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EPIPELAGIC MEROPLANKTON, JUVENILE FISH, AND FORAGE FISH: DISTRIBUTION AND RELATIVE ABUNDANCE IN COASTAL WATERS NEAR YAKUTAT

by

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Interim Report

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INTRODUCTION

Alaska's Continental Shelf supports abundant and diverse fish and shellfish populations. At the same time, these areas contain or may contain natural gas and oil. Since the 1970's, the Outer Continental Shelf Environmental Assessment Program (OCSEAP) has been funding research over much of the Alaskan shelf. These studies collected biological, chemical, geological, and physical baseline data to be used in managing the natural resources of the shelf.

The shelf off Yakutat represents only a small portion of Alaska's Continental Shelf; however, it supports several fish and shellfish taxa of commercial and ecological importance (Table 1). While adult distributions and abundances for many taxa are known from commercial trawl catches, relatively little is known about epipelagic larval and egg stages of these taxa or about forage fish which also frequent the epipelagic zone.

This report constitutes Part I of a proposed two-part study of meroplankton (pelagic eggs and larvae of fish and shellfish), juvenile fish, and forage fish in the Yakutat Bay area, and is preliminary to field work to be conducted in spring, summer, and fall of 1981. The specific objectives of this report were to: 1) review and analyze information on the distribution and abundance of the selected taxa and on the basis of this information to assess their probable occurrences, geographic distributions, and relative abundances in the region off Yakutat; 2) present information on general spawning biology, history of the commercial fisheries, and adult catch statistics.

Part II of the study will include three field sampling periods (2- 3 weeks, each) and the objectives will be to: 1) determine seasonal occurrence, spatial distribution, and relative abundances of epipelagic life stages of selected species of commercially important fish, shellfish, and forage fish, 2) assess the potential vulnerability of those species to spilled hydrocarbons with respect to position in the water column, season, relative abundance in the study area, and known effects on epipelagic life stages of the organisms, and 3) identify information gaps and present an approach for future study in the region.

Table 1. Target species for Yakutat meroplankton and juvenile fish and forage fish survey, 1980-1981.

Taxa	Life stage Egg	Larvae	Juvenile	Adult
Forage Fish				
Pacific herring-*Clupea harengus pallasi*		x	x	x
Pacific sand lance-*Ammodytes hexapterus*		x	x	x
Capelin- *Mallotus villosus*		x	x	x
Salmon				
Pink salmon-*Oncorhynchus gorbuscha*			x	
Chum salmon-*O. keta*			x	
Coho salmon-*O. kisutch*			x	
Sockeye salmon-*O. nerka*			x	
Chinook salmon-*O. tshawytscha*			x	
Demersal fish and shellfish				
Pacific cod-*Gadus macrocephalus*		x	x	
Walleye pollock-*Theragra chalcogramma*	x	x	x	
Pacific ocean perch-*Sebastes alutus*		x	x	
Sablefish-*Anoplopoma fimbria*	x	x	x	
Arrowtooth flounder-*Atheresthes stomias*	x	x		
Pacific halibut-*Hippoglossus stenolepis*	x	x		
Starry flounder-*Platichthys stellatus*	x	x		
Butter sole-*Isopsetta isolepis*	x	x		
Dungeness crab-*Cancer magister*		x*		
Tanner crab-*Chionecetes bairdi*		x*		
Weathervane scallop-*Patinopecten caurinus*	x	x		
Razor clam-*Siliqua patula*	x	x		

*Further sorting and analysis to zoea and megalops stages.

STUDY AREA

The Yakutat region is located in the northeastern Gulf of Alaska about halfway between Prince William Sound and southeastern Alaska. It is largely open coast, with the exception of Yakutat Bay. Mountains rise from sea level rather abruptly and, in some areas, attain heights of 900 to 5,400 meters. From many of these emerge large alpine glaciers. The coastline is intersected by a large number of glacially fed rivers and streams and the shoreline is composed of wide sandy beaches. The Continental Shelf is about 60 to 90 km wide, except for incursions at Yakutat Bay and Dry Bay (Alsek Canyon). The waters over the shelf support commercial fisheries for salmon, halibut, groundfish, king crab, tanner crab, Dungeness crab, shrimp, and scallops.

The Alaska current is the prevailing current of the area and flows in a northwesterly direction at about 16 cm/sec (Arctic Environmental Information and Data Center and Institute of Social, Economic, Government Research, 1974). At Yakutat, the diurnal tide range is about 3.1 m. Because of the close proximity to the sea, there is a marine influence on the climate, resulting in cloudy skies, fog, heavy annual precipitation, and fairly mild temperatures. Rain occurs on an average of 63% of the days in a year, and the average annual precipitation totals over 335 cm (132 inches). The prevailing wind direction is westerly and the average wind speed is 7.7 knots. Sea ice is not generally found although pieces of ice do break off in sites of coastal glaciers (Brower et al. 1977).

Sampling is proposed for April-May, July-August, and October. Average air temperatures for these months are about 2^{o}, 6^{o}, 12^{o}, 12^{o}, and $4.5^{o}C$, respectively and the frequency of precipitation, based on hourly observations, ranges from 24.9% in April to 41.0% in October. The percent frequency of occurrence of obstructions to vision (fog) based on hourly observations is 9.0, 9.7, 19.7, 21.3, and 10.8 for the above months, respectively (Brower et al. 1977).

The proposed study area (Fig. 1) encompasses the waters of the Continental Shelf between Point Manby (on the north shore of Yakutat Bay) to Cape Fairweather. Yakutat Bay opens to the southwest, extending inland for about 63 km before it bends to the south ending in a diverticulate fjord; the longer arm (Russell Fjord) is an additional 58 km. Depth at mid-bay is about 60 fm. Hemlock-spruce forests are located around the main part of the bay with meadows and barren areas in the vicinity of the glaciers at the head of the fjords.

The coniferous forests extend southward from Yakutat Bay to Dry Bay but are interrupted by a strip of watersedge tundra in the low-lying areas near the coast. This area is considerably moist, containing many river drainages. The Continental Shelf in this vicinity is relatively wide. Dry Bay itself is very shallow and is fed by the Alsek River, the largest river in the area. From just south of Dry Bay to Cape

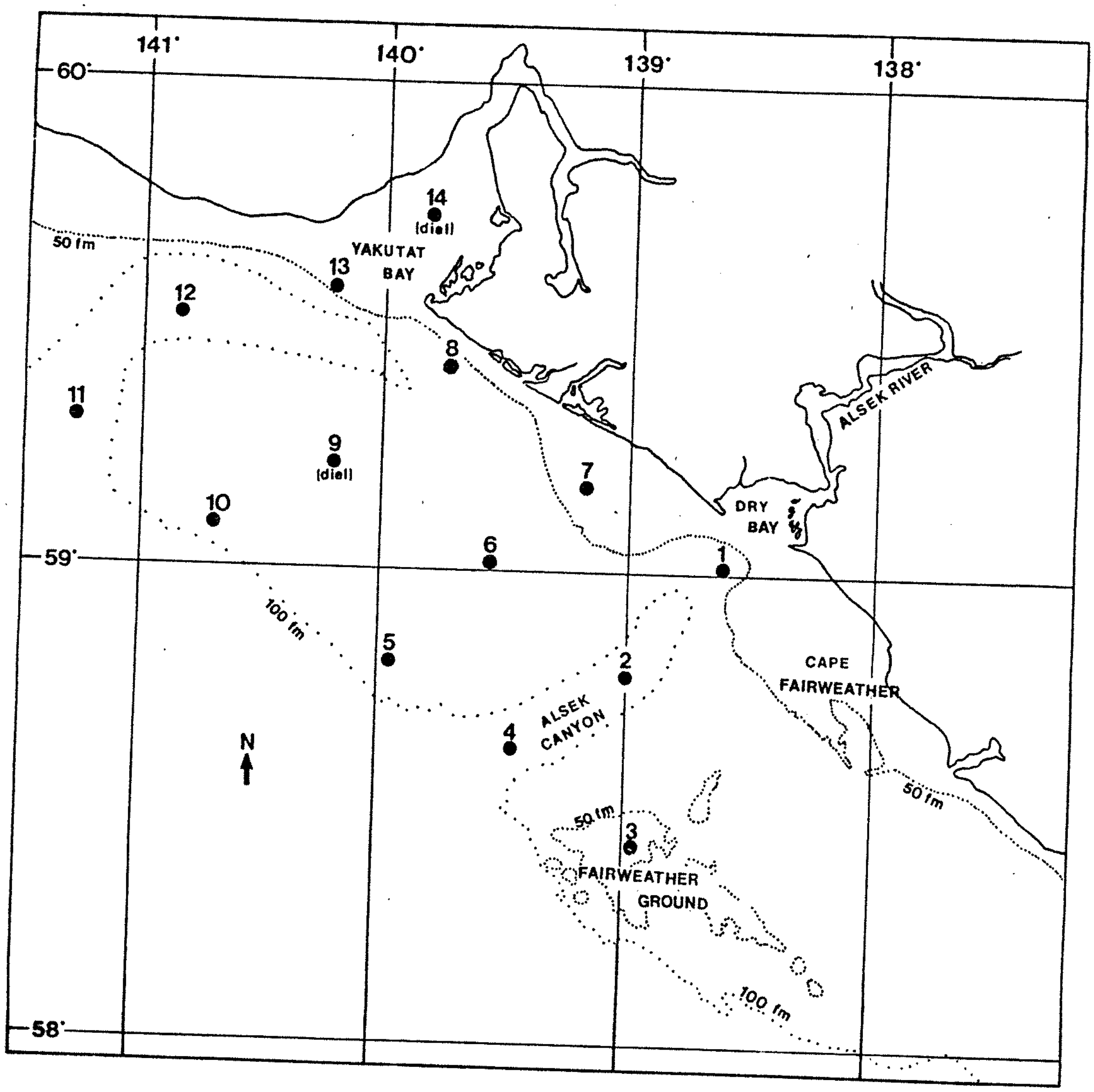

Fig. 1. Proposed station locations in the Yakutat study area, 1981.

Fairweather, the hemlock-spruce forest continues in a thin coastal strip. The local relief is much greater here and is comprised of alpine meadows, peaks above timberline, glaciers, and barren rock. The 4670-m tall Mt. Fairweather is here. The Continental Shelf is also relatively wide south of the Alsek Canyon and contains the Fairweather Ground, which has depths of only 30-40 fm.

DISCUSSION

Studies of distributions and abundances of fish eggs and larvae have been conducted in various parts of Alaska (Table 2). In some cases, studies have been located in important fishing areas such as the Bering Sea, Kodiak shelf, and Cook Inlet. Other surveys have been restricted to single larval species (Lisovenko 1964; Thompson and Van Cleve 1936) and in some, larval fish were secondary to trawl catches (Aron 1958) or zooplankton surveys (LeBrasseur 1970). Emphasis has generally been on sampling in the spring and summer when the ichthyoplankton fauna in the Northeast Pacific is more diverse and abundant.

Few studies have included stations adjacent to or near the proposed Yakutat study area. Lisovenko (1964) reports catches of rockfish larvae near Yakutat and Thompson and Van Cleve (1936) surveyed shelf waters for halibut eggs and larvae. During October, English (1976) included a three-station transect off Yakutat Bay during an ichthyoplankton survey of the Gulf of Alaska. Results of these studies and ichthyoplankton studies in other areas are included in sections for individual species.

Spawning times for the proposed taxa are known from other areas (Table 3) and can be used to predict the time of occurrence of eggs and larvae in the Yakutat area (Table 4). Winter spawners include Pacific sand lance, sablefish, Pacific halibut, Pacific cod, and arrowtooth flounder. The following are spring and/or summer spawners: Pacific herring, capelin, walleye pollock, Pacific ocean perch, butter sole, starry flounder, razor clams, weathervane scallops, tanner and Dungeness crabs. Spring and summer sampling in the Yakutat area should yield the most kinds and greatest abundances of fish and shellfish eggs and larvae as well as juvenile salmon and adult forage fish. However, juveniles of some species will most likely occur in fall.

General distributions of eggs and larvae in the Yakutat area can be estimated from knowledge of spawning behavior of adults. For example, some species--herring and capelin--spawn in bays or on beaches and their larvae are located near these inshore areas. However distributions of pelagic eggs and larvae are not static, but change over time as larvae and eggs are transported by currents and later, for larvae, by their own power. It would not be unusual to find herring and capelin at some shelf stations. Similarly, species which spawn in deep water--halibut, arrowtooth flounder, sablefish--are not expected to occur as larvae in the inshore areas, but perhaps at some shelf stations. The remainder of the fish species probably spawn throughout depths of the shelf and their eggs and larvae should be widely distributed.

Predicting abundances of eggs and larvae in the Yakutat area is more difficult for several reasons: 1) lack of past catch data in the Yakutat area; 2) lack of data on year to year variations in timing and abundance of eggs and larvae, and 3) limitations of using abundance data from other studies in other areas, due in part to different methods,

Table 2. Summary of studies which include data on fish eggs and larvae from the Northeast Pacific.

Location	Dates	Reference
Bering Sea	Jun-Sep 1958 Mar 1959	Musienko 1963
	Jun-Jul 1962	Kashkina 1970
	Apr-May 1977	Waldron and Vinter 1978
	May-Jun 1971	Dunn and Naplin 1973
Kodiak Shelf	Apr-May 1972	Dunn and Naplin 1974
	Oct-Nov 1977 Mar-Apr 1978 Jun-Jul 1978 Oct-Nov 1978 Feb-Mar 1979	Kendall et al. 1980
Kodiak Bays	Mar-Aug 1978 Nov 1978 Mar 1979	Rogers et al. 1979
Cook Inlet	Apr-May 1976 Jul-Aug 1976 Oct 1976 Feb 1977	English 1977, 1978
NE Pacific		
- Willapa Bay to Dixon Entrance	Oct-Nov 1971	Naplin et al. 1973
- Gulf of Alaska	Jul-Sep 1957	Aron 1958
- Gulf of Alaska	May-Sep 1956 Mar-Sep 1957 Mar-Aug 1958 Mar-Jul 1959	LeBrasseur 1970
- Northern Gulf of Alaska	Apr-Jul 1963	Lisovenko 1964*
- Northern Gulf of Alaska	Sep-Oct 1975	English 1976*
- Gulf of Alaska	Jan-Jun 1928-1934	Thompson and Van Cleve* (1936)

*Studies which included some stations near the proposed Yakutat meroplankton study area.

Table 3. Spawning times, by months and geographical areas, for proposed fish species in the Yakutat meroplankton and forage fish survey.

Species	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Area	References[1]
Pacific herring	X	X	X	X									California	Scattergood et al. 1959
	X	X	X	X									Oregon	Scattergood et al. 1959
		X	X	X	X	X							British Columbia	Outram and Humphreys 1974
			X	X	X	X							Southeast Alaska	Scattergood et al. 1959; Skud 1959
				X	X								Cook Inlet	Rounsefell 1930
				X	X								Prince William Sound	Rounsefell 1930
				X	X	X							Kodiak Island	Kasahara 1961
				X	X								Western Alaska	Scattergood et al. 1959
					X								Southeast Bering Sea	Rumyantsev and Darda 1970
					X	X							Northeast Bering Sea	Rumyantsev and Darda 1970
Capelin									X	X			Straits of Georgia	Hart and McHugh 1944
										X			Sitka	Marsh and Cobb 1908
					X	X							Kodiak	
					X	X							Bristol Bay	Blaxter 1965
						X	X	X					Bering Sea	Kashkina 1970
								X	X				Point Barrow	Andriyashev 1954
Pacific sand lance	X	X										X	Northeast Pacific	Trumble 1973
Pacific cod	X	X										X	British Columbia	Hart 1973
	X	X											Bering Sea	Musienko 1970
Walleye pollock			X	X									British Columbia	Hart 1973
			X	X	X								Western Gulf of Alaska	Hughes and Hirshhorn 1978
		X	X	X	X	X							Northeast Bering Sea	Serobaba 1968
				X	X	X							Kamchatka Peninsula	Kanamaru et al. 1979
Sablefish	X	X											British Columbia	Hart 1973
	X	X							X	X	X	X	Vancouver-Oregon	Kodolov 1968
	X	X							X	X	X	X	Bering Sea	Kodolov 1968
Pacific ocean perch	X								X	X	X	X	[2]Gulf of Alaska	Lisovenko 1972; Lyubimova 1965
				X	X	X	X						[3]Gulf of Alaska	Lisovenko 1964

Table 3. Spawning times, by months and geographical areas, for proposed fish species in the Yakutat meroplankton and forage fish survey - continued.

Species	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Area	References[1]
Butter sole	X	X	X	X	X								Oregon	Richardson et al. (In press)
		X	X	X									British Columbia	Hart 1973
		X	X										Skidgate Inlet, B.C.	Levings 1968
Starry flounder	X											X	California	Orcutt 1950
		X	X	X									Puget Sound	Hart 1973
		X	X	X									British Columbia	Hart 1973
					X	X							Bering Sea	Musienko 1963
Pacific halibut	X										X	X	British Columbia	Hart 1973
	X	X	X								X	X	Northeast Pacific	Bell and St. Pierre 1970
	X	X							X	X	X	X	Bering Sea	Pertseva-Ostroumova 1961
Arrowtooth flounder	X	X	X									X	North Pacific	Pertseva-Ostroumova 1960

[1]References for herring, capelin, and sand lance summarized from Macy et al. 1978.
[2]Time of mating.
[3]Time of release of larvae.

Table 4. Predicted time(s) of occurrence for egg, larval, juvenile, and/or adult stages of fish and invertebrate taxa in the Yakutat study area.

Species	Stage	Proposed sampling months Apr-May	Jul-Aug	Oct	Remarks
Pacific herring	larvae	x	x		
	juveniles			x	
	adults	x			
Capelin	larvae		x		
	juveniles			x	
	adults	x			
Pacific cod	larvae	x	x		
	juveniles			x	
Walleye pollock	eggs	x	x		
	larvae	x	x		
	juveniles			x	
Sand lance	larvae	x	x		
	juveniles			x	
	adults	x			
Pink salmon	juveniles		x	x	
	adults		x		
Chum salmon	juveniles		x	x	
	adults		x	x	
Coho salmon	juveniles		x		
	adults		x		
Sockeye salmon	juveniles		x		
	adults		x		
Chinook salmon	juveniles		x		
	adults	x	x		
Rockfish (*Sebastes* spp.)	larvae	x	x	x	
	juveniles			x	
Sablefish	eggs				Occur in winter
	larvae	x	x		
	juveniles		x		
Arrowtooth flounder	eggs	x			Occur primarily in winter
	larvae	x	x		
Pacific halibut	eggs				Occur in winter
	larvae	x	x		
Starry flounder	eggs	x			
	larvae		x		
Butter sole	eggs	x			
	larvae		x		
Razor clams	eggs		x		Eggs approx. 90 μ
	larvae		x		Settle at approx. 325 μ
Scallops	eggs				Eggs are demersal
	larvae		x		larvae are 80-200 μ
Dungeness crab	larvae	x	x		
Tanner crab	larvae	x	x	x	

gears, and expressions of catch statistics. However, after sampling is underway, it should be possible to compare relative abundances of taxa between Yakutat and other areas in Alaska. In addition, thorough knowledge and duplication of methods used in Kodiak ichthyoplankton work (Rogers et al. 1979; Kendall et al. 1980) will allow comparisons between catches in the western Gulf of Alaska and in the eastern portion off Yakutat.

Forage Fish

Forage fish may be defined as those species that are present in sufficient quantities during their larval, juvenile, and adult stages to constitute a major part of the diet of larger predators including birds, marine mammals, and fish. Important forage fish species in the Yakutat area include Pacific herring, sand lance, and capelin.

Pacific Herring *(Clupea harengus pallasi)*

General Biology. In the eastern Pacific, herring are distributed from northern California through Canada and Alaska to the Beaufort Sea (Hart 1973).

Pacific herring are schooling fish and their local distribution is related to environmental and biological factors such as salinity, temperature, food sources, age, and spawning condition. In general, during fall or early winter, large schools of mature herring move inshore and remain there until spawning. After spawning, schools either move into deeper water offshore to feed or remain inshore. In the Gulf of Alaska, feeding schools during summer are not as dense as wintering schools and have been reported close to the surface in passages in Southeast Alaska and Prince William Sound (Macy et al. 1978).

The primary commercial concentrations of herring in the Gulf of Alaska have occurred historically in Southeast Alaska, Prince William Sound, and Kodiak Island. In the past, small-scale fisheries have occurred in Cook Inlet, Chignik, Shumigan Islands, and Yakutat. Herring are also important as prey items for many invertebrates, fish, birds, and marine mammals. Eggs, larvae, juveniles, and adults of Pacific herring are consumed, often in large quantities (Macy et al. 1978).

A comprehensive review of the biology and early life history of Pacific herring is given by Macy et al. (1978) and is summarized below.

Pacific herring are late-winter to late-spring spawners, depending on geographic location. In general, southern stocks spawn earlier than the more northern populations. In Alaskan waters, herring spawning occurs in March through June in Southeast Alaska, April and May in Cook Inlet and Prince William Sound, April through June in Kodiak and western Alaska, and May and June in the Bering Sea.

In Alaska, Pacific herring generally are mature at age 3 or 4 and at lengths of 15-20 cm. Fecundity is related primarily to body length and secondarily to age, hence large, old herring produce the most eggs. Females may produce between 10,000 and 134,000 eggs. Pacific herring in North America are generally smaller and produce fewer eggs than Asian stocks.

Large schools of mature fish move into sheltered bays, along steep or shelving rocky beaches, or along open sand beaches to spawn. Spawning takes place in shallow water at high tide and the water may become discolored with milt. Eggs are usually deposited on vegetation, but may also be attached to gravel, boulders, logs, and tree limbs. Eggs may be deposited in several layers, and two to four layers are considered optimal for larval production. Salinity and temperature during spawning are variable, and ranges of 8-28°/oo and 5-9°C are reported as conducive to the spawning of herring in North America.

Eggs hatch in 12-50 days, depending on water temperature. In Prince William Sound, average hatching time was 12 to 21 days. Normal development occurs at temperatures of 5-9.2°C and salinities of 6.7-25.8°/oo. Fraser (1922) describes egg development after fertilization. Newly hatched larvae are 4-8 mm long, and herring reach 90-100 mm by the end of their first year. Transformation from larval to juvenile fish begins at about 35-40 mm.

Food of first-feeding larvae consists of small, relatively immobile planktonic organisms such as invertebrate eggs, diatoms, and copepod nauplii. Postlarval (20-100 mm) herring feed primarily on copepods, followed by cirrepedes, molluscs, ova, and other zooplankters. Food items of juvenile herring include mysids, euphausids, and amphipods. Herring do not have a strong preference for particular foods, but consume organisms of a suitable size which predominate in the plankton. Hence food habits may differ among locations and seasons.

History of the Fishery. Yakutat Bay has supported a commercial herring fishery only twice in recent years. In 1970-1971 and 1972-1973, the catches were 44 and 158 short tons, respectively. These catches were insignificant compared to those in Southeast Alaska which were 4,093 and 5,837 short tons, respectively (Moberly 1973, 1974). The herring fishery at Yakutat supplied the local bait fish market, although generally fishermen rely on outside sources (Don Ingledue, Alaska Department of Fish and Game (ADF&G), personal communication). The current sentiment is that the herring populations should be preserved as a food source for king salmon in the area (Alex Brogall, ADF&G, personal communication).

Distribution and Abundance.

Adults. Spawning areas of Pacific herring in the Gulf of Alaska are shown in Fig. 2. Currently, an estimated 2,000-3,000 tons of herring spawn from April to early May along the east shore of Yakutat

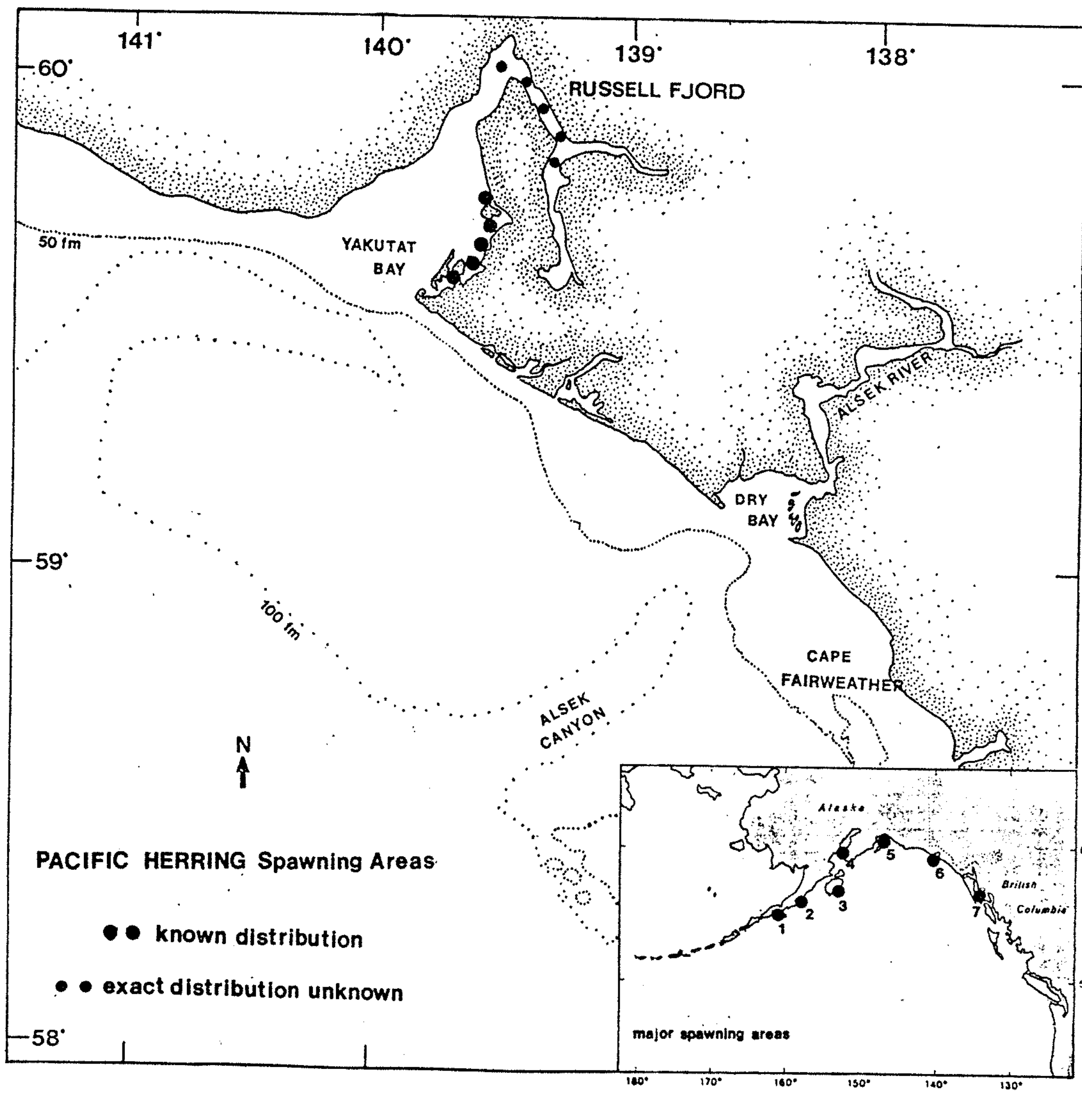

Fig. 2. Spawning areas of Pacific herring in the Yakutat area and Gulf of Alaska (1-Shumigan Islands, 2-Chignik, 3-Kodiak Island, 4-Kachemak Bay, 5-Prince William Sound, 6-Yakutat, 7-Southeast Alaska).

Sources: A. Brogall, personal communication; Macy et al. 1978.

Bay. A population estimated to be three times that size spawns in Russell Fjord; however, because of ice the area is inaccessible at the time of spawning, so the actual size of that population is unknown (A. Brogall, personal communication).

Larvae. Initially, we would expect to find herring larvae in greatest abundance close to the spawning grounds. Unfortunately, these areas are in shallow water and are often not accessible to plankton gear. We may catch small larvae which drift out into Yakutat Bay during late April and May, but the peak in larval abundance may occur later. By July and August, herring larvae will be actively schooling near the spawning grounds. These schools may reach deeper water by late summer, residing below the surface during the day and rising to the surface at dusk (Macy et al. 1978). These herring may be captured by plankton gear at night, but otherwise will probably avoid capture. Lampara net sets at dusk and beach seine hauls in Yakutat Bay during the summer may yield herring juveniles. At the end of summer, juvenile herring may either migrate to offshore waters or remain inshore. No one knows if they remain in Yakutat Bay through the winter.

Pacific Sand Lance *(Ammodytes hexapterus)*

General Biology. Pacific sand lance range from southern California to Alaska and the Bering Sea (Hart 1973) and are mainly in shallow water close to shore. Because they lack a swim bladder, sand lance exist by actively swimming, resting on the bottom (Trumble 1973), or burying in sand or fine gravel (Nikol'skii 1954 cited in Macy et al. 1978). They may form large pelagic feeding schools during the day and return to the bottom at night (Trumble 1973).

Sand lance adults and larvae are an important food item to many commercially important fish such as juvenile sockeye and coho salmon (Straty and Jaenicke 1971), cod, chinook salmon, halibut, ling cod (Bean 1889; Hart 1973), and hake (Outram and Haegele 1972). Sand lance are also consumed by fur seals and birds.

Spawning of Pacific sand lance in the Northeast Pacific probably occurs in winter (Trumble 1973). Sand lance up to 15 mm long were caught during early March near Kodiak Island, which also indicates that sand lance spawn during the winter (Rogers et al. 1979).

Fecundity of Japanese sand lance is about 1,000-8,000 eggs, and spawning takes place at depths of 25-100 m in areas of strong currents. Spawning fish may be 1-3 years old (Hamada 1966). Eggs are demersal, adhesive, and are deposited in clusters of three or four eggs on a sand bottom. Mature eggs are .72-.97 mm in USSR (Nikol'skii 1954 cited in Macy et al. 1978), .66 mm in Japan (Inoue et al. 1967), and .67-.91 mm in the Atlantic (Williams et al. 1964). Descriptions of sand lance eggs are given in Williams et al. (1964).

Larvae hatch at 3-4 mm and under natural conditions remain buried in the sand until the yolk sac is absorbed. At this point, larvae become planktonic and remain so until metamorphosis to the adult stage at 30-40 mm (Trumble 1973). Larval illustrations are given in Kobayashi (1961).

First-feeding larvae consume diatoms and dinoflagellates, but they switch to copepod nauplii and copepods as they grow (Trumble 1973).

Distribution, and Abundance

Adults. At present, there is no fishery in the Northeast Pacific on sand lance; however, they are commercially fished in Japanese waters. Their distribution and abundance off Yakutat is unknown.

Larvae. Sand lance larvae are relatively abundant in plankton hauls in the Bering Sea and Gulf of Alaska during spring. In the Kodiak area, small (5-15 mm) larvae were found within the bays as well as distributed over the shelf. In summer, the larvae (averaging 35-45 mm long) disappeared from the bays, but continued to be caught offshore. No larvae were caught during fall (Table 5).

In the Yakutat area, the largest catches of larval sand lance will probably occur during April and May. They may be caught anywhere from Yakutat Bay to the 100 fm contour, although they may be concentrated nearshore. Older larvae and juveniles may occur in the study area during summer and be distributed throughout the area. We expect that only juveniles and adults occur in October and in relatively low abundance compared to other months. Because the eggs are demersal, they will not be sampled by the plankton gear.

Capelin *(Mallotus villosus)*

General Biology. Capelin occur along the Northeast Pacific coast from the Strait of Juan de Fuca to Arctic Alaska. They are especially abundant in the Bering Sea and along the Aleutian Islands (Macy et al. 1978).

Capelin are an important forage food for fish and marine mammals, particularly during spawning migrations. Predators on capelin include salmon, cod, dogfish, Arctic char, seals, porpoise, and killer and baleen whales. They are also eaten by gulls and terns.

Reproduction and early life history information for capelin have been summarized by Trumble (1973), Jangaard (1974), and recently by Macy et al.(1978). In the Straits of Georgia and near Sitka (southeastern Alaska) spawning occurs in the fall. However, at Kodiak and in Bristol Bay, capelin spawn in late spring. Capelin in the Bering Sea spawn in summer, and far-northern (Pt. Barrow) populations spawn in late summer.

Table 5. Distribution and abundance of larval sand lance in the Northeast Pacific Ocean and Bering Sea,

Location	Time	Gear	Station depths, m	Larval length, mm	Abundance	Reference
Bering Sea	Apr-May 1977	bongo[1]	100-2000 (caught at stations <200m)	6.7-29	Third most abundant larvae; accounted for 3% of all larvae caught.	Waldron and Vinter 1978
Bering Sea	Jun-Jul 1962	CPN[2]	20-120	10.0-47.0	Average catch of 4 larvae per haul; ranged from 0-445 per haul.	Kashkina 1970
Bering Sea	Jun-Sep 1958 Mar 1959	CPN	35-2100	7.4-33.7 35.9-95.6	Caught in late July-early Sep. averaged about 8 larvae per haul.	Musienko 1963
Kodiak Shelf	Apr-May 1972	bongo		5-13	Second most abundant larvae caught; accounted for 11.3% of all larvae caught.	Dunn and Naplin 1974
Kodiak Bays	Mar-Aug 1978 Nov 1978 Mar 1979	bongo	31-171	5-34	Second most abundant overall; occurred primarily Mar-Jun.	Rogers et al. 1979
Kodiak Shelf	Oct-Nov 1977 Mar-Apr 1978 Jun-Jul 1978 Oct-Nov 1978 Feb-Mar 1979	bongo	40-1000	5.5-58	Most abundant larvae caught during Mar-Apr 1978.	Kendall et al. 1980
Cook Inlet	Apr-May 1976 Jul 1976 Aug 1976 Oct 1976	bongo	35-210		Most abundant during Apr-May; catches ranged from 0-344 per $10 m^2$ or 0-1296 per 1000 m^3.	English 1977, 1978

[1]Bongo net, 60 cm opening, 505µ mesh.
[2]Conical plankton net, 80 cm opening, No. 140 mesh.

Mature capelin range in length from 89-146 mm. Fecundity varies among locations and ranges from 3,020-6,670 eggs per female in British Columbia to 15,000-57,000 eggs per female in the Sea of Japan. Larger fish may account for higher fecundities in some areas.

During most of the year, capelin reside in large schools in bottom waters, sometimes far from shore. However, in the spring these concentrations move toward shore and about one month before spawning, are located at about 50 m depths or less.

Capelin commonly spawn on beaches, avoiding rocky areas, and preferring sand grain sizes of 0.04-.2 mm. Deposition of eggs occurs at night or on overcast days, and spawning may be greatest just after high tide. One or two males accompany a female to the beach where fertilization takes place, and eggs are subsequently buried in the sand by wave action. Spent females return to deeper water and it is not known if females spawn more than one batch of eggs in a given season. Males may remain inshore to fertilize other females. Spawning in deep water may also occur in Alaskan waters. Postspawning mortality is assumed to be high and may be as high as 90% of the fish spawning for the first time.

Capelin eggs are 1.0-1.1 mm in diameter and stick to gravel or sand. Hatching occurs in 1-4 weeks, depending on water temperature. Descriptions of capelin larvae are given by Templeman (1948). Newly hatched larvae are swept out to sea and spend most of their early life in deep water.

Distribution and Abundance

Adults. Currently there is no large-scale commercial fishery on capelin stocks in the Northeast Pacific and only a limited recreational fishery. The abundance and distribution of adult capelin offshore from Yakutat are unknown.

Larvae. Larval capelin have been sampled from the Bering Sea, Kodiak Shelf, and Gulf of Alaska. In several studies, they were numerically important components of the ichthyoplankton (Table 6). Initially, capelin larvae are located nearshore in close proximity to the beaches where spawning occurred. This can lead to large concentrations of larvae during summer, and this occurred in Kodiak bays and lower Cook Inlet. After hatching, larvae are immediately susceptible to transport by local currents and thus are dispersed over the shelf. By fall and winter, the larvae have metamorphased into mobile juveniles and range from nearshore to the edge of the shelf.

Capelin spawning in the Yakutat study area takes place on beaches between Dry Bay and Yakutat Bay (Fig. 3) from July to mid-August. It is a relatively large population (A. Brogall, personal communication). We expect to catch larval capelin during July and August nearshore as well as out to the 100 fm contour. In the fall we will probably capture

Table 6. Distribution and abundance of larval capelin in the Northeast Pacific Ocean and Bering Sea.

Location	Time	Gear	Station depths, m	Larval length, mm	Abundance	Reference
Bering Sea	Apr-May 1977	bongo[1] neuston[2]	100-2000	31-65	Accounted for .2% of all larvae caught in the bongo and 8% (third in abundance) of larvae from neuston.	Waldron and Vinter 1978
Bering Sea	Jun-Sep 1958 Mar 1959	CPN[3]	25-375	5.5-27.3	Occurred in July and late August-early September; maximum concentration was 250 per m^2.	Musienko 1963
Kodiak Bays	Mar-Aug 1978 Nov 1978 Mar 1979	bongo neuston	31-171	3.0-40.0	Only identified as "Osmeridae;" accounted for >90% of all larvae in bongo tows. First in abundance over all cruises in both gear types.	Rogers et al. 1979
Kodiak Shelf	Nov 1977 Mar-Apr 1978 Jun-Jul 1978 Oct-Nov 1978 Feb-Mar 1979	bongo neuston	40-1000	12-55	Occurred in all seasons, although only identified as "Osmeridae" during summer. Osmerids ranked third in abundance in bongo tows in summer.	Kendall et al. 1980
Cook Inlet	Apr-May 1976 Jul 1976 Aug 1976 Oct 1976 Feb 1977	bongo	35-210		Peak catches in July-August. Catches range from 0-2505 per $10m^2$ (or 0-2766 per $1000m^3$)	English 1977, 1978
Gulf of Alaska	Sep-Oct 1975	bongo	30-2500	9-27	Third most abundant larval taxa collected.	English 1976

[1]Bongo net, 60 cm opening, 505µ mesh.
[2]Sameoto neuston sampler, .3m x .5m opening, 505µ mesh.
[3]Conical plankton net, 80cm opening, No. 140 mesh.

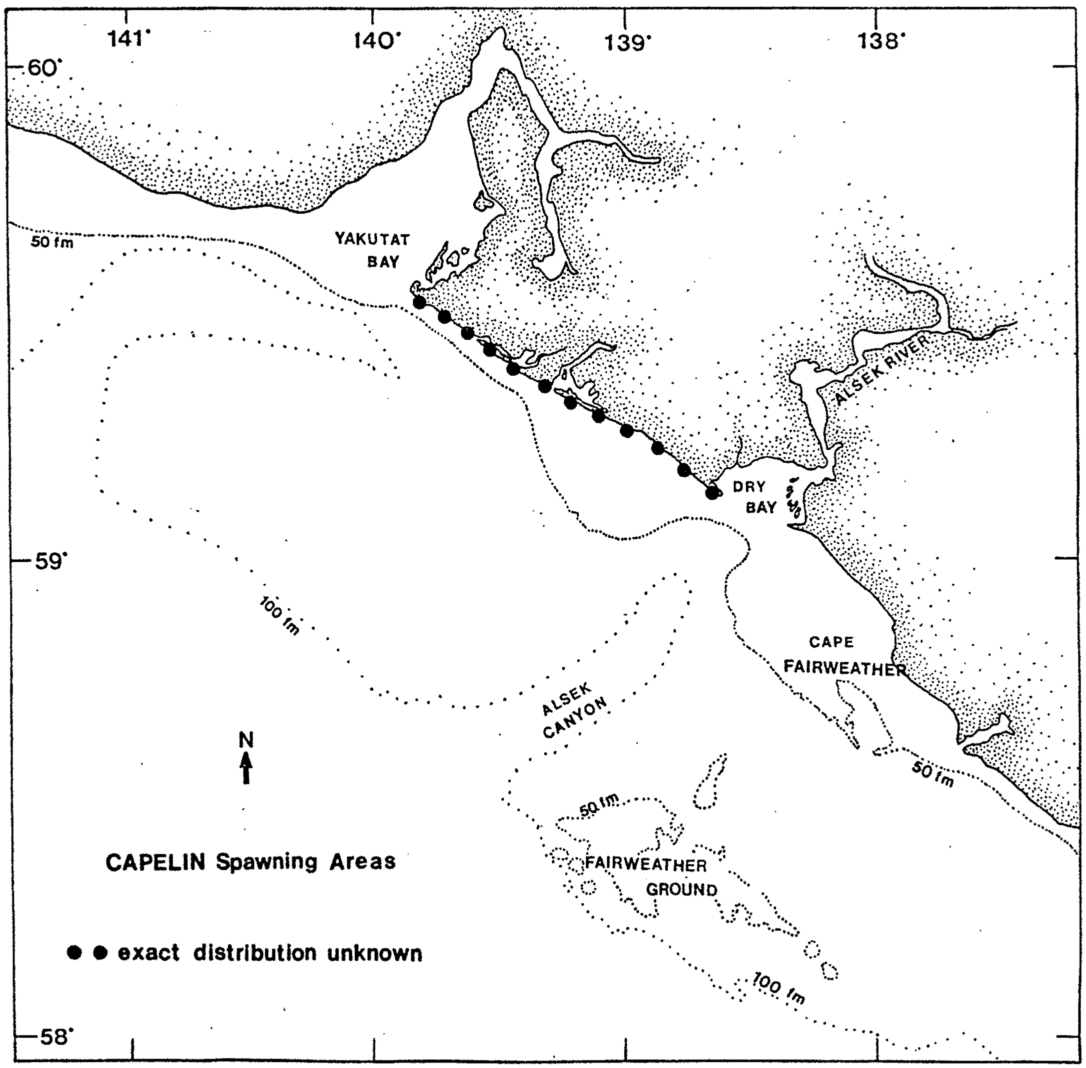

Fig. 3. Spawning areas of capelin in the Yakutat area.

Source: A. Brogall, personal communication.

juvenile capelin. Eggs will probably not occur in the plankton samples because of their demersal, adhesive quality.

Eulachon (*Thaleichthys pacificus*)

Eulachon were not targeted for this study; however, since they are a potentially important species to the ecology of the Yakutat area, we have included this section in the report.

Large numbers of adult eulachon spawn in the Yakutat study area during March to early June (A. Brogall, personal communication). Eulachon are anadromous, sometimes traveling tens of miles upstream to spawn. The eggs are spawned over gravel and sand and become attached to the sediment by an outer adhesive membrane. The larvae are carried out to sea as soon as they hatch and little is known about their marine life.

Eulachon are not presently exploited commercially in Alaska, although they are an important forage fish (Macy et al. 1978). We expect to see larval eulachon at nearshore stations during spring and/or summer. However, it will be difficult to distinguish among species of smelt when the larvae are small (i.e., prior to the development of fin rays).

Pacific Salmon

The Fishery

The first salmon cannery in Alaska which became operative in 1857, was located on Prince of Wales Island. Since that time, the salmon fishery has become the dominant fishery in Alaska. Salmon represented 39 to 63% of the value of the total commercial catch of fish and shellfish in Alaska between 1966 and 1977 (Terry et al. 1980).

Generally, the commercial catch of salmon in the Yakutat management area (Cape Suckling to Cape Fairweather--see Fig. 4) is small relative to the rest of Alaska; however, the salmon fishery is important to the local economy. Off Yakutat, this fishery is by set gillnets and trolling gear. Boats in the setnet fishery are small (<25 ft long), generally with a crew of one, and primarily based in Yakutat. Trollers are much larger (35-45 ft), with a crew of two to three, and most are based outside the area (Terry et al. 1980).

Most of the salmon from the Yakutat area are produced at the southeast edge of the bay and in coastal river systems to the southeast. Thus, setnet sites are located primarily in Yakutat Bay and to the southeast along the coast (McLean and Delaney 1978). In the Gulf of Alaska there is a small sport fishery on coho, chum, and chinook salmon, which is insignificant compared to the commercial catch.

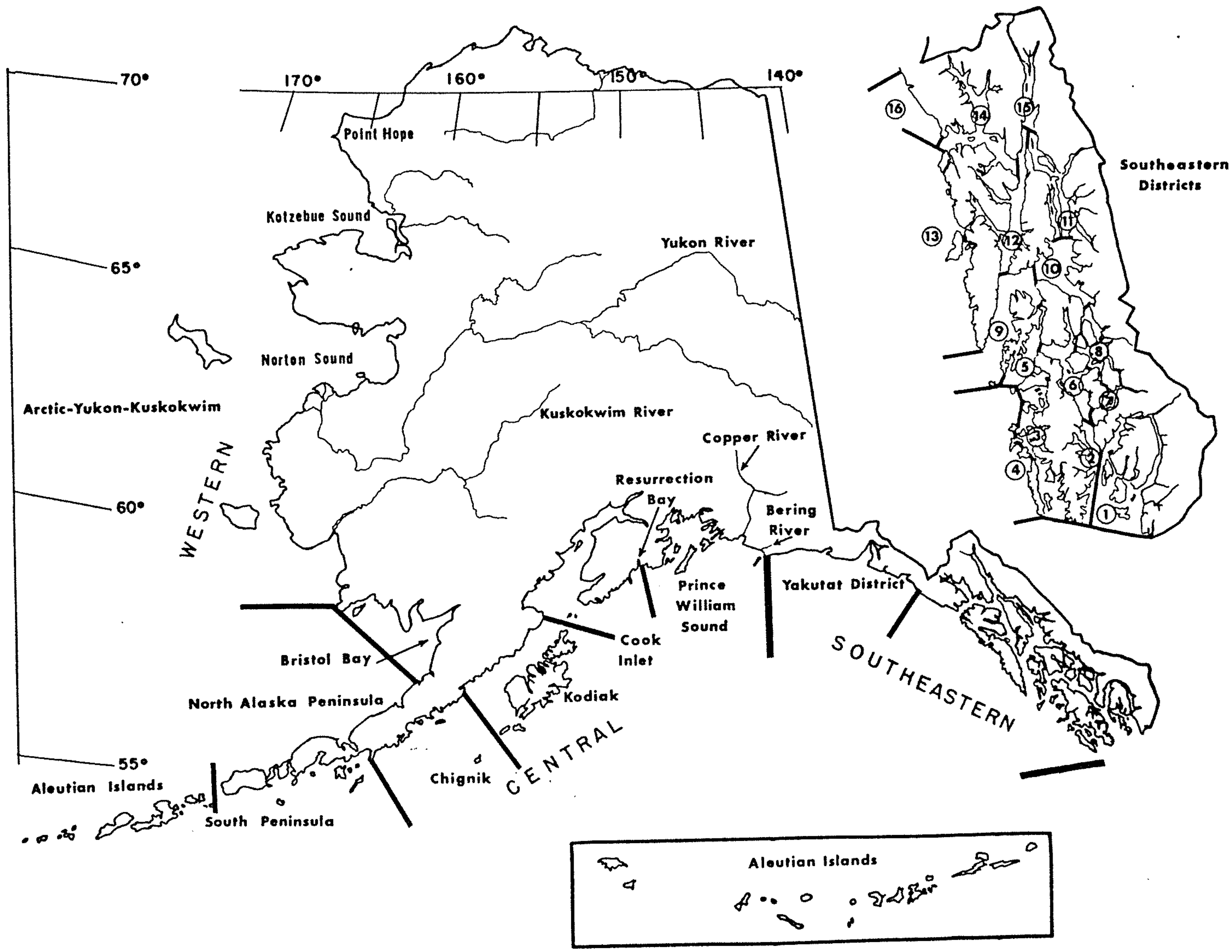

Fig. 4. Statistical divisions of the State of Alaska.

Source: International North Pacific Fisheries Commission 1979.

Stern et al. (1976) estimated that if the average catch in the Yakutat District was 30% of the run, then annual runs to the district average about .4 million salmon, with a potential of up to 1.3 million.

Migrations in the Northeast Gulf of Alaska

All five species of North American salmon are anadromous, although some pink salmon spawn intertidally. Adults spawn in the fall and fry emerge from the gravel the following spring. Chum, pink, and most chinook fry migrate directly to saltwater; however, sockeye fry generally reside in freshwater nursery lakes for 1-2 years. Coho and some chinook fry remain in freshwater for about 1 year, entering saltwater the following spring as smolts. If entering an estuary, most juveniles remain near the water surface and gradually, as the summer progresses, move offshore. Fry entering an unprotected coastline tend to move directly offshore over the Continental Shelf. By July-August, the catch-per-unit-effort (CPUE) of juvenile salmon is high over the shelf, indicating movement from estuaries and coastal rivers. Many chum and pink salmon remain over the shelf as late as October, but after October the abundance of all species is low because the juveniles have moved offshore over deeper waters.

While in waters over the Continental Shelf, the juveniles may migrate hundreds of miles, generally in a counterclockwise direction along the broad arc of the Gulf of Alaska. Juveniles from stocks as far south as California mix with those from Alaska in coastal waters off Yakutat.

Adult salmon bound for spawning grounds in the northeast Gulf also tend to migrate extensively along the coast. Adults tagged off Yakutat have returned to spawn in southeastern Alaska. (This section was derived from Stern et al. 1976.)

Pink Salmon *(Oncorhynchus gorbuscha)*

General Biology. Pink salmon occur along the west coast of North America from California to the Aleutian Islands and Arctic Ocean. They usually spawn after two summers at sea in the late summer or early fall. The average size at maturity is 1.4-2.3 kg, although they can attain a maximum size of 5.4 kg and 76 cm long. Fecundity is related to length, with usually 1,500-1,900 eggs per female. Spawning is in coastal streams and rivers or in the intertidal zone. Eggs develop in gravel during the winter and fry emerge the following spring. Fry emerging in freshwater migrate immediately to saltwater. During their first summer at sea, the fry remain close to shore, feeding primariy on zooplankton, insects, and epibenthic crustacea (Rogers et al. 1980). Pink salmon in the Gulf of Alaska prefer temperatures of 7-15°C. Thus, they are primarily surface dwellers, avoiding the thermocline (Stern et al. 1976). The maturing fish grow rapidly in their last spring and summer at sea, feeding extensively on euphausids, copepods, amphipods, fish and squid. (Most of the preceeding was modified from Hart 1973).

Distribution and Abundance. Experimental purse seine catches of juvenile pink salmon were low over the Continental Shelf near Yakutat in April-June, but high July-October, therefore migration from estuaries and coastal rivers probably begins in July (Stern et al. 1976). After October, they migrate offshore.

Spawning runs peak during August (Fig. 5), the adults returning to spawn in several streams, rivers, and along some beaches in Yakutat Bay. Two spawning sites are of major importance, one located near the town of Yakutat and the other in the Situk River to the southeast. Adult pink salmon have been observed in a few other rivers, but spawning sites have not been verified (McLean and Delaney 1978).

Pink salmon catches in the Yakutat District average only 0.1% of the catch in the entire state (Table 7). In the Yakutat area, pink salmon ranked third in the number of salmon landed, whereas they ranked first in the state of Alaska.

Chum Salmon *(Oncorhynchus keta)*

General Biology. Chum salmon range from northern California through the Aleutian Islands to the Arctic Ocean. Their maximum size at maturity is 102 cm and 15 kg. Most return to spawn after 3-5 years at sea, although the range is 2-7 years. This species tends to spawn later than the other four species of Pacific salmon--one stock in British Columbia spawns as late as April. In Asia, where there are both fall and spring runs, spring run females carry 2,000-3,000 eggs, while those spawning in the fall run carry 3,000-4,000 eggs. Spawning takes place in coastal rivers and streams. In the spring, after fry have emerged from gravel, they migrate directly to saltwater, generally between April and July. Juveniles consume zooplankton, insects, and small epibenthic crustacea such as amphipods, where they occupy the coastal strip (Rogers et al. 1980). Chum salmon can tolerate a wide range of temperatures, and perhaps for this reason they are not closely tied to the surface waters as are pink and sockeye salmon (Neave et al. 1976) (the preceding, with noted exceptions, was derived from Hart 1973).

Distribution and Abundance. In the Yakutat District, runs of returning spawners peak in September (Fig. 6), although the migration continues well into October. Only two watersheds contain documented spawning sites: the Italio River and East Alsek River drainages, although chum have also been observed in the Situk, Ahrnklin, Akwe, and Alsek River drainages. Since the runs are quite sparse, the average yearly catch (1959-1979) has been only 10,000 fish as opposed to 6,014,000 in Alaska (Table 8). Chum salmon rank fourth in the number of salmon caught in Yakutat and third in Alaska.

Near Yakutat, juveniles occupy the coastal strip between July and October (Stern et al. 1976) and are probably in the estuaries somewhat earlier.

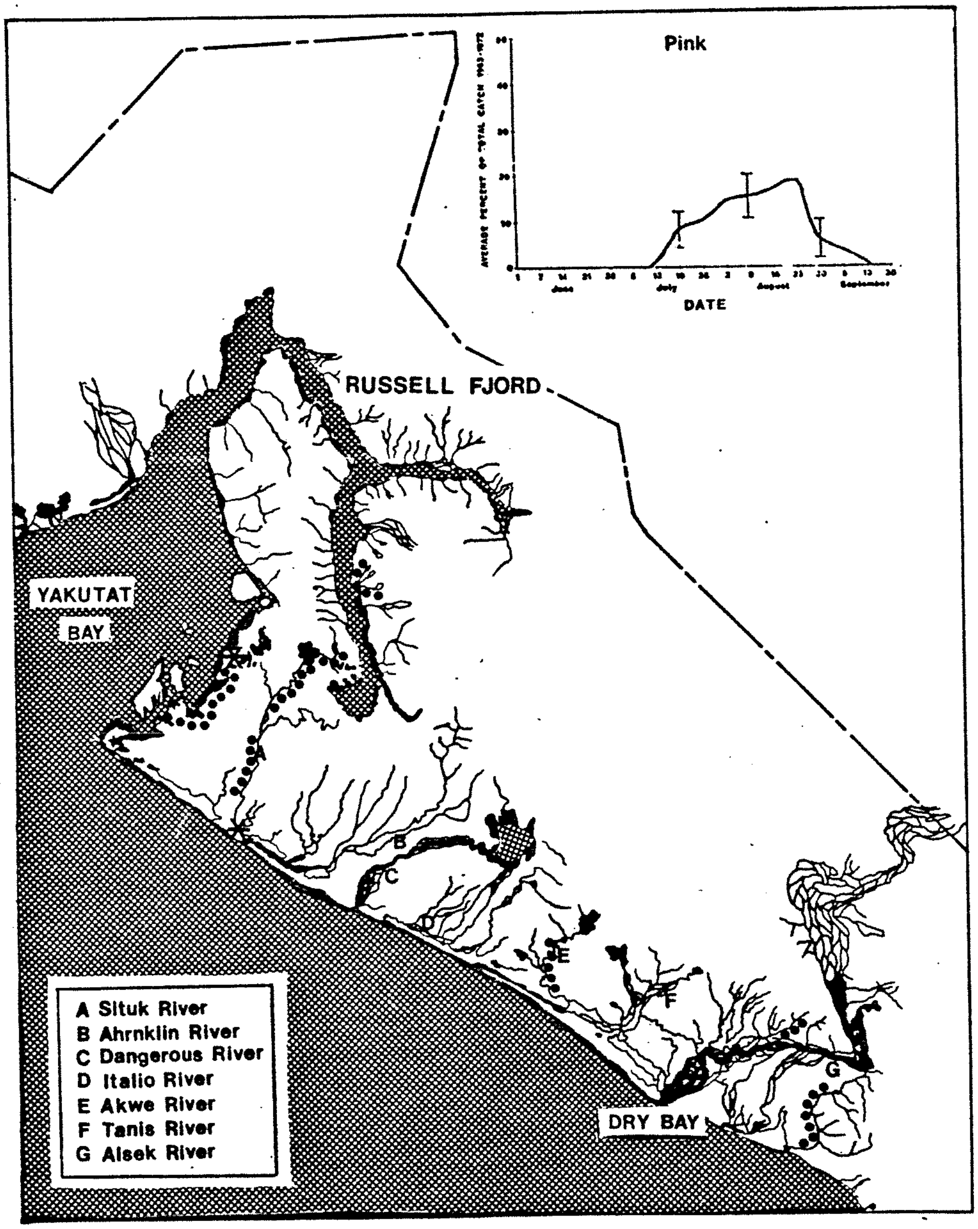

Fig. 5. Spawning sites of pink salmon in the Yakutat area (dots). The inset graph shows the average timing of pink salmon runs to the district with 95% confidence intervals on selected dates (determined from weekly catch statistics, 1963-1972).

Sources: Atkinson et al. 1967; McLean and Delaney 1978; and Stern et al. 1976.

Table 7. The commercial catch (numbers x 1000) of pink salmon in the Yakutat District, southeastern Alaska, and Alaska, 1959-1979.

Year	Yakutat	Southeastern Alaska	Alaska
1959	12	7,851	10,930
1960	14	2,985	16,079
1961	65	12,638	21,506
1962	28	11,585	43,864
1963	79	19,145	34,276
1964	40	18,581	45,291
1965	4	10,880	20,347
1966	1	20,438	40,051
1967	32	3,111	6,559
1968	2	25,085	44,727
1969	64	4,870	25,767
1970	4	10,657	31,147
1971	80	9,345	23,528
1972	3	12,400	15,920
1973	17	6,455	9,802
1974	4	4,889	9,859
1975	80	4,027	12,984
1976	29	5,330	24,751
1977	75	13,458	28,098
1978	30	19,988	52,668
1979	152	10,304	48,518
$\bar{X}$	40.8	11,701.1	28,333.7

Sources: International North Pacific Fisheries Commission 1979; Alaska Department of Fish and Game, preliminary data.

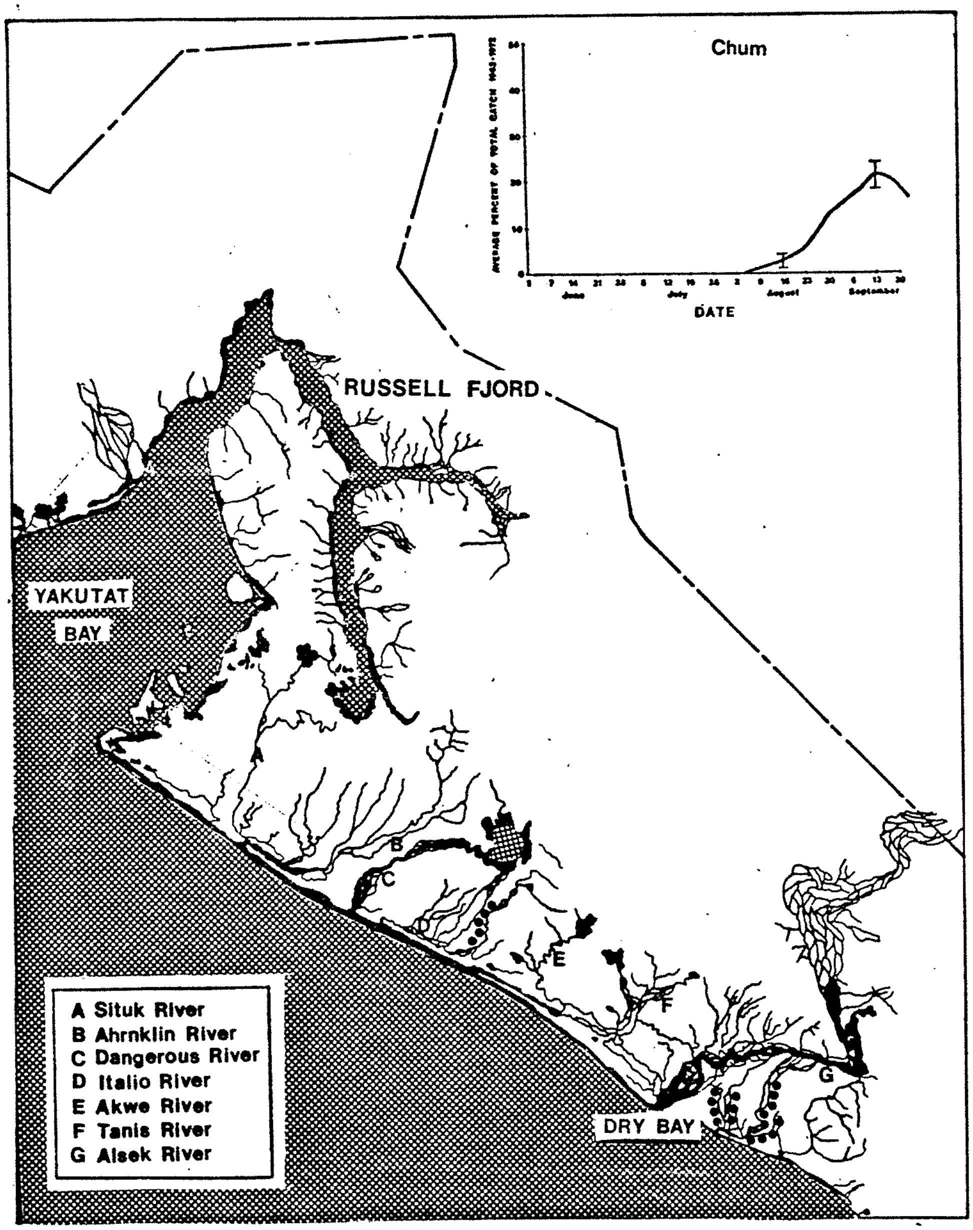

Fig. 6. Spawning sites of chum salmon in the Yakutat area (dots). The inset graph shows the average timing of chum salmon runs to the district with 95% confidence intervals on selected dates (determined from weekly catch statistics, 1963-1972).

Sources: Atkinson et al. 1967; McLean and Delaney 1978; and Stern et al. 1976.

Table 8. The commercial catch (numbers x 1000) of chum salmon in the Yakutat District, southeastern Alaska, and Alaska, 1959-1979.

Year	Yakutat	Southeastern Alaska	Alaska
1959	37	1,291	4,086
1960	12	1,019	6,625
1961	12	2,559	5,631
1962	18	1,996	7,149
1963	11	1,479	4,464
1964	6	1,936	7,271
1965	4	1,474	3,364
1966	3	3,273	6,456
1967	4	1,810	3,654
1968	14	2,644	6,082
1969	15	561	2,953
1970	7	2,446	7,500
1971	5	1,946	7,679
1972	8	2,942	7,065
1973	9	1,832	6,020
1974	4	1,683	4,730
1975	4	687	4,322
1976	8	1,031	5,925
1977	8	632	7,177
1978	6	597	6,368
1979	7	786	5,757
$\bar{X}$	10.1	1,731.2	6,013.9

Sources: International North Pacific Fisheries Commission 1979; Alaska Department of Fish and Game, preliminary data.

Coho Salmon *(Oncorhynchus kisutch)*

General Biology. This species is distributed along the west coast of North America from central California to the Aleutian Islands and Norton Sound, with a center of abundance between Oregon and southeastern Alaska. Coho range up to 98 cm long and 14 kg in weight. They spawn in the late fall in rivers and streams. Fecundity is related to the size of the female with 2,500 eggs per female 55 cm long to 5,000 eggs per female 70 cm long. Fry emerge in the early spring and remain in freshwater for about 1 year. Foods of juveniles that have reached saltwater include zooplankton, insects, small epibenthic crustacea such as gammarid amphipods, other benthic organisms, and fish (Rogers et al. 1980). After the coho migrate offshore, they feed on squid, amphipods, and shrimp. The maturing salmon feed and grow a great deal on their homeward migration. Their favored foods include herring and Pacific sand lance. (The preceding section is primarily derived from Hart 1973).

Experimental longlining and gillnetting in the Gulf of Alaska has revealed that coho salmon most frequently occur near the surface between 0-10 m and that they do not move below the thermocline (Godfrey et al. 1975).

Distribution and Abundance. The highest CPUE of juvenile coho salmon in coastal waters off Yakutat occurs during July and August, after which, most apparently move offshore. A large proportion, however, may reside in coastal water throughout their lives (Stern et al. 1976).

Spawning runs to the Yakutat District peak between late August and mid-September (Fig. 7). Coho occupy nearly every stream in the Yakutat area, and spawning populations have been observed in many of these. A large population spawns in the Situk/Ahrnklin River drainages.

Coho are the second most numerous salmon in commercial catches off Yakutat, but they only rank fourth in Alaska. Over 5% of the total catch of coho in Alaska orginated from the Yakutat District (Table 9).

Sockeye Salmon *(Oncorhynchus nerka)*

General Biology. In North America, sockeye salmon are distributed from northern California to the Aleutian Islands and the Canadian Arctic. They usually mature after 2-3 years at sea, with a maximum length at maturity of 84 cm long. Spawning occurs in rivers, streams, and on beaches of some lakes. Spawning grounds usually have access to lakes where the fry generally reside for 1-2 years. The number of eggs per female is related to size of the fish and ranges from 2,200-4,300. The length of incubation is temperature-dependent and ranges from 50-150 days. After hatching, the alevins remain in gravel for 3-5 weeks. Fry usually migrate into nursery lakes after emerging from the gravel. Migrations of smolts out of lakes begin in the spring when water

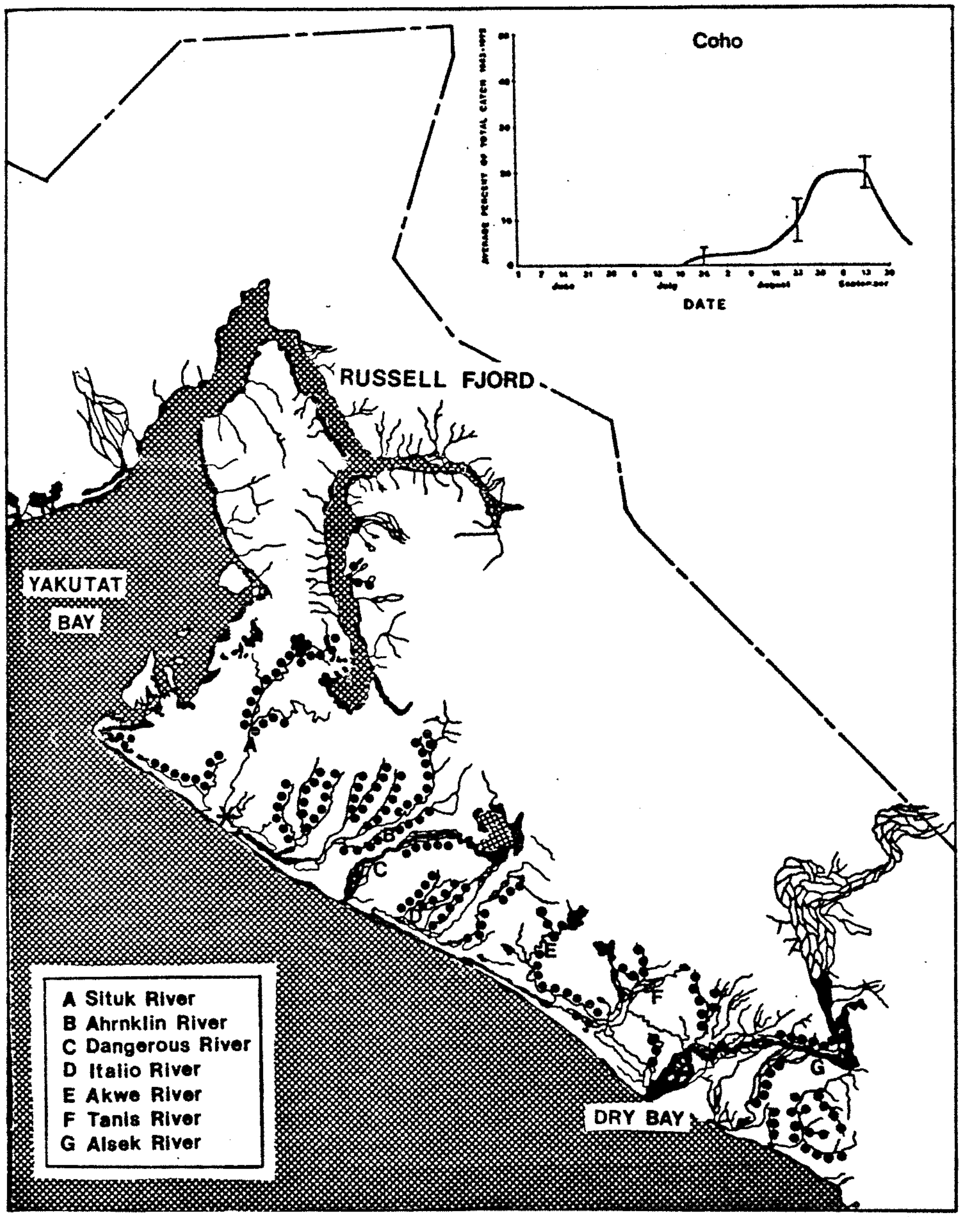

Fig. 7. Spawning sites of coho salmon in the Yakutat area (dots). The inset graph shows the average timing of coho salmon runs to the district with 95% confidence intervals on selected dates (determined from weekly catch statistics, 1963-1972).

Sources: Atkinson et al. 1967; McLean and Delaney 1978; and Stern et al. 1976.

Table 9. The commercial catch (numbers x 1000) of coho salmon in the Yakutat District, southeastern Alaska, and Alaska, 1959-1979.

Year	Yakutat	Southeastern Alaska	Alaska
1959	139	1,024	1,433
1960	121	721	1,404
1961	130	889	1,314
1962	190	1,223	2,039
1963	146	1,275	2,022
1964	170	1,588	2,558
1965	125	1,548	1,998
1966	67	1,227	1,921
1967	120	866	1,489
1968	122	1,543	2,751
1969	60	596	1,133
1970	39	759	1,527
1971	41	914	1,448
1972	56	1,509	1,831
1973	43	836	1,457
1974	79	1,278	1,855
1975	38	427	1,014
1976	52	824	1,432
1977	83	708	1,593
1978	130	1,573	2,614
1979	95	1,102	2,935
$\bar{X}$	102.3	1,121.5	1,888.4

Sources: International North Pacific Fisheries Commission 1979; Alaska Department of Fish and Game, preliminary data.

surface temperatures are 4-7°C. While in the coastal strip, the juveniles consume insects, zooplankton, small epibenthic crustaceans, and small fish (the preceding was modified from Hart 1973).

While in saltwater, sockeye stay in the upper 60 m between mid-May and early June. They continue to be in the upper 36 m in late June-July and are mostly shallower than 10 m during the summer. Sockeye salmon migrate toward the surface at night and probably always remain above the thermocline. During the winter, approximately 90% of the sockeye captured by test gillnets were within 15 m of the surface (Stern et al. 1976). According to Godfrey et al. (1975), sockeye tend to be in shallower water than the other four species of salmon.

Distribution and Abundance. Juvenile sockeye are in the coastal belt in July and August, after which they migrate offshore (Stern et al. 1976).

Mature sockeye spawn in several rivers in the Yakutat area (Fig. 8). More sockeye are caught commercially in the Yakutat area than any other species of salmon, but the catch in Yakutat is less than 1% of the total catch of sockeye in Alaska (Table 10). The peak of the run to Yakutat occurs in early July.

Chinook Salmon (*Oncorhynchus tshawytscha*)

General Biology. This species is distributed from central California to the Aleutian Islands and north to Norton Sound, and possibly Kotzebue Sound. The largest of the *Oncorhynchus* species, chinook salmon, mature at a maximum of 147 cm and 59 kg. Spawning runs occur throughout the year. Maturation is usually after the fourth or fifth year at sea and one female carries an average of 4,800 eggs. The fry generally migrate to sea soon after hatching, although some reside in freshwater for about one year. After reaching saltwater, the juveniles consume a variety of small fish, zooplankton, and small epibenthic crustaceans (from Hart 1973).

Chinook salmon occupy the greatest vertical range of all the Pacific salmon. They were frequently captured in herring trawls off the west coast of British Columbia and were common in water 20-110 m deep (Taylor 1969, cited in Major et al. 1978). Chinook salmon were captured in these trawls even during the summer when all the other species of salmon were in surface waters.

Distribution and Abundance. Like coho salmon, a large proportion of chinooks may reside in the coastal belt of the Northeast Pacific (Stern et al. 1976). The highest CPUE for juvenile chinook salmon is in July-August, after which, most apparently move offshore (Stern et al. 1976).

Chinook salmon spawn in only two rivers near Yakutat: the Situk and the Alsek (Fig. 9). Their spawning migration is earlier than the other

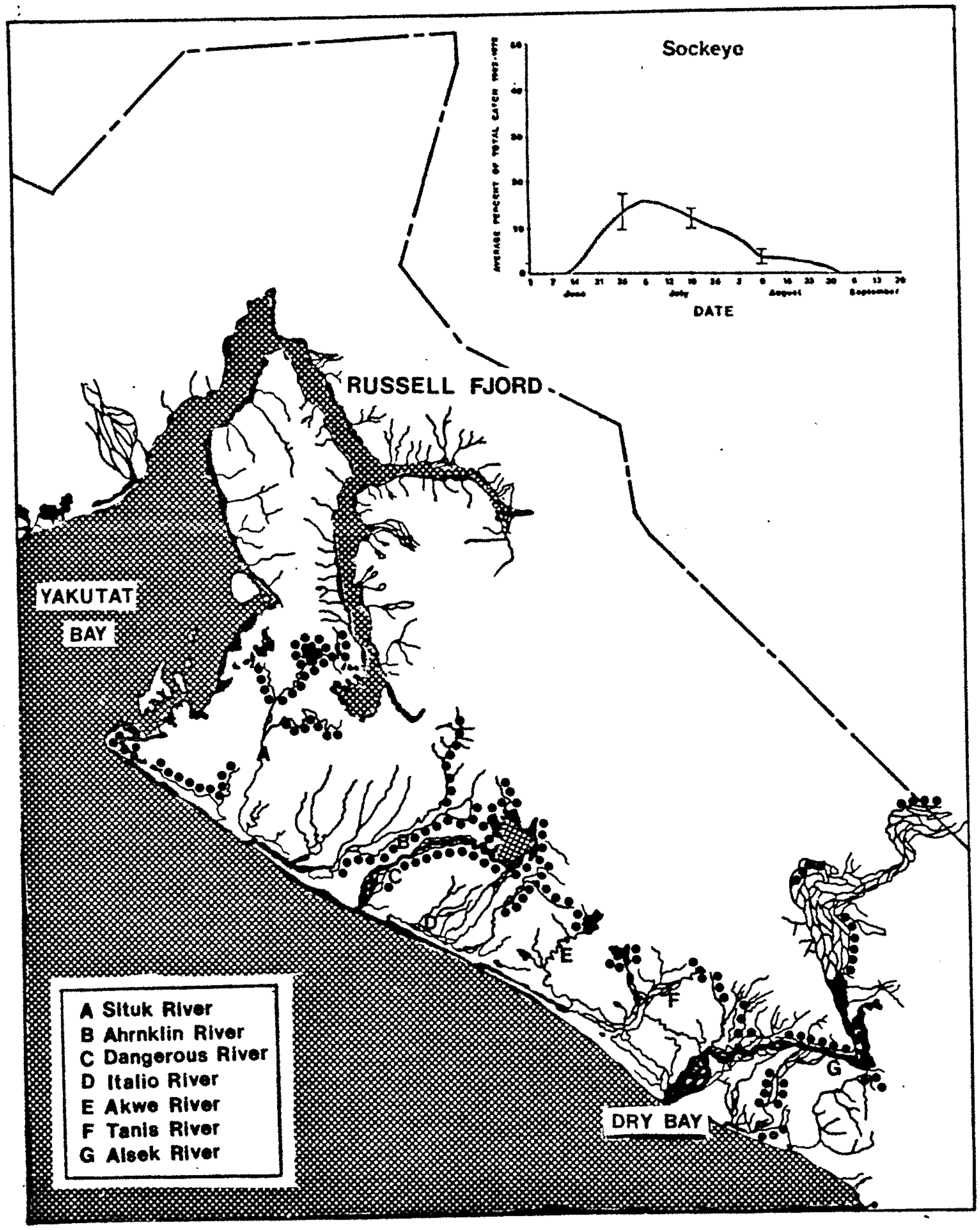

Fig. 8. Spawning sites of sockeye salmon in the Yakutat area (dots). The inset graph shows the average timing of sockeye salmon runs to the district with 95% confidence intervals on selected dates (determined from weekly catch statistics, 1963-1972).

Sources: Atkinson et al. 1967; McLean and Delaney 1978; and Stern et al. 1976.

Table 10. The commercial catch (numbers x 1000) of sockeye salmon in the Yakutat District, southeastern Alaska, and Alaska, 1959-1979.

Year	Yakutat	Southeastern Alaska	Alaska
1959	77	891	8,077
1960	48	588	17,834
1961	83	744	16,081
1962	81	772	9,297
1963	53	678	6,215
1964	92	924	9,966
1965	123	1,085	29,770
1966	185	1,054	15,073
1967	88	972	8,576
1968	81	831	8,130
1969	118	812	11,417
1970	112	668	27,634
1971	129	623	14,180
1972	131	917	6,590
1973	128	1,011	4,490
1974	83	687	4,869
1975	73	245	7,455
1976	130	595	11,783
1977	184	995	12,049
1978	128	692	17,787
1979	166	996	28,789
$\bar{X}$	114.6	839.0	13,803.1

Sources: International North Pacific Fisheries Commission 1979; Alaska Department of Fish and Game, preliminary data.

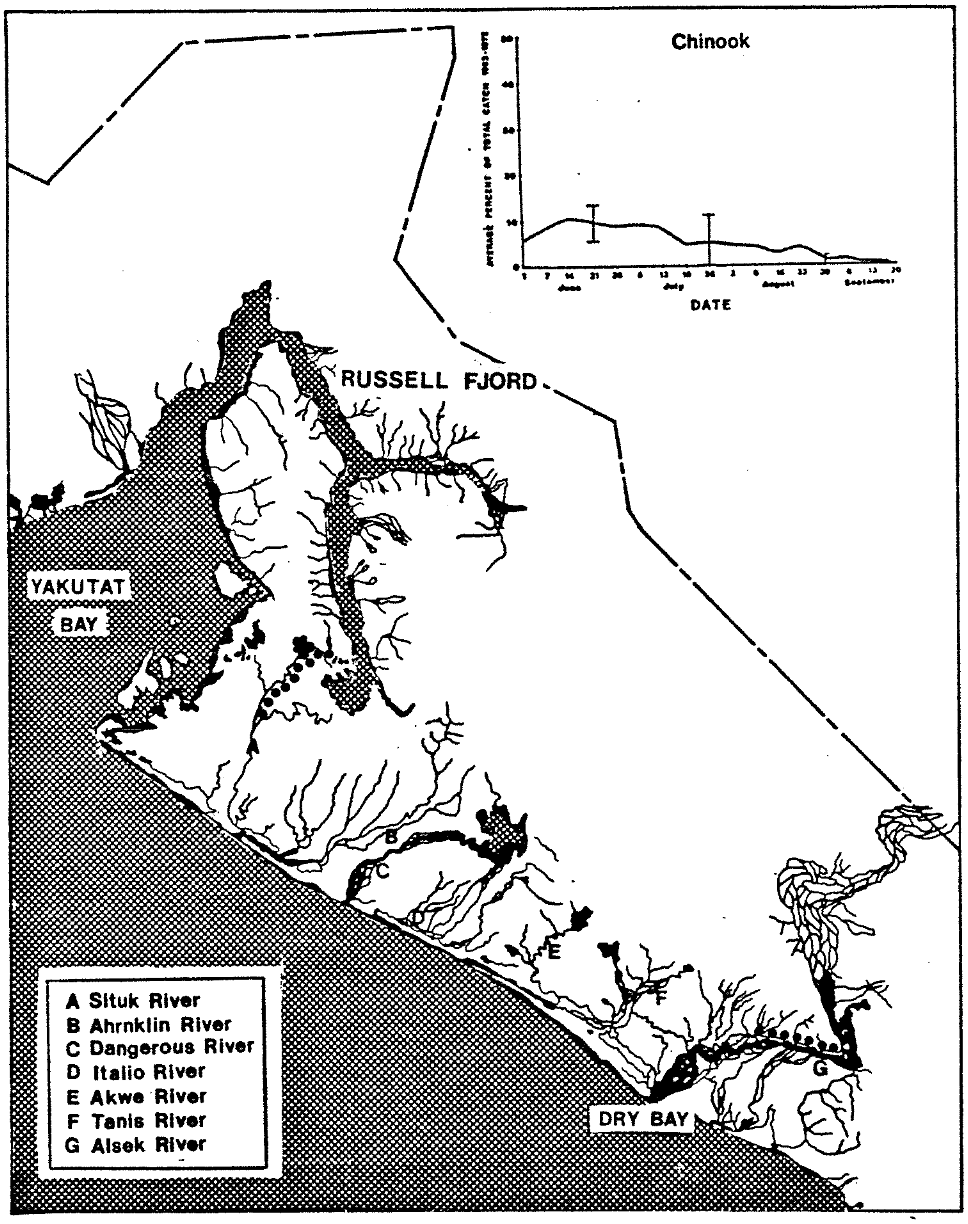

Fig. 9. Spawning sites of chinook salmon in the Yakutat area (dots). The inset graph shows the average timing of chinook salmon runs to the district with 95% confidence intervals on selected dates (determined from weekly catch statistics, 1963-1972).

Sources: Atkinson et al. 1967; McLean and Delaney 1978; and Stern et al. 1976.

salmon species, with the peak of the migration occurring in early June to mid-June. Annual catches have averaged only 4,200 fish. Chinook are thus the least abundant salmon in the Yakutat District and average less than 1% of the total catch of chinook salmon in Alaska (Table 11).

Demersal Fish and Shellfish

In recent years, there have been a number of exploratory studies on distribution, abundance, and species composition of ground fish species in the Northeast Pacific Ocean and the Gulf of Alaska. Hitz and Rathjen (1965) conducted a survey during the summer and fall of 1961 and the spring of 1962 in the northeastern Gulf of Alaska from Dixon Entrance to the Kenai Peninsula (Fig. 10). They trawled 617 stations to obtain an accurate account of the bottom topography to determine the extent of trawlable ground and the abundance and species composition of demersal fish and shellfish. A summary showing the ranking of species and species groups by depth (0-250 fm) is presented in Table 12.

Ronholt et al. (1978) reported on cruises that took place during June-August 1962, September-November 1962, and April-October 1973-1976 from Cape Spencer to Unimak Pass (Fig. 10). Alverson (1968) evaluated available information on exploited and unexploited fish and shellfish resources of the Northeast Pacific to document general distribution and stock magnitude. Maturgo (1972) compiled a report for the Shell Oil Company with figures on catch statistics gathered from about 2,500 exploratory drags by the National Marine Fisheries Service (NMFS) from 1950-1968 in the Gulf of Alaska.

Most catch statistics (foreign and domestic, where domestic includes both United States and Canadian catches) originate from the International North Pacific Fisheries Commission (INPFC). The INPFC's North Pacific region contains eleven areal divisions, and these are presented in Fig. 11. One of these is the Yakutat area, and it extends from 147°W longitude to 137°W longitude. Other catch statistics come from the Bureau of Land Management's (BLM) Yakutat Management area (Cape Suckling to Cape Fairweather) or the various regulatory areas, regions, and statistical areas (see Fig. 12) of the International Pacific Halibut Commission (IPHC).

Pacific Cod (*Gadus macrocephalus*)

General Biology. Along the shores of western North America, Pacific cod occur from Santa Monica, California, through Alaska to the Bering Sea (Hart 1973). The northern limit is reported as St. Lawrence Island (63°N) in the Bering Sea (Ketchen 1961). Pacific cod undergo seasonal vertical migrations, descending to depths of 300 fm in winter and entering shallower water in early summer. The extent of these migrations is influenced by seasonal temperature cycles (Ketchen 1961).

Table 11. The commercial catch (numbers x 1000) of chinook salmon in the Yakutat District, southeastern Alaska, and Alaska, 1959-1979.

Year	Yakutat	Southeastern Alaska	Alaska
1959	1	365	607
1960	1	310	547
1961	3	230	504
1962	3	206	461
1963	1	258	501
1964	2	357	639
1965	1	287	581
1966	2	308	540
1967	2	301	611
1968	4	332	611
1969	5	314	639
1970	10	322	646
1971	10	334	662
1972	6	287	553
1973	4	344	551
1974	8	347	556
1975	6	301	455
1976	6	242	533
1977	2	310	646
1978	3	389	794
1979	4	374	824
$\bar{X}$	4.2	325.9	623.0

Sources: International North Pacific Fisheries Commission 1979; Alaska Department of Fish and Game, preliminary data.

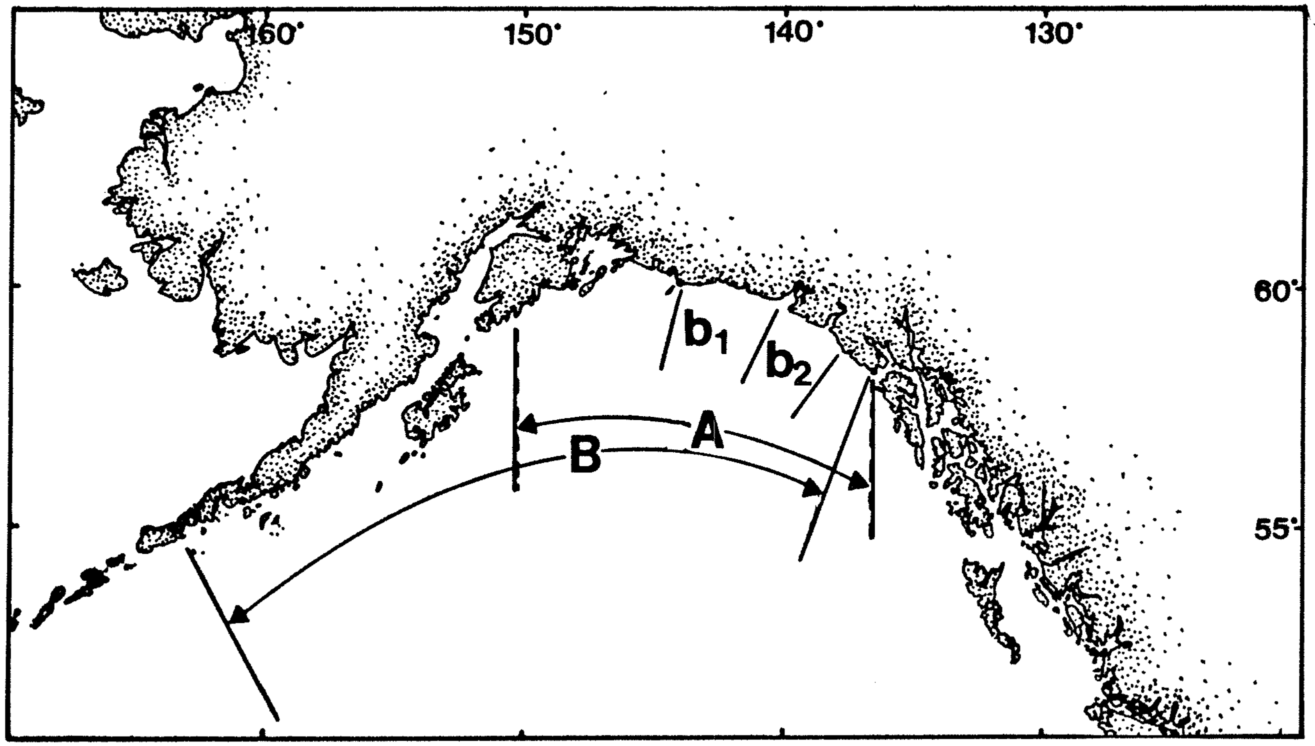

Fig. 10. Trawl surveys in the Gulf of Alaska:
A - Dixon Entrance to the Kenai Peninsula (Hitz and Rathjen 1965);
B - Cape Spencer to Unimak Pass;
b_1 - Yakutat region;
b_2 - Fairweather region (Ronholt et. al. 1978).

Table 12. Ranking of individual species or species groups by catch-per-unit-effort and depth for the Northeast Pacific. Figures in parentheses are pounds caught per hour trawled.

Depth (fm)					
1-50	51-100	101-150	151-200	201-250	All depths
PACIFIC COD (296)	ARROWTOOTH FLOUNDER (366)	ARROWTOOTH FLOUNDER (355)	Heart urchin (1,179)	Dover sole (499)	ARROWTOOTH FLOUNDER (330)
BUTTER SOLE (203)	Flathead sole (105)	Heart urchins (252)	ARROWTOOTH FLOUNDER (386)	SABLEFISH (428)	Heart urchins (171)
ARROWTOOTH FLOUNDER (129)	TANNER CRAB (84)	P.O.P. (204)	P.O.P. (158)	Other fish sp. (361)	P.O.P. (101)
STARRY FLOUNDER (125)	WALLEYE POLLOCK (84)	TANNER CRAB (106)	Dover sole (135)	Rougheye (336)	Flathead sole (82)
Starfish (81)	Starfish (78)	WALLEYE POLLOCK (91)	Flathead sole (72)	ARROWTOOTH FLOUNDER (218)	PACIFIC COD (76)
HALIBUT (61)	PACIFIC COD (74)	Flathead sole (78)	Rex sole (59)	Heart urchins (148)	TANNER CRAB (76)
DUNGENESS CRAB (38)	P.O.P. (58)	*Sebastolobus* (55)	HALIBUT (53)	Starfish (132)	WALLEYE POLLOCK (72)
English sole (37)	Heart urchins (58)	Starfish (49)	WALLEYE POLLOCK (30)	*Sebastolobus* (74)	Starfish (67)
Flathead sole (25)	HALIBUT (34)	SABLEFISH (42)	*Sebastolobus* (23)	Rex sole (24)	SABLEFISH (39)
SABLEFISH (13)	Skate (31)	Skate (36)	SABLEFISH (19)	Skate (20)	Dover sole (35)
Skate (13)	SABLEFISH (24)	Dover sole (35)	Skate (18)	Misc. invertebrate (19)	HALIBUT (32)
SCALLOP (10)	DUNGENESS CRAB (15)	Rex sole (31)	Starfish (9)	HALIBUT (8)	Skate (29)
Rex sole (10)	Misc. invertebrate (12)	Misc. invertebrate (18)	TANNER CRAB (5)	TANNER CRAB (8)	BUTTER SOLE (26)
WALLEYE POLLOCK (10)	Rex sole (11)	HALIBUT (18)	Other fish sp. (5)	Other rockfish (1)	*Sebastolobus* (22)
Rock sole (9)	Dogfish (9)	PACIFIC COD (12)	Shrimp (2)	PACIFIC COD (0.3)	Rex sole (20)
Dogfish (9)	Dover sole (7)	Rougheye (9)	Misc. invertebrate (1)	Dogfish (0)	STARRY FLOUNDER (16)

Source: Hitz and Rathjen (1965)

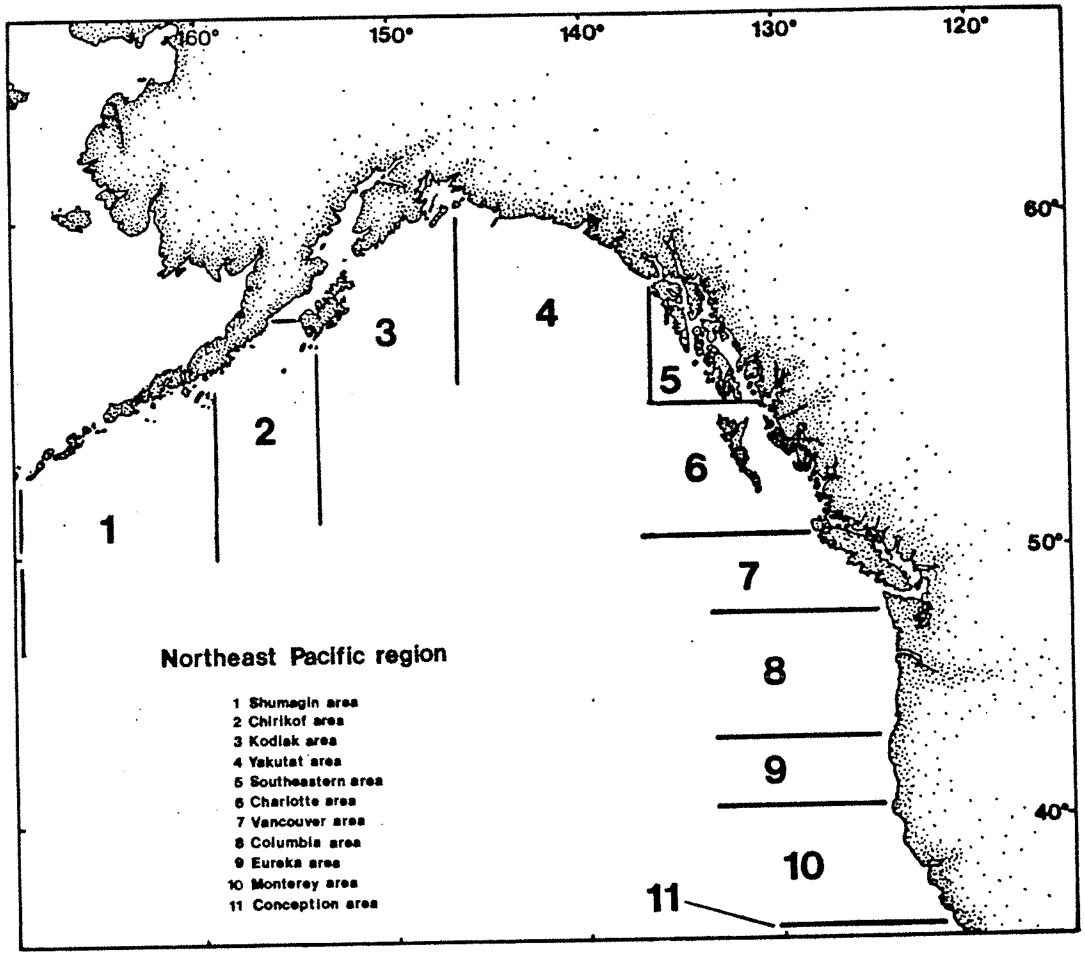

Fig. 11. Areal divisions of the Northeast Pacific region.

Source: Forrester et al. 1978.

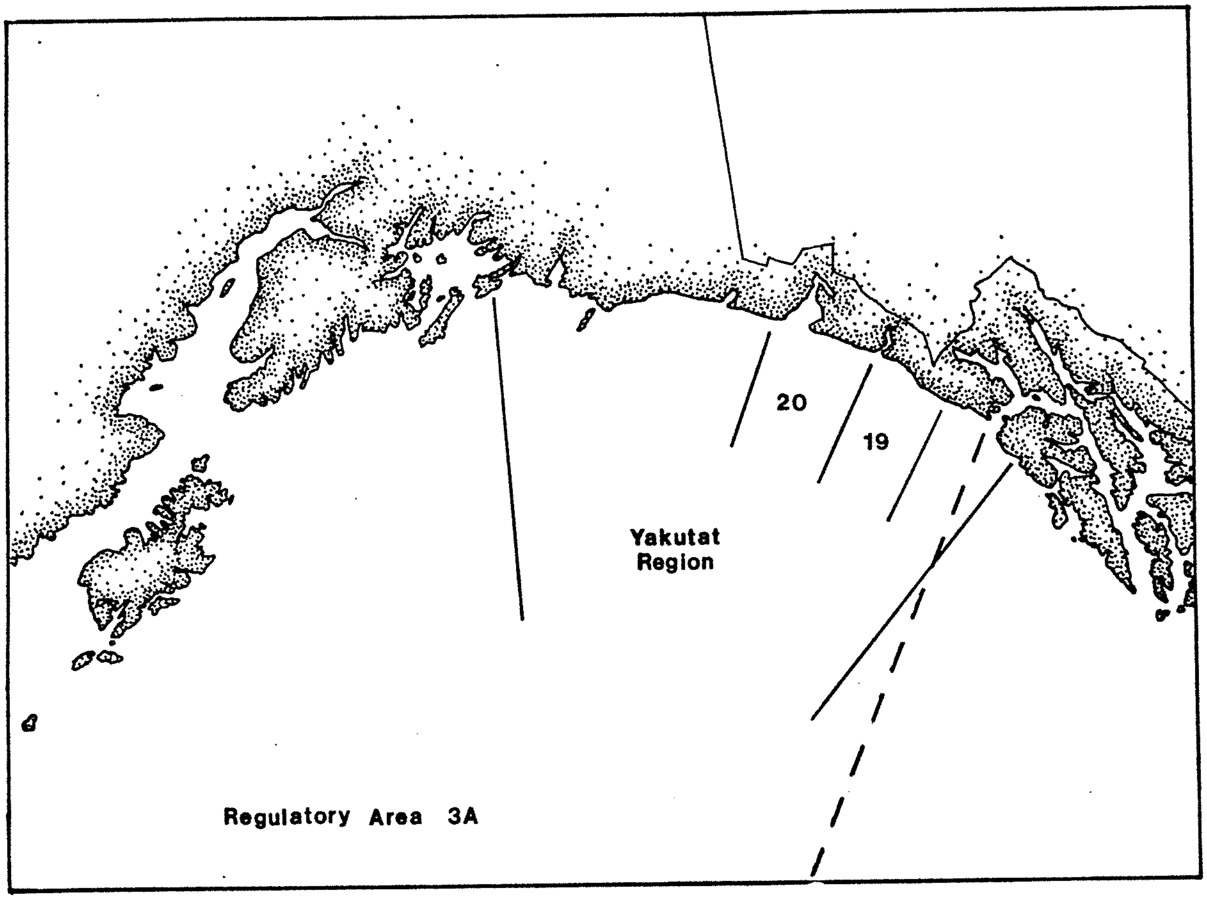

Fig. 12. The northeastern Gulf of Alaska showing a section of the International Pacific Halibut Commission's regulatory area 3A (Cape Spencer - dotted line - to Kupreanof Point), the Yakutat region, and statistical areas 19 and 20.

Source: Mayer et al. 1977.

Spawning of Pacific cod occurs in winter. Eggs are thought to be demersal (Thomson 1963; Forrester 1964) and range in diameter from .98-1.08 mm ($\bar{x}$ = 1.02 mm). Fecundity ranges from 1.5-3.0 million eggs for females 60-90 cm long (Thomson 1962). The size of fish at first maturity varies with area. In western Kamchatka, 50% of female Pacific cod were mature at about 70 cm (Moiseev 1953, cited in Hart 1973) while cod in British Columbia were mature at 55 cm for females and 50 cm for males (Thomson 1962). Age of first maturity is 2 or 3 years for both sexes (Ketchen 1961).

Hatching of eggs occurs in 1-4 weeks depending on water temperature: 8 days at 11°C, 17 days at 5°C, and 28 days at 2°C,and newly hatched larvae range from 3.5-4.0 mm (Forrester and Alderdice 1966; Forrester 1964). Larval illustrations are given by Gorbunova (1954). At one year, young cod from British Comunbia are 23-26 cm and at two years are 44-49 cm (Hart 1973).

Pacific cod tend to eat small epibenthic crustacea and zooplankton when they are small (Rogers et al. 1979), but as they grow, they rely less upon these organisms and more upon shrimp and fish. Several authors have named shrimp as the most important (and fish second) food item for Pacific cod (Hunter 1979; Feder 1977; Forrester 1969; Hart 1949; Karp and Miller 1977).

History of the Fishery. Unlike most demersal species, there has been a sizeable domestic fishery for cod for many years, the United States fishery beginning in the Okhotsk Sea in 1857. Until the turn of the century most fishing was in Asia and in the Bering Sea, but in 1907 processing stations were established in the Shumagin Islands and areas south of the Aleutian chain became more important. Cod line vessels were used during the early days of the fishery, but were discontinued in the early 1950's. Cod landings peaked during World War I at about 20,000 m.t. and in the 1960's have averaged about 10% of that (Table 13).

The Japanese catch most of their cod in the Bering Sea. In the Gulf of Alaska cod are taken in their stern trawl fishery, but between 1969 and 1971 less than 1% of this catch was Pacific cod. The Japanese stern trawl fishery has existed in the Gulf since 1963, but, except for one year, the Yakutat area has contributed very little to this catch. It has ranged from 0 to 7.2%, except for 1968 when it was 30.5% (Forrester et. al. 1978).

Distribution and Abundance

Adults. Pacific cod are relatively abundant and widely distributed in the Gulf of Alaska. In a trawl survey, Alverson (1968) reported that for the Northeast Pacific, cod ranked fourth by frequency of occurrence and fifth by abundance. Hitz and Rathjen (1965) reported that by catch-per-unit-effort (CPUE by weight), cod were the fourth most important fish species over all depths (1-250 fm) and that they were the

Table 13. Annual total catch (m.t.) of Pacific cod in the Northeast Pacific by the United States, Canada, and Japan.

Year	United States	Canada	Japan
1956	4,428	2,338	--
1957	5,364	3,858	--
1958	5,738	4,562	--
1959	6,033	4,167	--
1960	2,474	3,126	--
1961	1,390	2,063	--
1962	1,439	2,693	--
1963	2,887	4,047	180
1964	2,907	7,050	193
1965	4,597	11,098	584
1966	4,578	12,160	1,358
1967	3,986	6,601	2,156
1968	2,681	6,731	1,059
1969	1,730	4,394	1,345
1970	1,263	2,915	1,774

Source: Forrester et al. 1978.

most important species at depths of 1-50 fm (Table 12). Furthermore, Alverson et al. (1964) noted that cod occur in shallower waters than walleye pollock. Ronholt et. al. (1978) reported that cod were more abundant in waters to the north and west of Yakutat than in waters off Yakutat. For example, during the survey expeditions of April-October, 1973-1976, Pacific cod in the Fairweather region (Yakutat Bay to Cape Spencer) contributed only 1.1% to the total catch in the entire study area.

Larvae and Eggs. Pacific cod are reputed to spawn at depths of 100-250 m in the Bering Sea (Musienko 1970). In the Yakutat area, we can expect to find larvae distributed over the shelf. Larvae have been reported from the plankton in June and July in the Bering Sea (8.8-11.6 mm) (Musienko 1963), May and July in Cook Inlet (5.3-9.0 mm), April and May in Kodiak bays (Rogers et. al. 1979), and March-April, June-July on the Kodiak Shelf (Kendall et al. 1980). In every case, catches of cod larvae were low relative to other larval fish taxa found at these times. In most cases, walleye pollock was the dominant gadid larvae collected.

Spawning occurs in winter and eggs are demersal, hence not accessible to plankton tows. We expect to find larvae in April-May and July-August in the Yakutat area.

Walleye Pollock (*Theragra chalcogramma*)

General Biology. Walleye pollock range from central California through the Bering Sea (Hart 1973). In Alaskan waters, some of the largest concentrations of pollock are in the northeastern shelf of the Bering Sea (Serobaba 1968) and in the western Gulf of Alaska (Hughes and Hirschhorn 1978). Walleye pollock are found from the surface to below 200 fm (366 m) although most catches are primarily between 50 and 300 m. It is possible that pollock are bathypelagic at depths greater than 200 m (Hart 1973).

Walleye pollock are late winter to spring spawners throughout their range. In British Columbia, larval pollock (4-22 mm) occur during April and May and in the western Gulf of Alaska, over 85% of adult pollock examined had spawned prior to their collection in May, implying that spawning occurred in March and April. Ripe males and females were obtained as late as August but were less than 0.1% of the fish sampled (Hughes and Hirschhorn 1978). Spawning in the Bering Sea begins in late February with fish in the southeastern Bering Sea spawning first. Most spawning occurs from late March to mid-June with the highest spawning rate in May (Serobaba 1968).

Sexual maturity is reached at age 3 for both sexes, although a small percentage of 2-year-old males were in a spawning condition near Kodiak. Lengths of first-mature fish from the Gulf of Alaska were 29-32 cm for males and 30-35 cm for females (Hughes and Hirschhorn 1978).

Spawning occurs at temperatures of 1-3°C in the Bering Sea (Serobaba 1968) and there is some evidence that pollock may spawn under sea ice (Kanamaru et al. 1979).

High densities of pollock occurred at 91-270 m during spring and summer in the western Gulf of Alaska (Hughes and Hirschhorn 1978). Spawning pollock in the Bering Sea occurred between 50 and 300 m and were rarely found over the continental slope (i.e., >300 m) (Serobaba 1968).

Eggs are pelagic (Kanoh 1954) and range from 1.35-1.45 mm in British Columbia (Hart 1973) to 1.46-1.65 mm in the Bering Sea (Serobaba 1968). Illustrations of developing eggs are given by Gorbunova (1954). During development, eggs remain pelagic and newly hatched larvae are 3.5-4.3 mm. Larvae have been described and illustrated by Gorbunova (1954). Most larvae are collected in upper layers (≥50 m) (Kanamaru et al. 1979) and larvae may undergo vertical migrations which are associated with growth (Kobayashi 1963).

Copepods, mysids, and euphausids are often the most important foods of juvenile pollock (Rogers et al. 1979; Simenstad et al. 1977; Nikol'skii 1954; Bailey and Dunn 1979; Smith et al. 1978) but as the fish grow, their reliance upon such prey becomes less, and prey such as fish and shrimp become more important (Bailey and Dunn 1979; Smith et al. 1978; Rogers et al. 1979).

History of the Fishery. Commercial exploitation of walleye pollock by domestic fishermen has been minor. In both the United States and Canada, this species has been utilized almost exclusively for animal food (Forrester et al. 1978) and in general, North American ground fish fleets have not expanded into the Gulf of Alaska beyond the Queen Charlotte Islands (Reeves 1972). Through the 1960's and 1970's, United States and Canadian landings have only averaged around 100 m.t. (220,500 lbs) each (Forrester et al. 1978).

Foreign fleets utilize pollock to a much greater extent, but fish more in the Bering Sea than in the Gulf of Alaska. The Japanese have fished for pollock in the northeastern Gulf, and their catches have ranged up to almost 18,000 m.t. (Table 14). The proportion of this to their total catch off Alaska is small because of the size of the Bering Sea fishery. In 1970, over 1 million m.t. of pollock was taken in the Bering Sea. The Yakutat region (Cape Suckling to Cape Spencer) is relatively unimportant to the Japanese fishery for pollock in the Gulf, and has ranged from 0 to only 12.3% of the total, except for 49% in 1968.

Distribution and Abundance

Adults. Walleye pollock are widely distributed in the Gulf of Alaska. Alverson (1968) reported that pollock ranked as the fifth most frequently caught fish, and as the fourth most abundant fish. In a

Table 14. Annual Japanese catches (m.t.) of walleye pollock in the Yakutat region and the Northeast Pacific, 1963-1970.

Year	Yakutat[1]	Northeast Pacific[2]
1963	--	1,141
1964	3	1,126
1965	--	2,746
1966	63	9,117
1967	805	6,526
1968	3,107	6,345
1969	1,878	17,993
1970	292	9,701

[1] Cape Suckling to Cape Spencer.
[2] Shumagin to Columbia regions.

Source: Forrester et al. 1978.

similar study Ronholt et al. (1978) reported that during April-October, 1973-1976, pollock ranked highest in relative apparent abundance of any species captured. Hitz and Rathjen (1965) reported that pollock occurred over a wide depth range, but were most abundant in catches from between 51 and 200 fathoms (Table 12). In the Ronholt et al. (1978) study, catches in the Fairweather area were low during all cruises and comprised only 0.2% of the total catch during the latter cruise (April-October, 1973-1976).

Larvae and Eggs. Walleye pollock larvae and eggs are important components of the ichthyoplankton during early spring (April-May) in various parts of Alaska including areas in the southeastern Bering Sea, Kodiak shelf, and Cook Inlet. Eggs occur in the surface waters and are distributed throughout the water column. Larvae are caught more frequently and in higher abundances in subsurface waters than at the surface. During April and May larvae range from hatch size (3.5 mm) to 13 mm, and by summer, larvae are 16-38 mm (Table 15). We expect to find pollock eggs distributed throughout the Yakutat study area during April and May. In July, eggs may occur, but in lesser abundance than during spring sampling. Larvae are likely to be found during spring and summer and distributed over the shelf area. Pollock over 38 mm are not likely to be caught by plankton nets, but may be caught in other gears. These juvenile pollock may occur during October.

Pacific Ocean Perch (*Sebastes alutus*)

General Biology. Pacific ocean perch occur mainly offshore from southern California to the Bering Sea. In the Gulf of Alaska, Pacific ocean perch are at depths ranging from 50-450 m but usually are found near 180 m (Major and Shippen 1970). A well defined oxygen deficient layer may prevent movement into deeper water (Lyubimova 1965). Distribution may also be affected by food availability, state of maturity, and ecological factors (Major and Shippen 1970).

Rockfish mate before ovulation and sperm are stored in the ovary. Fertilized eggs are retained by the female (ovoviviparous) and larvae are extruded one to two months later (DeLacy et al. 1964). Descriptions of intraovarian larvae of some rockfish species, including Pacific ocean perch are given in Efremenko and Lisovenko (1972). Females contain between 2,000-69,000 eggs in the Gulf of Alaska (Lisovenko 1965) and 31,000-305,000 eggs off Oregon (Westrheim 1958). Lyubimova (1965) reported 10,000-270,000 larvae may be released and larvae are extruded at a size of 5-8 mm (Paraketsov 1963; Lisovenko 1964; Westrheim 1975). Separation of rockfish larvae by species is difficult from plankton samples and larvae will only be identified as *Sebastes* spp.

In the Gulf of Alaska, larvae were in upper layers over 200-250 m depths (Lisovenko 1964). In the Bering Sea, release of larvae was documented at 390-400 m depths and larvae ascended to 150 m off the bottom (Moiseev and Paraketsov 1961). Juvenile Pacific ocean perch remain

Table 15. Distribution and abundance of walleye pollock eggs and larvae in the Northeast Pacific Ocean and Bering Sea.

Stage	Location	Time	Gear	Station depths, m	Larval lengths, mm	Abundance	Reference
Larvae	Bering Sea	Apr-May 1977	bongo[1] neuston[2]	100-2000	3.1-11.8	Accounted for 84% of larvae caught in bongo tows; 34-108 larvae per haul or 194-695 per $10m^2$. Accounted for 6% of larvae caught in neuston net.	Waldron and Vinter 1978
Eggs	Bering Sea	Apr-May 1977	bongo[1] neuston[2]	100-2000		Accounted for 98% of eggs caught in the bongo; 32-154 per haul or 172-910 per $10m^2$. Comprised 97% of all eggs in the neuston hauls; 15-162 per haul or .6-6.7 per $10m^2$.	"
Larvae	Bering Sea	May-Jun 1971	bongo		5.4-8.0	Accounted for 1.5% of all larvae.	Dunn and Naplin 1973
Larvae	Bering Sea	Jun-Jul 1962	CPN[3]		16, 27	Only 2 larvae taken.	Kashkina 1970
Eggs	Bering Sea	Jun-Jul 1962	CPN			Only 16 stage I and II eggs.	"
Larvae	Bering Sea	Jun-Sep 1958 Mar 1959	CPN	135-3600[4]	5-13 21-38(fry)	Maximum concentration occurred in Mar and was 60 larvae per m^2.	Musienko 1963
Eggs	Bering Sea	Jun-Sep 1958 Mar 1959	CPN	77-3701[4]		Mass spawning in March, maximum concentration was 598 eggs per m^2.	"
Larvae	Kodiak Shelf	Apr-May 1972	bongo		3.5-5.2	Comprised 62% of all larvae; mean catch was 192 per $10m^2$; range was 0-12,118 larvae per $10m^2$.	Dunn and Naplin 1974
Eggs	Kodiak Shelf	Apr-May 1972	bongo			Accounted for 97% of all eggs; mean catch was 1792 per $10m^2$; range was 0-104,645 eggs per $10m^2$.	"

Table 15. Distribution and abundance of walleye pollock eggs and larvae in the Northeast Pacific Ocean and Bering Sea - continued.

Stage	Location	Time	Gear	Station depths, m	Larval lengths, mm	Abundance	Reference
Larvae	Kodiak Shelf	Nov 1977 Mar-Apr 1978 Jun-Jul 1978 Oct-Nov 1978 Feb-Mar 1979	bongo	40-1000		Second most abundant larvae during Mar-Apr.	Kendall et al. 1980
Eggs	Kodiak Shelf	Nov 1977 Mar-Apr 1978 Jun-Jul 1978 Oct-Nov 1978 Feb-Mar 1979	bongo neuston	40-1000		Most abundant egg species in each gear type during Mar-Apr.	"
Larvae	Kodiak Bays	Mar-Aug 1978 Nov 1978 Mar 1979	bongo neuston	39-171		In the bongo - eleventh most abundant larvae over all cruises and stations; average catch per bay was 0-102 larvae per $1000m^3$. Ranked 28th in neuston catches over all cruises and stations.	Rogers et al. 1979; Garrison and Rogers 1980
Eggs	Kodiak Bays	Mar-Aug 1978 Nov 1978 Mar 1979	bongo neuston			Second most abundant egg from bongo hauls over all cruises and stations; mean catch per bay ranged from 0-89 per $1000m^3$. Ranked third over all cruises and stations in neuston hauls; mean catch per bay ranged from 0-503 per $1000m^3$.	"
Larvae	Cook Inlet	Apr-May 1976 Jul-Aug 1976 Oct 1976 Feb 1976	bongo NIO[5]	35-210	3.6-9.4	Most abundant larvae in 6-13 Apr cruise; 32,083 larvae caught over 13 stations.	English 1977, 1978

[1]Bongo net, 60 cm diameter, 505μ mesh.
[2]Sameoto neuston sampler, .3m x .5m, 505μ mesh.
[3]Conical plankton net, No. 140 mesh.
[4]Depths of stations where larvae occurred.
[5]Nonclosing plankton net, 1m, 571μ mesh.

pelagic for 1-3 years before descending to a near bottom habitat (Lyubimova 1964; Carlson and Haight 1976). Juveniles make nocturnal vertical migrations to feed on planktonic crustaceans and the major food item of adults are euphausiids (Somerton 1978).

History of the Fishery. United States fishermen began to commercially exploit Pacific ocean perch in 1946 off the Oregon coast. Prior to 1946, other rockfish species were commercially fished in California and eventually the fishery moved northward. The Oregon-Washington areas became important fishing grounds and from 1961 to 1970, the bulk of the catch was from the Charlotte to Columbia areas. The fishing effort by United States fishermen for demersal species in the Northeast Gulf of Alaska has been low but there are plans to develop a groundfish fishery at Yakutat and four other Alaskan communities (Terry et al. 1980).

The bulk of the fishing has been carried out by foreign trawlers (Japanese, Soviets, South Koreans, Poles) and competition between them and domestic fishermen has been low in the Gulf of Alaska. By far, the Soviets and Japanese have carried on most of the fishing here. The Soviet fishery for Pacific ocean perch began in the Bering Sea in 1960 and briefly centered on the Gulf of Alaska before moving southward. Catches of over 225,000 m.t. were reported for the Gulf in 1964 and 1965 (Forrester et al. 1978). The Japanese, though, have largely concentrated on the eastern Gulf area. From 1966 to 1968, Yakutat (INPFC area) yielded the second highest catch of Pacific ocean perch (21% of all areas in the northeast Pacific region) in the Japanese stern trawl fishery. The Japanese catch of Pacific ocean perch at Yakutat from 1965-1974 is given in Table 16.

Distribution and Abundance

Adults. In the Gulf of Alaska, feeding schools of Pacific ocean perch occur in the Unimak, Shumagin, Kodiak and Yakutat regions during spring and summer (Lyubimova 1965). Both Pacific ocean perch and flatfish constitute a major portion of the standing stock of demersal fish in the Gulf. By 1972, catchable stocks of Pacific ocean perch were reduced to about 39% of their original levels in North America (Quast 1972). Even so, Pacific ocean perch are quite abundant. Alverson (1968) reported that Pacific ocean perch ranked second by abundance and sixth by frequency of occurrence. Hitz and Rathjen (1965) reported that (by CPUE) Pacific ocean perch were second in importance behind arrowtooth flounder and they became more important with depth (Table 12). Pacific ocean perch is abundant in the vicinity of Yakutat. Ronholt et al. (1978) reported that from 1973-1976, 17.6% of the total estimated Pacific ocean perch biomass (Cape Spencer to Unimak Pass, excluding the Shumagin region), occurred in the Yakutat and Fairweather areas. Pacific ocean perch seems to occur in large concentrations around submarine canyons (Reeves 1972) such as off Dry Bay (Hitz and Rathjen 1965). Comparisons of CPUE by decade (1962-1976) in both the Yakutat and Fair-

Table 16. Annual catch (m.t.) of Pacific ocean perch in the Yakutat region, the Fairweather area, and total catch for the Northeast Pacific.

Year	Yakutat[1]	Fairweather[2]	Total
1965	33	--	42,476[3]
1966	422	--	68,702[3]
1967	13,615	--	73,266[3]
1968	30,890	--	73,429[3]
1969	18,395	--	66,330[3]
1970	10,598	--	51,785[3]
1971	13,545	4,623	31,579[4]
1972	14,943	5,650	30,488[4]
1973	16,100	5,710	35,488[4]
1974	10,901	4,826	24,683[4]

[1] Cape Suckling to Cape Spencer.
[2] Yakutat Bay to Cape Spencer.
[3] Shumagin, Chirikof, Kodiak, Yakutat, and southeastern to Conception areas.
[4] Cape Spencer to Unimak Pass.

Sources: Forrester et al. 1978; Ronholt et al. 1978.

weather regions by Ronholt et al. (1978) seem to indicate a moderate decrease in Pacific ocean perch abundance. The largest decreases were in the upper slope area.

Larvae. Plankton studies from Alaskan waters report the distribution and abundance of rockfish larvae as *Sebastes* spp. due to the difficulty of separating species which may co-occur in plankton samples. *Sebastes* spp. have been reported from the majority of spring, summer, and fall cruises in Alaskan waters and significant concentrations of larvae have been reported from the Yakutat region during April and May (Lisovenko 1964).

Larvae may be distributed over the shelf, but more dense concentrations have been reported for areas over the slope (Lisovenko 1964; Kendall et al. 1980). They are also reported from bays in Kodiak Island (Rogers et al. 1979). Rockfish larvae have been caught in surface and subsurface tows and in greater abundance in tows during the night (Kendall et al. 1980). Rockfish up to lengths of 30 mm seem to be susceptible to capture in plankton nets (Table 17).

In the Yakutat study area, we expect to catch rockfish larvae in all seasons with relatively higher catches during spring. Larvae may be distributed over the shelf area and possibly at higher densities near the shelf edge.

Sablefish (*Anoplopoma fimbria*)

General Biology. Sablefish (or black cod) exist along the North American coast in the offshore waters from Cedrus Island, Baja California to Alaska and in the Bering Sea.

Sablefish spawn primarily from autumn through winter. From Vancouver Island to Oregon, spawning occurred from September to the end of February, and in the Bering Sea spawning peaked in fall and ended in early spring. However, some spawning continued into summer.

On the Pacific coast of North America, 50% of sablefish caught were sexually mature at ages 5-7 years and 60-70 cm in length. In the Bering Sea, 50% were sexually mature at 5-6 years and 60-62 cm in length (Kodolov 1968). Fecundity is high and increases with age for Bering Sea sablefish: 725 cm length - 438,000 eggs; 740 cm length - 468,000 eggs; and 825 cm length - 503,000 eggs (Kodolov 1968).

It is thought that sablefish spawn at considerable depth and probably beyond the continental slope. Eggs are pelagic, smooth, have a narrow perivitelline space, and range from 2.056-2.097 mm in diameter (Thompson 1941). Larvae have been illustrated by Kobayashi (1957) and post-larvae (21-35 mm) are described by Brock (1940).

Table 17. Distribution and abundance of *Sebastes* spp. larvae in the Northeast Pacific Ocean and Bering Sea.

Location	Time	Gear	Station depths, m	Larval length, mm	Abundance	Reference
Bering Sea	Apr-May 1977	bongo[1] neuston[2]	100-1000	5.0-8.3	Fourth in abundance in bongo hauls, comprising 3.7% of larvae caught. Accounted for .7% of all larvae from neuston tows.	Waldron and Vinter 1978
Bering Sea	May-Jun 1971	bongo		3.6-8.0	Accounted for 51% of larvae caught.	Dunn and Naplin 1973
Bering Sea	Jun-Jul 1962	CPN[3]		8.2-14.6	Total of 13 larvae caught.	Kashkina 1970
Bering Sea	Jun-Sep 1958 Mar 1959	CPN	58-3600	5.3-19.4	Caught in surface tows during July and August.	Musienko 1963
Kodiak Shelf	Apr-May 1972	bongo			Represented less than .1% of all larvae caught.	Dunn and Naplin 1974
Kodiak Shelf	Oct-Nov 1977 Mar-Apr 1978 Jun-Jul 1978 Oct-Nov 1978 Feb-Mar 1979	bongo neuston	40-1000		Occurred in bongo during summer and fall, second most abundant larvae during summer. Present in summer, fall, and winter in neuston catches.	Kendall et al. 1980
Kodiak Bays	Mar-Aug 1978 Nov 1978 Mar 1979	bongo neuston	31-171		Occurred June-August in relatively low abundances. Ranked 13th in bongo catches and 20th in neuston catches overall stations and cruises.	Rogers et al. 1979; Garrison and Rogers 1980.
Cook Inlet	Apr-May 1976 Jul 1976 Aug 1976 Oct 1976	bongo NIO[4]	35-210	3.0-18.0	Larvae caught during all cruises. Total numbers caught per cruise ranged from 3-57.	English 1977, 1978

Table 17. Distribution and abundance of *Sebastes* spp. larvae in the Northeast Pacific Ocean and Bering Sea - continued.

Location	Time	Gear	Station depths, m	Larval length, mm	Abundance	Reference
Gulf of Alaska	Sep-Oct 1975	bongo NIO		4-16	Most abundant larvae caught, 93 specimens.	English 1976
Gulf of Alaska	Apr-Jul 1963	CPN	90-3000		Highest concentrations: Yakutat - 100-200 per m^2; Kodiak - 40-50 per m^2; Shumagin - 20-30 per m^2; Unimak - 10-15 per m^2.	Lisovenko 1964
Gulf of Alaska	Summer 1957 Summer-Fall 1958	IKMT[5]			Reports catches of postlarvae and juveniles. Data not quantifiable.	Aron 1958
Northeast Pacific	May-Sep 1956 Mar-Sep 1957 Mar-Aug 1958 Mar-Jul 1959	NPN[6]			Most frequently occurring larvae during 1956-1959.	LeBrassuer 1970
Northeast Pacific	Oct-Nov 1971	bongo		10.6-30.6	Represented 2.3% of all larvae caught.	Naplin et al. 1973

[1]Bongo net, 60 cm diameter, 505µ mesh.
[2]Sameoto neuston sampler, .3m x .5m, 505µ mesh.
[3]Conical plankton net, No. 140 mesh.
[4]Nonclosing plankton net, 1m, 571µ mesh.
[5]Isaacs-Kidd midwater trawl, 3′ and 6′.
[6]Norpac net.

Larvae and young in early stages lead a pelagic life and remain in upper layers at surface temperatures of 9-16°C. Brock (1940) observed larvae 21-35 mm long in surface waters 100-180 miles from the Oregon coast during May. In summer large numbers of young sablefish remain over the continental slope and shelf although juveniles measuring 7.6-26 cm are also in surface waters along the shores of the United States, Canada, and well heated bays in Alaska (Kodolov 1968) and schools of juveniles occasionally come inshore into harbors (Cox 1948, cited in Hart 1973). When fry are about 12 cm and 5-7 months old they approach the shelf or upper slope and massive descent of fry takes place in the fall at sizes of 30 cm. In winter, young are on the shelf or adjoining parts of the slope (Kodolov 1968).

Sablefish are chiefly piscivorous (Shubnikov, 1963; Grinols and Gill, 1968; Rogers et al. 1979) but also consume ophiuroids, shrimp and other invertebrates (Shubnikov, 1963). Shrimp ranked a high second in the diet of sablefish caught in the nearshore zone of Kodiak Island (Rogers et al. 1979).

The History of the Fishery. The fishery for sablefish dates back to before 1900 off Washington and British Columbia and it later expanded to California, Oregon, and Alaska. During both World Wars, black cod was in demand. However, recently it has not been important to the domestic fishery. United States landings in the Northeast Pacific from 1956 to 1970 averaged over 1,000 m.t., and ranged from 739 to 2,485 m.t. The bulk was caught by longline gear (Table 18). Most of the Canadian longline fishery is off the southern British Columbia coast and southeastern Alaska. Since 1957, yearly catches by the Canadians in the the Northeast Pacific have not exceeded 1,000 m.t.

Although the Soviets have no specific fishery for sablefish, the Japanese have been fishing for this species since 1958. Their original efforts were in the Bering Sea and by 1963, they were fishing in the Gulf of Alaska (Table 19); first with sunken gillnets, then trawlers, then longline gear. By 1968, the bulk of sablefish were taken by longline gear and in 1970, the total catch by the Japanese in the Gulf of Alaska was nearly 30,000 m.t. Yakutat and southeastern Alaska have become major fishing grounds for sablefish to the Japanese and in 1968 these areas contributed 79% to their total sablefish longline catch (Reeves 1972).

Distribution and Abundance

Adults. Sablefish are an important species of groundfish in the Gulf of Alaska. In a trawl survey of demersal species, Alverson (1968) reported that they ranked as the eight most abundant and frequently caught fish in the Northeast Pacific Ocean. They are relatively important at all depths, but are caught mainly in water deeper than 200 fm (Table 12). Sablefish were taken mainly from the deepest 50 fm interval trawled (1-250 fm), and off Yakutat the CPUE was highest in the

Table 18. Annual total catch (m.t.) of sablefish by the United States, Canada, and Japan in the Northeast Pacific.

Year	United States	Canada	Japan
1956	2,485	354	
1957	924	1,019	
1958	852	383	
1959	1,254	362	
1960	1,505	705	
1961	919	306	
1962	1,910	428	
1963	1,085	396	1,819
1964	940	637	1,047
1965	988	649	2,217
1966	1,084	970	3,952
1967	749	591	7,526
1968	739	577	17,570
1969	1,104	391	24,673
1970	1,444	327	29,811

Source: Forrester et al. 1978.

Table 19. Annual catch (m.t.) of sablefish in the Yakutat region by year and the total catch for the Northeast Pacific. Catch data for 1971-1974 for stern trawl only.

	Yakutat[1]				Total[2]			
Year	Long-line	Stern trawl	Other	Total	Long-line	Stern trawl	Other	Total
1963			229	229		261	1,558	1,819
1964						1,046	1	1,047
1965		4		4		2,140	77	2,217
1966		32		32		3,841	111	3,952
1967	213	1,418		1,631	569	6,893	64	7,526
1968	3,112	2,454		5,566	12,029	5,541		17,570
1969	5,121	1,666		6,787	19,639	5,034		24,673
1970	6,935	1,318		8,253	25,670	4,141		29,811
1971	--	1,290	--	--	--	3,182	--	--
1972	--	2,666	--	--	--	6,521	--	--
1973	--	1,687	--	--	--	5,393	--	--
1974	--	1,280	--	--	--	3,100	--	--

[1]Approximately Cape Suckling to Cape Spencer.

[2]Total catch for 1963-1970 includes Shumagin, Chirikof, Kodiak, Yakutat, and southeastern to Conception areas. Total catch for 1971-1974 includes Cape Spencer to Unimak Pass.

Source: Forrester et al. 1978; Ronholt et al. 1978.

canyon off Dry Bay (Hitz and Rathjen 1965). Furthermore, Terry et al. (1980) reported that commercial quantities of black cod adults are most abundant from 200 to 500 fm. According to Ronholt et al. (1978), there appears to have been a general decline in the density of sablefish in the eastern Gulf of Alaska from 1962 to 1976. The importance of the catch from the Fairweather area (Cape Spencer to Yakutat Bay) in relation to other areas (Fairweather through Kenai) varied by date. Fairweather area ranked second and first in the catch of sablefish, containing 28% and 69% of the total catch respectively. However, during April-October, 1973-1976, this area contained less than 2% of the total catch.

Larvae and Eggs. Sablefish larvae (11.5-43 mm) have been reported from plankton sampling during spring and summer in the Bering Sea (Waldren and Vinter 1978; Kashkina 1970; Kobayashi, cited in Kashkina 1970), and during the summer off the Kodiak Shelf (Kendall et al. 1980). In the Bering Sea, larvae were over depths of 105-115 m and in Kodiak they occurred at stations near the shelf break. Larvae have been caught in both surface (neuston) and subsurface (bongo) plankton tows, but usually in relatively low abundance.

It is unclear if sablefish in the eastern Gulf of Alaska spawn in fall or winter or throughout both seasons. However, since young remain pelagic through fall of the following year they may be in plankton samples during spring and summer. Since larvae are relatively well developed by summer, they may be able to avoid plankton gear except at night. Lampara sets at the surface may yield larger larvae and juveniles in late summer. Larvae are expected to occur over the shelf area and possibly be more abundant at deeper stations.

Arrowtooth Flounder (*Atherestes stomias*)

General Biology. Arrowtooth flounder range from central California to the eastern Bering Sea. They are generally caught at depths from 400 to 499 fm (730-900 m) and young have been caught at depths greater than 700 m (Hart 1973).

Little information is available on the early life history of arrowtooth flounder. Spawning is thought to occur in December-March, with peak activity in January and February, at depths greater than 150 m, and at temperatures of 2-3°C (Pertseva-Ostroumova 1960).

In the Asian arrowtooth flounder, *A. evermanni*, females reach sexual maturity at 9 or 10 years and males at 6 or 7 (Pertseva-Ostroumova 1961). Eggs are large, 2.5-3.5 mm and bathypelagic-developing in deep water. Larvae are distinct from other flatfish in that they have spines on the preoperculum and above the eyes. Descriptions and illustrations of larvae are given in Pertseva-Ostroumova (1961).

Arrowtooth flounder feed largely on crustaceans and fish. Smith et al. (1978) reported that the most frequently consumed food was euphausiids and that they increased in importance as the fish grew to 350 mm long. For larger arrowtooth flounder, fish became the most important food. Rogers et al. (1979) indicate that arrowtooth flounder feed primarily upon fish and secondarily upon shrimp. This specialized feeding is further echoed in the literature; Hart (1973) listed shrimp and herring, and Hunter (1979) stated that fish (mostly pollock) comprised comprised 98.6% to the weight of the diet of arrowtooth flounder sampled near Kodiak Island.

History of the Fishery. Arrowtooth flounder or turbot is one species of flatfish important to domestic commercial trawl fisheries. However, United States and Canadian efforts have largely been south of the Queen Charlotte region.

Japanese efforts for flatfish in the Gulf are small compared to their effort in the Bering Sea, but catches in the Gulf of Alaska from 1963 to 1970 averaged around 4,000 m.t. In 1969 and 1970, about 40% of this was arrowtooth flounder (Table 20). Japanese catches of arrowtooth flounder from 1969 to 1974 in the Gulf of Alaska averaged 2,371 m.t.

Distribution and Abundance

Adults. The arrowtooth flounder is a very common species in the northeastern Gulf of Alaska. According to Alverson (1968), it was the most frequently encountered and most abundant demersal species in the northeastern Pacific. In fact, in one study, it occurred in 90% of all trawl tows in the Gulf (Alverson et al. 1964). These large abundances and high frequency of occurrence are perhaps related to its wide geographic and/or bathymetric distribution. Hitz and Rathjen (1965) reported that it was the most important species (by CPUE in lbs) for all depths (1-250 fm) and that for each 50 fm interval it ranked in the top five (Table 12). Furthermore, Taylor (1967) stated that catches of arrowtooth flounders (using a midwater trawl) were highest near the surface at night. Within the northeastern Gulf area, arrowtooth flounder are very abundant (CPUE) off Yakutat Bay (Ronholt et al. 1978) and off Dry Bay (Hitz and Rathjen 1965) with the latter yielding up to 4,500 lbs per hour trawled. Comparisons between 1962 surveys and 1973-1976 surveys indicate an area-wide change. Ronholt et al. (1978) state that the CPUE for almost all species declined from one period to the next and that the CPUE ratio between "decades" showed a moderate decrease for arrowtooth flounder in the Fairweather region (Yakutat Bay to Cape Spencer) and a moderate increase for arrowtooths in the Yakutat region (Cape Suckling to Yakutat Bay). Both areas contributed a combined 27.5% to the total (Cape Spencer to Unimak Pass, except the Shumagin region), during April-October, 1973-1976.

Table 20. Annual Japanese trawl catches (m.t.) of arrowtooth flounder in the Fairweather and Yakutat regions, and in the Gulf of Alaska, 1969-1974.

Year	Fairweather[1]	Yakutat[2]	Gulf of Alaska[3]
1969	359	474	1,467[4]
1970	504	301	1,588[4]
1971	88	125	1,293
1972	166	202	1,612
1973	216	1,406	5,110
1974	50	356	3,157
$\bar{X}$	230.5	477.3	2,371.1

[1] Yakutat Bay to Cape Spencer.
[2] Yakutat Bay to Cape Suckling.
[3] Cape Spencer to Unimak Pass.
[4] This compares with a total Japanese catch (of all flatfish other than halibut) of 3,480 and 4,091 m.t. for 1969 and 1970, respectively.

Sources: Ronholt et al. 1978; Forrester et al. 1978.

Larvae and Eggs. Catches of arrowtooth flounder larvae and eggs are reported from the eastern Bering Sea, Kodiak Shelf and Gulf of Alaska in winter and spring. Larval catches were relatively low partly because of the time and location of plankton surveys. Generally, larvae are most often taken in waters beyond the shelf (>200 m) and over depths as deep as 3,000 m. Plankton-caught larvae range in length from 5-38 mm (Table 21).

In the proposed study area, eggs and larvae are expected to occur primarily at stations near the edge of the shelf during April-May, however they may drift landward into shallower stations. Larvae may transform at fairly large sizes (Musienko 1963) hence remaining susceptible to plankton nets through summer. By October, arrowtooth flounder juveniles will have assumed a demersal lifestyle and be out of reach of our gear.

Starry Flounder (*Platichthys stellatus*)

General Biology. Starry flounder occur off the coast of North America from southern California to the Bering Sea at depths of a few inches to approximately 150 fm (Hart 1973). Adults seem to prefer soft sand but may be found on gravel, clean shifting sand, hard stable sand, and mud substrates; however, they avoid rocky bottoms (Orcutt 1950). Starry flounder are euryhaline and may be found at river mouths and in some cases many miles upstream. They spawn at sea at depths of 11-75 m (Musienko 1970).

Spawning of starry flounder occurs in winter through early spring and takes place in shallow water. Age of maturity for males is two years when they are about 300 mm, whereas as females mature at three years (350 mm). Spawning occurs once per season and in a relatively short period of time. A 565 mm female was reported to release about 11 million eggs (Orcutt 1950).

Starry flounder eggs are pelagic, lack oil globules, and are .89-.94 mm long in California waters (Orcutt 1950) and .97-1.01 mm in Japanese waters (Yusa 1957). At present, early-middle stage eggs of starry flounder cannot be distinguished from early stages of several other pelagic flatfish eggs from plankton samples.

At 12°C development of eggs takes about 68 hours. At colder temperatures (2.0-5.4°C) eggs hatch in about two weeks. Egg and larval development has been documented by Orcutt (1950) and Yusa (1957). Newly hatched larvae are 1.93-2.08 mm, slender, transparent, and pelagic. Estuarine conditions may be important to juvenile starry flounder as large number of 0-1 year age classes have been caught upstream in the Columbia River (Haertel and Osterberg 1967).

The diet of starry flounder consists mainly of benthic organisms. Rogers et al. (1979) reported that they ate anthozoans and gammarid

Table 21. Distribution and abundance of arrowtooth flounder eggs and larvae in the Northeast Pacific Ocean and Bering Sea.

Stage	Location	Time	Gear	Station depths, m	Larval length, mm	Abundance	Reference
Larvae	Bering Sea	Apr-May 1977	bongo[1]	100-2000 (caught at stations >200 m)	8-10	Comprised 1% of all larvae caught, but second most abundant flatfish.	Waldron and Vinter 1978
Larvae	Bering Sea	May-Jun 1971	bongo	1281-3109[2]	6-13	Accounted for 9.0% of all larvae, 87% of all flatfish caught.	Dunn and Naplin 1973
Larvae	Bering Sea	Jun-Sep 1958 Mar 1959	CPN[3]	540-3100	13 (June) 27-38 (July)	Rare	Musienko 1963
Larvae	Kodiak Shelf	Apr-May 1972	bongo		6.1-7.0	Comprised .2% of all larvae.	Dunn and Naplin 1974
Larvae	NE Pacific	Apr-May 1957 Mar-Jul 1958	NPN[4] IKMT[5]			Rare, catches ranged from 1-5 per haul.	LeBrasseur 1970
Larvae	Kodiak Shelf	Oct-Nov 1977 Mar-Apr 1978 Jun-Jul 1978 Oct-Nov 1978 Feb-Mar 1979	bongo	40-1000 (caught at stations >200 m)	7-8	Feb-Mar 1979: Overall mean catch 8.2 per $10m^2$, only flatfish larvae present.	Kendall et al. 1980
					5-10	Mar-Apr 1978: Overall mean catch 7.5 per $10m^2$, second abundant flatfish larvae caught.	"
Eggs	" "	" "	"	"		Feb-Mar 1979: Fourth abundant egg taxa out of 6 species occurring.	"

[1]Bongo net, 60 cm opening, 505 μ mesh.
[2]Depths of stations where larvae were caught.
[3]Conical plankton net, No. 140 mesh.
[4]Norpac net.
[5]Isaacs-Kidd midwater trawl, 3′ and 6′.

amphipods while Hunter (1979) reported that they ate clams. According to Cross et al. (1978) polycheates and gammarids predominated in the diet. Skalkin (1963) listed clams, polycheates and sand lance as important foods and Miller (1967) discovered that priapulids and nemertian worms predominated by volume.

History of the Fishery. Starry flounder is not a species exploited by either domestic or foreign fisheries, although flatfish in general are. United States exploitation of flatfish has centered on species found in relatively deep water from the Queen Charlotte area south (landings averaged 22,000 m.t. from 1961-1970, Forrester et al. 1978).

Japanese and Soviet fleets have fished largely in the Bering Sea for yellowfin sole. The Japanese have done some fishing for flatfish in the Gulf of Alaska and up to 87% of the catches (of flatfish other than halibut and arrowtooth flounder) in their trawl fishery are from the Yakutat and Fairweather regions (Table 22). This fishery is outside the zone of maximum abundance of starry flounder, so probably very few of the fish taken by this fishery are starry flounder.

Distribution and Abundance

Adults. In relation to other demersal species, starry flounder are not very abundant in the northeastern Gulf of Alaska. Catches of starry flounder in the study by Hitz and Rathjen (1965) were similar to those of butter sole. Overall, starry flounder ranked as the sixteenth most important species by CPUE (weight), but was common (ranking fourth) in areas that were less than 50 fm deep (Table 12). Within 10 fm increments, starry flounder were mainly caught (CPUE) between 11 and 20 fm and 21 and 30 fm (Alverson 1960).

Larvae and Eggs. Late stage starry flounder eggs have been reported from plankton samples during spring (March 28-April 20) and summer (June 19-July 9) off Kodiak Island (Kendall et al. 1980) and stage I eggs have been collected off Kamchatka on the western Bering Sea in July (Musienko 1963). In both instances, only small numbers of eggs were caught.

Larvae in the Kodiak bay and shelf region were only caught in summer and in low abundance (Rogers et al. 1979; Kendall et al. 1980). Only one 17 mm larvae was reported in July 1976 from Cook Inlet (English 1977).

Starry flounder larvae were relatively more abundant off Oregon where they occurred March-June, ranged from 3-9 mm, and were the fourth most abundant flatfish and eight most abundant larvae in a coastal assemblage of larval fish (Richardson and Pearcy 1977). In Skagit Bay, Washington, larval starry flounder were the predominant flatfish species during March-June (Blackburn 1973).

Table 22. Annual Japanese trawl catches (m.t.) of flatfish other than halibut and arrowtooth flounder in the Fairweather and Yakutat regions, and the Gulf of Alaska, 1969-1974.

Year	Fairweather[1]	Yakutat[2]	Gulf of Alaska[3]
1969	124	160	361
1970	162	31	222
1971	69	127	502
1972	562	903	2,099
1973	1,687	1,662	6,230
1974	249	852	3,524
$\bar{X}$	475.5	622.5	2,156.3

[1] Cape Spencer to Yakutat Bay.
[2] Yakutat Bay to Cape Suckling.
[3] Cape Spencer to Unimak Pass.

Source: Ronholt et al. 1978.

Only late stage starry flounder eggs can be identified and are expected to occur in the Yakutat area during spring and summer. They may initially be distributed nearshore (<50 fm), but will probably be dispersed over the Shelf. Larvae can be expected during summer and distributed over the entire area.

Pacific Halibut (*Hippoglossus stenolepis*)

General Biology. Pacific halibut occur as far south as Santa Rosa Island, California (34°N) and as far north as Norton Sound (63°31'N). Halibut are generally associated with water temperatures of 3-8°C and greatest catches occur over banks where bottom temperatures are within this range (Thompson and Van Cleve 1936). The bathymetric range for halibut is between 15 and 600 fm.

Pacific halibut spawning occurs mostly in the winter in the Northeast Pacific and may begin in fall in the Bering Sea. Halibut spawn at bottom temperatures of 3-8°C and laboratory reared eggs hatch in 12-20 days at 5-8°C (Forrester 1973). Age of first-maturity for female halibut is reported to be 8-16 years with an average age of 12 years. Average age for males is 7-8 years (Bell and St. Pierre 1970). Spawning occurs once a year and number of eggs released is related to length and weight of female halibut. Large females (140-180 cm) may produce 2-3 million eggs (Kolloen 1934). Eggs range in size from 2.9-3.8 mm, have a large colorless yolk without oil globules, and a small perivitelline space. Descriptions and illustrations of eggs and larvae are given by Thompson and Van Cleve (1936).

Spawning takes place in relatively deep water (275-412 m) along the edge of the Continental Shelf and eggs have been found between 40 and 1,488 m with concentrations at 100-200 m (Thompson and Van Cleve 1936; Pertseva-Ostroumova 1961). Eggs and larvae are transported horizontally at depth by subsurface currents and in the Gulf of Alaska are carried offshore in a counterclockwise direction around the gulf. Larvae hatch at 6-7 mm in length (Forrester 1973) and are located deeper than egg concentrations (i.e. $\geq$ 200 m). As larvae develop, they rise in the water column and at 3-5 months of age are at 100 m or less and are carried onshore by surface currents. At 6-7 months (about May and June) larvae have metamorphosed and are on the bottom in shallow coastal bays. Juvenile halibut may remain inshore 1-3 years before moving offshore (Thompson and Van Cleve 1936). Movement of juveniles occurs in directions opposite to drift of eggs and larvae and has been hypothesized as the factor for replenishing halibut populations (Skud 1977).

The diet of halibut consists mainly of fish, crab, and shrimp (Rogers et al. 1979). Hunter (1979) and Novikov (1963) divided halibut into size groupings and in each study, halibut less tha 300 mm long had eaten shrimp (Hunter listed fish and crab also). Those longer than 300 mm switched to fish, although according to Hunter, crab was of secondary importance.

History of the Fishery. The commercial halibut fishery began in 1888 off the coast of Washington and during the early years the bulk of the fishing was in the Southeast Alaska through Columbia areas, but by 1916 the fishery had expanded as far as the Shumagin Islands. The International Fisheries Commission (which in 1953 became the International Pacific Halibut Commission) was formed in 1924 to manage the overfished resource. By 1954 production rose to 43,000 m.t., taken from the entire Halibut Convention Area (Forrester et al. 1978). Both Canada and the United States have historically been active in the fishery. By the late 1970's the total catch was about one-half of the 1954 catch and regulatory area 3A contributed the majority of the total (Table 23). The catch-per-unit-effort (CPUE) for selected statistical areas and regions (1931-1979) is presented in Table 24.

Distribution and Abundance

Adults. The Yakutat region extends from the east side of Prince William Sound to Cape Edward (south of Cross Sound). Within the Yakutat region are statistical areas 20 and 19. Area 20 extends from Sitkagi Bluffs (just north of Yakutat Bay) to an area around the Dangerous River, and area 19 goes from the latter point to a point between Lituya Bay and Icy Point (Fig. 12). Historically the CPUE for the Yakutat region was usually higher than the CPUE for the entire Northeast Pacific (total) and the sector just north of Yakutat (IPHC statistical area 20) has had higher CPUE than the sector to the south (IPHC statistical area 19), but in recent years neither sector has consistently been higher or lower.

Larvae and Eggs. Knowledge of spawning locations in the Northeast Pacific is limited, although major sites are known from Cape St. James, Langara Island, and Frederick Island in British Columbia, and Yakutak, "W" grounds, and Portlock Bank in the Gulf of Alaska. Other spawning sites have been reported near Goose Islands, Hecate Strait, and Rose Spit in British Columbia, and Cape Ommaney, Cape Spencer, Cape St. Elias, Chirikof, and Trinity Grounds in Alaska. Spawning concentrations also occur in the Bering Sea (Skud 1977).

Distribution and relative abundance of halibut eggs and larvae were examined in the Gulf of Alaska by Thompson and Van Cleve (1936). Eggs and early stage larvae were commonly taken at depths greater than 100 fm, but may drift onto shelf waters during larval development. Other plankton surveys in Alaska report halibut larvae in spring in the Bering Sea (18-23 mm; Waldren and Vinter 1978), Cook Inlet (13 mm; English 1977) and Kodiak Shelf (14.4, 17.8 mm; English 1977). In most cases larvae were caught at stations >200 m and in low abundance.

The Yakutat area supports a large spawning population of Pacific halibut; however, since spawning occurs in winter, and at depths >200 m eggs will probably not be taken during the proposed sampling months.

Table 23. Catch of Pacific halibut (lb) and effort (in standard skates, where one skate is 1,800 ft long with 100 hooks) for IPHC regulatory area 3A, 1975-1979.

Year	United States		Canada		Total Catch in North America
	Effort	Catch	Effort	Catch	
1975	1,412	8,841	489	3,772	12,613
1976	1,567	9,052	616	4,130	13,182
1977	1,276	7,842	405	2,717	10,559
1978	1,493	11,276	386	3,100	14,376
1979	1,410	10,031	153	1,638	11,669

Sources: Myhre et al. 1977; International Pacific Halibut Commission annual reports and unpublished data, 1976-1979.

Table 24. Catch per unit effort of halibut from IPHC statistical areas 19 and 20, the Yakutat region, and over all area.

Year[1]	Area 19	Area 20	Yakutat	All areas
1931-1935	69.7	72.7	75.0	62.7
1936-1940	84.0	82.9	88.8	79.7
1941-1945	88.5	102.6	109.1	97.0
1946-1950	76.9	92.1	91.3	98.3
1951-1955	96.0	109.3	108.9	116.2
1956-1960	106.8	105.9	117.3	124.9
1961-1965	100.5	111.8	111.7	110.1
1966-1970	91.5	94.0	95.4	98.7
1971	77.9	96.1	88.3	89.5
1972	85.0	73.0	79.4	80.9
1973	81.2	72.3	73.7	64.9
1974	59.1	56.4	71.0	62.2
1975	68.8	83.4	73.2	63.3
1976	14.5	16.5	58.4	54.0
1977	53.9	48.3	53.8	60.2
1978	82.2	77.9	79.5	67.3
1979	92.1	109.8	105.8	70.8

[1] 1931-1970 are 5-year averages of annual means.

Sources: Myhre et al. 1977; International Pacific Halibut Commission annual reports and unpublished data, 1976-1979.

During spring and summer larvae may "stray" up over the Shelf and be caught within the study area.

Butter Sole (*Isopsetta isolepis*)

General Biology. Butter sole occur from southern California to southeastern Alaska in shallow water but are occasionally at 150-200 fm (274-366 m) in western Alaska (Hart 1973).

Butter sole spawn in late winter to early spring. Eggs are planktonic, spherical, have a narrow perivitelline space, lack oil globules and range in length from .93-1.1 mm ($\bar{x}$ = 1.0 mm; Levings 1968). Hence at early-middle stage of development, eggs of butter sole are indistinguishable from several other flatfish species (Richardson et al. in press). Spawning in Skidegate Inlet, British Columbia occurred at depths of 15-35 fm (Manzer 1949; Levings 1968) and at conditions of 4°C and 25°/oo (Levings 1968).

Larvae are abundant off Washington and Oregon in winter and spring (Richardson et al. in press) and were found in Kodiak bays and shelf during June-August (Rogers et al. 1979; Kendall et al. 1980). Transformation from larval to juvenile characters takes place when larvae are 18-23 mm. Recently transformed benthic juveniles seem to be offshore rather than in bays and other nearshore habitats (Richardson et al. in press). Average length at age two is 143 mm for males and 190 for females. By age 10, females are 394 mm and males average 352 mm (Hart 1943). Eggs and larvae are described and illustrated by Richardson et al. (in press).

The food of butter sole includes marine worms, young herring, shrimp and sand dollars (Hart 1973).

History of the Fishery. Although flatfish have been one of the most important groups of fishes exploited by the United States and Canada, butter sole are not commercially important, whereas arrowtooth flounder, Dover, petrale, English, Rex, and rock sole are. Furthermore, Japanese and Russian efforts have concentrated largely on yellowfin sole in the Bering Sea. There are a lack of catch statistics specifically for butter sole. American catches of flatfish since 1958 have been dominated by the Dover sole (Forrester et al. 1978) and fishing has largely occurred at depths where this species occurs. Hitz and Rathjen (1965) reported that from 1-250 fm, Dover sole was most abundant between 201-250 fm. Furthermore, United States and Canadian efforts have been from the Charlotte area south. For flatfish other than halibut and arrowtooth flounder, the Yakutat area (Cape Suckling to Yakutat Bay) and the Fairweather area (Yakutat Bay to Cape Spencer) ranked first and second, respectively in annual Japanese trawl catches from Cape Spencer to Unimak Pass (Ronholt et al. 1978).

Distribution and Abundance

Adults. Butter sole are not one of the more abundant fishes of the Gulf of Alaska. Hitz and Rathjen (1965) reported that butter sole ranked thirteenth by CPUE (weight) for all depths (1-250 fm) but second for the 1-50 fm interval (Table 12).

Larvae and eggs. Catches of butter sole eggs and larvae have only been reported in a few plankton studies from Alaskan waters. In Kodiak, larvae were in bays in June-August, ranging in length from 3.0-11.0 mm in June to 8.5-21.0 mm in August. They ranked fifteenth in abundance over all times and stations (Garrison and Rogers 1980). In the offshore shelf region butter sole larvae occurred only during the summer cruise (June 19-July 9) and ranked eleventh in abundance (Kendall et al. 1980). In Cook Inlet, larvae were present in early and late May cruises with higher catches in the latter time period. Larvae were small, ranging from 2.1-6.7 mm. No larvae were caught in July or August (English 1977).

Off Oregon and Washington, however, larval butter sole are a dominant member of the ichthyoplankton and ranked fifth in overall abundance in April and May (Waldron 1972) and third in abundance in a coastal assemblage of larval fish off Oregon (Richardson 1977; Richardson and Pearcy 1977).

Butter sole spawning is expected to occur shoreward of 50 fm and possibly within Yakutat Bay during late winter-early spring. Eggs and larvae may be concentrated at nearshore and bay locations during spring sampling (April-May), but probably distributed over the shelf during summer. By October, butter sole larvae will have transformed to juveniles and assumed a benthic habitat, hence they are no longer susceptible to plankton nets.

Dungeness Crab (*Cancer magister*)

General Biology. The Dungeness crab is an important commercial species and occurs from Baja California to Amchitka Island, Alaska. The northeastern Gulf of Alaska supports substantial commercial harvests.

Dungeness crabs inhabit bays, estuaries, and open (coastal) ocean from the intertidal zone to depths greater than 50 fm. They are usually most abundant on sand or mud-sand bottoms (Hoopes 1973). The distribution of these crabs by depth seems to vary with life history stage and season. Butler (1956) found that post-larval stages were abundant on shallow (<5 fm) sand bottoms; McKay (1942) observed juveniles (2-3 3/4") buried in intertidal sands in late winter and in spring, and concluded that adults migrate offshore during winter and return to the nearshore in the spring.

The sex ratio appears to be unequal, with the sexes separated geographically (McMynn 1948, cited in Mayer 1972). Sexual maturity is reached in 2 years for females and 3 years for males (Hoopes 1973). According to various authors, this corresponds to a carapace width of > 110 mm for males and about 100 mm for females (Butler 1960). Butler (1961) reported that both sexes matured at the eleventh or twelfth post-larval instar. Males are polygamous and mating occurs when adults move into shallow water during the spring molt period. Transfer of sperm can only occur after the female has molted and before her new shell has hardened. Females then carry viable sperm in their oviducts throughout the summer. In the fall, eggs pass through the oviduct, are fertilized, and then carried under the female's abdomen (Hoopes 1973). Egg bearing occurs during October to June in British Columbia (McKay 1942) and larvae emerge between December and April off Oregon (Reed 1969, cited in Mayer 1972). The number of eggs deposited by a female is related to size; as many as 1.5 million eggs have been found on a single female (Hoopes 1973).

Eggs hatch into free swimming larvae during the spring, after they have been carried by the female for 7-10 months (Hoopes 1973). The distribution of planktonic larvae is assumed to be associated with the nearshore location of the female in late spring (Mayer 1972). Larvae first hatch as 1.16 mm long zoea with a rostrum and three spines on the front of the head and then progress through five stages by a series of molts taking 3-4 months (Hoopes 1973). The zoea then transforms into a 13 mm long megalops that resembles the juvenile crab, and there is only one megalops stage (Poole 1966, cited in Mayer 1972). When the megalops stage is complete, it settles out as a post-larva or juvenile. This occurs after a larval period of 128-158 days (as indicated by post-larval instars; Poole 1966, cited in Mayer 1972). At Kodiak, larvae spend up to 3 months in the plankton (Alaska Environmental Information and Data Center (AEIDC) 1975), with a peak of larval release in spring or early summer (Kendall et al. 1980). In general, larvae in inshore areas (Kodiak) are within the upper strata of the water column during the day (70% found between 10-30 m) and dispersed into deeper strata at night (50% plus were between 50-90 m), while those larvae in offshore areas are usually deeper at night (Kendall et al. 1980).

During the first year, a juvenile crab may molt as many as six times, thus growth is rapid. After the first year, the carapace width is approximately 25 mm and after the second year it is approximately 102 mm (Hoopes 1973). All of this growth occurs during a 1 to 2 day molting period. Both sexes grow at about the same rate until sexual maturity is reached, after which males grow faster (Hoopes 1973). The increase in size decreases with each molt. Increases are about 40% in the early post-larval stages and 10-15% when the crabs are about 13.0-13.5 cm (McKay and Weymouth 1935). Males may reach as much as 20 cm in carapace width, while females may exceed 15 cm in width. The commercial size at Kodiak is 6 3/4" or roughly 17.1 cm (AEIDC 1975).

Dungeness crabs are carnivores, frequently eating crustaceans (shrimp, crab, barnacles, amphipods, and isopods), clams and polycheates (McKay 1942; Hoopes 1973). Larval stages of this crab are preyed upon by a variety of fish species. Juveniles are canabalized by adults, while juveniles and adults are consumed by many larger fish (Mayer 1972).

History of the Fishery. The fishery for Dungeness crab is one of the older ones in Alaska with commercial harvest at Kodiak, Cook Inlet, Southeast Alaska, Yakutat (Fig. 13), and the Copper-Bering rivers and Prince William Sound. Most fishing is done by crab pot or trap baited with razor clams, squid, or herring in about 3 to 30 fm of water. Different areas allow a different number of pots per boat. In Yakutat, a boat may carry a relatively high number - up to 600 (Mayer 1972). Although the Yakutat crab fishery has been stable since 1960 (except for low harvests of 1975-1977), the fishery is declining in most areas of Alaska (Terry et al. 1980). The catch is possibly influenced by the supply of other species of crab and the fishery for Dungeness crab in the Pacific Northwest (Ronholt et al. 1978). Also, the fishery primarily depends on one year class, so fluctuations occur from year to year (AEIDC 1975). Even so, production in the Yakutat management area averaged over 1.3 million pound for the past 10 years, which is an important contribution to the total harvest in Alaska (Table 25). From 1969 to 1975, 89% of the United States catch (from Cape Spencer to Unimak Pass) came from 24 subareas (Ronholt et al. 1978). Included were Yakutat Bay (2.8% of the total), Yakutat Bay to Dry Bay (7.5%), and Dry Bay to Cape Fairweather (2.2%). See also Table 25 for the catch from 1971-1975 for the entire Fairweather region.

Distribution and Abundance

Adults. The Dungeness crab is widely distributed in the Gulf of Alaska. Hitz and Rathjen (1965) reported that this species largely inhabits depths between 1 and 100 fm. The Yakutat area has large concentrations of Dungeness crab. Maturgo (1972, cited in Anonymous 1976) presented figures which indicated Yakutat (Cape St. Elias to Cape Spencer) had the highest catch-per-unit-effort (174 lbs/hr of trawling) in the Gulf of Alaska. Furthermore, surveys in the early 1960's (reported in Ronholt et al. 1978) show that the Yakutat (Cape Suckling to Yakutat Bay) and the Fairweather (Yakutat Bay to Cape Spencer) regions contain about 20% of the total biomass of Dungeness crab in the Gulf of Alaska (Cape Spencer to the Kenai Peninsula).

Larvae. Since the eggs are carried by the adult crab, they will not be in the plankton. Larvae will probably be largely in nearshore areas in the spring, and their distribution associated with the location of the females at that time. As the season progresses larvae should become more dispersed by the currents and be in offshore areas as well. Since the larval period is about four months, Dungeness crab larvae should be caught by our plankton gear in both the April-May and July-August cruises. We expect zoea to predominate in the former

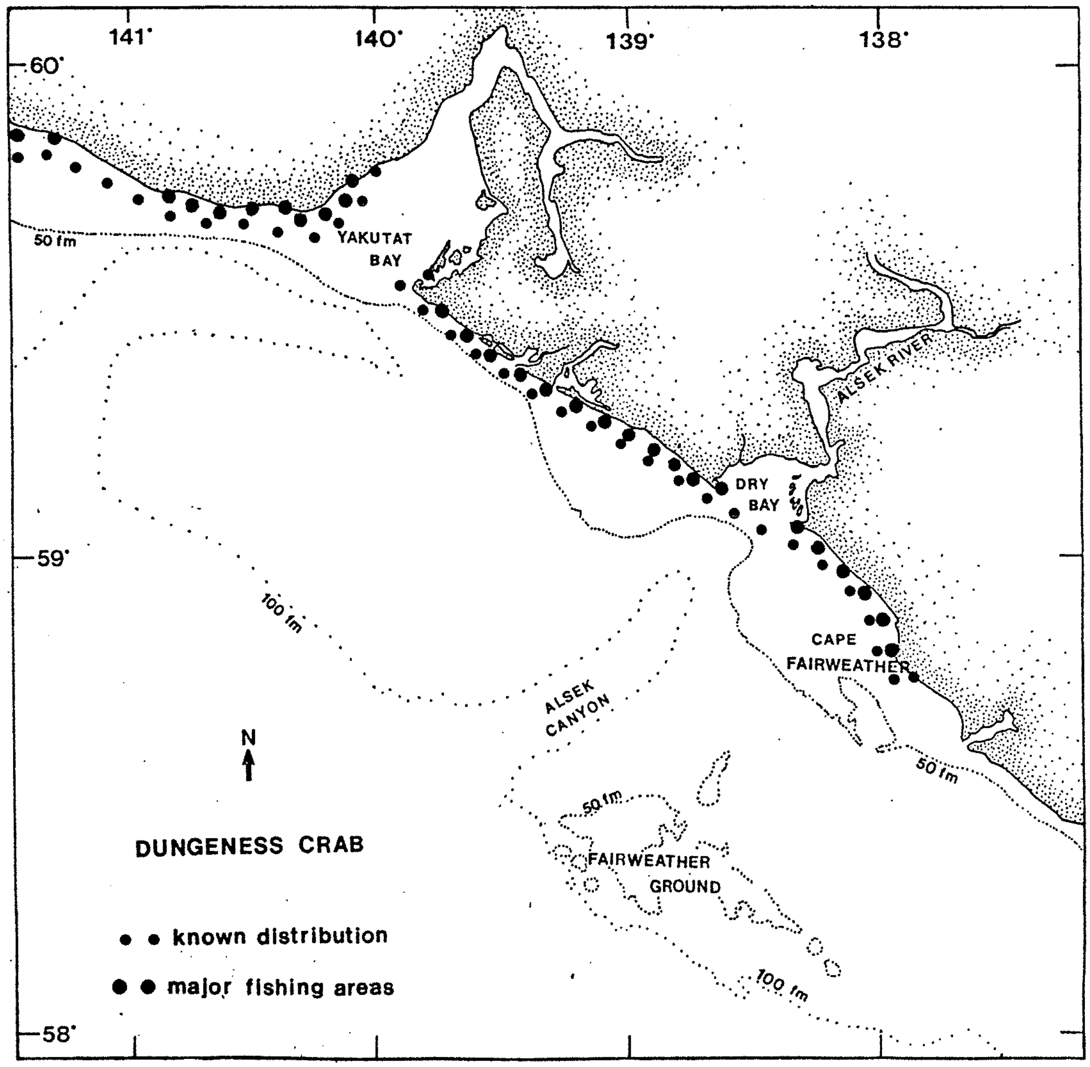

Fig. 13. The distribution and major fishing areas of Dungeness crab in the Yakutat area.

Source: McLean and Delaney 1978.

Table 25. Annual catch (lb x 1000) of Dungeness crab in the Yakutat and Fairweather regions, and the total Alaskan catch.

Year	Yakutat[1]	Fairweather[2]	Alaska
1971	1,669	443	3,749
1972	1,993	1,014	5,448
1973	2,347	1,136	6,423
1974	1,632	240	3,818
1975	541	216	3,034
1976	529	--	--
1977	124	--	--
1978	1,900	--	--
1979	1,496	--	--
1980	859	--	--

[1]Cape Suckling to Cape Fairweather.
[2]Yakutat Bay to Cape Fairweather.

Sources: Terry et al. 1978; A. Brogall, personal communication; Ronholt et al. 1978; Alaska Department of Fish and Game 1975.

sampling period and the megalops stage to be more abundant in the latter period than in the former. We also expect that the larvae will be captured largely in the upper 50 m during the day and slightly deeper during the night.

Tanner Crab (*Chionocetes bairdi*)

General Biology. The name tanner crab is often used to describe the species of *Chionocetes*. *Chionocetes bairdi* is the principle species of the Continental Shelf off Yakutat, but some references to *C. opilio* are made where life history information on *C. bairdi* is lacking.

Chionecetes bairdi is the commerically exploited species in the Gulf of Alaska (commercial harvest began in the late 1960's). It occurs from Puget Sound, Washington to the Bering Sea and from shoal water to a depth of 259 fm (Brown 1971).

The sex ratio is approximately one to one (Hilsinger 1976), but appears to be similar to Wenners (1972) "anomalous" pattern where the ratio changes from differential mortality and growth of one and then the other sex. The age at which tanner crabs mature is not well known because of the difficulty in aging them; however, size of the female at maturity may vary between 71 mm-116 mm. The size and age at maturity is perhaps a function of growth per molt, frequency of molting, and timing of gonad maturation. Maturity of *C. opilio* is reached by the ninth post-megalops molt, at or about age 6 or 7 (Eldridge 1972). It is unknown whether the female can mate after her shell has hardened (Dungeness females cannot). Mating occurs in late winter or early spring in shallow waters (Science Applications, Inc. 1980; Hilsinger 1976) and the fertilized eggs are carried by the female for about 11-12 months, after which, they hatch and larvae are released, usually in two batches (Eldridge 1972a). There is much variation in the number of eggs that are carried. Hilsinger (1976) gives a range of 24,000 to 318,000 eggs per female, and AEIDC (1975) reports a range of 5,000 to 140,000 eggs per female with an average of 30,000 to 80,000. The variation in egg number may be accounted for by varying sizes of the females and by a decrease in clutch size in old crabs (Terry et al. 1980).

Larvae drift with the surface waters and go through four developmental stages; a prezoea stage, two zoea stages, and a megalops stage. In Kodiak, larvae occur in the spring and summer (Science Applications, Inc. 1980). Bright (1967, cited in Eldridge 1972) concluded that in Cook Inlet, larvae develop quickly, about two weeks from the prezoea to the first juvenile stage. Early and late larval stages occur inshore at Kodiak during most of the year, perhaps because of a protracted period of larval release (Kendall et al. 1980). About 98% of these tanner crab larvae in nearshore waters are between 10-50 m during the day, and about 74% are between 50-90 m at night.

Megalops settle out in the summer and immediately cover themselves in debris where they begin to feed on detritus (Eldridge 1972). Most growth work has been done with *C. opilio* and such studies indicate that tanner crab females continue to grow only until sexual maturity is reached and that males continue to grow after they mature, reaching commercial size in two additional molts and maximum size in two further molts (Anonymous 1971, cited in Eldridge 1972). The growth rate decreases with increasing size. The average age of tanner crabs is probably about 12 to 16 years, with a maximu life span of 17 years (Eldridge 1972). Maximum size of females is about 13 cm in carapace width and maximum size of males is about 20 cm (AEIDC 1975).

Chionecetes feeds largely upon ophiuroids, decapods, amphipods, and bivalves (Eldridge 1972), but Paul et al. (1979) reported that stomach contents typically reflect the benthic species common to any given station and that crabs of different size, sex, and state of maturity consumed similar prey. Tanner crabs are in turn fed upon by many large fish.

History of the Fishery. The tanner crab fishery began in 1968, supplementing the king crab fishery and remained relatively small until technological problems with meat extraction were solved. The total catch rose to almost 64 million lb in 1974. The fishery at Yakutat occurs largely from January through April and catches increased there in 1974 (Table 26; note the discrepancy in the literature for catch data in the Yakutat management area compared to the Fairweather region). The Yakutat management area (Cape Suckling to Cape Fairweather) contributed over 2.5 million lb in 1980 (A. Brogall, personal communication).

Distribution and Abundance

Adults. Tanner crabs are quite common in the northeastern Gulf of Alaska. Hitz and Rathjen (1965) reported that tanner crab were the sixth most abundant species (CPUE) in their trawl samples and that they were most abundant between 51 and 150 fm (Table 12). Logbook data from fishermen in the Bering Sea and Aleutians (Adak Island) to southeastern Alaska show the highest catch per pot was in depths of 100-120 fm (Brown 1971). CPUE data (NMFS exploratory drags, 1950-1968) indicates that tanner crab abundance for the region from Cape St. Elias to Cape Spencer is second only to the Cook Inlet region at 200 lbs/hr of trawling (Maturgo 1972, cited in Anonymous 1976). Tanner crabs are distributed throughout the Yakutat area (Fig. 14), and a high abundance in the Fairweather area (Yakutat Bay to Cape Fairweather) contained an estimated 12% of the total tanner crab biomass in the Gulf of Alaska during June-August, 1962 (Ronholt et al. 1978).

Larvae. Eggs are carried by the female and therefore, will not be captured by plankton gear. Larvae drift with the surface waters during their development, and we may find them throughout the study area in all three sampling periods; larger abundance may occur during the

Table 26. Catches (lb x 1000) of tanner crab in the Yakutat and Fairweather regions, and the total catches in Alaska.

Year	Yakutat[1]	Fairweather[2]	Alaska
1971			12,880
1972	15	29	30,135
1973	207	293	61,719
1974	1,872	620	63,906
1975	2,021	1,160	46,857
1976	1,714	--	--
1977	1,016	--	--
1978	990	--	--
1979	974	--	--
1980	2,528	--	--

[1]Cape Suckling to Cape Fairweather.
[2]Yakutat Bay to Cape Fairweather.

Sources: Terry et al. 1980; A. Brogall, personal communication; Alaska Department of Fish and Game 1975; Ronholt et al. 1978.

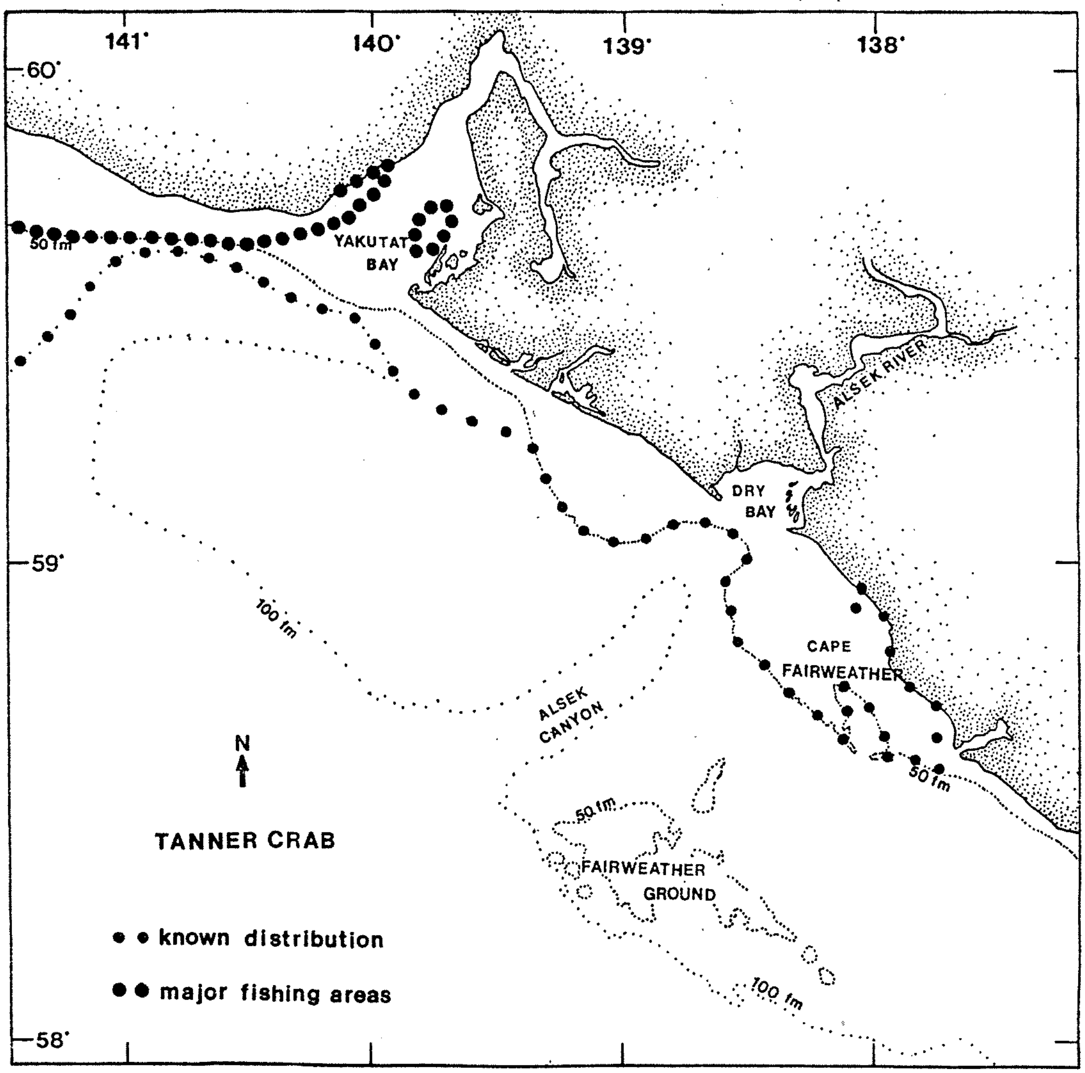

Fig.14. The distribution and major fishing areas of tanner crab in the Yakutat area.

Source: McLean and Delaney 1978.

spring and summer. During the day larvae should be captured mainly in the upper 50 m of the water column and during the night, 50-100 m below the surface.

Northern Pink Shrimp (*Pandalus borealis*)

Pink shrimp were not targeted for this study; however, since they are a potentially important species to the economy of Yakutat, we have included this section.

The shrimp fishery in Alaska has largely been centered around Kodiak. However, during this past season, the fishing effort there was too intense, which resulted in overloading the handling facilities at Kodiak. Shrimp fishing was then initiated in Yakutat Bay. The ADF&G set a quota there of 1.5 million lb and after this was surpassed by 200,000 lb, the bay was closed to the fishery for the year. After the closure of the fishery, experimental trawling in Yakutat Bay indicated a density of about 136,000 lb/sq mile (A. Brogall, personal communication).

Weathervane Scallop (*Patinopectin caurinus*)

General Biology. The weathervane scallop occurs from California to Alaska, with commercially harvestable beds around Kodiak Island and in the Yakutat region (Hennick 1970a).

Scallops inhabit mud, clay, sand, or gravel bottoms, and usually live in a slight depression in the sediment surface. They are most abundant between 20 and 70 fm (AEIDC 1975), with the majority around 50 fm.

Sexes are separate in scallops and the sex composition of mature individuals is approximately one to one (Hennick 1970a). Hennick reported that most scallops are mature when three concentric rings are present on their upper valve. Haynes and Powell (1968) reported that most scallops less than 76 mm are immature. Fertilization is external. Depending on the sex, the eggs or sperm are expelled on different sides of the hinge. Spawning takes place once a year, in June or early July (Hennick 1970a), and is possibly induced by changes in water temperature. Fertilized eggs settle to the bottom and attach for a maturing period of a few days before hatching (AEIDC 1975).

Larvae are from 80 to 200 μ long and drift with the tides and currents for 2 to 3 weeks (AEIDC 1975). They then metamorphose and settle, attaching with the help of byssus threads.

Attached juveniles range in size (valve height) from 6 to 75 mm; by their third year, when many are sexually mature, they may be 7.6 to 12.7 cm in height. Their maximum size is around 23 cm. Scallops caught commercially range from 7 to 11 years old, but some live more than 15 years (AEIDC 1975). Scallops feed by filtering plankton from the water.

History of Fishery. The catches for the Yakutat management area and all of Alaska are presented in Table 27 for 1968-1977. The Yakutat area was important during the first two years of the fishery and then again during 1974-1977 when catches were low. A decline in the resource and adverse market conditions rendered the fishery inactive in 1978 and 1979 (Terry et al. 1980). This past year (largely May-August, 1980), however, the fishery was again active and A. Brogall (personal communication) estimates the harvest to be at about 250,000 lb.

Distribution and Abundance

Adults. In 1968, the Viking Queen experimentally fished for scallops from Cape Fairweather to Kodiak Island. Only the Kodiak and Yakutat regions supported commercially harvestable populations (Hennick 1970b). Scallops were more abundant in the Yakutat region but grew slower and were smaller at maturity than the scallops at Kodiak (Hennick 1970a). Figure 15 shows the distribution of sea scallops within the Yakutat area. Alverson (1968) reported that scallop catches were highest at Cape Fairweather, off Icy Bay and east of Cape St. Elias.

Larvae and eggs. Sea scallop eggs are demersal. Veliger larvae are small (80-200 μ) and present in the plankton during the summer. They should be distributed throughout the study area and if any of the larger larvae are captured it will be during the July-August sampling period.

Razor Clam (*Siliqua patula*)

General Biology. The Pacific razor clam (*Siliqua patula*) is an important recreational and commercial species on the West Coast. Populations extend from northern California to the Aleutian Islands, occurring in almost 50 different sites in Alaska.

Razor clams are on sandy surf-pounded beaches and occur in fair numbers to a depth of 30 ft (Cumbow 1978). Densities within a particular habitat are a function of topography, substrate type, and tidal regimes. In general, the majority of clams inhabit areas between -0.91 m and +0.91 m of the mean lower low water mark (Kaiser and Konigsberg 1977). At Yakutat, the estimated upper habitable tide level, relative to mean lower low water, is +1.14 m (Nickerson 1975).

Sexes are separate in razor clams and the spawn ripens in the foot (Cumbow 1978). The number of males and females seems to be equivalent and individuals of both sexes reach maturity at approximately 2.5 years. The influence of growth is greater than the process of maturation in determining the age at which a clam can spawn (Weymouth et al. 1925).

Table 27. Annual catch (lb x 1000) of scallops in the Yakutat area, and the total Alaskan catch, 1968-1977.

Year	Yakutat	Alaska
1968	903	1,734
1969	836	1,888
1970	23	1,440
1971	85	931
1972	128	1,167
1973	174	1,109
1974	357	504
1975	139	436
1976	190	265
1977	22	22
$\bar{X}$	285.7	949.6

Source: Terry et al. 1980.

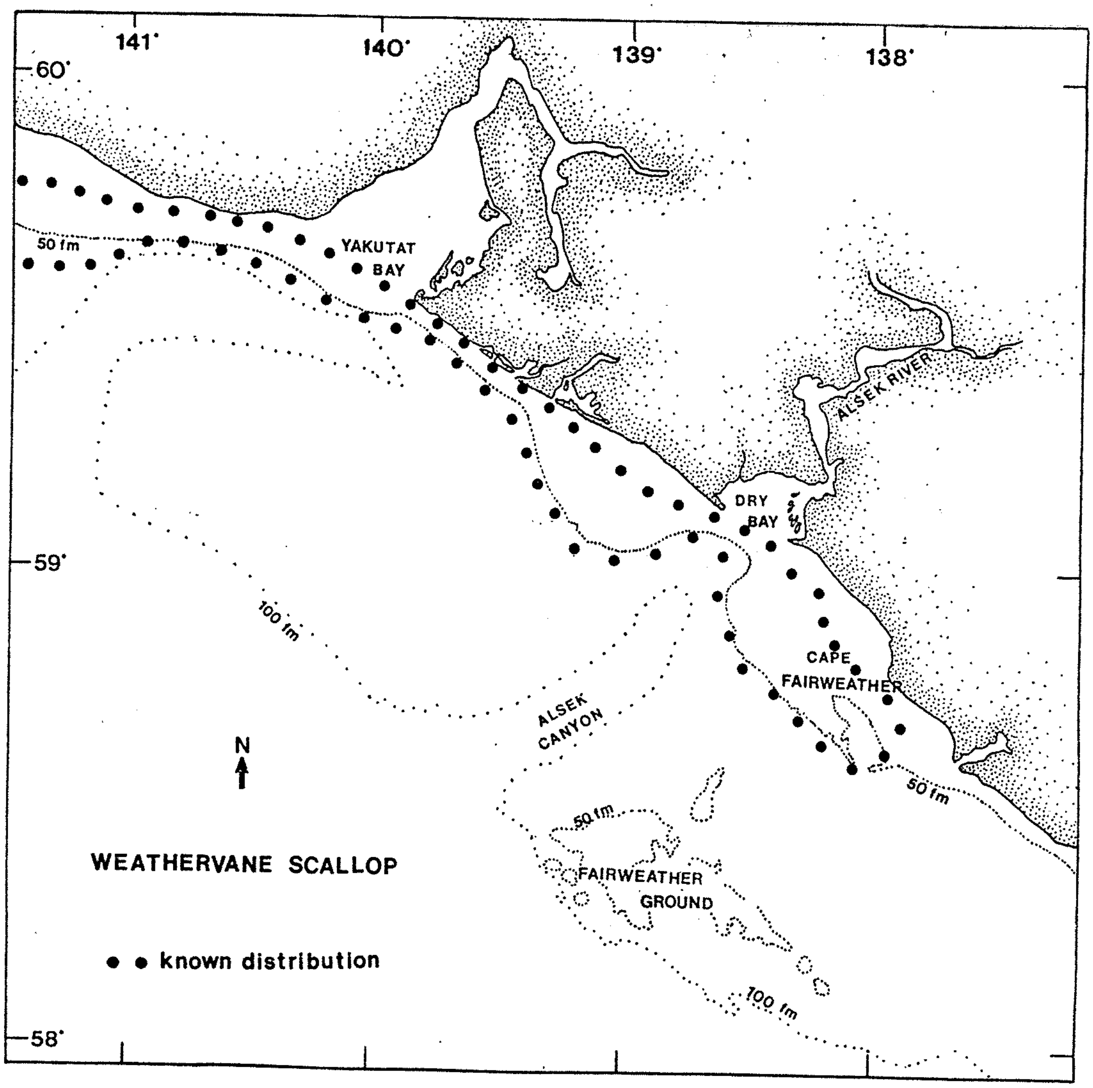

Fig. 15. The distribution of weathervane scallops in the Yakutat area.

Source: McLean and Delaney 1978.

Clams on one section of beach spawn simultaneously (McMillin 1924). The eggs and sperm are discharged through the excurrent siphon. A single female may produce 6-10 million eggs annually (Nosho 1972; Cumbow 1978). Fertilization occurs randomly and fertilized eggs may hatch within a few hours to within a few days (Nosho 1972). The eggs are small; ripe ova measure slightly greater than 90 microns (Nickerson 1975). The onset of spawning occurs when seawater temperatures reach around 13°C (Nosho 1972; Weymouth et al. 1925; Fraser 1930), but varies somewhat with area (Bourne and Quayle 1970), and may continue throughout the summer and fall (Cumbow 1978). Nickerson (1975) reported that razor clams in the Cordova area would spawn if sustained water temperatures of 5.5 to 8.8°C occurred for a period of 30 days followed by an abrupt increase in temperature. Therefore, some spawning may take place from early June to September, but the majority of the activity is in July and August (Weymouth et al. 1925; Nosho 1972; Nickerson 1975).

By 10 days the larva reaches the early swimming stage and by 3 weeks it has the shape of a clam (McMillin 1924). At this time, the entire animal is transparent and a velum extends from within the valves. Two weeks later, very few larvae are in the plankton; each larva has almost doubled in size and a foot has appeared (McMillin 1924). "Settling" seems to occur 8-10 weeks after spawning (Kaiser and Konigsberg 1977). Larvae are distributed by ocean currents and, according to McMillin (1924), most of the last two weeks of the swimming stage is spent in the sand. The length of larval existence of razor clams is longer than for many other molluscs (Weymouth et al. 1925), and the clams settle out at about 325 μ.

Some clams may reach 12.5 mm by their first fall and 89 mm by their second fall (Cumbow 1978), growth is dependent upon location and temperature. In general, Alaskan razor clams grow slower than their counterparts in Washington, but live longer. The life expectancy of razor clams in Washington is about 8 to 11 years, while that of clams in Alaska is about 11 to 19 years (Cumbow 1978; Weymouth and McMillin 1931). Juvenile mortalities may reduce the number of clams that have set to about a third by late fall (Weymouth et al. 1925). Heavy surf causes much of this reduction, and adult mortality is estiamted at about 10% per year (McMillin 1924).

The diet of razor clams consists mainly of diatoms, which are very abundant during the summer months.

History of the Fishery. Commercial razor clamming began in Alaska in 1916 when a small cannery at Cordova went into operation. Historically, Cordova remained a major growing area, along with Cook Inlet and Swikshak. Since 1916, the industry has had it ups and downs. These downs have been caused by poor growing conditions, adverse market conditions, governmental regulations and restrictions (size and poundage limitations, and season closures, etc.), competition from foreign and east coast clam packers, and sanitation problems (Nickerson 1965).

Perhaps the largest blow to the industry came in 1964 when the Alaska earthquake destroyed much of the razor clam habitat. The razor clam harvest in Central Alaska has averaged over 169,000 lb annually from 1960-1969 (Nosho 1972). This is a decline from the 1940's and 1950's and Nosho (1972) feels this may be a result of overfishing, lack of marketing resources, increased productions costs, and/or increased education on the problem of paralytic shellfish poisoning in Alaska.

Cordova is by far the major area for commercial production with harvests during the 1960's averaging over 141,000 lb. Production has fallen since 1969 and from 1970 to 1973, an average of only 31,750 lb was harvested (Nickerson 1975).

Distribution and Abundance

Adults. Yakutat does not have a commercial razor clam fishery because clam beds in the area are inaccessible. Clam beds are probably within a second shelf of breakers that are about one-quarter to one-half mile offshore at a zero tide along the open coast (A. Brogall, personal communication) (Fig. 16). Other sources (Kaiser and Konigsberg 1977; Nickerson 1975) claim that a small bed of clams occurs in a slough near the town of Yakutat and clams there are in subsistence quantities. According to A. Brogall (personal communication), however, they are not razor clams.

Larvae and eggs. Razor clam eggs are very small ($\sim 90\mu$) and quickly hatch into larvae. Therefore, we probably will not find any in our samples. If they are captured, however, the most likely time would be during the July-August sampling period. Larvae are also quite small but our plankton gear should capture some. This could occur during either the summer or fall, but most likely in the summer. Eggs and early larval stages will be mainly close to the shore but can occur throughout the study area because they are dispersed by the ocean currents during a development period of up to 10 weeks.

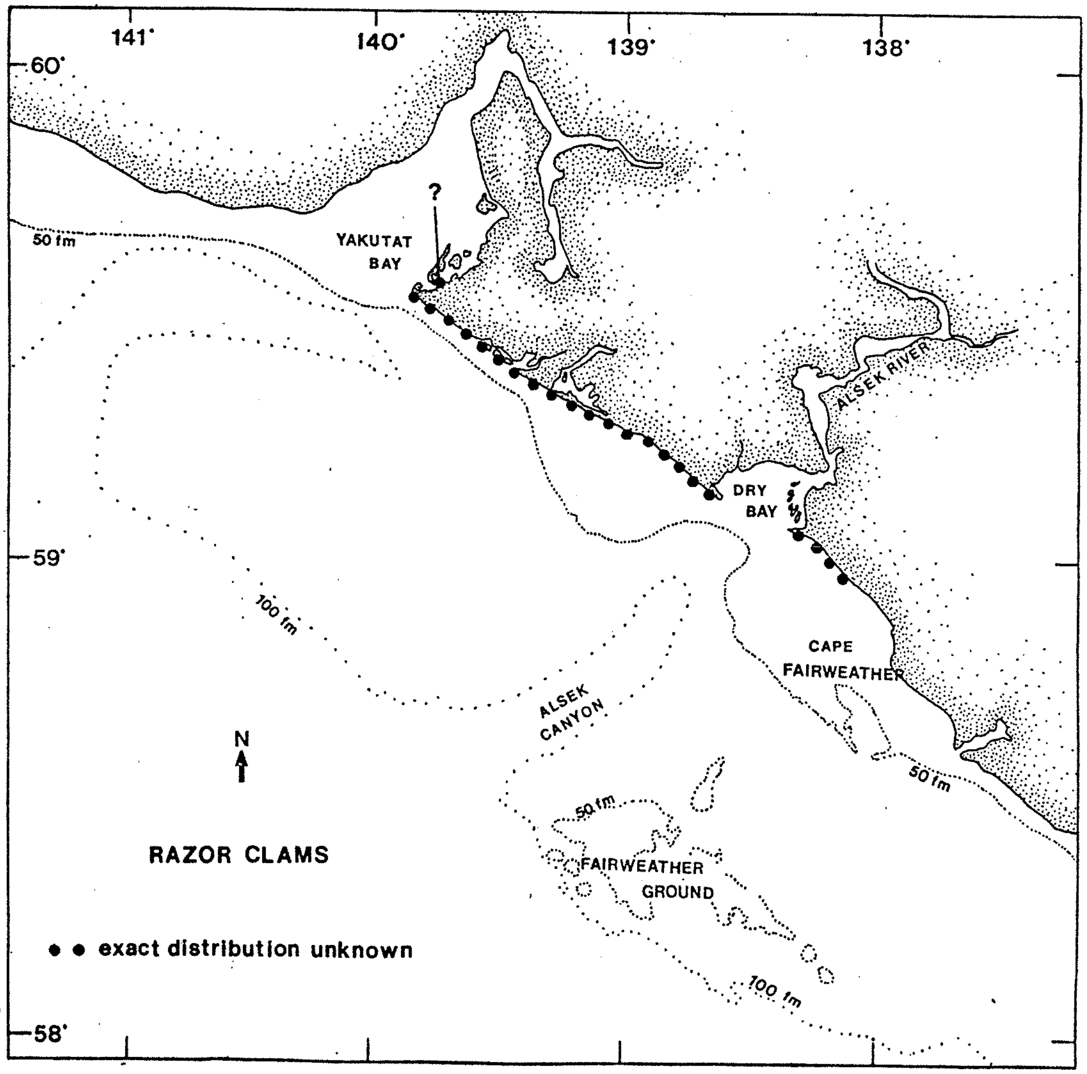

Fig.16. The distribution of razor clams in the Yakutat area.

Source: McLean and Delaney 1978.

SUMMARY

1) The ichthyoplankton and meroplankton components of the zooplankton communities off Yakutat are virtually unstudied. Inferences on seasonality, reproductive biology, etc. of key species must be drawn from studies in other areas.

2) Pacific sand lance, sablefish, halibut, Pacific cod, and arrowtooth flounder spawn in the winter whereas herring, capelin, walleye pollock, Pacific ocean perch, butter sole, starry flounder, razor clams, weathervane scallops, tanner crab, and Dungeness crab reproduce in the spring or summer. Juvenile salmon and adult forage fish will probably be most abundant in the spring and summer. We expect to sample the greatest diversity and densities of organisms during these warmer seasons of the year.

3) Herring and capelin spawn in bays or on beaches and initially, their larvae will be inshore.

4) Halibut, arrowtooth flounder, and sablefish spawn in deep water offshore. We do not expect to see their larvae inshore. The other species of fish spawn at a variety of depths, hence their larvae will be widely dispersed.

5) Salmon spawn in nearly every stream in the Yakutat area, but the most important spawning areas are the southeast shore of Yakutat Bay (pink salmon) and coastal rivers to the southeast of the bay.

6) There has been a herring fishery in Yakutat Bay only twice in recent years. About 2,000 to 3,000 tons spawn yearly in Yakutat Bay and a larger population spawns in Russell Fjord. Herring serve as important forage fish to other species such as chinook salmon.

7) Pacific sand lance, capelin, and eulachon are probably all abundant off Yakutat, but actual densities are unknown. There is no commercial fishery on any of these species, but they are important sources of food to larger fish, mammals, and birds.

8) The Yakutat area is not a major producer of salmon relative to the rest of Alaska; however, adults on their spawning migrations and juveniles from stocks far outside the Yakutat area mix in waters off Yakutat. Juvenile salmon are most abundant offshore over the Continental Shelf during July and August, although catches of pink and chum salmon are still high in September and October.

9) Generally, there is no domestic (United States or Canadian) commercial fishery by groundfish fleets in the Gulf of Alaska beyond the Queen Charlotte Islands; however, there are plans to develop a groundfish fishery in Yakutat and four other Alaskan communities.

Currently, groundfish stocks off Yakutat are primarily fished by the Japanese.

10) Pacific cod and walleye pollock are abundant and widely distributed in the Gulf of Alaska. Catches by the Japanese in the Gulf of Alaska are, however, relatively insignificant compared to catches in the Bering Sea.

11) Pacific ocean perch and sablefish are both abundant off Yakutat and this area is one of the most important areas to the Japanese fisheries on these two species.

12) The arrowtooth flounder is widely distributed and abundant in the Gulf of Alaska and it is an important species in the domestic fisheries to the south of the Queen Charlotte Islands. The Japanese primarily fish for flatfish in the Bering Sea, so their efforts off Yakutat are negligible.

13) The northern Gulf of Alaska (IPHC's area 3A), which includes Yakutat, is the most significant domestic halibut fishing area.

14) Starry flounder and butter sole are relatively uncommon in the Gulf of Alaska and they are not commercially important species. However, flathead, English, Dover, and rex sole are abundant in the Gulf of Alaska and the last three species are commercially exploited by domestic fleets.

15) There are high concentrations of both Dungeness and tanner crabs off Yakutat and catches in the area are important relative to the overall catches in Alaska.

16) In 1980, there was a shrimp fishery in Yakutat Bay and there are estimated densities of 136,000 lb/sq mile remaining in the bay.

17) The weathervane scallop fishery off Yakutat was active in 1968, 1969, and 1972-1976 followed by a crash caused by low densities of scallops and poor market conditions. The fishery was active again in 1980.

18) The razor clam beds near Yakutat are inaccessible and therefore there is no commercial or sport fishery on them in the Yakutat area.

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