AKU-T-72-001

THE COOK INLET ENVIRONMENT

A BACKGROUND STUDY OF AVAILABLE KNOWLEDGE

Alaska District, Corps of Engineers
Anchorage, Alaska

August 1972

THE COOK INLET ENVIRONMENT

A BACKGROUND STUDY

OF AVAILABLE KNOWLEDGE

by

Charles D. Evans

and

Eugene Buck, Richard Buffler, Greg Fisk, Robert Forbes, and Walter Parker

Prepared for

Department of the Army

Alaska District, Corps of Engineers

In accordance with Contract No. DACW85-72-C-0052

University of Alaska

Resource and Science Service Center

Alaska Sea Grant Program

Anchorage, Alaska

August 1972

TABLE OF CONTENTS

FIGURES

TABLES

* table follows listed page

* table follows listed page

*table follows listed page

PLATES

THE COOK INLET ENVIRONMENT

A BACKGROUND STUDY OF AVAILABLE KNOWLEDGE

INTRODUCTION

This report is designed to provide a basis for environmental impact statements that the Corps of Engineers anticipates will be required under section 102 (2) (C) of the Environmental Policy Act of 1969 for activities relating to the exploration, development and production of petroleum in Cook Inlet.

The report consists of three phases: Phase 1 is a discussion of the environment, resources and cultural activities in the Inlet that would affect, or would be affected by, such petroleum operations as geophysical surveys, both reflection and refraction, drilling, either from barges, vessels or platforms and transportation of personnel, equipment and materials resulting from these operations. It also discusses qualitatively the relationships between these operations and the environment of the Inlet. The report describes conditions in the Inlet as they are at present, either based on current information or inferred from historical data. The magnitude and direction of probable changes is discussed also.

Where basic information on certain aspects of the environment is either lacking or is scarce, such absence of information is pointed out in the text. The report area includes all water and submerged land below the mean higher high water of Cook Inlet north of a line between Cape Douglas and Cape Elizabeth. Some aspects of the adjacent uplands are discussed also. Phase 2 is a discussion of the economics of petroleum and competing resources and activities in the Cook Inlet area and the economic and social effects of petroleum exploration and development on the community. Data are presented on the dollar value of the industry and its products as realized to date. The impacts this economic activity has had on selected communities in the area is briefly discussed.

Phase 3 is a series of descriptions of what could occur in a given set of circumstances - effects of the environment on structures and operations and the resulting impact on the environment. Because of unforeseeable changes in technology and methods of operation, this section is not intended to be all-inclusive, but is limited to providing a few examples of what could occur. Regulatory responsibilities and procedures are not discussed in this report.

PHASE 1

PHYSICAL CHARACTERISTICS

LOCATION AND PHYSIOGRAPHY

Cook Inlet, a large tidal estuary in South Central Alaska flows into the Gulf of Alaska just east of the base of the Alaskan Peninsula (Fig. I-1). It lies on a northeast-southwest axis and is about 150 nautical miles wide at its widest point. Knik and Turnagain Arms at the head of the Inlet are 45 and 43 nautical miles long, respectively.

The Inlet is bordered by more than 100 square miles of tidal marsh (Wagner et al. 1969). Most of the marshes are found in the Susitna flats at the northwest end, and in Trading and Redoubt Bays, also on the northwest side of the Upper Inlet. The Chickaloon Flats occupy the south side of Turnagain Arm. Other smaller marshes occur elsewhere, mainly in bays.

Cook Inlet is bordered on three sides by mountains: the Aleutian Range and Alaska Range on the northwest, the Talkeetna Mountains to the northeast and the

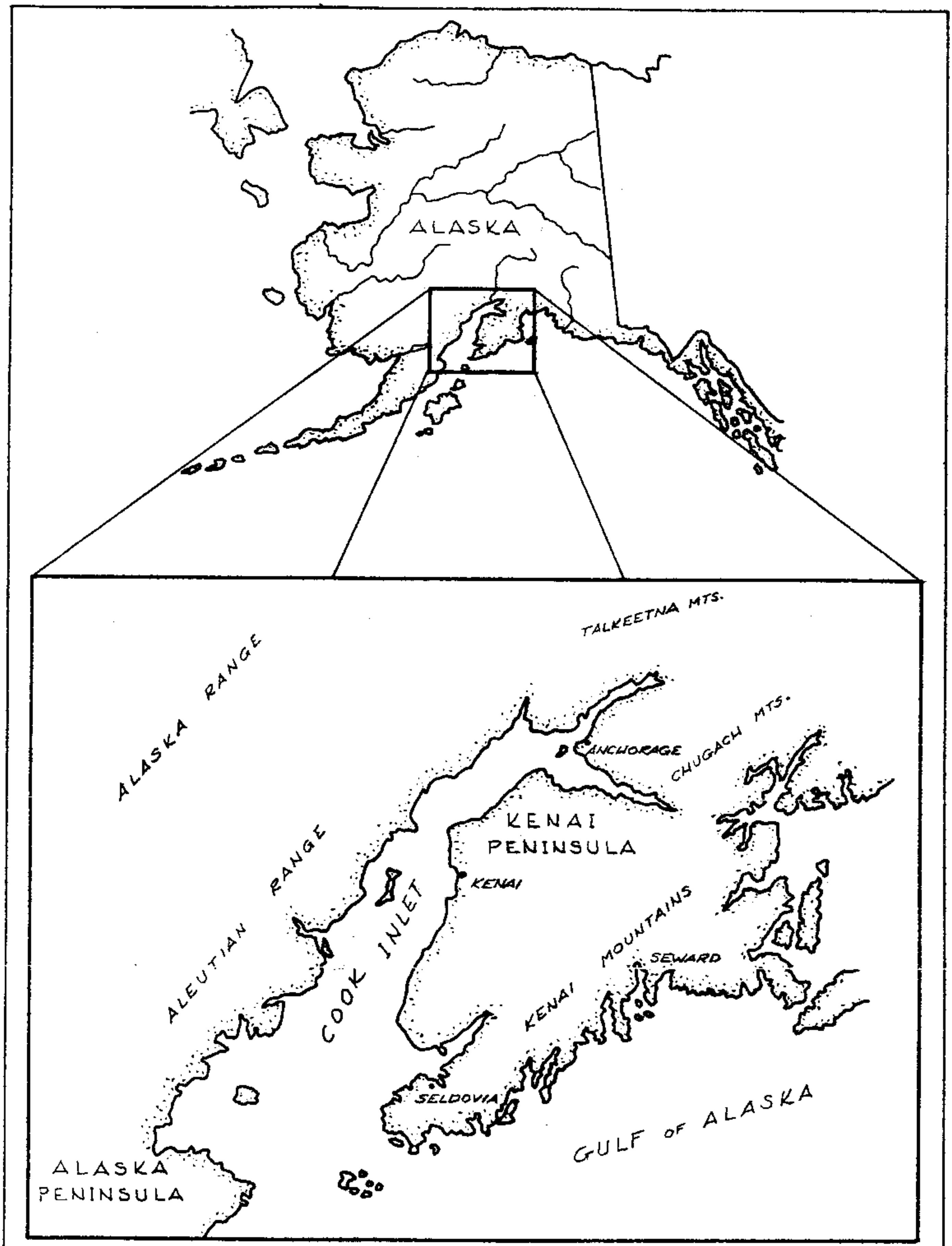


Fig. I-1 LOCATION MAP - COOK INLET AREA

Chugach and Kenai Mountains on the southeast (Fig. I-2). Glaciers are common throughout these mountain ranges and many of the streams tributary to the Inlet carry heavy glacial sediment loads.

Major tributaries include the McNiel, Tuxedni, Drift, McArthur, Chackachatna, Beluga, Susitna, Little Susitna, Matanuska, Knik, Eagle, Twenty-mile, Placer, Resurrection, Swanson, Kenai, Kasilof, Ninilchik, Anchor and Fox Rivers. Numerous smaller rivers and creeks contribute to the flow into the Inlet.

The Susitna River and the tributaries to Knik Arm, with mean combined annual flows of 43,600 cubic feet per second, contribute to a high proportion of the fresh water to the Inlet. Most of these are heavily laden with glacial silt and, together with other glacial streams, contribute a heavy sediment load to the Inlet, particularly at its upper end.

Five active volcanoes, Mts. Augustine, Spurr, Redoubt, Iliamna and Douglas, border the Inlet on the west side.

A rim of lowlands separate the mountains from most of the Inlet. This is in places very narrow and is sometimes absent, as along the southern margins of the Inlet and in fjords where the mountains rise directly from the water. It is often wide in the Upper Inlet, and the lake-dotted Kenai lowlands extend for more than 60 miles from the East Foreland to the Kenai Mountains. The valley of the Susitna River is also a broad, lake-studded lowland, in places more than 60 miles wide.

CLIMATE

Cook Inlet is, in general, a transition zone from the interior, with its cold winters, hot summers, low precipitation and moderate winds to the maritime with

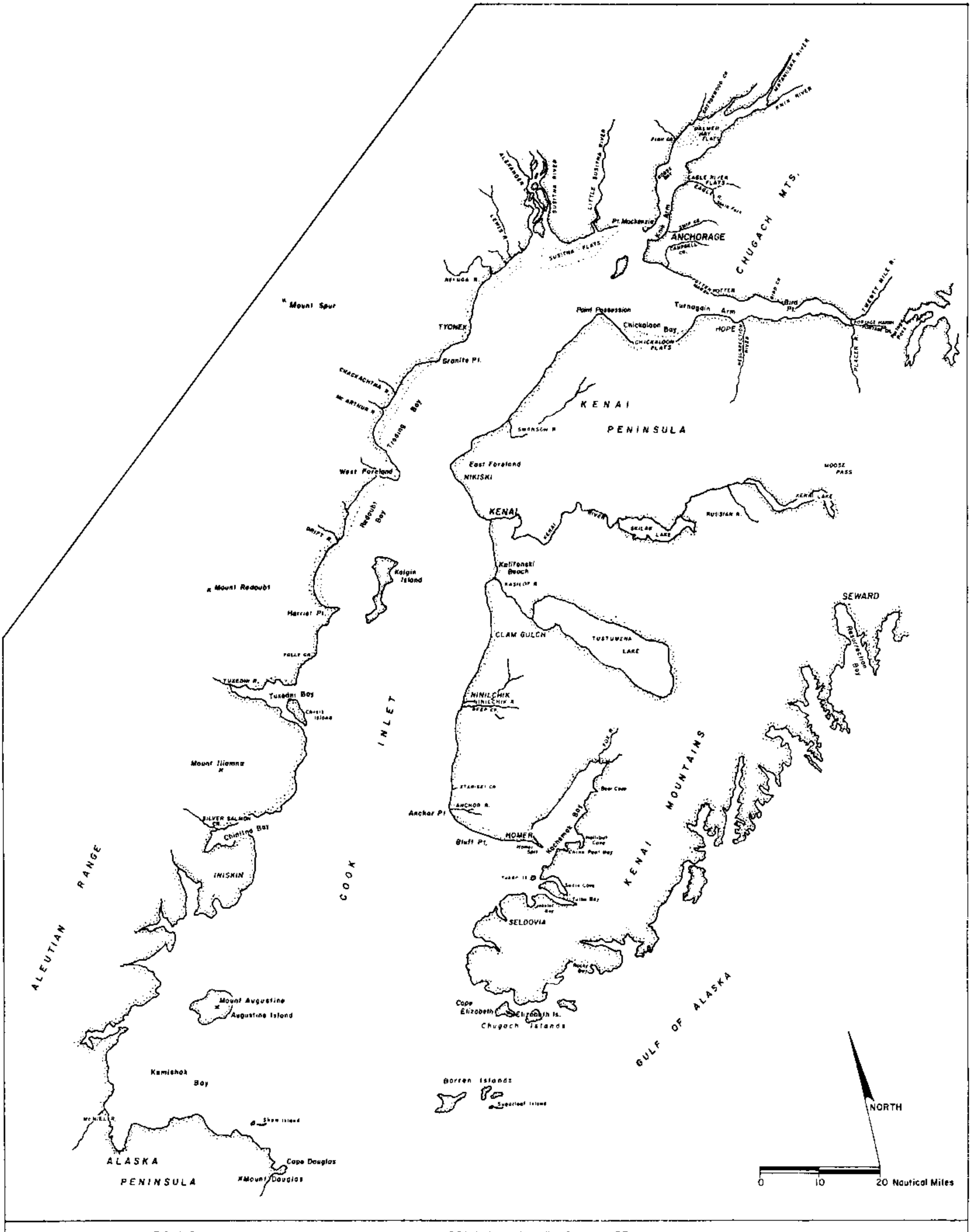


FIG. 1-2 REGIONAL MAP OF COOK INLET

cool summers, mild winters, high precipitation and frequent storms with high winds. Many areas in the Inlet provide exceptions to this rule, particularly with respect to winds in portions of the Upper Inlet that are aligned with passes and where high winds may be common.

Table I-1 summarizes climatological data from seven stations in Cook Inlet. With two exceptions, data are from the records of the National Weather Service, NOAA. Data for Tyonek and Seldovia were obtained from the Standard Industrial Survey Leaflets for those villages.[1/] Data from these stations is spotty and may vary somewhat from long-term averages.

Some data are also available from Bear Cove and Iniskin. Bear Cove, however, has too short a series of records to be of value. Iniskin would be important in filling in a void in the Southwest portion of the Inlet. That station, however, is situated at an elevation of 300 feet above sea level in a mountain valley six miles from the water. Searby (viva voce)[2/] believes that records from there should not be used to characterize any portion of the Inlet.

With this elimination of the Iniskin record, data for the west side of the Inlet below Tyonek are absent. Searby believes, however, that for a comparable latitude, precipitation is about 50 percent higher on the west side than on the east, that temperature differences between the east and west sides would be minor, and

---

1/ Anon. No date. Look north to Seldovia, Alaska, and Look north to Tyonek, Alaska. Standard Industrial Survey. Dept. of Econ. Pouch EE. Juneau, Alaska.

2/ Searby, Harold W., Chief Climatologist, National Weather Service, NOAA, Anchorage.

TABLE I-1
CLIMATOLOGICAL DATA - COOK INLET

Station	January					July					Year							
	Temp.[1] Min. Ave.	Temp. Mean Ave.	Temp. Max. Ave.	Total[2] Precip.	Snow[2]	Temp. Min. Ave.	Temp. Mean Ave.	Temp. Max. Ave.	Total Precip.	Snow	Temp. Min. Ave.	Temp. Mean. Ave.	Temp. Max. Ave.	Total Precip.	Snow	Elev. (feet)	Prev. Wind Direct.	Mean Hourly Wind Speed
Susitna 1932-1947	2.4	12.6	22.8	1.38	14.5	45.5	57.8	70.1	2.55	0.0	24.8	35.6	46.5	28.05	64.2			
Anchorage Airport 1943-1971	3.6	11.4	19.2	0.88	11.7	49.9	57.6	65.3	2.07	0.0	26.9	34.7	42.5	14.83	71.4	114	N	6.6mph
Tyonek *	4.3		19.9	0.80	11.9	50.3		66.0	1.86	0.0	28.1		43.4	14.71	64.8	114	N	7.5mph
Kenai 22 year	3.7	12.7	21.6	1.12	13.4	46.1	53.5	61.0	2.23	0.0	24.5	33.1	41.7	19.91	68.7	86'	N	6.6mph
Kasilof 32 year	3.7	12.2	20.6	1.12	10.4	45.2	55.0	64.8	2.00	0.0	25.3	34.4	43.6	17.77	55.6	80'	N	
Homer 1943-1971	14.0	20.7	27.3	1.73	10.4	44.6	52.4	60.2	1.69	0.0	29.2	36.4	43.6	23.08	55.4	67	NE	6.5mph
Seldovia*	18.1	23.2	28.2	2.3	10.2	48.6	55.8	57.7	1.40	0.0	33.7	41.0	48.2	26.3	50.8	0-30	N	11.5-17.5mph

* Unofficial local records

1 Degrees Fahrenheit

2 Inches

that the west side would be somewhat cooler in summer and warmer in winter.

Some generalizations can be drawn from Table I-1. January temperatures are warmer toward the southern portion of the Inlet while July temperatures are cooler there.

With the exception of Susitna, which is at a distance from the Inlet and undoubtedly influenced by the slope of the land, total annual precipitation increases toward the mouth of the Inlet. Precipitation toward the mouth occurs mainly in autumn with summer precipitation somewhat less there than in the Upper Inlet. The Lower Inlet, with its warmer winter temperatures, receives more winter precipitation in the form of rain and less snowfall than the Upper Inlet.

Mean hourly wind speed is moderate, with Seldovia the highest.

Searby points out that the open waters of the Inlet, where friction is reduced, are subject to higher winds than onshore areas, usually 15-25 knots. Under extreme conditions, winds of 75-100 knots can occur over the open water and storms with 50-75 knot winds are experienced there nearly every winter.

The distribution of mean monthly precipitation for Anchorage, Kenai and Homer is shown in Fig. I-3. The large difference between the upper and lower portions of the Inlet occurs in autumn and early winter, and the stations are similar in late winter and spring.

Fig. I-4 shows the distribution of mean monthly temperatures and points out the smaller range of seasonal fluctuations toward the mouth of the Inlet.

Strangely enough, temperature extremes at Kenai (80°F. to -48°F.) are greater than at Anchorage (85°F. to -30°F.). Homer, as might be expected, has a narrower

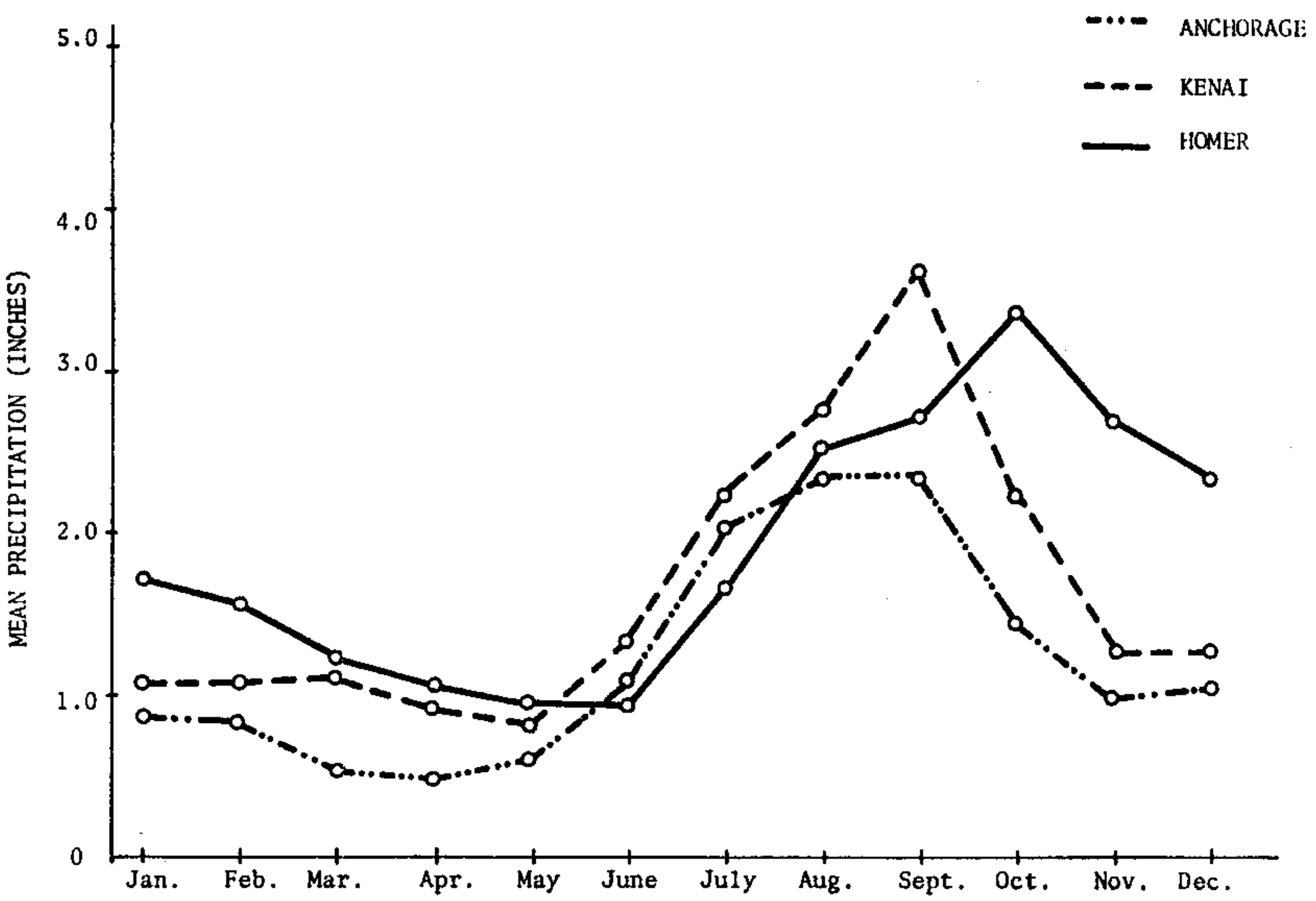


Fig. I-3 MEAN MONTHLY PRECIPITATION - SELECTED COOK INLET STATIONS

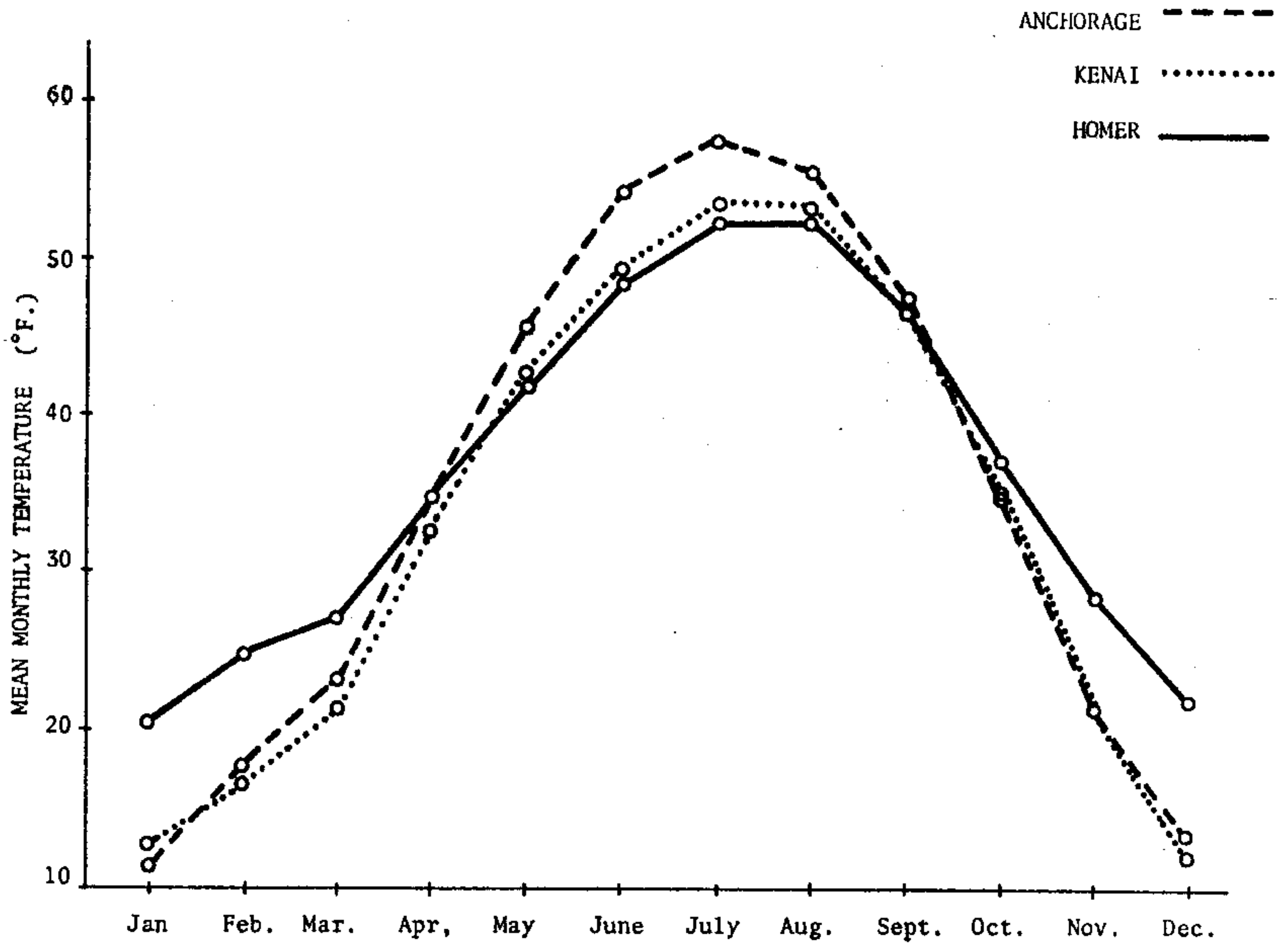


Fig. I-4 MEAN MONTHLY TEMPERATURES - SELECTED COOK INLET STATIONS range (80°F. to -21°F.).

Records for cloud cover are surprising in that Anchorage with an annual mean of 64 days clear, 53 partly cloudy and 248 cloudy has more cloud cover than Homer with 69 days clear, 67 partly cloudy and 229 cloudy, even though Homer has considerably more precipitation.

The absence of usable data for the lower west side of the Inlet is unfortunate, particularly in view of the possibility that there may be considerable differences between the east and west sides. Stations over water would also be advantageous, particularly if fog occurrence were included in observation records. Personal experience suggests that during winter, fog occurs more often over water than over land.

Air quality has been monitored at Anchorage since 1969 and more recently for Kenai and Nikiski. Records have been kept by the Greater Anchorage Area Borough, Department of Environmental Quality. Tables I-2a and I-2b summarize data available.

Total particulate matter is relatively high at Anchorage because of the heavy traffic on unpaved roads (Mikkelson, viva voce).[1/] This is related somewhat to the amount of rainfall and was high in 1969, a dry year, and high again the second quarter of 1972, another dry period. Kenai and Nikiski with less traffic are lower in total particulates.

The benzene soluble fraction, a measure of hydrocarbon content, is somewhat higher at Anchorage than at Kenai and is apparently being reduced at Anchorage.

1/ Mikkelson, Richard. Air quality officer, Greater Anchorage Area Borough.

TABLE I-2a

AIR CONTAMINANTS - COOK INLET 1969-72

(GEOMETRIC MEANS)

Total Particulate Matter
(ug/m^3)

Quarter	ANCHORAGE FS 2/	KENAI	NIKISKI
1st 1969	112 (3) 1/		
2nd 1969	136 (25)		
3rd 1969	107 (32)		
4th 1969	93 (26)	17 (4)	
1969 average	110 (86)	17 (4)	
1st 1970	66 (55)	39 (8)	
2nd 1970	148 (47)	91 (10)	
3rd 1970	95 (29)	50 (8)	
4th 1970	67 (19)	42 (11)	
1970 average	91 (150)	53 (37)	
1st 1971	34 (11)	21 (6)	11 (8)
2nd 1971	171 (15)	36 (9)	16 (6)
3rd 1971	135 (14)	64 (5)	10 (28)
4th 1971	43 (13)	-- -	23 (2)
1971 average	82 (53)	35 (20)	12 (44)
1st 1972	58 (17)		14 (7)
2nd 1972	217 (15)		21 (7)
3rd 1972			
4th 1972			

1/ figures in parenthesis denote number of samples
2/ fire station

TABLE I-2b

AIR CONTAMINANTS - COOK INLET 1969-72

(GEOMETRIC MEANS)

Benzene soluble fraction (ug/m^3)

Quarter	ANCHORAGE FS[2/]	KENAI
1st 1969	24.5 (3)[1/]	
2nd 1969	17.0 (25)	
3rd 1969	13.4 (32)	
4th 1969	17.6 (26)	3.9 (4)
1969 average	15.9 (86)	3.9 (4)
1st 1970	16.5 (55)	6.2 (8)
2nd 1970	14.4 (47)	10.5 (10)
3rd 1970	8.8 (28)	8.1 (8)
4th 1970	11.3 (20)	6.0 (11)
1970 average	13.4(150)	7.5 (37)
1st 1971	8.9 (11)	7.8 (6)
2nd 1971	13.2 (15)	3.3 (9)
3rd 1971	10.2 (14)	3.5 (5)
4th 1971	9.5 (13)	--- -
1971 average	10.5 (53)	4.3 (20)
1st 1972	11.7 (17)	
2nd 1972	13.7 (15)	
3rd 1972		
4th 1972		

1/ figures in parenthesis denote number of samples
2/ fire station

Sulfates and nitrates are no longer being monitored.

Modification of prevailing wind patterns by mountainous terrain and the occurrence of temperature inversions, particularly frequent during the winter season, restrict the diffusion of pollutants and alter air quality characteristics locally (Public Health Service, 1970).

Air contaminants resulting from petroleum operations, such as burning off of sump pits (Plate 1) and flaring from producing wells, should not be a factor in future operations. Regulations enforced by the Cook Inlet Air Quality Control District prohibits burning off of sump pits and flaring of waste gas is being phased out under state laws.

GEOLOGY

A discussion of the geology of the Cook Inlet estuary cannot be separated from a discussion of the entire Cook Inlet basin. This portion of the report, therefore, is expanded in scope to cover the entire basin.

The Cook Inlet basin is a topographic, structural and sedimentary basin containing approximately 60-70,000 cumulative feet of marine and non-marine sedimentary and volcanic rocks ranging in age from Late Paleozoic to Recent (Crick, 1971; Kelly, 1963, 1968; Kirschner and Lyon, 1971). It is a narrow elongate troughlike depression that covers an area of roughly 15,000 square miles and is approximately 70 miles wide and 200 miles long (Fig. I-5). It lies between the extensive metamorphic and igneous terrains that comprise the southern Alaska

Plate 1 Burning is a common means of disposing of waste oily materials, but is no longer permitted in Cook Inlet. U.S. Fish and Wildlife Service photo. C.D. Evans.

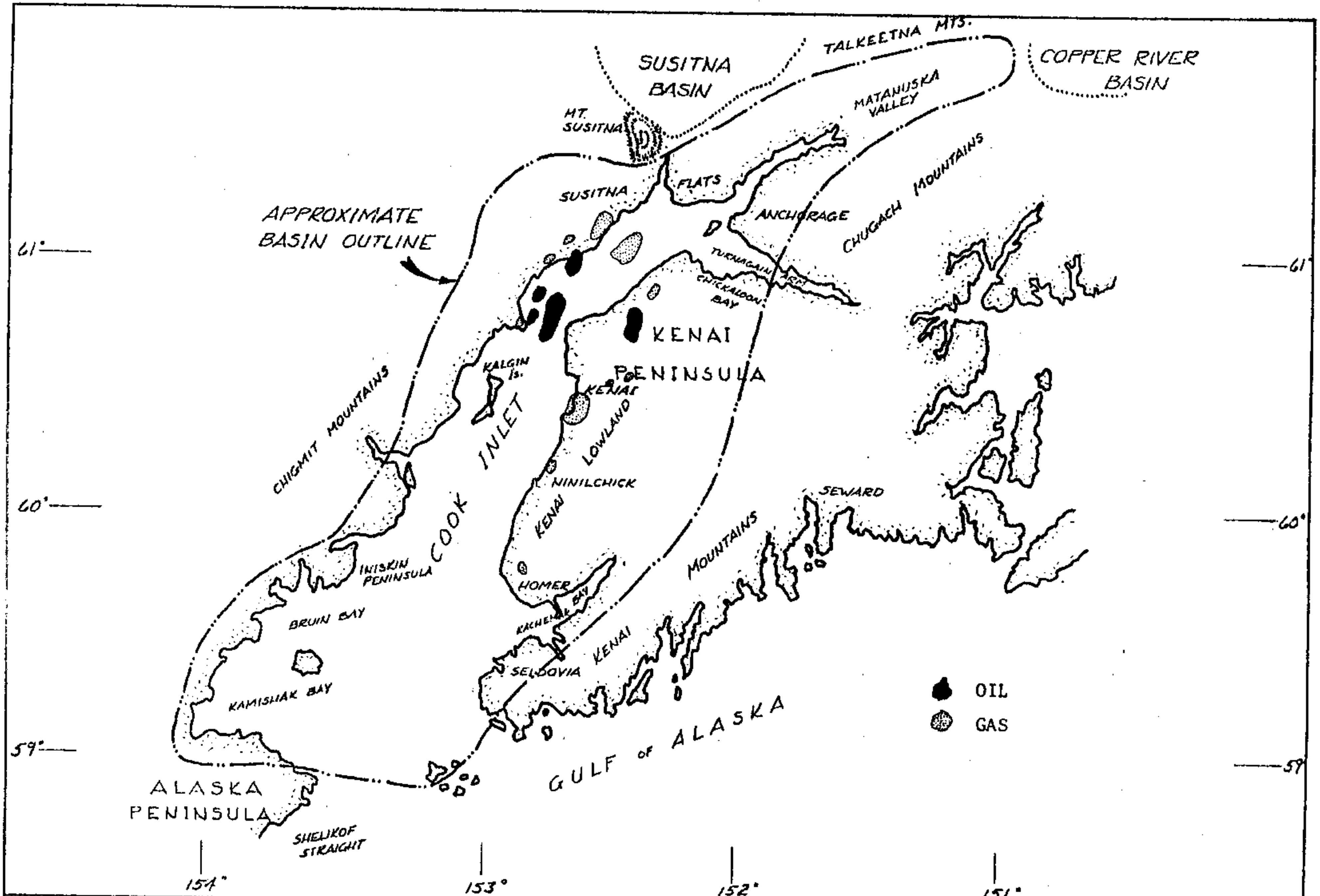


Fig. I-5 MAP OF COOK INLET BASIN, ALASKA, SHOWING BORDERING STRUCTURAL FEATURES AND LOCATION OF PRODUCING OIL AND GAS FIELDS

Range and Talkeetna Mountains on the north and west and the meta-volcanic, slate and greywacke terrains of the Kenai-Chugach Mountains on the southeast. The marine waters of Cook Inlet and its tributary bays cover about 70 percent of the basin.

The geologic history of the Cook Inlet Basin is highly complex and reflects a history of repeated geosynclinal sedimentation, deformation and intrustion beginning in late Paleozoic time and extending to the present. The stratigraphic succession in the basin includes as much as 40,000 feet of late-Paleozoic and Mesozoic marine strata and as much as 30,000 feet of Tertiary nonmarine and estuarine strata (Fig. I-6 and I-7). Three Mesozoic cycles of sedimentation and two Tertiary cycles have been recognized, each closed by a period of mountain building.

Rocks of Mesozoic age consist of limestone, chert, volcanics and clastics deposited in a variety of marine environments ranging from the deep ocean basin to shallow shelf seas. By the end of this era (Upper Cretaceous) a trough had formed in the approximate present day location of the Cook Inlet basin between an ancestral Alaska Range on the northwest and the rising Kenai-Chugach mountains on the southeast. These rocks outcrop around the periphery of the basin and are also found in the subsurface beneath the Tertiary rocks.

During the Tertiary, sediments were deposited in a broad linear intermontane trough that opened south to the sea not unlike the present day Cook Inlet basin. Climatic conditions were warm and temperate and adjacent highlands were of only low to moderate relief. Sediments were derived from both interior Alaska and western Canada, as well as the adjacent borderlands. They were deposited mainly

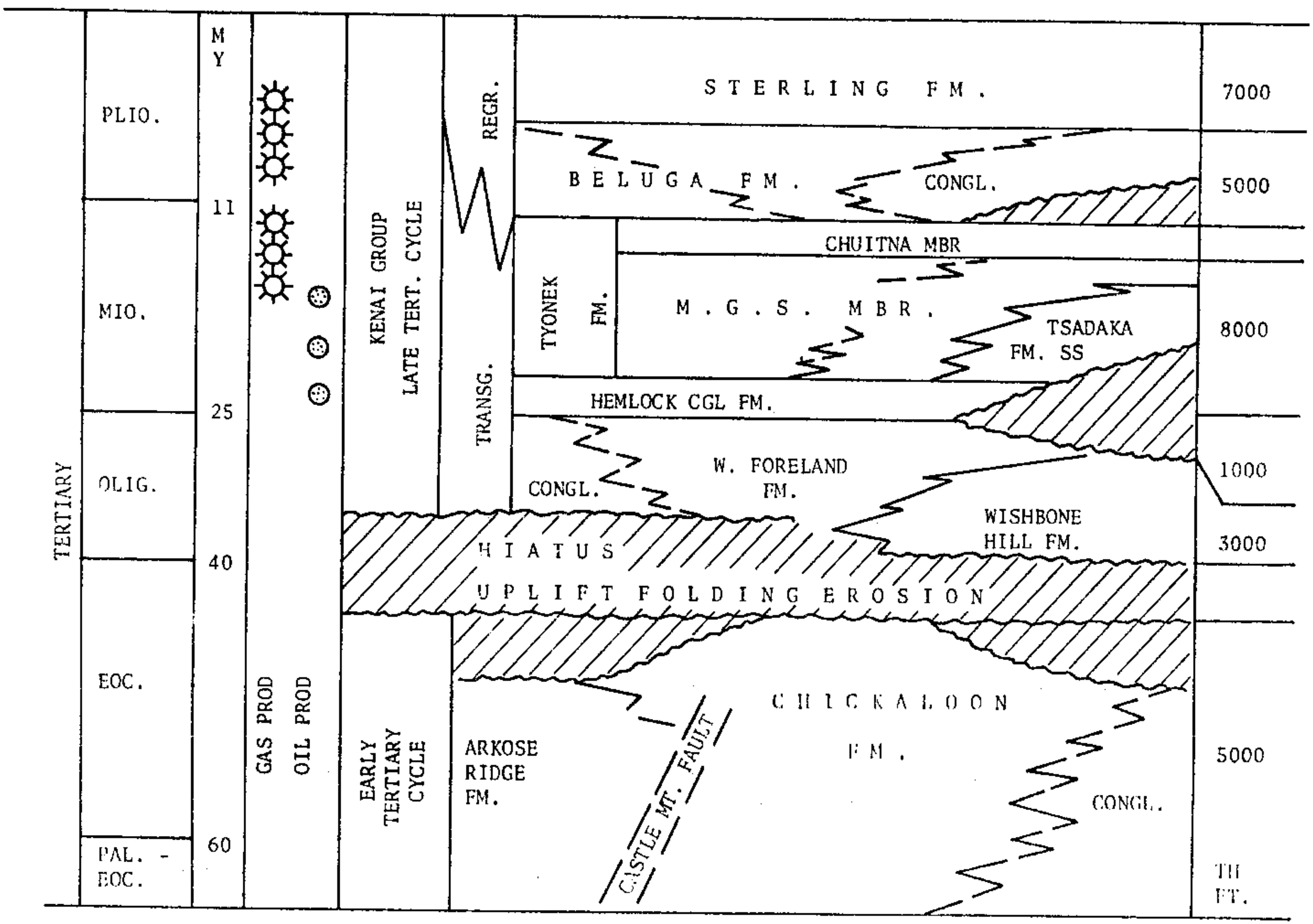


Fig. I-6 CORREL CHART COOK INLET BASIN

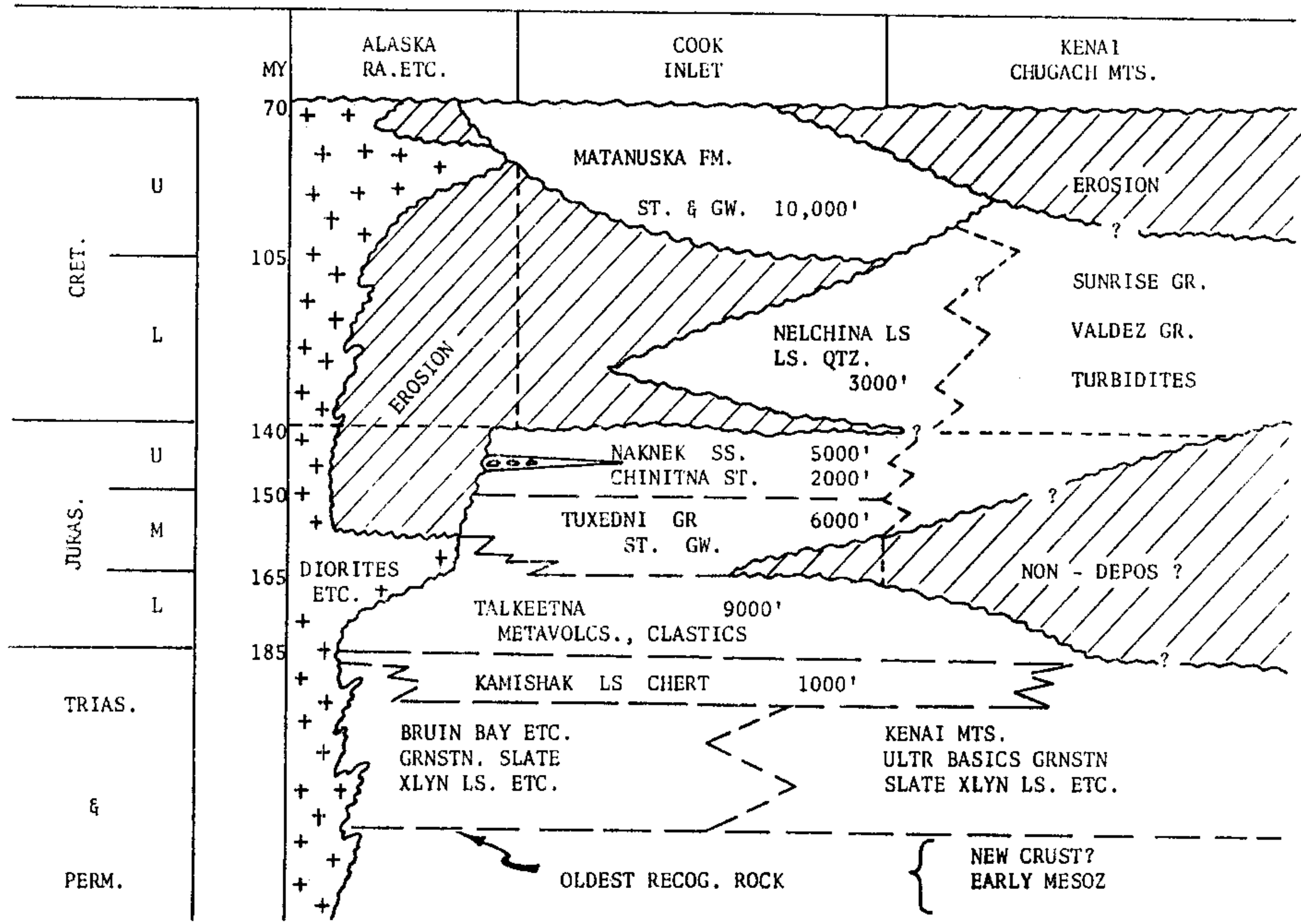


Fig. I-7 MESOZOIC CORREL CHART COOK INLET BASIN by aggrading streams as well as by deltas and marine estuaries at the distal end of the trough.

Early Tertiary sedimentation centered in the present Matanuska Valley area, where several thousand feet of conglomerate, sandstone, siltstone and coal were deposited. During the late Tertiary as much as 25,000 feet of sediments were deposited in a slowly subsiding trough centered in the present Upper Cook Inlet area - the Kenai Group (Fig. 1-8). The Kenai Group consists of approximately 18,000 cubic miles of sediments, a mixture of conglomerate, sandstone, siltstone, claystone and coal deposited mainly by streams and marine estuaries. It has been divided into five formations (Calderwood and Fackler, 1972 in Fig. 1-9).

The Kenai Group contains all the present oil and gas production in the basin as well as all the proven recoverable reserves estimated by the Alaska Division of Oil and Gas at more than 500 million barrels of oil and more than 5 trillion cubic feet of gas and by Crick (1971) at 645 million barrels of oil and 5 trillion cubic feet of gas. The bulk of the oil production comes from the Hemlock Formation and the lower Tyonek Formation, while most of the gas production comes from the upper sands of the Beluga Formation and the basal sands of the Sterling Formation.

By the end of the Tertiary, the major topographic elements of the area were established. The subsequent geologic history has consisted largely of erosion and modification of mountaineous areas during glacial and interglacial cycles and partial filling of lowland areas and valleys with Quaternary glacial drift and associated deposits. At least five major Pleistocene glaciations have been recognized in the Cook Inlet region (Karlstrom, 1969). The Quaternary deposits vary in thickness up to several thousand feet and cover much of the lowlands area masking most of the underlying Tertiary deposits.

SYSTEM	SERIES	GROUP	FORMATION Thickness	DESCRIPTION	PAY ZONE
CENOZOIC	QUAT.		Alluvium and glacial deposits		
CENOZOIC	TERTIARY	Kenai Group	Sterling Formation 0-11,000	Massive sandstone and conglomerate beds with occasional thin lignite bed.	✿
CENOZOIC	TERTIARY	Kenai Group	Beluga Formation 0'-6000'	Claystone, siltstone and thin sandstone beds, thin sub-bituminous coal beds.	✿
CENOZOIC	TERTIARY	Kenai Group	Tyonek Formation 4000'-7700'	Sandstone, claystone and siltstone interbeds and massive subbituminous coal beds.	✿ * *
CENOZOIC	TERTIARY	Kenai Group	Hemlock Conglomerate 300'-900'	Sandstone and conglomerate	*
CENOZOIC	TERTIARY	Kenai Group	West Foreland Formation 300'-1000'	Tuffaceous siltstone and claystone. Scattered sandstone and conglomerate beds.	*
			RESTS UNCONFORMABLY ON OLDER TERTIARY, CRETACEOUS AND JURASSIC ROCKS		

✿ Oil * Gas

Fig. I-8 PROPOSED STRATIGRAPHIC NOMENCLATURE FOR KENAI GROUP

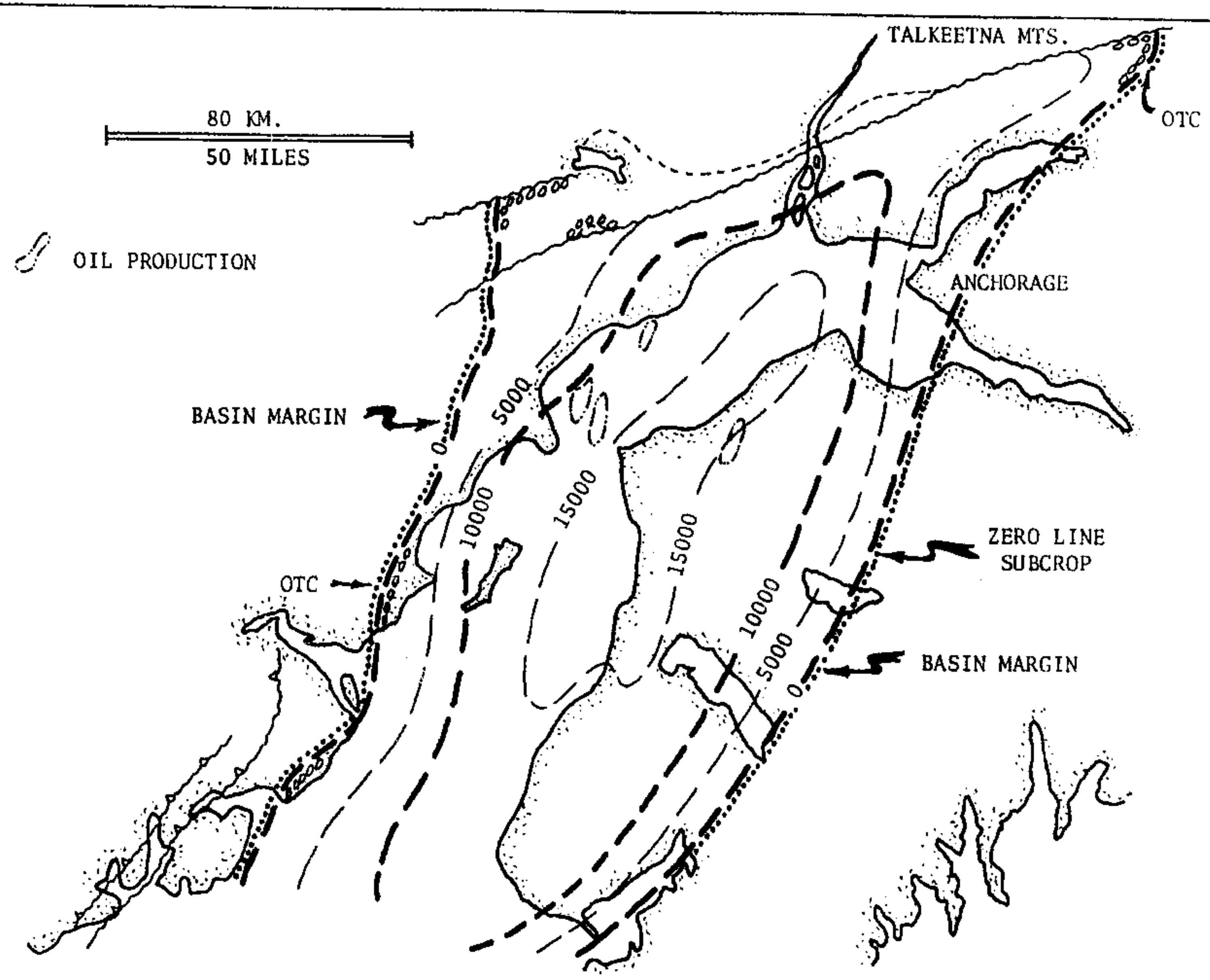


Fig. I-9 ISOPACH KENAI GROUP, GENERALIZED

Regionally, the Cook Inlet area is near the axis of the Alaskan orocline, the dominant arcuate tectonic feature that is expressed so clearly by the topography of southern Alaska (Fig. I-10 from Crick, 1971). The axis of the orocline represents the juncture of two great tectonic systems - the northeast trending western Pacific arc systems terminating in the Alaska Range and Kenai-Chugach Mountains and the northeast trending orogenic belts of western North America terminating in the eastern Alaska Range and eastern Chugach Mountains (Foster and Karlstrom, 1967).

Structurally, the Cook Inlet Tertiary basin is an elongate, deep moderately asymmetrical basin that is superimposed on older sedimentary rocks. The Tertiary rocks dip moderately toward the regional synclinal axis of the basin (Fig. I-11), which trends approximately N 30° E subparallel to the major tectonic elements flanking the basin - the Alaska Range and the Kenai-Chugach Mountains. In its simplest form the basin is a graben, bounded by major fault zones on the north, west and east, that have been active at various times during the Tertiary. Recent activity has been observed only along the Castle Mountain fault, as evidenced by lineations and offsets in glacial deposits.

The Tertiary sediments in the basin have been deformed into a series of en echelon asymmetric folds that trend parallel to the standard grain (Fig. I-12). All of the oil and gas fields found to date are near the crests of these folds (Fig. I-13).

The structures of the basin imply regional compressive forces acting in a northwest-southeast direction. The concept of continental underthrusting of the

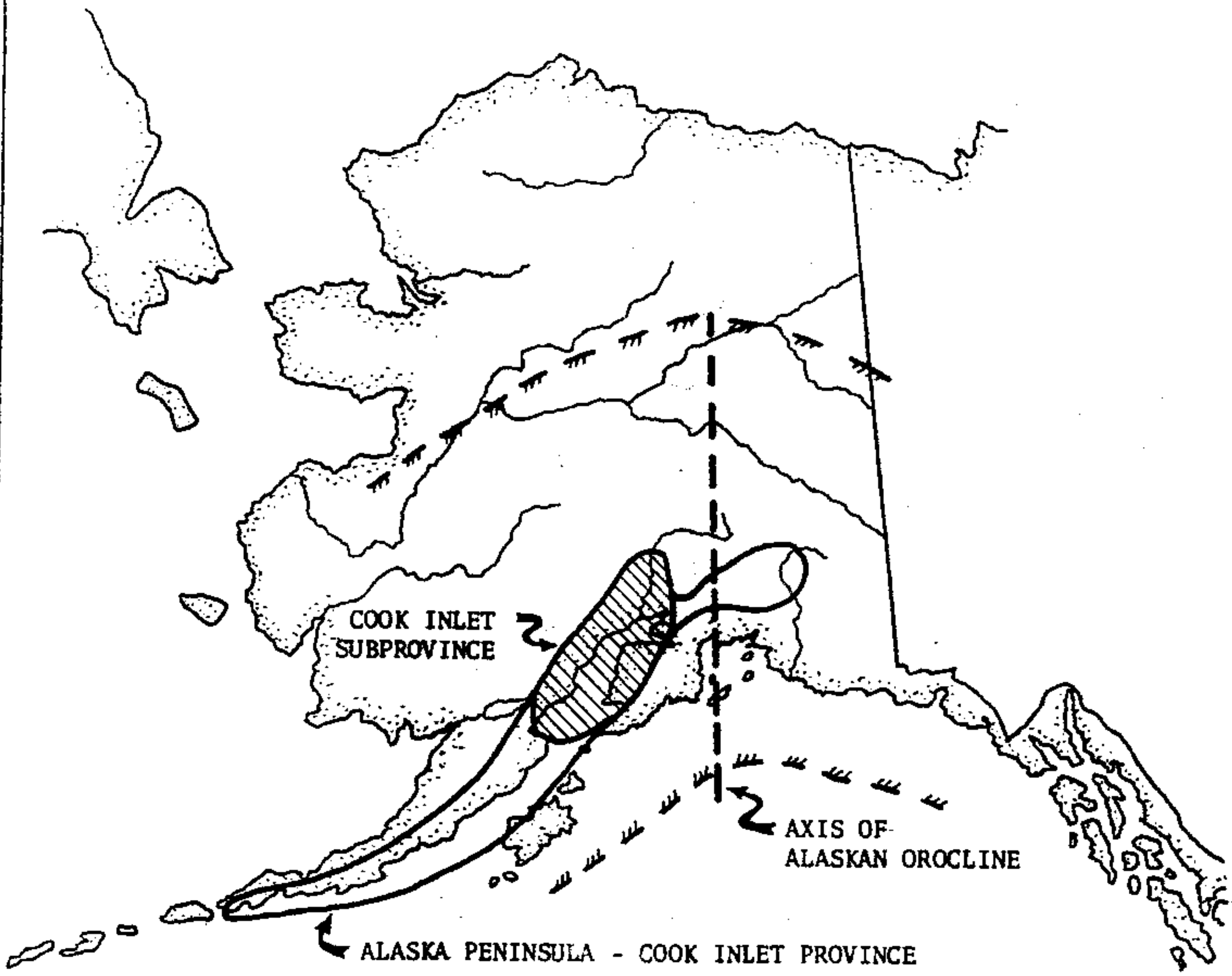


Fig. I-10 MAP OF ALASKA SHOWING ALASKA PENINSULA - COOK INLET PROVINCE

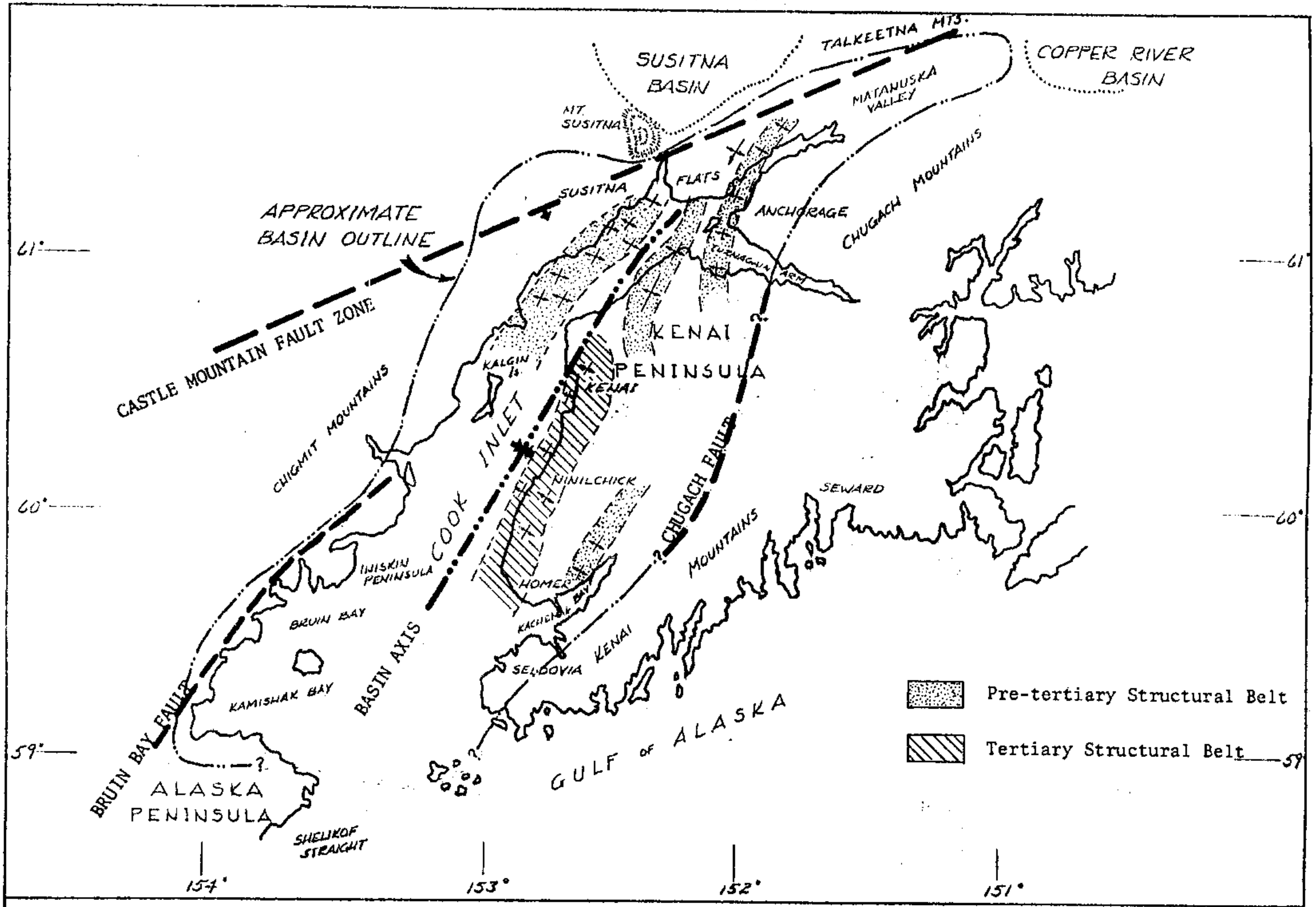


Fig. I-11 TECTONIC MAP OF COOK INLET BASIN, ALASKA

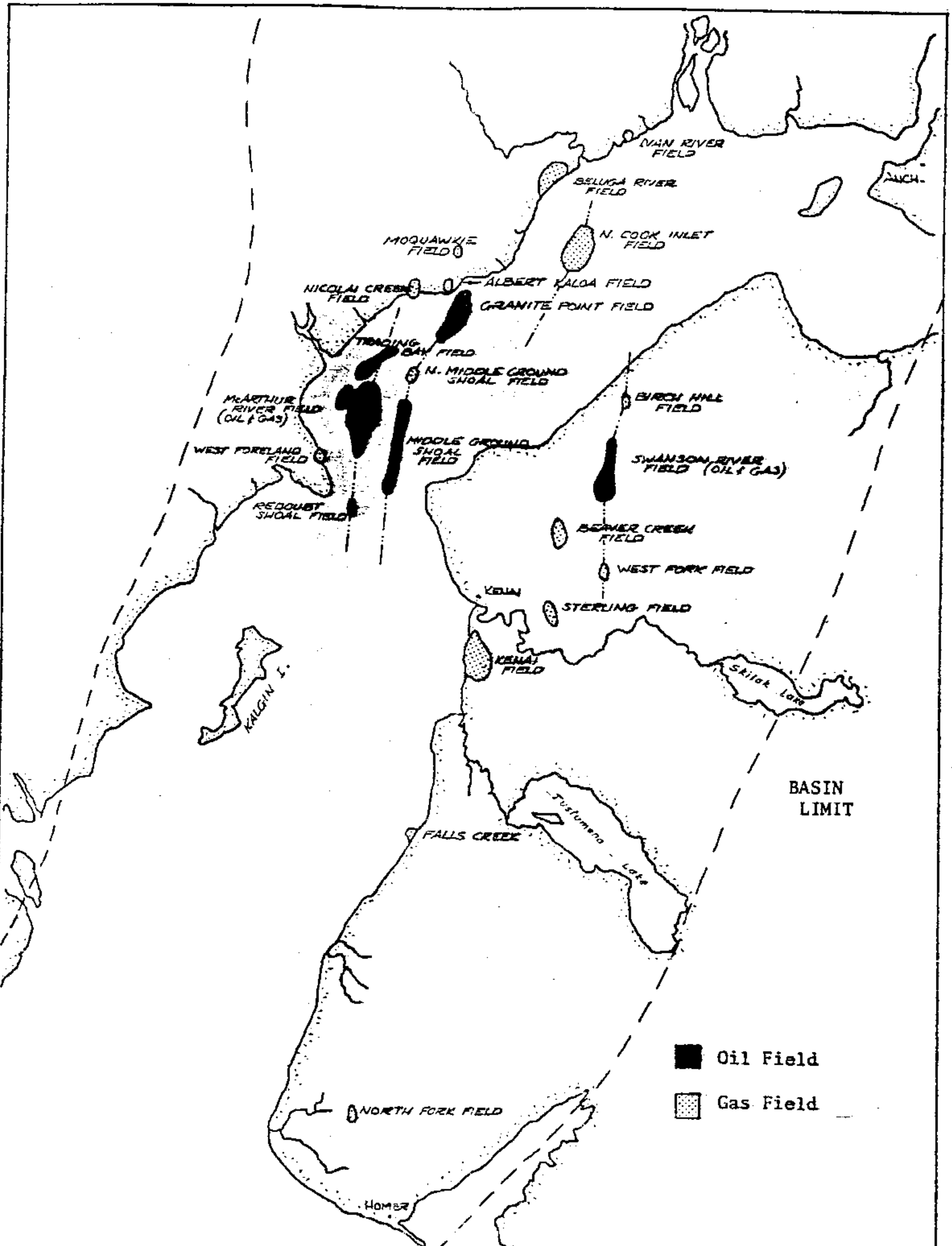


Fig. I-12 MAP OF COOK INLET BASIN SHOWING STRUCTURAL TRENDS AND OIL AND GAS FIELDS

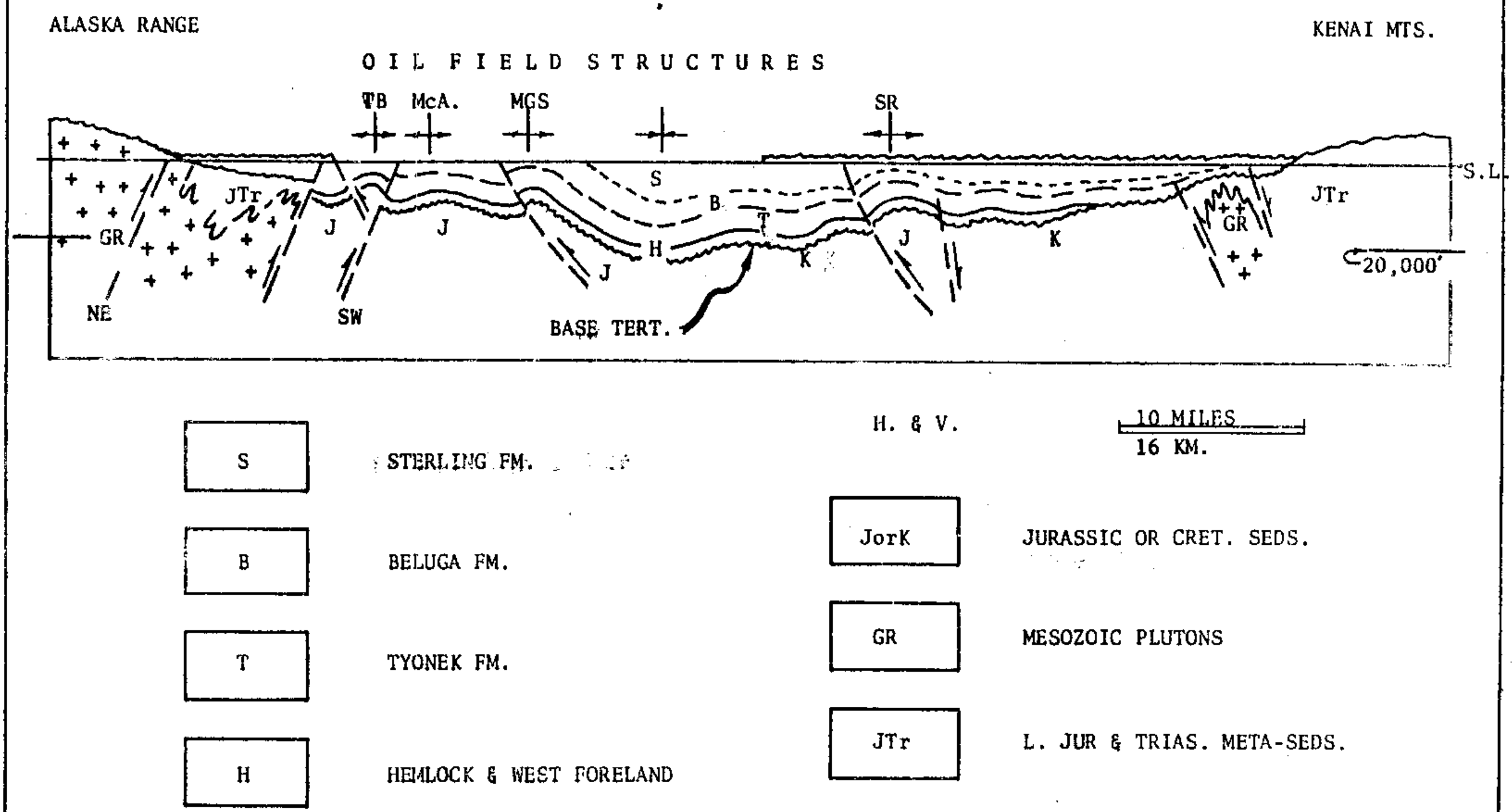


Fig. I-13 CROSS SECTION COOK INLET BASIN SHOWING TERTIARY STRUCTURE ocean floor along the Aleutian trench could be an adequate model to account for this Tertiary structural deformation in the Cook Inlet basin (Plafker, 1969).

Additional information on the geology and resources of the Cook Inlet basin can be found in the references listed in Geological Literature on the Cook Inlet Basin and Vicinity, Alaska (Maher and Trollman, 1969).

ESTUARY CHARACTERISTICS

PHYSICAL AND CHEMICAL

The Institute of Marine Science of the University of Alaska has established sampling stations throughout the Inlet basin which were surveyed in 1968 for salinity, oxygen, suspended sediments and nutrients including nitrate, nitrite, ammonia, silicate, particulate organic carbon, dissolved organic carbon, and percent organic carbon in sediments. They also measured biological activity in terms of abundance and taxa in the phytoplankton, zooplankton and littoral communities.

The distribution of these parameters is displayed graphically in Kinney et al. (1970b) and further information is provided for stations located near the outfall of the Collier Carbon and Chemical Corporation plant at Nikiski (Rosenberg et al. 1967, 1969; Hood et al. 1968).

Where these data can be applied directly in analysis of other parameters, they are used elsewhere in this report. Otherwise, their greatest utility is as baseline data for measurement of change and they are not included here.

Bathymetry

The Upper Inlet (Fig. I-2) is a shallow, silt-laden basin. Below the Forelands, the bottom slopes downward to depths of more than 100 fathoms just south of the Inlet entrance east of the Barren Islands. A deep hole lies south of Homer near Yukon Island. Relatively deep areas, apparently resulting from scouring, lie between the Forelands and just east of Harriet Point. Kamishak Bay in the Lower Inlet is generally shallow.

Tides and Currents

Wagner et al. (1969) describes the tides of Cook Inlet. They are semi-durnal with a marked inequality between successive low waters. The mean diurnal range varies from 13.7 feet at the mouth of the Inlet to 29.6 feet at Anchorage (Table II-1). The time lag between high water at the mouth and at Anchorage is about 4.5 hours.

The tides within the lower portion of the Inlet have a mean diurnal range on the east side of 19.1 feet and on the west side of 16.6 feet. A tidal bore sometimes occurs in Turnagain Arm that may reach a height of 10 feet.

Wagner et al. (1969) also describes currents as of moderate velocity. In the region of the Forelands, they reach a mean maximum velocity of 3.8 knots with peak maximum velocities exceeding 6.5 knots at monthly tidal extremes. Tidal currents are detailed in tables published by NOAA (1971).

Taylor (personal communication)[1/] cites a tidal current project scheduled for lower Cook Inlet in 1973 which will include the area between latitudes 59° and 60°N and will include Kachemak and Kamishak Bays. This will be conducted by the Oceanographic Division, National Ocean Survey, Rockville, Md.

Ice

Ice conditions in Cook Inlet are monitored by the Marine Forecast Section of NOAA (Hutcheon 1971). Ice thickness is forecast on the basis of frost degree days. A frost degree day is defined as a daily mean temperature 1°F. below an arbitrary base of 32°F.

With the season of 1970-71 as a base, some idea of expected ice conditions

1/ Taylor, Norman E. RADM, NOAA, Director, Pacific Center, Seattle, Wash.

TABLE II-1
COOK INLET TIDES IN FEET

Datum Plane	Kenai (Lower Cook Inlet)	Anchorage (Upper Cook Inlet)
Highest Tide	26.00	35.80
Mean Higher High Water	20.70	29.60
Mean High Water	19.90	28.90
Mean (half) Tide Level	11.05	15.55
Mean Low Water	2.20	2.20
Mean Lower Low Water	0.00	0.00
Lowest Tide	-6.00	-4.90
Mean Range	17.70	26.70
Diurnal Range	20.70	29.60
Extreme Range	32.00	40.70

in the Inlet can be obtained. Fig. II-1 shows the cumulative distribution of frost degree days during the winter of 1970-71, for the warmest year (1930-31), the coldest year (1965-66) and the average of records dating from the 1923-1924 winter.

The 1970-71 winter was a severe ice season, but based on the records for frost degree days, it is far from the most severe that could be expected.

Hutcheon states that by the end of January, 1971, ice extended as far south as Cape Douglas on the western side of the Inlet and as far as Anchor Point on the eastern side, with fast ice extending up to 3 miles off the northern shore of Kachemak Bay. Most ice in the Inlet is floe ice which is estimated to increase in thickness as much as 1 inch per day and cakes may be as much as four feet thick. It is usually mixed with smaller chunks or "brash ice."

The situation is complicated by large piles of ice (stamukhi) formed on the tidal flats from beach ice broken free, deposited higher on the flats and frozen to the underlying mud. Ice floes are then piled on top of this and as the tides recede, the overhanging portions break off leaving stacks of layered ice with nearly straight sides. These may go adrift in abnormally high tides. Some were observed in 1970-71 with thicknesses greater than 40 feet which had grounded in shallow areas.

Ice caused some difficulties to shipping during the 1970-71 season and numerous reports were received the last half of January. One tanker was also observed frozen in the ice at the Drift River terminal. Several reports were received of ships damaged by striking stamukhi which had been lifted afloat by high tides.

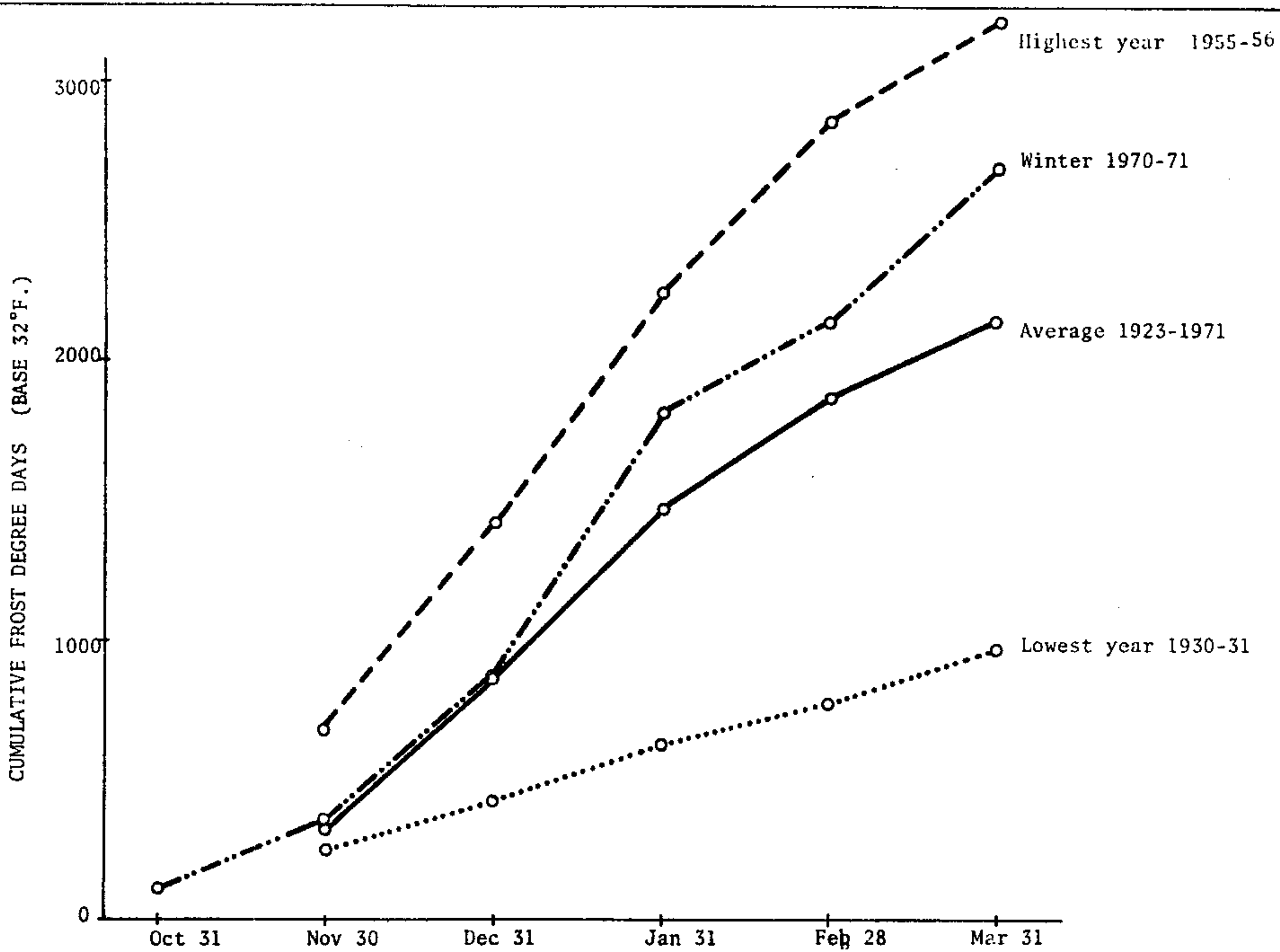


Fig. II-1 TOTAL FROST DEGREE DAYS TO DATE - ANCHORAGE ALASKA

Another report indicated that a ship was nearly torn from its moorings at the Anchorage City dock by the force of the ice during tidal change. Vissner (1969) in relation to design of oil platforms, states that in general, forces exerted by winds, waves or earthquakes are minimal compared with ice forces. Beazley (viva voce) 1/ states that ice forces are the overriding factor by four times in the design of structures in Upper Cook Inlet.

Based on frost degree day information, considerably more difficulty can be expected in extreme cold years and problems can be expected at least as far south as Drift River on the west side. Plate 2 illustrates a work boat temporarily halted by ice in mid-Inlet during the winter of 1968-69.

Circulation and Sediments

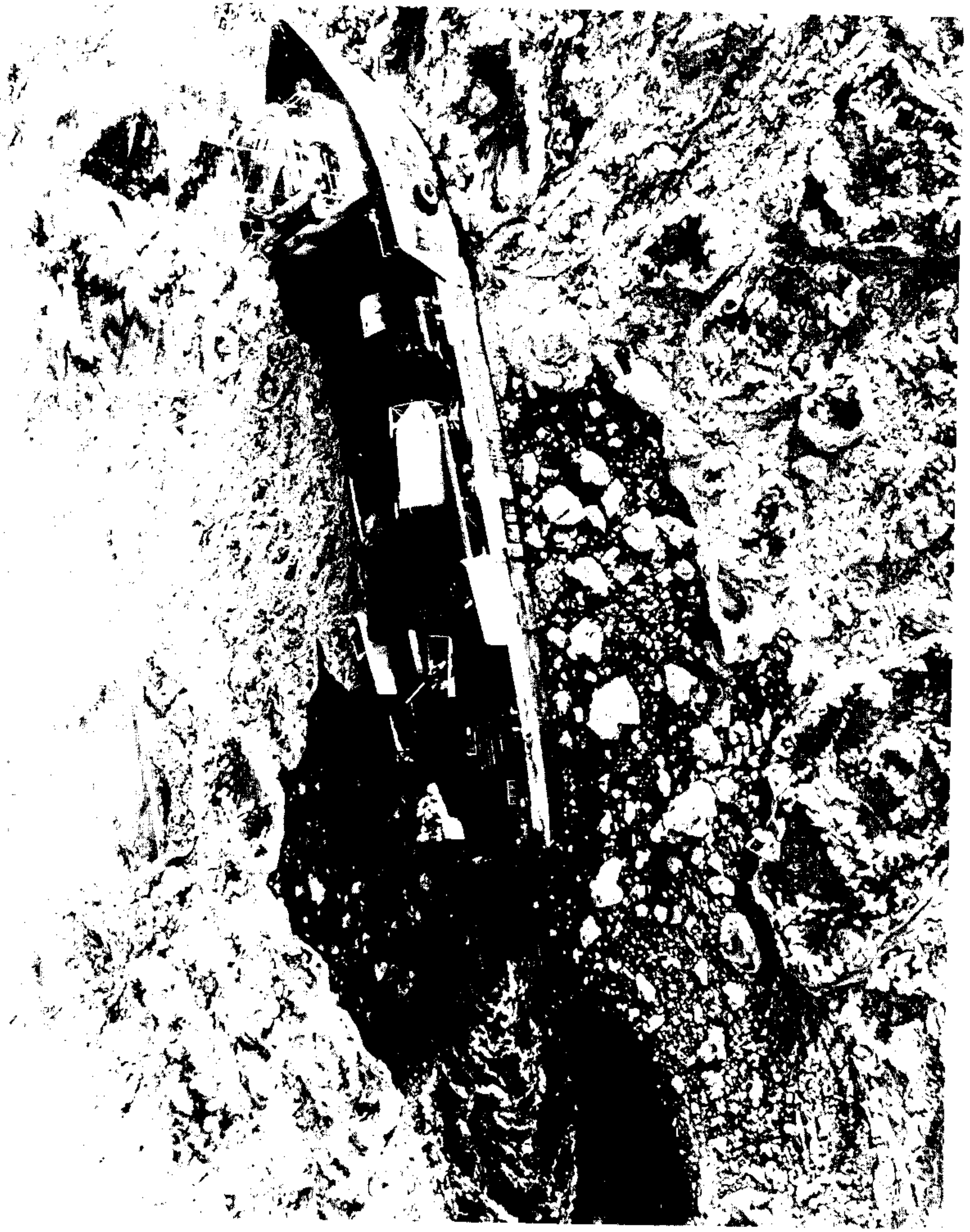
Circulation and local tidal currents are important factors in the Inlet. First, the general pattern of circulation determines the distribution of nutrients and hence the productivity of various portions of the water body. Second, circulation determines the localized impact of contaminants in the water - For instance, the dispersion of sewage wastes from Anchorage or the immediate distribution of oil from a leaky valve along a shoreline. Third, broad patterns of circulation would determine the eventual distribution of such a substance as floating oil from a major spill. Fourth, the effect of strong tidal currents on unconsolidated bottom sediments is of crucial consideration in the engineering design and construction of oil pipelines, platforms and terminals.

Two basic approaches are available to determine the gross pattern of circulation in a large water body, such as Cook Inlet. Matthews and Mungall (1972) used data on tidal currents and developed a mathematical model from which velocity and

---

1/ Beazley, M.B. Associate production Engineer, Mobil Oil Co., Anchorage.

Plate 2 Ice can be a major navigation problem in the Upper Inlet. U.S. Fish and Wildlife Service photo. C.D. Evans.



direction of flow could be predicted. According to Carstens (*viva voce*)[1/], this has not been developed to the point where it can provide detailed information on specific locations that is sufficiently accurate to be of use in engineering design. It does, however, provide a basis for interpreting field data.

Another approach involves the use of data describing the distribution of salinity, sediments, such chemical factors as nitrites and phosphates, and the fresh water inflow to derive an understanding of flow patterns. Such data were obtained during an early cruise of the Institute of Marine Science Research vessel Acona as reported by Kinney *et al.* (1970b). Such data can be supplemented by specific localized studies such as have been conducted in conjunction with the Collier Carbon and Chemical Company outfall as reported by Rosenberg *et al.* (1967, 1969) and Hood *et al.* (1968); and in Kachemak Bay (Knull and Williamson, 1969a, b and c).

Bathymetry, morphometry and fresh water drainage combine with tidal effects to divide the Inlet into three segments for purposes of discussing circulation. The Upper Inlet lies east of a line extending northward from Point Possession and includes both Knik and Turnagain Arms. The Middle Inlet includes waters from the Upper Inlet southwestward to the latitude of Tuxedni Bay southward. This is different from the usual division into Upper and Lower Inlet at the Forelands.

Waters of the Upper Inlet, because of the large tidal fluctuations in a shallow narrow basin, are well mixed laterally, longitudinally and vertically with each tidal cycle. In summer with a large inflow of glacial meltwater in tributary

---

1/ Carstens, Torkild. Professor of ocean engineering, University of Alaska, College, Alaska.

streams, there is a net outward movement of Upper Inlet waters of as much as a mile with each tidal cycle. In winter, however, with reduced runoff in tributary streams, there is practically no net outflow from the Upper Inlet and water merely sloshes back and forth with each tide (Murphy et al. 1972). Fig. II-2 shows bottom sediments of the Inlet, which in this section are largely sand. The distribution of bottom sediments is related to circulation patterns and current velocities. Most fine sediments are prevented from settling out in areas of high velocity or turbulent flow (Sharma and Burrell, 1970).

The Middle Inlet is characterized by a net inward movement of saline oceanic water up the eastern shore and a net outward movement of fresh runoff water from Knik Arm and the Susitna River (Fig. II-3) along the western shore. These water masses are well mixed vertically because of turbulence caused by swift currents and high coriolis force (Wagner et al. 1969) and lateral separation is maintained throughout the mid-Inlet, resulting in a shear zone between the highly saline incoming water on the east side and the less saline waters on the west. Fig. II-4, showing surface salinity distribution illustrates the band of higher salinity proceeding up the eastern side (Kinney et al. 1970b).

Even in the Middle Inlet, observations of ice movements indicate that each tidal cycle is of greater magnitude than the net inflow up the east side and outflow down the west, even though the net effect of the latter is eventually of greater consequence in determining the characteristics of the water mass.

Some of the highest tidal velocities, as shown in Fig. II-5, occur in mid-Inlet (Matthews and Mungall, 1972) where they reach an average maximum velocity of 3.8 knots and exceed 6.5 knots at extreme tides (NOAA, 1971). Carstens (viva voce)

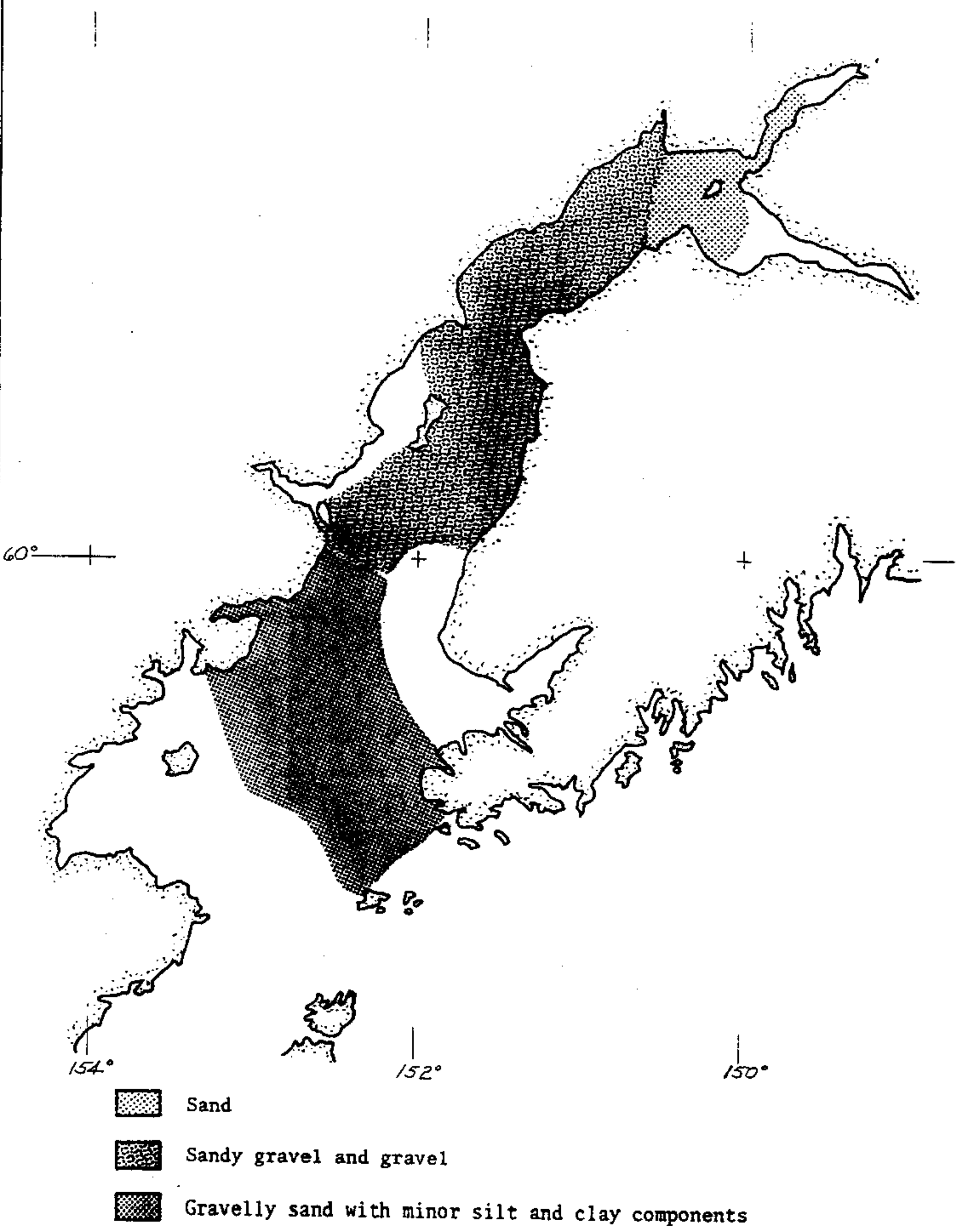


Fig. II-2 BOTTOM SEDIMENTS IN COOK INLET (From Sharma and Burrell 1970)

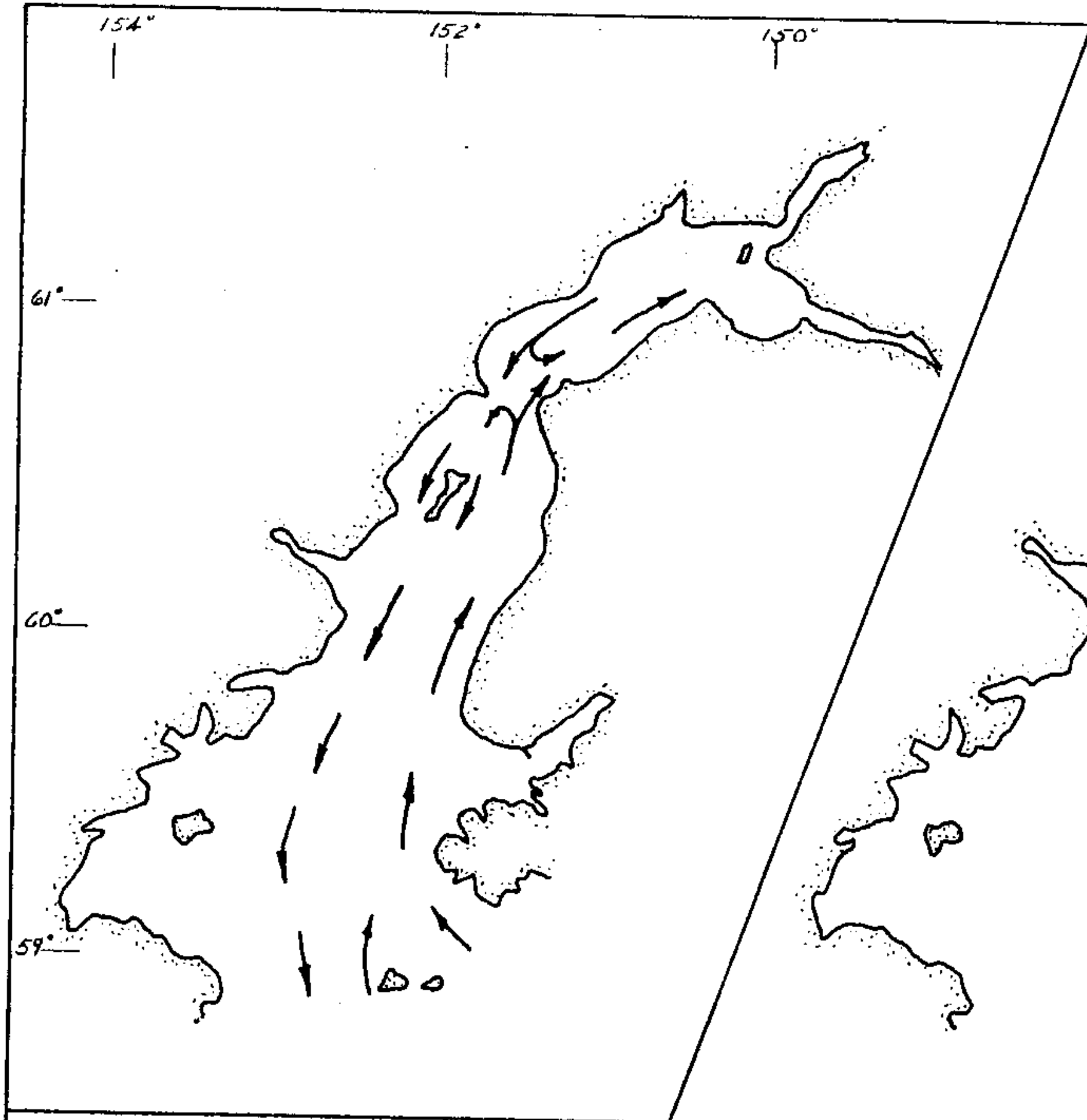


Fig. II-3 SURFACE CIRCULATION PATTERN - COOK INLET

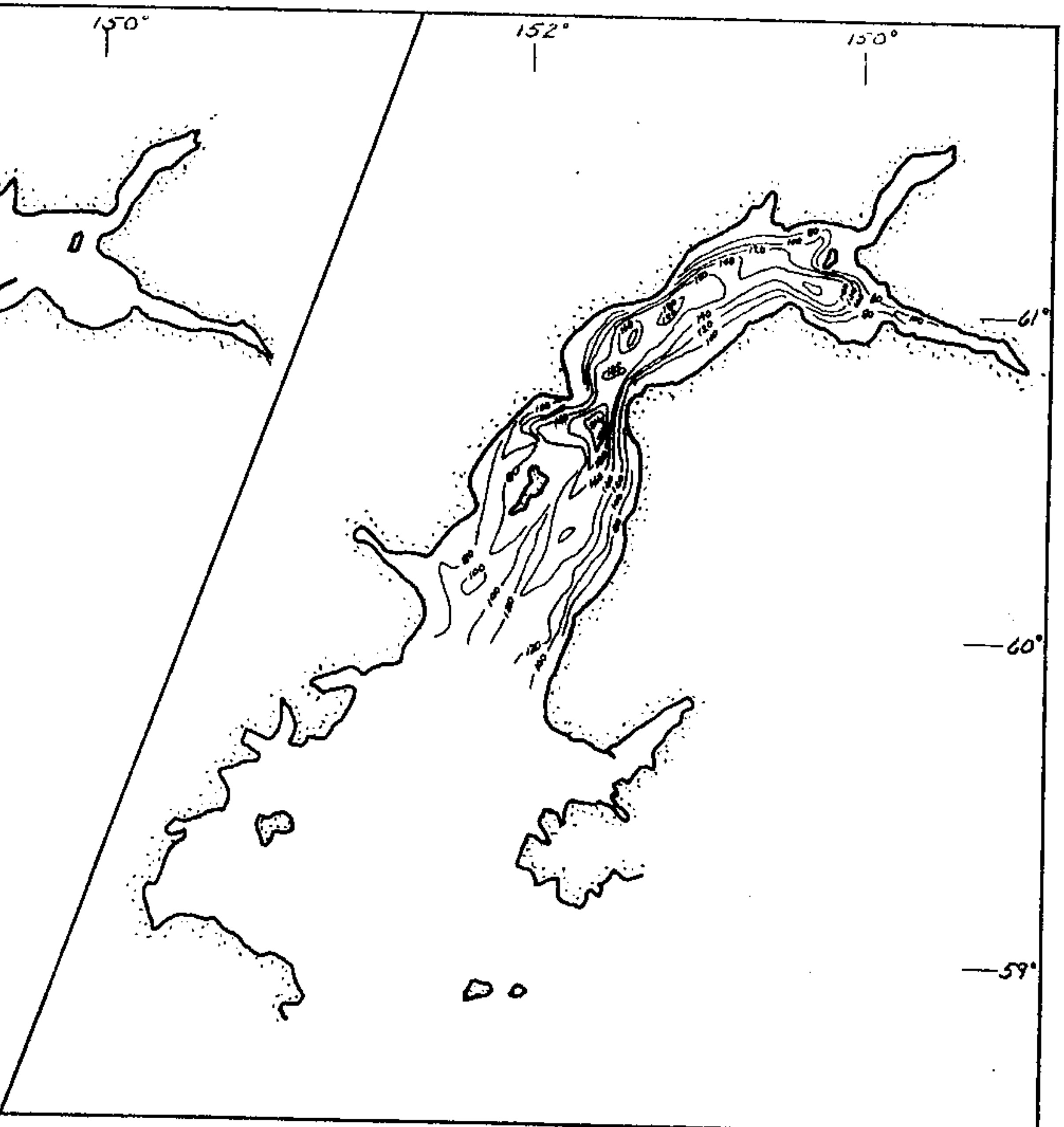


Fig. II-5 MAXIMUM TIDAL-CURRENT CONTOURS PREDICTED FOR COOK INLET. CONTOUR VALUES ARE GIVEN IN CENTIMETERS PER SECOND.

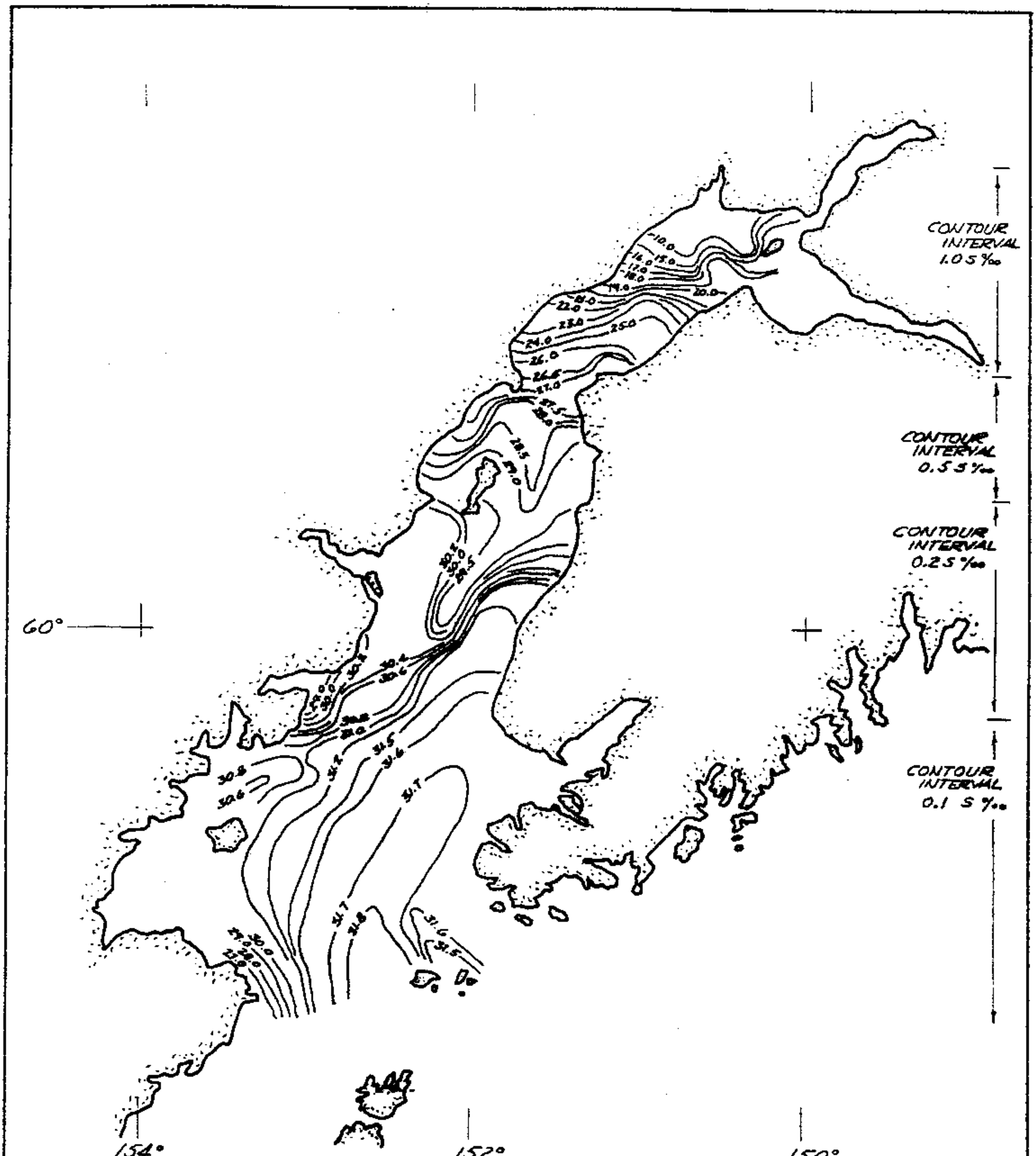


Fig. II-4 SURFACE SALINITY DISTRIBUTION, COOK INLET states that local velocities of 8 knots are known in several areas. Higher velocities can be expected in the deeper channels.

Sandy gravel and gravel are the sediments found typically in this region.

In the Lower Inlet, water masses of differing salinity retain their separation. In the western sector, a vertical stratification develops with colder, saline, oceanic water that underlies warmer, less saline Inlet waters. At the latitude of Tuxedni Bay, the rising bottom of the basin forces the deeper oceanic water to the surface during tidal inflow where it mixes with Inlet water. This action is most significant in moving nutrients such as phosphorus and nitrites into the photic zone from deeper waters (Fig. II-6 and II-7; Kinney et al. 1970b). These waters of deeper origin are also usually colder and slightly lower in dissolved oxygen than surface waters adjacent to this area.

Sediments of the Lower Inlet are gravelly sand with minor amounts of silt and clay interspersed.

Fresh water runoff into the Upper Inlet is a second important source of nutrients and sediments to the basin. Large quantities of nitrate, nitrite, silicate and suspended sediments with particulate organic carbon enter the Inlet with fresh water. Concentrations are especially high in the initial runoff each spring. These additions decrease in concentration down the Inlet upon subsequent mixing with saline oceanic waters and tidal action (Figs. II-8, II-9 and II-10). The large input of fresh water dilutes and tends to reduce salinity and phosphate concentration around river mouths. The outflow of this fresh water proceeds down the western side of the Inlet passing oceanward east of Augustine Island and west of the Barren

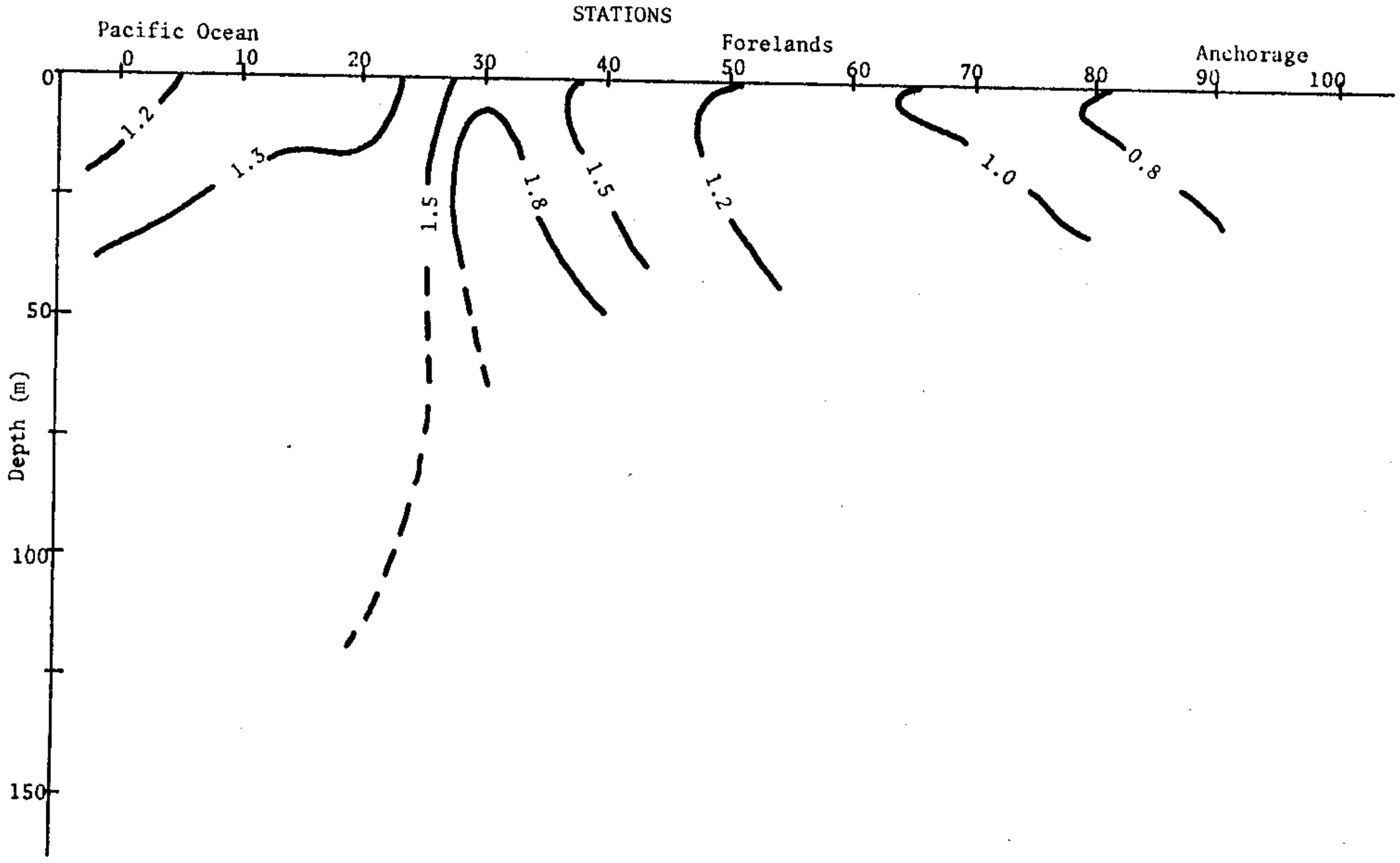


Fig. II-6 COOK INLET - MEDIAN TRANSECT ISOPLETHS OF PHOSPHORUS IN μg-At P/1

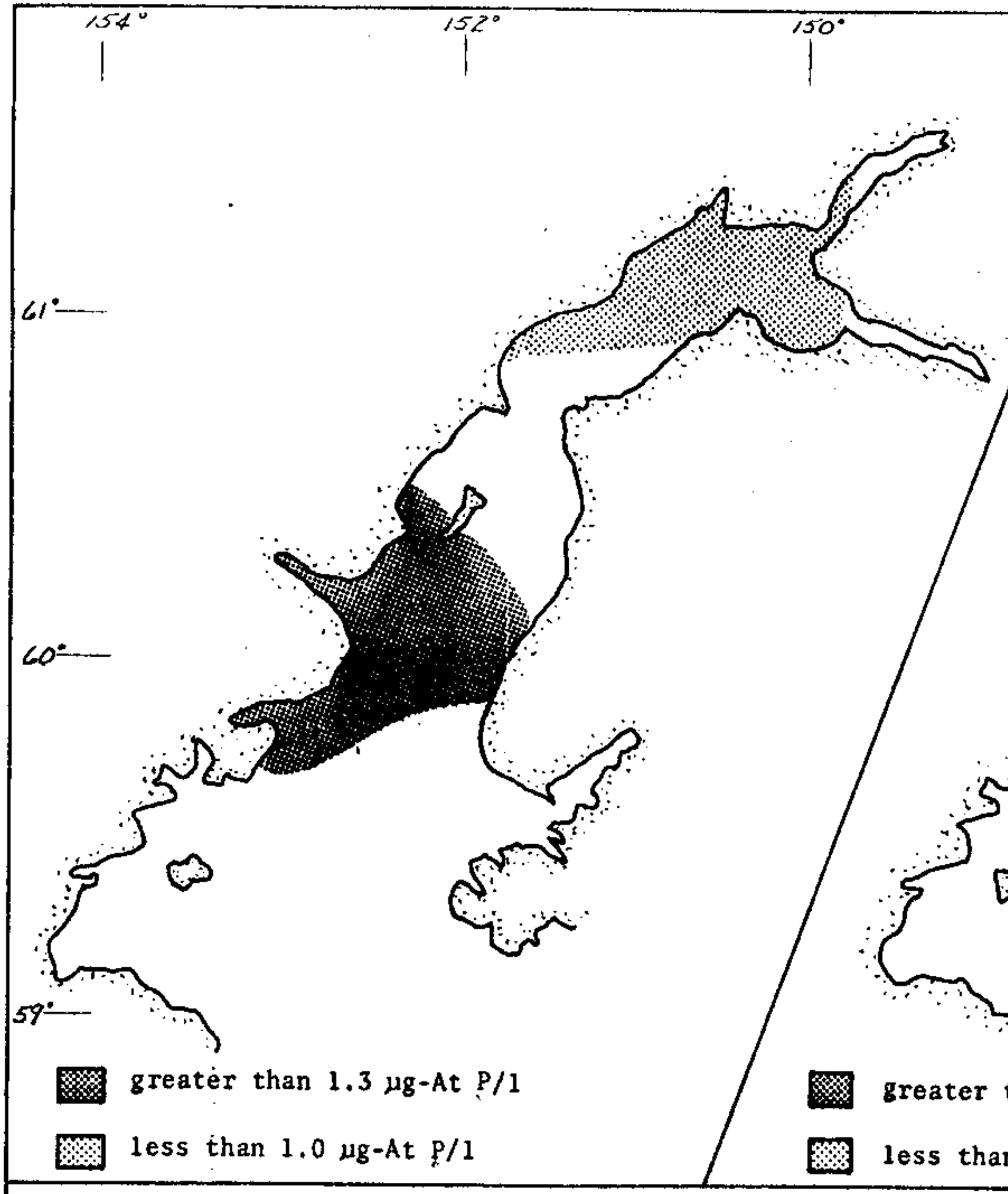


Fig. II-7 SURFACE PHOSPHORUS CONCENTRATIONS

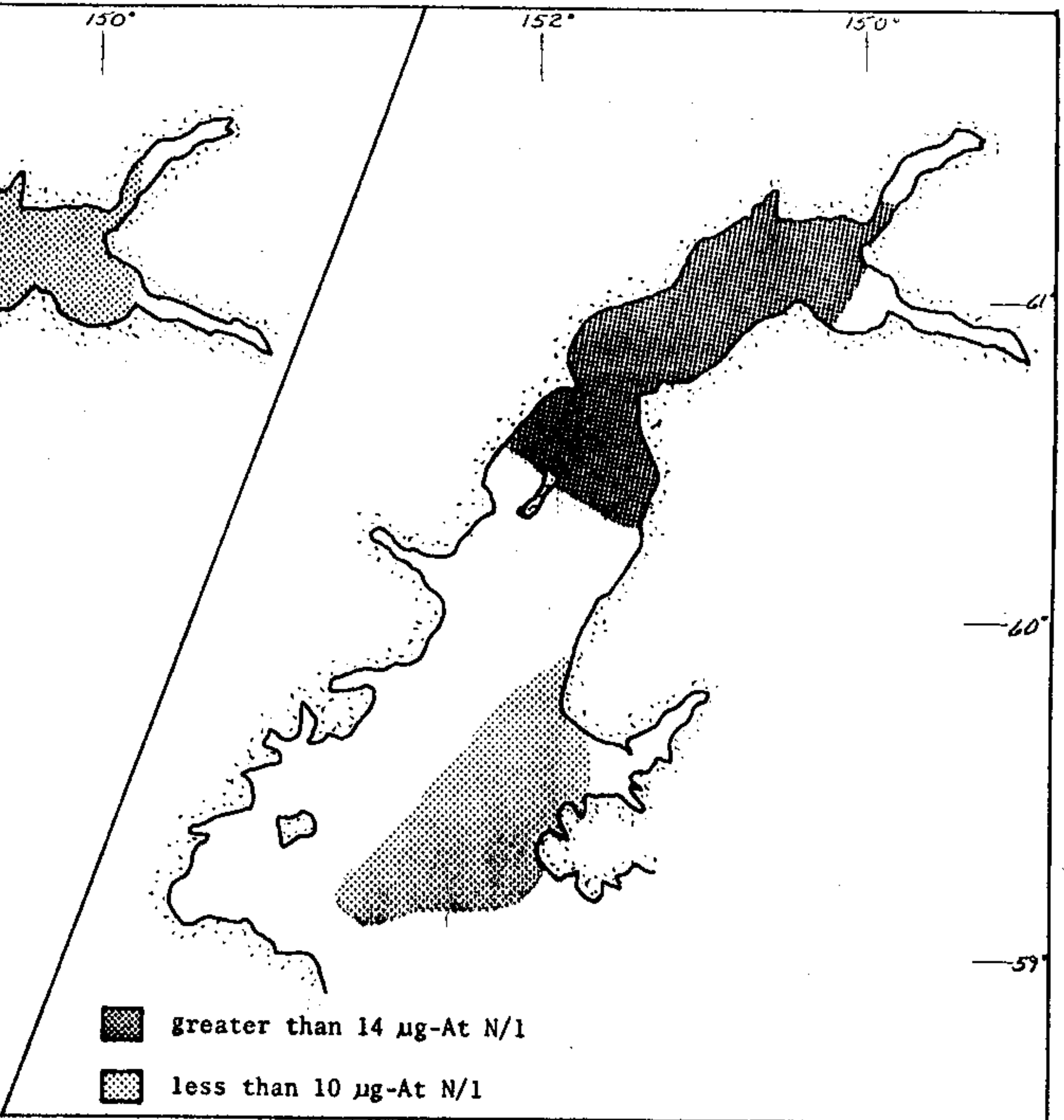


Fig. II-8 SURFACE NITRATE CONCENTRATIONS

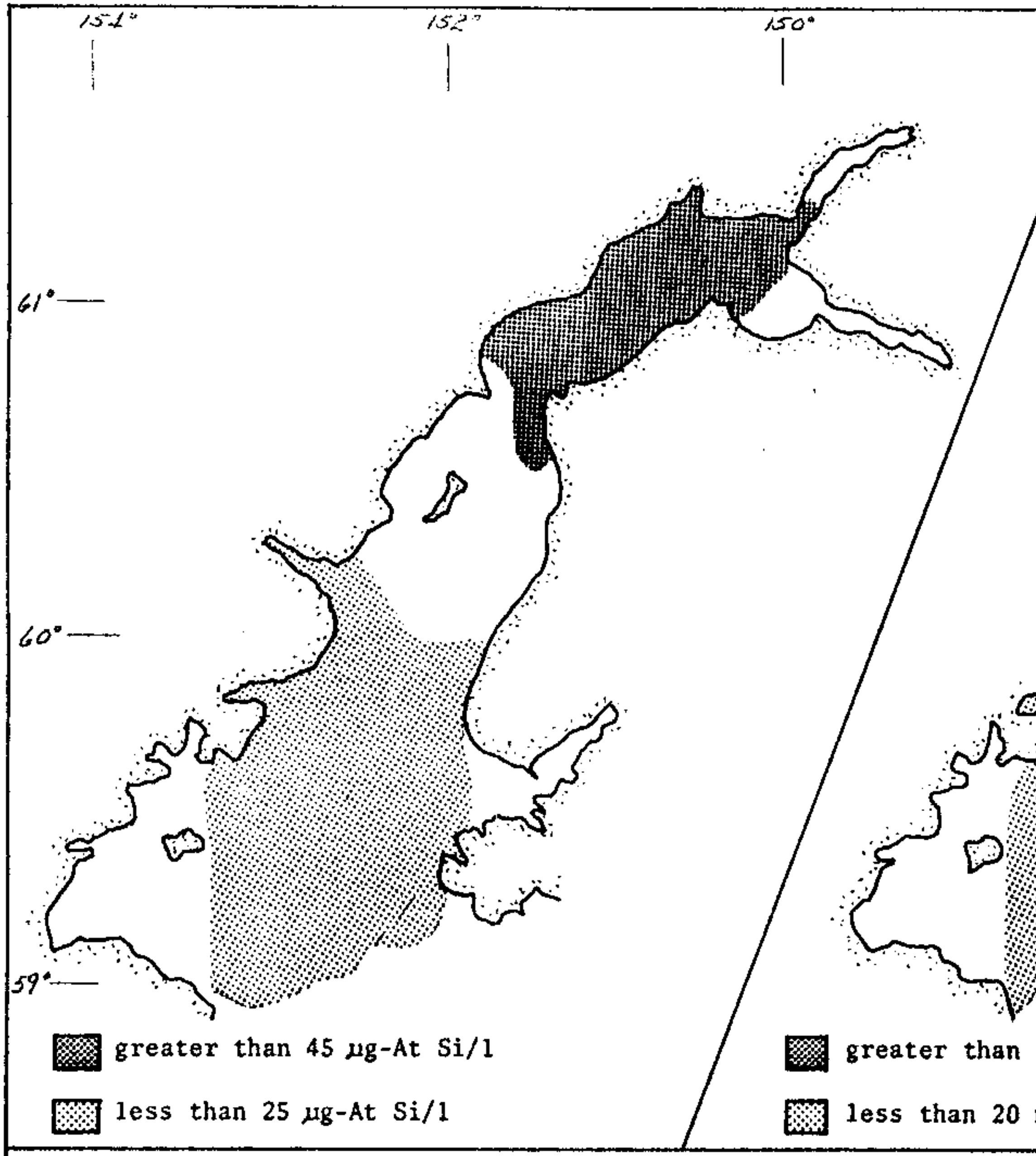


Fig. II-9 SURFACE SILICATE CONCENTRATION

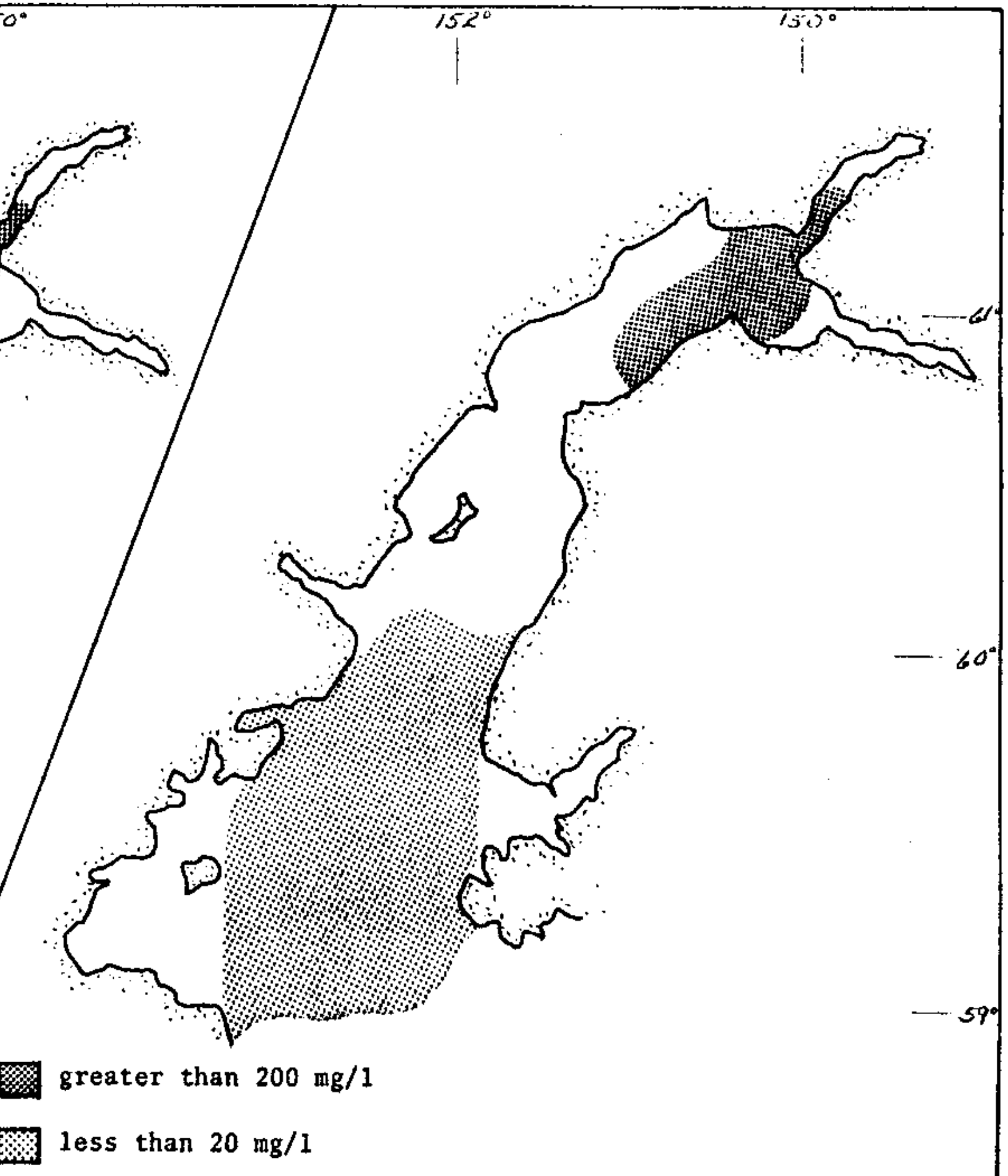


Fig. II-10 SURFACE SUSPENDED SEDIMENTS CONCENTRATIONS

Islands (Kinney et al. 1970b).

Phytoplankton blooms, particularly in the Lower Inlet, modify the general pattern of water chemistry by increasing oxygen and organic carbon locally while reducing nutrients such as phosphate, nitrate, and silicate. The reduction in silicate is most marked where the bloom is primarily diatom in composition.

Seasonal variations occur primarily in fresh water melt and runoff. Heavy runoff causes increasing movement of water out of the Inlet and generally less saline conditions in the Upper Inlet from May through September. During the remainder of the year, runoff into the basin is greatly reduced and there is a net intrusion of saline water up the Inlet. This pattern is illustrated by Knik Arm salinity measurements of 7-9 ppt during August and 23 ppt in April (Murphy et al. 1972).

Following this pattern; floating debris would move, in an oscillating path, down the Inlet in the warmer months. This movement might be as much as one mile net oceanward in Knik Arm at such times (Murphy et al. 1972). During the colder months, debris would tend to oscillate about a fixed point, since no net outward movement of water occurs.

Floating materials in the Middle and Lower Inlet would tend to circulate with the general flow up the east side and down the west side, and eventually out into the Shelikof Strait.

This generalized picture of circulation in the Inlet should be applied with caution to specific design proposals. Carstens (viva voce) believes detailed studies should be required before approval is given for structures that would be influenced by flows along the shoreline where irregularities could exert influence. This seems reasonable in the light of Matthews and Mungall's (1972) determination that a tidal phase error of as much as 13^{o} could result from application of his mathematical model. Plate 3 illustrates this problem as it applies to a loading terminal where proper alignment of the wharf with tidal currents would have facilitated berthing operations.

Carstens (viva voce) also pointed out that a physical model might be difficult to construct and operate because of the high coriolis force exerted on Inlet waters resulting from the high latitude and swift current velocities.

Plate 3 Detailed tidal current studies can prevent the difficulties inherent in the misalignment of structures.
U.S. Fish and Wildlife Service photo. C.D. Evans.

BIOTA OF COOK INLET

PLANKTON AND INTERTIDAL ORGANISMS

Plankton abundance is a measure, not only of the productivity of a body of water, but also of the food supply for higher forms. Baseline information on plankton species and their abundance in the Inlet at various seasons that could provide a measure of change are limited. Such studies have been conducted in detail in very few places in Alaska. Available material on Cook Inlet should be used as a baseline standard only with caution. It has value for comparison, however, and the sampling stations should probably be re-run when changes in quality or productivity of the water are suspected.

Phytoplankton

Studies carried out for the Collier Carbon and Chemical Corporation monitoring program (Rosenberg et al. 1967, 1969; Hood et al. 1968), for the Greater Anchorage Area Borough for its sewer system (Murphy et al. 1972), baseline studies of Cook Inlet conducted by the Institute of Marine Science of the University of Alaska (Kinney et al. 1970b) and oceanographic studies conducted by the U.S. Bureau of Commercial Fisheries in Kachemak Bay (Knull and Williamson, 1969 a, b and c) have included some information on species composition and abundance of phytoplankton.

Phytoplankton surveys in Cook Inlet indicate that number of species and abundance increase as one moves down the Inlet oceanward. Primary production appears limited in the Upper Inlet by reduced light penetration resulting from high suspended sediment loads and photosynthesis is confined to a shallow photic zone (Murphy *et al.* 1972).

The high silicate content of incoming sediments (Murray, 1972) and the high silicate content of Inlet waters (Kinney *et al.* 1970b) appear to favor the growth of diatoms which are by far the dominant phytoplankters.

Table III-1 lists the dominant species of phytoplankton found in the Forelands region - all diatoms (*Bacillariophyceae*). There are also scattered reports of silicoflagellates and tintinnids. In all, a total of 34 genera of diatoms have been reported in the Upper Inlet with several additional taxa of phytoplankters reported in the Lower Inlet during one sampling period. Data are available on seasonal species composition and abundance at Nikiski, but they appear to be closely correlated with variability in the number of stations sampled and they have not been included.

Table III-1 MAJOR PHYTOPLANKTON SPECIES IN COOK INLET

Melosira sp.

Melosira fulcata

Biddulphia aurita

Coscinodiscus sp.

Coscinodiscus lineatus

Coscinodiscus oculus-iridis

Coscinodiscus stellaris

Actinoptychus sp.

Actinoptychus undulatus

Fragilaria sp.

Cocconeis sp.

Cocconeis scutellum

Ditylum brightwellii

Cyclotella sp.

Asterionella sp.

Asterionella kariana

Studies within Kachemak Bay (Knull and Williamson,. 1969 a, b and c) found Chaetoceros defilis usually the most abundant species except for two stations in the inner bay where a Thalassirosira species was dominant early in the year and later replaced in dominance by a Cerataulina species. In the outer bay, Fragilaria and Thalassiosira were numerous early in the year and were replaced by Chaetoceros in July.

A summer survey of Knik Arm in the Anchorage vicinity (Jackson, 1970) identified 10-20 taxa of diatoms. Predominent genera were Actinoptychus, Coscinodiscus, Pleurosigma, Rhizosolenia and Melosira. In Turnagain Arm this same investigator found Naviculoid diatoms to be dominant.

Zooplankton

As in the case of phytoplankton, detailed information on species abundance and diversity has not been obtained. The same data sources are available, however.

The Institute of Marine Science (Hood et al. 1968; Rosenberg et al. 1969) in their studies for Collier Chemical Corporation at Nikiski lists 65 species of the phyla and orders shown in table III-2.

Jackson (1970) in his surveys of plankton in the Upper Inlet, listed species of

TABLE III-2
ZOOPLANKTON RECORDED IN COOK INLET AT NIKISKI

Phylum	Order	Number of taxa
Protozoa	Radiolaria	2
Coelenterata	Hydrozoa	9
	Scyphozoa	1
Ectoprocta	-	5
Nematoda	-	1
Annelida		6
Mollusca	Gastropoda	1
	Unidentified	1
Chordata		2
Arthropoda	Copepoda	6
	Cladocera	1
	Ostracoda	1
	Amphipoda	9
	Isopoda	1
	Mysidacea	4
	Euphausiacea	3
	Decapoda	5
	Cumacea	3
	Pycnogonida	4
8		65

Cladocera, Copepoda, Protozoa and Rotifera in Knik Arm.

Intertidal Organisms

The Institute of Marine Science also sampled intertidal organisms at Nikiski (Hood et al. 1968; Rosenberg et al. 1969). Table III-3 lists the 46 taxa they found growing in situ. They also recorded another 2 taxa which had washed ashore.

Jackson (1970), in his reconnaissance of the Upper Inlet intertidal zone listed the forms in table III-4.

Hood et al. (1968) and Rosenberg et al. (1969) provide data on abundance and number of species by month, but it appears to be so influenced by the number of stations sampled that the information is not included here.

Other records that would provide useful Inlet-wide baseline information are not available.

The impact of oil development on plankton and intertidal organisms in Cook Inlet is difficult to predict. U.S.D.I. (1972) believe that the effects of toxicity in spilled oil would be more serious in the case of chronic low level spills than a single major spill. They cite Mileikovsky (1970) who believes that in the case of a single spill, new populations would be brought in from other areas. With the relatively low rate of circulation in Cook Inlet, however, it might be expected that such replacement would be slow. The same source (U.S.D.I., 1972) cites Mironov and Lanskaye (1968) as stating that the diatom Ditylum brightwellii (common in Cook Inlet) was the most sensitive to crude oils and kerosene of 20 species of marine phytoplankton tested. They believe there is a wide variation between species in this regard.

TABLE III-3
INTERTIDAL ORGANISMS RECORDED AT NIKISKI

Phylum	Order	Number of taxa
Chlorophyta	-	5
Coelenterata	Hydrozoa	4
	Anthozoa	1
Ectoprocta	-	4
Platyhelminthes	-	1
Brachiopoda	-	1
Annelida	Polychaete	2
Mollusca	Gastropoda	6
	Lamellibranchia	5
Arthropoda	Amphipoda	7
	Cirripedia	2
	Decapoda	3
	Isopoda	4
	Pychnogonida	1
		46

TABLE III-4

INTERTIDAL FORMS IN UPPER COOK INLET
(from Jackson, 1970)

Knik Arm	Turnagain Arm	Kalifonsky Beach
Vaucheria	Amphipods	Amphipods
Cladophora	Decapods	Decapods
Ulothrix	Fucus	Mytilus
Enteromorpha		Acorn barnacles
Oscillatoria		Clams
Flatworms		Sea anemones
Oligochaetes		Snails
Nematodes		Brown algae
Amphipods		
Decapods		
Diptera		

FISHERIES

The greatest potential for impact by development activity in Cook Inlet appertains to fishery resources. These renewable resources are not only of significant commercial value, but also provide important recreation and secondary economic and social benefits associated with sport fishing and tourism.

The fishery resource is sensitive to numerous factors related to human activities, including exploration for and production of petroleum. Water pollution, for instance, can alter quality and the productivity of marine ecosystems, and such activities as geophysical surveys may include detonation of explosives that can damage the fish themselves.

Various species of both fin fish and shellfish are important in the economy of Cook Inlet. Exploratory deep water trawls conducted by the U.S. Bureau of Commercial Fisheries, for instance, revealed the presence of 25 species of fin fish, of which butter sole, yellow fin sole, turbot and pollock were most abundant. They also recorded five species of shrimp, three species of crabs, octopus, scallops and other invertebrates. Systematic inventories of pelagic species have not been made.

Appraisal of probable impacts of any activity on such a biotic resource as fisheries depends, among other things, on the abundance in time and place of the fish population and its food supply and on the sensitivity of the species and its food supply to impact from the proposed activity at various times and places.

Fin Fish

Fish populations in Cook Inlet include anadromous species, such as the salmon and eulachon, and resident species, such as flounders and sculpins. Other species, while not anadromous, may be considered migratory, coming into shallower water at certain times of the year. The halibut falls into this category.

Salmon

All five North American species of Pacific salmon, the chinook (*Oncorhynchus tshawytscha*), sockeye (*O. nerka*), pink (*O. gorbuscha*), coho (*O. kisutch*) and chum (*O. keta*) inhabit Cook Inlet in important numbers.

The Cook Inlet - Resurrection Bay area has been divided for management purposes into seven districts as shown in Fig. III-1. The dividing line between the Kamishak Bay district and the Outer District nearly coincides with the boundary of Cook Inlet as it is described for purposes of this report. Remarks relating to commercial fisheries will refer to the five districts in Cook Inlet - Northern, North Central, South Central, Southern and Kamishak Bay. Some of the data sources also combine the North Central and South Central into one district.

Ideally, information would be provided on numbers of fish of each species in each district at various seasons. Such information is not available for salmon, however. Because much of the Cook Inlet salmon population is widely distributed and either spawns in or travels through turbid waters, spawning ground survey information

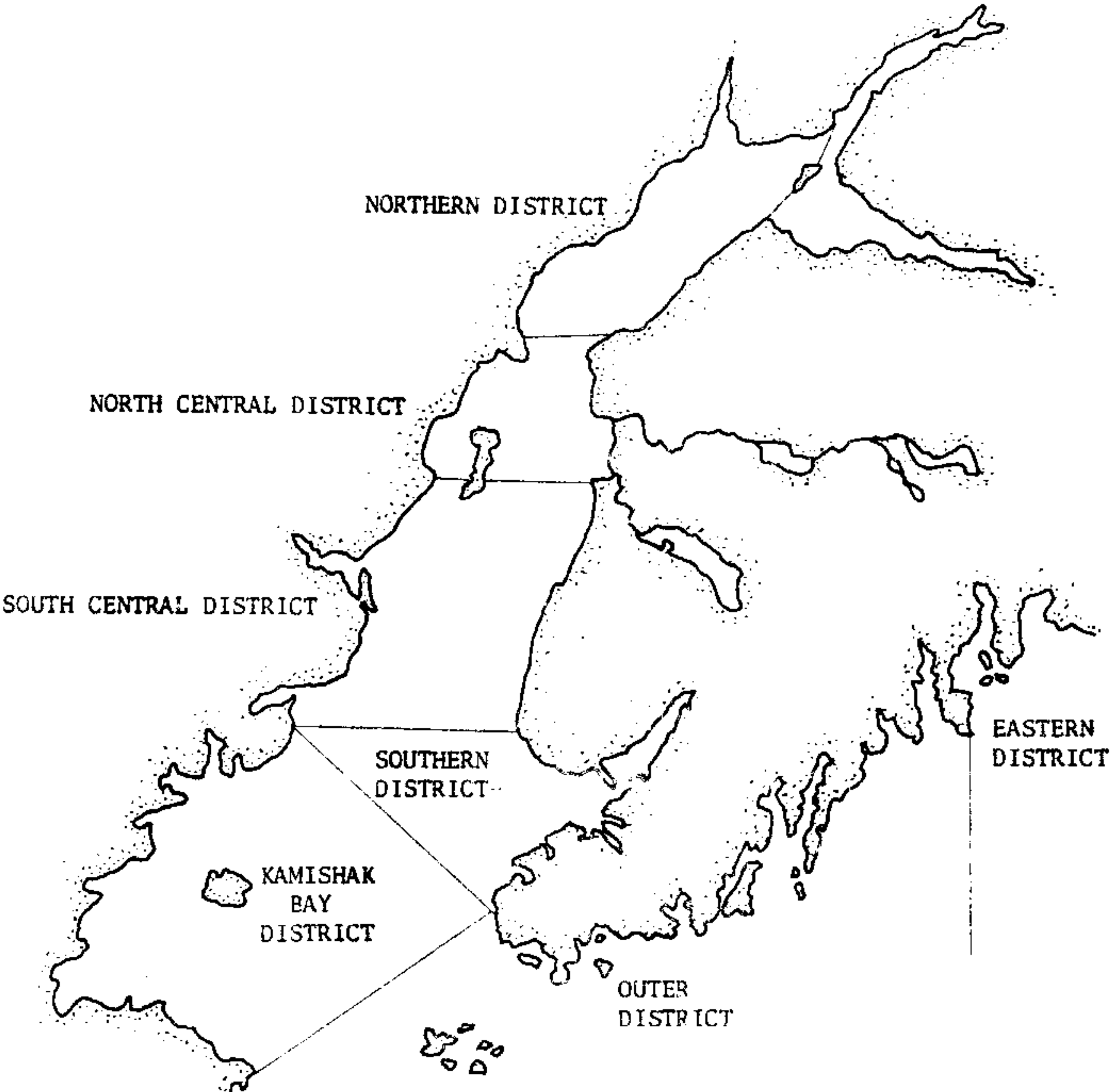


Fig. III-1 COOK INLET - RESURRECTION BAY COMMERCIAL FISHERY MANAGEMENT DISTRICT is limited and exploratory fishing has not been intensive enough to provide usable information. Reliance, therefore, must be on catch information supplemented by such stream survey data as is available.

Catch information has been derived from records of the Alaska Department of Fish and Game, Commercial Fish Division. In order to determine trends, some old records, dating back to 1893 have been used. Recent data are emphasized, however.

Catch records do not in themselves tell the entire story of either the distribution of the fish or the distribution of the fishing effort, both of which can vary independently.

As an example, table III-5 shows the licensed gear for the five districts for the 1968 season. There is no information, however, on the amount of gear actually fished or of the length of time it was fished. Many people may have had licensed gear for that year with no intent to use it because of anticipated curtailment of entry into the fishery. Other licenses were believed to be held in the belief that holders of existing licenses would receive preferential treatment in the allocation of future licenses. Regulations, such as gear restriction or length of fishing periods, also affect the distribution of the catch. Effort in 1968, as represented by licensed gear, was greatest in the Central Districts (Flagg, 1970).

TABLE III-5

LICENSED COMMERCIAL FISHING GEAR - COOK INLET 1968

(1395 Salmon Gear License Holders)

District	Type of Gear Permitted	License Holders
Northern	Set nets only	About 150 set netters
North Central	Set nets	About 350 set net sites*
South Central	Drift nets	612 drifters
Southern	Handpurse seiner	80 seiners
	Set nets	12 set netters
Kamishak Bay	Seines only	10 seine boats

* Up to 3 set nets permitted at one site, depending on district and year

Trends in salmon harvest for the 76 year period 1893 to 1969 are shown in terms of ten-year averages in table III-6. Several trends are brought out in this table. There has been in recent years a drastic reduction in harvest of chinook salmon. The catch for the period 1960-69 was only 14.5 percent of the maximum ten-year average of 91,600 fish for the period 1940-49. How much of this results from a reduction in salmon population and how much results from more restrictive regulation can only be conjectured.

Harvests of sockeye have held relatively steady, although concern was expressed over an inadequate escapement in the late 50's (ADFG, 1959). Even-numbered years during the 1960-69 period produced the highest average pink salmon harvest in the history of this fishery.

Surprisingly, the coho and chum harvests appear to be highest in even years, even though these species are normally four-year fish.

This information, while not directly applicable to the problem at hand,

TABLE III-6
TEN YEAR HARVEST AVERAGES COOK INLET SALMON

(Thousands of fish)

	Chinook	Sockeye		Pink	Coho	Chum	Total
1893-1899	19.3	382.3					
			O*		39.0(3)		402.8
			E*	38.0(1)+	43.3(3)		495.0
1900-1909	39.4	486.7					
			O	5.3(3)	83.2(4)		555.2
			E	172.7(3)	57.4(5)		727.8
1910-1919	51.4	1395.9					
			O	40.0	104.8	34.4	1637.4
			E	1108.0	160.0	79.8	2771.4
1920-1929	49.3	1250.9					
			O	137.0	187.0	54.8	1649.6
			E	597.0	313.0	85.4	2324.6
1930-1939	64.6	1606.6					
			O	364.6	211.8	138.6	2230.2
			E	821.4	340.2	143.4	3132.2
1940-1949	91.6	1645.6					
			O	1061.2	333.8	274.4	3349.2
			E	1714.6	488.2	365.8	4363.2
1950-1959	78.6	1352.5					
			O	539.4	186.2	553.0	2624.2
			E	2045.6	287.4	630.8	4460.4
1960-1969	13.3	1176.3					
	(14.5%)++	(71.5%)	O	177.5(16.7%)	152.0(45.6%)	356.1(64.5%)	1875.2(56.0%)
			E	2659.5(100%)	379.2(77.8%)	920.1(100%)	5148.4(100%)

*O=odd numbered years
E=even numbered years

+ Figures in parenthesis indicate number of years data available
++ The percentage of maximum 10 year average catch represented by the 1960-69 average catch.

serves to point out some of the problems involved in interpreting available information.

Better information on distribution of fishing effort would permit derivation of catch per unit effort and provide data on population trends.

A further breakdown of the 1960-69 average harvest by species by district is shown in table III-7.

TABLE III-7

TEN-YEAR AVERAGES 1960-69 SALMON HARVEST - COOK INLET
(thousands of fish)

District	Chinook	Sockeye	Coho	Pink	Chum	Total
all years						
Northern	3.8	108.5	91.1	225.5	65.4	494.3
Central	9.5	1,051.2	171.0	955.0	536.9	2,723.5
Kamishak	tr	1.5	0.5	41.9	26.1	70.0
Southern	tr	15.1	3.0	196.1	9.7	223.9
Total Harvest	13.3	1,176.3	265.6	1,418.5	638.1	3,511.8
even years						
Northern			144.4	443.0	96.5	796.2
Central	as	as	230.4	1,887.1	781.0	3,959.3
Kamishak	above	above	0.1	46.7	31.0	79.3
Southern			4.3	282.6	11.6	313.6
Total even year			379.2	2,659.5	920.1	5,148.4
odd years						
Northern			37.9	8.0	34.3	192.5
Central	as	as	111.5	22.8	292.7	1,487.7
Kamishak	above	above	0.9	37.1	21.2	60.7
Southern			1.8	109.6	7.8	134.3
Total odd year			152.0	177.5	356.1	1,875.2

The very low catch in the Kamishak District could result as much from its remoteness as from lack of fish. Flagg (viva voce) [1/] points out that since

[1/] Flagg, Loren B., Commercial Fish Div., Alaska Dept. of Fish and Game, Homer.

1968 the catch of pink and chum salmon in that district has increased, probably as a result of increased interest. The high catch in the Central District could result from the fact that fish destined for spawning areas in the Upper Inlet as well as the productive Kenai-Kasilof systems pass through there.

Data are available by statistical area (Fig. III-2) in the files of the Alaska Department of Fish and Game. Its use is complicated, however, by lack of information on distribution of fishing effort and reduced size of individual samples. It will also be noted that subdistrict boundaries do not coincide with district boundaries. At the present time, the districts appear to be as fine a breakdown as is practical.

Chinook salmon - Fig. III-3 is a plot of the distribution of the commercial harvest of Chinook salmon by district for the years 1954 through 1971. Table III-8 presents these data in terms of the 1960-69 average catch.

TABLE III-8

TEN YEAR AVERAGE CHINOOK SALMON HARVEST

COOK INLET 1960-69. (thousands of fish).

District	No. of salmon	Percent of fish
Northern	3.8	28
Central	9.5	71
Kamishak	tr	--
Southern	tr	0.5
Total	13.3	

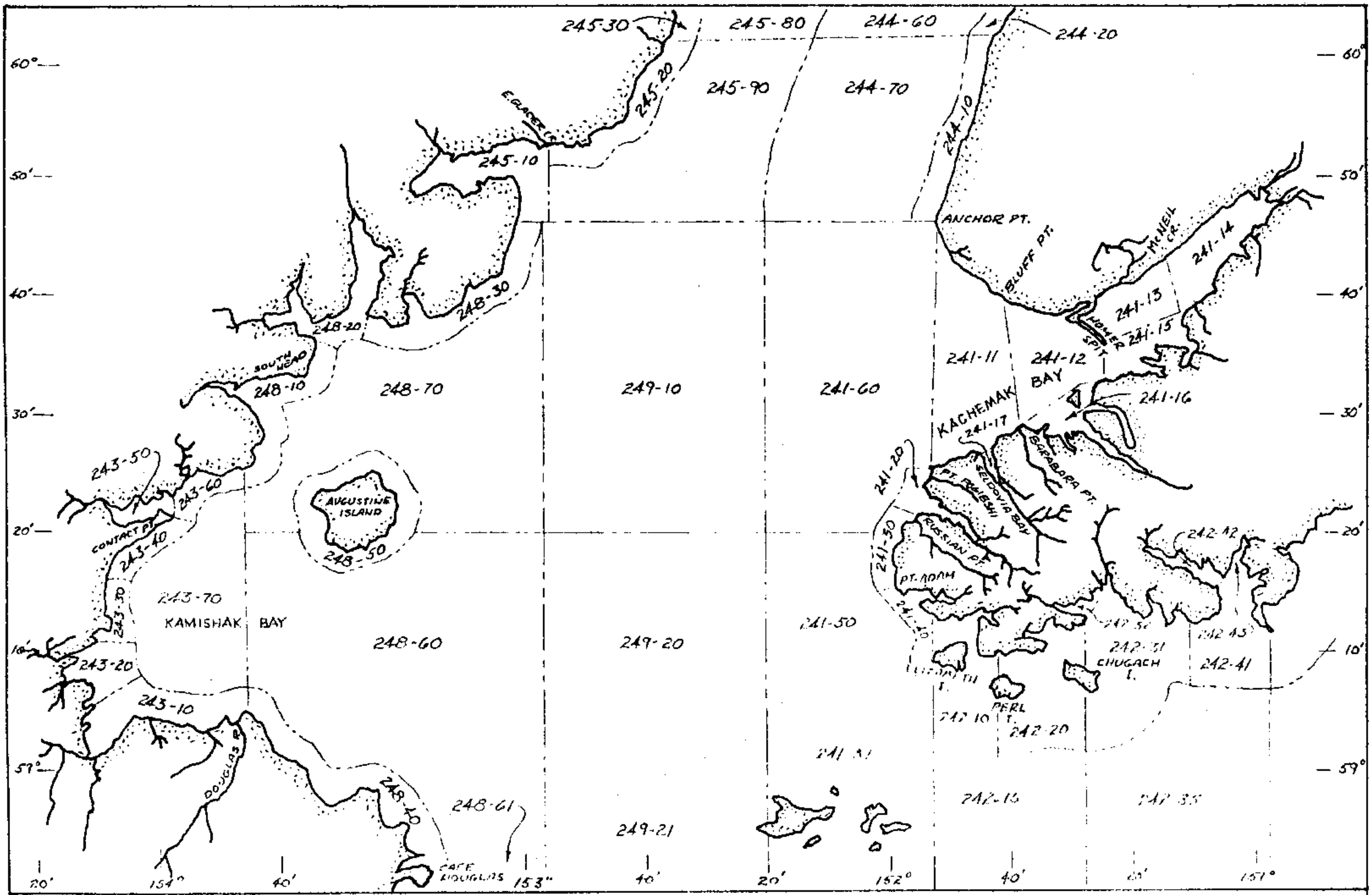


Fig. III-2 COMMERCIAL FISHING STATISTICAL AREAS OF LOWER COOK INLET

Fig. III-3 COOK INLET CHINOOK SALMON HARVEST 1954-1971

The declining harvest probably results in part from regulations imposed which outlawed chinook salmon gear, but permitted fishermen to retain chinook caught incidentally. The extreme reduction in catch in the Northern District for the years 1964-68 could result from effective protection of spawners bound for the Susitna system by a late opening of the commercial season. This is supported by increased escapements into Upper Cook Inlet streams recorded from 1964 onward (Table III-9) and an increased Northern District commercial harvest in 1971 when the season opened almost 2 weeks earlier than in any of the previous 5 years. Reduction of remnant runs by relatively successful harvest in the Central District or difference in timing of the runs are alternative explanations. Fig. III-4 shows the timing of the chinook salmon harvest for years 1966-71 in the Northern and Central Districts. The clear portion of the bars represent the initial and final 10 percent of the year's catch. When the entire initial or final 10 percent occurred in the first or last day of fishing, there is no such clear area. The transverse line is the date by which 50% of the year's catch had been attained. In general, the harvest in the Northern District is earlier, as indicated by the 50 percentile date. The heavy first day's catch (usually more than 10 percent of the year's harvest) in both districts indicates that the run was well under way before fishing started. In 1971, greater than 40 percent of the harvest for the Northern District was made on one day in the early part of the fishing season. In two cases, more than 50 percent of the year's catch was on opening day. It would appear that the harvest

TABLE III-9

CHINOOK SALMON ESCAPEMENT COUNTS, UPPER COOK INLET STREAMS, 1962-1969

Stream	1969	1968	1967	1966	1965	1964	1963	1962
Deshka River	5,652	4,863	2,500	2,000	2,749	2,422	131	998
Alexander Creek	735	727	500	300	400	205	750	19
Lake Creek	1,540	1,300	1,000	300	172	290	46	53
Chunilna Creek	375	1,000	*	300	8	319	38	70
Total	8,302	7,890	4,000	2,900	3,329	3,236	965	1,140
Ship Creek	710	500	200	50	207	94	119	58
Campbell Creek	*	125	300	15	119	116	187	40
S.F. Eagle River	*	28	50	49	159	123	135	*
Total	710	653	550	114	485	333	441	98
Willow Creek	290	125	24	103	35	51	55	71
Little Willow Creek	150**	12	6	38	3	7	11	26
Montana Creek	250**	5	2	100	57	75	23	75
Sheep Creek	150	*	*	100	3	*	24	35
Total	840	142	32	341	98	133	113	207

*No count available
**Schooled at mouth - counted by Commercial Fisheries Division

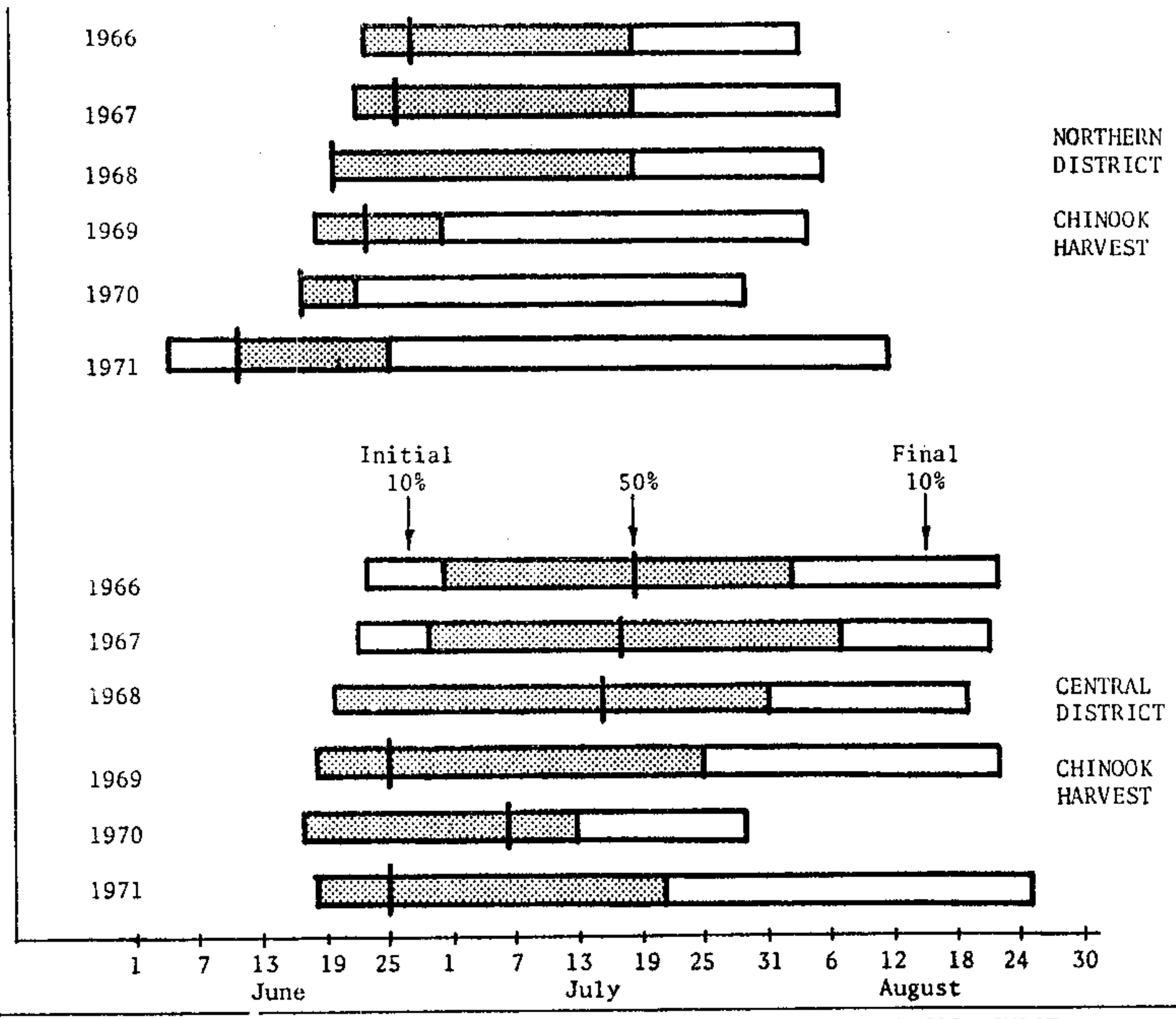


Fig III-4 TIMING OF CHINOOK SALMON HARVEST - UPPER COOK INLET occurs after most of the fish have passed through. It is then probable that the data reflect fishing for Susitna River fish in the Northern District and Kenai Peninsula-bound fish in the Central District. Table III-9 indicates the improved escapement to the Upper Inlet streams following regulation changes in 1964 (Kubik, 1970).

The probability that the catch is made up of late segments of the run is born out by observations of escapement. Chinooks were first seen in Alexander Creek in the Susitna drainage May 17 in 1961 (Kubik, 1962). In 1965, the run in the lower Susitna began late May, peaked in June 2-12 and was 97 percent over by June 25 (Kubik, 1966). The chinook run on the Anchor River in 1954 was reported to begin May 19-28, peak the first week in June and continue through the first week in August (Davis, 1955). Clearly, there are chinook salmon in the Inlet earlier than is indicated by the catch data and the discrepancy is probably greatest in the Upper Inlet.

Sockeye salmon - Sockeye salmon harvests for the years 1954-71 are shown in Fig. III-5 for the Northern and Central Districts. There are not enough data for the Southern and Kamishak Districts from which to draw conclusions. Again, most of the catch is in the Central District.

According to Davis (1969), major sockeye spawning systems are the Kenai-Russian Rivers, the Kasilof and Susitna Rivers and Fish Creek. These and other sockeye systems are shown in Fig III-6 taken from Davis and Kissner (1971). Fig. III-7 shows the timing of the sockeye salmon harvest from 1966 through 1971. Note the relatively even distribution of the initial

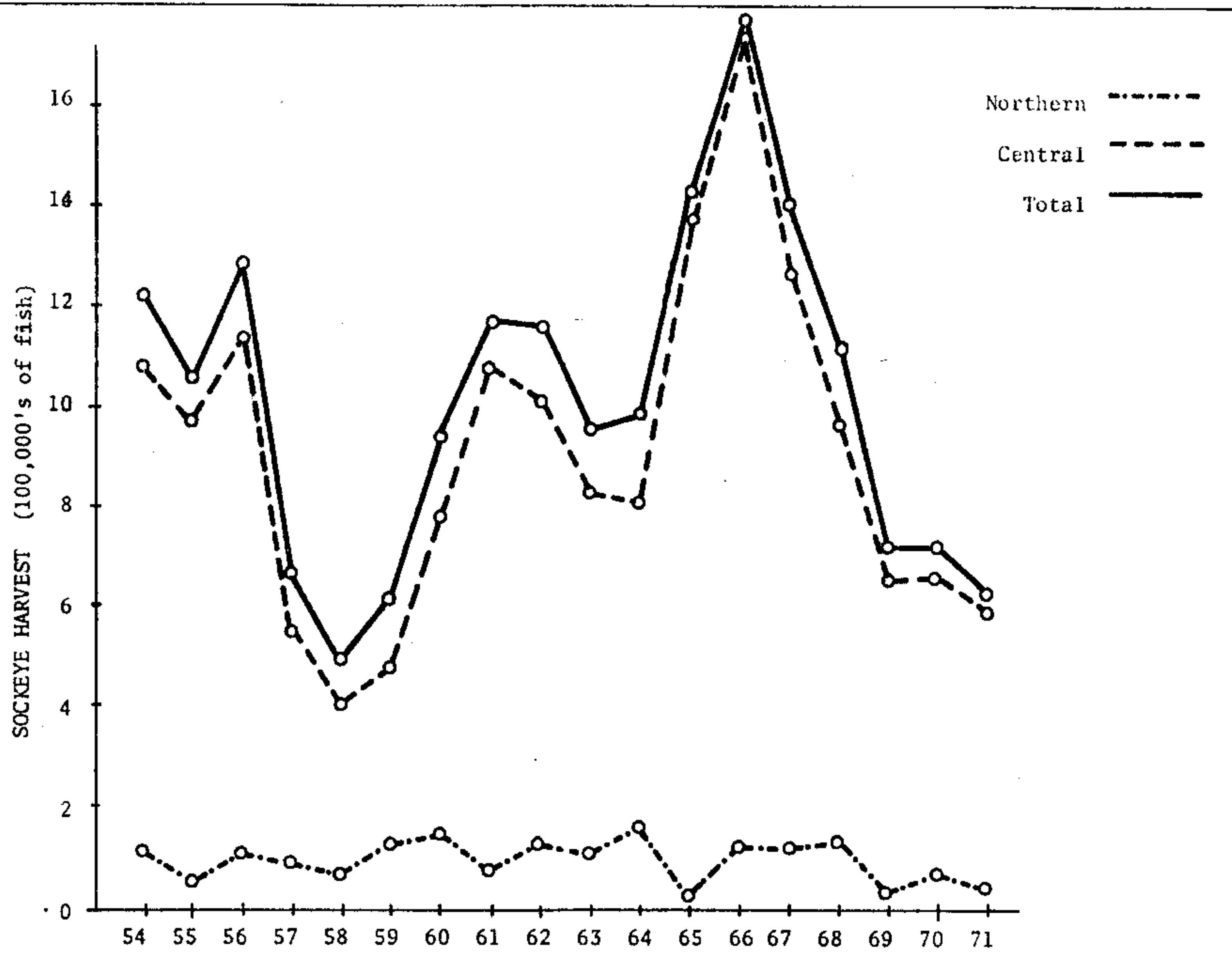


Fig.III-5 COOK INLET - SOCKEYE SALMON HARVEST 1954-1971

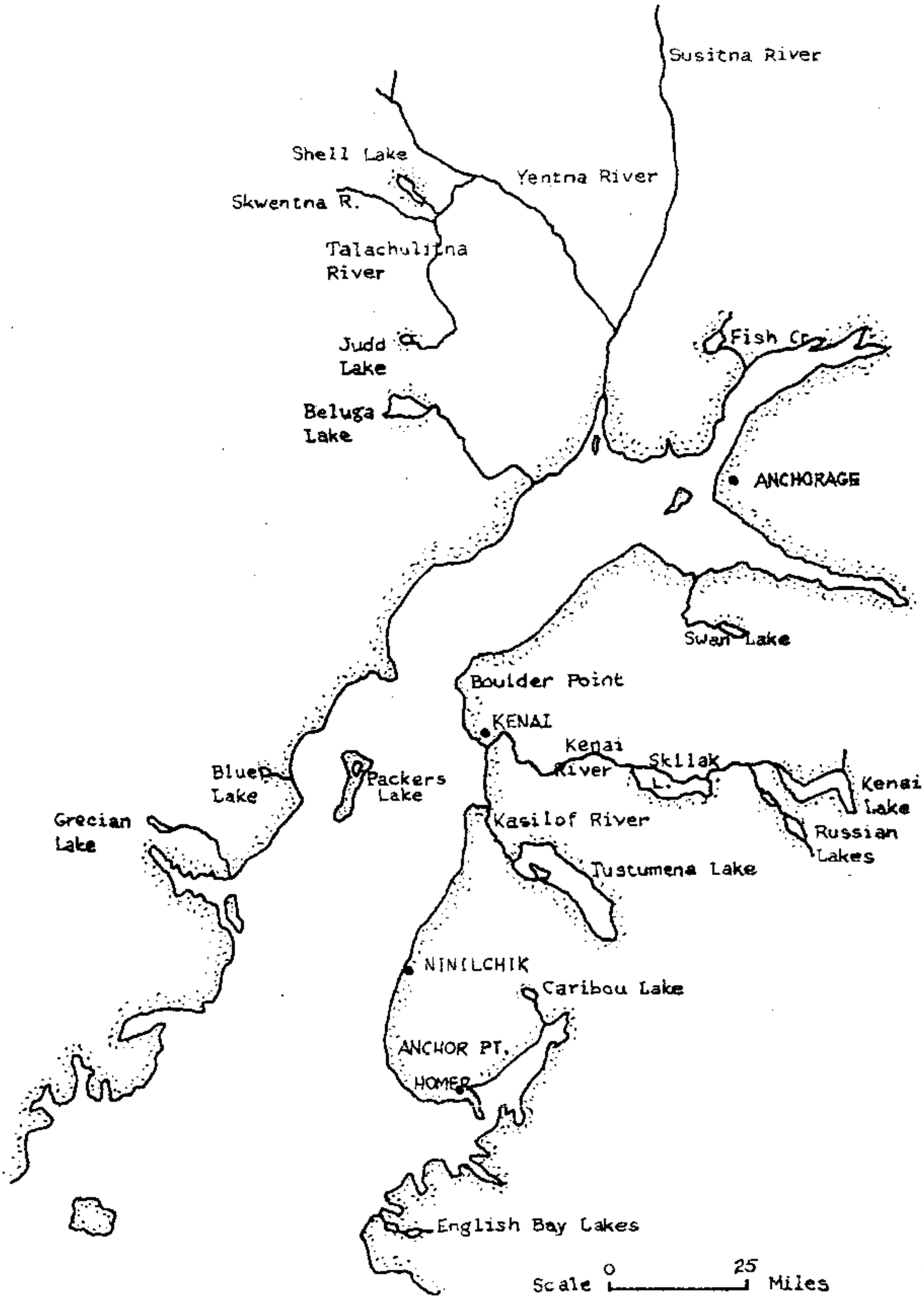


Fig. III-6 SOCKEYE SALMON SPAWNING SYSTEMS

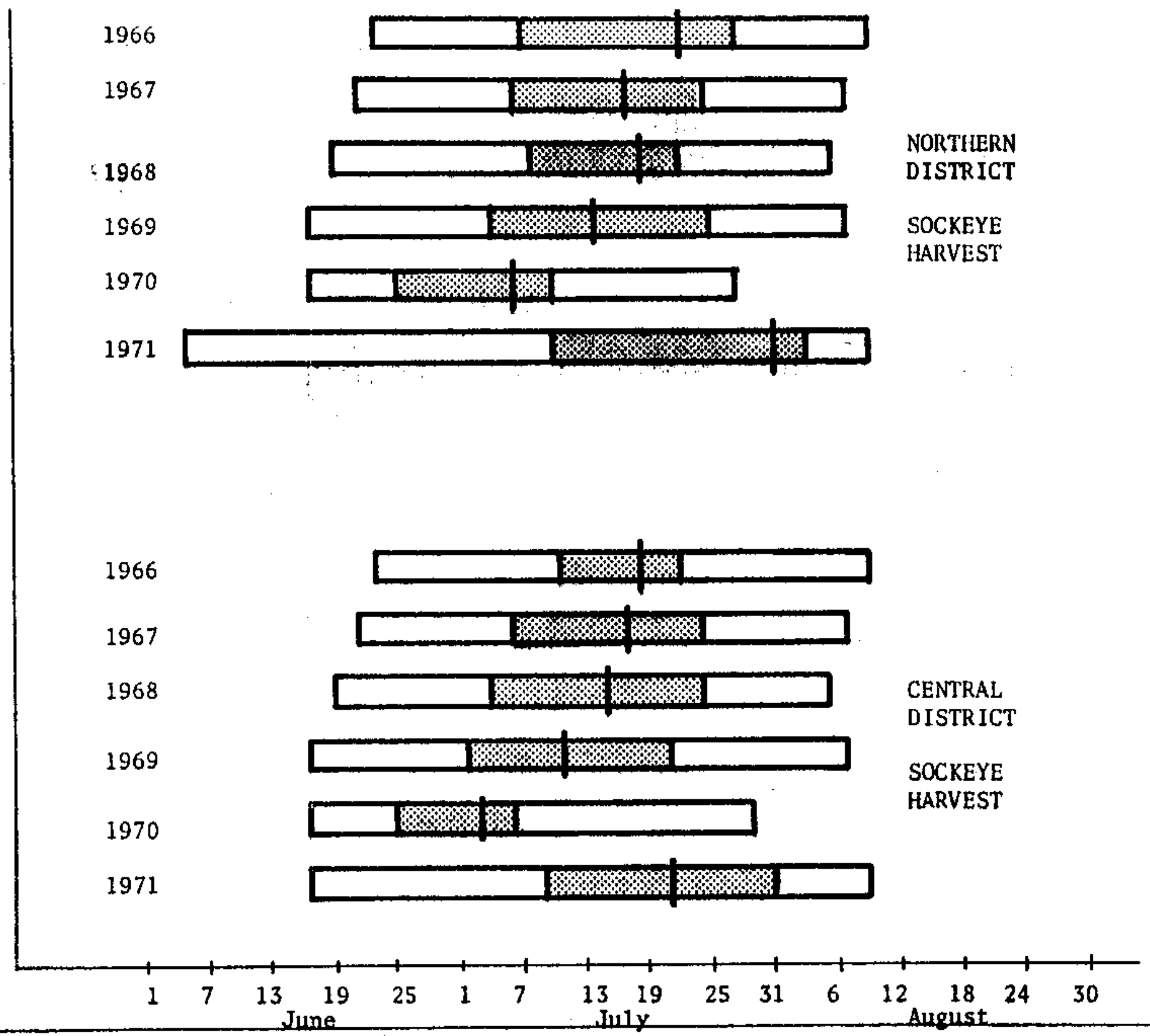


Fig. III-7 TIMING OF SOCKEYE SALMON HARVEST UPPER COOK INLET and final 10 percentile and the midpoint of the harvest, suggesting that the harvest was well distributed throughout the run. The skewness of the 1971 harvest distribution in the northern district is an exception which is, as yet, unexplained.

Observations of the run on spawning streams in 1969 indicate that the early run in the Russian River, judged to be all fish to arrive before July 15, peaked June 20-22. The late run, those fish arriving after July 15, peaked July 30 - August 6 (Davis and Kissner, 1970). Davis (1968) believes the Russian River receives about half the Kenai River run and that the Kenai River supports about 30 percent of the Inlet sockeye fishery. Comparison of the timing of the Kenai River runs for 1969 with the timing of the harvest for that year suggests that much of the early run into the Kenai River system escaped the fishery and that there were sockeye salmon in substantial numbers destined for the Kenai River system in the Inlet earlier than is indicated by the harvest data.

Pink salmon - Fig. III-8 presents the size of the pink salmon harvest for the years 1954-1971 for the Northern, Central and Southern Districts. The small harvest from the Kamishak District makes it insignificant to plot the catch for that area.

The ten-year average harvest for the period 1960-69 was 225,000 in the Northern District (16%), 955,000 for the Central District (67%), 42,000 for the Kamishak District (3%) and 196,000 for the Southern District (14%).

Because of the marked even-year periodicity in the pink salmon runs,

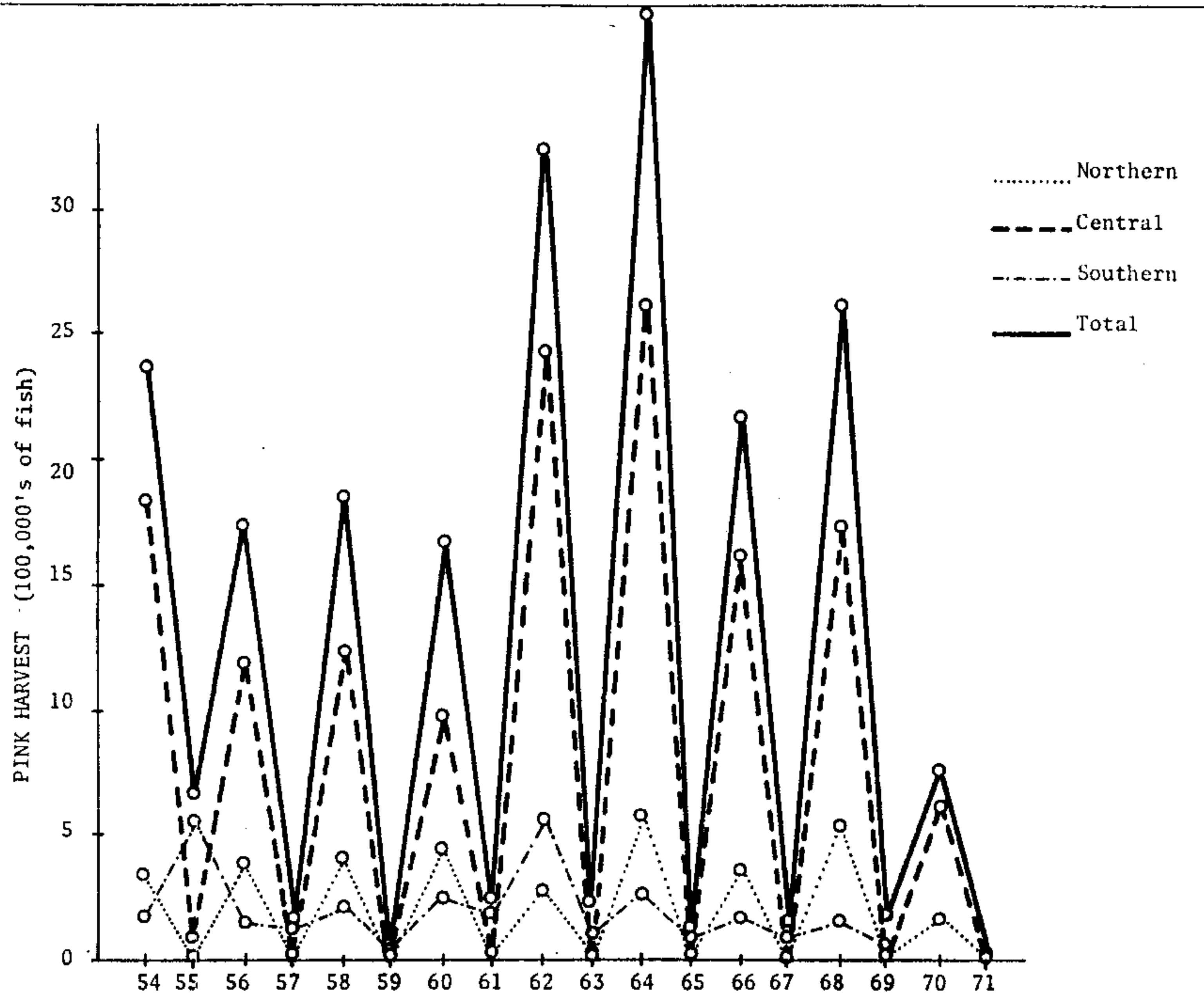


Fig. III-8 COOK INLET - PINK SALMON HARVEST 1954-1971 the even and odd year total catches for the period 1954 through 1971 have been plotted separately in Fig. III-9. Table III-10 shows the ten-year average for the period 1960-69 by district and points out that by far the greatest disparity between years is in the Northern and Central Districts. Fig. III-10 shows the timing of the pink salmon harvest for the even years 1966,68 and 70. The Northern District, which according to Davis (1970) is mostly supported by the streams of the Susitna River system, has a short harvest period. The Central District, with runs into more streams, has a longer harvest period. Again, as in the sockeye salmon, the harvest appears evenly distributed, suggesting that the run is fairly well sampled by the fishing effort.

TABLE III-10

PINK SALMON CATCH BY DISTRICT - ODD AND EVEN YEARS

TEN YEAR AVERAGE 1960-1969 (thousands of fish)

District	Even Years	Odd Years
Northern	443	8
Central	1,887	23
Kamishak	47	37
Southern	282	110
Total	2,659	178

Southern District pink salmon streams important to the Cook Inlet salmon fishery are shown in table III-11a from Davis (1970). Table III-11b provides some further detail on fishing efforts for pink salmon in the Southern District.

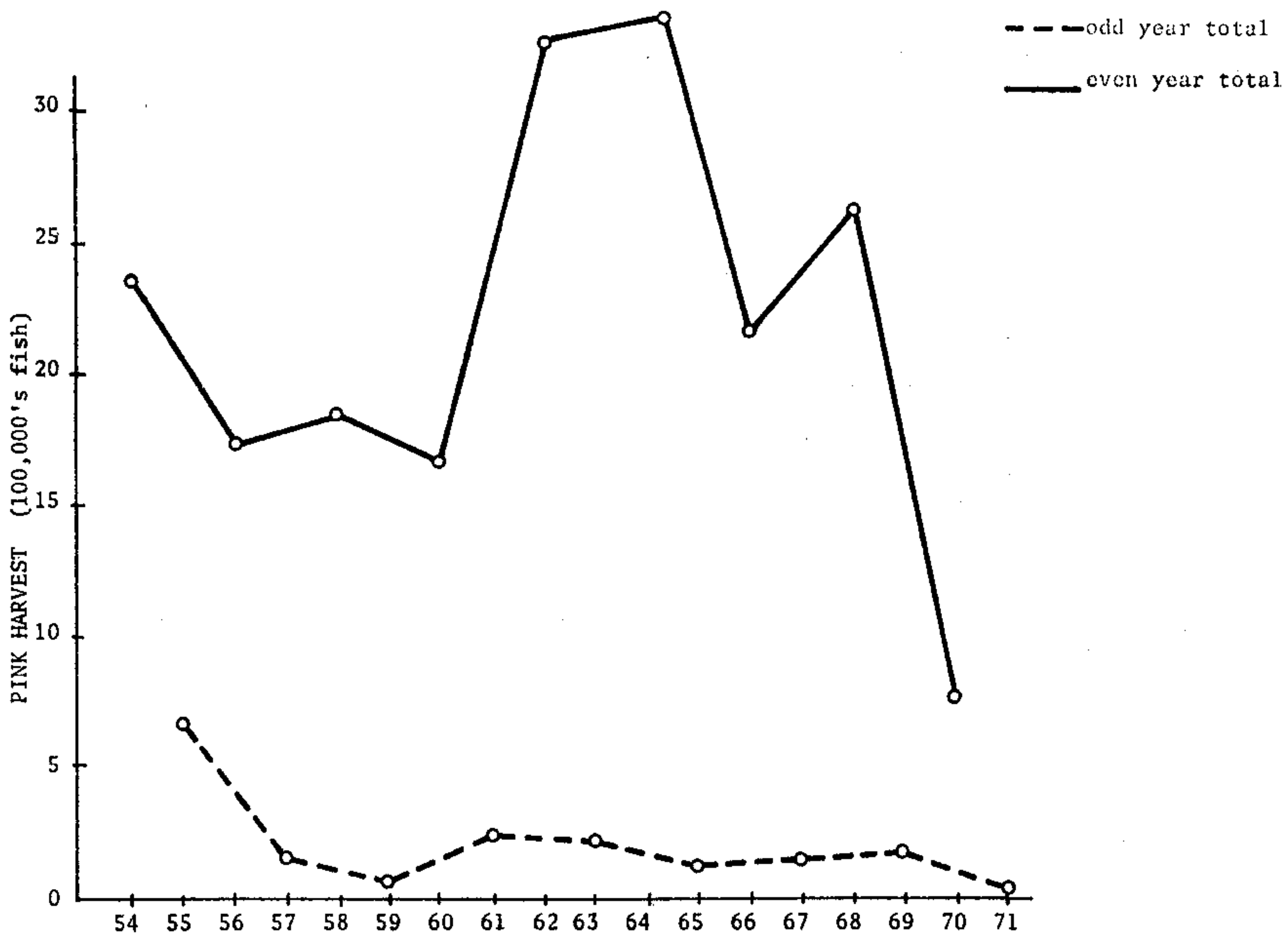


Fig. III-9 COOK INLET - PINK SALMON HARVEST 1954-1971

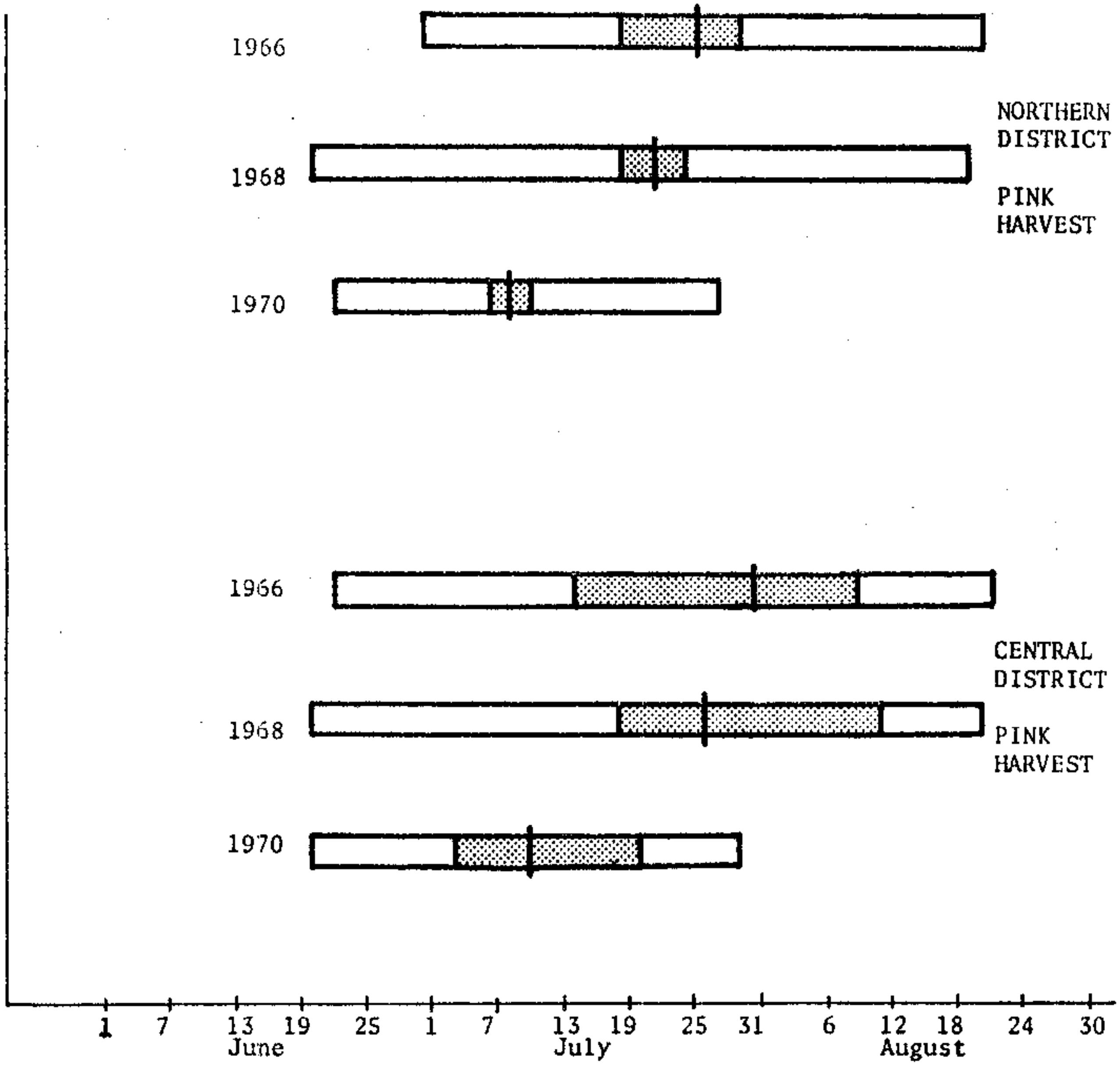


Fig. III-10 TIMING OF PINK SALMON HARVEST - UPPER COOK INLET

TABLE III-11a

COOK INLET - ESTIMATED PINK SALMON ESCAPEMENTS

(thousands of fish)2/

Stream	1962	1963	1964	1965	1966	1967	1968	1969	8 yr average
Humpy	56.0	34.7 1/	18.5 1/	28.0 1/	30.0	25.0	24.7	5.4	27.8
Tutka	30.0	10.0	20.0	20.0	12.0	7.0	7.9	6.5	14.2
Seldovia	50.0	15.0	60.0	30.0	86.0	55.0	53.2	60.0	51.2
Pt. Graham	50.0	2.0	16.0	1.5	24.0	2.0	24.4	4.0	15.5
Totals	186.0	61.7	114.5	79.5	152.0	89.0	110.2	75.9	108.7

TABLE III-11b

COOK INLET PINK SALMON CATCHES BY BAY DURING

1962,1964,1966, AND 1968 3/ (thousands of fish)

Catch Location	1962	1964	1966	1968
Upper Kachemak 4/	110	83	41	81
Tutka	269	101	54	27
Seldovia	145	44	59	24
Port Graham	10	36	24	19
English	8	2		4
Totals	5 42	266	178	155

A further breakdown of timing of the pink salmon runs is provided by Davis (1970) for the Southern District, Kalifonsky Beach east side of Cook Inlet, North Central, and Northern Districts (Fig. III-11a and III-11b). These figures also

1/ Weir count

2/ Escapement estimates were derived from peak counts or calculated from counts made throughout the spawning season. When series counts were available the total fish days was divided by average stream life (2.5 wks.) to estimate total escapement.

3/ Source - fish ticket receipts.

4/ Includes catches of pink salmon bound for Humpy and China Poot creeks.

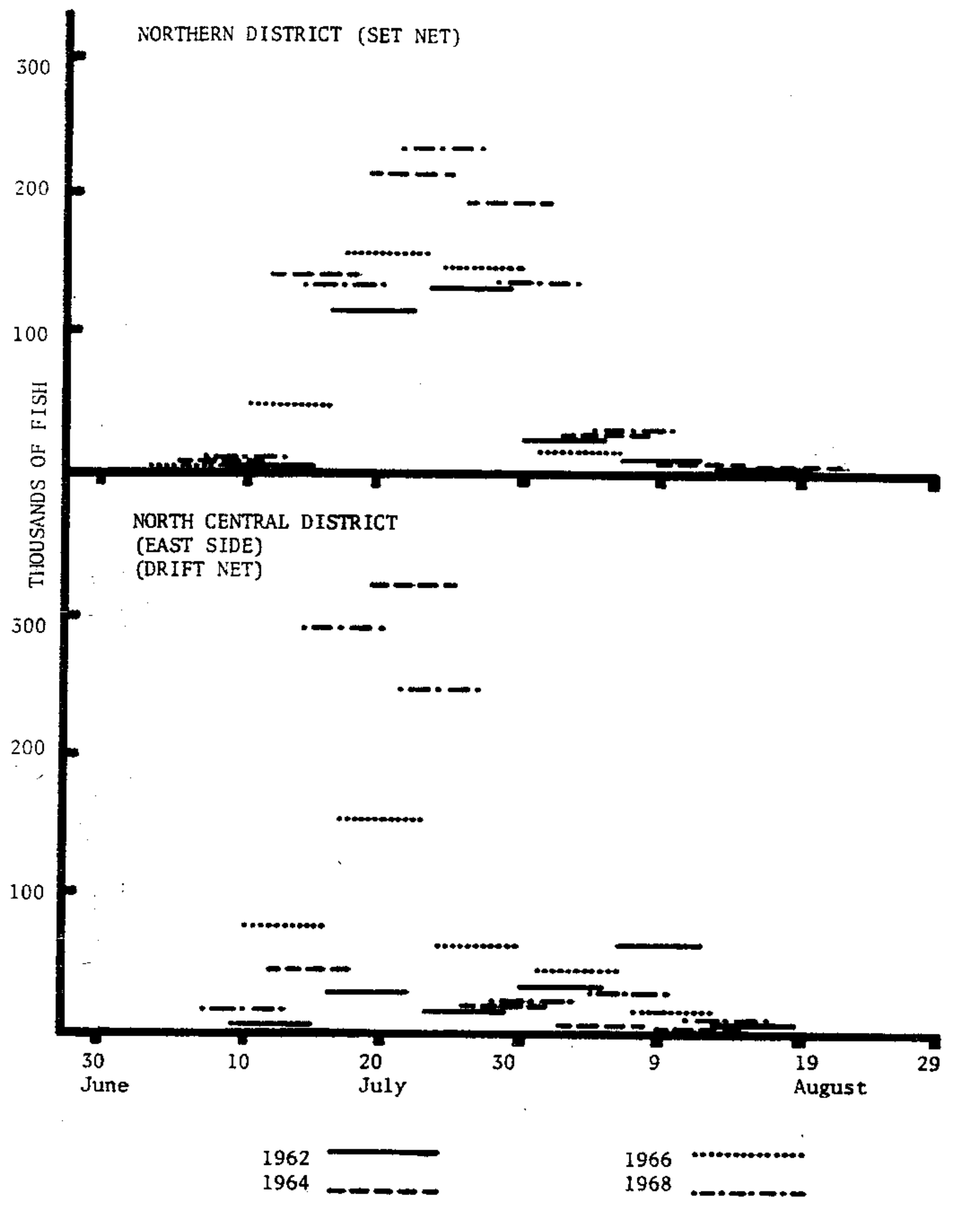


Fig. III-11a Pink salmon catches in selected seine net districts of Cook Inlet, 1962, 1964, 1966, and 1968.

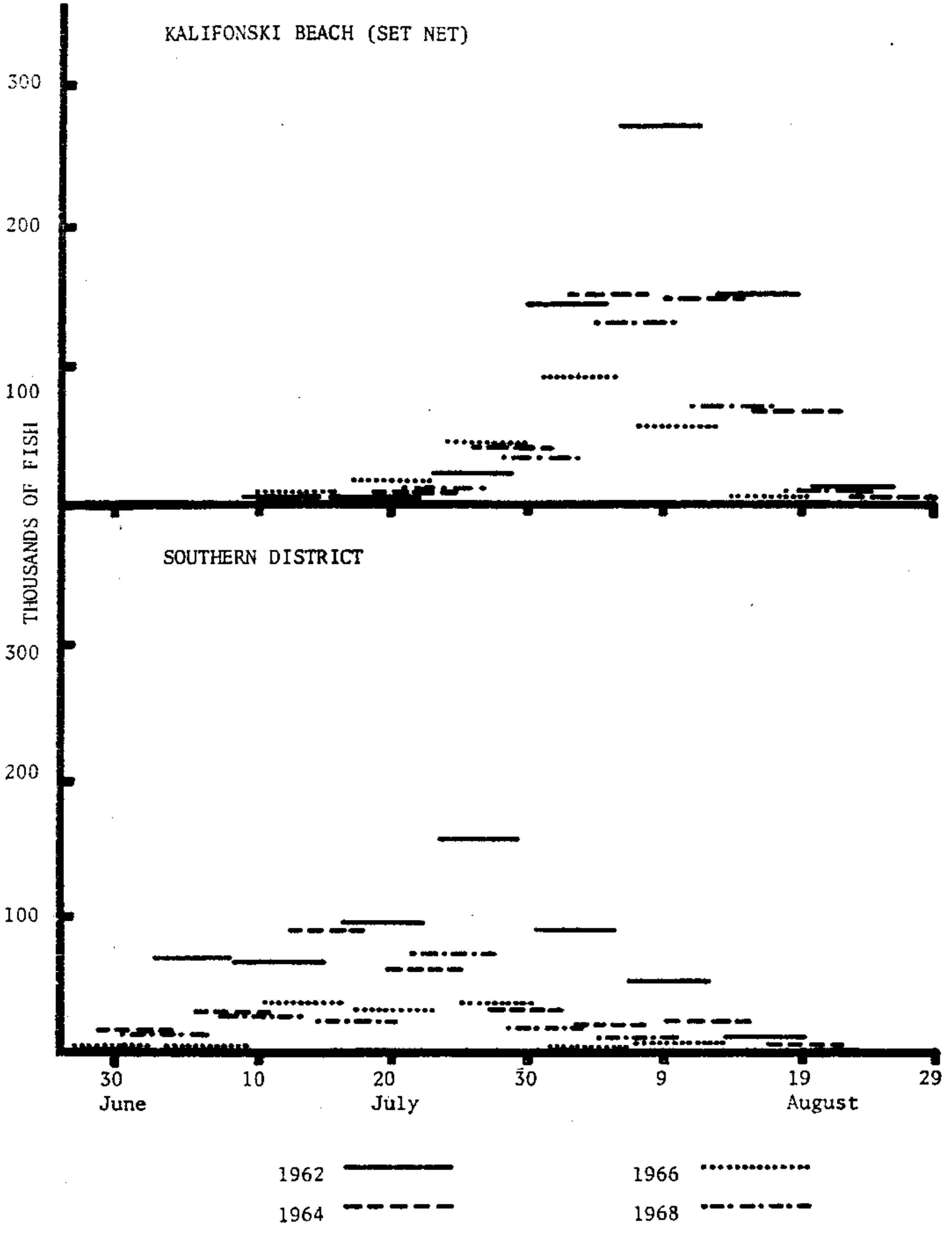


Fig. III-11b Pink salmon catches in selected gill net districts of Cook Inlet, 1962, 1964, 1966, and 1968.

show a short catch period for the Northern District, beginning in early July. The Southern District has a much wider spread. Many fish are caught before the end of June and a high rate of fishing activity continues into mid-August. Davis (1970) believes there are two pink salmon runs in the inlet. The first run is bound for the Susitna River system and the harvest starts in the first week of July and continues into early August. The second run is bound for the Kenai and Kasilof Rivers and peaks during the first week in August. This is supported by the difference in timing of peaks of harvest between Kalifonsky Beach and the Northern and North Central Districts.

There are , unfortunately, no definitive data on timing of escapements to permit further comparison of catch statistics with actual presence of fish in the Inlet.

Coho salmon - The coho salmon harvest in the Northern and Central Districts for the years 1954-71 are shown in fig. III-12. A minimal harvest precludes the inclusion of data on Southern and Kamishak Districts. Table III-12 shows the average total catch of coho salmon by district for the period 1960-69.

TABLE III-12

TEN YEAR AVERAGE COHO SALMON CATCH BY DISTRICT
1960-69 (thousands of fish)

District	No. of fish	Percent of total
Northern	91	34.4
Central	171	64.3
Kamishak	1	.2
Southern	3	1.1
Total	266	100.0

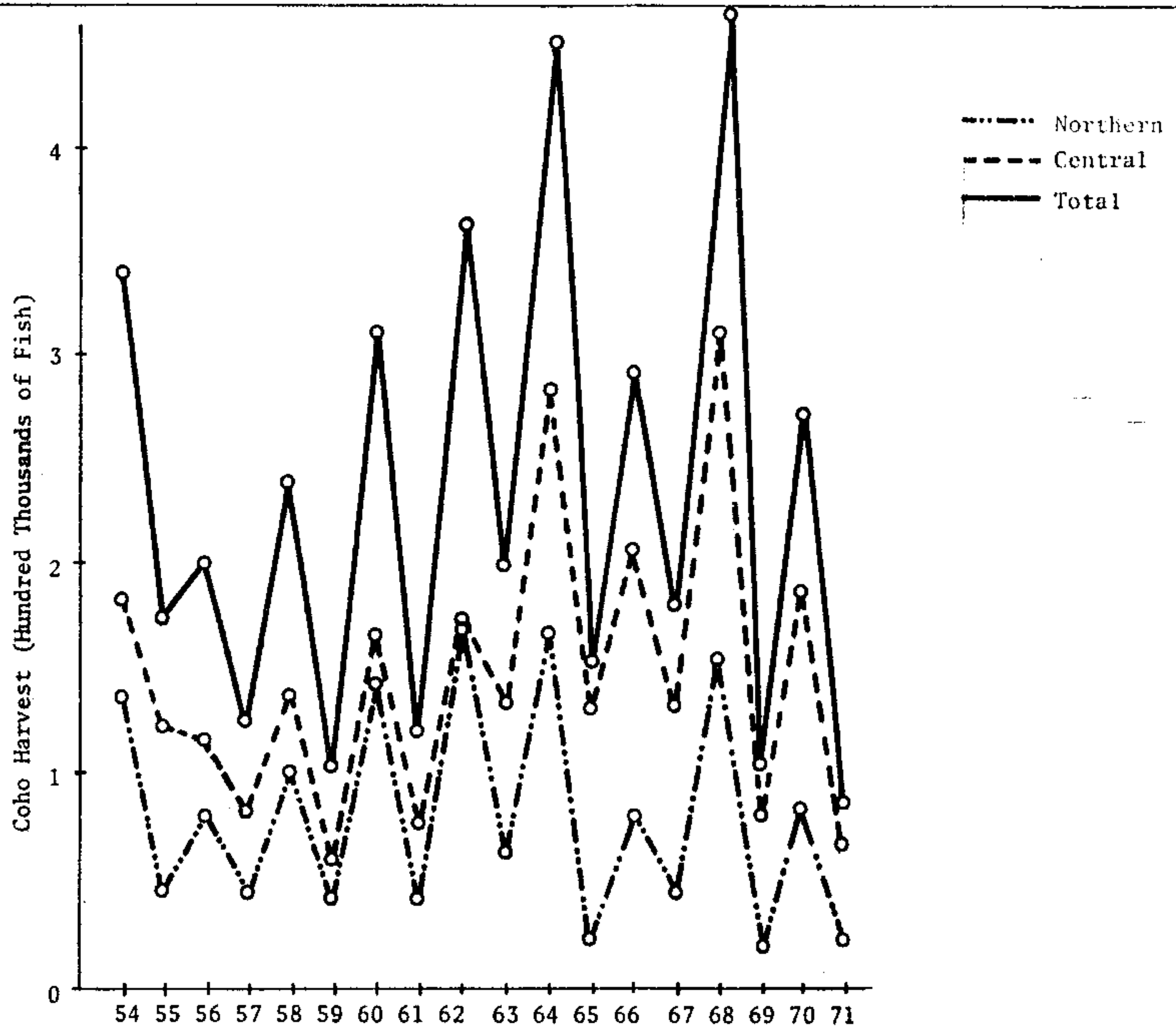


Fig. III-12 COOK INLET COHO SALMON HARVEST 1954-1971

The even year periodicity shown by this figure might result from a periodicity of fishing effort based on expected strength of pink salmon runs. Kubic (1968), however, points out that the coho salmon sport catch in fresh water in the Upper Inlet is normally greater in even years. This periodicity, as shown by fig III-13, although not as marked as in the pink salmon, is none the less consistent. Table III-13 shows the magnitude of the differences.

TABLE III-13

COHO SALMON CATCH BY DISTRICT ODD AND EVEN YEARS

TEN YEAR AVERAGE 1960-69 (thousands of fish)

District	Even years	Odd years
Northern	144	38
Central	230	111
Kamishak		1
Southern	4	2
Total	379	152

Surprisingly enough, the harvest begins slowly in late June, as shown by fig III-14. It does not peak until considerably later, however. The extended period for the beginning and ending 10 percentiles of the catch again suggest that the run of cohos is fairly well sampled by the fishing effort. Davis (1966) states that cohos enter streams of Upper Cook Inlet mid-July to September, and that some are in the Inlet until mid-October. In an earlier report (Davis, 1955), he states that cohos entered the Anchor River August 3 and that the run is substantially over by the end of September. This is a considerably later schedule than is

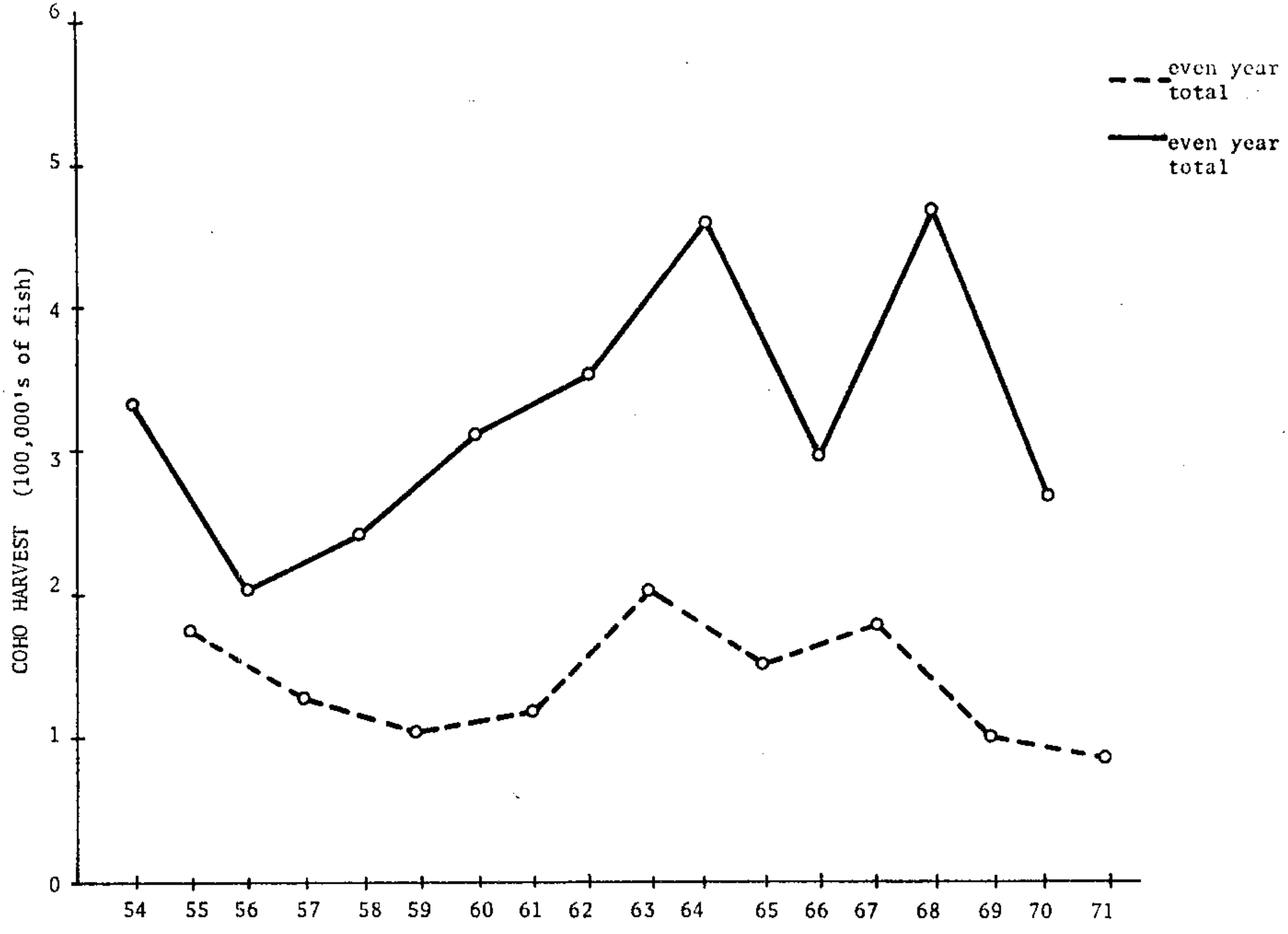


Fig. III-13 COOK INLET - COHO SALMON HARVEST 1954-1971

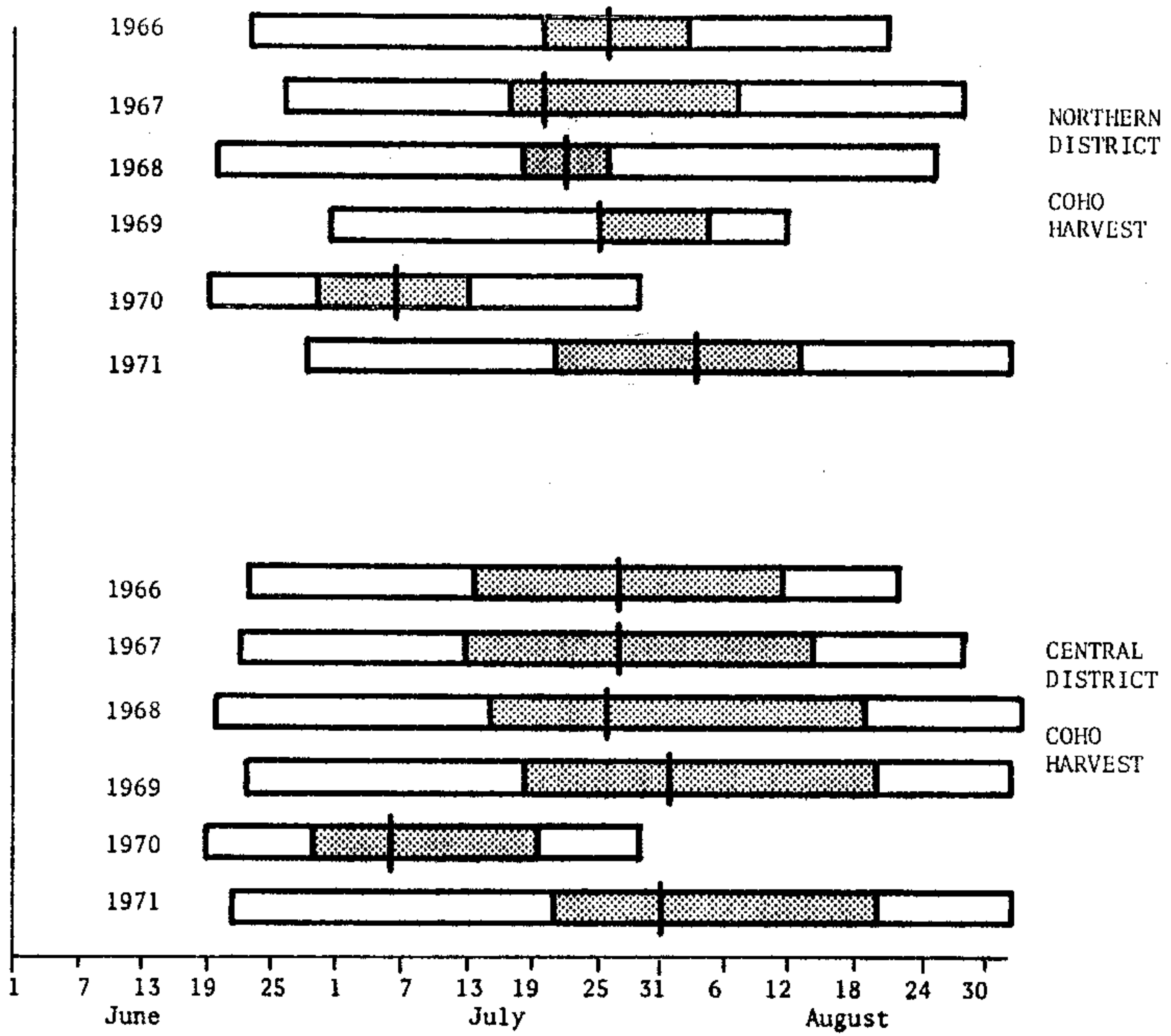


Fig. III-14 TIMING OF COHO SALMON HARVEST - UPPER COOK INLET indicated by the catch data, suggesting that cohos spend a long period in the Inlet before entering spawning streams.

The major coho spawning streams in the Inlet are from Ninilchik north on the east side and include the Kasilof, Kenai and Susitna Rivers. Davis (viva voce)[1/] states, however, that the species is widespread and that about any wet spot will support a pair of cohos.

Chum salmon - The chum salmon harvest for the years 1954-1971 in the Northern and Central Districts is shown in fig. III-15. The average for the four management districts during the period 1960-69 is shown in table III-14. The catch data for the chum salmon is similar to the coho in its even-year periodicity, probably for the same reason. There is a difference, however, in the chum data as shown in fig. III-16. This shows the even year and odd year harvests separately for the same period, and shows an odd-year high in 1957 and an even-year low in 1958. The average chum salmon harvest for odd and even years 1960-69 is shown in table III-15 for the four management districts. Davis (viva voce) lists the Susitna Basin, Cottonwood Creek, Iniskin River, McNiel River, Chinitna Bay and other west side streams as being chum producers. There are no chums reported in the Kenai or Kasilof Rivers.

1/ Davis, Allen S., Commercial Fish Div., Alaska Dept. of Fish and Game, Homer.

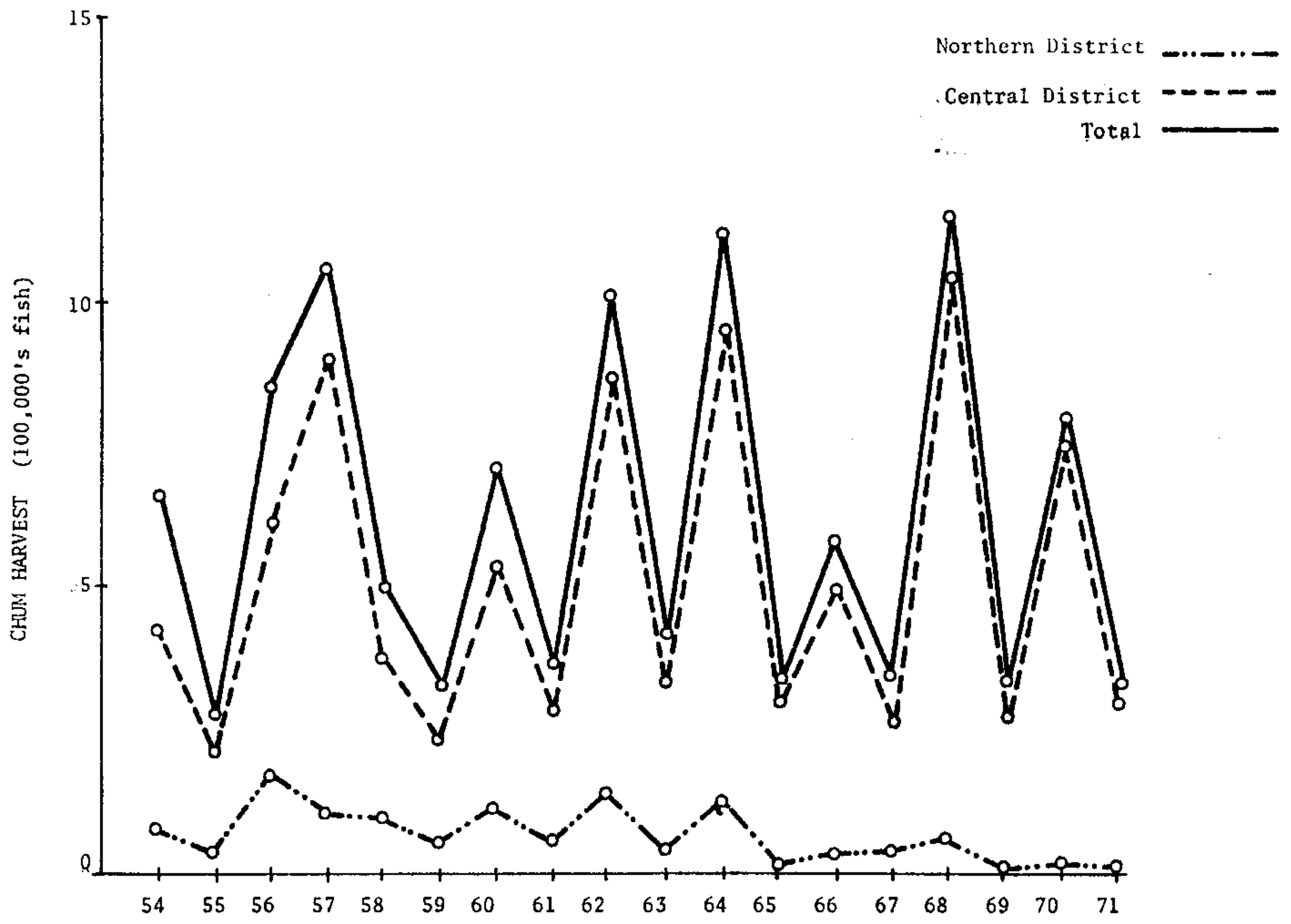


Fig. III-15 COOK INLET - CHUM SALMON HARVEST 1954-1971

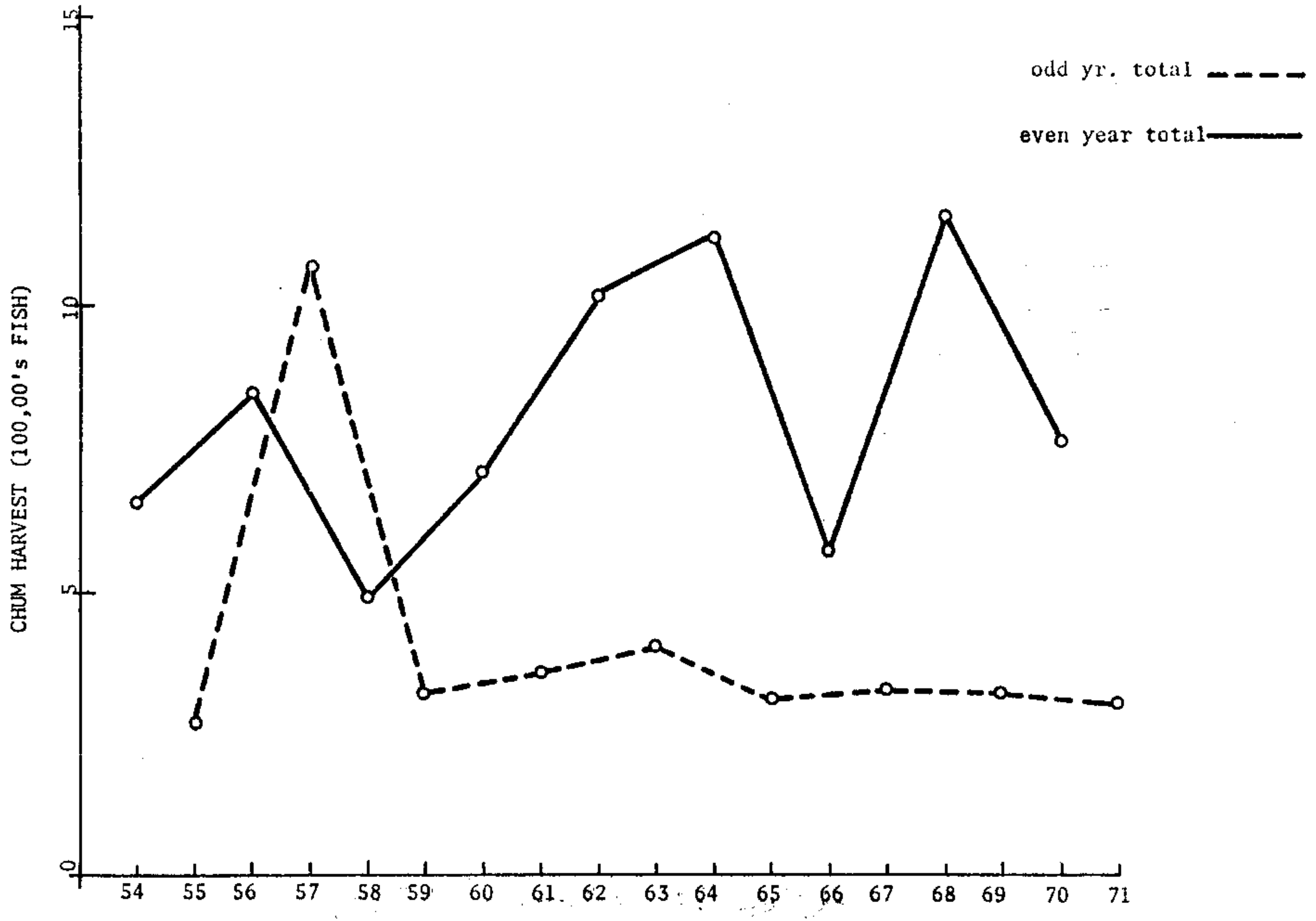


Fig. III-16 COOK INLET - CHUM SALMON HARVEST 1954-1971

TABLE III-14

CHUM SALMON CATCH BY DISTRICT 1960-69

TEN YEAR AVERAGE thousands of fish

District	No. of fish	Percent of catch
Northern	65	10
Central	537	84
Kamishak	26	4
Southern	10	2
Total	638	

TABLE III-15

CHUM SALMON CATCH BY DISTRICT 1960-69

TEN YEAR AVERAGE ODD AND EVEN YEARS thousands of fish

	No. of fish	
District	Even years	Odd years
Northern	97	34
Central	781	293
Kamishak	31	21
Southern	12	8
Total	921	356

The timing of the chum salmon harvest in the Northern and Central Districts is shown in Fig. III-17. Again, too few data are available for the Southern and Kamishak Districts to be useful. The initial 10 percent of the catch is extended in all cases, suggesting that the early portion of the run is being sampled and that it begins about June 20 in these two districts at least.

The 1971 catch in the Northern District is extremely skewed, however, and more than 10 percent of the season's catch was made on the last day. The data for 1969 and 1970 in the Northern District and for 1970 and 71 in the

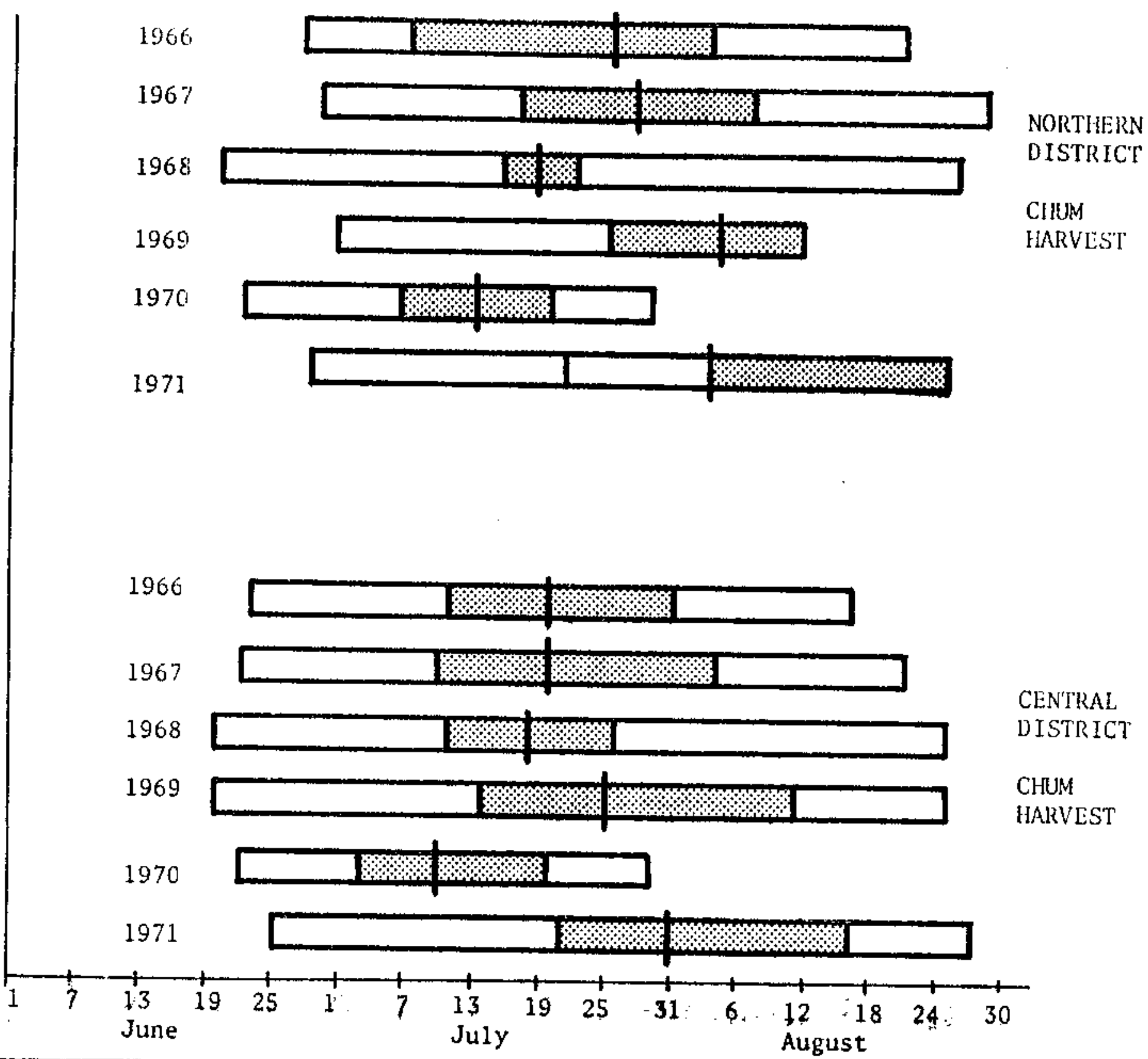


Fig. III-17 TIMING OF CHUM SALMON HARVEST - UPPER COOK INLET

Central District show some of this tendency also. It appears that chum salmon may be in the Inlet in considerable numbers into September.

Seasonal Presence of Salmon - It is of particular interest to note the entire period when salmon are in Cook Inlet in significant numbers. Figs. III-18 and III-19 summarize, by species, the mid 80 percent of the catch for the period 1966-71. The initial and final ten percent have not been included. These bar graphs are cumulative of the data for each year, 1966-1971. The height of the graph indicates the number of years that significant harvest occurred during that portion of the fishing season. The highest portion of the graph indicates the period during which harvest was most active. The check mark indicates the average date by which 50 percent of the catch had been made. Beginning with chinooks in the Northern District June 11 and ending with chums in the Northern District on Aug. 25, there is a period of 75 days when significant numbers of adult salmon are being caught in the Inlet.

Fig. III-20 summarizes these data and serves as an indicator of the harvest rate for all species combined in the Northern and Central Districts. The period of greatest activity is from July 1 to August 10. Too small a sample is available for the Southern and Kamishak Districts to include them in the graph.

Because the timing of the catch is only a rough indication of the presence of fish, inferences based on the shape of the catch curve and stream survey information as discussed previously have been used to

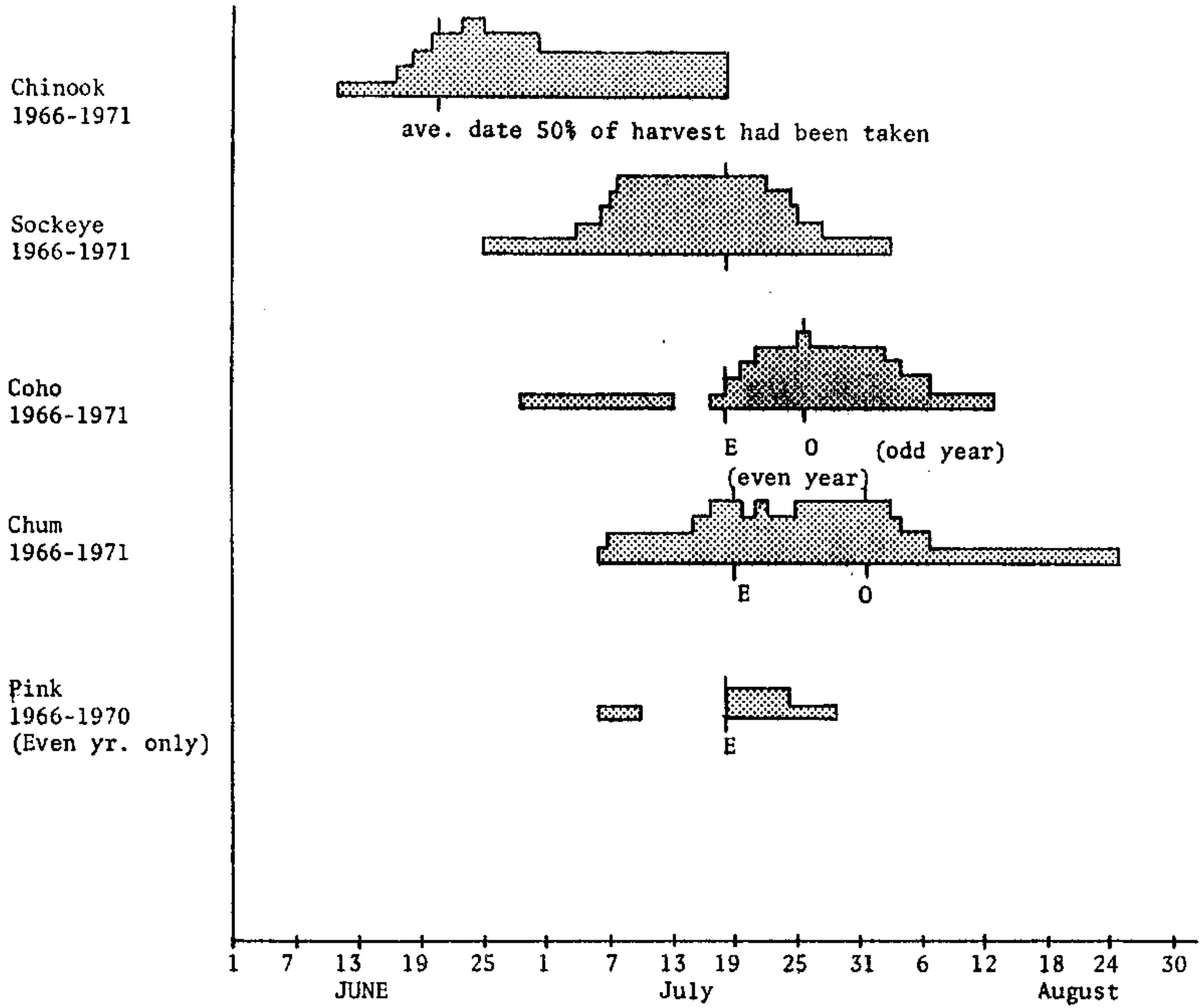


Fig. III-18 TIMING OF SALMON HARVEST - NORTHERN DISTRICT COOK INLET

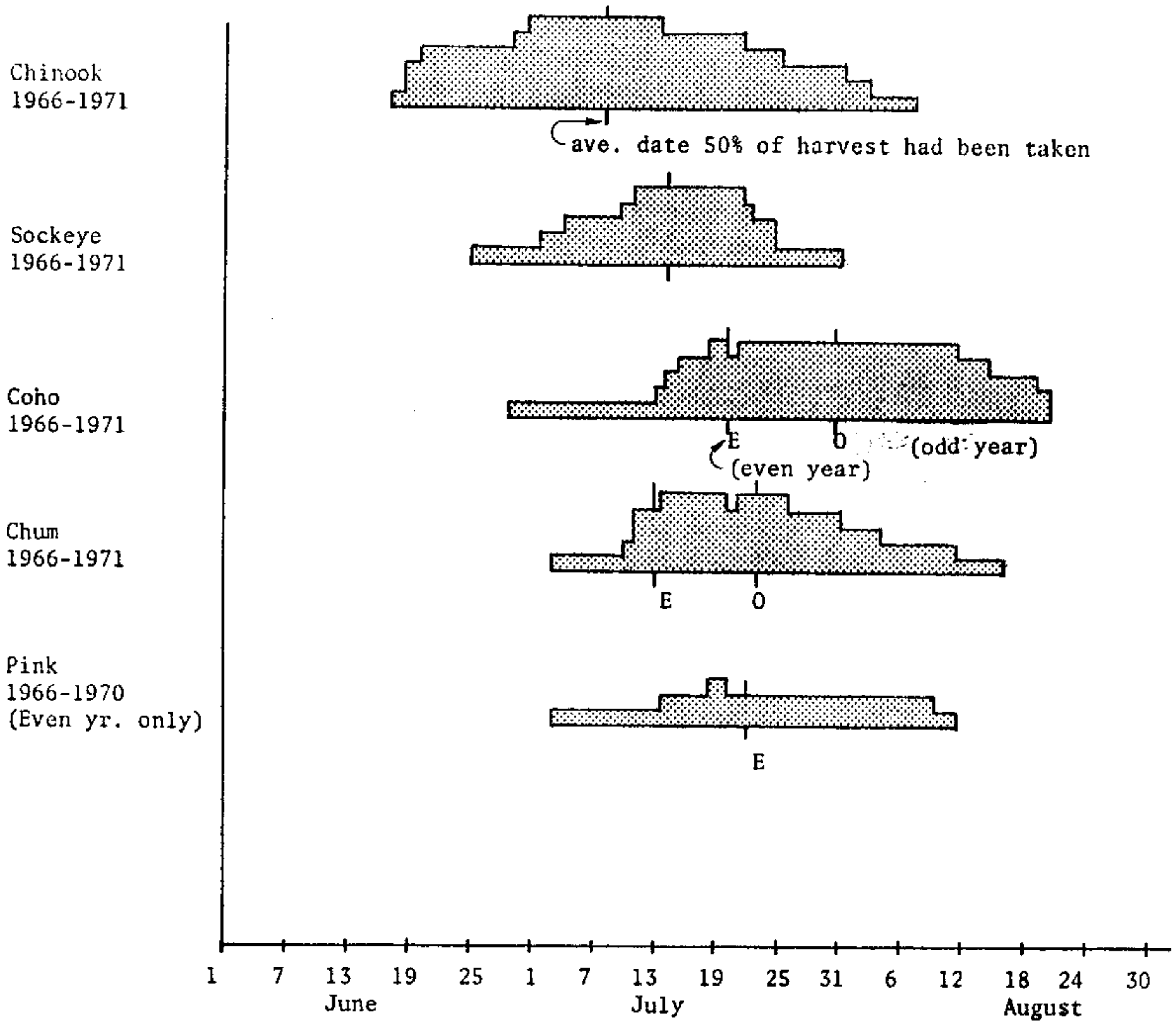


Fig. III-19 TIMING OF SALMON HARVEST - CENTRAL DISTRICT COOK INLET

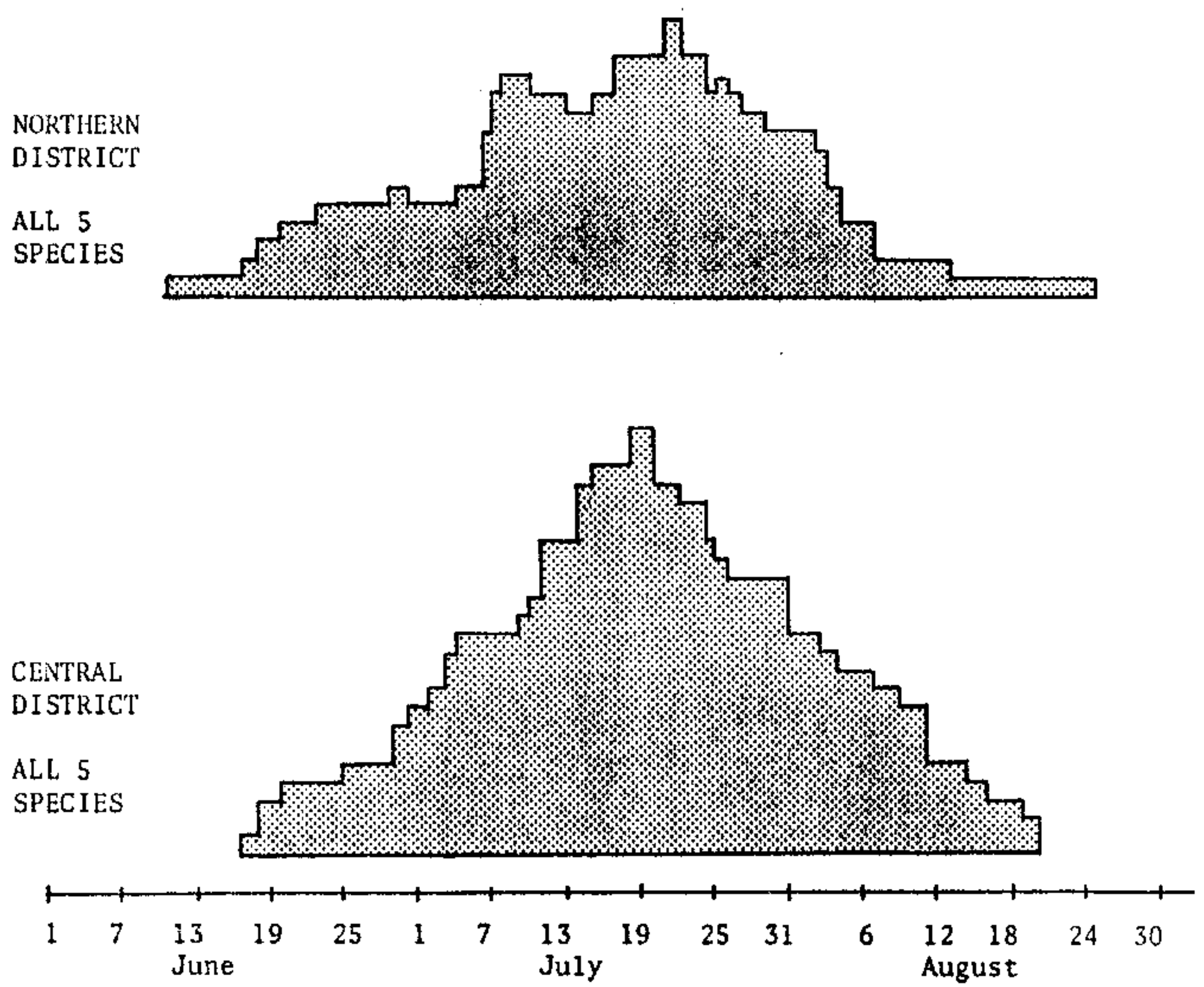


Fig. III-20 TIMING OF SALMON HARVEST - UPPER COOK INLET extend the catch curves. We can thus infer the period when adult salmon probably are present in significant numbers. These periods are probably minimal and sampling of the Inlet for fish populations would probably extend them further (Fig. III-21).

Probable presence of significant numbers of adult salmon in the Inlet begins with chinook about May 15 and ends with coho about September 20, a period of nearly 130 days.

Of equal importance to the adults, is the presence of smolts in the Inlet. Davis (viva voce) states that smolts of all the salmon species are moving down the Inlet during the period May through August. He states (Davis, 1967) that the sockeye and coho smolt outmigration from the Kenai River in 1967 began in strength May 25 and peaked June 5 and 6. A mark and recapture program in 1967 indicated that 5,000,000 sockeye smolts migrated down the Kenai River. There is, however, no quantitative information on abundance or timing of presence of salmon smolts in the Inlet. The probable presence of smolts is also graphed in Fig. III-21.

Available information indicates that salmon, either adults or smolts, are present in Cook Inlet waters from about May 1 to about September 20.

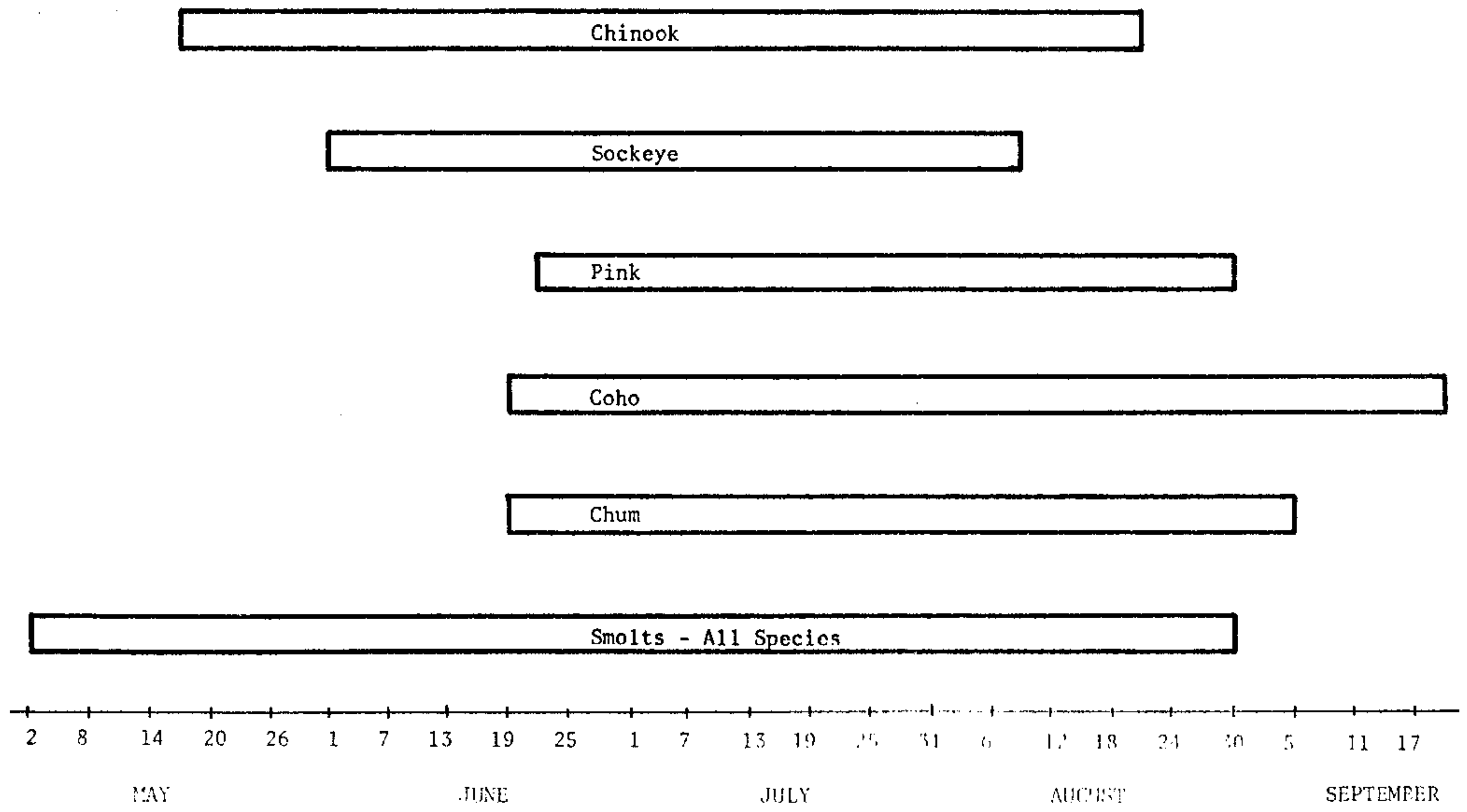


Fig. III-21 PROBABLE PERIOD DURING WHICH SIGNIFICANT NUMBERS OF ADULT SALMON ARE IN COOK INLET, BASED ON CATCH DATA, SHAPE OF CATCH CURVE AND STREAM SURVEYS

Salmon - sport fishery - The Cook Inlet salmon are an important recreational resource. Most sport fishing for salmon to date has been in fresh water streams. Table III-16 is a list of Cook Inlet streams which are recognized by personnel of the Sport Fish Division, Alaska Dept. of Fish and Game as supporting a significant sport fishery. The species of salmon involved are listed also.

Engel (1966) lists the sport harvest of chinook from the Anchor River, one of the most heavily fished streams for that species, from 1954 to 1963. During that period, from 355 (1954) to 1,158 (1963) chinooks were taken there by sport fishermen. Fishing effort to take these fish varied from 2,010 man-days (1956) to 6,165 man-days (1961). Since 1963 fishing has been either closed or under a quota system and the harvest has been reduced sharply (Table III-17a).

A new sport fishery for chinooks is developing in salt water off the mouth of Deep Creek. Engel (viva voce)[1/] reports that about 200 chinooks were taken there in 1971 and about 2,175 in 1972. (1,759 of the 1972 catch were taken in June, few in May, and 419 in July). This catch involved about 2,000 man-days of sport fishing in June and 1,700 in July with a success rate of 2.27 chinooks per boat in June and 0.605 in July. A substantial number of pink salmon, a few hundred sockeyes and a few cohos were taken incidentally in the fishery. The shoreline in this area also sustains a sport fishery for pinks and cohos.

1/ Engel, Larry. Fishery Biologist. Sport Fish Division. Alaska Dept. of Fish and Game. Soldotna.

TABLE III-16
COOK INLET STREAMS WITH SPORT FISHING FOR SALMON

Streams	Chinook	Sockeye	Pink	Coho	Chum	Steelhead
	Species Caught					
Northern District						
Lewis River	*		*	*		
Susitna R + tributaries	*	*	*	*	*	
Little Susitna	*	*	*	*	*	
Fish Cr (Big Lake)		*	*	*		
Cottonwood Cr		*		*		
Wasilla Cr				*		
Matanuska R + tributaries	*		*	*	*	
Eagle R	*		*	*		
Ship Cr	*		*	*	*	
Campbell Cr	*	*1/	*	*		
Bird Cr	*		*			
Twenty-mile R				*		
Resurrection R			*	*		
Swanson R		*		*		
North Central District						
Kenai R	*	*	*	*		
Kasilof R	*	*	*	*		
South Central District						
Ninilchik R + tributaries	*		*	*		*
Deep Cr + tributaries	*		*	*		*
Stariski Cr + tributaries	*			*		*
Silver Salmon Cr				*		
Polly Cr				*		
Kamishak Bay District						
McNiel R					*	
Southern District						
Anchor R + tributaries	*		*	*		*
Tutka Bay + tributaries				*		

1/ known from past records but run insignificant for current sport fishery

TABLE III-17a
SUMMARY OF CHINOOK SALMON SPORT FISHERY FOR COOK INLET, 1966-1969

	1969	1968	1967	1966
King salmon (KS) cards issued (entire Cook Inlet)	6688	9524	5977	8853
Upper Cook Inlet				
Quota (KS over 20")	250	250	250	250
Punch-card catch (over 20")	339	398	315	263
Punch-card catch (under 20")	81	416	167	163
Total Catch	420	814	482	426
Stream Breakdown (KS over 20")				
Deshka River	310	324	234	205
Alexander Creek	21	71	20	26
Lake Creek	8	3	61	28
Chunilna Creek	-	-	1	4
Kenai Peninsula				
Quota (KS over 20")	200	500	500	500
Reported Catch	254	552	510	-
Estimated Catch	273	614	545	est.500
Stream Breakdown (KS over 20")				
Anchor River	78	222	222	-
Ninilchik River	121	185	110	-
Deep Creek	37	141	171	-
Kenai River	18	4	7	-

Probably the most intensive sport fishing on Cook Inlet is on the Russian River, tributary to the Kenai River. Engel (1970) shows data for the sport fish harvest on sockeyes and compares it with the total escapement. Table III-17b shows his figures for the period 1962-1969.

TABLE III-17b

RUSSIAN RIVER SOCKEYE SALMON SPORT HARVEST

1962 - 1969

Year	Harvest Early Run	Harvest Late Run	Total Escapement	Effort (Man-Days)
1962	3,410	1,290	56,670	6,595
1963	3,670	1,390	65,500	7,880
1964	4,970	1,885	59,630	4,940
1965	7,760	2,940	43,330	8,320
1966	16,360	5,460	51,090	17,890
1967	8,500	3,640	63,190	16,470
1968	8,250	4,480	58,080	17,300
1969	5,430	1,100	34,000	13,970

Vulnerability of salmon to impact - Salmon could be affected by petroleum exploration and development either through reaction to explosives, pollution or mechanical damage to habitat. Fishing activities could also be affected by excessive disturbance.

Considerable work has been done to evaluate the effect of explosives on fish. The large charges of high velocity explosives, such as nitromon, often used in refraction surveys have been found to kill fish. (Kearns and Boyd, 1964; Washington Dept. of Fisheries, 1962 and others). The lethal range depends on the velocity of the shock wave as well as the size of the charge. High velocity charges were most lethal and slow velocity impacts, such as those generated by black powder, resulted in lower mortalities.

"Vibroseis" and "air gun" equipment is relatively harmless. Species of fish also vary in their susceptibility to injury. In general, fish species with swim bladders are more seriously affected than those without (ADFG, 1960).

Work done by the Alaska Dept. of Fish and Game (1960) indicates that salmon eggs in the gravel are quite susceptible to damage from explosives.

The impact of geophysical activity can be reduced significantly by scheduling surveys when no concentration of fish or fishing effort are in the intended survey area.

Possible impacts on salmon from oil pollution are not well understood. The U.S. Fish and Wildlife Service (USBCF, no date) has reported that the migration habits of both adults and juvenile sockeyes make them especially vulnerable to oil pollution. Both age groups travel at or near the surface, where they would presumably be exposed to effects of oil pollution.

The impact of petroleum activity on the habitats of salmon would be slight in most of the Inlet which is primarily utilized as a migration route during the period May through September. Salmon might be present in the Lower Inlet at other times of the year, however. It is conceivable that migration patterns which are controlled to some extent by organic derivatives in the water (Hasler, 1966), could be altered by persistant introduction of hydrocarbons into the Inlet during the migration period.

Intertidal spawning at the mouths of streams could be seriously affected by activities during the time the fish were inshore or when eggs and fry were in the gravel. Damage could be caused either by explosives, siltation or disturbance of the stream bed. The Alaska Department of Fish and Game is developing an up-to-date bibliography on impact of explosives on fish, but do not have a completion date on the project.

Steelhead (*Salmo gairdneri*)

Steelhead are known to run in the Anchor River, Deep Creek, Ninilchik River and Stariski Creek (Logan, *viva voce*).[1/] Sport fishermen have reported taking fish in the Kenai River, but the Alaska Department of Fish and Game has not substantiated that there is a run there. The Anchor River sustains the strongest of the known runs, which numbers about 500 fish (Davis, 1955).

Steelhead move downstream in late May and June. They move out of the Inlet to the open sea where they remain for a little more than a year before returning. Davis (1955) reports that the return run begins about August 15 and continues until about October 14.

Steelhead are probably an under-utilized sport fish in streams around Cook Inlet. Impacts on this species in waters of the Inlet would probably be most severe during the period they are migrating into streams, August 15

1/ Logan, Sidney M., Area Management Biologist, Alaska Department of Fish and Game, Soldotna.

to October 14, and go out to sea during late May and June. The impact of toxic elements in oil would depend on this migration habit.

Dolly Varden (*Salvelinus malma*)

Logan (*viva voce*) states that Dolly Varden are widely distributed about the Inlet and says that they must move out under the ice, as they have never been observed in their outmigration. They move down to Kachemak Bay where they are often caught during the summer. They move back up the streams July through October. Davis (1955) states that the 1954 run in the Anchor River began July 4, peaked July 18 and continued into early October. The total run that year was 7,000 fish in the Anchor River.

Dolly Varden are an important sport fish in many streams around the Inlet. Their relationship to petroleum activity in the Inlet itself would probably be similar tc steelhead.

Halibut (*Hippoglossus stenolepsis*)

Davis (*viva voce*) states that halibut are in the Inlet from Kalgin Island south from May through August. Although most winter offshore, a few may remain in the Inlet in winter where they are taken in shrimp hauls in Kachemak Bay.

Fig. III-22 shows the distribution of halibut taken in trawls in the Southern and Kamishak Districts during three U.S. Bureau of Commercial Fisheries exploratory fishing cruises in July, August and September of various recent years. Highest concentration of halibut were in Kachemak Bay.

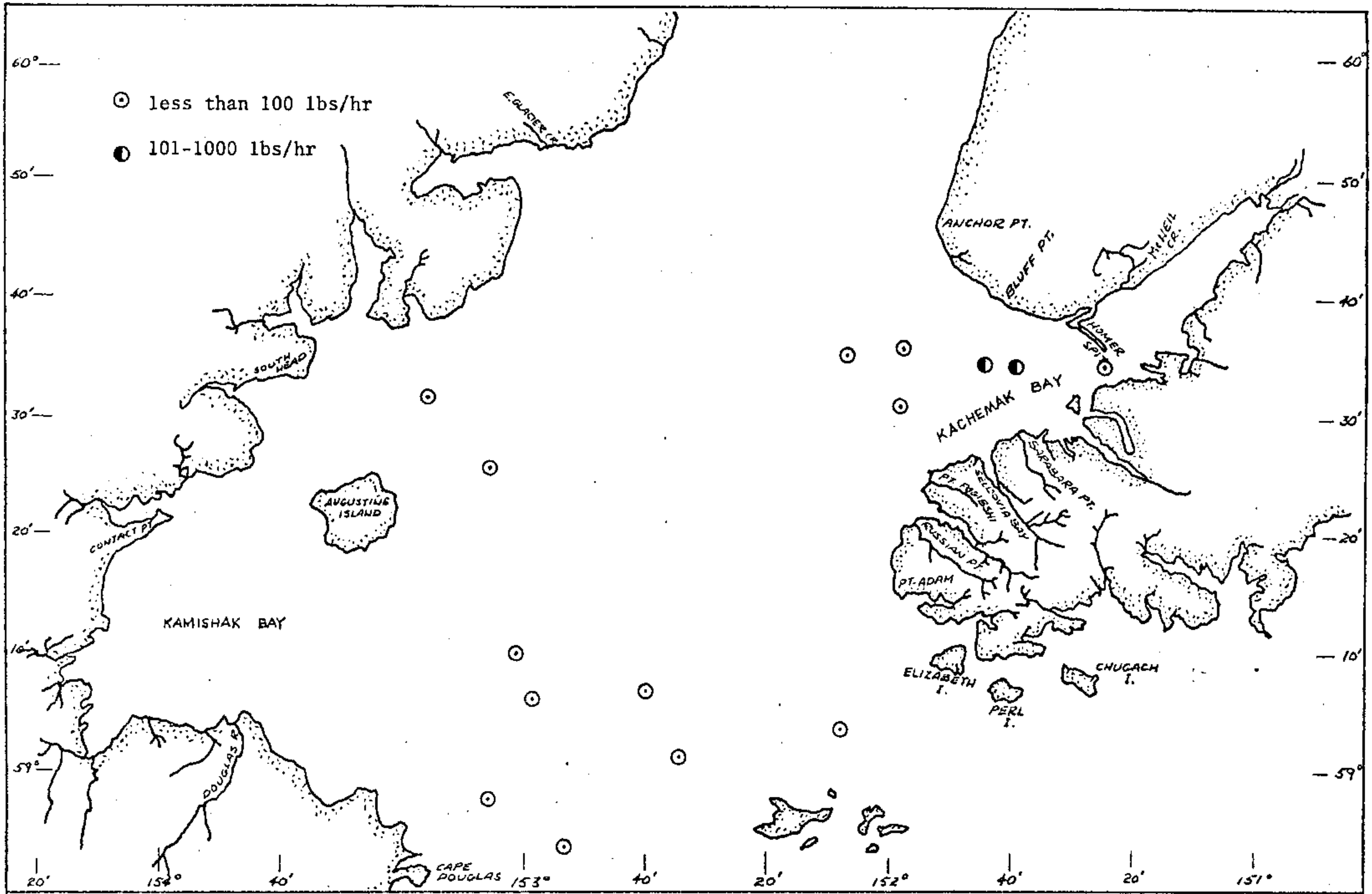


Fig. III-22 HALIBUT EXPLORATORY TRAWLS

Sport fishermen take halibut in the Lower Inlet when they are available, generally from May through August.

Vulnerability of halibut to petroleum activity probably would be slight in the Inlet as long as water quality and bottom fauna are unaffected. It should be stressed, however, that if heavy materials, such as barite, were used to sink contaminants from the surface, they could be brought into contact with the halibut and its habitat. Dispersants could well have the same effect.

Herring (*Clupea pallasii*)

Herring have been harvested in Cook Inlet in considerable quantities (table III-18), with catches reaching almost 20 million pounds. Davis (*viva voce*) reports that herring are inshore in spring and summer, with active spawning in the Southern District in Kachemak Bay and southward into the Outer District. They are most abundant in Kachemak Bay.

TABLE III-18

COOK INLET HERRING HARVEST
(pounds)

1914	311,346	1924	14,080,002
1915	29,400	1925	19,228,331
1916	138,474	1926	14,272,399
1917	1,886,745	1927	7,181,349
1918	3,970,029	1928	4,304,157
1919	5,296,386		
1920	1,918,497	1969	1,103,041
1921	5,222,176	1970	5,417,385
1922	1,007,690	1971	25,050
1923	7,562,356	1972	2,046

Herring spend much of their time at or near the surface and would probably be affected by toxic materials in the water or by disturbance of their habitat. USDI (1972) states that the larvae are vulnerable to minute amounts of oil. Kuhnhold (1970), as reported in U.S.D.I. (1972), states that herring larvae are unable to avoid oil-contaminated water, especially mixtures of oil and chemical dispersant.

Smelt (Eulachon) (*Thaleichthys pacificus*)

Smelt run into streams of the Upper Inlet beginning about May 15-20 (Trent, *viva voce*).[1/] They peak about the end of May. The run in the Kenai River is about a week earlier. Two to three weeks are required for the eggs to hatch and the young move downstream immediately.

Runs are known to occur in the Kenai, Twenty-mile and Knik Rivers. In the Susitna River, smelt proceed as far upstream as the Deshka River. The Placer and Portage Rivers supported runs prior to the earthquake, but have not recovered.

Creel census information is not available, but Trent (*viva voce*) reports that as many as 120 anglers at one time may fish the run on the Twenty-mile River.

1/ Trent, Tom. Sport Fish Division, Alaska Dept. of Fish and Game, Anchorage.

Shellfish

Crabs

King Crab (Paralithodes camtschatica) - The king crab fishery began in Cook Inlet on a commercial basis in 1951 (Flagg, 1972) and developed through 1959. By 1960, 60 boats were registered for king crab. Forty-eight were registered in 1971. After 1964, there was a shift in effort from Cook Inlet toward Kodiak and westward. A quota system was established in 1969 to improve the distribution of effort in Cook Inlet from Kachemak Bay in the Southern District into the Kamishak Bay District. Table III-19 shows the harvest for the period 1951 to 1971 and reflects the shift outward from Kachemak Bay.

Value of the crab catch to the fishermen exceeded one million dollars in 1971 and the first wholesale value of the catch exceeded $3,000,000. The fishery is estimated to have the potential for producing 5 million or more pounds per year (Anon. 1967). Fig. III-23 shows the distribution of king crab in Cook Inlet as determined by exploratory fishing conducted by the U. S. Bureau of Commercial Fisheries. Heaviest catches were made in the deeper waters between Augustine and the Barren Islands.

King crabs are somewhat migratory in the Inlet. Flagg (1972) cites evidence that much of the winter fishery in Kachemak Bay is based on transient crabs that are resident near the Barren Islands and Kodiak during late summer and fall. Crabs tagged east of Cape Douglas occupied deep water in summer and later moved into shallower water around Augustine Island and

TABLE III-19
KING CRAB HARVEST (POUNDS) COOK INLET

	Southern	Kamishak	Barrens	Total Inlet
1951	3,119			3,119
1952	87,968			87,968
1953	1,710,880			1,710,880
1954	1,275,852			1,275,852
1955	1,915,821			1,915,821
1956	2,129,035			2,129,035
1957	620,858			620,858
1958	752,990			752,990
1959	2,191,437			2,191,437
1960	4,219,776			4,219,776
1961	2,988,880	1,205,679		4,194,559
1962	1,968,980	4,305,444		6,274,424
1963	2,667,279	5,538,349		8,205,628
1964	1,731,577	4,934,366		6,665,943
1965	1,811,022	963,412		2,774,434
1966	1,887,948	1,974,559		3,862,507
1967	1,279,708	1,530,943		2,810,651
1968	1,001,398	2,810,683	154,975	3,967,056
1969	1,303,655	1,335,019	97,818	2,736,492
1970	1,495,759	1,899,224	447,134	3,842,117
1971	1,237,802	2,302,583	599,720	4,140,105

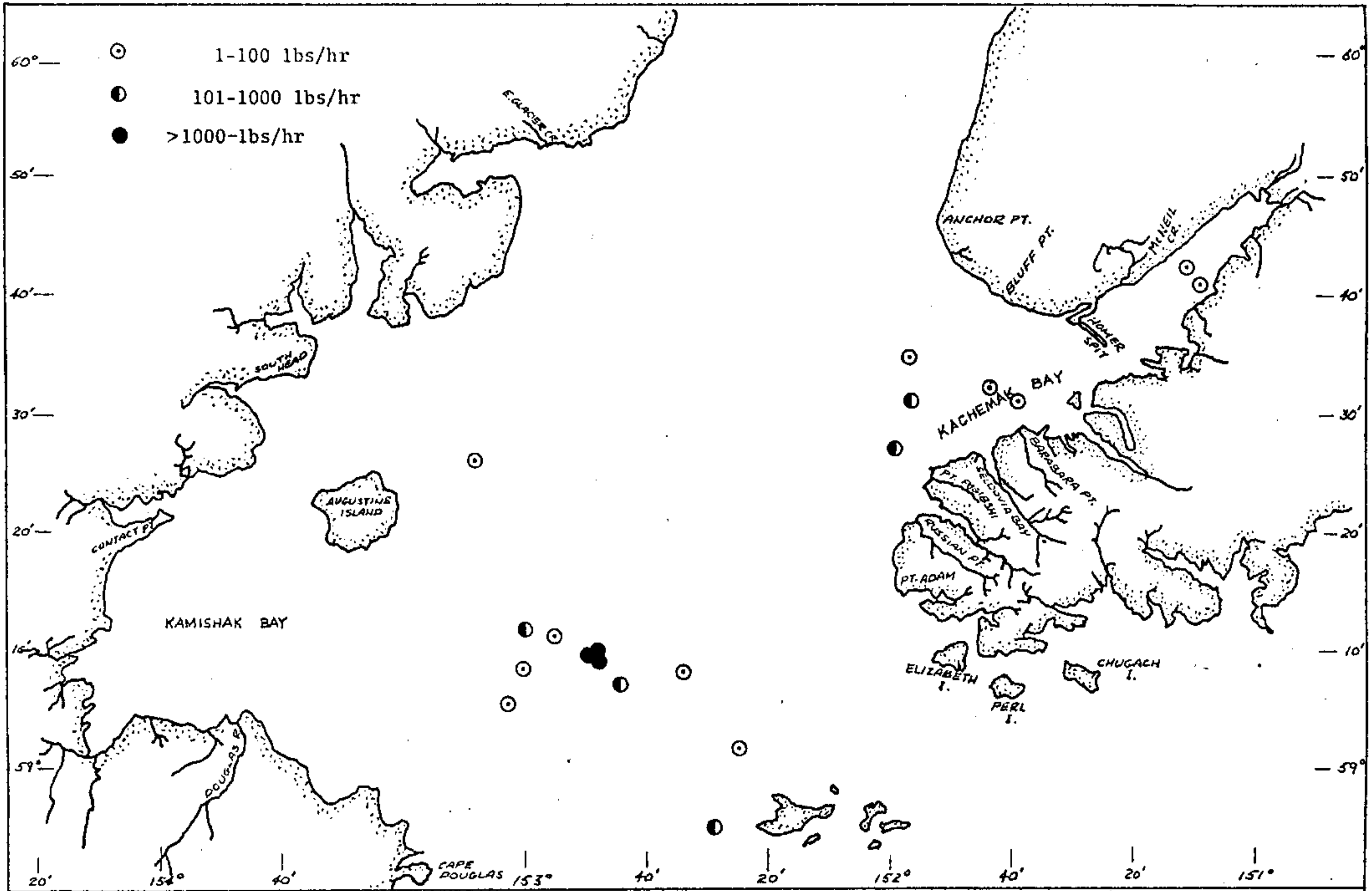


Fig. III-23 KING CRAB DISTRIBUTION IN COOK INLET. (Based on exploratory cruises conducted by U.S. Bureau of Commercial Fisheries)

Kachemak Bay (Powell and Reynolds, 1965). Some populations, however, are resident in Kachemak Bay. Flagg (viva voce) states that king crabs are found in commercial abundance in all waters south of a line between Anchor Point and Chisik Island.

Oregon State (1969) summarizes the life history of the king crab. In early spring the adults move from deep waters (about 100 fathoms) to the shallows (15-30 fathoms) to breed following moulting by females. Flagg (viva voce) also states that king crabs moult from February to May. Eggs are laid in spring and are carried for a year to hatch the following spring (mid-March to early May). The hatching peak occurs about the third week in April. The free-swimming young occupy the middle and bottom zones of shallower waters (15-30 fathoms).

The distribution of king crab harvest by month, in Cook Inlet is shown in table III-20 for 1971. Slight differences from table III-19 in values for Kamishak District result from use of different data sources with differing treatment of field data.

The state of Alaska is undertaking an active management program for the species through regulation and research and a breeding sanctuary has been established near Bluff Point in Kachemak Bay.

Vulnerability - Tests conducted by the Alaska Dept. of Fish and Game in Cook Inlet (Bright, 1959) indicated that nitromon and black powers have negligible effect on king crab. Geophysical surveys would, therefore, not

TABLE III-20
KING CRAB CATCH AND DELIVERIES BY DISTRICT - COOK INLET - 1971

	Southern District		Kamishak District		Total	
Mo.	Pounds	No. Del.	Pounds	No. Del.	Pounds	No. Del.
Jan	107,782	54	41,000	4	148,782	58
Feb	128,484	131	12,907	5	141,391	136
Mar	79,039	21	9,894	3	88,933	24
Apr						
May						
Jun						
Jul						
Aug	552,377	280	1,007,566	42	1,559,943	322
Sep	159,142	172	916,419	41	1,075,561	213
Oct	39,836	52	231,459	17	271,295	69
Nov	21,763	23	319,702	9	341,465	32
Dec	149,379	73			149,379	73

be expected to have much impact. The crabs would logically be the most vulnerable to impact during the breeding season and in the juvenile stages when they are in shallower waters. They should be relatively immune to effects of pollution of surface waters as long as their food source is unaffected. Use of materials such as barite to add weight to and sink spilled oil could alter this situation and place the oil in contact with the crabs and also more directly with their habitat. The use of dispersants could conceivably have similar effects. It should be pointed out also that the major concentration of king crab lie in the path of waters which are coming out of the Inlet and any contaminants introduced into the Inlet would probably flow through this area.

Tanner Crab (Chionectes sp.) - The commercial harvest of tanner crab in Cook Inlet began in 1968 (ADFG, 1971) and reached nearly 2,000,000 pounds in the Southern and Kamishak Districts in 1971 (table III-21). This resulted partly from an increase in number of boats from 25 in 1970 to 40 in 1971. The fishery appears to be increasing rapidly throughout the state (Flagg, 1972).

TABLE III-21

COOK INLET TANNER CRAB HARVEST (pounds)

1968	165,100
1969	1,479,700
1970	1,328,700
1971	1,989,193

Although there is a 12-month season for tanner crabs, the catch falls off in autumn (table III-22 from Flagg, 1972).

Distribution of tanner crab in Cook Inlet, based on exploratory fishing cruises of the U.S. Bureau of Commercial Fisheries, is shown in Fig. III-24. These crabs were caught in greatest numbers in the deep water midway between Augustine and the Barren Islands.

The life history of tanners, in terms of movement, appears identical to the kings (Flagg, viva voce). Timing is different, however, and tanners breed and moult in June and July. After hatching, the young spend two weeks to four months, depending on species, as floating larvae (NMFS, 1971).

Vulnerability - This species should be affected in much the same manner as king crab by oil exploration and development, except that their breeding season is later in the year and the floating larvae could be more susceptible to damage than the free-swimming king crab larvae.

Dungeness crab (Cancer magister) - The harvest of dungeness crab in Cook Inlet has been fluctuating to a high of more than 1.5 million pounds in 1963 (table III-23). Catches are made predominantly in Kachemak Bay during the period June through October (Flagg, 1972).

Adult dungeness crab move into and out of Kachemak Bay seasonally, migrating into shallow waters in spring and summer and returning to deeper waters in fall and and winter. Flagg (viva voce) states that the distribution

TABLE III-22
TANNER CRAB LANDING, BY AREA, COOK INLET, 1971

Month	Southern	Kamishak	Outer	Total
January	26,545	1,758	1,258	29,561
February	107,832	2,468	2,816	113,116
March	227,506	690		228,196
April	358,024	7,876		365,900
May	231,751	175,222		406,973
June	82,357	349,115		431,472
July	3,024	268,925		271,949
August				
September	728			728
October	602	328		930
November	56,992		21,712	78,704
December	87,450		101,870	189,320
	1,182,811	806,382	127,656	2,116,849

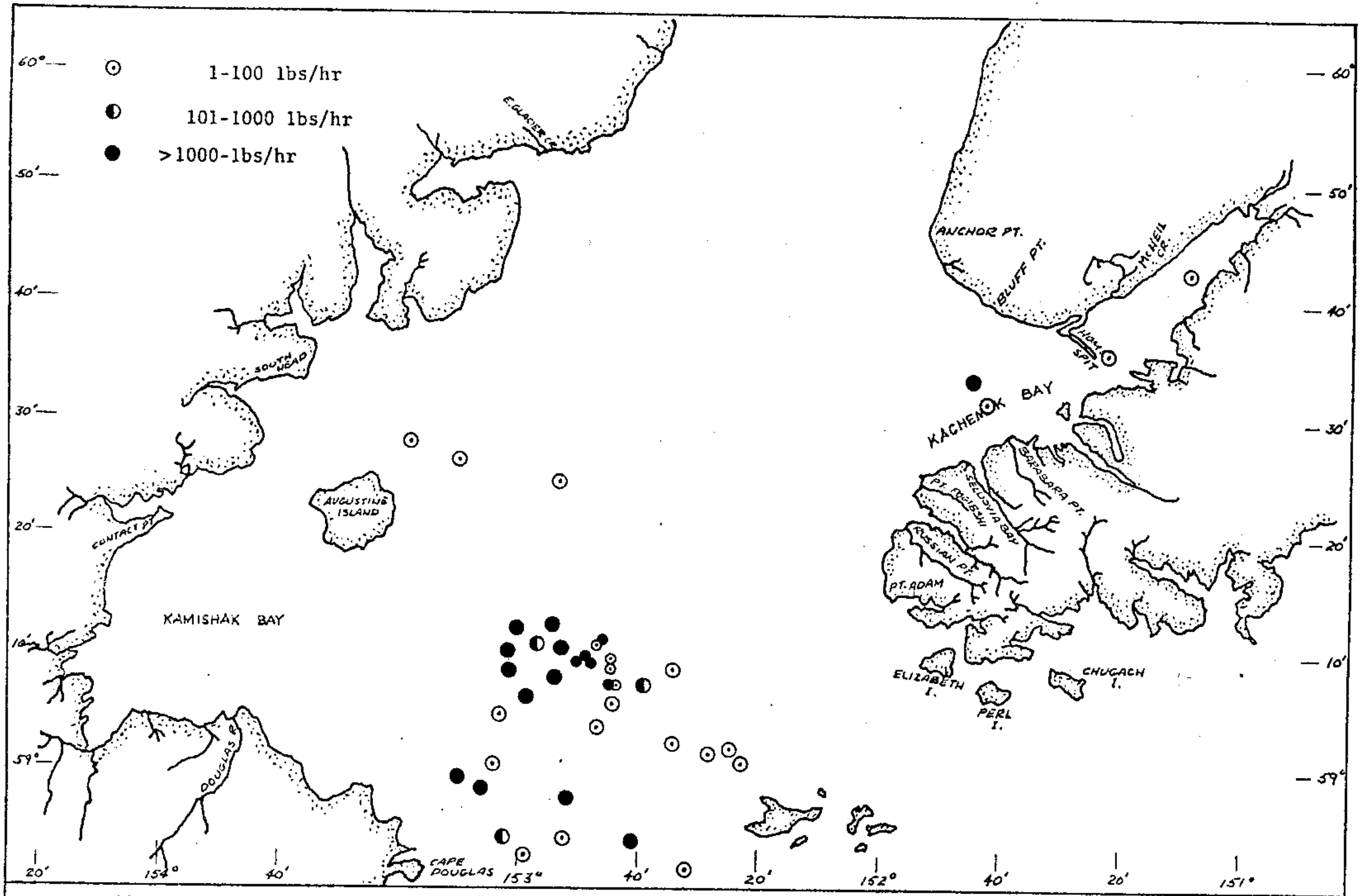


Fig. III-24 TANNER CRAB DISTRIBUTION IN COOK INLET. (Based on exploratory cruises conducted by U.S. Bureau of Commercial Fisheries)

TABLE III-23
COOK INLET DUNGENESS CRAB CATCH, 1961-1971

Year	Crab	Pounds
1961		191,588
1962	204,573	460,725
1963		1,677,204
1964	177,708	421,452
1965	32,378	82,280
1966	45,625	127,977
1967	2,141	7,168
1968		481,764
1969		48,501
1970	84,686	208,577
1971	35,387	96,846

of dungeness is similar to that of king crab, but that they are seldom taken in deep waters.

Dungeness crabs mate in May and June. The eggs are laid in fall and are carried by the female until they hatch in spring into free-swimming larvae (Cleaver, undated).

Vulnerability - Dungeness probably have the same vulnerability characteristics as king crab.

Shrimp

The shrimp harvest in Cook Inlet is made up of several species (Barr and McBride, 1967). Their greatest catches during abundance surveys were pink shrimp (*Pandalus borealis*), humpy shrimp (*P. goniurus*), and coonstripe shrimp (*P. hypsinotus*). Spot shrimp (*P. platyceros*) and sidestripe shrimp (*Pandalopsis dispar*) were also abundant at some locations. Several species of families *Hippolytidae* and *Crangonidae* were abundant in most of Kachemak Bay.

Commercial harvest began in 1958 and has grown rapidly in recent years, as shown in table III-24. There is presently a 5,000,000 pound quota in effect for Cook Inlet. Monthly distribution of the catch in 1971 was relatively even with a high in March and lows in January, May and December. The winter lows resulted from poor weather (Flagg, 1972).

TABLE III-24

COOK INLET SHRIMP HARVEST (Pounds)

1960	711,355
1961	1,045,170
1962	582,291
1963	1,897,580
1964	601,410
1965	128,100
1966	309,700
1967	741,400
1968	43,400
1969	1,847,200
1970	5,817,500
1971	5,448,578

Exploratory trawls by the U. S. Bureau of Commercial Fisheries found highest concentrations, predominantly pink shrimp, in Kachemak Bay and from deep waters east of Cape Douglas (Fig. III-25).

Flagg (viva voce) states that the breeding season for shrimp generally begins in September with moulting of adults. They lay eggs in October and carry them through May, when they hatch. Studies are being conducted by the National Marine Fisheries Service and the Alaska Department of Fish and Game to further define the life histories of the various species. Flagg (1972)

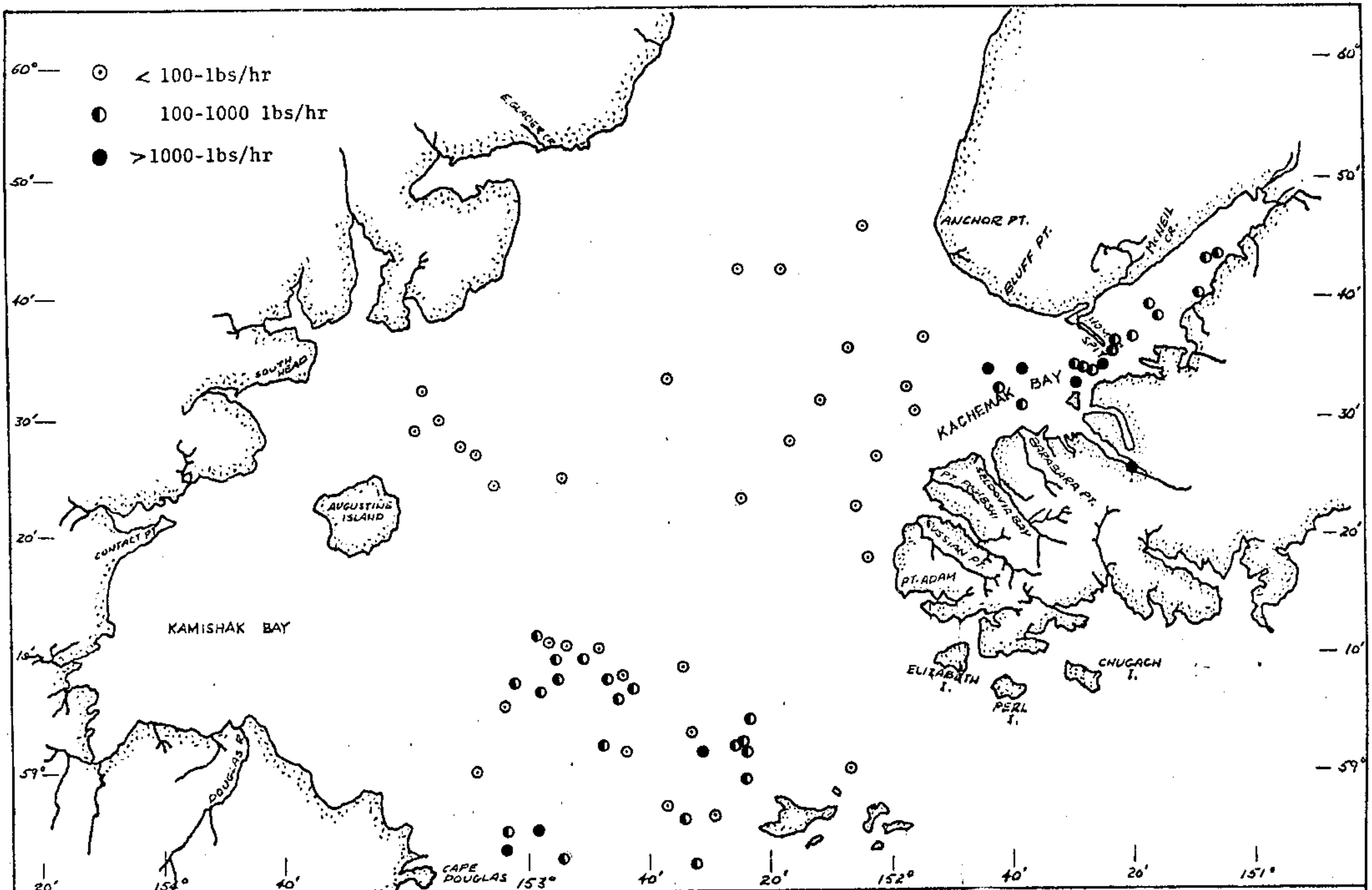


Fig. III-25 COOK INLET SHRIMP ABUNDANCE FROM EXPLORATORY FISHING CRUISES states that during February, March and early April of 1971, shrimp were concentrated in the deep hole off Yukon Island south of Homer. During May, the population was dispersed which accounted for the low harvest that month. The predictability of this movement is uncertain and Flagg indicates that different species have different movement patterns.

Sport Fishery - There is a small "sport" or "personal use" fishery for shrimp developing off the Homer spit. No figures on the size of this fishery are available.

Vulnerability - Shellfish, presumably including shrimp are relatively immune to the effects of explosives (ADFG, 1960). No studies have been conducted on their reaction to pollution, but they probably are similar to crabs in this respect.

Razor Clams (*Siliqua patula*)

Razor clams occur on the eastern beaches of Cook Inlet between the Kasilof River to Homer Spit with greatest abundance in the Clam Gulch and Deep Creek-Stariski Creek areas. On the western side of the Inlet, they are scattered on various sandy beaches from Harriet Point southward. Heavy concentrations occur at Polly Creek and the northeast side of Chinitna Bay (Logan, personal communication).

Use of this resource for sport has been increasing steadily in recent years until, in 1972, more than 400,000 clams were harvested by sport diggers (Table III-25). The majority of this harvest was made on the easily accessible eastern beaches, with more than 50 percent at Clam Gulch, although diggers are making increasing use of beaches on the western side. On one weekend day in 1972, 62 airplanes were found at Polly Creek during a routine check on this beach. Half of the total sport effort is normally exerted during the month of May.

TABLE III-25

COOK INLET RAZOR CLAM SPORT HARVEST

Year	Effort (man-days)	Clams Harvested
1965	1,800	63,000
1966	1,900	76,000
1967	2,300	68,000
1968	4,600	126,000
1969	12,200	375,000
1970	11,100	307,000
1971	6,800	188,000
1972	14,700	411,000

Commercial exploitation of razor clams within the Inlet has been sporadic since early in this century. A peak was reached in 1923 when $1\frac{1}{2}$ square miles of beach on the western side of the Inlet between Chisik Island and Harriet Point were commercially harvested for clams (USBCF, 1925). Currently, a small commercial operator is harvesting clams in the vicinity of Polly Creek.

The clam harvest has not decreased the productivity of this resource and, during the past 8 years, diggers have consistently averaged about 30 razor clams per trip. The average size has not declined, despite the increase in digging pressure.

Razor clams in Alaska spawn in late June, July and early August. The larvae remain in a free-swimming stage about eight weeks, during which they live in or on the sand near where they were spawned (Loosanoff, 1947).

Vulnerability - As a condition of their intertidal habit, razor clams would be especially susceptible to floating toxic materials which could accumulate in the surf zone. Exposed larvae would probably be affected by such materials washed into the intertidal zone.

Scallops (*Patinopecten caurinus*)

Scallops occur in Cook Inlet, but all districts are presently closed to commercial fishing (Flagg, *viva voce*). The only commercial effort was in 1969 when 240 pounds were harvested in the Kamishak District (ADFG, 1971). Scallops were, however, taken in exploratory surveys conducted by the U.S. Bureau of Commercial Fisheries. Greatest abundance was in the Kamishak District between Augustine and the Barren Islands (Fig. III-26).

No seasonal movements are known for the species.

Hennick (1970) found that most Kodiak scallops spawned between June 3 and June 8, although some spawning further extended into July.

Vulnerability - Vulnerability of scallops is probably similar to that of other deep-water shellfish, such as king crab . Testimony by Dr. Clarence M. Tarzwell (U.S. Senate, 1971), as cited in USDI (1972, p. 199) states that

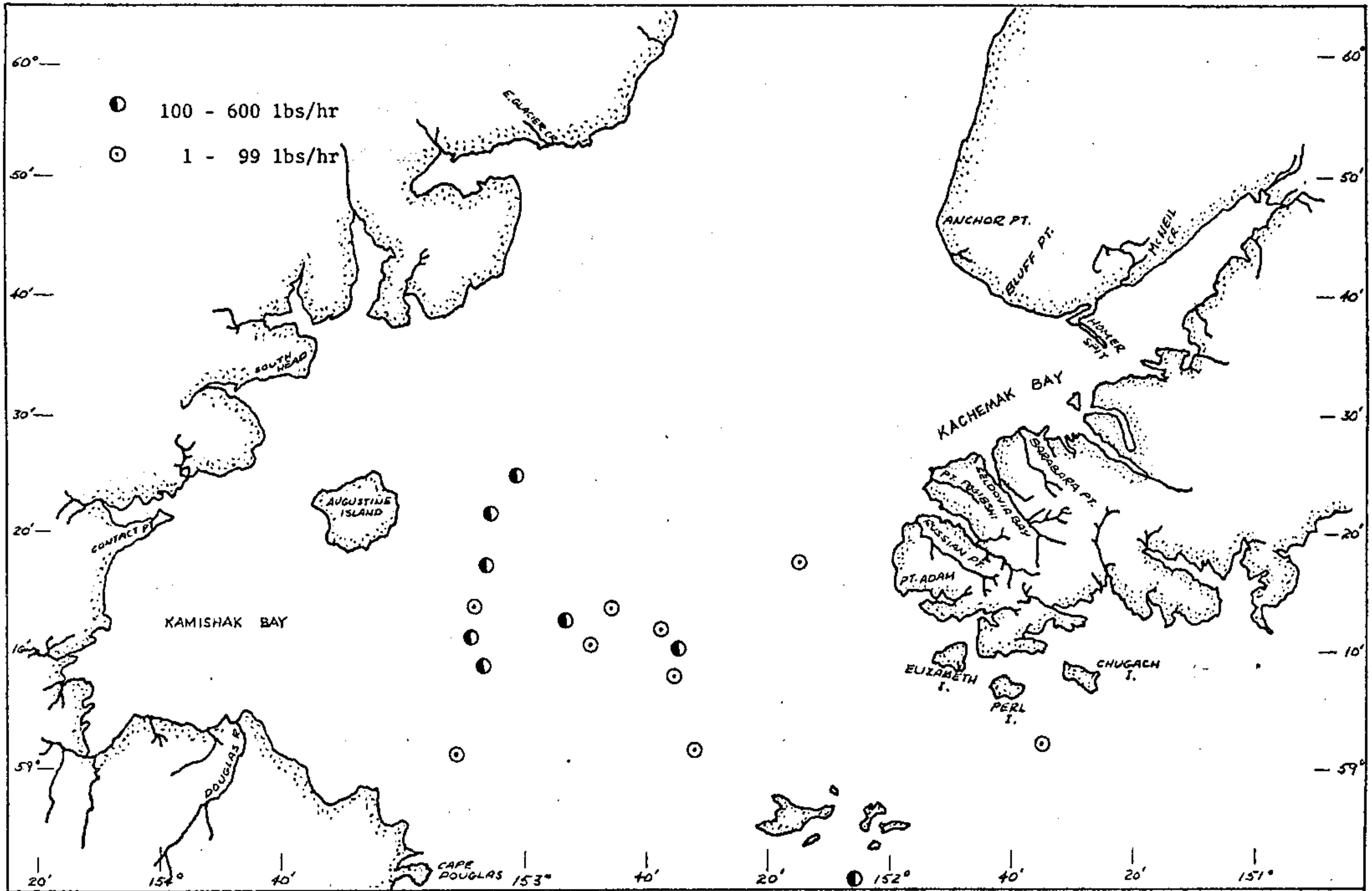


Fig. III-26 SCALLOP EXPLORATIONS. FISHING LOG OF THE FV Viking Queen, CRUISES 3, 4, and 5, May 14 to June 6, 1968, YAKUTAT BAY TO KODIAK ISLAND.

scallops were the most sensitive to oil pollution of several species of molluscs tested.

BIRDS

Very little quantitative information is available on birds in Cook Inlet. A few studies have been conducted at specific locations that provide lists of species found there, sometimes with notes on their abundance.

One hundred five species of birds have been observed at several locations around the Inlet that resulted from work of several observers. Gibson (1967) recorded observations along the shoreline of Katmai National Monument, somewhat south of the Inlet, but probably representative of species found in the southwestern portion. Quimby (1971) recorded birds on the Chickaloon Flats along the south side of Turnagain Arm. Krohn (1966) and Snarski (1971a) recorded birds at and near Chisik Island. Tremblay (1966) surveyed Kamishak and Kachemak Bays, primarily for waterfowl. Bader (1970) compiled a record of birds found on the Potter Marsh on the north side of Turnagain Arm. Snarski (personal communication) reported observations made on flights back and forth across the Inlet (Fig. III-27). He did not calculate the amount of area covered, but counted the number of birds seen. Most abundant were scoters (5, 000), kittiwakes (1, 148) and tufted puffins (704). Sowl and Evans [1/] covered open

1/ Sowl, L. S. and C. D. Evans, Results of an aerial survey conducted August 3, 1972 covering open waters of Cook Inlet.

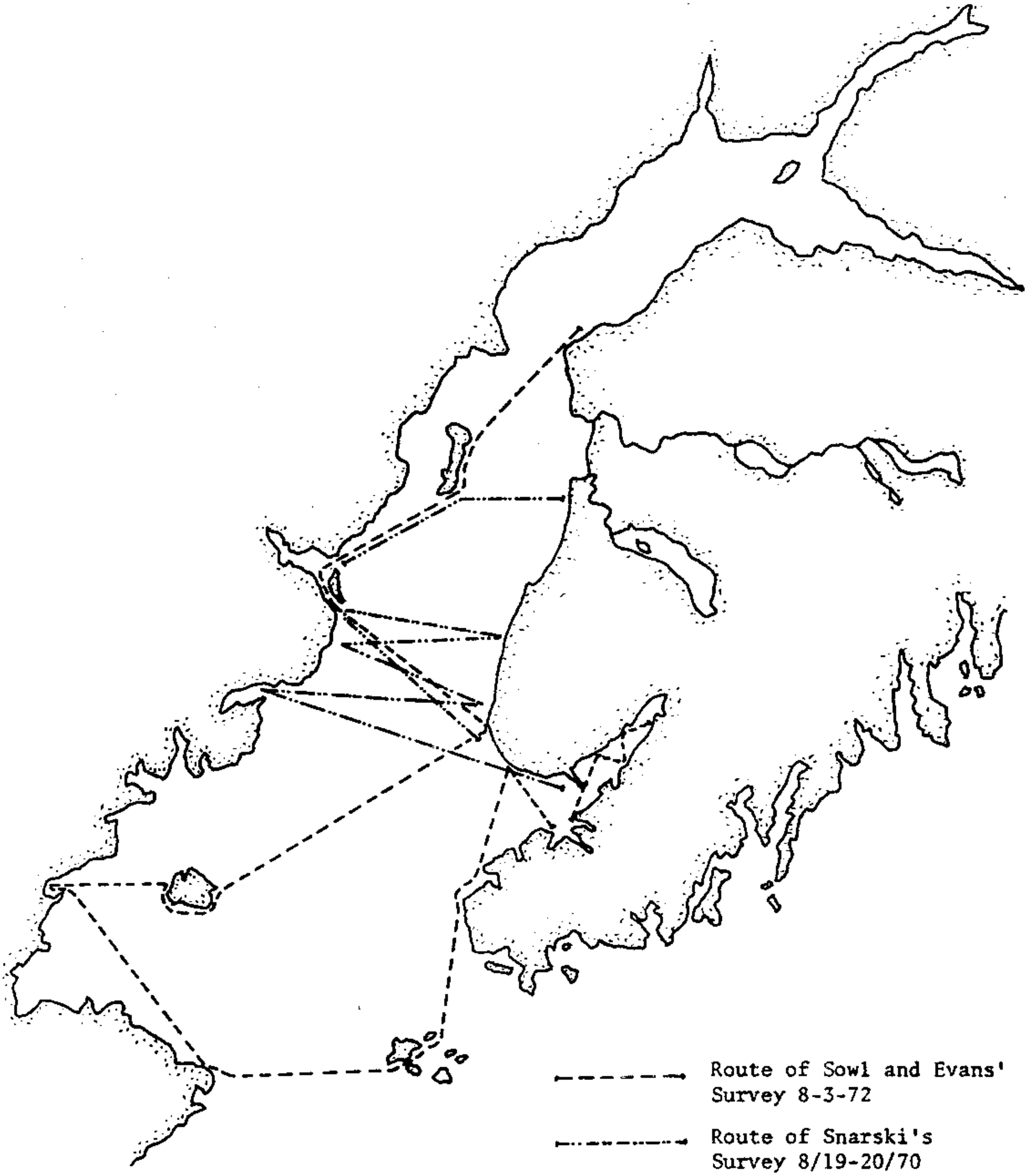


Fig. III-27 MARINE BIRD SURVEYS, COOK INLET, 8/19-20/70 and 8-3-72 waters of the Inlet in a non-random flight as shown in Fig. III-27. Table III-26 is a compilation of these observations. Presence of a species is indicated in this table by an asterisk. Two asterisks indicate that the species was "common", and three indicate it was "abundant". The species are also rated as to their use of salt water, according to Robbins et al. (1966) and Gabrielson and Lincoln (1959). Fifty-nine species of birds were recorded that make at least frequent use of salt water or come into frequent contact with it. Sixteen more species were recorded that come into at least occasional contact with salt water. Eight more species occasionally contact salt water, mostly in hunting or searching for food, and 22 species make significant use of coastal marshes.

Sowl and Evans, on their aerial survey of a strip 1/8 mile wide covered only 50.3 square miles in a sampling pattern governed by available flight time, rather than sampling theory. It also represents only one season of the year. It did, however, provide some measure of bird densities on the Inlet. Densities were analyzed arbitrarily by commercial fishery management districts. Birds were inconspicuous on open waters of the Northern District and were not recorded there. Abundance was low in the North and South Central Districts, but very high in the Southern and highest in the Outer District, where 16 species totalled 301 individuals per square mile (table III-27).

These observations were almost certainly minimal as to numbers of birds and number of species. Fulmars, otherwise not recorded in the Inlet, averaged more than 30 per square mile. They were most abundant near the Barren Islands and northeast of them. Scoters and eiders were numerous in Kamishak Bay. Kachemak Bay contained numerous scoters, also.

A number of marshes important to birds surround Cook Inlet. They

TABLE III-26

BIRD OBSERVATION - COOK INLET - SUMMER UNLESS OTHERWISE INDICATED

Species	Gibson (Katmai)	Quimby (Chickaloon Flats)	Krohn & Snarski (Tuxedni)	Snarski Open water	Tremblay 3-1-66 Kachemak Bay	Tremblay 4-5-66 (Kamishak Bay)	Bader (Potter Marsh)	Sowl and Evans: N. Central	Sowl and Evans: S. Central	Sowl and Evans: Kamishak	Sowl and Evans: Southern	Sowl and Evans: Outer	Habits 1/
Common Loon	**	}	*										SW
Arctic Loon	*	2/ }	**				*		*				O
Red-throated Loon	**	}	*										SW
Red-necked Grebe		*	*				**			*			SW
Horned Grebe	**	*	*				*						SW
Fulmar										**	**	***	SW
Sooty Shearwater			**	**					*	*		**	SW
Fork-tailed Petrel	*									*	*	**	SW
Double-crested Cormorant	**	}	* }						}	}		}	SW
Pelagic Cormorant	**	}	** }	**					}*	}*		}**	SW
Red-faced Cormorant	*	}	}						}	}		}	SW
Whistling Swan	*	*	*				**						O
Trumpeter Swan							*						O
Lesser Canada Goose		}	*			}	**						O
Cackling Canada Goose		}*				}*	*						O
Black Brant	**		*	*									SW
Emperor Goose													SW
White Fronted Goose			?				*						O
Snow Goose		**					*						O
Mallard	**	*	*		**	**	**						O
Gadwall		*					*						O
Pintail	**	*	**	*			**						O
Green-winged Teal	*	*	*										O
Blue-winged Teal							**						M
American Widgeon	*	*	*				*						O
European Widgeon							*						O
Shoveler	*	*	*				**						O
Canvasback		*					*						O
Greater Scaup	*	*	*		*		*						SW
Lesser Scaup							*						SW
Common Goldeneye	*	*	*		}	}	*						SW
Barrin's Goldeneye					}**	}*	*						SW
Bufflehead	*				*		*						SW
Oldsquaw	*		*		**	*							SW
Harlequin	**	*	*				*						SW
Steller's Eider	*	}	}	}		}							SW
Common Eider	*	}	}**	}*		}*				**			SW
King Eider	*	}	}	}		}							SW
Spectacled Eider		}	}	}		}							SW

TABLE III-26 Cont'd

Species	Gibson (Katmai)	Quimby (Chickaloon Flats)	Krohn & Snarski (Tuxedni)	Snarski Open water	Tremblay 3-1-66 Kachemak Bay	Tremblay 4-5-66 (Kamishak Bay)	Bader (Potter Marsh)	Sowl and Evans N. Central	S. Central	Kamishak	Southern	Outer	Habits 1/
White Winged Scoter	*		*		*	*			*	**	*	*	SW
Surf Scoter	*		***	**	**	*		*		**	**		SW
Common Scoter	**		** *								*		SW
Common Merganser	*		*				*						SW
Red-breated Merganser	**	*	*		*		*						SW
Rough-legged Hawk	*						*						I
Bald Eagle	**	*	*		*	*	*			*			I
Golden Eagle							*						I
Marsh Hawk	*	*	*				*						I
Osprey			*				*						I
Peregrine	*		*				*						I
Gyrfalcon			*				*						I
Pigeon Hawk	*		*				*						I
Sandhill Cranes		*	*				**						M
Black Oyster Catcher	**		*							*			SW
Semipalmated Plover	*	*	*				*						M
Killdeer							*						M
American Golden Plover	*	*					*						M
Black-bellied Plover	*	*											M
Surfbird	*		*				*						SW
Ruddy Turnstone	*	*											SW
Black Turnstone	**		*										SW
Common Snipe	*	*	*				*						M
Whimbrel	*	*	*										M
Spotted Sandpiper	**	*	*				*						O
Solitary Sandpiper							*						M
Wandering Tattler	*		*										M
Greater Yellowlegs	**	*	*				**						M
Lesser Yellowlegs			*	*			**						M
Rock Sandpiper	*												SW
Pectoral Sandpiper		*					**						M
Baird's Sandpiper	*		*	Shorebirds			*						M
Least Sandpiper		*	*				**						M
Dunlin	*		*				*						SW
Short-billed Dowitcher	*		*				**						M
Long-billed Dowitcher		*					*						M
Semipalmated Sandpiper		*	*										SW
Western Sandpiper	*	*	*										SW
Marbled Godwit	*												M
Hudsonian Godwit							*						M
Sanderling							*						SW
Northern Phalarope	*	*	*				**					*	SW
Pomarine Jaeger									*				SW
Parasitic Jaeger			*	*					*		*	*	SW
Long-tailed Jaeger													SW

TABLE III-26 Cont'd

Species	Gibson (Katmai)	Quimby (Chickaloon Flats)	Krohn & Snarski (Tuxedni)	Snarski Open Water	Tremblay 3-1-66 Kachemak Bay	Tremblay 4-5-66 (Kamishak Bay)	Bader (Potter Marsh)	Sowl and Evans N. Central	Sowl and Evans S. Central	Sowl and Evans Kamishak	Sowl and Evans Southern	Sowl and Evans Outer	Habits 1/
Glaucous Gull			*				*						SW
Ivory Gull							*						SW
Glaucous-winged Gull	***	*	**	**			**	**	*	**	*	*	SW
Herring Gull							**						SW
Mew Gull	**	*	*	*			**	**	*	*	*	*	SW
Franklin's Gull			*										SW
Bonaparte's Gull		*	*	*			**						SW
Black-legged Kittiwake	*		***	***				**	***	*	***	**	SW
Arctic Tern		*	*	*			**	**		*	**	*	SW
Common Murre	*		***	**					*	*	*	**	SW
Pigeon Guillemot	*		**	*					*	*	*		SW
Marbled Murrelet	*		*										SW
Kittlitz's Murrelet			} *	} *					} *	} *	} *	} *	SW
Ancient Murrelet													SW
Parakeet Auklet			*										SW
Rhinoceros Auklet			*									} *	SW
Horned Puffin	**		**	**					} *	*	*		SW
Tufted Puffin	**		**	**						*	*	***	SW
Short-eared Owl	*		*				*						M
Common Raven	*		*										M
Northwestern Crow	**												M

Key to Habits

1/ SW - Predominantly salt water residents at least part of the year
O - Make at least occasional use of salt water
M - Marshes or Inlet shores only
I - Incidental contact with salt water

2/ Brackets indicate cases where observers grouped species. In this instance, observations were recorded as "Loon".

TABLE III-27

COOK INLET BIRD SURVEY, AUGUST 3, 1972

Species	District											
	North Central (4.5)		South Central (8.4)		Kamishak (15.5)		Southern (13.9)		Outer (8.0)		Total (50.3)	
	No	/per sq mi	No	/per sq mi	No	/per sq mi	No	/per sq mi	No	/per sq mi	No	/per sq mi
Loon			1	.1	1	.1					2	tr.
Fulmar					110	7.1	152	10.9	1461	182.6	1723	34.3
Shearwater			2	.2	5	.3	5	.4	37	4.6	49	1.0
Petrel					21	1.4	15	1.1	13	1.6	49	1.0
Cormorant			6	.7	18	1.2	1	.1	34	4.3	59	1.2
Common Eider					315	20.3			18	2.3	333	6.6
Scoter	5	1.1	7	.8	731	47.2	1039	74.7	10	1.3	1792	35.6
Black Oyster Catcher					50	3.2					50	1.0
Northern Phalarope									30	3.8	30	.6
Jaegar			5	.6			7	.5	5	.6	17	.3
Glaucous Winged Gull	13	2.9	3	.4	296	19.1	63	4.5	22	2.8	397	7.9
Black Legged Kittiwake	25	5.6	66	7.9	84	5.4	311	22.3	265	33.2	751	14.9
Arctic Tern	35	7.8			3	.2	100	7.2	20	2.5	158	3.1
Common Murre			1	.1	34	2.2	50	3.6	203	25.3	288	5.7
Pidgeon Guillemot			11	1.3	4	.3	3	.2			18	.4
Puffin			7	.8	41	2.6	36	2.6	257	32.1	341	6.8
Murrelet			21	2.5	5	.3	23	1.7	5	.6	54	1.1
Mew Gull	12	2.7	5	.6	18	1.2	3	.2	20	2.5	58	1.2
Bonaparte's Gull							50	3.6			50	1.0
Other			4	.5	3	.2			8	1.0	15	.3
	90	20.0	139	16.5	1739	112.2	1858	133.7	2408	301.0	6234	123.9

are listed below with some indicators as to their use by birds. Their use by waterfowl hunters is as indicated in Shepherd et al. (1967), Havens (1970 and 1971), Tremblay (viva voce) [1/] and personal observations.

Palmer Hay Flats - Geese, swans and ducks during spring and fall migration-some nesting, much hunting. 2.2 ducks per hunter checked.

Goose Bay - Ducks and geese during migration-some hunting, some nesting.

Susitna Flats - Ducks, geese and swans during spring and fall migration. Some nesting, much hunting. As many as 38 private aircraft on the flats in one day (Tremblay, viva voce). 3.2 ducks per hunter checked.

Trading Bay - Ducks and geese in spring and fall migration. Some nesting, some hunting.

Redoubt Bay - Ducks and geese in fall migration. Some hunting, some nesting.

Chickaloon Flats - Heavy concentrations of ducks and geese in migration. As many as 20,000 or more Canada geese and 500 or more swans. Heavily hunted at times. Used extensively by sandhill cranes during migration. Nesting ducks.

Other small marshes (Potter, Eagle River, Portage) are migration stopovers and are hunted. Some nesting.

Table III-28a shows waterfowl populations in four marsh areas around the north and west side of the Inlet as observed and recorded by Tremblay (viva voce). Geese are an important segment of the bird population of these marshes, particularly in spring. The same is true of the Chickaloon Flats, where birds often concentrate when bad weather closes Portage Pass (Fig. 1-2). Havens (1970) remarks that as many as 6,000 ducks and 4,000 geese may be found there in late summer and early

[1/] Tremblay, R.H., U.S. Game Management Agent, Bureau of Sport Fisheries and Wildlife, Anchorage.

TABLE III-28a
DATA FROM SPRING AND FALL SURVEYS OF FOUR MARSHES IN COOK INLET

	May 2, 1972				August 24, 1967				
	Pt. MacKenzie Little Susitna	Little Susitna to Big Susitna	Big Susitna to Beluga River	Palmer Flats	Pt. MacKenzie Little Susitna	Little Susitna to Big Susitna	Trading Bay	Redoubt Bay	
Swans	30	500	50	100					
Canada Geese	1700	3300	300	800	40				
White Fronted Geese	150	10	50	2		40	300		
Snow Geese	1300	2200	50	80					
Mallard							100		
Pintail					150	150	300	100	
	150	200	50	250					1/
Teal					50	250	500		
Widgeon					300	400	700	200	
Scaup									
Goldeneyes									2/
		50		30					
Scoter									
Cranes	3		3	4					
TOTAL WATERFOWL	3333	6260	503	1266	540	840	1900	300	

1/ Brackets indicate species grouped in dabbling ducks .

2/ Brackets indicate species grouped in diving ducks.

fall. He also reported 21,000 Canada geese and 200 snow geese there October 5, 1971 (Havens, 1971). Havens provides data from six separate counts in 1970 and five in 1971 that illustrate to some extent the seasonal trends in waterfowl populations on the Susitna Flats (Tables 29b and 28c). Fluctuations in population during the migration period are sometimes very rapid and sufficient data are not available to determine just when these peaks normally occur or the shape of the population curve.

Tremblay (viva voce) describes the fall buildup in these marshes as beginning early August and peaking when the Interior of the state freezes up in late September. Frequently 10,000 or more waterfowl occupy the area at that time. The marshes usually freeze over about mid-October in the Upper Inlet and the migration is then at an end.

Highest populations of these marshes are in spring when they are used by several thousands of lesser Canada and snow geese, a few thousand ducks and occasional swans and cranes. Tremblay emphasizes that there is an unknown exchange of birds during migration so that there is no way to estimate the total number of birds that make use of inlet marshes.

The Fox River Flats may have as many as 6,000 mallards (Havens, 1970). Smaller numbers of ducks and geese numbering in the hundreds are often found in such places as Halibut Cove, China Poot Bay, Sadie Cove, Tutka Bay, and other bays and coves around the Inlet (Havens, 1971, and personal observation).

Waterfowl Hunting - Shepherd et al. (1967) lists harvest information for that year when an unknown number of hunters took an average of 2.2, 4.4 and 3.2 ducks per day on the Hay Flats, Anchorage road system and the Susitna Flats respectively. Havens (1970) checked hunters on the Upper Inlet (Eagle River, Upper Inlet areas and Chickaloon Flats). They had taken

TABLE III-28b
WATERFOWL SURVEY DATA, SUSITNA FLATS [1/]

Species	April 16, 1970	May 5, 1970**	May 28, 1970	June 25, 1970	Aug. 12, 1970	Sept. 28, 1970	Oct.5,1970
Dabbler	0	0	0	0	525	2570	4484
Pintail	134	1440	122	659	1855		
Pintail w/brood	0	0	0	1	0		
Mallard	31	990	69	126	846		
Widgeon	0	625	56	1321	1185		
G-W Teal	0	110	8	121	1045		
G-W Teal w/brood	0	0	0	1	0		
Shoveler	0	30	9	179	0		
Gadwall	0	0	2	0	0		
Scaup*	0	0	119	46	0		
Canvasback	0	0	6	3	0	6	
Goldeneye*	0	0	9	0	0		
Divers	0	0	0	0	0	20	165
TOTAL DUCKS	165	3195	400	2457	5452	2596	4649
Canada Geese	312	3395	493	6	685	125	100
B. Brant	0	0	50	0	0	0	0
W-F Geese	15	600	58	9	420	0	0
W-F w/brood	0	0	0	3	0	0	0
Snow Geese	0	200	0	0	0	0	0
TOTAL GEESE	327	4195	601	18	1105	125	100
Swan*	0	509	2	7	2	157	1296
Crane	0	0	4	0	5	0	0
TOTAL WATERFOWL	492	7899	1007	2482	6564	2878	6045

* Not identified to species.

** Estimates by D. Bader

1/ From Havens, 1970.

TABLE III-28c
WATERFOWL SURVEY DATA, SUSITNA RIVER [1/]

Species	May 6, 1971	Aug. 27, 1971	Sept. 17, 1971	Oct. 5, 1971	Oct. 27, 1971
Dabbler	35,000	8,650	6,750	1,375	2,425
Canada Geese	17,500	1,200	140	270	695
Snow Geese	17,500				
Swan	*	*	26	1,288	1,032
TOTAL WATERFOWL	70,000	9,850	6,916	2,933	4,152

* Not surveyed

1/ From Havens, 1971.

1,084 ducks which were predominantly pintails, mallards, baldpates and green-winged teal. Of 57 geese in the bag, 43 were lesser Canadas.

There is little information on hunting effort in the Inlet. Tremblay (viva voce) states, however, that he has counted as many as 38 aircraft in marsh areas on the west side of Cook Inlet on a busy weekend.

Vulnerability of birds - Explosives used in geophysical surveys should have negligible impact on birds, except where their food source might be significantly affected. This impact would seem most likely adjacent to such rookeries as Chisik Island. Erickson (1963) in USDI (1972) states that the use of important feeding grounds has declined greatly after pollution by oil, either because of elimination of important food and cover or because fouling of the habitat had reduced the attractiveness of the areas.

The effect on the birds themselves of oil floating at the surface of the water is well documented by numerous authors. Instances have occurred in the Cook Inlet area (USDI, 1970; Evans, 1969; and others). Birds appear to have no mechanism for recognizing the danger of oil and do not avoid it. A significant amount of oil on a bird leads to compaction of the feathers and loss of insulation, usually resulting in death. Attempts to rehabilitate affected birds are expensive and recovery rates have usually been low.

The last column of table III-26, indicating the habits of the species relative to salt water, gives some idea of the relative susceptibility of the various species to damage. Species such as murres, scoters, puffins, eiders and others that spend most of their time on salt water would be most likely affected. Such birds as loons, mallards, widgeon and others that make use of salt water occasionally would be equally vulnerable, but only at the time they were on salt water. This is most often during spring and fall migration and sometimes in winter. It has been noted in Cook Inlet by King (viva voce) [1/] that some species of marsh-dwelling dabbling ducks make heavy use of the tideline adjacent to marshes in the Inlet, apparently in search of food, making use of seeds of sedges windrowed there. To date, the combination of tidal currents, circulation and winds has been such that no oil spilled in the Inlet has been known to go ashore except at the north end of Kalgin Island (Kinney et al., 1970a). These birds appear, however, to be in a vulnerable situation.

Marsh dwelling birds would not ordinarily be affected by oil spilled on the Inlet, unless such a combination of winds and tides occurred that oil was driven into the marsh. Such an incident would not only kill birds but would undoubtedly damage their habitat.

1/ King, James G., Waterfowl supervisor, U. S. Bureau of Sport Fisheries and Wildlife, Juneau.

MARINE MAMMALS

Lower Cook Inlet is habitat for several species of marine mammals. A few reach the Upper Inlet, even up the Susitna River.

Sea Otters (*Enhydra lutris*) - Schneider (*viva voce*) [1/] reports that about 1,000 sea otters are distributed in the west side of the Inlet from Shakun rocks to Chinitna Point. These animals are mainly concentrated in the vicinity of Augustine Island and Cape Douglas. He points out that recent experience suggests the population figures in his earlier report (Schneider, 1970) are too low and probably should be doubled. The present population is a considerable increase from the 40 reported for the area in 1957 (Kenyon, 1969).

Schneider also believes the population east of the Inlet now numbers several hundred and that about 1,000 inhabit the Barren Islands.

Pupping of sea otters peaks in late spring, but may occur at any time of year. Pups may be with their mother at any season.

Vulnerability - Kenyon (1969) stresses the fact that cleanliness is necessary to the sea otter's survival. If the fur becomes soiled by foreign matter, it loses water repellency and the animal dies. The sea otter would also be affected if its habitat were degraded or its food supply reduced. The Augustine Island-Cape Douglas population is situated close to the major outflow of water from the Inlet, as discussed in the circulation section of this

---

1/ Schneider, Karl, Marine mammals biologist, Alaska Department of Fish and Game, Anchorage.

report. Any major contaminants in the Inlet would probably pass at least close to this habitat.

The impact on sea otters of such explosives as are used in geophysical surveys is not well documented. Kenyon (1969) points out, however, that even large juveniles that have been deserted are unable to maintain themselves. Excessive disturbance could well be a mortality factor.

Harbor Seals (Phoca vitulina) - Schneider (viva voce) reports that several hundred harbor seals may at times occupy Augustine and Shaw Islands. They may be seen throughout Kachemak Bay with a concentration found on Yukon Island northeast of Seldovia. They occur on the entire west side with a concentration at the mouth of the Susitna River. They seldom reach north of Kachemak Bay on the east side. The Chugach Islands, east of Cook Inlet, have a pupping population from late May through July. There is also a concentration of more than 1,000 harbor seals at Sud Island in the Barren Islands.

Vulnerability - Harbor seals appear to be resistant to effects of oil (USDI, 1972). Any activity that would affect their food supply could also affect the seals themselves Schneider believes explosives would be damaging during the pupping period.

Sea Lions (Eumetopias jubata) - Schneider reports a year-round population of 6,000 to 10,000 sea lions on the Barren Islands, just south of Cook Inlet. Most pupping takes place on Sugar Loaf Island in June and July.

There is some hunting of pups in the Barren Islands.

Vulnerability - USDI (1972) concludes that most marine mammals are relatively resistant to oil pollution and can avoid slicks.

Beluga Whales (Delphinapterus leucas) - Schneider believes the Cook Inlet belugas are a discrete population and Klinkhart (1966) reports a summer population in the Inlet of 300 to 400 animals. They run up Cook Inlet as far as the Susitna River and Ship Creek. The presence of salmon, of which both adults and smolt are important food items, probably accounts for the presence of beluga in the turbid waters of the Upper Inlet. Schneider (viva voce) states that winter movements of the Cook Inlet beluga are not known.

An attempt at commercial harvest was made in the 1930's but was abandoned after 100 animals had been taken. Sport hunting of belugas has developed recently in Cook Inlet. Whales are presently on the endangered list, however (USDI, 1966 and addenda),[1/] and harvest is probably not a consideration.

Most reproductive activity in Alaskan belugas (Klinkhart, 1966) probably takes place in May and June. Gestation probably takes 12 months and this would be the date of calving. The calf remains with its mother several years after an eight-month lactation period.

Vulnerability - Klinkhart (1966) reports that explosives appear to disturb the beluga's orientation mechanism rather than harming the animals.

Like the sea lion, the beluga is probably little affected by oil.

Other Marine Mammals - Schneider (viva voce) indicates that other whales are commonly observed in the Lower Inlet and killer whales (Orcinus orca) are sighted in Kachemak Bay. This is born out by reports of

[1/] Federal Register Vol. 35, no. 233, Dec. 2, 1970, pp. 18319 to 18322 and Dept. of the Interior supplemental list of Dec., 1971.

fishermen in Kachemak Bay and observations of Sowl and Evans during their bird survey August 3, 1972, when a killer whale and 12 Dall porpoises (*Phocoenoides dalli*) and two harbor porpoises (*Phocoena phocoena*) were seen in the Lower Inlet.

ENDANGERED SPECIES

The list of endangered species of the United States (USDI, 1966) has been revised several times, most recently in December 1971. It is presently being reissued in an up-to-date form and should be available in the near future.

The peregrine falcon has been reported by several observers in Cook Inlet, but has not been identified positively as the rare and endangered subspecies *anatum* or *tundrius*. Although the peregrine is not an aquatic bird, Gibson (1967) described the kill of a harlequin duck on salt water in the Katmai National Monument during which the peregrine dragged the duck 30 feet to shore. This situation or others similar would have exposed the peregrine to effects of oil floating on the water.

Whales are now on the list as endangered and would include the beluga, a common resident throughout Cook Inlet waters.

GEOLOGIC RISK PHENOMENA

EARTHQUAKE RISK

Southern Alaska and the adjoining Aleutian chain constitute one of the world's most active seismic zones (Fig. IV-1). Extending from Fairbanks on the north to the Gulf of Alaska on the south, the Alaska seismic zone is but a part of the vast near-continuous seismically and volcanically active belt that circumscribes the entire Pacific Ocean basin (Fig. IV-2). Between 1899 and May, 1965, nine Alaska earthquakes have equalled or exceeded Richter magnitude 8, and more than 60 have equalled or exceeded magnitude 7. About seven per cent of the earthquake energy released annually on the globe originates in the Alaska seismic zone (Hansen *et al.*, 1966).

This highly active zone is circumferential to the Gulf of Alaska and parallel to the Aleutian Trench. It embraces the rugged mountainous region of southern Alaska, Kodiak, the Aleutian Islands, and the continental shelf and continental slope of the Aleutian Trench. Most of the earthquakes originate at shallow to intermediate depths - mostly less than 50 km - between the Aleutian Trench and the Aleutian Volcanic Arc. Foci are generally deeper away from the trench toward the arc (Hansen *et al.*, 1966).

A brief discussion of seismicity in Alaska and a history of Alaska earthquakes is contained in Wood (Ed. , 1966).

This seismic and volcanic activity is the result of tectonic processes that have recently been recognized as active and coherent on a worldwide scale. In South Central Alaska two major tectonic structures meet. One is the Aleutian

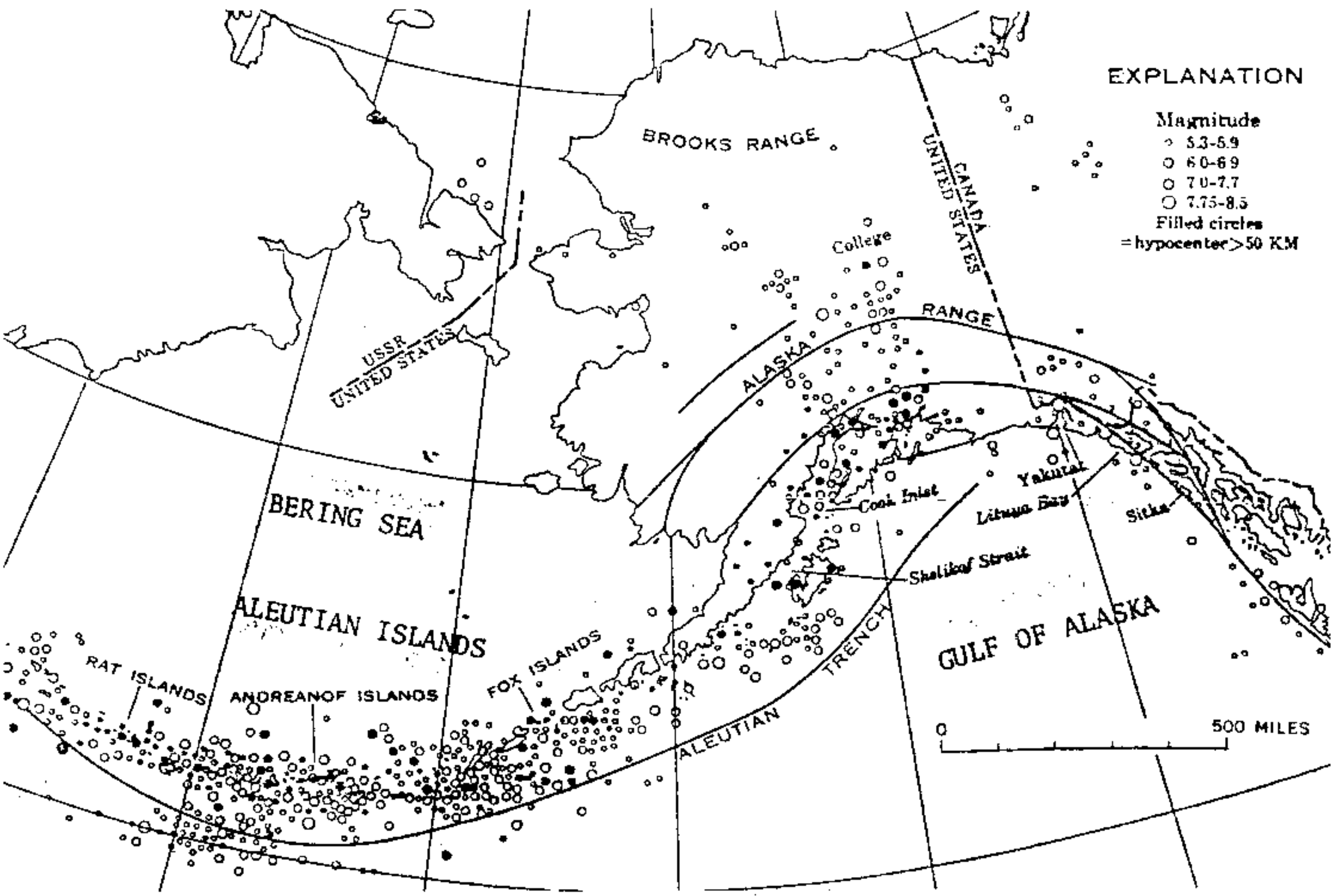


Fig. IV-1 EPICENTERS OF MAJOR ALASKAN EARTHQUAKES, 1898-1961
(from Hanson et al., 1966)

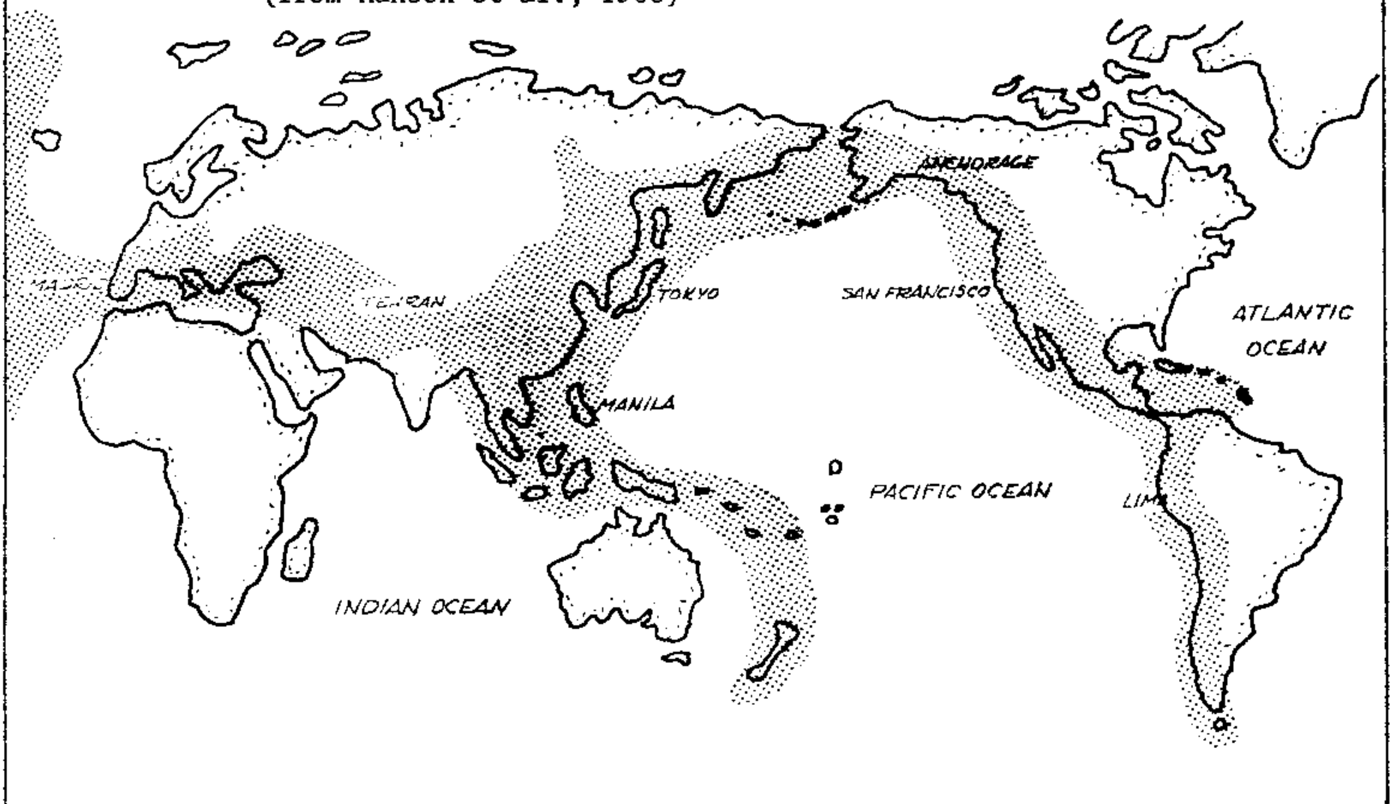


Fig. IV-2 EARTHQUAKE BELTS OF THE WORLD. THESE BELTS COINCIDE WITH THE EARTH'S OROGENIC ZONES AND CONTAIN MOST OF THE EARTH'S ACTIVE VOLCANOES

Island arc where the crust of the Pacific Ocean is being underthrust northward beneath the islands and continent into the mantle. Earthquakes, both shallow and deep, and volcanoes are manifestations of the underthrusting. The other tectonic feature is the system of large strike-slip faults along the coasts of British Columbia and Alaska that likely connects with the Denali fault in South Central Alaska. These faults are characterized by shallow earthquakes. The juncture between these two structures probably includes most of South Central Alaska.

The Cook Inlet region lies within the zone of high seismic activity described above and is highly susceptible to earthquakes. A list of all the earthquakes that have occurred in the Cook Inlet region since 1961 is currently being compiled by NOAA's Palmer Seismological Observatory. Both deep and shallow earthquakes have occurred. Many earthquakes of magnitude greater than 6.0 have been recorded in the area since 1899 (Fig. IV-3), and undoubtedly will continue to occur. The Cook Inlet region is included in seismic risk zone 3, defined as areas susceptible to earthquakes with magnitude 6.0 - 8.8 and where major structural damage could occur (Fig. IV-4 from Federal Field Committee, 1971). This area is the population and industrial center of the state, and earthquakes are a major hazard to life and property. As the population increases and economy rapidly expands, the potential loss due to earthquakes and related natural catastrophes similarly rises.

Damage due to earthquakes can be severe and can be caused by a variety of factors including direct seismic vibration, ground breakage, mud or sand emission

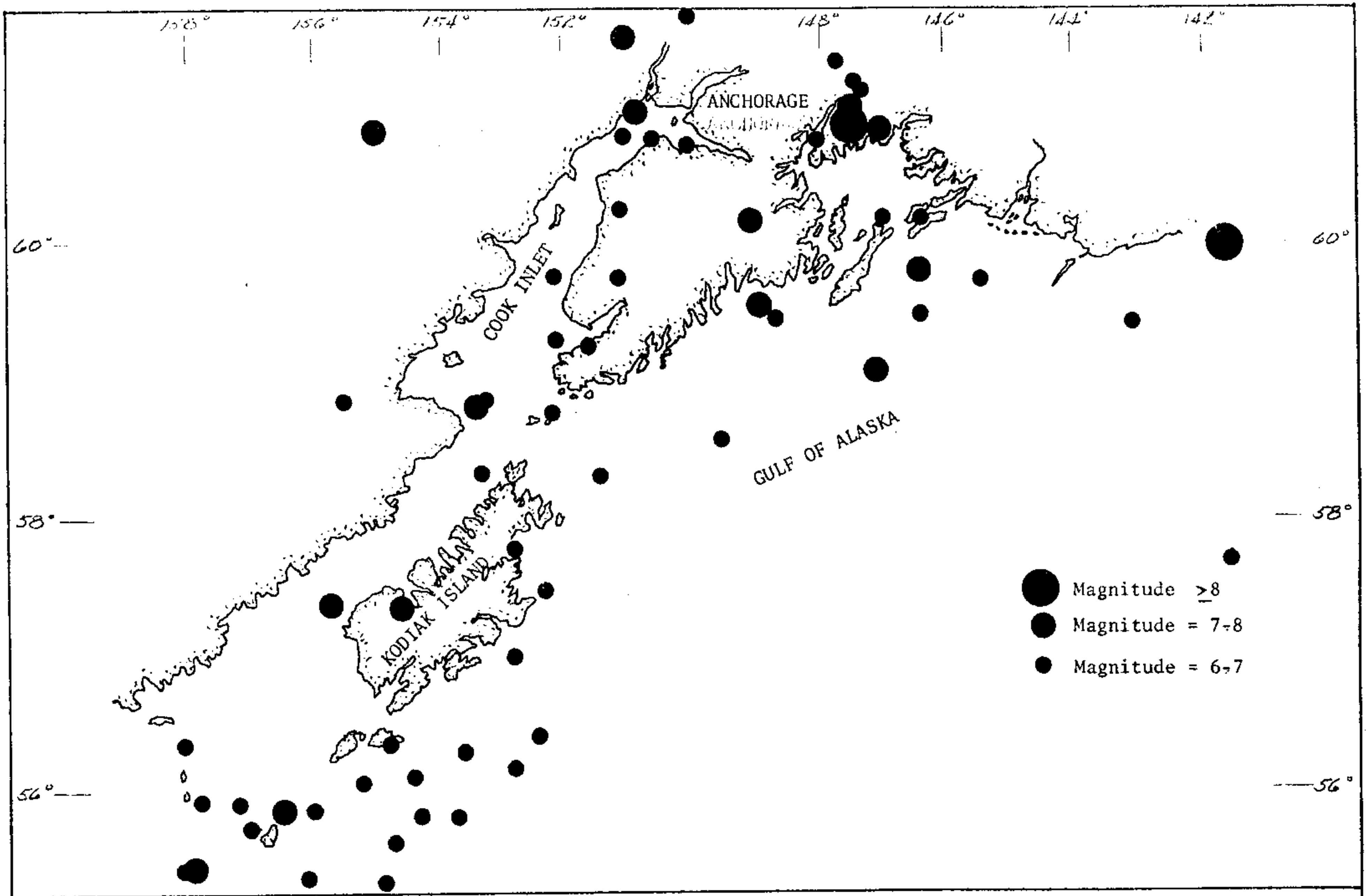
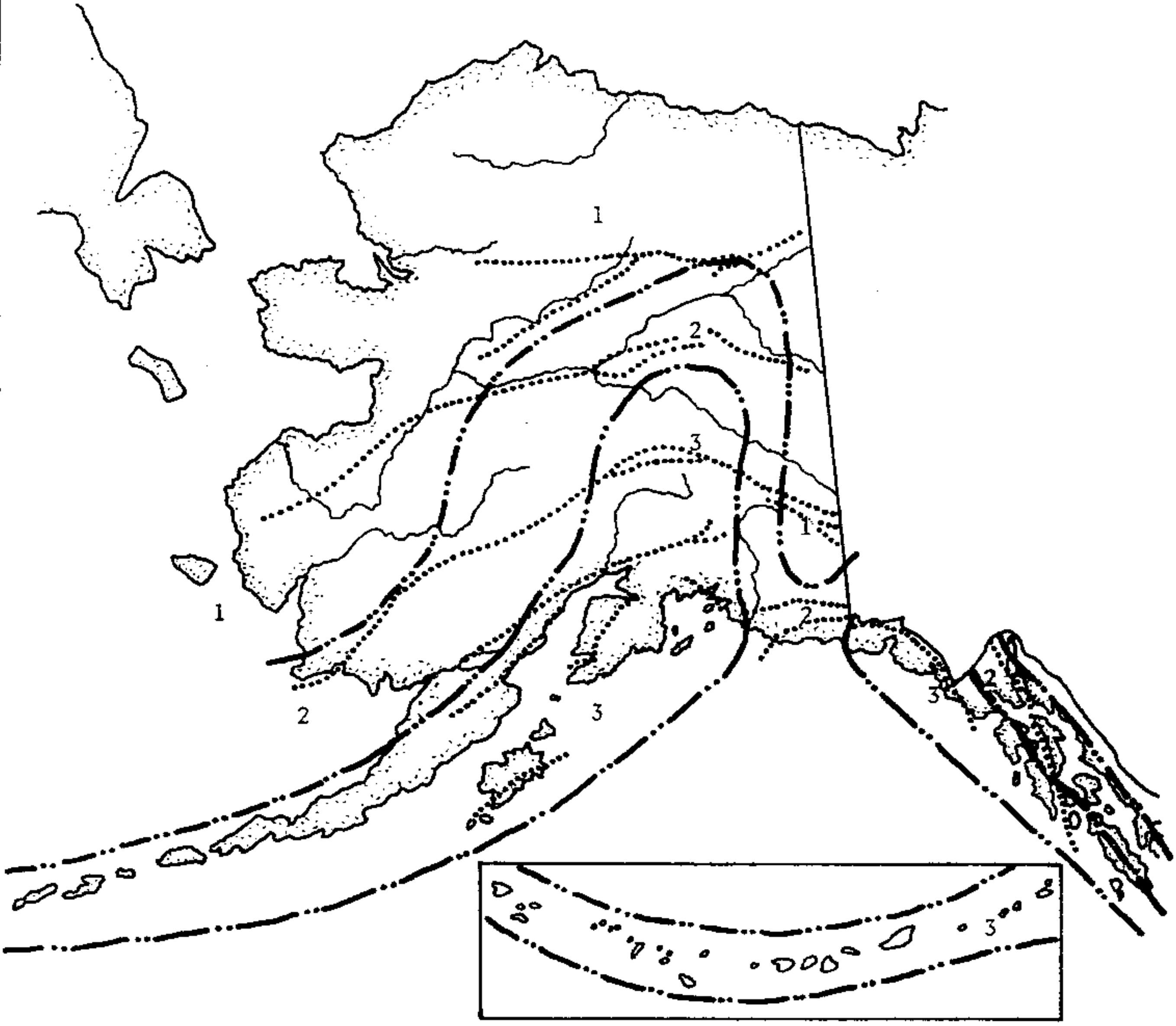


Fig. IV-3 EARTHQUAKES WITH MAGNITUDE ≥ 6.0 IN THE COOK INLET - PRINCE WILLIAM SOUND AREA, 1899-1964



Major Faults

Seismic Zones

1--Minor structural damage (3.0-4.5)
2--Moderate structural damage (4.5-6.0)
3--Major structural damage (6.0-8.8)

Source: Compiled in 1971 by the Federal Field Committee for Development Planning in Alaska from authoritative sources.

Fig. IV-4 FAULTS & SEISMIC AREAS IN ALASKA from cracks, ground lurching, subaerial and submarine landslides, fires, seawaves, and land level changes. Past experience in Alaska has shown that areas of poor soil stability, including offshore areas, and waterfront areas exposed to possible seawave (tsunami) innundation are the most vulnerable. Consequently, this makes all oil and gas facilities and operations in Cook Inlet extremely vulnerable to earthquake damage.

The effects of these factors can be well illustrated by the results of the great Alaskan "Good Friday" earthquake. Late in the afternoon of March 27, 1964, one of the greatest geotectonic events of our time occurred in Southern Alaska. Half of Alaska was rocked and jarred by the most violent earthquake to occur in North America this century. This earthquake has become renowned for its desstructiveness, long duration, and great breadth of its damage zone. Its magnitude has been computed by various observers to range from 8.3 to 8.75 on the Richter Scale. Few earthquakes in history have been as large. Thousands of people were made homeless, 114 lives were lost, and the economy of the entire state was disrupted. Seismic seawaves swept the Pacific Ocean from the Gulf of Alaska to Antarctica.

The epicenter of the earthquake was located at the head of Prince William Sound on the south flank of the Chugach Mountains about 80 miles east-southeast of Anchorage. The hypocenter, or point of origin, was at a depth of 12 to 30 miles. The duration of the earthquake has to be estimated because of lack of instrumentation, but observers fixed the duration of the shock at three to four minutes.

Numerous reports have been written describing the impact of this earthquake.

Especially pertinent are the series of Professional Papers published by the U.S. Geological Survey, a three volume publication by the U.S. Department of Commerce, and an eight volume report published by the National Academy of Science.

An area of at least 70,000 square miles, and possibly 110,000 square miles, was tectonically uplifted or depressed during the earthquake. Much of Cook Inlet was in an area of general subsidence and a section of Kamishak Bay is believed to have been uplifted (Plafker, 1969).

In Anchorage, damage was caused by direct seismic vibration, by ground cracks, and by landslides. Direct seismic vibration affected chiefly multistory buildings and buildings having large floor areas. Most small buildings were spared. Ground cracks caused damage throughout the Anchorage Lowland. Landslides caused the most damage and were attributed to the failure of Bootlegger Cove Clay, which, under vibratory stress of the earthquake, failed along zones of low shear strength. The Bootlegger Cove Clay is a glacial estuarine-marine deposit underlying much of the Anchorage area (Hansen, 1965).

The earthquake shook the Homer area for about three minutes, causing a two to six foot general subsidence of the mainland and Homer Spit, an earthflow, and several landslides on the Homer Escarpment. The greatest damage was to Homer Spit, a four-mile long gravel and sand bar intruding into Kachemak Bay. After the earthquake and resulting tectonic subsidence, much of the spit was below high tide levels. A submarine landslide at the end of the spit destroyed much of the harbor breakwater (Waller, 1966a).

The earthquake caused considerable ground breakage throughout the rest of the Cook Inlet area. The breakage occurred mostly in thick deposits of unconsolidated sediments. The principal area of ground breakage in the Cook Inlet area was in a northeast trending zone 60 miles long and six miles wide in the northern part of the Kenai Lowland. Cracks were as much as 30 feet across and 25 feet deep. A few avalanches and slumps occurred along the coast of Cook Inlet and tidal flats were cracked. Observations along the coasts indicated changes in sea level which, although caused partly by compaction of unconsolidated sediments, may largely be attributed to crustal deformation accompanying the earthquake. Most of the Cook Inlet area was downwarped, although the northwest side may have been slightly upwarped. Maximum change in the Cook Inlet area was probably less than six feet (Foster and Karlstrom, 1967).

The earthquake also greatly affected the hydrology of South Central Alaska (Waller, 1966b). Groundwater was drastically affected in unconsolidated aquifers for at least 160 miles from the epicenter. Lake and river ice was broken for distances of 450 miles from the epicenter by seismic shock and seiche action. The surging action temporarily dewatered some lakes. Landslides and avalanches temporarily blocked streams and rivers, in some cases diverted them permanently.

Within 100 miles of the epicenter, including the upper section of Cook Inlet, vast quantities of sediment-laden water were ejected into flood plains of glaciofluvial valleys. Subsidence was also common near submarine landslides and was probably caused by loss of water pressure and spreading of sediments.

Deep aquifers in unconsolidated sediments, which in most cases were under high hydrostatic pressure, were also greatly affected. Seismically induced pressure on groundwater was instrumental in causing most of the disastrous slides

(Waller, 1966b).

Damage during the earthquake was widespread and was caused by all the factors listed above. Landslides probably caused the most damage to man-made structures and seawaves took the most lives. Anchorage, because of its size, bore the brunt of property damage, even though it was located 80 miles from the epicenter (Hansen et al., 1966). The widespread and extensive damage reflects the fact that most communities in South Central Alaska are built on relatively unstable sedimentary rocks that amplify seismic motions. This geologic factor greatly increases the seismic hazard.

In addition to the less frequent large deep focus earthquakes that can cause widespread damage, there is also significant risk associated with smaller, shallow shocks occurring more frequently and closer to population and industrial centers. For example, a small quake in December 1969, located on the west side of Cook Inlet caused minor damage on nearby drilling platforms. Movements along active faults such as the Castle Mountain fault could cause such quakes.

Since the 1964 earthquake, many new and taller buildings have been built in Anchorage and many new oil and gas facilities have been constructed in Cook Inlet, further increasing the risk in the area. Seismic risk can be reduced if the design of structures and coastal and offshore facilities takes into consideration earthquake forces. In addition, the location of such structures and facilities must take into account the susceptibility of the soil for earthquake damage as well as the area's vulnerability to tsunamis and their associated forces. Offshore drilling platforms in Cook Inlet evidently have been designed to withstand wave and earthquake forces, and these forces are considered to be small as compared to forces created by ice movement (Visser, 1969).

The U.S. Geological Survey is currently embarking on a program of "seismic microzonation" or "earthquake geologic hazards mapping" in the San Francisco Bay region, which is directed towards developing methods to quantify hazards and to express these hazards in map and other formats useful for hazard reduction. This study is identifying landslide areas, active fault zones, areas with liquefaction potential, as well as studying and mapping the seismic response of the various geologic deposits. This data will be furnished to various levels of government and to many facets of the private sector in the development of suitable decision-making and administrative techniques for hazard reduction (Wallace and Brown, 1972). A similar type study could be valuable in reducing earthquake risk in the Cook Inlet region.

Earthquake monitoring and dissemination of warnings to the public, especially of earthquake generated tsunamis, also are effective ways of reducing earthquake hazard. The latter subject is discussed separately in the following section.

Detailed monitoring of earthquakes in the Cook Inlet region is currently being carried out by the U.S. Geological Survey (USGS), the National Oceanic and Atmospheric Administration (NOAA) and the University of Alaska (U. of A.) Fig. IV-5). The U. of A. and NOAA stations are designed to study the overall

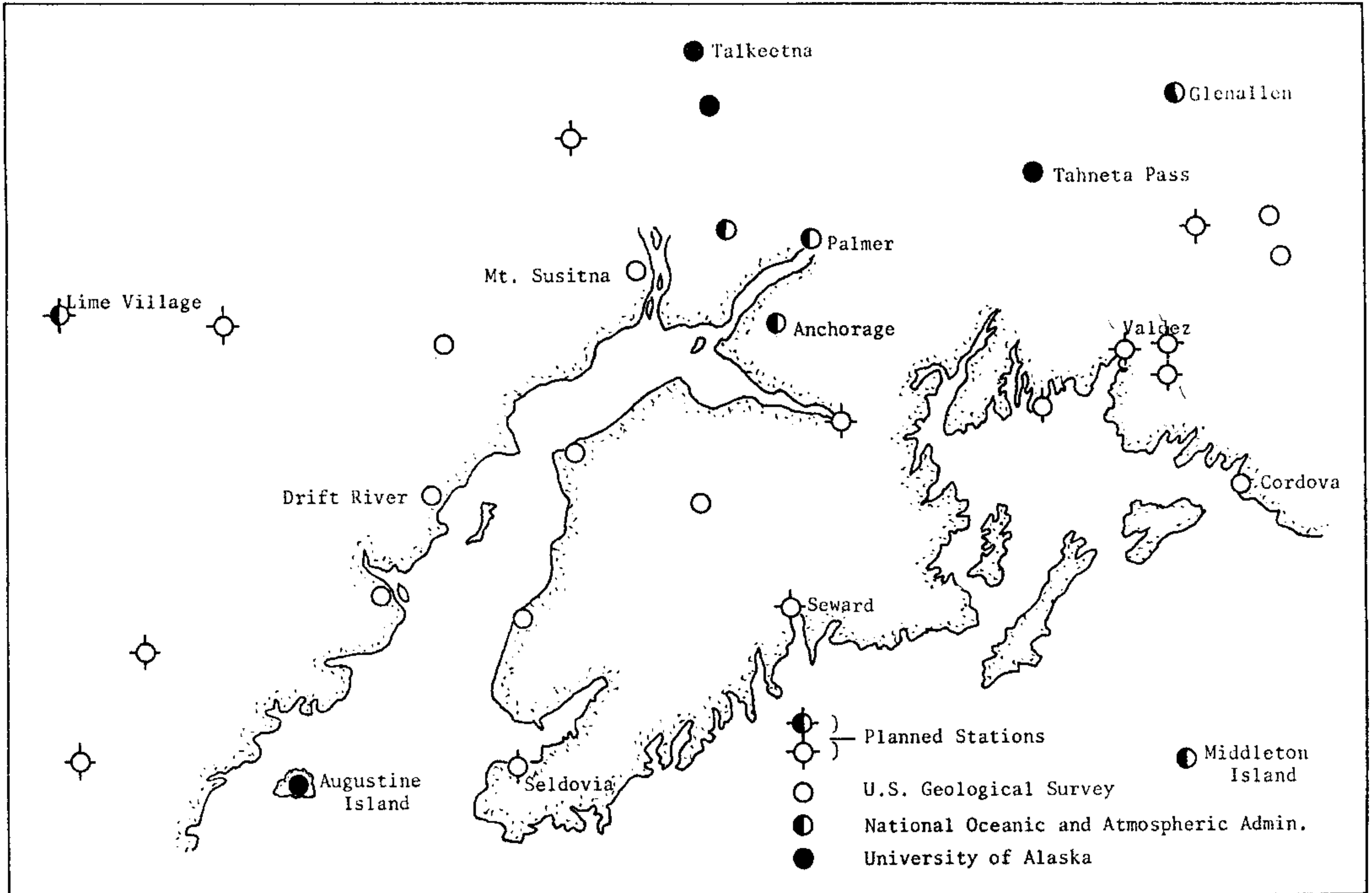


Fig. IV-5 LOCATION OF EXISTING AND PLANNED SEISMOGRAPH STATIONS IN SOUTH-CENTRAL ALASKA regional seismicity of Alaska. In addition, the NOAA stations furnish information to the Pacific tsunami warning system (see next section). The USGS stations have been established just recently to obtain accurate data for the detailed study of tectonic processes in South Central Alaska and for the evaluation of seismic and related tectonic risks (Page, viva voce).[1/] Detailed data from this study will permit earthquakes to be correlated with specific geologic features and will enable the identification of active faults and volcanoes. This network also will monitor seismic activity in the vicinity of the Cook Inlet oil fields where high-pressure fluid injection into the oil-bearing strata is being utilized to increase recovery. In Colorado such pumping apparently has stimulated the occurrence of earthquakes.

TSUNAMI RISK

Tsunamis or seismic seawaves are a series of travelling ocean waves set in motion by large oceanic disturbances. These waves are frequently called "tidal waves" even though they have nothing to do with the tides.

Tsunamis are believed to originate as vertically displaced columns of ocean water, but the displacing agent has not been positively identified. Seismic or volcanic alterations of the ocean floor, provided they impart some vertical movement to the water column, may cause tsunamis. It has also been postulated that submarine avalanches on the slopes of the Pacific trenches produce tsunamis.

Some investigators have turned to long-period ground waves which sometimes

---

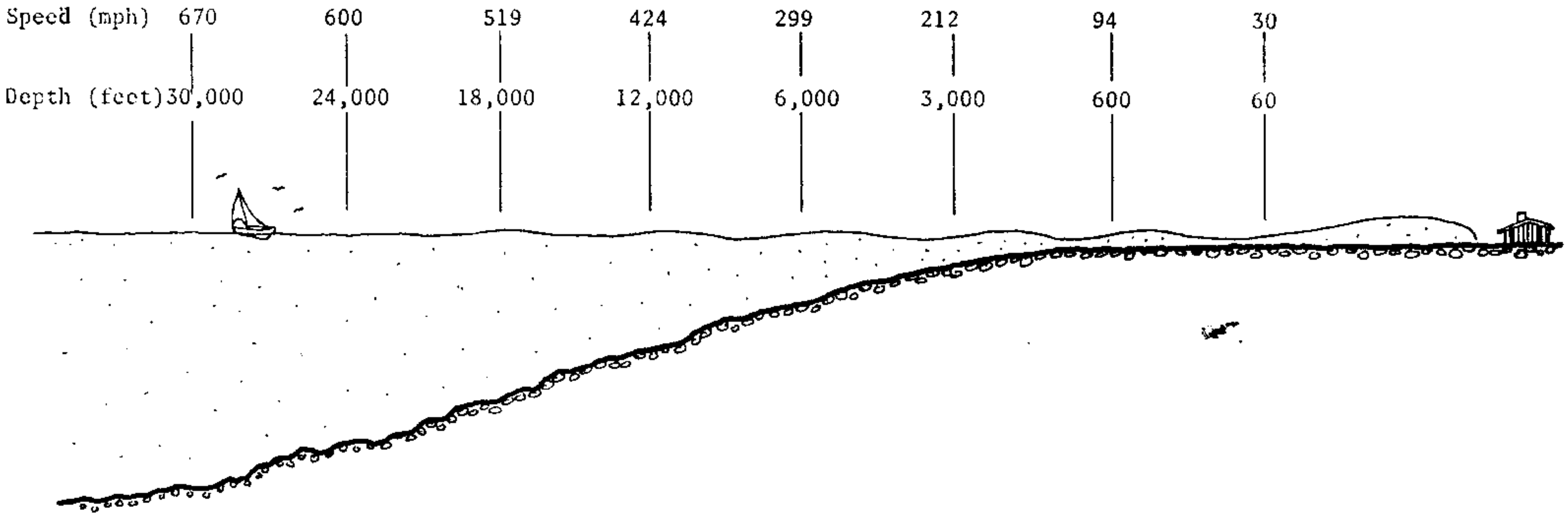
1/ Page, Robert, Seismologist, National Center for Earthquake Research, U.S. Geological Survey, Menlo Park, Calif.

accompany large earthquakes, as possible generators of tsunamis. Deformation of the sea floor as these waves travel across it could reach sufficient amplitude to produce large displacements at the water surface, particularly in the region of troughs or trenches. It is possible that long-period earthquake waves generate tsunamis by setting up resonant oscillations of trench water, with consequent displacements at the surface of the sea.

Although it has been established that a relationship exists between seismic or volcanic disturbances and tsunamis, the nature of this relationship is not well-defined. Tsunami magnitude appears to be a function of earthquake magnitude and depth, water depth in the region of tsunami generation, extent and velocity of crustal deformation, and efficiency of energy transfer from the earth's crust to sea water; but the specific effect upon tsunamis of these independent factors is imperfectly understood.

Tsunami waves in the deep ocean are very long and low. Their period is of the order of a thousand seconds; their length from crest to crest may be a hundred miles or more; and their height from trough to crest only a few feet. They cannot be felt aboard ship and they cannot be seen from the air, but the energy represented by tsunamis is impressive.

A tsunami "feels the bottom" even in the deepest ocean, and their velocity is controlled by the depth of water (Fig. IV-6). Over great distances having varying depths, speed will vary and the speed determined from observed travel time from epicenter to observing station will be an average for the whole distance. Seismic seawave travel time charts have been prepared to expedite the rapid



Tsunami speed is determined solely by water depth, and this fixed relationship makes it possible to forecast tsunami arrival-times for distant locations. The tsunami illustrated here, although somewhat exaggerated in the vertical dimension, is characteristic.

Fig. IV-6 TSUNAMI SPEED VERSUS WATER DEPTH (from Tsunami, Department of Commerce) computation of the time that a tsunami will arrive at a specific point.

As a tsunami enters the shoaling water of a coastline in its path, the velocity of its waves diminishes and wave height increases. If near its origin, the first wave of a tsunami may be the largest, while at greater distances the largest is normally between the second and seventh wave. As the waves hit the shore they can be almost negligible in size or they can crest to heights of more than 100 feet and can strike with devastating force. No definite correlation has been possible between the configuration of specific regions of the ocean floor and tsunami configuration in those regions. It is not completely clear, for example, why a tsunami's waves may be of negligible size at one point along a coast, and of much larger proportions at other coastal points nearby. Nor is it possible to predict whether the destructive component of a tsunami will lie in its powerful surge across a beach, or in a gradual rising of sea level followed by a rapid draining back to sea.

Thus it is impossible to say with any certainty what shape a tsunamis will assume at specific locations, or how it will accomplish its destructive work. In treating of tsunamis, exceptions are the rule.

Studies are continuing on factors which influence the height of tsunamis. Some of the factors which do effect the height are coastal slope of ocean floor, direction of wave propagation to the coastline, speed of waves, etc. Until such time as wave height can be accurately predicted, it will be necessary to evacuate all potential danger areas each time a tsunami is forecast for that area.

In the 36 year period from 1928 through 1963, a total of 84 tsunamis occurred throughout the world. Of these, 66, or about 80 percent, were reported from the Pacific Ocean. The greatest number of tsunamis during one year was 6 in 1963 while no tsunamis were observed in 1930, 1935, 1936, 1937 and 1954.

Tsunamis have a long history of destruction throughout the Pacific Rim. Of the 66 waves in the Pacific during the period from 1928 to 1963, 3 caused slight local damage, 17 caused death or destruction near their source, 5 were widely destructive and 41 caused no damage.

Some of the more destructive tsunamis on record are listed below:

Date	Country	City	Explanation
1400 BC	Crete	Amnisos	City demolished, all population drowned
684 Nov. 29	Japan	Shikoku	Eight sq. mi. sank
1293	Japan	East Coast	30,000 lives lost
1575 Dec. 16	Chile	La Imperial	2 Spanish ships lost
1605 Feb. 3	Japan	Kiushiu, Shikoku	5,000 dead
1611 Dec. 2	Japan	Yamada	4,800 lives lost
1724	Peru	Lima	Sank 19 ships
1771 Apr. 24	Japan	Isigakizima	Wave killed 9,400
1783 Feb. 5	Italy	Straits of Messina	30,000 killed
1792 Apr. 1	Japan	Shimabara	707 killed
1792 May 21	Japan	Shimabara	1200 killed
1837 Nov. 7	Chile	Concepcion	Valvidia destroyed
1861 Mar. 9	Sumatra	Padang	Great loss of life
1868 Apr. 2	Hawaiian Island	Keauhou	Village swept away
1883 Aug. 26	Java	Mera	Wave heights to 135 ft.
1896 June 15	NE Japan	Kamaishi	100 ft. waves 27,000 lives lost
1927 Mar. 7	Japan	Minoyama	1,100 lives lost
1945 Nov. 27	India	Karachi	4,000 lives lost
1946 Apr. 1	Hawaiian Island	Epicenter in Aleutian Trench	173 killed, damage over $10,000,000
1946 Aug. 4	Santo Domingo	Matanzas	100 lives lost

(table continued on next page)

1946 Dec. 21	Japan	Shikoku Island	1,500 lives lost Deaths: Hawaii - 61 Philippines - 20 Japan - 100 Damages: $75,000,000
1964 Mar. 27	Alaska		Lives lost on west coast of United States

The Coast and Geodetic Survey established the Seismic Sea Wave Warning System in August 1948, to protect the inhabitants of the Hawaiian Islands from tsunamis. Since its initiation, the Warning System has been slowly expanded and strengthened through the addition of strategically located tide and seismic stations, the availability of better communication channels for rapid dissemination of information, the development of better instrumentation for tide and seismic stations, and research into the generation and propagation of seismic sea waves.

As part of this expanding system the National Oceanic and Atmospheric Administration (NOAA) established in 1967 the Seismological Observatory in Palmer, Alaska. In addition to being used for seismic investigations, this observatory provides the tsunami warning system for Alaska and the Northern Pacific - the Alaska Regional Tsunami Warning System.

The primary function of this warning system is detecting and locating major earthquakes in the Northern Pacific region and determining if the size and location is sufficient to generate a tsunami. Immediate tsunami information and warnings are issued to coastal populations of Alaska, Washington, Oregon, California and Canada in order to minimize the hazards of tsunamis, especially those to human life and health. Information is also furnished to Hawaii and Japan.

The observatory records seismic data from an extensive network of 17 seismic stations throughout Alaska, as shown by solid triangles in Fig. IV-7. It also receives data from 8 tide guage stations.

As soon as an earthquake is recorded at the observatory, its epicenter and magnitude are determined. Past experience with tsunamis suggests that there is a minimal chance for tsunami generation from earthquakes less than magnitude 7. If the epicenter is located in a coastal or oceanic setting, the following procedures are carried out depending on the magnitude:

6 3/4 - 7 - Issue immediate Tsunami Watch for an area within at least a 300 kilometer radius of the epicenter but large enough to include the nearest Warning System tide station on each side of the epicenter. Inspect marigrams (recordings of tide stations) and take further action if significant wave activity is observed.

7 - 7 3/4 - Issue an immediate Tsunami Warning message to an area within at least a 300 kilometer radius of the epicenter but large enough to include the nearest Warning System tide station on each side of the epicenter. Issue an immediate Tsunami Watch to the remainder of the Alaska coastline. If and when significant tsunami wave activity is identified on the marigrams or tsunami effects are reported, extend the Tsunami Warning to the entire Alaskan coastline.

Greater than 7 3/4 - Issue an immediate Tsunami Warning message to an area within at least an 800 kilometer radius of the epicenter but large

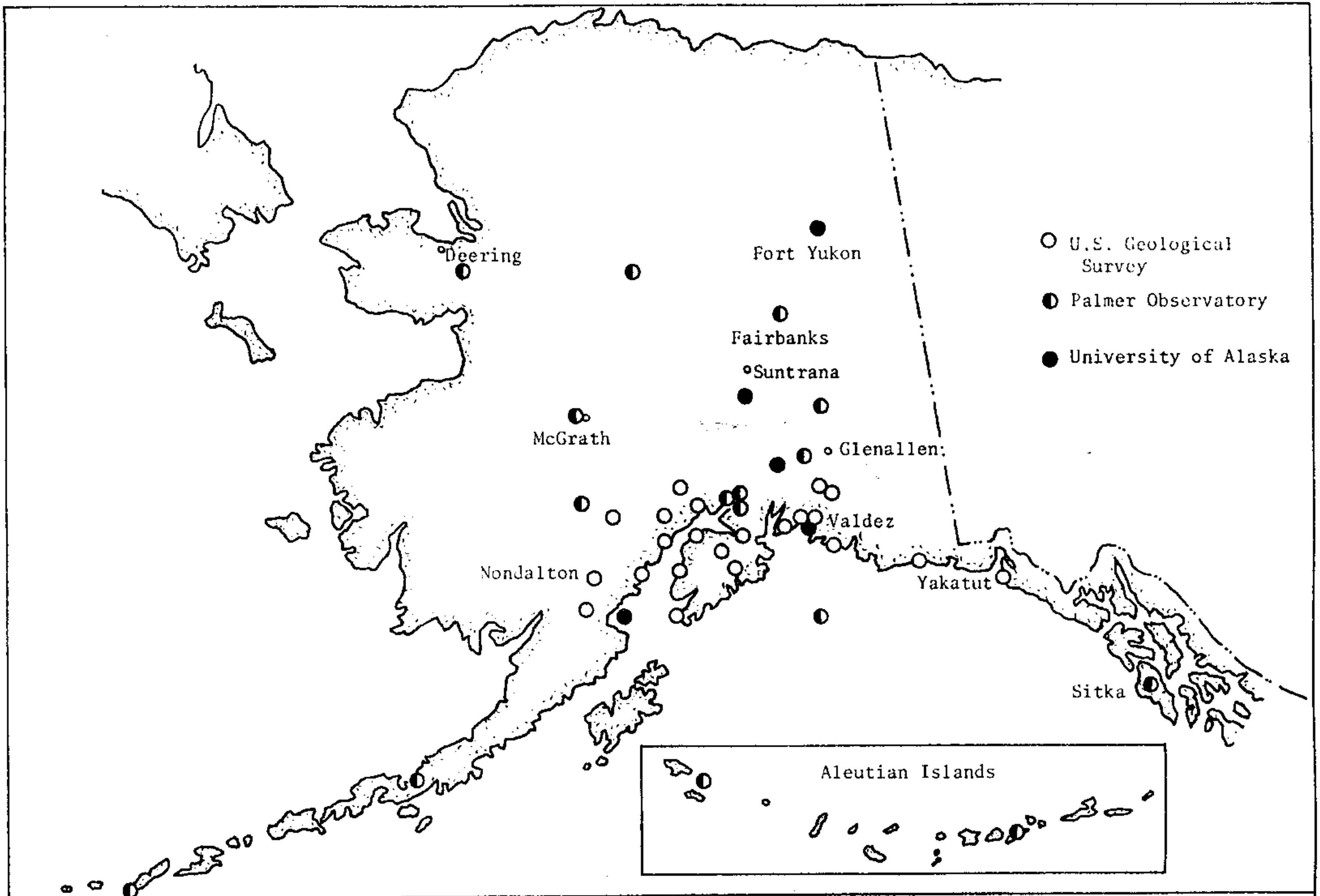


Fig. IV-7 SEISMIC STATIONS TO BE RECORDED AT PALMER OBSERVATORY (from NOAA, Palmer Seismological Observatory, Palmer, Alaska) enough to include the nearest Warning System tide station on each side of the epicenter. Issue an immediate Tsunami Watch to the remainder of the Alaska coastline. If and when significant tsunami wave activity is identified on the marigrams or tsunami effects are reported, extend the Tsunami Warning to the entire Alaskan coastline.

All Watch or Warning messages will be updated at least hourly. If negative or minor unusual tide activity has been noted on the nearest tide stations 30 minutes after the ETA's, the Watch or Warning status may be Cancelled. If a tsunami is generated, dissemination agencies will follow established All Clear procedures of the Tsunami Warning System, i.e., all action agencies shall assume All Clear when free from damaging waves for two hours or, two hours after ETA, if no major waves are recorded. Danger to navigation due to rapid current fluctuations in channels and harbors may continue for several hours.

Magnitude Definitions: Large: 6.5-6.9

Major: 7.0-7.7

Severe: 7.8-and above

Watches and Warnings can be issued within 10 to 15 minutes after receiving the first indication of an earthquake.

Risk due to tsunamis in Cook Inlet probably is minimal compared to areas in the Outer Coastal zones. Because of its protected location, waves generated outside of the Inlet would enter the Inlet only with great difficulty. In addition, the shallow waters plus the turbulent nature of the Inlet's tides and currents would effectively dampen any wave and reduce its impact (Butler, viva voce). [1/]

Although it is minimal, there still exists a tsunami risk in Cook Inlet. Fig. IV-3 shows that since 1899, 10 earthquakes with magnitudes greater than 6 have had epicenters located along the coast or under the waters of Cook Inlet. Quakes of this magnitude could produce a significant wave that could sweep up or down the Inlet. The wave probably wouldn't exert much force against fixed structures out in the open water such as platforms, but it could cause significant damage to vessels and low-lying coastal facilities. The close proximity of the source probably would not allow much time for warnings to be disseminated.

Risk of damage due to tsunamis can be minimized by planning for safe economic development and land use in the coastal zone. Required should be adequate charts showing areas of tsunami risk as well as timely warnings and an effective state system for disseminating warnings and securing effective public response (Federal Field Committee, 1971).

1/ Butler, Howard M., Chief, Palmer Seismological Observatory, Palmer, Alaska

VOLCANIC RISK IN THE COOK INLET REGION

Geographic and Geologic Setting of the Cook Inlet Volcanoes

The Cook Inlet volcanoes are located on the southeast margin of the Alaska Peninsula, and define a belt of volcanic activity which extends from Mt. Spurr to Mt. Douglas, and includes Spurr, Redoubt, Iliamna, Augustine and Mt. Douglas volcanoes (Fig. IV-8). This belt is contiguous with the accurate zone of volcanoes which continues to the southwest through the Katmai District and into the Aleutian Archipelago. The Alaskan volcanoes are an integral segment of the much larger circum-Pacific seismic and volcanic belt (Fig. IV-2).

The circum-Pacific volcanic belt is also a zone of high earthquake activity, and the two processes are believed to be related. Hypocenter plots of earthquakes occurring along this belt define a zone, the "Benioff Zone", which dips under the continent from the adjacent ocean basins. The "Benioff Zone" is believed to be caused by the underthrusting or subduction of the ocean floors under the margin of the continental blocks or Island arcs. Lavas erupted by Pacific Rim volcanoes are probably generated by the partial melting of oceanic crust and upper mantle rocks as they are subducted under the continents.

Explosivity of Andesitic Volcanoes

Pacific Rim volcanoes tend to erupt lavas and ejecta composed of more viscous melts (andesitic) than those produced by the volcanoes in the ocean basins (basaltic). Andesitic volcanoes are more explosive, and therefore more destructive than oceanic volcanoes.

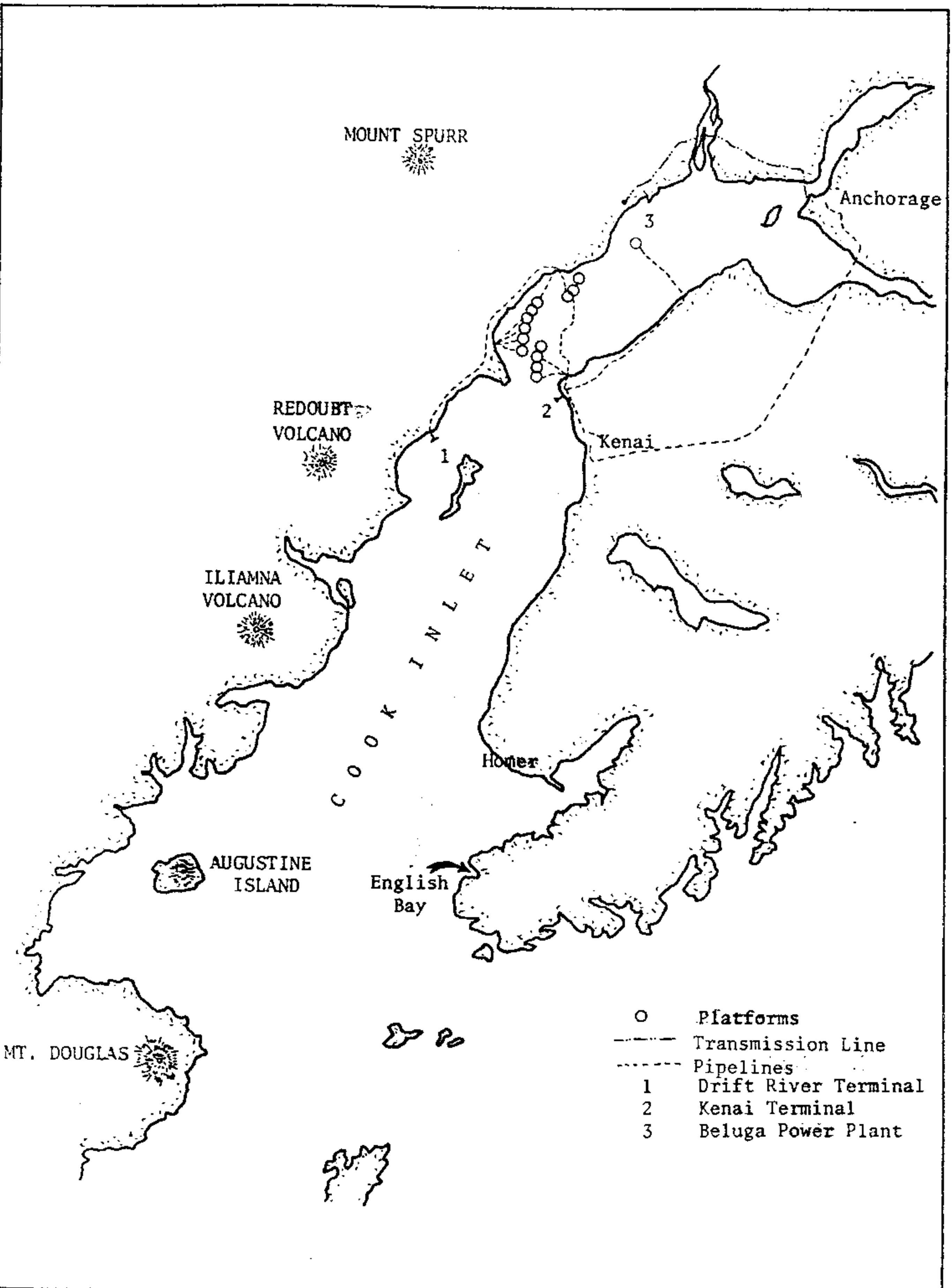


Fig. IV-8 VOLCANOES OF THE COOK INLET REGION

Eruptive History of the Cook Inlet Volcanoes

Table IV-1 summarizes all of the eruptions of Cook Inlet volcanoes in historic time. As shown in Table IV-1, all of the Cook Inlet volcanoes, with the exception of Mt. Douglas, have erupted in historic time; and there have been three eruptive outbreaks (Spurr, 1953; Augustine, 1963-64; Redoubt, 1966) in the last 20 years.

Augustine has been the most active Cook Inlet volcano, and is presently the most dangerous of the group.

Damage Caused by Previous Eruptive Activity

The Augustine eruption of 1883 created a series of seawaves which washed boats away and damaged dwellings in the old settlement of English Bay, near Port Graham (Fig. IV-8).

The 1953 Mt. Spurr ash cloud eruption dropped ash on the outskirts of Anchorage, causing damage to aircraft and necessitating the expenditure of considerable funds for clean-up activities.

A flash flood associated with the 1966 Redoubt eruption threatened a seismic survey party in the Drift River Valley, and a helicopter evacuation was required.

A man was evacuated from a temporary navigational aid station on Augustine Island in 1964, when eruptive activity proved hazardous to the safety of the camp.

Types of Eruptive Phenomena Involved in the Estimation of Volcanic Risk

The eruptive phenomena listed below should be considered in the estimation of volcanic risk in the Cook Inlet region:

(1) Krakatoan eruptions

(2) Directed blasts, nuées ardente

TABLE IV-1
ERUPTIVE HISTORY OF COOK INLET VOLCANOES

Four volcanoes have erupted in the Cook Inlet Area in historic time. These volcanoes and their recorded eruptive activity are listed below:

	Augustine	Redoubt	Iliamna	Spurr
	1812; active	1778; active	1741; grew quiet	1953; ash eruption (fall out on Anchorage)
	1883; violent eruption with ash and mudflows	1819; smoke	1768; smoke	1954; ash eruption
	1885; steaming shore to summit	1902; active	1778; resumed action	
	1895; crater steaming	1933; smoke	1779; active	
	1935; lava eruption	1966-1968; recurrent explosions and turbulent clouds to elevations over 40,000 feet	1786; smoke	
	1963; Nov. 7th		1867; ash eruption	
	1964; July 5th, and August 19th		1876; smoke	
			1933; smoke	
			1947; smoke	
			1952-53; smoke	
Present State:	Lava dome moving upward, and continually degassing; recurrent microearthquake activity	Small lava dome extruded at head of fissure vent in 1967-68. Dome is degassing; micro-earthquake activity level presently unknown	Continuing fumarolic activity near summit	Continuing fumarolic activity near summit

(3) Pyroclastic flows

(4) Lava flows

(5) Volcanic mudflows

(6) Turbulent ash clouds and columns

(7) Explosive blasts and associated block balls

(8) Ash falls

(9) Corrosive rains - volcanic gas

(10) Flash floods

(11) Break-out of ice dammed lakes

(12) Lightning discharges

(13) Seawaves

(14) Volcanic earthquakes

1972 Activity State of Volcanoes

Mt. Douglas Volcano: Mt. Douglas has displayed fumarolic activity since it was first described by early observers. This volcano has not erupted in historic time, and when last viewed by aerial survey in 1971, was emitting steam from a few fumaroles at the usual rate.

Mt. Douglas volcano is presently classified as quiescent, based on the absence of historic eruptive activity and no visible change in fumarolic activity.

Augustine Volcano: Augustine Volcano (Plate 4) has displayed a higher frequency of eruptive activity than the other Cook Inlet volcanoes, as shown by the data in (Table IV-1). At present, Augustine is the only volcano in the region which is under continuous seismic surveillance. The volcano has produced resurgent micro-

Plate 4 Augustine Volcano, the most active on Cook Inlet, lies in the midst of important fishing grounds and could have direct impact on activities in the Lower Inlet. Sea Grant photo. C.D. Evans.

earthquake swarm activity since the first instruments were first installed in 1970. Geodetic surveys also indicate that the large lava dome which caps Augustine Volcano has shown some growth in the years following the 1964 eruption.

Most recently, a small eruption was observed in October, 1971, by bear hunters at Iniskin Bay, which is believed to be a valid report. The eruption occurred after an intense microearthquake swarm, and swarm activity decreased markedly after the reported eruption.

This volcano is active and potentially eruptive, and it presently poses the greatest volcanic hazard in the region due to its activity state, marine setting and proximity to fisheries, airlines, petroleum installations and coastal communities.

Augustine is an island volcano, and therefore the only volcano of the group which is potentially capable of producing a "krakatoan" eruption. Such eruptions are characterized by large magnitude explosions caused by the possible break-through of sea water into the conduit system when new melt is moving into the lower levels of the volcano. Krakatoan eruptions are capable of producing very destructive seawaves, and such a wave could produce great damage in the Cook Inlet region.

The 1883 Augustine eruption produced a series of seawaves with a maximum amplitude of 20 ft., as recorded at English Bay. These waves, however, were apparently generated by the impact of a large mud flow which reached the sea on the north slope of the volcano.

Augustine Volcano is capable of producing damage in the Cook Inlet region through several eruptive mechanisms, including:

(1) Seawaves

(2) Ash falls (fall out)

(3) Explosive ash clouds producing turbulent columns up to 40,000 ft.

Seawaves constitute the greatest hazard, based on the vulnerability of coastal populations and activities of Port Graham, Seldovia, Homer Spit and the Kamishak Bay area. Large magnitude seawaves could reach the upper waters of Cook Inlet, and such waves would constitute a serious threat to petroleum installations including production platforms, pipelines and tanker terminal facilities (Fig. V-2 appearing near the end of this report).

Preliminary computer modeling experiments indicate that only very large waves could affect the upper reaches of the Inlet; waves with amplitudes and periods greater than those generated by the 1883 eruption.

Crab, salmon, shrimp and halibut boats, of course, would be more vulnerable, if they were sailing near the island when such waves were generated.

Turbulent eruptive clouds are a definite threat to aircraft, and such eruptive behavior would require the re-routing of air traffic in the area.

Iliamna Volcano: Iliamna has not produced any major eruptive activity in recent years. Fumarolic activity near the summit has continued at about the present rate since detailed observations began about 10 years ago by the U. of A. Geophysical Institute. Based on these observations, the volcano is classified as active but presently quiescent.

A major eruption of Iliamna would constitute less of a threat to Cook Inlet installations than Augustine, Redoubt or Spurr, due to its remote location.

Explosive clouds could endanger aircraft, however, and flooding of peripheral streams from the melting of snow and ice on the higher elevations of the volcano could endanger cabins and individuals in the immediate area. Ash falls from a potential Iliamna eruption, could have a much wider distribution, as controlled by prevailing winds.

Redoubt Volcano: This volcano produced impressive eruptive displays in 1966, accompanied by flooding of the Drift River Valley.

Recent air observations of the 1966 crater show the presence of a small lava dome at the head of the main vent, which is degassing at a rather low rate. This state is similar to that observed over the last few years. Redoubt Volcano is classified as active, and potentially eruptive.

Flooding of the Drift River Valley would constitute a definite hazard to the Drift River Pipeline Terminal, and explosions and turbulent clouds would also endanger unsuspecting aircraft. Ash fall-out zones could extend across the Inlet, as governed by wind patterns.

Mt. Spurr Volcano: The 1953 crater of Mt. Spurr is now water-filled, and fumarolic activity is restricted to a few small vents. Spurr Volcano is classified as active, but quiescent.

Volcanic hazards from possible eruptive activity include explosive clouds, flooding of related stream systems (including the possible breakout of an ice-damned lake) and ash fall-out similar to that experienced in 1953.

Volcano Surveillance Warning.

Currently, Augustine is the only Cook Inlet volcano which is under continuous geophysical surveillance. It is believed that a major eruption could be detected at least one week in advance of the first major outbreak of activity.

An integrated Cook Inlet volcano monitoring and warning system should include the addition of a tiltmeter to the instrumentation on Augustine Island, and the installation of at least one remote seismometer on each of the other volcanoes.

Additionally, annual or semi-annual infra-red and visual air surveys should be made of each volcano, and satellite surveillance and monitoring capabilities should be applied to the problem.

In fall and winter 1972, a series of meetings will be held in Anchorage to develop an integrated Cook Inlet volcano alert and warning system involving state, federal and community agencies.

OTHER COMPETING RESOURCES

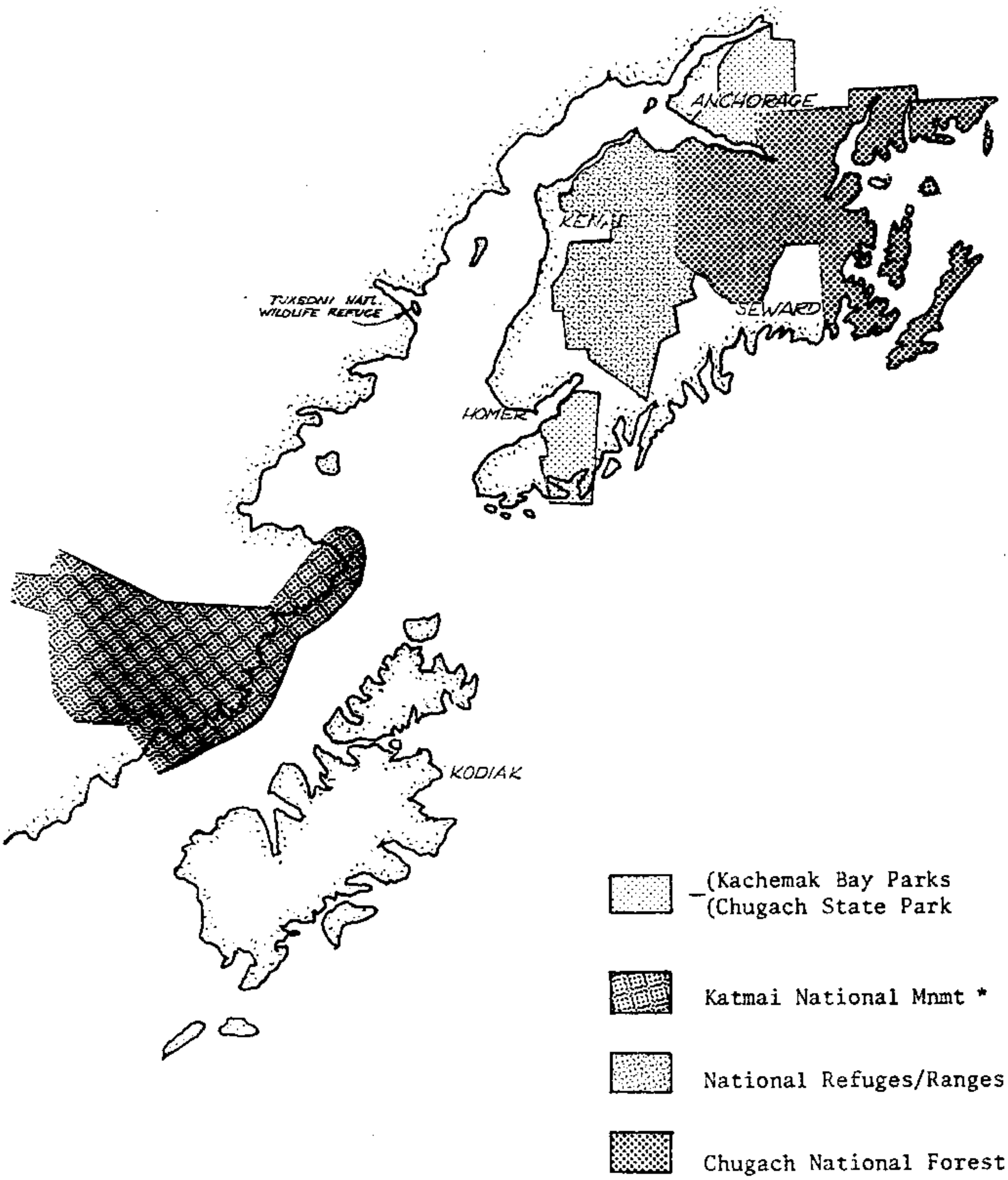
RECREATION

Recreational usage of Cook Inlet is distributed and modified by ease or difficulty of access, population centers, recreational potential and weather.

The presence of six major federal and state resource management areas bordering on the Inlet focuses tourism and use to some extent (Fig V-1). The value of the Inlet to tourism, other than as a scenic background, is limited in the Upper Inlet by turbidity and extensive mud flats. In the Lower Inlet, shorelines are more attractive and are often used by tourists for beachcombing, clamming and fishing.

The Dept. of Natural Resources, Alaska Division of Parks, maintains six wayside-campground facilities on Cook Inlet; two on Turnagain Arm and four on the Kenai Peninsula bordering the Lower Inlet. These are used extensively by tourists during the summer season and are used at other seasons by hunters and fishermen. An irregular count of visitor use registered 24,072 total visitors in 197 individual censuses of these facilities during 1970 or an average of 122 visitors using a park when counted. The parks censused contained 117 camping or pincicking units, total capacity (Alaska Division of Parks, 1971).

The U.S. Forest Service, Chugach National Forest, maintains one campground near Hope on Turnagain Arm which saw 5,800 visitor-days of use during 1970. This area contains 24 camping units (U.S.F.S. statistics,



* Boundary extends offshore by proclamation. Water is owned by State of Alaska.

Fig. V-1 RECOGNIZED RECREATION OR MANAGEMENT UNIT ON COOK INLET viva voce).[1/]

Recreational boating is primarily restricted to the Lower Inlet and particularly concentrated in Kachemak Bay. The Homer small boat harbor contained 108 vessels in 18 ft. stalls, 100 vessels in 24 ft. stalls and about 100 transient recreational vessels in July, 1972. Ninilchik has a small harbor which is used only during the salmon season. The use of this harbor has increased with interest in sport fishing for chinook salmon off the mouth of Deep Creek. Halibut Cove and Seldovia each harbor less than 10 recreational vessels (Homer Harbormaster, viva voce). A significant uncensused trailer-boat migration occurs in summer months, predominately from Anchorage to the Lower Inlet during the salmon season.

It has been pointed out in the discussion on sport fishing and waterfowl hunting that significant recreational use is made of resources that are dependent on continued high water and shoreline quality in the Inlet.

No quantitative dollar estimate can be made of the value of such use. Stefanich (viva voce)[2/] believes that the average expenditure per sport-caught chinook salmon in Cook Inlet is in the range of $200. A survey of the value of the sport fishery for chinook in Cook Inlet is being conducted

---

1/ District Office, Chugach National Forest, U.S. Forest Service, Anchorage.

2/ Stefanich, Frank. Sport Fish Division, Alaska Department of Fish and Game, Anchorage.

by the Institute of Agricultural Science of the University of Alaska, Palmer, but the results will not be available until the winter of 1972-73. This survey is based on fisherman expenditures.

A waterfowl hunt in any of the marshes on the west side of Cook Inlet or the Chickaloon Flats almost invariably involves flying. Cost of a charter flight for a duck hunt is advertized by Ketchum Air Service at Anchorage at $40.00 per person. The cost to operate a private aircraft is probably in the same range.

These examples involve only cost and are not a measure of full value, but serve to indicate that the recreational use of the fish, wildlife and scenic resources of the Inlet has substantial value.

Vulnerability

As tourism is a major aspect of recreational use of Cook Inlet, any activity which would reduce the scenic impact of the Inlet or its shoreline would be detrimental to recreation. The vulnerability of the fish and wildlife resource has been discussed previously in this report.

TRANSPORTATION SYSTEMS IN THE MARINE ENVIRONMENT OF COOK INLET

Marine shipping and traffic in Cook Inlet can be divided into several categories, namely,

- general cargo
- outbound petroleum product shipment
- inbound petroleum product shipment
- fishing boats
- transportation of fish and fish products
- marine ferry
- transportation of timber products

Some of these systems share common facilities, while others require specialized treatment that has no other utility.

General Cargo

Almost all general shipments into the Cook Inlet region come in through the Port of Anchorage or from ports outside the region. Only Anchorage has the facilities to handle containerized cargo at this time. General cargo from the Kenai Peninsula is either routed through Anchorage or through Seward where it goes by rail to Moose Pass, thence by truck, or by truck all the way from Seward. Cargo to smaller points that are not connected to the road net is handled as broken bulk or is shipped on the marine highway system.

There are two or three container ships or barges per week operating into Anchorage. The 1971 total shipped by van was 357,821 tons. About 40,000 tons is expected to be lost to Kodiak when that port's container facilities are finished in October 1972.

Outbound Petroleum Products

There are two principal oil shipment ports, Nikiski and Drift River. Shipments from Nikiski in 1971 amounted to about 19 million barrels of crude, residuum, and finished products, while regular shipments of liquified natural gas (LNG) were made from this port on a weekly basis. Urea is also made at Nikiski and shipped from there to Japan.

Shipments of crude oil from Drift River amount to about 60 million barrels per year. This amount will remain constant for the next several years, then decline unless further discoveries are made in the Upper Cook Inlet.

Inbound Petroleum Products

The great bulk of petroleum products shipped into Cook Inlet ports are destined for Anchorage where 10,305,396 barrels were received in 1971. Minor shipments are received at Seldovia, Kenai and Homer. Some of the shipments are intra-regional transfers from Nikiski to Anchorage.

Fishing Boats

About 350 and 150 boats work north and south of Anchor Point in the Inlet, respectively. The great bulk operate out of Kenai, Homer, Seldovia and Ninilchik, since these are the locations with canneries. Anchorage also has a cannery but is not a popular port because of its greater distance from the fishing areas.

Transportation of Fish and Fish Products

Fishing boats with larger hold capacity normally take their catch directly to the cannery and freezing plants, while smaller drift net boats utilize fish barges that are stationed around Cook Inlet. Fish products, after processing, are normally shipped through Anchorage or Seward, depending upon their point of origin. The total weight of fisheries products transported is low, the number of movements is high. Fishing boats and fish barges are estimated to make more than 6,000 trips per year to and from their stations and fishing grounds.

Marine Ferry

The Alaska Marine Highway System operates the MV Tustumena between Anchorage, Homer, Seldovia, Kodiak and Seward in the summer and between the last four ports in the winter. Anchorage is dropped in the winter because of ice conditions in the Upper Inlet that increase operational expenses and the danger of damage to vessels.

Anchorage, Homer, and Seldovia are served twice a week in summer, while the latter ports receive weekly service in winter. The Tustumena makes about 70 trips into Cook Inlet annually.

The marine highway is the major means of getting vehicles and freight to Seldovia at this time.

Transportation of Timber Products

At present, commercial timber cutting is limited to the area of Rocky Bay, from whence logs are carried by road to the South Central Timber Development Company mill site on Jakolof Bay. Timber is also brought to this mill by barge from the Yakataga area. Dry storage is used for logs at the mill and theoretically there is no log rafting in Cook Inlet at this time, except for an occasional raft of cants from the mill site to waiting freighters (Plate 5). The present volume of timber being processed at South Central is estimated at 25 million board feet (MMBF) per annum.

For the past several years there has been intermittent timber cutting in Jakolof Bay and other areas around Kachemak Bay. Logs were rafted from these cuttings to the mill site. However, none of these operations

Plate 5 The South Central Timber Development Corp. mill, out of sight at the head of Jakolof Bay is the center for processing logs from Kachemak Bay, Rocky Bay and Cape Yakataga into cants for shipment to Japan. Sea Grant photo. C.D. Evans.

are presently underway. A very small and intermittent amount of rafting is reported to take place from Homer to the mill site.

Pipelines

There is an extensive offshore pipeline system above the Forelands in Cook Inlet. This system connects to onshore pipelines on both sides of the Inlet and is shown on Fig. V-2.

About 180,000 barrels per day, or 5.4 million barrels per month, are pumped through 20 oil pipelines in this complex. The individual fields and their production are shown in table V-1.

TABLE V-2

PRODUCTION FROM COOK INLET OIL FIELDS 1/

Code (Fig.	Oil Field Name	Number Pipelines Serving Field	Production per month (bbl)
B	Granite Point	4	750,000
C	Middle Ground Shoal	4	800,000
D	Trading Bay 1 & 2	6	850,000
E	McArthur River	6	3,000,000
		20	5,400,000

There are, in addition, two pipelines serving the North Cook Inlet gas field (Fig V-2 Code A). This field supplies the gas for conversion to LNG at Nikiski.

None of the above pipelines is crossed by shipping enroute to Drift River or Nikiski from the south. Ships going to Anchorage cross ten of

1/ From files of Alaska Dept. of Natural Resources, Division of Oil and Gas, Anchorage

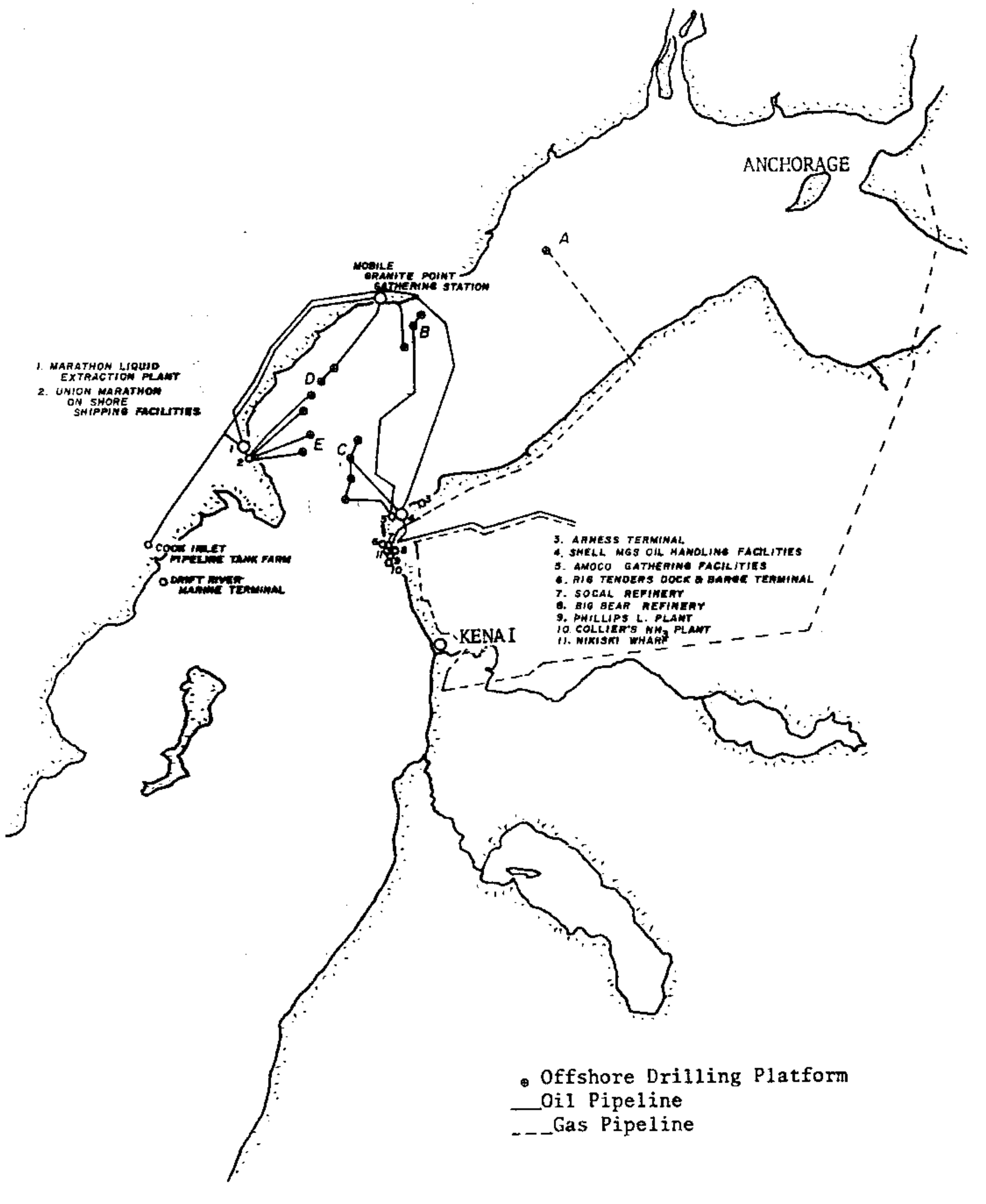


FIGURE V-2 PETROLEUM INSTALLATIONS IN COOK INLET BASIN the lines, eight oil and two gas, on their way to that port.

The pipeline supplying the natural gas to Anchorage crosses Turnagain Arm between Bird Point and Potter. There is no shipping in this Arm.

Gas lines are presently being constructed to Granite Point and other fields in order to meet the Alaska Oil and Gas Conservation Committee's order to cease and desist flaring. This construction should be finished by October 1972 in order to meet the date specified by the committee. After completion of these lines, little further exploration or construction activity is expected in the area of the present pipeline systems.

The development of other oil and gas fields in the Northern Inlet could present difficulties if they were undertaken in the shallow waters northwest of Point Possession. It might prove necessary to bury pipelines in order to secure them in place, as was done with the Turnagain Arm line. This would also provide them with necessary protection from shipping.

South of the Forelands there is plenty of water depth and there should be little conflict between pipelines and shipping that uses the present traffic lanes. Pipelines in shallow waters around Kalgin Island and the coastlines of the Inlet could cause some problems with fishing boats, but it is not likely that severe problems would arise if reasonable caution is used when constructing in areas that are heavily fished.

If oil fields are developed far offshore in Lower Cook Inlet, it might prove beneficial to utilize offshore terminals for loading tankers, rather than constructing long pipelines to shore based facilities. Such offshore terminals are in use in the North Sea and other areas, and there seems to be no reason why they would not work in Cook Inlet.

COASTAL FACILITIES - GENERAL

There are five major ports and four small boat harbors serving Cook Inlet at present. The ports handle more than 11 million tons of petroleum products per year and more than 400,000 tons of general cargo. Almost 90 percent of the general cargo is containerized.

Use of all port and harbor facilities is inhibited by the tremendous tidal ranges (up to 30 feet) in Cook Inlet. Many small boat harbors, docks, and anchorages are unuseable at low tide and any boats or ships using them will be bottomed.

Major ports

In table V-2, a port is shown as an oil or gas or timber port only if those commodities make up a significant part of its total cargo. Ports are treated as complexes and may cover areas 20 miles long as at Kenai/Nikiski- or they may be compact, as at Anchorage.

TABLE V-2

MAJOR PORTS IN COOK INLET

Name	General Cargo	Oil & Gas	Fish Processing	Timber Processing	Ferry Terminal
Homer	x	x*	x		x
Seldovia	x		x	x	x
Drift River		x			
Kenai/Nikiski		x	x		
Anchorage	x	x	x		x**

*No major shipments through the port, but tankers lie in the roadstead at times awaiting improvements in ice conditions or weather.

**Summer schedule only.

Small Boat Harbors

The fishing fleet in Cook Inlet is primarily based on available small boat harbor facilities (table V-3). While Anchorage and Kenai have considerable small boat traffic and storage, they do not have small boat harbors yet, but must rely upon utilizing the mouth of Ship Creek and the Kenai River estuary respectively for boat protection and storage.

TABLE V-3

SMALL BOAT HARBORS IN COOK INLET

Name	Vessel Capacity	Fish Processing	Recreation	Tourism
Halibut Cove	Open		x	x
Homer	250	x	x	x
Ninilchik	Open	x	x	
Seldovia	100	x	x	x

Anchorage

The Port of Anchorage serves about 55-60 percent of the state's population. Its cargo volume has increased 20 fold in the past ten years and new plans for expansion are underway. The area available for port expansion is limited and distant storage areas are contemplated for further expansion beyond the next planned phase.

The port has two general cargo berths, 600 and 610 feet long, and one petroleum terminal 612 feet in length. There are four high speed gantry cranes available for unloading. Both covered and uncovered storage is available.

The port is a part of the Anchorage transportation complex and is the only port in Cook Inlet offering intermodal ties to all four modes of transport - rail, highway, air, and water. The port is in year round use, even though floe and pan ice is encountered in Upper Cook Inlet from the end of November until the end of February. This ice does not normally freeze solid due to the tidal action.

A 32 foot channel is maintained to the port but recent problems with a rock projecting 12 feet above the bottom of Knik Arm Shoal have made it necessary to exert extreme care and ships must limit crossing to periods of half tide or better.

Over 95 percent of the cargo for the port is either petroleum products or containerized freight. Except for vehicles and cement, little small lot cargo is handled. The result is a highly efficient cargo handling system.

Cargo totals for 1971 were 1,839,098 tons, comprised of 1,440,802 tons petroleum products, 357,821 tons of containers, and 40,475 tons of other general cargo. There were 292 arrivals at this port for the first 6 months of 1972 and 654 during CY 1971 (Port of Anchorage).

Drift River

Drift River is composed of a deep draft marine terminal for the loading of crude oil from the oil fields on the west side of Cook Inlet that includes the offshore Trading Bay, McArthur River and Granite Point fields. There is one ballast treatment plant.

The Drift River facility ships 9,000,000 tons per year of crude oil. There were 91 arrivals at the port in the first six months of 1972.

Homer

The Port of Homer has space for one Coast Guard cutter or ship of similar size and the Alaska State Ferry at its present docks. There are no crane or roll on/off facilities. Thus containerized cargo cannot be handled except by ships carrying their own lifting capability.

The Homer small boat harbor is the best equipped in Cook Inlet and is capable of being utilized at all tide stages. This harbor is presently providing service to more than 500 boats, including transients.

There is a major seafood processing plant in the dock area which both cans and freezes fish products. The dumping of fish waste by this plant has caused some concern to the water quality control agencies at the state and federal levels and plans are being made for a fish meal plant.

A limestone crushing plant is located in the port area that utilizes stone barged across Kachemak Bay from Seldovia.

There were 30 arrivals by ocean going ships at Homer during the first half of CY 1972. Most of these were ships awaiting better ice conditions or a pilot.

Seldovia

This port has space for the Alaska Marine Ferry to tie to its 200 foot dock and ships of similar size can use the facilities when the ferry does not need them. Seafood processing is the major industry and the South Central Timber Development Company mill nearby also contributes to port activity. Cants are cut at this mill and loaded on freighters lying offshore. Seldovia has an adequate small boat harbor.

Kenai/Nikiski

The port of Kenai stretches from the cannery wharves in the Kenai River estuary to the Arness barge terminal lying north of the East Foreland. It includes three terminals for shipment of petroleum products.

More than 2,600,000 tons of petroleum products are shipped from these terminals annually. There were 144 ships utilizing the Kenai facilities in CY 1971 and 57 during the first half of CY 1972. This number should remain relatively constant.

Little general cargo passes through the Port of Kenai since there are no facilities for handling containerized cargo and the present needs are handled through Anchorage and Seward. There are two ballast treatment facilities at Kenai.

Bridges and Causeways

There are no major bridges affecting the Cook Inlet system at this time, except for the complexes crossing the Matanuska and Knik Rivers at the head of Knik Arm and other minor stream crossings. The only effect of these is that they provide access to estuarine areas that would otherwise be available only to those using boats or float planes.

Plans have been underway for some years to build a causeway across both Knik and Turnagain Arms. The Alaska Department of Highways last reported the cost of the Knik Arm causeway at $140 million and no cost figures have been developed for the Turnagain crossing.

The Knik Arm crossing would probably cut 10 miles off the present distance to Fairbanks and other points on the Alaska Highway north of the Big Lake cutoff. It would provide much faster access to the lands lying along the west shore of Knik Arm. The population of the west shore area, other than recreational users, is less than 100 people.

Claims have been made that this land is necessary for the expansion of Anchorage, but the Greater Anchorage Borough Planning Department in recent studies has stated that the available area on the east side of Knik Arm can accommodate the region's growth until 2020 without even utilizing lands presently under military withdrawal.

The Turnagain Causeway would cut mileage to Kenai from Anchorage by more than 50 miles. It would also provide a crossing for lines carrying power, gas, and other petroleum products.

Power Line Crossing

There is an aerial crossing of Turnagain Arm at Bird Point that presents some conflict with aviation traffic but none with marine shipping because of the absence of ships or boats from Turnagain Arm in recent years. A submarine cable crossing at Point MacKenzie brings power to Anchorage from the Beluga gas generation electric plant.

TRANSPORTATION CONFLICTS AFFECTING THE COOK INLET ESTUARINE SYSTEM

The major dangers to the various transportation usages in Cook Inlet are caused by ice, tides, wind, poor visibility, and conflicts between the users themselves. Wind and visibility are not discussed at length since the problems that they cause are largely the same as high winds and poor visibility cause in any area and are not of special concern to Cook Inlet. Ice conditions and tides are of special concern and occur in Cook Inlet in a way that is not replicated elsewhere.

Usage Conflicts

There appears to be no conflict between shipping lanes and the existing oil production platforms or the pipelines serving them. If platforms are set up in Lower Cook Inlet it should be possible to locate them so as to interfere as little as possible with shipping. Oil development in Upper Cook Inlet could create problems with the already constricted approach to the Port of Anchorage if maximum consideration is not given to the needs of navigation.

Shipping and fishing appear to have major interference problems only in the Kachemak Bay area. The areas of extensive drift net fishing around Kalgin Island are usually clear of the major shipping lanes. Likewise, the major crabbing and shrimping areas, except for Kachemak Bay, are not heavily traversed by shipping at this time.

Recreation uses do not appear to be in conflict with any other uses at this time except for Kachemak Bay which is generally crowded at times with both commercial and recreational fishermen. There do not appear to be any particular problems between recreation users and shipping other than those that occur in any harbor area with a high level of activity. Fortunately, Homer and areas with high recreational activity have little shipping during the months of peak recreational activity. This is because the Kachemak Bay roadstead is most heavily used during the winter months by ships waiting to move on to Drift River, Nikiski, and Anchorage.

Conflicts with Ice

Drift River, Anchorage, and Nikiski all have ice problems in their port areas and approaches that must be recognized as serious, both in an economic and evnironmental sense. From January through April 1972, there were 8 ships damaged by ice in Cook Inlet (Coast Guard, 1972)[1/] which was six percent of the 142 ocean going vessels that operated in the ice-stressed areas of Cook Inlet for that period. Some of this damage was major, causing the unloading of entire tanker loads in some cases.

In addition to the ships damaged by ice, there are constant pressures from ice during loading and unloading that are particularly dangerous to ships handling petroleum products. Emergency disconnects are often necessary as ice begins to pile up or to move between the ship and the dock. There were five oil spills reported from January through April 1972,

1/ From the files of Captain of the Port, U.S. Coast Guard, Anchorage.

resulting from disconnects and failure of loading systems (Coast Guard, 1972).

Conflicts with Tides

It is the interaction between tides and ice that creates such severe problems in winter months in Cook Inlet. However, during ice free months the tides themselves create problems in approaching and holding ship handling. There is not only the problem of emergency disconnects but the constant strain on equipment that eventually causes failure long before the normal usage period of such equipment in other areas has elapsed.

From August through December of 1971, there were 8 oil spills due to failure of the loading or unloading systems at Cook Inlet ports. These are only the incidents reported. Successful disconnects, where there is little or no loss of oil, are not reported.

Tidal action can be particularly severe at those docks that are set so that the ship is slightly broadside to the current. This is the case at Drift River which appears to be about 13 degrees offset to normal tidal currents. Likewise, the open moorages at Nikiski can encounter severe tidal and ice problems under certain conditions. At the Port of Anchorage, ice and tide problems are compounded by the lack of maneuvering room at certain tidal stages.

Conclusions on Transportation Conflicts

Tides and ice are the major problems for ocean going shipping in Cook Inlet. If development of oil or other resources generates major cargo flows to be routed through Cook Inlet, the location of port facilities may depend to a large extent on availability of measures for combating the more extreme tide and ice problems. It was pointed out in the earlier discussion of ice that recent years have not been particularly severe. The ice problems described here are not the worst that could be encountered in the Inlet.

Ice breaking does not solve the problem of ice buildup on ships in their loading and unloading stages. Also, the extreme movement back and forth, due to tidal action of the Cook Inlet ice pack, makes ice breaking in shipping lanes less effective than it would in areas with less tidal action.

TIDELANDS AND TIDELAND MANAGEMENT

Exploration for and development of petroleum resources will undoubtedly require operations in tidelands. Most of these will require a permit or lease from the Water Resources Office of the Alaska Division of Lands, which also maintains a file of existing permits and leases. They have also plotted set net sites on a map which is available for inspection at their office in the McKay Building, 4th and Eagle, Anchorage.

Such structures as tideland fills, docks, pipelines and oil platforms require a permit from the Corps of Engineers. Such permits are administered by the permit Section of the Construction Division at the office of the District Engineer on Elmendorf Air Force Base where a Cook Inlet file is maintained.

Management of Tidelands

Although the Alaska Department of Fish and Game has major interests in tidelands, they are under the jurisdiction of the Department of Natural Resources. The Department of Fish and Game has, however, developed management agreements for protection of wildlife habitats. Havens (viva voce)[1/] described these lands and the management agreements as follows:

1. Susitna Flats - Under cooperative management agreement between the Alaska Department of Fish and Game, the Matanuska-Susitna Borough and the Department of Natural Resources. Wildlife Management is designated as the major use.

2. Palmer Hay Flats - Cottonwood Creek to Knik River. Intertidal marshes are zoned for recreation and public use by the Matanuska-Susitna Borough. This is designated as waterfowl habitat and moose calving and wintering area.

3. Potter Marsh - Part of the marsh is wildlife refuge and management authority is with the Department of Fish and Game. Part of this marsh is private land.

4. Chickaloon Flats - Under joint management by the U.S. Forest Service, Kenai National Moose Range and State of Alaska. The Department of Fish and Game is considering creation of a landing strip to spread out the hunting activity.

1/ Havens, Philip D., waterfowl biologist, Alaska Department of Fish and Game, Anchorage.

5. Fox River Flats - Has been designated as a critical habitat. Under recent legislation, amending Sect. 16.20.220 of the Alaska Statutes, the Commissioner of Fish and Game is empowered to review proposals for land use or disposal in such areas and assist the user in developing adequate plans for the protection of fish and wildlife.

6. Kalgin Island - Designated as critical habitat.

Havens indicates that the Department of Fish and Game probably would not undertake physical management of most marshes because they do not own them. The Potter Marsh could be an exception.

Spencer (viva voce) 1/ indicated that the Bureau of Sport Fisheries and Wildlife might at some future date undertake marsh management in the Chickaloon Flats.

Many other undesignated marsh and shoreline areas also have high values for fish and wildlife resources and should receive consideration. Trading and Redoubt Bay marshes and Polly Creek clam beaches come readily to mind, as do intertidal estuaries of salmon streams.

POTENTIAL MINERAL RESOURCE DEVELOPMENT

To date, mineral resource development in the Cook Inlet region has been dominated by exploration and production of oil and gas. Coal mining has been a minor industry, mainly to supply local energy needs. Mining

---

1/ Spencer, David L., Refuge Supervisor, Bureau of Sport Fisheries and Wildlife, Anchorage.

of metallic and non-metallic locatable minerals has been relatively insignificant.

The Cook Inlet Basin has a significant potential for additional oil and gas reserves which could be increased significantly in the future by: 1) extension of exploration into unexplored Tertiary areas such as the Susitna basin north of the Castle Mountain fault, the eastern Kenai Peninsula, and the lower Cook Inlet, most of which is submerged (about 40% of the basin); 2) drilling deeper beneath the Tertiary into older Mesozoic age rocks; and 3) drilling for stratigraphic (off-structure) traps. Industry already has spent more than $1.5 billion, but exploration is currently slow partly due to land tenure problems. Estimates indicate that the Cook Inlet basin may have potential petroleum reserves in place as high as 7.9 billion bbl. of oil and 14.6 trillion cu. ft. of gas (Crick, 1971).

Quite large deposits of bituminous and sub-bituminous coal occur in the Cook Inlet area. The largest and perhaps the most significant coal field is the Beluga River deposit located in the Susitna Lowlands in the vicinity of the Beluga and Yentna Rivers. This deposit contains at least 2.3 billion tons of coal and probably several times that figure. Since one ton of coal, energy-wise, is approximately equivalent to 3 bbl of oil, this represents an equivalent reserve of at least 7 billion bbls of oil. This deposit is significant because it is one of the few coal fields located near tidewater. It undoubtedly will be exploited sometime in the future. Since there is no nearby big power consumer, the coal probably will be shipped out to Pacific Rim markets. This will increase considerably the ship traffic through the Inlet.

The Beluga coal has a low BTU value and contains a high content of ash and moisture. The U.S. Office of Coal Research is developing a solvent process for refining this coal to remove the moisture, ash and other impurities, leaving an almost pure pollution-free product. If this process proves successful in the current pilot study at Tacoma, Washington, this product will become highly competitive in the energy market. It is possible that mining could begin within 5 to 10 years (O'Patch, viva voce)[1/].

The Cook Inlet basin has significant potential for development of other mineral resources as well. Occurrences of minerals have been reported from throughout the basin and include copper, silver, gold, zinc, lead, molybdenum, graphite, chromite, marl, pumice, diatomite and iron. Large low-grade chromite deposits occur near the southwest tip of the Kenai Peninsula adjacent to ice-free waters and offers an attractive prospect. Perhaps the deposits that offer the most possibility for future development and future ship traffic in the Inlet are the low-grade titaniferous magnetite (iron) deposits and associated copper, silver and gold occurrences located

1/ O'Patch, Ben, Geologist, American Exploration and Mining Company, Anchorage.

in Southwest Alaska. These deposits occur in a belt 200 miles long extending from Tuxedni Bay on Cook Inlet west to Illiamna Lake and to Kemuk Mountain east of Tikchik Lakes. They contain about 15 percent magnetite, and their proximity to coal, natural gas and oil, as well as to the ice-free portion of Cook Inlet, makes them attractive. The Japanese have been especially interested in these deposits (Maloney, viva voce)[1/].

1/ Maloney, Ray, Engineer, U.S. Bureau of Mines, Juneau (now deceased).

PHASE 2

THE NATURAL RESOURCE INDUSTRIES

THE PETROLEUM INDUSTRY

The petroleum industry in the Cook Inlet basin far outdistances any other primary economic activity in dollar value. Moreover, the relative value of the industry is likely to increase substantially at least through the next decade. While fisheries, second in rank of the resource based industries of the region, have experienced a nearly steady-state economic condition during the past ten years, the petroleum industry has shown rapid growth from the embryonic stages of exploration and early production in the late 1950's to large scale production from 8 major oil and gas fields and several smaller ones by the 1970's (Fig. VI-1). Production increases have currently levelled off. To date, only a small percentage of the area deemed favorable for the occurrence of petroleum in the Cook Inlet basin has been intensively explored. The lower 2/3 of the Cook Inlet basin is essentially untouched. If the producing formations of the Upper Inlet prove to extend south of the Forelands for any great distance, substantial increases over present production levels are to be expected. Present estimates of potential reserves run as high as 7.9 billion barrels of oil and 14.5 trillion cu. ft. of gas for the entire region. With known reserves in the ground estimated at approximately 2.6 billion bbls. of oil and 5 trillion cu. ft. of gas (Crick, 1971), the margin for growth is great. The Alaska Division of Oil and Gas estimates that about 500 million barrels of this oil are recoverable.

Estimates of Cook Inlet basin reserves qualify the region as one of the major petroleum producing areas of the world. Already, Cook Inlet's oil and gas fields have produced 450 million bbls. of oil and 1 trillion cu. ft. of gas (more than 99

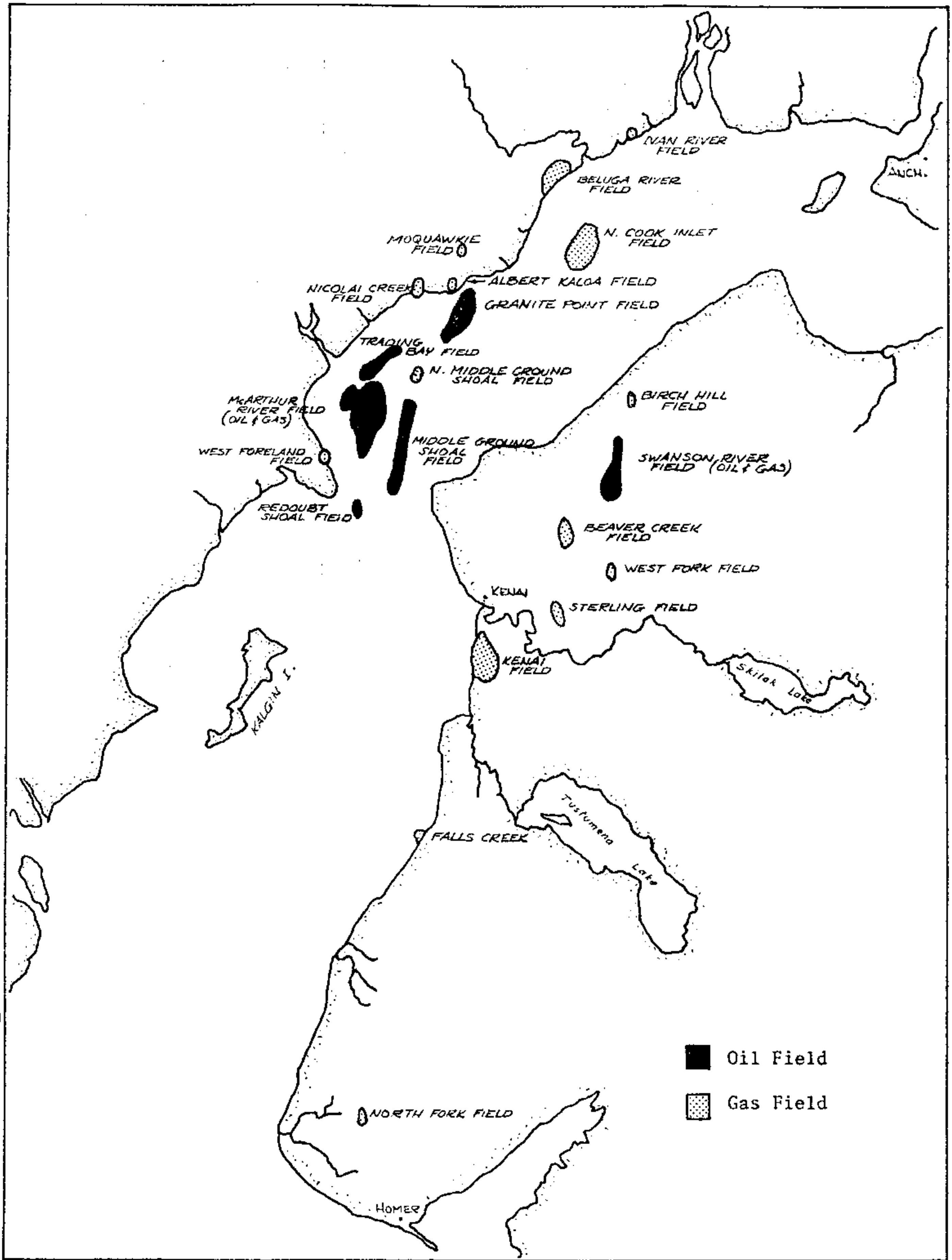


Fig. VI-1 OIL AND GAS FIELDS OF THE COOK INLET AREA percent of the state's production to date), and rank Alaska seventh among the petroleum producing states (Fig. VI-2 and VI-3). Total values for these products are estimated to be more than 1.1 and 0.6 billion dollars respectively (Table VI-1).

Cumulative income to the State of Alaska from lease bonuses, rents, taxes and royalties from Cook Inlet petroleum development now exceed 250 million dollars (Table VI-2). Production royalties account for approximately 1/2 of this figure. Further, 100 million of the total 127 million dollars in royalties have accrued to the state during the four years since 1968, the year in which the last of the offshore drilling platforms was completed. The State of Alaska, Department of Natural Resources estimates that the current level of royalty payments, in excess of 25 million dollars per year, will continue at that rate for at least several more years (Denton, viva voce). [1/]

Additional income to the state appears in the form of taxable wages and salaries from the petroleum industry proper, its support industries, spin-off industrial growth and general services. Both state and local governments receive income from taxation of the properties and physical plants of all these developments. Statistics presented in Table VI-3 and Fig. VI-4 indicate the close correlation between the expansion of petroleum development and the growth of the construction industry in the Kenai-Cook Inlet area. Since the construction industry figures reflect all contract construction, not solely that undertaken for the petroleum industry, the sharp rise in employment and total payroll indicates a generalized effect on the

---

1/ Denton, Pedro, Chief, Minerals Section, Division of Lands, Dept. of Natural Resources, Anchorage.

Fig. VI-2

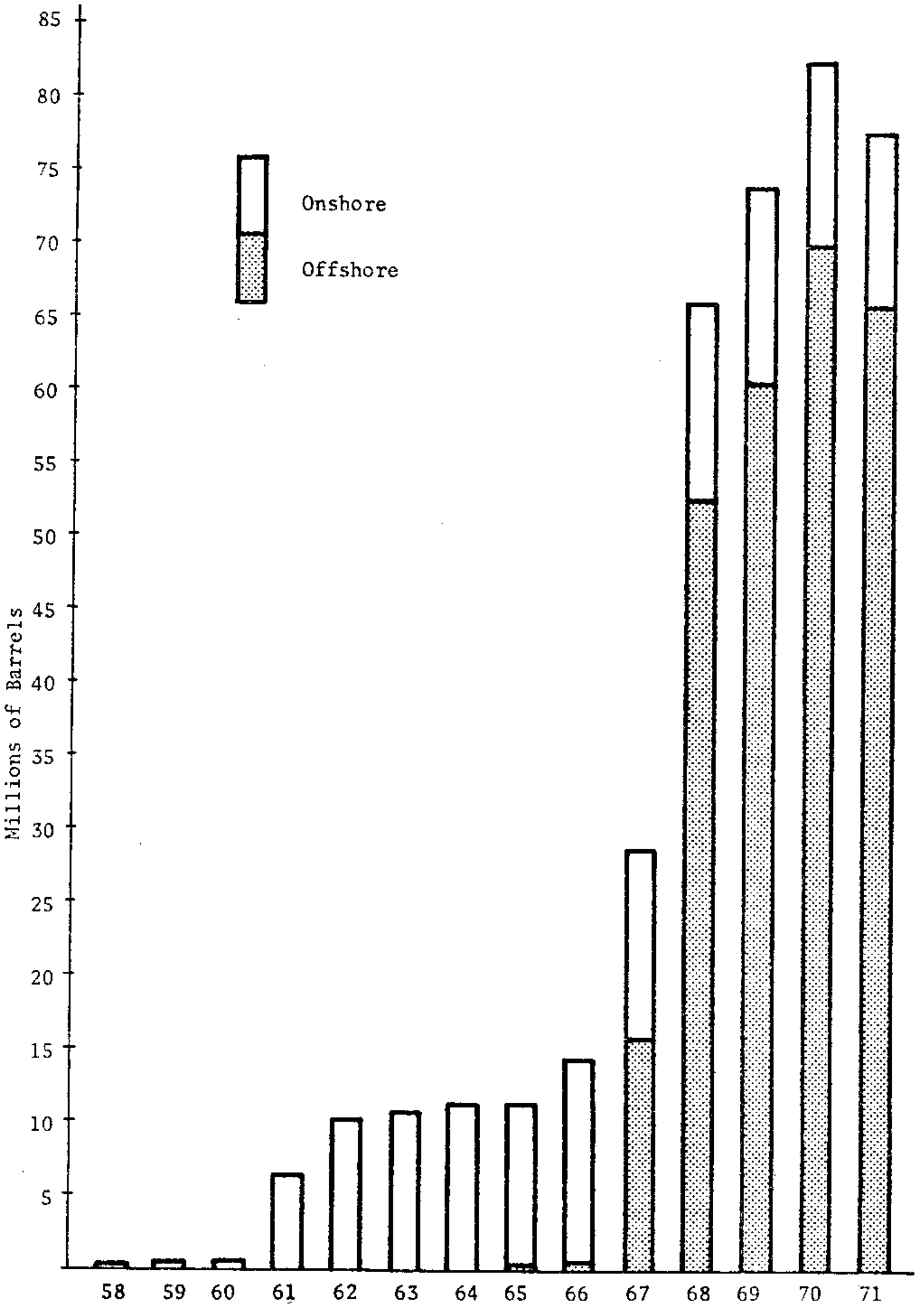


Fig. VI-2 OIL PRODUCTION IN THE COOK INLET BASIN

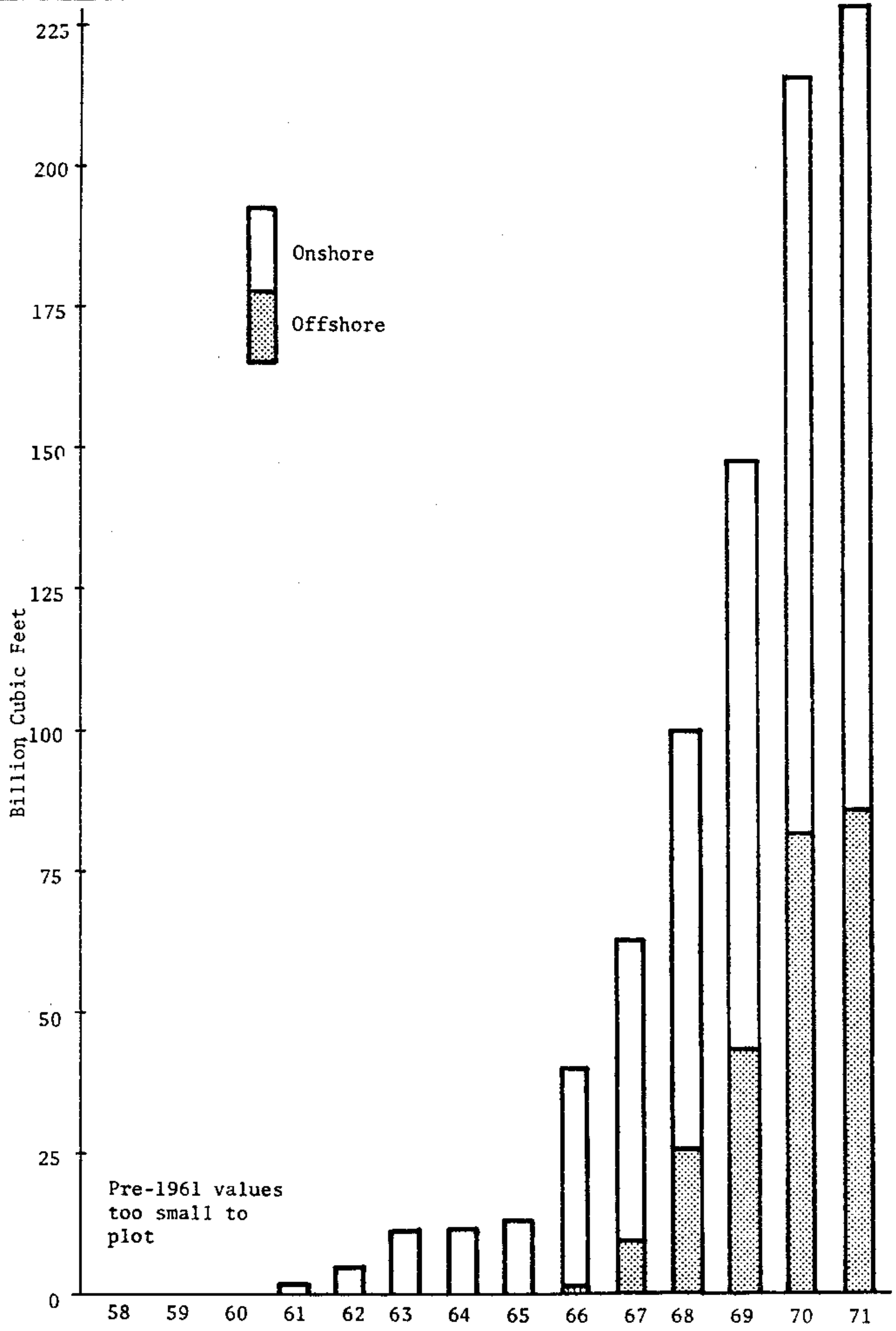


Fig. VI-3   NATURAL GAS PRODUCTION IN THE COOK INLET BASIN

Table VI-1 VALUE OF OIL & GAS PRODUCTION IN COOK INLET BASIN

(Thousands of Dollars)

	1959	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	Total
Value of Oil Production	295	1,230	17,652	31,187	32,650	33,627	34,073	44,007	91,164	186,695	200,829	232,829	234,337	1,139,974
Value of Gas Production	16	30	129	467	1,111	1,719	1,799	2,794	3,610	4,388	11,158	18,164	17,972	63,357
Total	311	1,260	17,781	31,654	33,761	35,346	35,872	46,801	94,774	191,083	211,386	250,993	252,309	1,203,331

Table VI-2 STATE REVENUES DERIVED FROM PETROLEUM DEVELOPMENT IN COOK INLET BASIN

(Thousands of Dollars)

	1959	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	Total
Royalty Payments														
Oil-State Lands	0	0	0	0	0	0	0	942 1/	3,517 1/	14,233	17,395	22,146	27,731	86,180
Gas-State Lands	0	0	0	4	40	76	96			241	391	756	897	2,285
Oil & Gas-Federal Lands	13	97	1,640	2,499	3,860	3,375	3,266	3,601	4,071	4,955	5,189	2,876	3,047	38,489
Total	13	97	1,640	2,503	3,900	3,451	3,362	4,543	7,588	19,429	22,975	25,778	31,675	126,954
Lease Bonuses & Rents														
Bonuses	2,977	79	14,411	15,626	3,682	1,056	4,581	1,241	18,127	0	0	0	0	76,802
	(Onshore bonuses not available by year, but are reflected in total figure)													
Rentals-State Lands Total	(Information not available by years for Cook Inlet Area; State share of federal rentals not available													16,000**
Taxes														
Production Severance	3	11	160	270	298	313	314	397	676	2,276	5,406	7,397	11,411	28,932
Disaster Severance	0	0	0	0	0	0	0	0	24	1,526	1,794	1,561	0*	4,905
Conservation	1	1	22	45	52	46	54	57	113	164	314	247	0*	1,116
Total	4	12	182	315	350	359	368	454	813	3,966	7,514	9,205	11,411	34,953
Total State Revenues														254,709

** Estimate from Pedro Denton, State Department of Natural Resources, Division of Mines and Geology
* State of Alaska Department of Natural Resources, Division of Oil and Gas. Various statistical reports.
State of Alaska Department of Natural Resources, Division of Lands. Various Unpublished Data.

1/ 1966 and 1967 figures are for oil and gas combined/no breakdown available.

TABLE VI-3

EMPLOYMENT & PAYROLLS

State of Alaska, Dept. of Labor, Statistical Quarterly 1960-71

	Crude Petroleum & Natural Gas Extraction		Contract Construction	
	Average Monthly Employment	Payroll	Average Monthly Employment	Payroll
1960	51	460,118	52	551,892
1961	142	1,717,557	57	552,870
1962	184	2,323,895	95	1,076,113
1963	159	1,881,437	99	1,166,623
1964	180	2,182,600	128	1,736,046
1965	195	2,650,471	270	4,205,041
1966	416	5,796,903	470	10,333,794
1967	916	14,570,909	821	17,176,211
1968	1099	18,289,716	1209	25,305,624
1969	966	16,194,289	736	14,790,152
1970	652	10,933,205	354	5,863,843
1971	527*	6,784,509*	400*	5,046,211*
TOTAL		83,785,609		87,804,420

* Through third quarter only

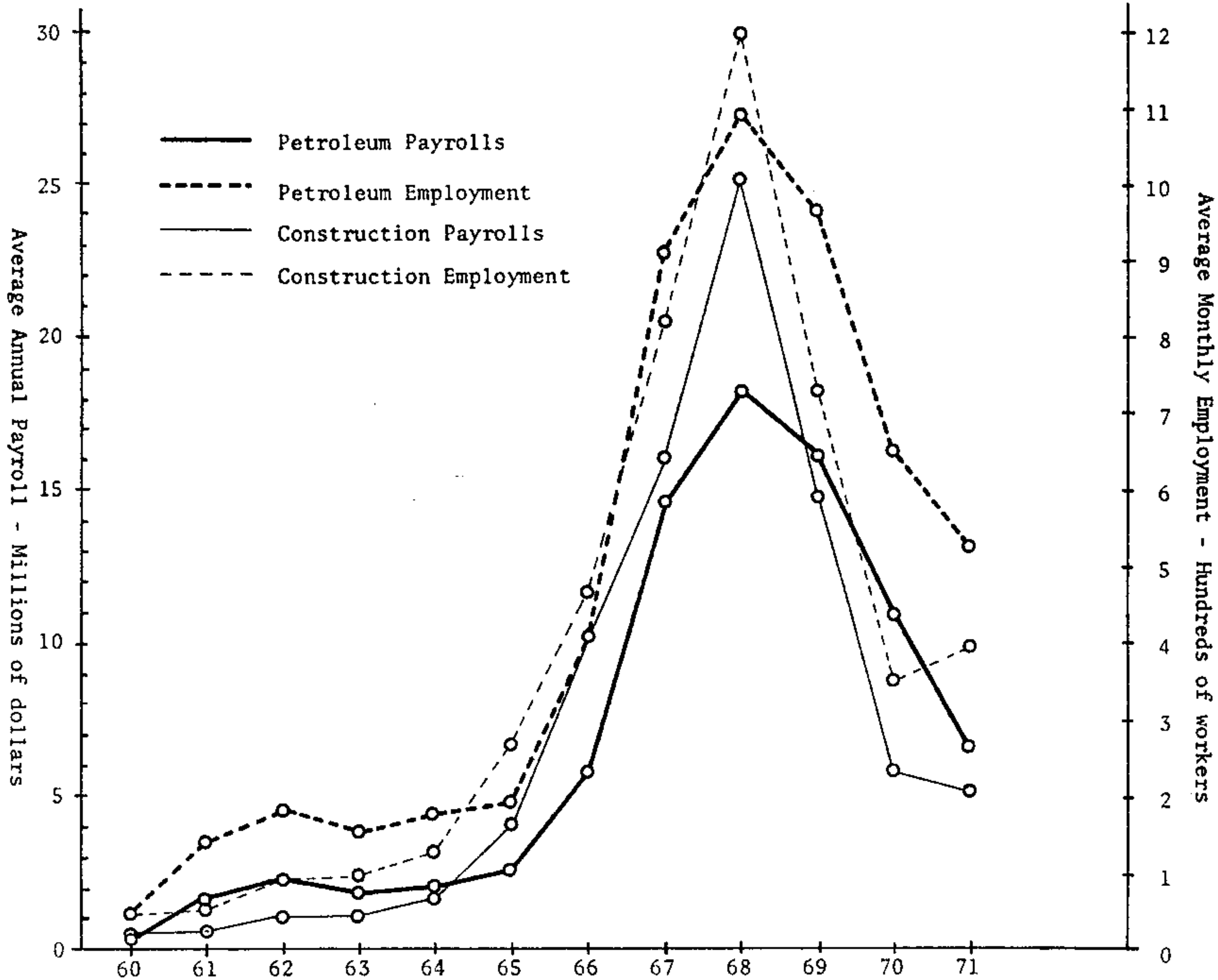


Fig. VI-4 Employment and Payroll in the Petroleum and Construction Industries community as a whole coincident with the "oil boom". However, the completion of the major oil and gas production, transport and storage facilities (Fig. V-2), while signalling a marked increase in state revenues, was followed by an equally dramatic decline in total employment in the petroleum and construction industries and a general economic slowdown in the Kenai-Cook Inlet area.

Such a "boom and bust" phenomenon is typical of economically undiversified areas, particularly those dependent upon a highly, technologically intensive industry such as petroleum extraction which, once geared-up, requires few operating personnel for production. Anchorage, unlike Kenai, possessed a much larger and more diversified economy based on government and statewide services, hence was less vulnerable to such economic fluctuations. Further economic peaks and slumps may be expected should significant petroleum industry expansion in the Cook Inlet area precede the development of a broader and more stable economic base than now exists.

THE FISHERIES INDUSTRY

Although the fishing and fish processing industries of Cook Inlet have been relegated to second place behind the petroleum industry in terms of annual dollar value of production, they are still a very important segment of the regional economy. The salient feature of the resource is that it is renewable. With proper management and conservation it can provide the State of Alaska with a valuable and relatively stable industry indefinitely. Unlike oil fields, the productive lives of which are measured in decades, fisheries values can be thought of, if not projected, in terms of centuries and millenia. In this light, comparison of values for 1970 - $5 million for fisheries vs. $250 million for petroleum - take on an entirely different meaning.

Another important point to consider in assessing the value of the fisheries is the present structure and technological development within the industry. Fishing in Cook Inlet, as throughout the United States, is, for the most part, carried out by small, inefficient units which cannot afford to use many of the technological and managerial innovations now available to the better organized foreign fleets. Improved technology, including aquaculture and better management of the resource hold the promise of greater production and profits for the future.

The present state of the fisheries economy is difficult to analyze because of large gaps in available data. Particularly deficient are figures on the number of persons actually engaged in fishing and breakdowns as to whether or not these persons are full or part-time fishermen. This in turn makes it impossible to determine the health of the industry in terms of value to those engaged in it. The study by the Alaska Department of Fish and Game of the fishery in the Cook Inlet 1968 salmon season (Flagg, 1970) is currently the best available. Selected data from this study are shown in Tables VI-4 and VI-5. This study, however, deals only with the salmon fishery. The total number of persons engaged in salmon fishing and processing was estimated to be 1,910: 1,275 in fishing and 635 in processing. Estimates of the total value to fishermen, from all species from 1962 through 1970 are shown in Fig. VI-5.

TABLE VI-4 COOK INLET SALMON FISHERY - 1968

Est. # of Fishermen	Ave. Gross Salmon Receipts	Total Gross Receipts	Average Operating Expenses	Total Expenses	Ave. Net Income	Total Net Income
1275	$5,162	$6,581,629	$2,221	$2,832,235	$2941	$3,749,775

Est. # of Vessels	Ave. Value of Vessels	Total Value of Vessels	Ave. Value of Gear	Total Value of Gear
697	$11,156	$7,775,874	$1,585	$1,195,967

TABLE VI-5 ECONOMIC DATA FROM 18 COOK INLET CANNERIES

Average number of years operated in Cook Inlet	11
Number of salmon purchased in 1968	3,434,474
Average number of salmon purchased per cannery	381,608
Number of people employed at peak of operation	635
Average number of people employed per cannery	35
Number of tenders operated in 1968	21
Number of fishing boats owned	102
Total value of fishing boats	$922,000
Average value per boat	$9,039
Average capital investment per cannery	$262,372
Average operating expense per cannery	$45,209
Average gross receipts per cannery	$65,653
Percent of total receipts from sale of salmon products	97

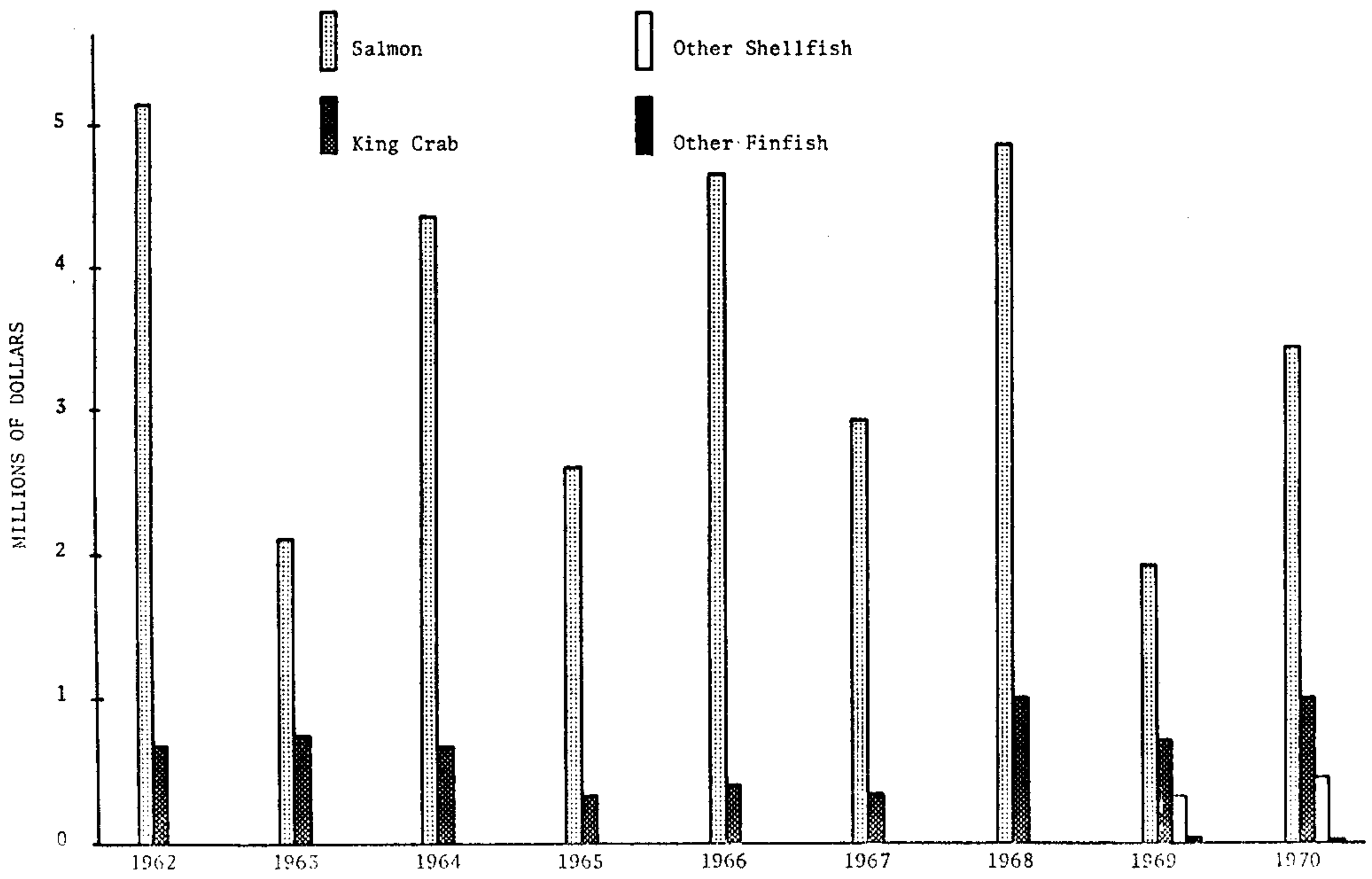


FIG. VI-5 VALUE OF THE COOK INLET FISHERIES, 1962-1970

THE TIMBER INDUSTRY

Timber is not a resource of great value in the Cook Inlet Basin. Most stands are overmature and of low value. Many of the better stands have been excluded from future cutting through their inclusion in wilderness and park areas.

Although there are numerous timber processing operations in the Cook Inlet region, all but one are of very limited size. Many of those listed with the State are not actually producing. The only sizeable venture is the South Central Timber Development Company operation at Jakolof Bay near Seldovia, which produces cants for the Japanese market.

The majority of the logs processed at this mill do not come from the Cook Inlet area, but are barged to the mill from Icy Bay. Cuttings in the Kachemak Bay region averaged about 1 million board feet (MMBF) per month from the inception of the operation through 1971 but have declined to only about 1/4 of that value in 1972 (McGill, viva voce).[1/] Total production is estimated to be $130 per 1000 BF (McGill, viva voce), which would total approximately $6,500,000. To date the State has received $95,000 in stumpage fees from timber sales for this operation.

Cutting operations employ 12-15 loggers fulltime, with total salaries of 350-400 thousand dollars yearly. About the same amount is earned by the 15 year round employees of the Jakolof Bay mill.

Though there is potential for further expansion of timber harvesting in the Cook Inlet basin, it is likely that production will fall rather than rise through the forseeable future due to the low grade of the resource in conjunction with marketing problems (McGill, viva voce).

1/ McGill, Thomas, Forester, Division of Lands, Dept. of Natural Resources, Anchorage, Alaska.

PHASE 3

IMPACTS AND COMPETITION

INTRODUCTION

A review of the data discussed in phase 1 provides an overview of the various resources and systems that could act upon, or be acted upon by petroleum exploration and development. There is an impact, not only from the proposed activities on the environment, but also the impact of a difficult environment on the proposed activities. If parts of the operational system should fail, the environment could be affected. For instance, the pressure of ice could rupture a pipeline full of oil which could escape and damage habitats.

IMPACT OF THE COOK INLET ENVIRONMENT ON PETROLEUM OPERATIONS

Ice - Ice is a major factor in the design of fixed structures, particularly oil platforms. Ice also is a major hazard to marine navigation and could influence design of vessels and location of facilities.

Bottom Sediments - Bottom sediments are generally unstable to great depth. Pilings as deep as 200' below the Inlet floor may be required to support oil platforms (Beazley, *viva voce*).

Suspended Sediments - Suspended sediments can exert a cutting action on materials in motion or fixed structures in areas of tidal currents, such as oil platforms (Visser, 1969).

Bathymetry - The conformity of seabed physiography is a factor in the design of platforms and other structures, particularly on unstable bottom sediments. Beazley (*viva voce*) believes it is, at present, economically infeasible to operate in depths of more than several hundred feet within the Inlet, even though it is technologically possible to do so.

Currents and Circulation - Currents and circulation patterns are factors in design, particularly of platforms and pipelines where bottom sediments may scour. Tides and currents are also a factor in navigation. Visser (1969) discusses the problems attendant on erecting a preconstructed platform base and securing it during a slack tide period. Strong tidal currents prevent most small boat use in Turnagain Arm.

Earthquakes - Crustal movements are important design factors for structures, particularly on unstable soils. Visser (1969) reports, however, that where severe ice conditions are encountered, as in the case of oil platforms in Cook Inlet, design criteria to withstand the forces exerted by the ice are so stringent that no additional structural requirements are necessary when earthquakes are considered.

Tsunamis - Probability of severe waves is slight in the Upper Inlet. They could occur in the Lower Inlet causing severe damage to shore structures and boats in shallow water.

Volcanoes - Eruptive activity could damage structures and small boats in the vicinity. An eruption of Augustine Island could create a seismic seawave.

High Winds - Gale force winds are major factors in small boat navigation. Winds are probably a minor concern for most navigation when compared to currents and ice.

IMPACT OF PETROLEUM OPERATIONS ON THE COOK INLET ENVIRONMENT

Explosives - Explosives can kill fish, particularly fin fish with swim bladders and larval forms. Explosives also can disrupt pupping activities of sea mammals. USDI (1972) suggests that explosives may disrupt nesting activities of birds. If habitats were disrupted significantly by an intensive survey pattern in littoral areas, reduction of food supplies for higher animals could result.

Oil spills - Oil spills can and do occur. Federal Water Pollution Control Administration (no date) details spills that have occurred in the Cook Inlet area.

Significant spills were numerous during the development phase of the Cook Inlet fields and originated from platforms, pipelines and vessels. Even though they can be minimized, USDI (1972) suggests they will continue and will be roughly proportional to the amount of oil handled.

Spilled oil in Cook Inlet can have long-lasting effects on plankton and littoral organisms that are an important basis of the food chain of higher forms. Blumer et al. (1971) suggests that damage can be difficult to detect and can be widespread and long lasting. Toxic elements of the oil may be spread through the water column and affect organisms at some depth.

Fin fish, particularly those that travel near or at the surface, can be affected. Clam beaches can be damaged and Blumer et al. (1971) report a two-year closure of a clam beach following an oil spill. Deep water forms should be more immune to impacts.

Birds are affected directly and kills have been recorded in Cook Inlet (Evans, 1969). Birds also would be affected if their habitat were damaged. Most marine mammals are reported to be relatively immune to oil. The sea otter is an exception in Cook Inlet where their population could be decimated by a severe spill.

Dispersants - Dispersants have been used to expedite mixing of oil with water. It has been found, however (FWPCA, 1969), that dispersants usually increase the toxicity of oil. Their use has been curtailed by Environmental Protection Agency policy (EPA, 1972). Use of dispersants or sinking agents on spilled oil would also endanger species at greater depths which might otherwise escape the effects of untreated oil.

CASE EXAMPLES

Based on available information, some rather rough predictions can be made as to what could occur in Cook Inlet from postulated spill incidents.

Upper Inlet

A major spill of oil in Upper Cook Inlet could cause a long-lasting problem. Circulation information suggests that in winter, most of the oil would remain indefinitely amidst the ice in the Upper Inlet, moving back and forth with each tidal cycle, but leaving the Upper Inlet only as a result of dispersive forces in the oil itself and as small amounts of the ice pass the Forelands. Ramseier (1971) believes there are no means for cleaning up oil under ice.

Studies by the Institute of Marine Science (Kinney *et al.*, 1969) indicate that in the course of a month or so, the oil would be biodegraded. The effects of cold temperatures and ice could, however, retard this process and the oil might remain in the Upper Inlet for an extended period.

During winter, the Upper Inlet, except for the intertidal areas and marshes, is relatively devoid of life. Even the marshes are covered with snow and ice. The major potential for damage in such a situation would be a combination of wind and tide that could drive the oil onto the marshes surrounding the Upper Inlet, killing vegetation and such animals, mainly invertebrates and fur animals, as remain on the marsh in winter, and causing long-term damage to habitats. Oil has not yet been observed to be driven onto the marshes in this manner and it is possible that the entire mass could move back and forth in the Upper Inlet until most of it disappeared, merely leaving a tarry residue on boats, dock pilings, other structures and rocky beaches. On the basis of available information, it is impossible to state whether or not substantial damage would result, or what form it would take.

If the same incident occurred in spring, summer, or during the fall bird migration, significant kills of birds, particularly waterfowl, could occur.

Migrating salmon, steelhead, Dolly Varden and smelt would be affected also. Seals and belugas would be present, but probably would be little affected.

Because of the fresh water runoff at this season, the oil would probably move out of the Upper Inlet and down the west side, where it could encounter habitats occupied by marine birds, the kittiwake colony on Chisik Island and other large sea bird populations as it passed out of the Inlet. Sea otters in the vicinity of Augustine Island would be in its path also. By the time it reached the Middle and Lower Inlet, the lighter fractions of the oil should have been evaporated and dispersed. Work by Blumer et al. (1971) suggests, however, that such a situation should be checked carefully for damage to marine organisms.

Lower Inlet

A large oil spill off Port Graham in summer could have devastating effects on Lower Cook Inlet.

Circulation up the east side of the Inlet would probably carry it northward toward Bluff Point. There, the slick probably would split, part of it going into Kachemak Bay where it would pass eastward to the Homer Spit. From there it is uncertain whether it would pass eastward up the south side of Kachemak Bay or be distributed along the south shore westward of China Poot Bay. It would probably spread in both directions.

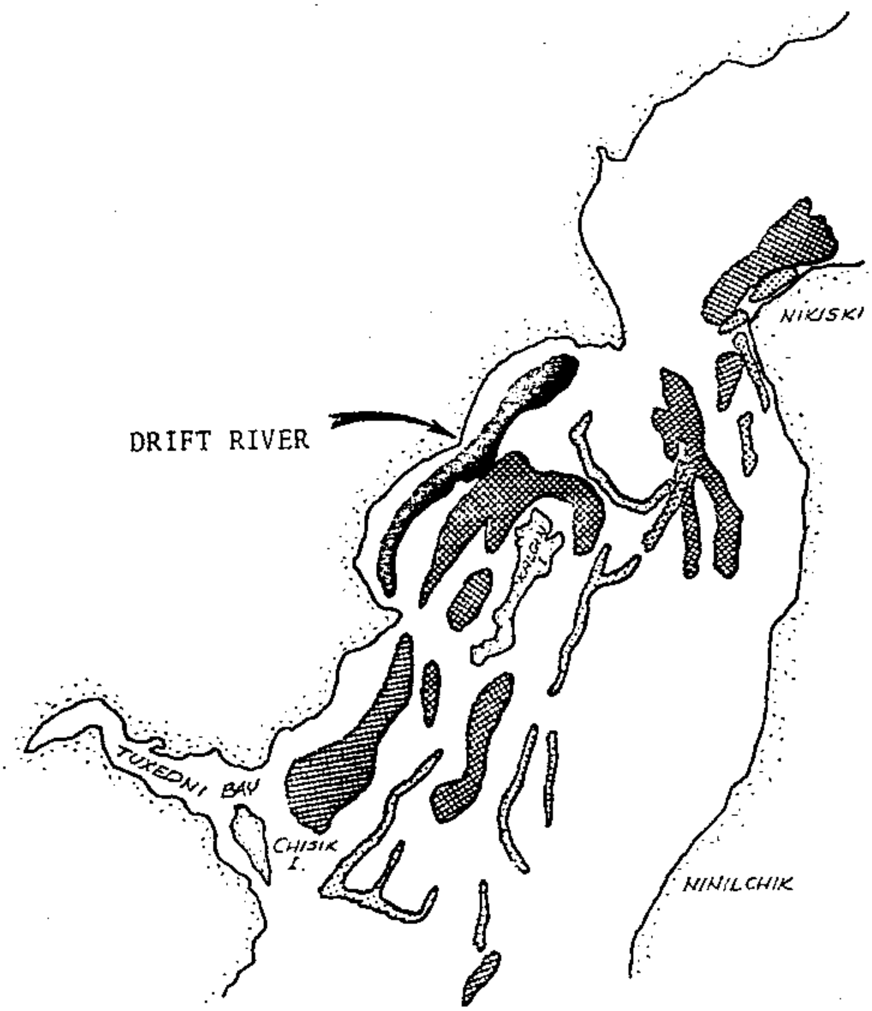
A spill of this type would have tremendous impact on valuable recreational and scenic resources of Kachemak Bay. Visual impacts of oil on the rocky coastline would be a cost in itself, and the damage would probably include part of Kachemak Bay State Park. Sport fishing and recreational boating would be severely affected. Toxic elements of the relatively fresh oil would affect the littoral zone of the productive bays and would affect shrimp, crabs and molluscs, particularly their eggs and larval forms.

Large numbers of marine birds - kittiwakes, gulls, puffins, jaegers and others would be killed.

The remainder of the oil probably would pass up the east side of the Inlet along valuable clam beaches as far as the Kasilof River. It would affect migrating fish at the mouth of some of the most important salmon streams in Cook Inlet.

At the East Foreland it would probably divide again, some continuing along the east side into the Upper Inlet while the remainder would be carried over to the west side and start back down the Inlet. All along the east shore of the Upper Inlet, it would be in contact with migrating salmon and with set net fishermen. It would also threaten waterfowl marshes of the west side. The remainder of the oil that circulated westward below the Forelands would pass along both sides of Kalgin Island, threatening the waterfowl marshes of Redoubt Bay and the sea bird populations farther south. Conceivably, it could affect sea otters and sea birds in the Kamishak Bay area.

The progress of such an oil spill could be difficult to trace. Experience in Cook Inlet (Kinney <u>et. al</u>, 1969) has been that after about three days, a spill can no longer be traced. Fig. VII-1 shows repeated observations on the course of 1,700



- extent of oil spill 12-30-67 at 1200
- extent of oil spill 12-31-67
  Nikiski at 1310
  So. of Kalgin Island at 1100
- extent of oil spill 1-1-68 (west side of inlet not checked)
- extent of oil spill 1-3-68 at 1100

Fig VII-1 DISTRIBUTION OF OIL FROM SPILL AT DRIFT RIVER DECEMBER 30, 1967 barrels of crude oil spilled at Drift River about 6:00 a.m. December 30, 1967 (personal observations). The day following the spill, the oil was easily visible as dark, tarry masses with considerable irridescence. It had spread in a pattern difficult to comprehend at the time, but easily understood in the light of information on circulation now available. It was still easily visible two days following the spill, but could not be traced because of fog. By January 3, the next day of flying weather, only traces of metallic sheen could be seen to indicate the presence of oil.

A subsequent observation four days following another spill found no trace of oily sheen or irridescence to indicate the presence of oil. Close inspection of windrowed vegetation, however, revealed a coating of brown, oily material about 1/8 inch thick on every particle in the mass. Apparently all the observable irridescent and shiny material had evaporated from the oil. Whether or not this is a common phenomenon and whether or not this marks the end of its toxicity are unknown.

COMPETITION AMONG RESOURCE USERS

Although resources in Alaska are managed under the multiple use principle, freedom from interference and complete compatibility between users can never be assured and competition for space is almost certain to occur. Many factors contribute to adjustments within this competition that are beyond the scope of this report, which will merely point out where competition exists.

The five major competitors that have evolved in this study are as follows:

The commercial fishery

Timber

Recreation and sport fishing

Marine transportation

Petroleum exploration and development

The Commercial Fishery

The commercial fishery, with an annual value of $5,000,000 to the fisherman, has little impact on the Inlet other than on the fish themselves and other predators on them - predaceous fish, birds, mammals and sport fishermen. Left to itself, under proper management, the Cook Inlet commercial fishery could continue to produce indefinitely. Conflicts would be minor and would be limited to problems of dividing the catch between commercial and sport fishermen.

Timber

Timber harvest, with an annual value of $1,500,000, competes with the fishery and with recreation for space on the Inlet. It also has an impact on the fishery in the case of spawning and log storage areas. Streams can be damaged and scenic values affected by poor timber harvest practices.

Recreation and Sport Fishing

Recreation and recreational use of fish and wildlife resources is difficult to evaluate. The cost of participation is only a part of its value. Steinhoff (1969) has pointed out that recreational values of the Cook Inlet area are a major factor in the selection of Anchorage as a place of residence. Recreational activities can be carried out indefinitely with minimal impact on other resource users. The only costs it imposes are the restraints on other resource users to assure that impairment of recreational values is minimized and to demand of the commercial fishery that the harvest be shared.

Marine Transportation

Marine transportation can also be carried out with little cost to other resource users. The only requirement is space for navigation and for loading sites. This is true, however, only if no dangerous cargoes are handled and accidents do not occur. When such cargoes as oil are carried, however, the potential for conflict is considerable. The record (FWPCA, no date) indicates clearly that oil has been lost frequently in Cook Inlet. The forecast (USDI, 1972) is that it will continue. The record is less clear, however, as to the actual impact that has occurred in Cook Inlet.

Petroleum Exploration and Development

The oil industry in its exploration and development phases, with an annual production value of $250,000,000, is a heavy competitor for the Cook Inlet environment. While fishing, timber, recreation and most marine transport operations have used the same environment with only minor impact on it or on each other, the petroleum industry has the capacity for severe competition and impacts as have been described.

Fig. VII-2 has been prepared to illustrate geographically the principal areas of conflict and competition between major resource users of the Inlet. It summarizes the portions of the Inlet used most heavily by the competing interests and points out where additional competition would probably result in conflict. For instance,

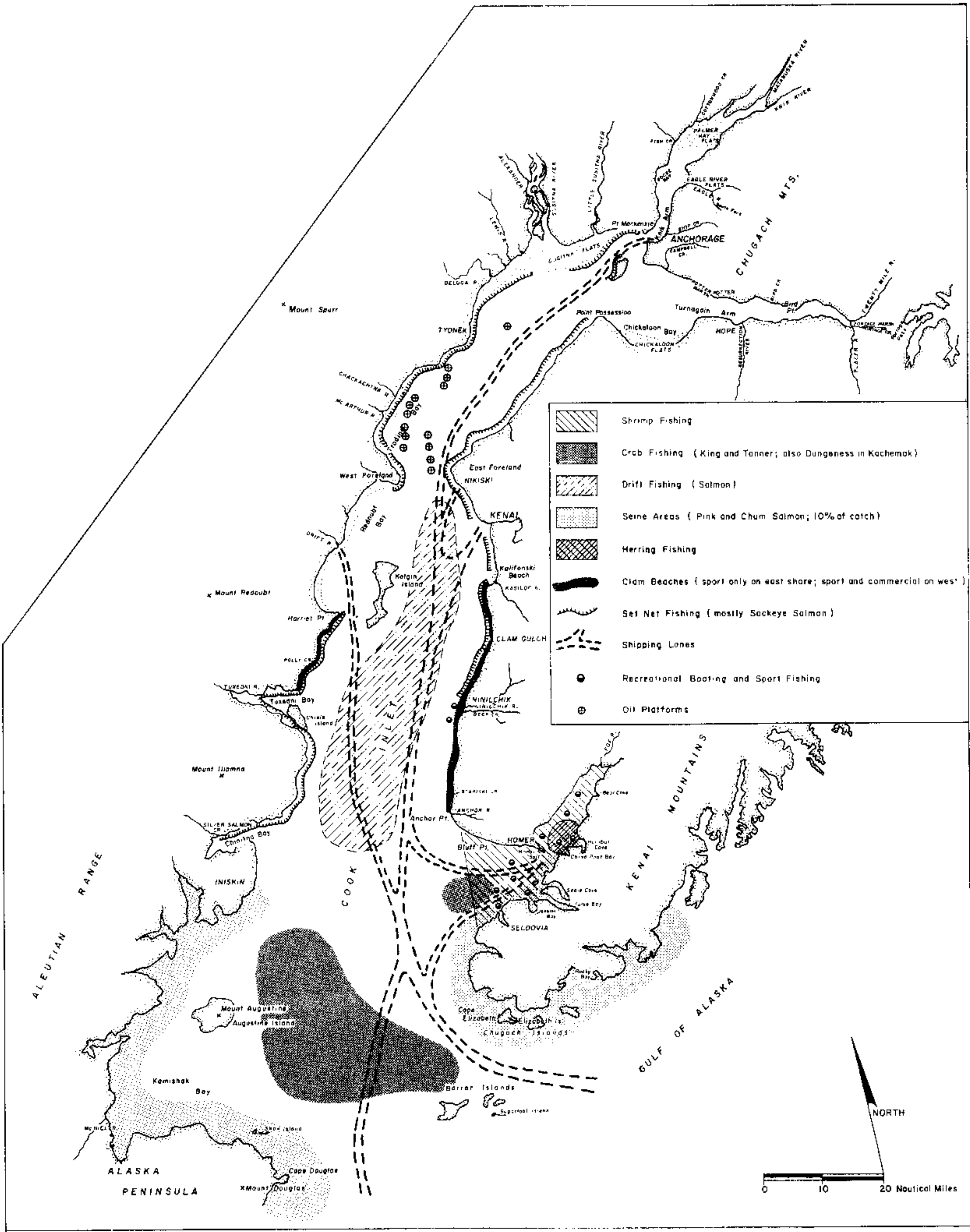


FIG. VII-2 PRINCIPAL AREAS OF CONFLICT AND COMPETITION BETWEEN MAJOR RESOURCE USERS the planning of shore installations in areas traditionally used by set netters should include provisions for protection of their interests. An installation which might deflect migrating fish or degrade the water quality would be in conflict. Where other uses are intense, such as in Kachemak Bay, considerable care would have to be used.

Literature Cited - Phase 1

Alaska Department of Fish and Game,1959,Annual Report #10 (1958) State of Alaska 123 pp.

Alaska Department of Fish and Game,1960,Annual Report #11 (1959) State of Alaska.

Alaska Department of Fish and Game,1971, Alaska Catch and Production: Commercial Fisheries Statistics 1970, Statistical Leaflet #21, State of Alaska.

Alaska Division of Parks 1971, 1970,Visitation to the Alaska State Park System, Department of Natural Resources, Alaska Division of Parks.

American Petroleum Institute,1972,Planning, Designing and Constructing Fixed Offshore Platforms, American Petroleum Institute Division Prod., Dallas, Texas.

Anonymous, 1967, A Review of the King Crab Fishery in Cook Inlet,1960-1967. Files of Alaska Department of Fish and Game.

Bader, Dmitri A.,1970, Letter to Planning Department, Greater Anchorage Area Borough on Birds of the Potter Marsh, June 12, 1970.

Barr, Louis and Roland McBride,1967, Surface-to-bottom pot fishing for pandalid shrimp. U. S. Fish and Wildlife Service, Spec. Sci Report. - Fisheries No. 560.

Bright, Donald, 1959, Experiment to Evaluate the Effect of Submerged Explosions on Bottom-dwelling King Crab. (Typescript).

Calderwood, K. W. and W. C. Fackler,1972, Proposed Stratigraphic Nomenclature for Kenai Group, Cook Inlet Basin, Alaska. A.A.P.G. Bull. V. 56, p. 739-754.

Carlson, Robert F. and Charles E. Behlke,1972, A Computer Model of the Tidal Phenomena in Cook Inlet, Alaska IWR- Univ. of Alaska., Fairbanks, Alaska Report No. IWR-17, 69 p.

Cleaver, Fred, undated, Life History and Habits of the Commercial Crab, Cancer Magister Alaska Department of Fish and Game,State of Alaska.

Collier Carbon and Chemical Corp., 1967, Summary Report, Effluent Research Studies for Kenai Plant of Collier Carbnn and Chemical Corp. Res. and Dev. Department, Oct 1967.

Collier Carbon and Chemical Corporation,1969, 1968 Annual Report, Effluent Monitoring Program for Kenai Plant of Collier Carbon and Chemical Corporation. Res. and Dev. Department, Jan 1969.

Crick, R. W., 1971, Potential Petroleum Reserves, Cook Inlet, Alaska IN Future Petroleum Provinces, North America, A.A.P.G. Memoir 15, V.I p109-119.

Davis, Allen S., 1955, Game Fish Investigations of Alaska Anchor River File, Project F-1-R-4, Quarterly Progress Report, Oct 1, 1954 - Dec 31, 1954, U. S. Fish and Wildlife Service and The Alaska Game Commission.

Davis, Allen S., 1967, Cook Inlet Sockeye Salmon Investigations, Quarterly Progress Report. July 1, 1967 - Sept 30, 1967, Commercial Fisheries Research and Development Act, Alaska Department of Fish and Game, State of Alaska 28 pp.

Davis, Allen S., 1968, Cook Inlet Sockeye Salmon Investigations.Quarterly Progress Report 5-6-R-4, July 1, 1968 - Sept 30, 1968, Commercial Fisheries Research and Development Act, Alaska Department of Fish and Game, State of Alaska 21 pp.

Davis, Allen S., 1969, Cook Inlet Sockeye Salmon Investigations.Quarterly Progress Report 5-6-R-4, October 1, 1968 - December 31, 1968, Commercial Fisheries Research and Development Act, Alaska Department of Fish and Game, State of Alaska 9 pp.

Davis, Allen S., 1970, Forecast Research on the 1970 Cook Inlet Area Pink Salmon Fisheries. ADFG Information Leaflet #143, Alaska Department of Fish and Game, State of Alaska 17 pp.

Davis, Allen S. and Paul D. Kissner, 1970, Sockeye Salmon Investigations Annual Technical Report 5-18-R-1, 1969 Field Season, Commercial Fisheries Research and Development Act, Alaska Department of Fish and Game, State of Alaska.

Davis, Allen S. and Paul D. Kissner, 1971, Sockeye Salmon Investigations Annual Technical Report 5-18-R, 1970 Field Season, Commercial Fisheries Research and Development Act, Alaska Department of Fish and Game, State of Alaska 40 pp .

Engel, Larry J., 1966, Evaluation of the King Salmon Fisheries on the Lower Kenai Peninsula, ADFG - Federal Aid in Fish Restoration Annual Report of Progress Project F-5-R-7, Vol 7: 101-107.

Engel, Larry J., 1970, Studies on the Russian River Red Salmon Sport Fishery. ADFG - Federal Aid in Fish Restoration Annual Report of Progress Project No. F-9-2, Vol 11: 129-134.

Erickson, R. C., 1963, Oil Pollution and Migratory Birds: Atlantic Naturalist, 18(1): 5-14.

Evans, C. D. 1969, Environmental Effects of Petroleum Development in the Cook Inlet Area. Proceedings Alaska Science Conference 20:213-221.

Federal Field Committee for Development Planning in Alaska, 1971, Economic Outline for Alaska: Anchorage, Alaska.

Flagg, Loren B., 1970, An Economic Survey of the Cook Inlet Salmon Fishery ADFG Information Leaflet #145, State of Alaska 30 pp.

Flagg, Loren B., 1972, 1971 Cook Inlet Annual Report, Shellfish Section Alaska Department of Fish and Game, Commercial Fisheries Division.

Foster, H.L. and T.N.V. Karlstrom, 1967, Ground Breakage and Associated Effects in the Cook Inlet Area, Alaska, Resulting from the March 27, 1964 Earthquake, U.S.G.S. Prof. Paper 543-F.

Gabrielson, F.N. and F.C. Lincoln, 1959, Birds of Alaska, Stackpole Co., Harrisburg, Pa. 922 pp.

Gibson, Daniel D., 1967, Bird Observations on Katmai National Monument - 24 February through 1 September 1967. Administration Report to National Park Service, Anchorage, Alaska.

Hansen, W. R., 1965, Effects of the Earthquake of March 27, 1964, at Anchorage, Alaska; U. S. Geological Survey Prof. Paper 542A, p.A1-A68.

Hansen, W. R., et. al., 1966, The Alaska Earthquake, March 27, 1964: Field Investigations and Reconstruction Effort: U.S. Geological Survey Prof. Paper 541, 111 pp.

Hasler, Arthur D., 1966, Underwater Guideposts: Homing of Salmon; Univ. of Wisconsin Press.

Havens, P.D., 1970, Waterfowl Survey - Inventory Progress Report. In ADF&G Report of Survey and Inventory Activities part III. Waterfowl and Small Game. Vol. II Federal Aid in Wildlife Restoration project W-17-3.

Havens, P. D., 1971,Report of Survey and Inventory Activities - Waterfowl. Vol III ADF&G Federal Aid in Wildlife Restoration Project W-17-4.

Hennick, Daniel P., 1970, Reproductive Cycle , Size at Maturity and Sexual Composition of Commercially Harvested Weathervane Scallops. (Patinopecten caurinus) in Alaska, Journal of Fisheries Restoration Board, Canada 27:2112-2119.

Hood, D.W., K.V. Natarajan, D.H. Rosenberg and D.D. Wallen, 1968, Summary Report on Collier Carbon and Chemical Corporation Studies in Cook Inlet, Alaska; IMS-Univ. of Alaska, College, Alaska. 16 pp.

Hutcheon, Richard J., 1971, 1970-1971 Ice Season - Cook Inlet, Alaska 9 pp.(Processed).

Jackson, H.W., 1970, Summary of Reconnaissance Collections in Cook Inlet, Alaska: July 26 - August 1, 1970; Environmental Protection Agency, Office of Water Programs, Cincinnati, Ohio. 5 p.

Karlstrom, T.N.V., 1964, Quaternary Geology of the Kenai Lowland and Glacial History of the Cook Inlet Region, Alaska U.S.G.S. Prof. Paper 443.

Kearns, R.K., and F.C. Boyd, 1964, The Effect of a Marine Seismic Explosion on Fish Populations in British Columbia Coastal Waters; Department of Fisheries of Canada, Vancouver, B.C., April, 1964.

Kelly, T.E., 1963, Geology and Hydrocarbons in Cook Inlet Basin, Alaska in: Backbone of the Americas A.A.P.G. Memoir 2, p. 278-296.

Kelly, T.E., 1968, Gas Accumulations in Nonmarine Strata, Cook Inlet Basin, Alaska in: Natural Gases of North America A.A.P.G. Memoir 9, v. 1 p. 49-64.

Kenyon, Karl W., 1969, The Sea Otter in the Eastern Pacific Ocean. North American Fauna No. 68, U. S. Bureau of Sport Fisheries and Wildlife U.S.G.P.O., Washington, D.C.

Kinney, P.J., D.K. Button, D.M. Schell, B.R. Robertson and J. Groves, 1970a, Quantitative Assessment of Oil Pollution Problems in Alaska's Cook Inlet; IMS, Univ of Alaska, College, Alaska, Report #R-69-16, 116 p.

Kinney, P.J., J. Groves and D.K. Button, 1970b, Cook Inlet Environmental Data. R/V Acona Cruise 065- May 21-28, 1968, Institute of Marine Science, Univ. of Alaska, College, Alaska, Report # R-70-2, 120 p.

Kirschner, C.E. and C.A. Lyon, 1971, Stratigraphic and Tectonic Development of the Cook Inlet Petroleum Province; Unpublished Manuscript.

Klinkhart, E.G., 1966, The Beluga Whale in Alaska; Alaska Department of Fish and Game, Federal Aid in Wildlife Restoration Report, Vol. VII, proj. W-G-R and W-14-R.

Knull, J.R. and R. Williamson, 1969a, Oceanographic Survey of Kachemak Bay, Alaska, April, 1969; U.S. Department of the Interior, Bureau of Commercial Fisheries Manuscript Report - File MR-F No. 60, 54 p.

Knull, J.R. and R. Williamson, 1969b, Oceanographic Survey of Kachemak Bay, Alaska - July, 1969; U.S. Department of the Interior - BCF Manuscript Report - File MR-F #70, 76 p.

Knull, J.R. and R. Williamson, 1969c, Oceanographic Survey of Kachemak Bay, Alaska - October, 1969, U.S. Department of the Interior - BCF Manuscript Report - File MR-F #76, 24 p.

Krohn, W.B., 1966, A Brief Survey of the Tuxedni National Wildlife Refuge. 14pp inch map (Typed administrative report to Kenai National Moose Range, Kenai, Alaska).

Kubik, Stanley W., 1962, Population Studies of Anadromous Fish in Cook Inlet, ADFG - Federal Aid in Fish Restoration Annual Report of Progress (1961-1962) Project, Vol 3:

Kubik, Stanley W., 1966, Population Studies of Anadromous Fish in Cook Inlet, ADFG - Federal Aid in Fish Restoration Annual Report of Progress (1965-1966) Vol 7: p. 117-130.

Kubik, Stanley, 1968, Population Studies of Anadromous Fish in Cook Inlet, ADFG - Federal Aid in Fish Restoration Annual Report of Progress (1967-1968) Project F-5-R-9, Vol 9: p 157-171.

Kubik, Stanley W., 1970, Population Studies of Anadromous Species with Emphasis on Upper Cook Inlet Drainage. ADFG-Federal Aid in Fish Restoration Annual Report of Progress (1969-1970) Project: F-9-2, Vol II: p. 135-145.

Kuhnhold, W.W., 1970, The Influence of Crude Oils on Fish Fry: FAO Technical Conference on Marine Pollution, Dec. 9-18, 1970, Rome, Italy 10 p., mimeo.

Logan, Sidney M., 1972, Personal Communication - Letter dated August 15, 1972, (Razor Clams), Area Management Biologist, P.O. Box R, Soldotna, Alaska 99669.

Loosanoff, V.L., 1947, Commercial Clams of the Pacific Coast of the United States, Fishery Leaflet #223, Bureau of Commercial Fisheries.

Maher, J.C. and W.M. Trollman, 1969, Geological Literature on the Cook Inlet Basin and Vicinity, Alaska, Alaska Department of Natural Resources.

Matthews, J.B. and J.C.H. Mungall, 1972, A Numerical Tidal Model and Its Application to Cook Inlet, Alaska. Sears Foundation: Journal of Marine Research, Vol 30(1): 27-38.

Mileikovsky, S. A., 1970, The Influence of Pollution on Pelagic Larvae of Bottom Invertebrates in Marine Nearshore and Estuarine Waters, Marine Biology 6:350-356.

Mironov, O.G. and L.A. Lanskaya, 1968, Survival of Some Marine Plankton and Benthoplanktonic Algae in Sea Water Polluted with Petroleum Products Bot. zh. 53(5): 662-669.

Murphy, R.S., R.F. Carlson, D. Nyquist and R. Britch, 1972, Effect of Waste Discharges on a Silt-laden Estuary. A case study of Cook Inlet, Alaska; Institute of Water Resources, Univ. of Alaska, College, Alaska Report # IWR26, 42 pp.

Murray, Ann P., 1972, The Effects of Suspended Silts and Clays on Self-Purification in Natural Waters: Protein Absorption, IWR- Univ. of Alaska, Fairbanks, Alaska, Report # IWR-23, 52 p.

National Academy of Sciences, 1971, The Great Alaska Earthquake of 1964 - Geology: Washington, D. C.

National Marine Fisheries Service, 1971, Tanner Crab: Joint Plan for the Fishery. NMFS, 86 pp.

NOAA, 1971, Tidal Current Tables, Pacific Coast of North America and Asia. U. S. Department of Commerce, National Oceanic and Atmospheric Administration, National Ocean Survey. 254 p.

Oregon State University, 1969, Syllabus of the Commercially Important Invertebrate Fisheries. Department of Fish and Wildlife, Oregon State University Invertebrate Fisheries #466.

Plafker, G., 1969, Tectonics of the March 27, 1964, Alaska Earthquake U.S.G.S. Prof. Paper 543-I.

Powell, Guy C. and R.E. Reynolds, 1965, Movements of Tagged King Crab (Paralithodes Camtschatica (Tilesius) in the Kodiak Island, Lower Cook Inlet Region of Alaska. 1954-1963. Alaska Department of Fish and Game Informational Leaflet #55 .

Public Health Service, 1970, Report for Consultation on the Anchorage Intrastate Air Quality Control Legion (Alaska), U.S. Department of Health, Education and Welfare, 29 p.

Quimby, Ronald, 1971, Chickaloon Flats Weekly Report, May 4-11, April 26 - May 3, 1971. Administrative Report to Manager Kenai National Moose Range, Kenai (Processed).

Robbins, C.S., B. Bruun and H.S. Zim , 1966, Birds of North America - A Guide to Field Identification. Golden Press. New York.

Rosenberg, D.H., D.C. Burrell, K.V. Natarajan and D.W. Hood, 1967, Oceanography of Cook Inlet with Special Reference to the Effluent from the Collier Carbon and Chemical Plant. IMS - Univ. of Alaska, College, Alaska Report # IMS-67-3, 80p.

Rosenberg, D.H., K.V. Natarajan and D.W. Hood, 1969, Summary Report on Collier Carbon and Chemical Corporation Studies in Cook Inlet, Alaska, Parts I & II, November 1968 - September 1969, IMS - Univ. of Alaska, College, Alaska Report #69-13.

Schneider, Karl, 1970. Sea Otter Distribution and Abundance in Alaska, Alaska Department of Fish and Game Information Leaflet. 5pp. and map.

Sharma, G.D. and D.C. Burrell, 1970, Sedimentary Environment and Sediments of Cook Inlet, Alaska. The American Association of Petroleum Geologists Bulletin, Vol 54(4): 647-654.

Shepherd, P.E.K., B.L. Hilliker and J.H. Crow, 1967, Small Game and Fur Bearer Investigations. Waterfowl. Alaska Department of Fish and Game Project W-13-R-2 .

Snarski, D.A., 1971a, Observations of Birds on Tuxedni National Wildlife Refuge and Vicinity, Administration Report to U.S. Bureau of Sport Fisheries and Wildlife (Processed).

Snarski, D., 1971b, Report to U.S. Bureau of Sport Fisheries and Wildlife on Kittiwake Studies at Chisik Island. Administrative Report (Processed) .

Taylor, Norman E., RADM, NOAA, Director, Pacific Marine Center, 1801 Fairview Avenue East, Seattle, Washington 98102, letter dated August 14, 1972.

Tremblay, R.H., 1966, Waterfowl Winter Inventory. Administrative letter report to Waterfowl Supervisor, U.S. Bureau of Sport Fisheries and Wildlife, Juneau. April 22, 1966 .

U.S. Bureau of Commercial Fisheries, 1925, Growth and Age at Maturity of the Pacific Razor Clam, Siliqua patula (Dixon), Bulletin of the Bureau of Fisheries Volume 41 .

U.S. Bureau of Commercial Fisheries, no date, Briefing paper prepared for the Department of the Interior on Fish and Wildlife in the Gulf of Alaska, Cook Inlet and Bristol Bay Areas of Alaskan Coastal Water.

U.S. Department of Commerce, 1968, United States Coast Pilot, Pacific and Arctic coasts. Alaska. Cape Spencer to Beaufort Sea. Coast and Geodetic Survey, Oct 3, 1964, U.S. Government Printing Office .

U.S. Coast & Geodetic Survey, 1971, Tide Tables - West Coast of North and South America. U.S. Government Printing Office, Washington, D.C.

U.S. Department of Commerce, Tsunami, the Story of the Seismic Sea-wave Warning System: U.S. Government Printing Office, Washington, D. C.

U.S. Department of the Interior, 1966, Rare and Endangered Fish and Wildlife of the United States. Committee on Rare and Endangered Species. Resource Publication 34, Bureau of Sport Fisheries and Wildlife, Washington,D.C.

U.S. Department of the Interior, 1970, Kodiak Oil Pollution Incident, February - March, 1970. Summary Report, Federal Water Quality Administration .

U.S. Department of the Interior, 1972, Final Environmental Impact Statement - Proposed Trans-Alaska Pipeline, Vol 4, 637 pp .

Visser, R. C., 1969, Platform Design and Construction in Cook Inlet, Alaska. Journal of Petroleum Technology, April 1969, 411-420.

Wagner, D.G., R.S. Murphy and C.E. Behlke, 1969, A Program for Cook Inlet, Alaska for the Colelction, Storage and Analysis of Baseline Environmental Data. Institute Water Resources, Univ. of Alaska, College, Alaska. Report # IWR-7. 284 pp.

Waller, R.M., 1966a, Effects of the Earthquake of March 27, 1964, in the Homer Area: UsS. Geological Survey Prof. Paper 542-D D1-028.

Waller, R.M., 1966b, Effects of the Earthquake of March 27, 1964, on the Hydrology, South-Central Alaska: U.S. Geological Survey Prof. Paper 544A, pA1-A28.

Wallace, R.E., and R.D. Brown, Jr., 1972, Preliminary Analysis of Seismic Microzonation in the San Francisco Bay Region (Abs.),to be presented at 1972 annual meeting of Geological Survey of America.

Washington Department of Fisheries, 1962, Geophysical Operations in Coastal Waters whereby Explosives are used to create Seismic Reactions for the Purpose of Determining Geological Structures in the Substrata of the Ocean Floor. Letter report on Monitoring Operations, July, 1962.

Wood, F.J., (Ed.), 1966, The Prince William Sound, Alaska Earthquake of 1964 and Aftershocks, Vol. I: U.S. Department of Commerce, U.S. Government Printing Office, Washington, D.C., 263p.

Literature Cited - Phase 2

Alaska Oil and Gas Association (AOGA), Various Unpublished Data.

Bradner, T., 1970, Petroleum in Alaska Survey and Report: 1970-71, The Research Institute of Alaska, Inc., Anchorage, Stephen M. Brant and Robert M. Goldberg, Eds., p. 86-124.

Crick, R.W., 1971, Potential Petroleum Reserves, Cook Inlet, Alaska, in Future Petroleum Provinces, North America, AAPG Memoir 15, Vol. I, p. 109-119.

Denton, Pedro, Chief of Minerals Section, Division of Lands, Department of Natural Resources, State of Alaska, viva voce.

Department of Labor, Statistical Quarterly, 1960-1971 (3rd quarter), Employment Security Division, Department of Labor, State of Alaska.

Department of Natural Resources, Annual Report 1968-1971, Division of Oil and Gas, Department of Natural Resources, State of Alaska.

Department of Natural Resources, Report for the Year, 1963-65, Division of Mines and Minerals, Department of Natural Resources, State of Alaska.

Department of Resources, Statistical Report 1969 and 1971, unpublished, Division of Oil and Gas, Department of Natural Resources, State of Alaska.

Flagg, Loran B., 1970, An Economic Survey of the Cook Inlet Salmon Fishery, ADFG Information Leaflet #145, State of Alaska.

Tussing, Arlon, The Economy: An Alaska View, in Alaska Survey and Report: 1970-71, The Research Institute of Alaska, Inc., Anchorage, Stephen M. Brant and Reobert M. Goldberg, Eds., 1970, p. 71-73.

Literature Cited - Phase 3

Blumer, Max J., Howard L. Sanders, J.F. Grassel and G.R. Hampsen, 1971, A Small Oil Spill, Environment, 13(2), 2-12.

EPA, 1972, Region X Oil and Hazardous Materials Contingency Plan, Environmental Protection Agency, Anchorage, Alaska, Feb., 1972.

FWPCA, 1969, Chemical Treatment of Oil Slicks, Federal Water Pollution Control Administration, Edison Water Quality Laboratory, Edison, N.J., March, 1969.

Federal Water Pollution Control Administration, no date, Oil and refuse summary - Alaska, From files maintained by the U.S. Environmental Protection Agency, Anchorage, Alaska.

Kinney, P.J., D.K. Button and D.M. Schell, 1969, Kinetics of Dissipation and Biodegradation of Crude Oil in Alaska's Cook Inlet, Contrib. # 6, Institute of Marine Science, U. of Alaska, College, Alaska.

Ramseier, R.O., 1971, An Overview of Oil Pollution in the High Arctic, talk given to U.S. Glaciological Panel, U.S. Academy of Sciences, Tucson, Arizona, Nov. 11-12, 1971.

Steinhoff, Harold W., 1969, Values of Wildlife and Related Recreation on the Kenai National Moose Range, Report to the Chief, Branch of Wildlife Research, Bureau of Sport Fisheries and Wildlife, Washington, D.C., Sept. 1, 1969, 33 pp.