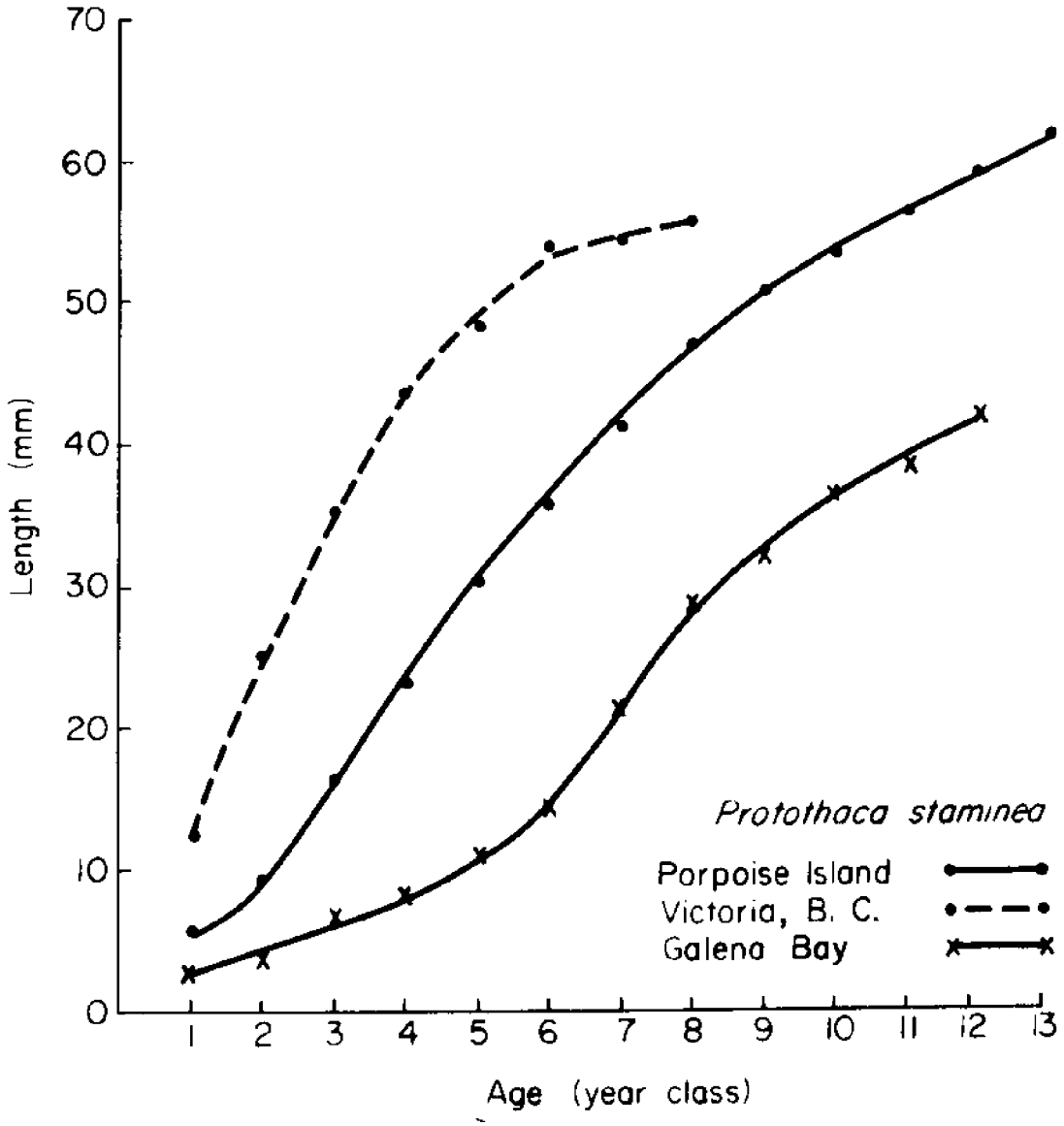

Figure 4. The relationship between shell length (mm) and age of *Protothaca staminea* from Porpoise Island, southeast Alaska; Galena Bay, Prince William Sound, Alaska; and British Columbia, Canada.

William Sound during the 1964 earthquake simulated the effects of a commercial harvest. Littleneck clams in Olsen Bay, Prince William Sound, successfully reestablished themselves within ten years of the earthquake in areas where spawning populations were decimated. (Paul, et al., 1976a).

The littleneck clam is harvested commercially in British Columbia and the state of Washington. In Washington, tractor-drawn intertidal clam dredges are used during low tide, but littlenecks can also be harvested with inexpensive hydraulic clam rakes or pumps (Bourne, 1967; Feder and Paul, 1973). Littlenecks are hardy enough to be marketed alive (Feder and Paul, 1973) and make excellent steamer clams. They are also marketed as frozen and canned products. There are no statewide abundance estimations for *Protothaca staminea*; however, based on the number of beaches inhabited by this clam, littlenecks must be considered a valuable, unexploited resource.

SOFT-SHELL CLAM (*MYA ARENARIA*)

The soft-shell clam is commonly encountered throughout southeastern and southcentral Alaska and in the Bering Sea to Barrow. Soft-shell clams are generally found high in the intertidal zone on tide flats at the head of embayments. They generally inhabit the firmer muds, but may be found on flats with mixed gravel, sand, and mud. Soft-shell clams are euryhaline and can adapt to salinities as low as 4 to $5^{o}/oo$ (Green, 1968). They are also tolerant of wide fluctuations in temperature, dissolved oxygen, and hydrogen sulfide levels (Kyte and Chew, 1975). This adaptability accounts for their wide distribution. Soft-shell clams occur in the sediment at a depth of about 1 foot (30 cm) (Amos, 1966).

A shell length of 2 inches (5.0 cm) is an acceptable commercial size for soft-shell clams and in southcentral Alaska soft-shell clams reach this size in six or seven years (Table 7). This is similar to the growth rates of northern Maine and northeastern Canada. No growth data is available for other areas of Alaska.

Soft-shell clams are sexually mature between 1 and 1.75 inches (2.5 to 4.5 cm) (Porter, 1974). No literature is available concerning the spawning or recruitment success of soft-shell clams in Alaskan waters. However, dense populations of soft-shell clams have successfully reestablished themselves in Port Valdez and Olsen Bay, Prince William Sound, following a drastic decline in numbers after the 1964 earthquake (unpublished). The soft-shell clam, like the razor clam, appears to be well adapted to spawning in the cold waters of Alaska.

Soft-shell clams are commercially harvested in Oregon (Amos, 1966) and Washington (Porter, 1974; Kyte and Chew, 1975). They are sold live for the steamer market or for canning. Soft-shell clams are not commercially harvested nor taken widely by sport diggers in southeast or southcentral Alaska. In the eastern Bering Sea, they are actively sought after by the people of the area (Rae Baxter, Alaska Department of Fish and Game, personal communication, 1976).

Soft-shell clams are harvested intertidally with hand tools, hydraulic rakes (Medcof and MacPhail, 1963) and subtidally with escalator dredges (Dow and Wallace, 1961; Hanks, 1963; Kyte and Chew, 1975). In New England,

Table 7.

Growth rates of soft-shell clams from southcentral Alaska. The measurements reported are shell lengths in centimeters (2.54 cm = 1 inch). Soft-shell clams are harvested at 5.0 cm (2.0 inches); harvestable sizes in the two regions are underlined below.

YEAR CLASS (AGE OF CLAMS)	SIMPSON BAY*	RESURRECTION BAY+
0	0.98	0.80
1	1.34	1.30
2	1.77	1.95
3	2.60	2.45
4	3.08	3.00
5	3.90	4.32
6	4.82	<u>5.75</u>
7	<u>5.75</u>	6.70
8	6.49	7.15
9	7.34	7.85
10	7.80	
11	7.68	
12	8.50	

* Data from Feder and Paul, 1974.

\+ Paul, unpublished data.

the soft-shell clam has proven to be a valuable renewable resource, and has been harvested exclusively with hand tools since the mid-nineteenth century (Hanks, 1963). However, the New England fishery is becoming less productive because of unmanaged fishing pressures and closure of many beaches because of pollution (Dow and Wallace, 1961). The Chesapeake Bay subtidal fishery is currently the major source for soft-shell clam products (Hanks, 1963). A small dredge fishery is now in operation in Washington state (Kyte and Chew, 1975).

No information is available concerning the extent of the soft-shell clam resource in Alaska; however, the Alaskan coastline is provided with innumerable mudflats of the type inhabited by soft-shell clams. The potential of this resource should be properly assessed as it may prove to be of great value.

MYA PRIAPUS

This soft-shell clam is commonly found from the northern Bering Sea, along the Aleutian Chain, and into Kachemak Bay (Abbott, 1974). *Mya priapus* is encountered both intertidally and subtidally to 30 fathoms (54.5 m), generally in gravelly mud substrates. *Mya priapus* is edible, and is harvested occasionally from intertidal areas. It is one of the major food sources of walrus (Rae Baxter, Alaska Department of Fish and Game, personal communication, 1976), but no information is available concerning the biology of this clam.

The present population of the Pacific walrus is about 120,000 animals, representing approximately 127,350 metric tons (Stoker, 1973). These animals are in residence in the Bering Sea about 270 days a year (Stoker, 1973), and it is not uncommon to find up to 80 pounds of siphons and other soft parts of primarily *Mya spp.* in a single walrus stomach (Sam Stoker, University of Alaska, personal communication, 1976). Further examination of population densities of *M. priapus* is necessary to adequately determine the economic potential of this clam.

THE TRUNCATE SOFT-SHELL (*MYA TRUNCATA*)

The truncate soft-shell clam occurs intertidally from southeastern Alaska to the Chukchi Sea. It also lives subtidally in the soft muddy substrates of the Bering, Chukchi, and Beaufort Seas. Little is known about the distribution, abundance, or basic biology of this clam. The flesh of the trancate soft-shell clam is edible and is of a quality comparable to its close relative, the soft-shell clam *Mya arenaria*.

PINKNECK CLAM (*SPISULA POLYNYMA*)

The pinkneck or redneck clam, is a large bivalve found intertidally and subtidally from Point Barrow to the Straits of Juan de Fuca. Intertidally, it is often found in association with razor clams. Dense aggregations of this clam have been observed intertidally on the Copper River flats, Hartney Bay, and in Farragut Bay near Petersburg. Experimental subtidal harvests of this clam have been conducted in parts of southeastern Alaska by the National Fisheries Service. Harvests

of 0.33 bushel (38 clams) to 3.7 bushels (345 clams) were reported for fifteen minute hauls with a modified east coast hydraulic clam dredge in the Icy Straits region of Alaska (Kessler and Hitz, 1971). Pinknecks of this size will have individual wet meat weights of up to 0.6 pounds (250 g) (Feder, et al., 1976). A similar examination of pinkneck stocks in the Bering Sea will be conducted in the spring of 1976. The results of this survey will be available through the National Marine Fisheries Service, Northwest Fisheries Center, in Seattle. The pinkneck clam is a common walrus food item in the Bering Sea (Sam Stoker, University of Alaska, personal communication, 1976).

On the east coast of the United States the closely related *Spisula solidissima* is harvested with hydraulic dredges. In 1965, 44.1 million pounds (20 million kg) of surf clam meats were landed by this fishery (Yancy and Welch, 1968). The meats of this clam are generally turned into canned products. *Spisula solidissima* is harvested at a length of 5 inches (12.8 cm).

The geographic distribution of the pinkneck clam in Alaska has been documented by Chamberlin and Stearns (1963). Growth rates of one south-central Alaskan intertidal population in Hartney Bay have been examined, and this study shows that intertidal pinkneck clams require 14 years to reach a harvestable size of 5 inches (12.5 cm) (Fig. 5) (Feder, et al., 1976). There are no statewide abundance estimations for this clam. Further surveys with east coast type subtidal hydraulic dredges will be necessary to assess the densities of this clam.

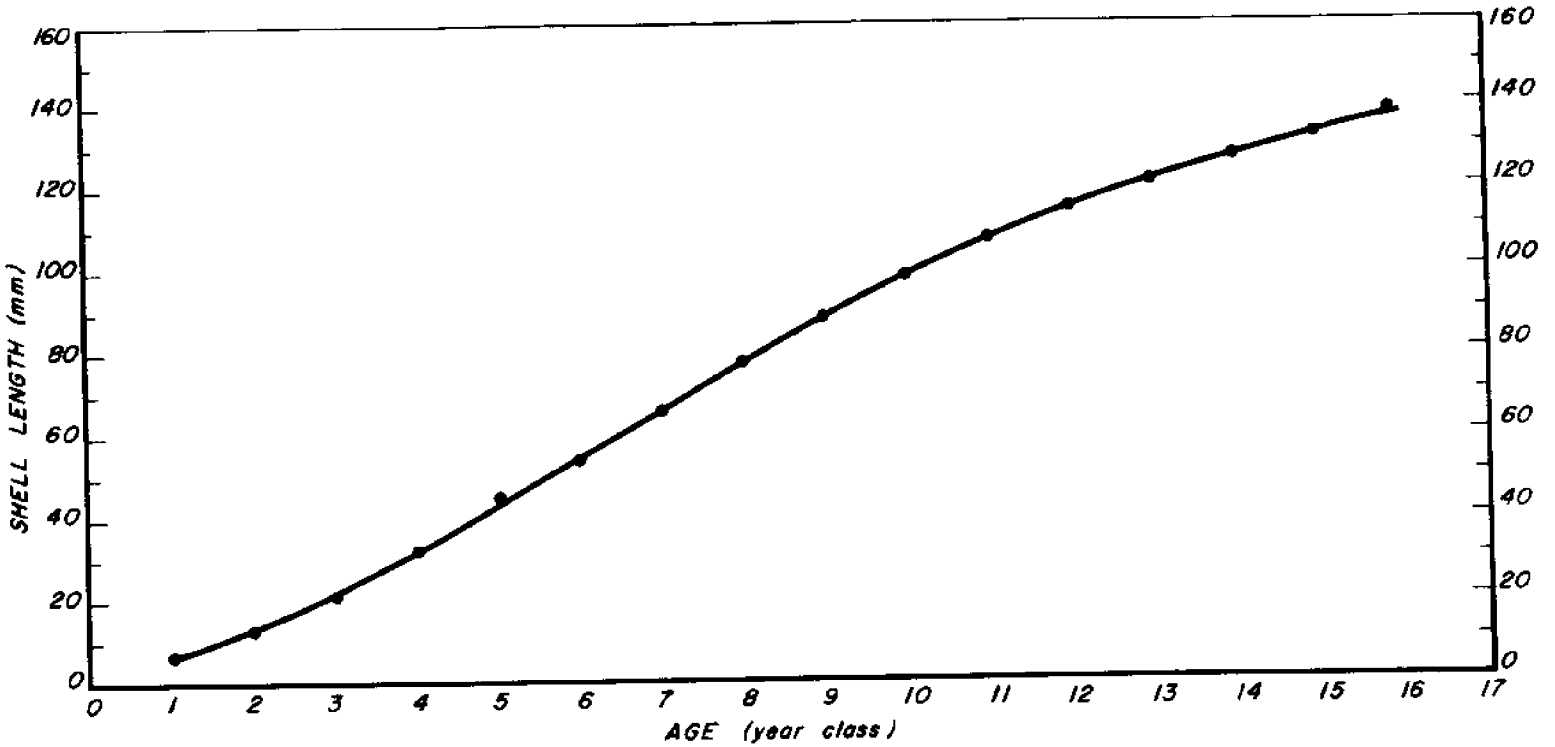

Figure 5. Growth of *Spisula polynyma* from Hartney Bay, Prince William Sound, Alaska. (from Feder, *et al.*, 1976)

BUTTERFLY TELLIN (*TELLINA LUTEA*)

The butterfly tellin is found from the Arctic Ocean to Cook Inlet (Abbott, 1974). They occur both intertidally and subtidally. Little is known about their basic biology or abundance. Like most Alaskan clams it grows slowly, requiring 12 to 15 years to reach a length of 2.5 inches or 6.4 cm (unpublished). Dense aggregations of this animal have been observed intertidally on Adak Island and subtidally in areas of the southeastern Bering Sea (H. M. Feder, unpublished). The people of Adak and other Aleutian islands harvest these clams intertidally for their own use. This clam is also harvested at Cape Prince of Wales and the Bering Strait (Sam Stoker, University of Alaska, personal communication 1976). This is the only known form of human exploitation of this resource. Further examination of population densities of this animal should be encouraged.

ADDITIONAL CLAM SPECIES

The following listing includes additional clam species which may have some small potential for human utilization, however, no information is available concerning the extent of their abundance:

Serripes groenlandicus

S. laperousi

Humilaria kennerleyi

Panope generosa

Tresus capax

Clinocardium ciliatum

BLUE MUSSEL (*MYTILUS EDULIS*)

Beds of blue mussels are common throughout southeastern and south-central Alaska and the southern Bering Sea. Mussels are probably the most abundant, harvestable intertidal bivalve in Alaska. They are usually found in the high intertidal zone, though if protected from predators they may live subtidally.

Blue mussels are harvested in Great Britain, Scandinavia, Spain, and France generally at about 2 inches (5 cm) in length. In the United States small quantities of blue mussels are landed in New England and the state of Washington, but none are harvested in Alaska.

There is no quantitative information on growth rates of blue mussels in Alaska. However, the authors have examined small quantities of mussels from the Resurrection Bay area and determined that five to seven years are required to reach 2 inches (5 cm) in length. Blue mussels are sexually mature at an approximate shell length of 1 inch (2.5 cm), and planktonic larvae may be found in the water throughout the year (Field, 1922; unpublished).

The blue mussel is highly regarded as a gourmet food item in various areas of Europe. France and Spain are the primary producers of mussels where these molluscs are cultured on floating rafts or on poles on intertidal flats (Bardach, et al., 1972). Similar culture techniques could also be used in Alaska. The current demand for this mussel in the United States is low. However, the ready availability of such an inexpensive, flavorful,

nutritious product (13 percent protein as compared to 1 to 5 percent for oysters (Ryther, 1968), should ultimately lead to its wide acceptance in this country. Recently, through the efforts of the marketing specialists of the National Marine Fisheries Service, restaurants in the northeast Seattle area have begun to serve mussels, and the product appears to be gaining acceptance in the Pacific Northwest (Glude, 1974). Mussels could also be used in the production of protein concentrates or meals.

An additional species of mussel, *Mytilus californianus*, is found on the outer coasts of southeastern Alaska to the Aleutian Islands. Little is known of the commercial potential of this organism.

OYSTERS

Two species of oysters are found in Alaska. One is a native species, *Ostrea lurida*, the olympic oyster. It is found only in southeastern Alaska, but is seldom encountered in dense aggregations there. Olympic oysters grow slowly and are relatively small, 2 to 3 inches (5.1 cm to 7.6 cm) in length. This organism is grown for the market in Washington. The Japanese oyster, *Crassostrea gigas*, was introduced into southeastern Alaska near Ketchikan in the early 1900's (Yancy, 1966). Initially, these organisms were grown on the bottom in protected bays. Utilizing this process, three years were required for Japanese oysters to reach a marketable size and natural mortality often exceeded 60 percent (Yancy, 1966).

During the period 1938 to 1960, 110 to 227 acres of tidelands were leased for oyster production (Yancy, 1966). In 1955 a pilot experiment utilizing raft culture was initiated by the North Gem Oyster Company. They were able to raise oysters to 6.5 inches (16.5 cm) in two years. Oyster production in Alaska was continued on a small scale until the 1960's (Table 8). However, the industry was largely dominated by under-capitalized companies with little experience (Yancy, 1966). Currently there are no companies involved in oyster production in the Ketchikan area (J. Westlund, Alaska Department of Fish and Game, personal communication).

The European oyster, *Ostrea edulis*, is not native to the Pacific. However, oyster culturists in Maine are having some success rearing this animal at temperatures of 50° to 75° F (10° to 24° C). Similar water temperatures are encountered in southeastern Alaska. Perhaps the introduction of this species to Alaskan waters would help increase the oyster production potential of Alaska.

Table 8.

Oyster Production, Coon Cove-Carroll Inlet
near Ketchikan, Southeastern Alaska, 1940-61.*

YEAR	COMPANY	ACRES IN PRODUCTION	GALLONS (shucked)	PRICE PER GALLON
1940	Alaska Oyster Co.	140	*	$4.00
1941	Alaska Oyster Co.	140	82	3.50
1943	Alaska Oyster Co.	140	550	4.00
1944	Alaska Oyster Co.	140	500	4.00
1947	Alaska Oyster Co.	140	299	4.00
1948	Alaska Oyster Co.	140	114	6.00
1949	Alaska Oyster Co.	140	177	5.29
1950	Alaska Oyster Co.	140	0	
1951	Alaska Oyster Co.	140	12	
1956	North Gem Oyster Co.	110	100	
1957	North Gem Oyster Co.	227	0	
1960	Alaska Oyster Co.	227	100	
1961	Alaska Oyster Co.	227	100	

* From Yancy, 1966.

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APPENDIX I

CLASSIFICATION OF COMMON ALASKAN BIVALVES DISCUSSED IN THIS REPORT

Phylum: Mollusca

Class: Lamellibranchia (Pelecypoda)

Order: Anisomaria

Family: Mytilidae

1. *Mytilus edulis* (blue mussel)
2. *Mytilus californianus* (California mussel)

Family: Ostreidae

1. *Ostrea edulis* (European oyster)
2. *Ostrea lurida* (Olympic oyster)
3. *Crassostrea gigas* (Japanese oyster)

Order: Heterodonta

Family: Cardiidae

1. *Clinocardium nuttallii* (basket cockle)
2. *Clinocardium ciliatum* (Iceland cockle)

Family: Veneridae

1. *Saxidomus gigantea* (butter clam)
2. *Protothaca staminea* (littleneck clam)

Family: Mactridae

1. *Spisula polynyma* (pinkneck clam)
2. *Tresus capax* (horse clam)

Order: Adapedonta

Family: Myidae

1. *Mya arenaria* (soft-shell clam)
2. *Mya priapus*
3. *Mya truncata* (northern soft-shell clam)

Family: Solenidae

1. *Siliqua patula* (Pacific razor clam)
2. *Siliqua alta* (Northern razor clam)

Family: Tellinidae

1. *Tellina lutea* (butterfly tellin)

APPENDIX II

METRIC CONVERSION VALUES

English		Metric
1 fathom	=	1.83 Meters (m)
1 foot	=	0.30 meters (m)
1 inch	=	2.54 centimeters (cm)
1 inch	=	25.40 millimeters (mm)
1 pound	=	454.60 grams (g)
1 pound	=	0.45 kilograms (kg)