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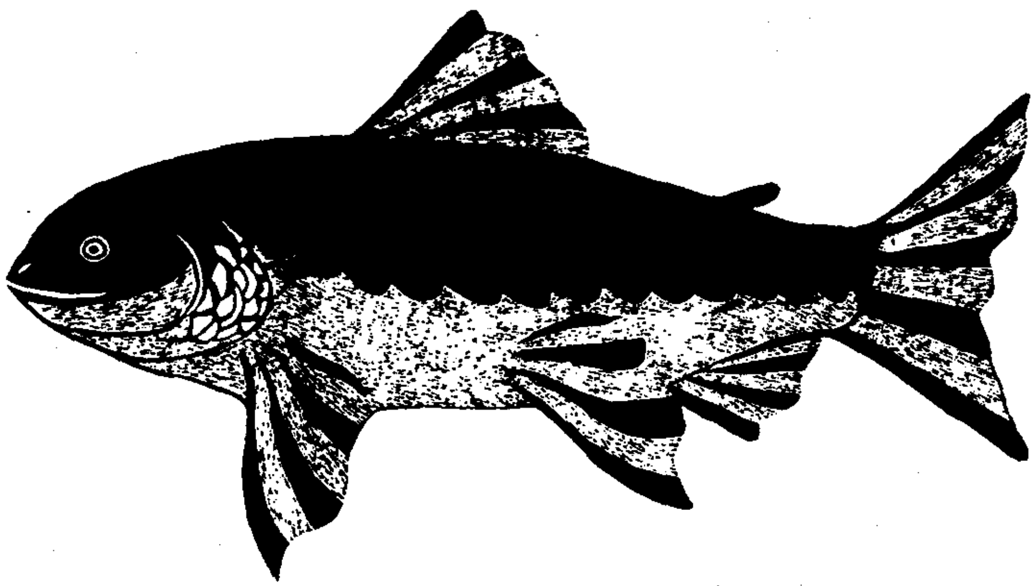
DEMERSAL FISH AND SHELLFISH RESOURCES OF NORTON SOUND, THE SOUTHEASTERN CHUKCHI SEA, AND ADJACENT WATERS IN THE BASELINE YEAR 1976



by
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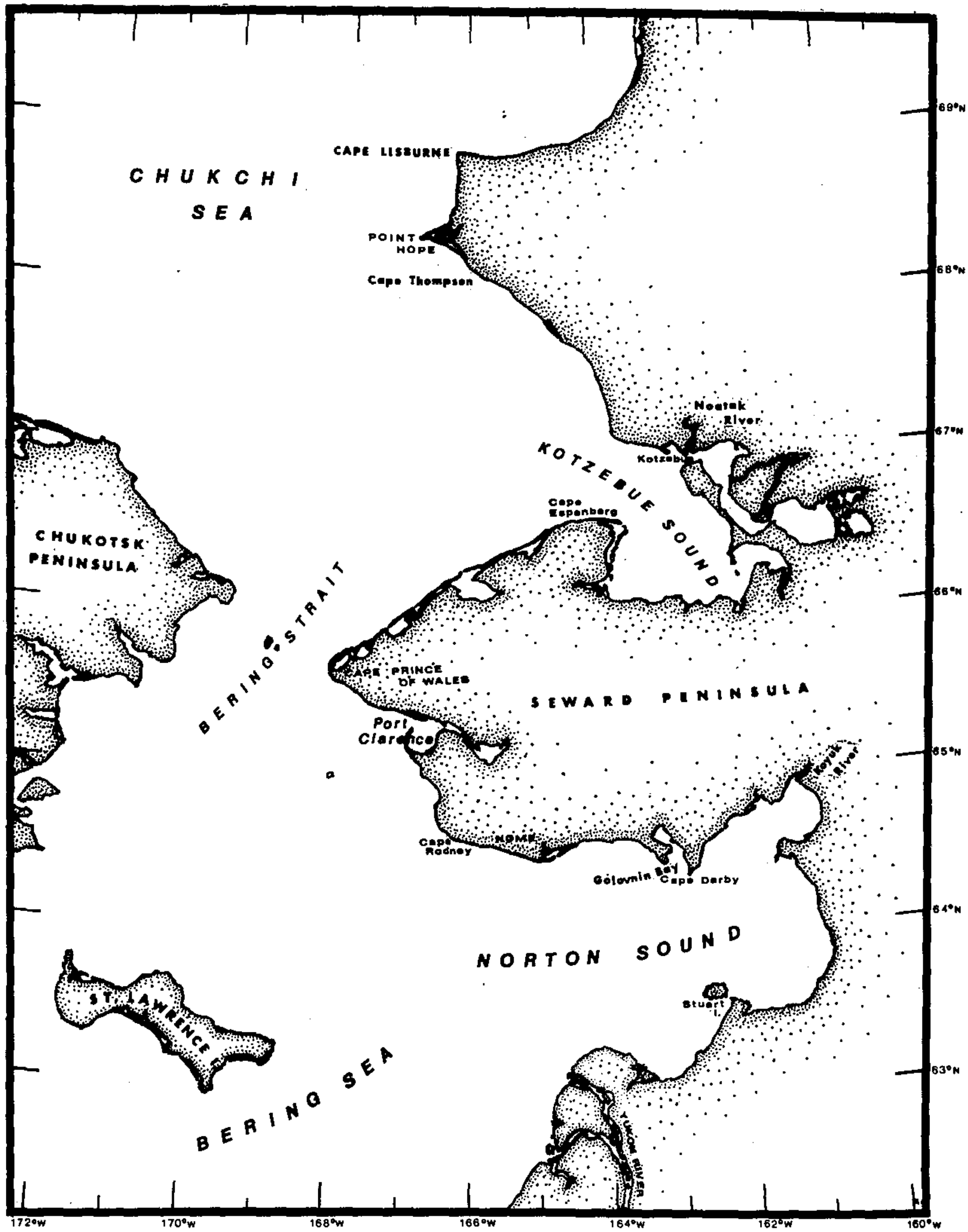
CHUKCHI SEA
CAPE LISBURNE
POINT HOPE
Cape Thompson
Noatak River
KOTZEBUE SOUND
Cape Espenberg
CHUKOTSK PENINSULA
BERING STRAIT
CAPE PRINCE OF WALES
SEWARD PENINSULA
Port Clarence
Cape Rodney
NOME
Golovnin Bay
Cape Darby
NORTON SOUND
Stuart I.
ST. LAWRENCE I.
BERING SEA
69°N
68°N
67°N
66°N
65°N
64°N
63°N
172°W
170°W
168°W
166°W
164°W
162°W
160°W

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SIGNIFICANT ACCOMPISHMENTS AND CONCLUSIONS

This report contains findings from an intensive six-week survey (September-October, 1976) of fish and shellfish fauna in Norton Sound, the southeastern Chukchi Sea, and adjacent waters and a brief review of other pertinent information on the survey region from other data sources.

Norton Sound, the northern Bering Sea, Kotzebue Sound, and the southeastern Chukchi Sea represent a northern portion of the Alaska continental shelf, and this report has provided the most comprehensive study of these regions in terms of areal coverage and biological data collected. Of the 242 separate demersal trawling sites planned for sampling, 192 were successfully surveyed. In addition to the systematic demersal trawl survey, 33 gillnet sets and 8 pelagic trawl tows were performed to provide some knowledge of the areal distribution of those fish stocks located near the sea surface in the survey region. Overall, 277 trawl and gillnet catches were obtained during the survey and these contained a total of nearly 30 metric tons of fish and invertebrates. Size composition or other biological information was obtained from over 46,000 specimens of fish, crabs, and snails. Over 200 fish and invertebrate species were encountered.

Results of the survey defined the distributions and centers of abundance of several fish, crab, and snail species within the survey region and period. In addition, standing stock estimates and species composition of demersal fauna by geographic subdivisions of the survey region were determined. Analyses of species associations showed recurrent groupings of certain species and their regional distributions. Estimates of biological characteristics, including size and age composition, length-weight relationships, and growth characteristics, were provided for dominant fish species and for several species of crabs and snails.

The 1976 baseline survey provided considerable information on the distribution and abundance of fish and shellfish in the study area. Overall, the relative abundance was very low for nearly all organisms intensively studied. A total biomass for all demersal fauna in the survey region was estimated at only 338,000 mt and those groups studied in detail (shellfish of potential economic importance and fish) comprised only 25% of this amount. In contrast, recent biomass estimates for similar faunal groups in the highly productive eastern Bering Sea are 60 times greater than that determined in our survey area.

Most species studied were found in highest relative abundance in shallow, warm-water regions and greatest density occurred in Norton Sound. Highest abundance in Norton Sound was especially apparent for the young age groups of many fish species.

Biological information gathered during the survey suggests possible stock segregation of several species within the survey region. For many fish species, growth rate and length-weight relationships determined from samples obtained in areas north of Bering Strait differed from those gathered to the south. Growth of most fish appeared greatest in areas studied south of Bering Strait. Size composition and growth information also indicated that individuals present in our survey region were smaller and grew to lesser maximum sizes than members of the same species in regions south of our study area.

Although this report may substantially add to our knowledge of certain marine resources in northern areas of the Alaska continental shelf, this study also indicates a need for considerably more information in order to more adequately understand the dynamic nature of living marine resources of this region. Other information should be obtained if we are to make the proper decisions as to how man may manipulate or utilize these resources and to understand to what extent environmental alterations such as exploration for energy sources may affect this region.

III

INTRODUCTION

BACKGROUND

During September-October 1976, the Northwest and Alaska Fisheries Center (NWAFC), National Marine Fisheries Service (NMFS) conducted an offshore baseline survey of fishes and economically important invertebrates inhabiting continental shelf waters of Norton Sound, the southeastern Chukchi Sea, and adjacent regions. This survey was funded by the Bureau of Land Management and provided resource information both for BLM's evaluation of the influence on the environment by proposed oil and gas development in the region and for the NMFS Marine Monitoring, Assessment, and Prediction (MARMAP) program.

The study area, a relatively important region for subsistence fisheries and for certain commercial fishing operations, includes extensive areas where substantial petroleum reserves may exist (Figure III-1). Knowledge of the living marine resources within such areas is essential if careful evaluation is to be made of benefits derived from petroleum development vis-a-vis potential detrimental effects to the environment.

The Bureau of Land Management has the responsibility for conducting the offshore leasing. By law, BLM must provide an environmental impact statement (EIS) assessing the environmental risks involved in developing potential offshore oil reserves in Alaskan waters. BLM therefore arranged with the National Oceanic and Atmospheric Administration (NOAA) to provide the necessary physical, chemical, and biological data for the regions considered in this report. In Alaskan waters, NOAA's Environmental Research Laboratories (ERL) manage the environmental studies through its Outer Continental Shelf Environmental Assessment Program (OCSEAP) Office. OCSEAP has contracted with various federal agencies, such as NMFS, the State of Alaska, and several universities to conduct the necessary research.

This report represents results from the 1976 baseline survey and from the analyses of pertinent historical fisheries research information and commercial fisheries data. It is a contemporary evaluation of fish and shellfish resources of the marine environment from Norton Sound northward through the Bering Strait and into the southeastern Chukchi Sea. The report provides considerable information to aid the BLM in an environmental assessment of the survey region and supplies the NMFS MARMAP program with a broad multispecies data base of resource and environmental measurements.

Figure III-1.--Study area for the 1976 BLM/OCS baseline survey of Norton Sound and the southeastern Chukchi Sea and approximate areas of the Alaskan continental shelf under consideration for leasing.

OBJECTIVES OF THE REPORT

The objectives of the report are:

(1) to describe the composition, distribution, and apparent abundance of demersal fish, shellfish, and certain pelagic fish resources of the marine environment from Norton Sound north into the Chukchi Sea;

(2) establish, for the more abundant and possibly economically important species, population characteristics that could change through environmental stresses (e.g., stock size, age and size composition, growth rate, and length-weight relationships); and,

(3) compare information from the 1976 baseline survey period with historical information.

ORGANIZATION OF FINDINGS

This report is organized in a manner similar to earlier NMFS baseline studies (NWAFC, 1976) and initially acquaints the reader with a physical description of the survey area (section IV) and then a description of the fauna (section V). These are followed by sections pertaining to historical information (section VI), an assemblage of data on fishery resource utilization (section VII), and results of the 1976 survey (section VIII). In the final section (IX) a synthesis and interpretation of the results of the baseline study are presented.

TERMINOLOGY

Terms frequently used in this report and those for which definitions may be difficult to find in standard fishery and statistical texts are defined here.

Species Names

The nomenclature used for fishes may be found in Quast and Hall (1972) and the American Fisheries Society (1970). With the exception of some crabs and molluscs, only scientific names are used for invertebrates. The common names given for crab are those developed in commercial fisheries, with one exception. The fishing industry prefers the name "snow crabs" for members of the genus Chionoecetes, but "Tanner crab," the standard name used in scientific reports, is retained here.

Fisheries-Related Terms[1/]

Age group.--Within a population, those fish or invertebrates of the same age. Age is the number of years of life completed.

Age structures.--For fish, these are otoliths (ear bones) and/or scales on which annual rings are laid down.

Carapace.--The dorsal convex portion of a crab's exoskeleton.

Catch per unit effort (CPUE), or "catch rate".--The catch in numbers or weight taken per standard length of tow or area swept by the trawl.

Clutch size.--Proportion of the crab's egg chamber filled by the egg mass.

Cohort.--Those individuals of a population of the same age group, i.e., of the same year class.

Exploitable biomass.--That portion of a population of a susceptible size and geographical distribution available to a fishery.

Maximum sustained yield (MSY).--The largest average catch or yield that can continuously be taken from a stock under existing environmental conditions.

Modeling.--The development of mathematical equations to describe population and/or ecosystem processes for heuristic and predictive purposes.

Mortality.--Often designated as "natural," "fishing," and "total" mortality; may be expressed either as an instantaneous exponential function or percentage decrease in population size per unit time.

Recruitment.--Addition of new fish or shellfish to the exploitable population by growth from smaller size groups.

Skip molt.--In reference to an individual which did not molt during the previous molting season.

Standing stock.--The total population of the species vulnerable to the fishing gear in a specific area. Standing stock may be described in terms of weight (biomass) or numbers of individuals (population).

Year class or brood year.--Year of birth of an age group.

1/ Some definitions are adapted from Ricker, 1975.

Geographical Designations

Arctic boreal.--A zoogeographic term describing species occurring in the Bering Sea, Okhotsk Sea, and the Sea of Japan that have ranges extending into the Arctic Ocean. Low Arctic boreal species are those limited to waters south of the Chukchi Sea in this region.

Inner Kotzebue Sound.--Defined here as that portion of Kotzebue Sound south of a line from Cape Espenberg to Cape Blossom (near the village of Kotzebue).

Inner Norton Sound.--That area of Norton Sound east of a line from Cape Darby to Stuart Island.

Kotzebue Sound.--Defined here as that area of the Chukchi Sea east of 165°W long. and south of 67°37'N lat.

Northern Bering Sea.--That portion of the Bering Sea north of a line connecting Cape Navarin, St. Lawrence Island, and the mouth of the Yukon River; west of Norton Sound; and south of Bering Strait.

Norton Sound.--Defined here as that body of water east of a line from Cape Rodney to the mouth of the Yukon River.

IV

DESCRIPTION OF THE STUDY AREA

The area of investigation during the 1976 survey includes waters of the northern Bering Sea, Norton Sound, Kotzebue Sound and the southeastern Chukchi Sea between 63° and $68^{\circ}40'$N latitude and from the US-USSR Convention line of 1867 eastward to the Alaska mainland. This northern portion of the Alaskan continental shelf is unique in several respects, especially its uniform shallowness. Maximum depth throughout the entire 140,000 sq km region barely exceeds 50 meters. Bottom slopes are very slight except on approach to land masses such as in Bering Strait and north of St. Lawrence Island. Isobaths are generally parallel to the Alaska coastline and extend into the embayments of Norton and Kotzebue sounds (Figure IV-1).

Geological features of the coastline and sediments in the survey area are typical of other regions of the Pacific Ocean (Fleming and Heggarty, 1966). Bottom composition close inshore consists of small rocks and gravel and changes to mud and sand and eventually to grey mud and sand in deeper offshore areas (Alverson and Wilimovsky, 1966). Extensive amounts of silt occur off the mouths of various large rivers such as the Yukon River in Norton Sound and Noatak and Kobuk rivers in Kotzebue Sound.

The survey region is influenced by a variety of oceanographic and climatological factors. Current systems within Norton Sound, the northern Bering Sea, and Chukchi Sea are barotrophic, fairly uniform from surface to bottom, and flow in a northward direction generally paralleling depth contours (Fleming and Heggarty, 1966).

Three water masses are associated with the survey area: the Anadyr, Bering Shelf, and Alaskan coastal which are descriptive of their sources. The latter two mentioned exert the greatest influence on the survey region, while the Anadyr water mass is important only in Bering Strait. Coachman, *et al.* (1976) stated that current flow across the region is not uniform. Currents generally are slow but accelerate markedly when constricted by straits and along the southern coastlines of westward projecting land masses.

The Chukchi Sea is part of the Arctic Basin and, in oceanographic terms, considered part of the Atlantic Ocean, separated from the Pacific Ocean at Bering Strait. Current flow through Bering Strait, however, is northward providing a continuity of conditions between the northern Bering Sea and the Chukchi Sea (Fleming and Heggarty, 1966).

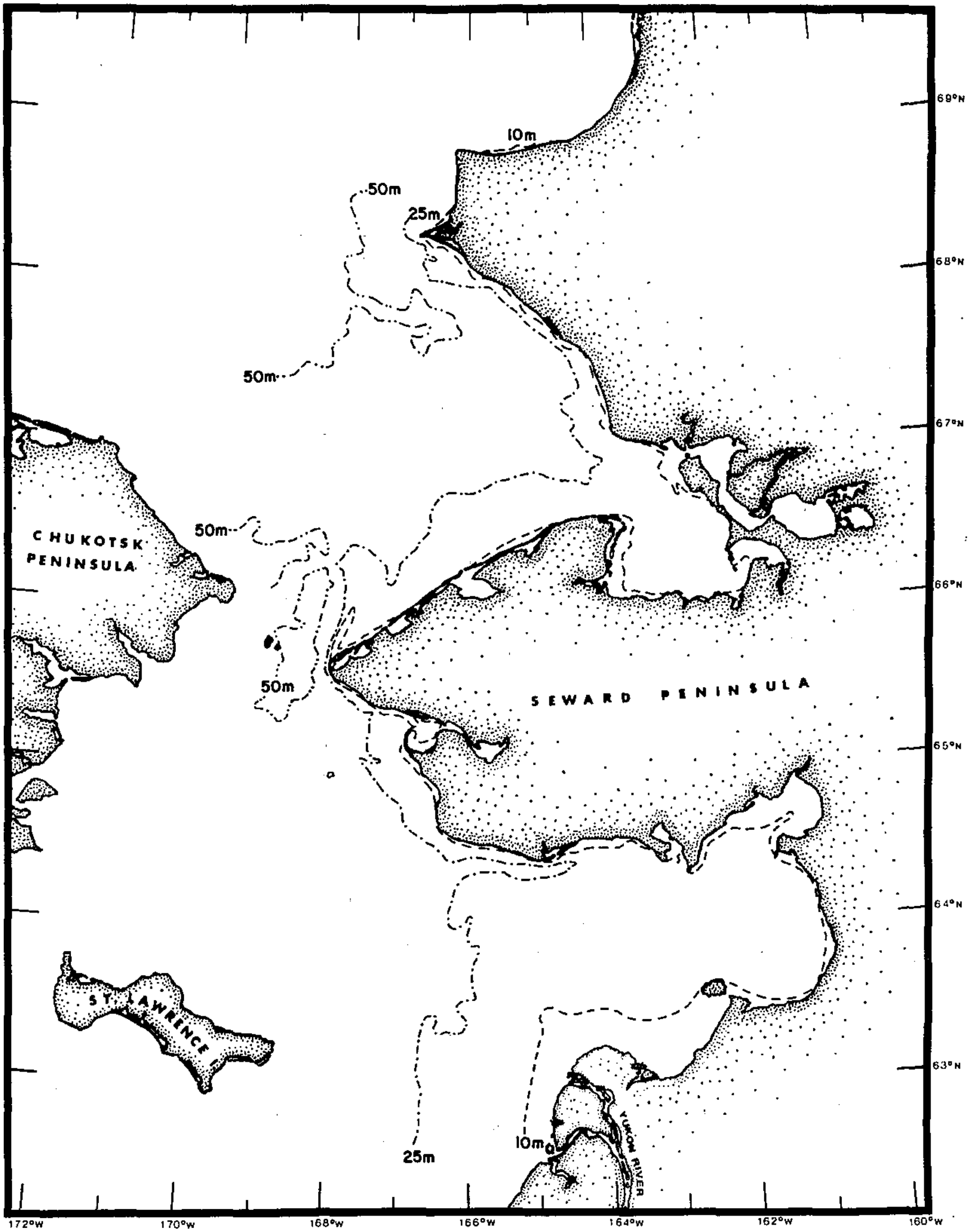


Figure IV-1.--Bathymetry of Norton Sound, the northern Bering Sea and southeastern Chukchi Sea.

Since the survey region is associated with arctic land masses, winters are extremely harsh. Ice covers the study area for over seven months, starting as early as mid-September in Kotzebue Sound with spring breakup occurring during late June-July (Alverson and Wilimovsky, 1966). Winter water temperatures near the sea bottom approach freezing throughout the region and vast ice flows cause extensive scouring of the littoral zone sea bed from the beach to depths of at least six meters (Sparks and Pereyra, 1966). In summer, water temperatures become relatively warm, especially adjacent to the Alaska mainland. This is due in part to the current system and overall shallowness of the study region. Waters at all depths nearshore reach 15°C (Fleming and Heggarty, 1966). Surface temperatures remain relatively warm throughout the survey area, but bottom temperatures drop from 15°C nearshore to 0-2°C at the western extremes of the survey area north of St. Lawrence Island and also in the northwesternmost portion of the study area in the Chukchi Sea (Figure IV-2). Shallow water areas which contain relatively cold bottom temperatures include inner Kotzebue Sound and the eastern extreme of Norton Sound.

River systems have a substantial effect on the study region. Significant quantities of fresh water are introduced into Norton Sound by the Yukon River during May-August. Small but locally significant quantities also flow into Kotzebue Sound from the Kobuk and Noatak rivers. The resulting fresh water substantially dilutes the sea water, and salinity is often less than 31°/oo adjacent to the Alaska coastline in the study region. Fleming and Heggarty (1966) noted that the influence of river systems (and currents) on waters of Norton and Kotzebue sounds creates more or less isolated environments in these embayments.

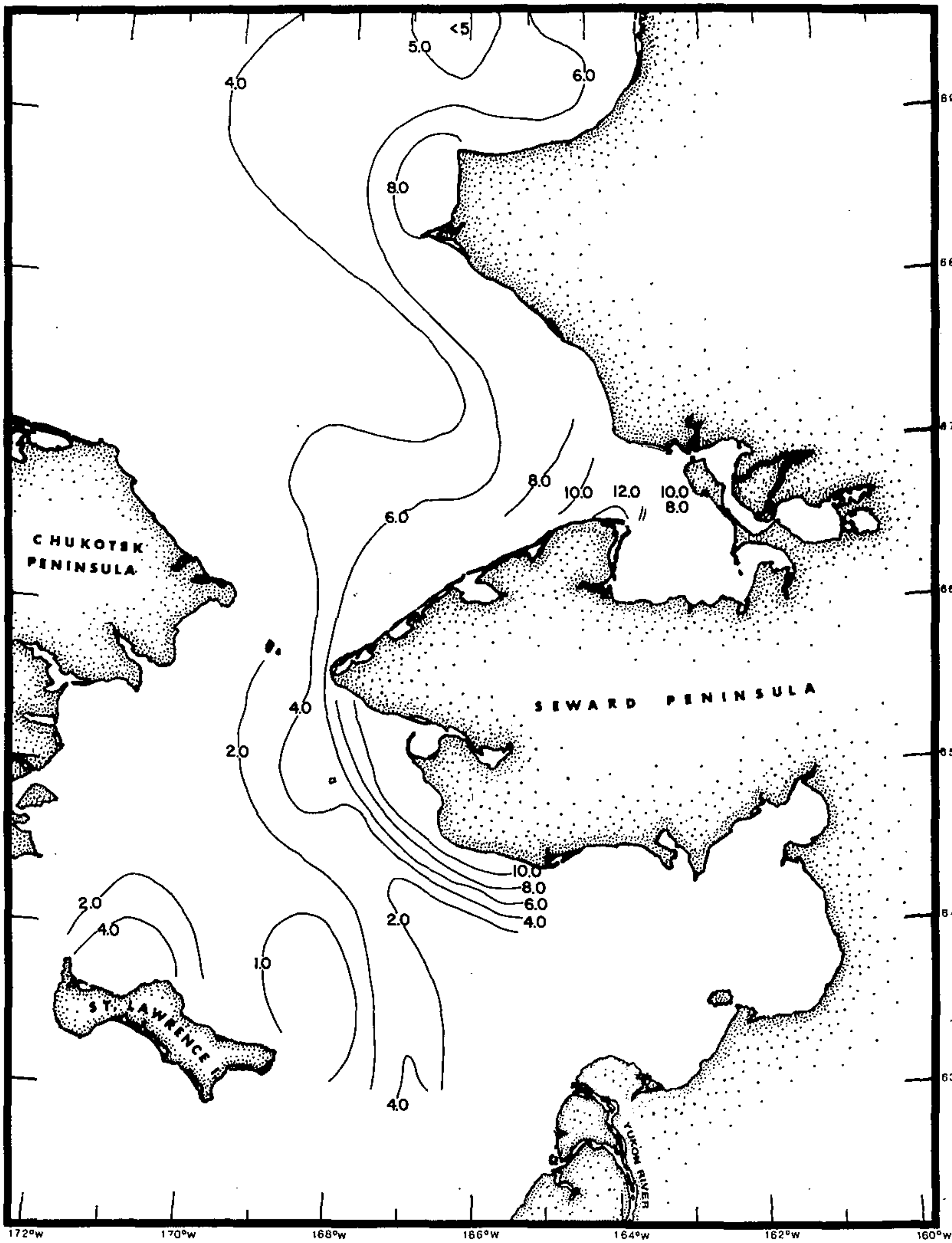


Figure IV-2.--Bottom temperature isotherms for Norton Sound, the northern Bering Sea and southeastern Chukchi Sea (from Fleming and Heggarty, 1966).

V

DESCRIPTION OF THE FAUNA

FISH FAUNA

Norton Sound and the southeastern Chukchi Sea support about 87 fish species belonging to 15 families (Table V-1). Of these, 78 species are considered marine forms and seven families comprise over 85% of the total fish fauna (Table V-2). Similar to the Bering Sea fish fauna, Norton Sound and the Chukchi Sea have a higher proportion of cottids and liparids than other oceans.

Schmidt (1950) reported only 66 species occurring in the northern Bering Sea. Increased diversity in the study area can probably be attributed to two reasons: inclusion of more arctic forms and extension of species ranges since Schmidt's study.

Benthic species comprise the majority of fish taxa (74% of total) in the study area. Since the entire region is relatively shallow (see Section IV), deep benthic fauna are absent. The remainder of the fish taxa can be considered pelagic, including a substantial number of anadromous and euryhaline forms. Most of the pelagic species are of commercial importance including such genera as Clupea, Osmerus, Oncorhynchus, and Salvelinus.

The fish fauna of Norton Sound, the southeastern Chukchi Sea, and adjacent waters are characterized by three distinct groups: (1) those coldwater groups indigenous to Arctic marine waters including such taxa as Arctic cod, longhead dab, Arctic flounder, and a number of cottoid and blennioid species; (2) a subarctic boreal group whose distribution is centered south of the study area in the Bering Sea or regions of the eastern and western Pacific which includes saffron cod, yellowfin sole, Alaska plaice, starry flounder, Pacific herring, and others; and (3) an anadromous fresh-water group with several forms such as char, whitefish, and smelt whose marine distribution occurs only in the estuarine and other near-shore environments.

Since the survey region is closely associated with arctic waters, 23 species have ranges which extend to the Atlantic Ocean. Fourteen species do not occur south of the northern Bering Sea or Gulf of Anadyr, and an additional 27 taxa do not occur south of the Alaska Peninsula-Aleutian Archipelago. According to Quast and Hall (1972), only 46 species can be considered "endemic" Pacific marine forms.

Table V-1. -- Families of fishes and approximate number of genera and species reported from Norton Sound, the southeastern Chukchi Sea and adjacent waters (after Quast and Hall, 1972).

Family	No. Genera	No. Species
Petromyzontidae	1 1/	1
Clupeidae	1	1
Salmonidae	4	14 2/
Osmeridae	3	3
Gadidae	4	4
Zoarcidae	3	10
Gasterosteidae	1	1
Hexagrammidae	1 3/	1
Cottidae	11	20 4/
Agonidae	5	6
Cyclopteridae (= Liparidae)	2	6
Anarhichadedae	1	1
Stichaeidae	7	7
Ammodytidae	1	1
Pleuronectidae	9 5-6/	11
TOTALS:	54	87

1/ Not mentioned as occurring in study region, but range extends both north and south of Norton Sound and the southeastern Chukchi Sea.

2/ Includes several freshwater forms which may enter saltwater.

3/ Whitespotted greenling, Hexagrammus stelleri, was not reported north of the Bering Sea by Quast and Hall (1972), however, several specimens were obtained as far north as the southeastern Chukchi Sea during the 1976 BLM/OCS survey.

4/ Yellow Irish lord, Hemilepidotus jordani, and the tadpole sculpin, Pyschrolutes paradoxus, were not reported from study region by Quast and Hall (1972), however, specimens were obtained during 1976 BLM/OCS survey.

5/ Pacific halibut, Hippoglossus stenolepis, not reported in study region by Quast and Hall (1972), however, one specimen was obtained in Bering Strait during the 1976 BLM/OCS survey.

6/ Rock sole, Lepidopsetta bilineata, not reported in study region by Quast and Hall (1972), however, Ellson et al,(1949) indicated two individuals captured 40 miles NE of St. Lawrence Is. and Andriyashev (1954) reported rock sole present between St. Lawrence Island and the Gulf of Anadyr.

Table V-2.--Proportion of seven predominant families to total species composition of Norton Sound-southeastern Chukchi Sea fish fauna.

Family	Percentage of total fish species
Cottidae	23
Salmonidae	16
Pleuronectidae	13
Zoarcidae	11
Stichaeidae	8
Agonidae	7
Cyclopteridae	7
Total of seven dominant families :	85

Species groups of importance in the survey area because of their relative abundance and/or diversity are: cods, flatfishes, sculpins, salmonids, eelpouts, pricklebacks, poachers, snailfish, smelts and herring.

Four species of cods (family Gadidae) are reported by Quast and Hall (1972) to occur in waters of the study area: the Arctic cod (Boreogadus saida), the saffron cod (Eleginus gracilis), the Pacific cod (Gadus morhua macrocephalus), and walleye or Alaska pollock (Theragra chalcogramma). The range of Pacific cod, however, extends northward only to the southern boundary of the survey area near St. Lawrence Island. The more northern cod forms, Arctic cod and saffron cod, are the dominant gadids in Norton Sound, the southeastern Chukchi Sea, and adjacent waters.

Flatfish (family Pleuronectidae) are represented in the study region by 10 species and 8 genera (Quast and Hall, 1972). These include arrowtooth flounder (Atheresthes stomias), flathead sole (Hippoglossoides elassodon), Bering flounder (H. robustus), Pacific halibut (Hippoglossus stenolepis), yellowfin sole (Limanda aspera), longhead dab (L. proboscidea), Arctic flounder (Liopsetta glacialis), starry flounder (Platichthys stellatus), Alaska plaice (Pleuronectes quadrituberculatus), and Greenland turbot (Reinhardtius hippoglossoides). Dominant pleuronectid species in the survey region include subarctic boreal forms such as starry flounder, Alaska plaice, and yellowfin sole.

The most diverse family in the study area in terms of species is the sculpins (family Cottidae). Quast and Hall (1972) list 20 species and 12 genera for this region. These include hamecon (Artediellus scaber), Arctic hookear sculpin (A. uncinatus), antlered sculpin (Enophrys diceraus), Leister sculpin (E. lucasi), Gymnocanthus pistilliger, Arctic staghorn sculpin (*G. tricuspis*), yellow Irish lord (*Hemilepidotus jordani*), *Hemilepidotus zapus*, spatulate sculpin (*Icelus spatula*), *Megalocottus laticeps*, belligerent sculpin (*M. platycephalus*), plain sculpin (*Myoxocephalus joak*), fourhorn sculpin (*M. quadricornis*), *M. platycephalus*, Arctic sculpin (*M. scorpoides*), shorthorn sculpin (*M. scorpius groenlandicus*), eyeshade sculpin (*Nautichthys pribilovius*), and tadpole sculpin (*Psychrolutes paradoxus*). Dominant sculpins in the survey area include the arctic boreal forms, plain sculpin and shorthorn sculpin, and an arctic form, the Arctic staghorn sculpin.

Other families with several representatives in the survey region include the salmon (family Salmonidae) with 14 species and 4 genera; the eelpouts (family Zoarcidae) with 10 species and 3 genera; the pricklebacks (family Stichaeidae) with 7 species and 7 genera; the poachers (family Agonidae) with 6 species and 5 genera; and the snailfish (family Cyclopteridae) with 6 species and 2 genera. The families Osmeridae and Clupeidae are represented only by 3 and 1 species, respectively, but the toothed or rainbow smelt (*Osmerus mordax dentex*, *O. eperlanus*) and Pacific herring (*Clupea harengus pallasi*) are numerous and commonly occur in the Norton Sound-southeastern Chukchi Sea region.

INVERTEBRATE FAUNA

Extensive studies by Sparks and Pereyra (1966) have provided substantial information for most invertebrate fauna in the southeastern Chukchi Sea, but very little data is available concerning invertebrates in Norton Sound. Prevailing currents in these areas are northerly and originate in the Bering Sea (see Section IV). Sparks and Pereyra (1966) stated that this results in great similarity between invertebrate fauna found in the southeastern Chukchi Sea and that present in the Bering Sea. Although little is known specifically about invertebrate stocks in Norton Sound, this portion of the study region lies between the Bering and Chukchi Seas, and therefore it seems reasonable to expect considerable similarity between Norton Sound and Chukchi Sea invertebrate fauna.

Invertebrates form the most diverse and abundant group in the benthic community of the study region. According to Abbott (1966) and Sparks and Pereyra (1966), 14 invertebrate phyla are present in the study area. When combined, these phyla represent 91 families, 145 genera, and over 220 species (Table V-3). Most organisms encountered are Pacific boreal, and the absence of many higher arctic forms probably results from the northward currents which impede southerly migrations by all but highly mobile forms.

Table V-3.--Invertebrate phyla and approximate number of classes, families, genera, and species reported present in the southeastern Chukchi Sea (after Sparks and Pereyra, 1966: and Abbott, 1966).

Phylum	Common names for phylum representatives	Numbers of various taxonomic levels present by phylum			
		Classes	Families	Genera	Species
PORIFERA	Sponges	2	9	11	12
COELENTERATA (=CNIDARIA)	Coelenterates	3	7	11	11
CTENOPHORA	Combjellies	1/	1/	2	2
NEMERTIA	Ribbon worms	1/	1/	1/	1/
BRYZOA (=ECTOPROCTA)	Moss animals	1/	1/	3	3
BRACHIOPODA	Lambspells	1/	1/	1/	1/
SIPUNCULOIDEA (=SPICULANA)	Coelomate worms	1	1	1	1
PRIAPULOIDEA (=PRIAPULA)	"	1	1	1	1
ECHIUROIDEA (=ECHIURA)	"	1	1	1	1
MOLLUSCA	Clams, snails, squids, etc.	4	35	54	97
ANNELIDA	Segmented worms	1/	1/	5	5
ARTHROPODA	Barnacles, shrimp, and crab	8	14	27	44
ECHINODERMATA	Starfish and others	4	11	15	21
CHORDATA (=TUNICATA)	Ascidians	1	7	12	23
Totals:		30	91	145	223

1/ Not reported.

Mollusca, Arthropoda, Echinodermata, and Tunicata are the dominant faunal elements of the benthic invertebrate community of the study region. These four phyla constitute 83 percent of all species present. Other phyla with several representatives include Porifera and Coelentrata.

Molluscs represent the most diverse phylum present in the study region. Sparks and Pereyra (1966) list four classes present: the bivalves (class Pelecypoda), snails and whelks (class Gastropoda), octopuses (class Cephalopoda), and amphineurids (class Amphineura) with the former two classes predominating.

Bivalve molluscs are represented by 16 families in the study region. Some principal families include the cockles (family Cardiidae), the macoma clams (family Tellinidae), and the nut clams (family Nuclididae). These three families comprise eight species in the study region including abundant forms such as the Greenland cockle (*Serripes groenlandicus*), Iceland cockle (*Clinocardium ciliatus*), chalky macoma (*Macoma calcarea*), and the smooth nut clam (*Nucula tenuis*). Although not taken during offshore sampling, Sparks and Pereyra (1966) observed windrows of the bay mussel, *Mytilus edulis*, on Chukchi Sea beaches.

Gastropod molluscs are an extremely diverse element of the fauna. Sparks and Pereyra (1966) listed 18 families present with the superfamilies Neptuneidae and Buccinidae contributing most species. Predominant members of these families include the fat neptune (*Neptunea ventricosa*), *N. heros*, the fragile buccinum (*Volutopsius fragilis*), Bering's buccinum (*Beringius beringii*), the polar buccinum (*Buccinum polare*), the silky buccinum (*B. scalariforme*), and *B. angulosum*. The latter two species are indicated by Nagai (1974) as comprising a significant portion of eastern Bering Sea commercial snail harvests by Japan.

Two classes and 14 families of Arthropods are present in the survey region according to Sparks and Pereyra (1966). Decapod crustacea is by far the dominant class comprising three shrimp families (Crangonidae, Hippolytidae, and Pandalidae) and four families of crab (Paguridae, Lithodidae, Majidae, and Atelicylidae). Prominent representatives of these families include organisms such as crangonid shrimp (*Sclerocrangon boreas* and *Argis lar*), humpy shrimp (*Pandalus gonurius*), hermit crabs (*Pagurus* spp.), king crabs (*Paralithodes* spp.), Tanner crab (*Chionoecetes opilio*), spider crabs (*Hyas* spp.), and the helmet crab (*Telemessus cheiragonus*). Several of these crustaceans are of economic importance in other regions. King crab comprise a relatively important portion of sport and subsistence fisheries catches within the survey region.

Echinodermata is represented by relatively few species (21); however, in terms of weight caught in trawls, this phylum is by far the dominant element of the entire benthic community of the study area (Sparks and Pereyra, 1966). Four classes are present, Asteroidea (starfish), Ophiuroidea (basketstars and brittlestars), Echinoidea (sand dollars), and Holothuroidea (sea cucumbers), with the former two classes being most prevalent. Asteroidea is represented in the survey region by four families, the most diverse being Asteriidae. Common forms of this family include *Leptasterias* spp., *Asteria amurensis*, and *Evasterias* spp. Four families of ophiuroideans also are present and consist of two types: a single species of basketstar (*Gorgonocephalus caryi*) and several species of brittlestars (*Ophiura sarsii*, *O. maculata*, *Ophiopholis aculeata*, and others).

The other dominant invertebrate group within Norton Sound and the southeastern Chukchi Sea is Tunicata, the ascidians. Abbott (1966) listed 7 families present in the study area with the more common being Styelidae and Pyuridae. Dominant forms in these families include: *Styela coriacea*, *S. rustica macrenteron*, *Dendroda puchella*, the sea onion (*Boltenia ovifera* and *B. echinata*), and the sea potato (*Tethym aurantium*).

A BRIEF SYNOPSIS OF RESEARCH IN NORTON SOUND AND THE SOUTHEASTERN CHUKCHI SEA

Although scientific activities have occurred within the survey region for nearly two centuries, most studies have been concerned with examining the hydrographic and geodetic aspects of these northern Alaska waters. Only in fairly recent times have surveys been directed specifically toward obtaining detailed information on fish and invertebrate resources. Early biological studies in the Chukchi Sea (summarized by Wilimovsky, 1966) primarily focused on the collection of indigenous fish and invertebrates and while these investigations greatly enhanced basic knowledge of arctic fauna, little quantitative information was obtained.

It seems likely that many investigators who passed northward through the Bering Strait also made observations in waters to the south, however, specific information is lacking regarding surveys of Norton Sound and the northern Bering Sea. The Soviet Union sponsored extensive trawl surveys of both the Chukchi and northern Bering Seas in 1932-33. Information from these surveys was used by Andriyashev (1937) to provide considerable knowledge on northern fishes. Exploratory fishing surveys of Norton Sound and areas north of St. Lawrence Island by the U.S. Fish and Wildlife Service in 1948-49 were reported by Ellson, Powell, and Hildebrand (1950), but only general comments were made regarding the distribution and abundance of fish and shellfish. Japan provided the most recent northern Bering Sea surveys (1968-1970); however, their area coverage only extended to just south of the 1976 BLM/OCS survey boundary.

The only extensive attempt to identify the magnitude and importance of marine resources in the survey region occurred as a result of studies funded by the Atomic Energy Commission in the Cape Thompson region of the southeastern Chukchi Sea in 1959-60. The investigations were performed as part of Project Chariot to establish environmental baselines for determining the effects of a nuclear explosion on the biota of the region. Data from several of these Cape Thompson studies provide much of the data base to which the 1976 BLM/OCS survey information could be compared. These investigations include studies of the oceanography (Fleming and Heggarty, 1966), benthic invertebrates (Sparks and Pereyra, 1966; and Abbott, 1966), and fishes (Alverson and Wilimovsky, 1966) of the region.

A REVIEW OF COMMERCIAL AND SUBSISTENCE FISHERIES IN THE SURVEY REGION

Utilization of fishery resources in the Norton Sound-Chukchi Sea region is fairly limited and falls into two categories--commercial operations and subsistence fisheries. Commercial activities are limited solely to harvests of salmon and herring, and subsistence fisheries, though also relying heavily on these pelagic fish, additionally utilize limited amounts of groundfish and shellfish (Table VII-I). This section presents a brief synopsis of both commercial and subsistence activities, identifying major harvest areas and catch levels over the past several years.

Table VII-1.--A partial list of fish and shellfish harvested commercially and for subsistence in Norton Sound, the southeastern Chukchi Sea, and adjacent waters in 1976. (Source: State of Alaska Department of Fish and Game.)

Chum salmon
Pink salmon
King salmon
Coho (silver) salmon
Red (sockeye) salmon
Whitefish (*Coregonus* spp.)[1/]
Sheefish[1/]
Pacific herring
Toothed smelt[1/]
Arctic cod[1/]
Saffron cod[1/]
Greenling (*Hexagrammus* sp.)[1/]
Sculpins[1/]
Halibut[1/]
Flounder (family Pleuronectidae)[1/]
Mussels[1/]
Clams[1/]
King crab[1/]

1/ Taken for subsistence only.

Salmon.--Salmon gillnetting is the principal commercial fishery in the survey region. Five species are harvested in Norton Sound waters with the vast majority of catches being pink and chum salmon. The only substantial fishery north of Bering Strait is in Kotzebue Sound, and chum salmon have accounted for over 99% of yearly harvests in this area. Local residents comprise nearly the entire commercial fishing force within the survey region.

Annual commercial salmon harvests in the Norton Sound region have ranged from 74,000-316,000 fish for the period 1962-1976 (Table VII-2) and have averaged about 170,000. During that time, chum salmon have comprised nearly 65% of the total catch, followed by pink salmon with 29%. Coho and king salmon account for most of the remainder, with red salmon taken only in trace amounts in any year. During the 15-year period examined, largest harvests occurred during 1974 and 1975. The commercial catch for 1976 of 192,000 salmon was considerably below the two highest catch years but still substantially above the 15-year average and only slightly less than the average salmon harvest for the past five years (1972-1976).

Table VII-2.--Commercial catches of salmon by year and species in the Norton and Kotzebue sound regions, 1962-1976. (Source: State of Alaska Department of Fish and Game).

	Norton Sound						Kotzebue Sound		
Year	King	Red	Coho	Pink	Chum	Area total	Chum	Others[1/]	Area total
1962	7,286	18	9,156	33,187	182,784	232,431	129,948	127	130,075
1963	6,613	71	16,765	55,625	154,789	233,863	54,445	143	54,588
1964	2,018	126	98	13,567	148,862	164,671	76,499	5	76,504
1965	1,449	30	2,030	220	36,795	40,524	40,034	--	40,034
1966	1,553	14	5,755	12,778	80,245	100,345	30,764	1	30,765
1967	1,804	--	2,379	28,879	41,756	74,818	29,400	--	29,400
1968	1,045	--	6,885	71,179	45,390	124,499	30,384	--	30,384
1969	2,392	--	6,836	89,949	82,795	178,972	59,335	48	59,383
1970	1,853	--	4,423	64,908	107,034	178,218	159,664	--	159,664
1971	2,593	--	3,127	4,895	131,362	141,977	154,956	1	154,957
1972	2,885	--	450	45,143	101,235	149,713	169,664	3	169,667
1973	1,918	--	9,282	46,499	119,098	176,797	375,432	5	375,437
1974	2,951	--	2,092	148,519	162,267	315,829	634,479	48	634,527
1975	2,321	--	6,218	32,820	216,443	257,802	561,710	--	561,710
1976	2,206	11	6,709	87,889	96,102	192,917	159,796	--	159,796

1/ Mostly pink salmon, but also includes king and red salmon.

Commercial catches in Kotzebue Sound have ranged from 29,000 to over 634,000 fish during the past 15 years and have averaged nearly 180,000. Chum salmon is essentially the only species taken in this region; a few pink, king, and red salmon are taken occasionally. Highest annual harvests again occurred in 1974 and 1975 (Table VII-2). Approximately 160,000 salmon were harvested commercially in 1976. This catch was the lowest since 1971 and only slightly more than half the average taken over the past five years.

Herring.--Commercial fishing for herring occurs primarily in Norton Sound by local inhabitants and foreign gillnet fleets. Fishing is performed primarily with gillnets and occasionally by beach seines; herring roe is the main product of commercial operations. Most harvests occur after winter ice break-up in May-June, while herring are in spawning concentrations.

Specific areas of herring harvests by local inhabitants are not known; however, most operations in Norton Sound are thought to occur near Stuart Island and in Golovin Bay.1/ Catch statistics for commercial fishing by local residents are extremely limited. The earliest record of commercial harvests was in 1964 when about 18 mt were taken (Table VII-3). Catches

Table VII-3.--Commercial harvest of Pacific herring by local inhabitants in Norton Sound. (Source: State of Alaska Department of Fish and Game).

Year	Catch in metric tons
1964	18.1
1965	—
1966	—
1967	—
1968	—
1969	—
1970	7.3
1971	17.7
1972	15.3
1973	32.3
1974	3.1
1975	2/
1976	7.7

1/ A separate research unit from the Alaska Department of Fish and Game has a two-year study which addresses herring spawning and harvest locations.

2/ Not available.

since that time have been small and sporadic with largest catches of 15-32 mt occurring from 1971-1973. The commercial herring harvest for 1976 was less than 8 mt.

Herring harvests by Japanese gillnet fleets also have been highly variable since operations started on a limited scale in 1968. The initial fishing operations that year appeared to be exploratory, with a total catch of 125 mt. From 1969-1971, effort increased dramatically (Table VII-4), but catches peaked in 1969 at 1,270 mt and never approached that amount thereafter. In 1972 Japanese gillnet effort dropped to low levels and remained low until 1974 when it nearly equalled levels of 1969-71. The total annual harvest at that later time, however, was only half the maximum amount taken five years earlier. In 1975, the last year for which Japanese catch statistics are available, total herring harvest and effort levels were the lowest recorded for the fishery.

Table VII-4.--Commercial harvests of Pacific herring by Japan in Norton Sound and the northern Bering Sea, 1968-1975. (Source: Japan Fisheries Agency.)

Year	Catch (mt)	Effort (tans)
1968	125	2,750
1969	1,270	33,380
1970	54	32,290
1971	621	45,720
1972	11	9,610
1973	25	9,270
1974	720	30,050
1975	5	450

Throughout the years that Japan has conducted a Pacific herring fishery in the survey area, catches have been taken almost entirely from central Norton Sound, especially near Stuart Island (Figure VII-1). Harvests outside Norton Sound (west of 165°W. longitude) in the northern Bering Sea have been very small, less than 5% of any yearly catch.

The extent that the Japanese harvests have affected Pacific herring stocks in the survey region is unknown. However, annual gillnet effort during 1970, 1971, and 1974 nearly equalled or exceeded amounts fished during the peak catch year of 1969, but catches during these later years failed to approach the 1969 harvest.

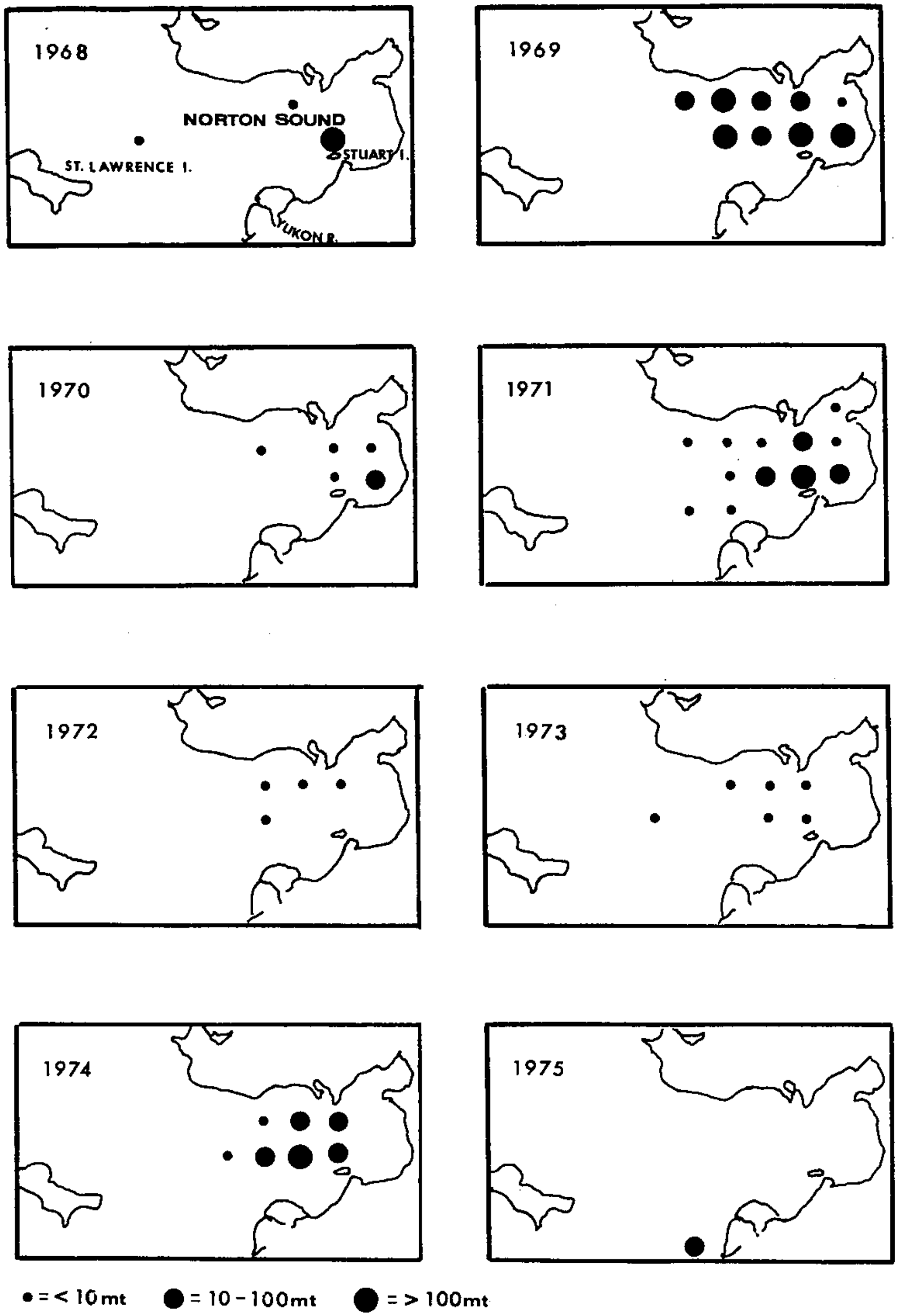


Figure VII-1.--Locations and relative catch magnitudes for Pacific herring caught by the Japanese gillnet fleet in Norton Sound and the northern Bering Sea, 1968-1975 (Source: Japan Fisheries Agency).

Subsistence Fisheries

Salmon.--Salmon taken in the subsistence fisheries are used both for human consumption and dog food. Subsistence catch data prior to the early 1960's is very limited but some early records indicate that over 2 million salmon were taken annually during the early 1900's (Alaska Department of Fish and Game, 1976). Declines in subsistence fishing started in the 1930's as airplanes replaced the sled dog as a mail carrier. This decline accelerated in recent years as welfare payments and employment opportunities increased (including commercial fishing) and snow vehicles came into use. Since considerable numbers of salmon (and other fish) were used to feed sled dogs, fewer fish were needed as canine populations declined. Thus, rather than reflecting fish abundance, the decline in subsistence fishing mainly reflects less fishing effort and less dependence on fish due to a changing way of life for inhabitants in the region.

Subsistence salmon harvests in Norton Sound have ranged from 22,800 to 55,000 fish (Table VII-5) and averaged about 35,000 during 1962-1976. For the same period, catches in Kotzebue Sound ranged between 16,000 and 70,000 fish (Table VII-5) with an overall average of about 29,000. As in the commercial fisheries, subsistence harvests in Norton Sound included catches of chum, pink, coho, and king salmon, while catches in Kotzebue Sound were almost entirely chum salmon.

Table VII-5.--Numbers of salmon by year and species taken for subsistence purposes in the Norton and Kotzebue sound regions, 1962-1976. (Source: State of Alaska Department of Fish and Game.)

	Norton Sound					Kotzebue Sound
Year	King	Coho	Pink	Chum	Area total	Area total 1/
1962	--	--	--	--	--	70,283
1963	5	118	16,607	17,635	34,365	31,069
1964	565	2,567	9,225	12,486	24,843	29,762
1965	574	4,812	19,131	30,772	55,289	30,500
1966	269	2,210	14,335	21,873	38,687	35,588
1967	817	1,222	17,516	22,724	42,279	40,108
1968	237	2,391	36,912	11,661	51,201	20,814
1969	436	2,191	18,562	15,615	36,804	29,812
1970	561	4,675	26,127	22,763	54,126	28,486
1971	1,026	4,097	10,863	21,815	37,801	23,959
1972	756	1,928	12,214	12,942	27,840	11,085
1973	392	520	14,770	7,185	22,867	18,942
1974	420	1,064	16,426	3,958	21,868	26,729
1975	186	192	15,078	6,449	21,905	27,605
1976	203	1,004	18,409	7,867	27,483	15,765

1/ Chum salmon only.

Herring.--The full extent of subsistence fishing for herring is unknown. In 1976, the only year for which data are available, the subsistence herring harvest in Norton Sound was estimated at about 14 mt, approximately twice the level of the commercial harvest. No figures are available for any other portion of the survey area. Apparently utilization of herring by local inhabitants decreases northward along the Alaska coast. Harvest levels north of the Yukon River are substantially lower than to the south. A primary reason for this difference is due to increased commercial fishing and greater availability of terrestrial big game animals in the more northern regions.

King crab.--A few red king crab are taken annually from Norton Sound by residents of Nome. Fishing occurs nearshore and during winter months with small crabpots or hand lines set through holes chopped in the ice. Annual amounts taken by this fishery are unknown; however, the State of Alaska has limited harvests to a maximum of 500 crab (either sex) per person.

VIII

RESULTS OF THE 1976 OCSEAP BASELINE SURVEY OF FISH AND SHELLFISH OF NORTON SOUND, THE NORTHERN BERING SEA, AND SOUTHEASTERN CHUKCHI SEA

METHODS

Survey Approach and Rationale

This 1976 OCSEAP survey was designed to estimate the spatial distribution, abundance, and population characteristics of fish and shellfish of potential economic importance in Norton Sound, the northern Bering Sea, and southeastern Chukchi Sea, which are areas under consideration for petroleum exploration and development. A study of demersal fauna was the primary thrust of the survey. Inasmuch as large segments of some fish stocks were thought to occur in mid-water and near the sea surface, limited off-bottom sampling was also incorporated into the survey design.

For sampling and analytical purposes, the survey area was subdivided into four major subareas. Demersal trawling stations were arranged in a systematic manner within each subarea (Figure VIII-1). At each station a one-half hour demersal trawl haul was performed. Subdivisions of the survey area and the density of demersal stations within each subarea were based on the location of potential oil lease sites, levels of impact from possible environmental alterations, and limited prior knowledge of the distribution patterns of principal fish and shellfish species in the study area. A description of each subarea with respective demersal sampling density follows:

Subarea 1, containing about 41,000 sq km, includes mostly offshore waters (from 25-65 m in depth) from Bering Strait to Point Hope, and nearshore areas along the north coast of the Seward Peninsula and north of Kotzebue Sound with depths greater than 9 m. This subarea is included in proposed oil lease regions and has been an occasional site of high-seas salmon fishing by foreign nationals. Sampling density was planned at one demersal station per 750 sq km.

Subarea 2, containing approximately 12,000 sq km, is another region of proposed oil exploration and an area for commercial and subsistence salmon fishing by residents of the Kotzebue area. This subarea includes all waters of Kotzebue Sound, deeper than 9 m., and waters outside Kotzebue Sound west to approximately 166°W longitude and north to approximately 67°30'N latitude. Sampling density was planned at about one demersal station per 375 sq km.

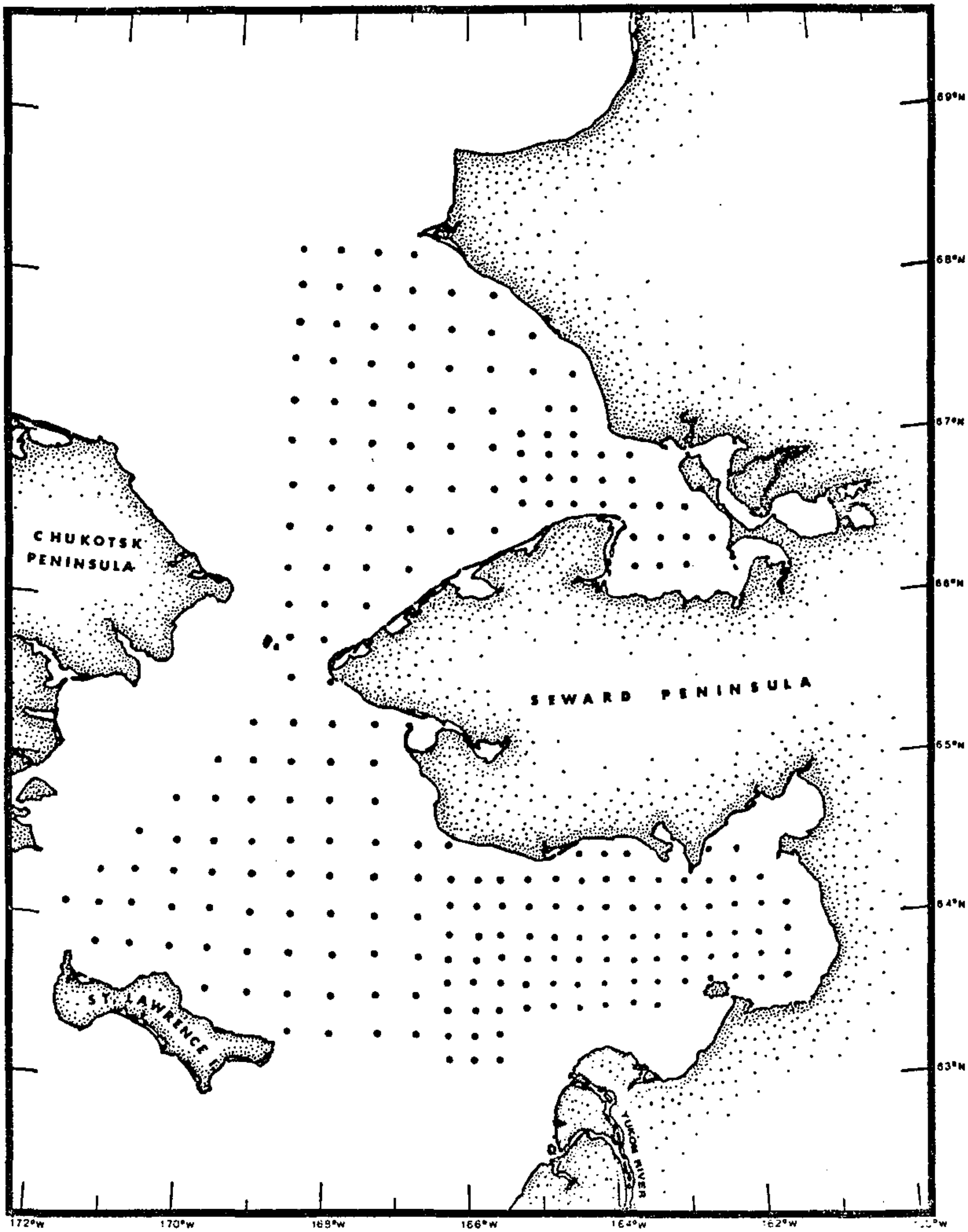


Figure VIII-1.--Planned sampling grid pattern for 1976 survey.

Subarea 3, containing nearly 47,000 sq km, is another region of possible oil exploration within the survey boundaries. This area includes waters of the northern Bering Sea, between depths of 9 and 65 m, from 165°W longitude west to the US-USSR Convention Line of 1867 and from St. Lawrence Island north to Bering Strait, including Port Clarence. Sampling density was the same as in subarea 1.

Subarea 4, containing over 31,000 sq km, includes most waters of Norton Sound east of 166°W longitude, ranging from 9 to 30 m in depth. This subarea is the occasional site of substantial herring fisheries by foreign nationals as well as the location of commercial salmon fishing and subsistence fisheries for residents of the coastal towns and villages of Nome, Unalakleet, St. Michael, Stebbins, and others. This region is also a possible area for petroleum exploration. Sampling density was the same as in subarea 2.

Preliminary examination of the 1976 survey information regarding species composition, size and age composition, and species catch rates indicated need for further division of the subareas for detailed analysis. Each subarea was divided into two sections forming a total of eight strata for the data analysis (Figure VIII-2). This subdivision was based on preliminary examination of data on all species combined rather than on individual species.

The above mentioned planning and sampling pattern pertains directly to demersal resource assessment, the primary portion of the survey. Mid-water trawling and surface gillnetting were incorporated into this demersal sampling system. Pelagic trawl tows were planned to occur on an opportunity basis, whenever off-bottom fish targets were encountered during transit between the demersal stations. The pelagic tows also were one-half hour in duration. The setting of gillnets occurred each evening and fishing time for this gear usually ranged between 8-10 hours. The location of each gillnet set was determined by selecting a site in close proximity to a series of demersal stations which could be occupied while the gillnets were fishing.

Because of the extensive amount of planned sampling and the relatively short time period in which the survey could be completed, it was necessary to deviate from the usual daytime-only trawling protocol as during earlier BLM baseline demersal trawl surveys. Trawling operations for this survey were conducted on an around-the-clock schedule. Since 24-hour operations were used, a portion of the alloted survey time was set aside to determine whether species composition and catch rates differed significantly between day and nighttime trawling. When differences were identified, fishing power factors were determined so that all catch information could be pooled into a standardized data base. Details regarding the design, analyses, and results of the day-night comparative fishing trials are given in Appendix D.

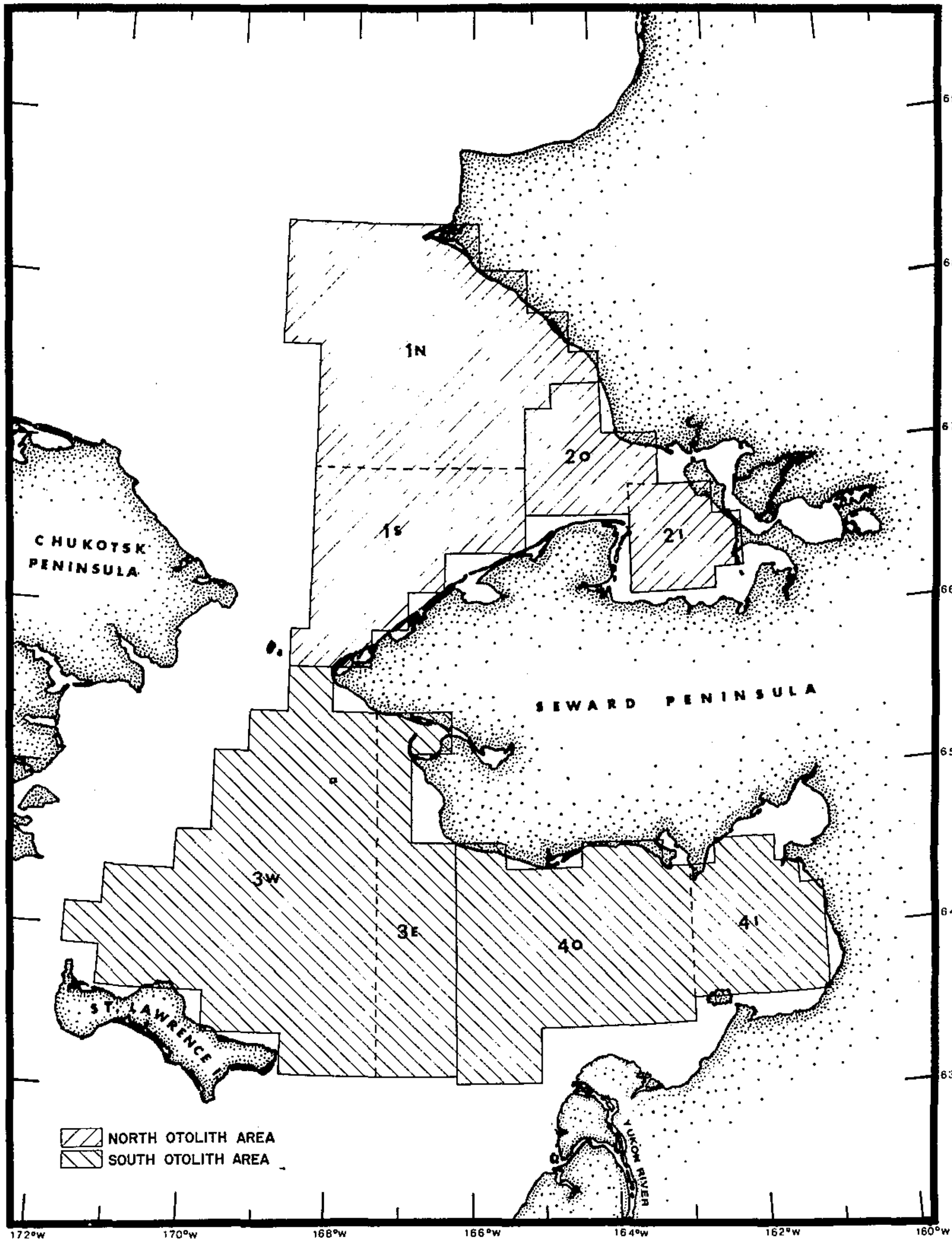


Figure VIII-2.--Otolith sampling areas and strata used for biomass analysis (1976 BLM/OCS survey).

Vessel and Fishing Gear

The NOAA research ship Miller Freeman was the only vessel used during the 1976 OCSEAP survey of Norton Sound, the southeastern Chukchi Sea, and adjacent waters. The Miller Freeman is a 1500 gross ton, 2200 horsepower stern trawler with an overall length of 65.5 m and equipped with a variable pitch propeller.

Fishing gear for the survey included the modified eastern demersal trawl used during earlier baseline surveys (NWAFC, 1976), the BCF Universal trawl for pelagic trawling, and a series of gillnet shackles connected together to form a 640 m long floating gillnet.

Each shackle of gillnet was 91 m (300 ft) x 5.5 m (18 ft) and contained a different mesh size of monofilament nylon. Seven mesh sizes (seven shackles) were planned to be fished at each gillnet station. These mesh sizes included: 21 mm (0.83") (stretched mesh measure), 35 mm (1.38"), 42 mm (1.65"), 63.5 mm (2.50"), 82.5 mm (3.25"), 114.3 mm (4.50"), and 133.4 mm (5.25"). The gillnet was fished with a radio buoy, marker pole, and floats attached to one end. Only a marker buoy and floats were attached to the other end of the gillnet set.

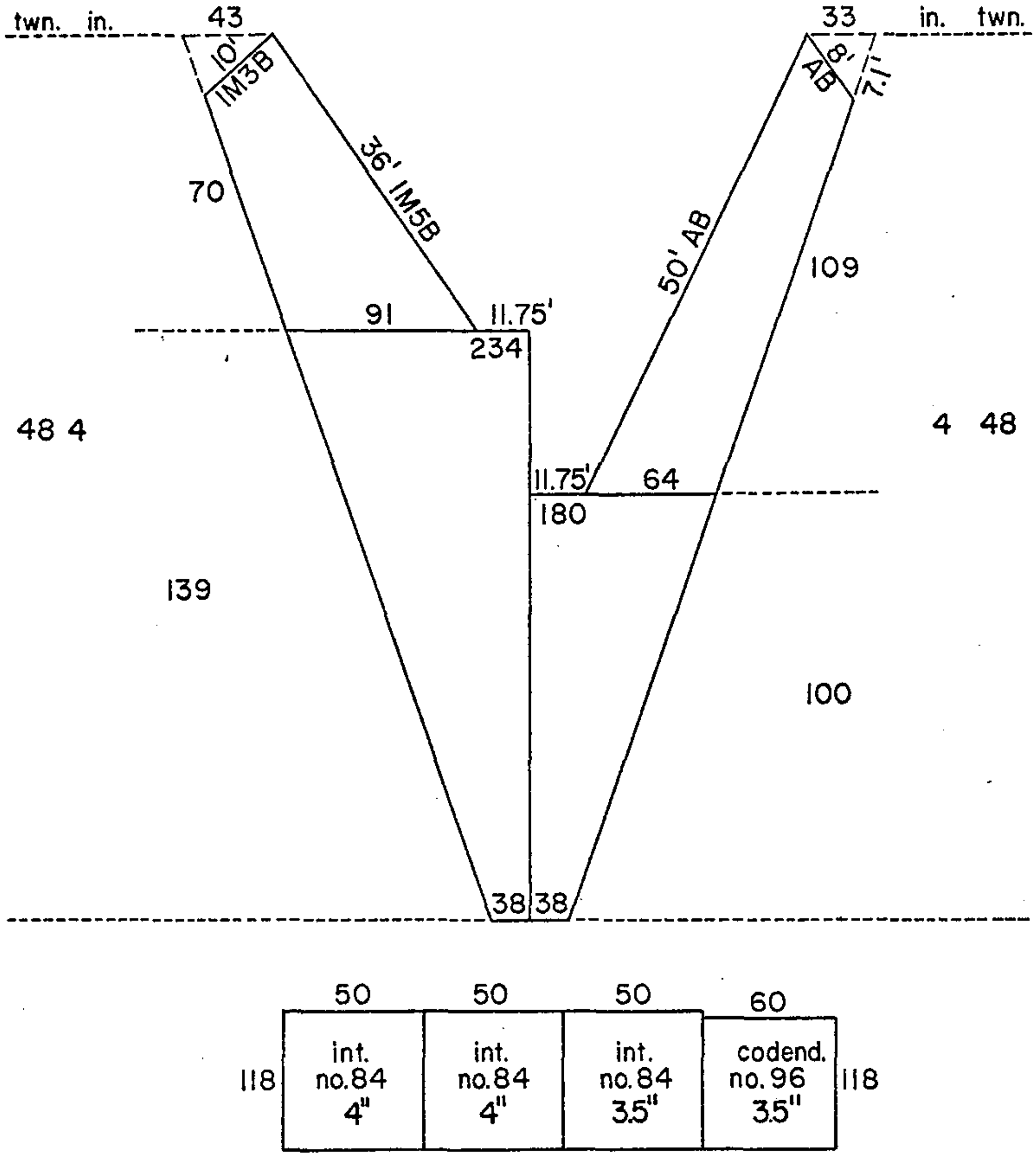
Both demersal and pelagic trawls were fished with 2.1 m x 3.0 m steel V-design trawl doors and their codends were lined with 31.8 mm (1.25") mesh web for retention of small fish. A set of four 45.7 m (150 ft) dandylines were fished with the demersal trawl, two connected to each wing. Six 54.9 m (180 ft) dandylines were used with the pelagic trawl, 3 connected to each wing. Descriptions of the trawls are given in Figures VIII-3 and VIII-4.

Sampling Procedures

Prior to the actual demersal fishing operations, some stations were first surveyed by echosounder to establish the condition of the bottom. At inshore stations where highly uneven or muddy and thus untrawlable bottom might be encountered, a two-mile echosounder transect was run over the station to determine both its trawlability and a course which would provide a uniform depth throughout the length of the tow. If the echosounder trace indicated rough bottom, the vessel proceeded to the next station rather than spending additional time searching for a trawlable area. If the echosounder trace indicated muddy bottom, a test set of 5-10 minutes was attempted. If extensive mudding of the trawl resulted from the test set, the station was abandoned.

Station positioning was by Loran C with radar fixes used at nearshore locations. Positioning accuracy of the tows in relation to planned station positions proved to be relatively good except in the northwest portion of the survey area where land masses were quite distant for radar fixes and only limited Loran fixes could be obtained.

MODIFIED EASTERN TRAWL NET



Netting: Dacron polyester body and wings, nylon intermediate and codend.

Headrope: 83 ft., 1/2-in. 6x19 galv. wire rope wrapped with 5/16-in. polypropylene rope.

Footrope: 112 ft., 5/8 in. dia. 6x19 galv. wire rope wrapped with 5/16-in. polypropylene rope.

Breastlines: 1/2-in. dia. braided nylon, 18 ft. long.

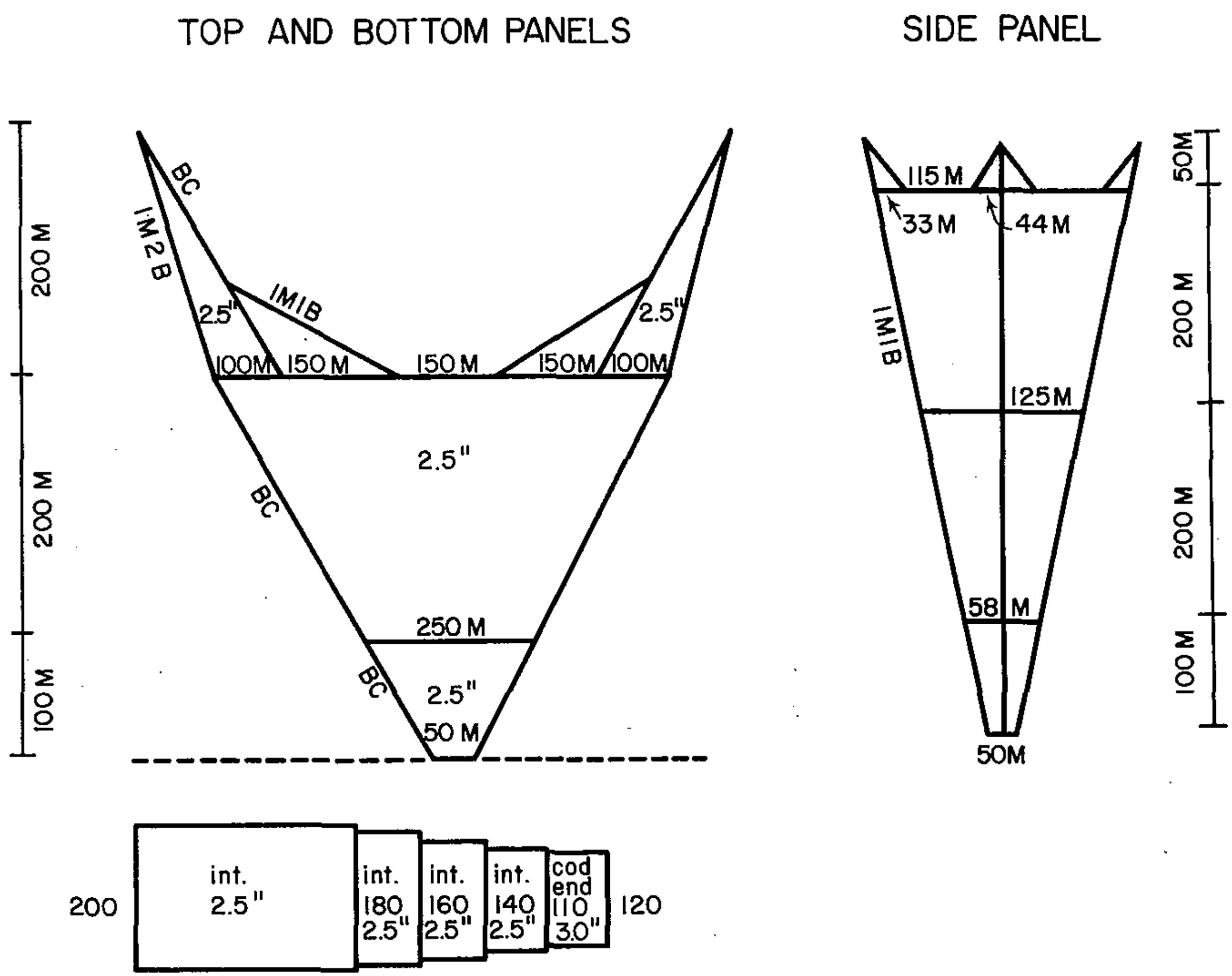
Riblines: 1/2-in. dia. braided nylon, extending length of first intermediate (webbing hung-in).

Flotation: 31-8 in. and 3-10 in. aluminum floats.

Dandylines: Single - 11 fath., 3/4-in. dia., double - 25 fath., one 3/4-in., one 5/9-in.

Otterboards: 7-10ft. Vee.

Figure VIII-3.--Diagram and description of the demersal trawl used during the 1976 BLM/OCS survey.



Netting: nylon

Headrope: 121 ft., 5/8 in. dia. braided nylon

Footrope: 121 ft., 5/8 in. dia. braided nylon

Breastlines and riblines: 5/8 in. dia. braided nylo

Floatation: 65-8 in. alumin floats

Dandylines: 6-180 ft.

Otterboards: 7-10 ft. Vee.

Figure VIII-4.--Diagram and description of the pelagic trawl used during the 1976 BLM/OCS survey.

The direction of the trawl tows varied depending on prevailing wind and sea conditions. Tows generally were made into the wind. For demersal trawl hauls, the trawl was set prior to reaching the station so that the actual station position was reached about midway through the trawl tow. Towing speed for the Miller Freeman averaged about 6.5 km/hr (3.5 n mi/hr).

Demersal tow duration was 30 minutes. Timing of the tow was started after the vessel was slowed to allow the trawl to settle to the bottom and as the trawl winch brake was set. The average bottom distance trawled was 1.65 km (range: 0.7-3.2 km).

Pelagic tow duration also was 30 minutes. Timing for the mid-water sets was started when the proper amount of trawl warp had been payed out, the winch brake was set, and the proper trawl towing depth was attained. Proper trawling depth varied, depending on where fish targets occurred in the water column. The desired fishing depth was attained by adjusting towing speed and was monitored by means of a transducer attached to the trawl headrope. Because a variety of off-bottom depths were fished and since maintenance of trawl position in the water column required changing trawling speed in relation to currents, distance towed varied among the pelagic trawl tows. Average pelagic trawling speed for the Miller Freeman was about 8.3 km/hr (4.5 n mi/hr).

Gillnets were fished for 8-10 hours and starting time for the set occurred when the first end of the gillnet shackles was released down the stern ramp. The gillnets usually were allowed to drift during the set with the arrangement of the various mesh sizes such that a minimum of looping or drifting together of the corklines occurred. When the gillnets were set in shallow or nearshore locations, the ends were anchored to prevent the set from drifting into shallow unnavigable waters.

The gillnets were retrieved by having the vessel back down to the gear with the bow thruster. The net was then brought up the stern ramp and wrapped onto one of the trawl net reels. After the entire gillnet was aboard, it was removed from the reel and placed in a bin for storage until the next set.

Expendable bathythermograph (XBT) casts were made at the completion of each gillnet set, and pelagic and demersal trawl hauls.

Catch and Biological Sampling

Initial Handling of Trawl Catches

The method of processing trawl catches depended on catch size. If the catch did not exceed the 1,150 kg capacity of the sorting table, it was dumped directly onto the table and completely processed. For larger catches, only a subsample of the catch was processed. The subsampling method used was based on a system developed by Hughes (1976) and followed procedures established for earlier BLM surveys aboard the Miller Freeman (Kaimmer et al., 1976). As with earlier surveys, prior to disposing of the unused portion of the catch overboard, all crabs were removed for separate counting and processing.

The size of catches in the survey area rarely exceeded 1000 kg. Of the 192 standard demersal tows completed, only three needed to be split before processing. All pelagic trawl catches were completely processed.

Initial Handling of Gillnet Catches

Catches from each mesh size were kept separate. As the gillnet sets were retrieved, catches from each shackle were removed and placed in tubs or baskets labeled for each mesh size as the net was wound on to the net reel.

Sorting and Weighing the Trawl Catch

After the catch was on the sorting table, it was sorted by species into wire bushel baskets and smaller plastic containers. For catches having a single dominant species, two to three baskets were filled simultaneously with that species and the baskets removed from the table in a set, weighed, and placed on deck as a group. While the dominant species was being sorted, other species were sorted into single baskets or other containers. The procedure of filling single or sets of baskets was repeated until the entire catch or subsample of the catch was sorted and weighed. Baskets were placed on deck in processing sequence in order to identify baskets of fish that came from the top, middle, and bottom of the trawl sample.

Baskets of fish were weighed to the nearest 0.5 kg on a 141 kg capacity platform scale or to the nearest 0.1 kg on a hand held spring scale when small catches occurred. Numbers of individuals by taxonomic group were determined by direct count or from subsample counts which were expanded to the total catch. Specimens that could not be identified to species were photographed, preserved, and labeled by genus or broader taxonomic group. Following the survey, unknown specimens were identified by taxonomic experts and the proper nomenclature transcribed onto the Trawl Catch Forms.

Sorting and Weighing the Gillnet Catch

After the entire gillnet catch was removed from the various shackles and placed in containers, each shackle catch was sorted by species into smaller containers. Weights and numbers caught were determined in a manner similar to that used in processing trawl catches.

Subsampling Demersal Catches for Biological Data on Fish

For the dominant species of fish encountered in demersal trawl hauls, catches were further processed for length composition, length-weight relationships, and samples of age structures (otoliths and scales). The species from which these data were collected and their order of priority for biological data were as follows:

1. Pacific herring
2. Saffron cod
3. Arctic cod
4. Yellowfin sole
5. Toothed smelt
6. Alaska plaice
7. Bering flounder
8. Starry flounder
9. Arctic flounder

A random sample for length frequency was taken from the catch of each species. Random samples consisted of from 200-300 saffron cod and 150-200 individuals of other fish species.

The procedure followed to obtain a random sample was as follows: as the baskets were taken from the sorting table and weighed, they were aligned on the deck in the order by which they were filled. When two or more baskets were filled simultaneously, they were kept together as parallel rows. To arrive at the desired number of fish for the sample, one row was picked at random to represent the catch. If there were still too many fish, the sample was further reduced by picking baskets from the front, middle, and end of the row. This procedure provided a subsample that would not be affected by any size stratification that might have existed on the sorting table. If an entire species catch resulted in numerous baskets of very small fish (400-1000 individuals/basket), the sample was obtained by taking random portions of the picked baskets from the front, middle, and end of the row. When catches of a species were equal to or less than the desired sample size, all individuals were measured.

Length-frequencies were recorded on plastic length-frequency strips. The fish were first sexed, then measured to the nearest centimeter from the tip of the snout to the middle of the caudal rays, except for Pacific herring which were measured from the tip of the snout to the posterior edge of the hypural plate. The sex of small juvenile fish was not always determined. Between stations or following the last station of the day, length-frequency data were transcribed from the plastic strips to standard length-frequency forms.

Samples for obtaining age structures and length-weight information were selected so as to obtain representative length classes of fish for each sex. At times, age structures or length-weight information were collected in conjunction with randomly collected length-frequency samples but at other times were selected independently. Independent samples for age and length-weight were obtained from specific geographical areas, referred to as "otolith areas". Two "otolith areas," north and south, were identified for the entire region (Figure VIII-2). The boundary between these areas, Bering Strait, was thought a possible point of separation between fish populations in the Norton Sound-northern Bering Sea region and in the southeastern Chukchi Sea. The otolith areas coincided with the demersal trawl sampling subdivision of the survey area, i.e., the north otolith region corresponded to subareas 1 and 2 combined and the south otolith region to subareas 3 and 4 combined.

Otoliths were the structures used for determining the age of all fish except salmon (Oncorhynchus spp.), for which scales were used. For each species up to 6 otoliths were obtained for each 1 cm size group by sex. This was done for each otolith area. Since few salmon were anticipated in catches, scale samples were obtained from every fish. The otoliths were stored in alcohol in glass vials. Scales were stored on gummed cards with acetate covers.

Length-weight data also were taken from 6 individual fish for each sex-centimeter group per otolith area. Individual fish were weighed to the nearest gram on a triple-beam balance.

Subsampling Trawl Catches for Biological Data on Crab

All king and Tanner crabs were removed from trawl catches regardless of catch size. If the number of crabs in the catch was less than 300, biological data were taken from all specimens. If the number exceeded 300 crabs, a subsampling procedure (Figure VIII-5) was used to provide a sample of about 300 crabs. The crabs were sorted by species and sex and then weighed and counted.

All crabs in the catch or samples of the catch were measured to the nearest millimeter using carapace width for Tanner crab and carapace length for king crab. Shell condition was also recorded for each individual.

Subsampling Trawl Catches for Biological Data on Snails

Many snail species are extremely difficult to identify in the field. For this reason, the operational plans called for the collection of random subsamples of snails at each station. No sorting or identification was to be done on the vessel. After all snails were removed from the catch, one to three cloth bags, depending on the size of the snail catch, were filled with a random assortment of snails and placed in a 55 gallon drum containing a 10% solution of formaldehyde. The maximum weight of a subsample collected at a station ranged up to about 7 kg. In addition to the collection of the random subsample, an actual count or estimate was made of total snail numbers in the entire catch and recorded on the Trawl Catch Form.

CRAB SAMPLING FLOW CHART

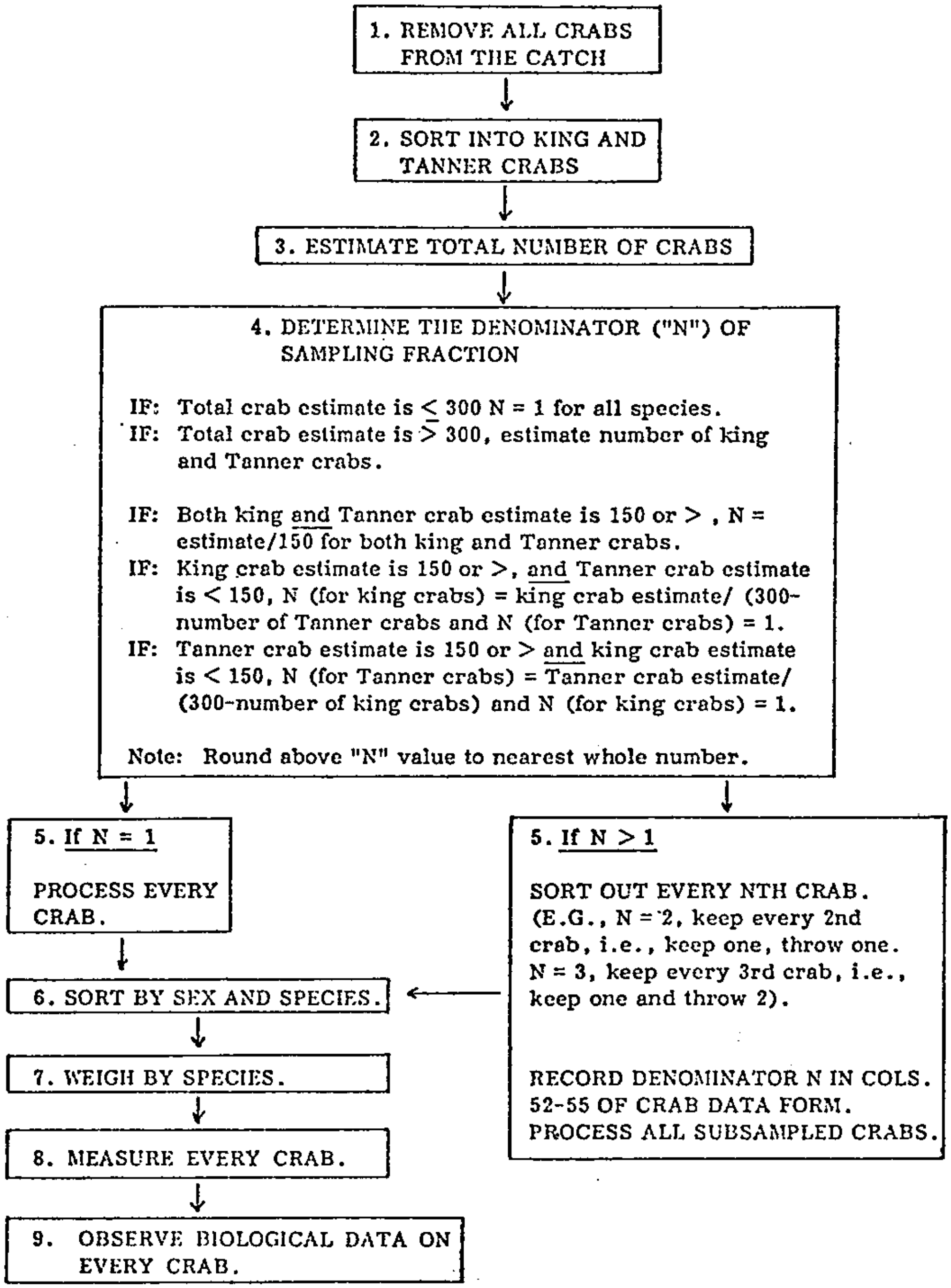


Figure VIII-5.--Sub-sampling procedure followed for processing species of crab during the 1976 Baseline Survey of Norton Sound and the southeastern Chukchi Sea.

The drums of snails were returned to the NWAFC's Kodiak facility where the snails were identified, sexed, and measured. Total shell length was measured from the apex of the spire to the anterior end of the anterior canal.

Sampling Trawl Catches for Biological Data on Other Invertebrates

All other invertebrates encountered in the survey trawl catches were examined by personnel from a separate research unit from the University of Alaska, Institute of Marine Science (IMS). Information in this report which pertains to catch rates and biomass estimates for invertebrates other than king crab, Tanner crab, and snails were developed through data provided from IMS.

Age Determination of Fish

Annual marks on scales and otoliths were the basis for age determination. Otoliths were read by trained readers at NWAFC in Seattle. Techniques and accuracy of age determination by otoliths were similar to those described in the 1975 baseline study report for the eastern Bering Sea (NWAFC, 1976). Scales were examined by trained personnel of the State of Alaska Department of Fish and Game in Anchorage, Alaska, using established techniques for age identification.

Shell Age Determination of Crabs

The status of individual crabs with respect to molting was determined primarily from the appearance of the carapace and ventral surface of the crab. The following criteria were utilized in determining this status: (1) the size and density of attached marine organisms, (2) the color of the carapace and sternum, (3) the sharpness of spines, and (4) the presence of scratches on the sternum. Crabs were assigned to shell age categories as follows:

Shell age category	Designation	Description
0	molting	-
1	soft	Molted within the past two weeks, shell free of encrustation, no scratches on carapace, and spines sharp.
2	new	Molted within the past twelve months but not within the past two weeks, little encrustation, minor scratching, and blunting of spines.
3	old	Skipped one annual molting.

Data Management

A standard data management procedure was followed from data collection through analysis at NWAFC. Aboard ship, station information for fish was coded on three standard forms (Trawl Catch Form, Length-Frequency Form, and Specimen Data Form) for later keypunching on 80-column ADP cards (see Appendix B for examples of standard forms). The information recorded on the Trawl Catch Form included basic station data such as station number and position, date, depths of trawling, and catch by species. Catch data were initially recorded on an on-deck sampling form during the processing of the catch and later transcribed to the Trawl Catch Form. A similar sequence was followed for handling length data. This information was first recorded on a reuseable plastic strip and transferred later to the Length-Frequency Form. The Specimen Data Form was used for recording information on the weight of individual specimens and lengths of fish from which age structures (otoliths, scales) were removed and stored. Station information for crabs was coded on two standard forms (Crab Summary Form and Crab Data Form). Information coded on the Crab Summary Form was similar to station data recorded on the Trawl Catch Form. In addition, the numbers of crabs measured and caught were recorded by tow, species, and sex. The Crab Data Form was used to record carapace size, sex, shell condition, egg clutch, and sampling fraction, as well as station identification for each crab measured.

The information on the standard forms was checked for accuracy and completeness and submitted for keypunching. The ADP cards were then edited by computer programs to detect obvious discrepancies (detailed quality control procedures are given in Appendix A). Computer listings of the data in easily readable formats were made for visual checking against the data on the original standard forms. After verification and correction were completed, the data on the ADP cards were transferred to disk files. Numerous editing programs were then used for additional screening. All survey data were eventually placed on magnetic tape for transfer to Environmental Data Services through the OCSEAP office in Juneau, Alaska.

Analytical Procedures

Standardization of Catches

Catches were standardized to a trawling distance of 1 km. These standardized catches were calculated as follows:

$$CPUE_{ijk} = \frac{C_{ijk}}{D_{ij.} F_{tk}}$$

where $\overline{CPUE}_{ijk}$ refers to the catch per unit of effort (kg/km) for species k at the jth station in the ith subarea. C_{ijk} equals the catch (kg), D_{ij} equals the distance trawled (km) computed from beginning and ending Loran C readings at each station, and F_{tk} is the relative fishing power correction factor time of sampling (day or night) t in respect to species k.

The relative fishing power correction factor was obtained through an analysis of results of comparative day-night fishing trials at several locations. The correction factors for nighttime catches were related to catches made during the day. These are given in Table VIII-1 for the principal species encountered in the survey area for which significant day-night catch differences were statistically established. Details of the methodology and analysis for estimating these correction factors are given in Appendix D.

Table VIII-1.--Fishing power coefficients calculated for principal fish species encountered during day-night trawling comparisons in Norton Sound and the southeastern Chukchi Sea during the 1976 baseline study.

	Species 1/				
Time	Starry flounder	Saffron cod < 15 cm	Saffron cod ≥ 15 cm	Toothed smelt	Pacific herring
Day	1.00	1.00	1.00	1.00	1.00
Night	1.69	1.52	1.50	2.08	1.45

1/ For other principal species, no differences in fishing power were established. For all other species, the fishing power correction factor was assumed equal to 1 for both day and night.

Catch Per Unit of Effort by Stratum and Total Survey Area

The mean CPUE by species and stratum was computed as follows:

$$\overline{CPUE}_{ik} = \frac{\sum_{j=1}^{n_i} CPUE_{ijk}}{n_i}$$

where n_i equals the number of successfully trawled stations in the ith stratum. The variance of this estimate was:

$$VAR\ (\overline{CPUE}_{ik}) = \frac{\sum_j (CPUE_{ijk})^2 - n_i\ (\overline{CPUE}_{ik})^2}{n_i\ (n_i - 1)}$$

The overall mean CPUE for the entire survey area ($\overline{CPUE}_{Tk}$) was determined as a weighted sum of the mean CPUE values by stratum:

$$\overline{CPUE}_{Tk} = \frac{\sum_i (\overline{CPUE}_{ik} \cdot A_i)}{A_t}$$

where $\underline{A}_i$ equals the area of the $\underline{i}$th stratum and $\underline{A}_t$ equals the area of all stratum combined.

The variance of this estimate was determined as a weighted sum of the individual variances by strata:

$$VAR\ (\overline{CPUE}_{tk}) = \sum_i \left(\left(\frac{A_i}{A_t} \right)^2 \cdot VAR\ (\overline{CPUE}_{ik}) \right)$$

Standing Stock Estimates

Population weight--Biomass estimates by subarea followed the methods described by Alverson and Pereyra (1969):

$$\hat{B}_{ik} = \overline{CPUE}_{ik} / q_k$$

where $\hat{\underline{B}}_{ik}$ equals the estimated standing stock by weight of the $\underline{k}$th species in the $\underline{i}$th stratum, and $\underline{q}_k$ is a coefficient of catchability, $\underline{w}$ is the average effective trawl width:

$$q_k = C_k\ (\overline{w}/A_i)$$

and $\underline{C}_k$ is the coefficient of vulnerability of species $\underline{k}$ for those individuals of sufficient size to be retained by the trawl which are within the area "swept" during a standard tow. The coefficient of vulnerability consists of two components: (1) $\underline{C}_h$, the vulnerability of those individuals that actually come within the influence of the trawl, and (2) $\underline{C}_u$, the proportion of the total individuals in the volume of water above the seabed area swept by the trawl which would come within the trawl's influence. Species-specific coefficients of vulnerability are not known for the survey area, but have been assumed to be constant and equal to 1.0. The estimated area covered by the trawl when towed 1 kilometer ($\bar{a}$) is equal to 0.017 km^2. 1/ Therefore, the biomass of species k within stratum i can be estimated:

$$\hat{B}_{ik} = (Ai/\bar{w})\ \overline{CPUE}_{ik}$$

having a variance of:

$$VAR\ \hat{B}_{ik} = \left(\frac{a_i}{\bar{a}}\right)^2 \cdot (VAR\ \overline{CPUE}_{ik})$$

where a is the mean bottom area sampled in 1 km trawl distance (km^2).

Ninty-five percent confidence intervals of the estimated biomass are then computed:

$$\hat{B}_{ik} \pm t_{(.05)(n_e)} \sqrt{VAR\ \hat{B}_{ik}}$$

The biomass estimate for a given species or taxonomic group and its variance for the total survey area were obtained by summing the sub-area biomasses and variances, respectively:

$$\hat{B}_{Tk} = \sum_{i=1} \hat{B}_{ik}$$

$$VAR\ \hat{B}_{Tk} = \sum_{i=1} VAR\ (\hat{B}_{ik})$$

$$= \sum_{i=1}\left(\left(\frac{A_i}{a}\right)^2 \cdot VAR\ \overline{CPUE}_{ik}\right)$$

Effective degrees of freedom (n_e) for the calculation of confidence limits for biomass estimates for the total survey area were determined according to Cochran (1962):

$$n_e = \frac{\left(\sum_{i=1} f_i \cdot VAR\ CPUE_{ijk}\right)^2}{\sum_{i=1} \frac{f_i^2 \cdot (VAR\ CPUE_{ijk})^2}{n_i - 1}}$$

where

$$f_i = \frac{N_i \quad (N_i - n_i)}{n_i}$$

1/ Based on an estimated 17-meter horizontal opening of the R/V Miller Freeman trawl while fishing.

and $\underline{N}_i$ equals equals the total number of sampling units in the $\underline{i}$th stratum (A_i/a) and $\underline{n}_i$ equals the number of stations in stratum $\underline{i}$.

Population numbers--Estimates of population numbers within strata and for the total survey area were determined in the same manner as population weight, simply substituting numbers for weight in all the calculations. Fishing power coefficients used to standardize catch rate by number between day and nighttime trawling were identical to those used for catch rate by weight.

Size Composition

Size composition by numbers in the population was estimated for those strata where sufficient length-frequency data were collected. Length-frequency data for individual stations were expanded by a weighting factor to give an estimate of the total standard catch in numbers by size and sex for a given species:

$$\hat{N}_{ijklm} = n_{ijklm} \cdot \hat{P}_{ijk} / \sum_{m=1}^{3} \sum_{l=1}^{L} n_{ijklm}$$

where $\hat{\underline{N}}_{ijklm}$ equals the estimated number of individuals of size category $\underline{l}$, sex $\underline{m}$, and species $\underline{k}$ at the $\underline{j}$th station of stratum $\underline{i}$ where length information was collected, and $\underline{L}$ is the total number of size categories. The independent variable $\underline{n}_{ijklm}$ is the number of fish, crab or snails in this category actually measured, and the weighting factor is the ratio of total number of individuals of species $\underline{k}$ per standard tow $(\hat{\underline{P}}_{ijk})$ to the number of individuals of species $\underline{k}$ measured in the length frequency sample. The number of fish, crab, or snails by size-sex category for individual strata $(\hat{\underline{P}}_{iklm})$ was obtained by summing the size-sex categories for those stations where this was available and expanding this sum to the total standing stock of fish, crab, or snails in each subarea:

$$\hat{P}_{iklm} = \frac{\sum_{j=1} N_{ijklm}}{\sum_{j=1} \sum_{k=1} \sum_{l=1} N_{ijklm}} \cdot \hat{P}_{ik}$$

When size composition estimates were available for all strata, overall estimates of the standing stock size composition of a species for the total survey area were obtained by summing the population numbers by size-sex category $(\hat{\underline{P}}_{iklm})$ for all strata. If size composition estimates were not available for all strata in which the species occurred, estimates of overall size composition for the total survey area were obtained by expanding the summed size composition data by a ratio of overall population estimate for the species $(\hat{\underline{P}}_k)$ to the summed population estimates of the strata for which size composition information was available.

Length and Weight

For most species of fish, the relationship between length and weight takes the form:

$$\text{weight} = a \cdot (\text{length})^b$$

A least-squares linear regression procedure was used to fit length-weight observations grouped by sex and otolith area to the logarithmic transformation of this equation:

$$\log(\text{weight}) = \log a + b \cdot \log(\text{length})$$

Estimates of the coefficients _a_ and _b_, and a coefficient of correlation _r_ were determined. The correlation coefficient _r_ was computed:

$$r = \sum_{i=1}^{n} (x \cdot y) \Big/ \sqrt{\sum_{i=1}^{n} (x^2 \cdot y^2)}$$

where _x_ and _y_ are the deviations of observed length and weight values from their respective means and _n_ equals the number of observations. An analysis of covariance (ANCOVA) was used to evaluate the statistical basis for pooling data sets, the regression coefficients determined for each treatment (data grouped by sex or otolith area) being tested for significant differences. This sequence of analyses was performed on all possible groupings of the data by species, resulting in comparisons of differences between area by sex, between sexes by area, and between areas by combined sexes.

Age Composition and Growth

Age-length tables were constructed by species and sex for each otolith area having sufficient data. These tables show the number of actual observations in each size-age class and estimates of mean length-at-age. Comparisons of plots of mean lengths-at-age were used to combine age-length data from otolith areas for which the approximated growth curves were not markedly dissimilar. The rationale for combining age data was: (1) to increase the number of observations of length-at-age within age classes to give more precise estimates of mean length-at-age; and, (2) to reduce the total number of data sets for further analyses.

Age-length tables were constructed from the otolith area groupings and used as keys to represent the age-length relationships of the respective species in the grouped strata.

Age composition--From the above keys, expanded age-length tables were constructed for each species by sex and strata using the method of K. R. Allen (1966). This method applies the age-length relationship for a region to population estimates in numbers at length, resulting in tables of numbers at-age-and-length by stratum. To make this conversion, the proportion of ages within any length interval were calculated from the keys and then applied to the corresponding numbers in the length-frequency distribution for a stratum. The result is an age-length table in which actual observations have been expanded to estimates of total numbers of individuals in the population at age and length. Estimates of the age composition (numbers of fish in each age class) for the population were obtained by summing the values in the expanded age-length table over all lengths by age. (In applying size composition data to the age-length key, lengths outside the length range of the key were not assigned ages. This, along with the truncation of size composition data, resulted in minor discrepancies between population estimates (numbers) for some strata and the sum total of numbers of individuals-at-age in those strata.)

Growth--Mean lengths-at-age for the grouped otolith areas from expanded age-length tables were used to fit growth curves in the form:

$$l_t = L_\infty \ (1-e^{k(t-t_o)})$$

where $\underline{l}$ equals length in centimeters at time $\underline{t}$ (years), $\underline{L_\infty}$ is an asymptotic length (cm), $\underline{k}$ ($year^{-1}$) is a growth completion rate, and $\underline{t_o}$ (years) is the intercept of the curve with the x-axis. Three methods were used, differing only in the data used for fitting the curve. First, curves were fit to all mean lengths-at-age as calculated from the expanded age-length table by otolith area or combinations at otolith areas. In the second fit, mean lengths which might have been biased because the complete size range for an age was not fully recruited to the fishing nets were deleted as were mean lengths derived from a relatively small number of observations at-age in the age-length key. Age of "complete" recruitment was estimated using logarithmic catch curve analysis (Ricker, 1975, p. 34). The third fit was created by adding the origin (0,0) as a data point to the above selected data set. This was done in order to compensate for missing data points for young ages which were not fully recruited by the gear.

The parameters $\underline{k}$, $\underline{L_\infty}$ and $\underline{t_o}$ were estimated by the iterative method of Fabens (1965).

ASSUMPTIONS AND DATA LIMITATIONS

We have provided for the various fish and shellfish population estimates of stock abundance, composition, and distribution based on an extensive trawl survey conducted over a period of six weeks. In providing these estimates, we have made certain assumptions regarding the adequacy of bottom trawls for sampling demersal populations and the time-space distribution of populations. We have assumed that the trawl obtained samples that were representative of the density and composition of the animals in the sampled area, and that the trawl's performance (vertical and horizontal width of the mouth opening and the bottom-tending characteristics) remained constant from station to station. A corollary to these assumptions is that changes in the catch of a species for a given unit of effort (distance fished) is directly proportional to changes in density. The other assumptions regarding the time-space distribution of populations is that, during the period of the survey, populations were static, i.e., there were no shifts in abundance within the survey area as well as no movements of animals in and out of the survey area.

These assumptions need to be qualified. Although the trawl continues to be the most effective gear for sampling bottomfish and large epibenthic invertebrates, it has certain limitations. Trawls are selective. Sizes, and even species, of animals captured are influenced by the mesh size, particularly in the bag or codend. Even species within the size range, which theoretically should be captured, may differ in their ability to escape the influence of the trawl. Because trawling is necessarily restricted to relatively smooth bottom to avoid hanging up and damage to the net, animals over uneven and rocky bottoms are not adequately sampled. The selective features of trawls thus alter the composition, sizes, and quantities of species captured from that which occur in its path. The degree to which the "apparent" distribution and relative abundance differs from the actual is unknown. Thus, estimates of standing stock are representative only for those species which are vulnerable as well as accessible to the trawl. However, our estimates assume that for a given species and size, all animals are vulnerable and accessible ($\underline{c}$ = 1.0), since we do not know what the actual value of $\underline{c}$ is for any of the species. For crabs the coefficient $\underline{c}$ may be close to 1.0, but for semi-demersal fish like Arctic cod and herring or for burrowing animals like snails, $\underline{c}$ may be much less than 1.0.

We have no way to account for the space-time distribution of populations during the survey period (September-October) and have assumed a static situation. The survey period was selected because it was assumed that movements of fish and shellfish populations were relatively limited at that time and weather conditions for the survey area were optimal. It is conceivable, however, that moving aggregations of animals may have been sampled more than once during the survey and that, for several populations like Arctic cod and herring, there may have been movements in and out of the survey area. To significantly reduce the duration of the survey while maintaining the demersal sampling coverage would have required extensive increases in the number of vessels and personnel.

In considering these limitations to our survey approach we hope that our findings provide some average conditions of demersal resource abundance, distribution, and composition, and a very general view of the types of pelagic species which occur in this northern region of the Alaska continental shelf.

RESULTS OF THE DEMERSAL SURVEY

A total of 242 demersal stations was planned for the survey. Of these, 192 were successfully trawled (Figure VIII-6) and were used in estimating biomass (Table VIII-2). The remaining planned stations either had rough or muddy bottoms preventing successful station completions (23 stations) (Figure VIII-7); were identified as untrawlable from echosounding transects (19 stations); or, though within the survey boundaries, were not fished because they were west of the continental shelf median line (8 stations). 1/

Table VIII-2.--Number of stations successfully trawled and sampling density by total survey area and stratum, BLM/OCS survey, September-October, 1976.

Subarea	1 Southeastern Chukchi Sea		2 Kotzebue Sound		3 Northern Bering Sea		4 Norton Sound		Total
Stratum	1N	1S	2Ø	21	3W	3E	4Ø	41	
Stations planned for sampling	36	19	20	13	48	16	64	26	242
Stations successfully trawled	29	15	19	8	32	14	58	17	192
Area in km^2	28,321	12,667	7,193	5,076	36,458	10,249	22,300	8,895	131,159
Sampling density (km^2/station)	976.6	844.5	378.6	634.5	1139.3	732.1	384.5	523.2	683.1

Fish and invertebrate taxa collected during the survey are listed in Tables VIII-3 and VIII-4, respectively.

Along with station and catch information for all of the trawling stations, specimen data included: 31,609 length measurements, 2,105 readable age structures, and 2,020 length-weight measurements for fish; 10,445 carapace measurements for crabs; and 4,147 measurements of shell size for snails (Tables VIII-5 to 9).

Bottom temperature isotherms as determined during the survey are shown in Figure VIII-8.

1/ A boundary established by the 1958 International Convention of the Continental Shelf for dividing shelf areas adjacent to two territories, in this instance, between the U.S. and U.S.S.R. The boundary limits the area for harvest or collection of creatures of the continental shelf such as crabs and other bottom-dwelling organisms.

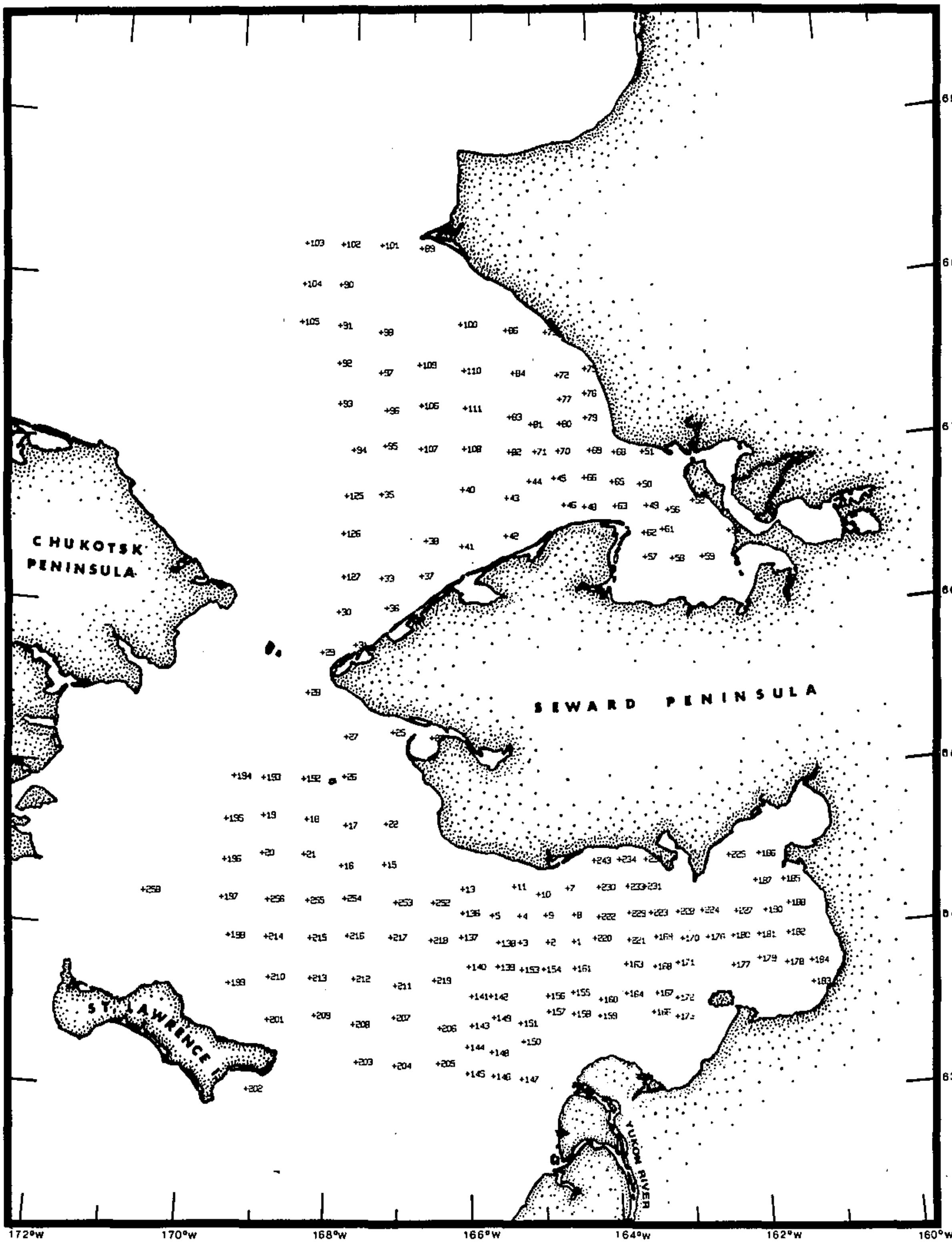


Figure VIII-6.--Demersal stations successfully sampled during the 1976 survey.

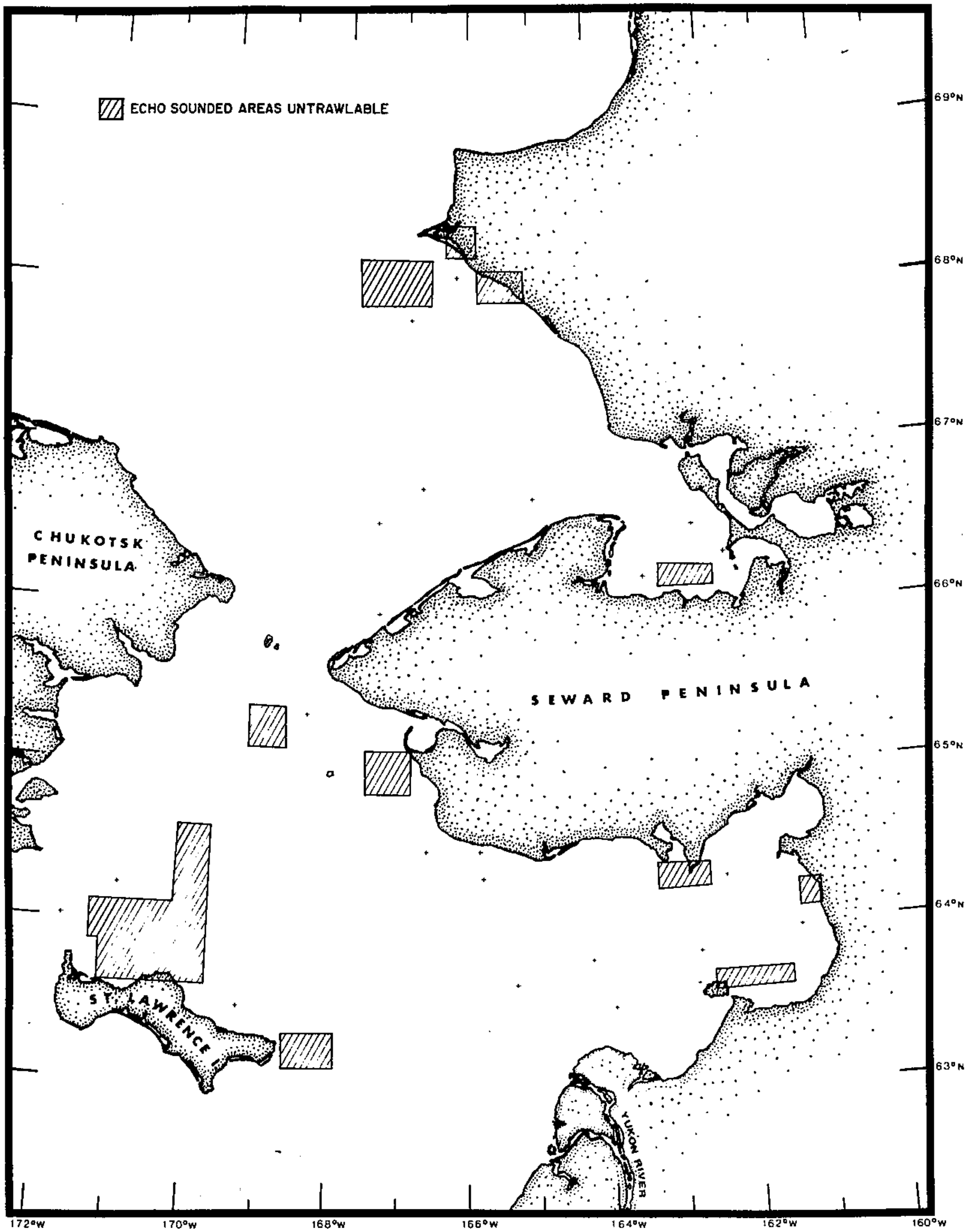


Figure VIII-7.--Untrawlable areas and unsuccessful trawl stations (indicated by "+") encountered during the 1976 BLM/OCS survey.

Table VIII-3.--List of fish species collected in Norton Sound, the southeastern Chukchi Sea and adjacent waters (BLM/OCS survey, 1976).[1/]

Species	Common Name
CLUPEIDAE	
Clupea harengus pallasi	Pacific herring
SALMONIDAE	
Oncorhynchus keta	Chum salmon
Oncorhynchus gorbuscha	Pink salmon
Oncorhynchus tshawytscha	King salmon
Coregonus laurettae	Bering cisco
Salvelinus alpinus	Arctic char
OSMERIDAE	
Mallotus villosus	Capelin
Osmerus mordax dentex	Toothed or rainbow smelt
Hypomesus olidus	Pond smelt
GADIDAE	
Boreogadus saida	Arctic cod
Eleginus gracilis	Saffron cod
Theragra chalcogramma	Pollock
Gadus macrocephalus	Pacific cod
ZOARCIDAE	
Lycodes turneri	Polar eelpout
Lycodes palearis	Wattled eelpout
Gymnelis viridus	Fish doctor
HEXAGRAMMIDAE	
Hexagrammos stelleri	Whitespotted greenling
COTTIDAE	
Artediellus uncinatus	Arctic hookear sculpin
Enophrys diceras	Antlered sculpin
Gymnocanthus pistilliger[2/]	Threaded sculpin
Gymnocanthus tricuspis	Arctic staghorn sculpin
Hemilepidotus jordani	Yellow Irish Lord
Megalocottus platycephalus	Belligerent sculpin
Myoxocephalus jaok	Plain sculpin
Myoxocephalus scorpius groenlandicus[3/]	Shorthorn sculpin
Myoxocephalus quadricornis	Fourhorn sculpin
Nautichthys pribilovius	Eyeshade sculpin
Psychrolutes paradoxus	Tadpole sculpin
Triglops pingeli	Ribbed sculpin

Table VIII-3 (Cont'd)

AGONIDAE	
Aspidophoroides olriki	Arctic alligatorfish
Occella dodecaedron	Bering poacher
Pallasina barbata	Tubenose poacher
Agonus acipenserinus	Sturgeon poacher
CYCLOPTERIDAE	
Cyclopteridae sp.	Snailfish sp.
Eumicrotremus orbis	Pacific spiny lumpsucker
ANARHICHADIDAE	
Anarhichas orientalis	Bering wolffish
STICHAEIDAE	
Chirolophus polyactocephalus	Decorated warbonnet
Lumpenus fabricii	Slender eelblenny
Lumpenus mackayi 2/	
Stichaeus punctatus	Arctic shanny
Eumesagrammus praecisus	Fourline snakeblenny
AMMODYTIDAE	
Ammodytes hexapterus	Pacific sand lance
GASTEROSTEIDAE	
Pungitius pungitius	Ninespine stickleback
PLEURONECTIDAE	
Hippoglossoides robustus	Bering flounder
Hippoglossus stenolepis	Pacific halibut
Limanda aspera	Yellowfin sole
Limanda proboscidea	Longhead dab
Liopsetta glacialis	Arctic flounder
Platichthys stellatus	Starry flounder
Pleuronectes quadrituberculatus	Alaska plaice
Reinhardtius hippoglossoides	Greenland turbot

1/ Nomenclature from American Fisheries Society 1970, unless otherwise noted.

2/ Nomenclature from Wilimovsky (1958).

3/ Personal communication from N. J. Wilimovsky.

Table VIII-4.--List of invertebrates collected in Norton Sound, the southeastern Chukchi Sea and adjacent waters during the 1976 BLM/OCS survey.[1/]

Phylum PORIFERA	SPONGES
Class Incalcarea	
Family Mycalidae	
Myxilla incrustans	
Stelodoryx sp.[2/]	
Family Microcionidae	
Microciona lambei	
Phylum CNIDARIA (COELENTERATA)	COELENTERATES
Class Anthozoa	
Family Actinstolidae	
Stomphia coceinea	
Family Actiniidae	
Tealia crassicornis	
Family Alcyonacea Nephtheidae	
Eunephthya rubermis	
Phylum TENTACULATA (ECTOPROCTA)	MOSS ANIMALS
Class Bryozoa	
Family Heteroporidae	
Heteropora pelliculata	
Family Diastoporidae	
Mesenteripora meandrina	
Unidentified Bryozoans[2/]	
Phylum SIPUNCULIDA	COELOMATE WORMS
Phascolosoma maritaceum	
Phascolosoma	
Phylum PRIAPULIDA	COELOMATE WORMS
Priapulus caudatus	
Phylum ECHIUROIDEA (ECHIURA)	COELOMATE WORMS
Class Echiurida	
Family Echiuridae	
Echiurus echiurus	
Phylum MOLLUSCA	SNAILS, CLAMS, OCTOPUSES AND OTHERS
Class Gastropoda	
Family Trochidae	
Margarites giganteus[3/]	Large margarite snail
Solariella obscura[3/]	Obscure solarelle
Solariella varicosa[3/]	Varicose solarelle
Solariella sp.[2/] [3/]	Unidentified solarelle snail
Family Turritellidae	
Tachyrhynchus erosus major[3/]	Eroded turret-shell
Tachyrhynchus reticulatus[3/]	Reticulate turret-shell
Family Calyptraeidae	
Crepidula grandis[3/]	Grand slipper-shell
Family Trichotropidae	
Trichotropis bicarinata[3/]	Two-keeled hairy-shell
Trichotropis insignis[3/]	Gray hairy-shell
Trichotropis kroyeri[3/]	Kroyer's hairy-shell

Family Naticidae	
Natica clausa[3]	Arctic natica
Natica russa[3]	
Natica sp.[2] [3]	Unidentified natica snail
Polinices pallidus[3]	Moon-shell snail
Family Lamellariidae	
Velutina plicatilis[3]	Oblique vetulina
Velutina undata[3]	Undate vetulina
Velutina velutina[3]	Smooth vetulina
Velutina sp.[2] [3]	Unidentified vetulina snail
Family Muricidae	
Boreotrophon clathratus[3]	Clathrate trophon
Family Buccinidae	
Buccinum angulossum[3]	
Buccinum glaciale[3]	Glacial buccinum
Buccinum fringillum[3]	
Buccinum polare[3]	Polar buccinum
Buccinum scalariforme[3]	Silky buccinum
Buccinum solenum[3]	
Buccinum tenellum[3]	
Family Neptuneidae	
Clinopegma sp.[3]	
Clinopegma magna[3]	
Beringius beringii[3]	Bering's buccinum
Beringius fragili	
Beringius stimpsoni[3]	Stimpson's buccinum
Colus hypolispus[3]	
Colus ombronius[3]	
Colus spitzbergensis[3]	Spitzbergen colus
Colus sp.[2] [3]	Unidentified colus welk
Liomesus ooides[3]	
Neptunea borealis[3]	
Neptunea heros[3]	
Neptunea lyrata[3]	Common northwest neptune
Neptunea ventricosa form *beringiana*[3]	Fat neptune
Plicifusus brunneus[3]	
Plicifusus kroeyeri[3]	
Plicifusus verkruzeni[3]	
Pyrulofusus deformis[3]	
Volutopsius castaneus	
Volutopsius filosus[3]	
Volutopsius fragilis[3]	Fragile buccinum
Volutopsius stefanssoni[3]	Stefansson's buccinum
Family Cancellaridae	
Admete couthouyi[3]	Common northern admete
Family Turridae	
Oenopota harpa[3]	
Oenopota nazanensis[3]	
Oenopota sp.[2] [3]	Unidentified lora
Obesotoma simplex[3]	
Family Pyramidellidae	
Odostomia arctica[3]	Arctic odostome
Family Scaphandidae	
Cylichna sp.[2] [3]	Unidentified barrel bubble
Family Dendronotidae	
Dendronotus arborescens	Free frond colis
Family Mopallidae	Amicula chiton
Amicula sp.[2]	

Class Polyplacophora	
Family Acanthochitonidae	
Cryptochiton stelleri	Giant Pacific chiton
Class Pelecypoda	
Family Nuculidae	
Nucula tenvis	Smooth nut clam
Family Glycymeridae	
Glycymeris subobsoleta	West coast bittersweet
Glycymeris sp.[2]	Unidentified bittersweet
Family Mytilidae	
Mytilus edulus	Blue mussel
Modiolus modiolus	Northern horse mussel
Musculus discors	Discord musculus
Musculus nigra	Black musculus
Family Astartidae	
Astarte borealis	Boreal astarte
Family Pectinidae	
Chlamys sp.[2]	Unidentified chlamys scallop
Chlamys islandica	Iceland scallop
Family Cardiidae	
Clinocardium ciliatum	Iceland cockle
Clinocardium nuttalli	Nuttall's cockle
Clinocardium californiensis	California cockle
Serripes groenlandicus	Greenland cockle
Family Carditidae	
Cyclocardia crebricostata	
Cyclocardia crassidens	
Cyclocardia sp.[2]	Unidentified cardita cockle
Family Myidae	
Mya arenaria	Softshell clam
Mya japonica	Japanese softshell clam
Family Veneridae	
Liocyma fluctuosa	Fluctuating liocyma
Family Mactridae	
Spisula polynyma	Stimpson's surf clam
Family Tellinidae	
Macoma calcarea	Chalky macoma
Macoma sp.[2]	Unidentified macoma clam
Macoma brota	Brota macoma
Family Hiatellidae	
Hiatella arctica	Arctic saxicave
Hiatella sp.	Unidentified saxicave
Panomya arctica	Arctic rough mya
Family Nuculanidae	
Nuculana sp.[2]	Unidentified nut clam
Nuculana fossa	Fossa nut clam
Yoldia sp.[2]	Unidentified yoldia clam
Yoldia amygdalea	Almond yoldia
Class Cephalopoda	
Family Octopodidae	
Octopus sp.[2]	Unidentified octopus
Phylum ANNELIDA	SEGMENTED WORMS
Class Polychaeta	
Family Pectinaridae	
Pectinaria sp.[2]	

Family Sternaspidae	
Sternaspis sp.[2]	
Family Nereidae	
Nereis sp.[2]	
Family Sabellidae	
Bispira polymorpha	
Family Flabelligeridae	
Brada sachalina	
Brada sp.[2]	
Phylum ARTHROPODA	BARNACLES, SHRIMP, AND CRAB
Class Crustacea (Decapoda)	
Family Pandalidae	
Pandalis goniurus	Humpy shrimp
Pandalis hypsinotus	Coonstripe shrimp
Family Hippolytidae	
Spirontocaris murdochi	
Spirontocaris arcuata	
Eualus sp.[2]	
Heptacarpis sp.[2]	
Lebbus sp.[2]	
Family Crangonidae	
Crangon dalli	
Argis lar	
Sclearograngon boreas	
Family Lithodidae	
Hapalogaster grebnitzbii	
Paralithodes camtschatica	Red king crab
Paralithodes platypus	Blue king crab
Family Majidae	
Chionoecetes opilio	Tanner crab
Hyas coarctatus alutaceus	Lyre crab
Hyas lyratus	Lyre crab
Family Paguridae	
Labidochiris splendescens	
Pagurus arcuatus	Hermit crab
Pagurus trigonochierus	Hermit crab
Pagurus rathbuni	Hermit crab
Pagurus ochotensis	Hermit crab
Pagurus capillatus	Hermit crab
Family Atelecyclidae	
Telemessus cheiragonus	Telemessus crab
Family Balanidae	
Balanus sp.[2]	Unidentified barnacle
Balanus cariosus	
Class Isopoda	
Family Idoteidae	
Synidothea bicuspida	
Synidothea nodulosa	
Saduria entomon	
Family Sphaeromatidae	
Tecticeps alascensis	
Class Amphipoda	
Family Stegocephalidae	
Stegocephalopsis ampulla	

Family Lysianassidae
Socarnes bidenticulatus
Anonyx nygax
Anonyx sp.[2/]
Family Podoceridae
Dulicha spinosissima
Family Eusiridae
Rhachotropis aculeata
Rhachotropis sp.[2/]
Eusirus cuspidatus
Family Hyperiidae
Parathemisto japonica
Family Gammaridae
Melita sp.[2/]
Melita dentata

Phylum ECHINODERMATA	STARFISH, BASKETSTARS, SEA URCHINS AND OTHERS
Class Asteroidea	
Family Pterasteridae	
Pteraster obscura	
Family Solasteridae	
Crossaster papposus	
Solaster endeca	
Family Asteridae	
Evasterias troschelli	
Evasterias echinata	
Asterias amurensis	
Leptastedias sp.[2/]	
Leptasterias polaris	
Lethasterias nanimensis	
Family Echinasteridae	
Henrica sp.[2/]	
Class Ophiuroidea	
Family Ophiolepididae	
Stegophiura sp.[2/]	
Ophiura sarsi	
Family Gorgonocephalidae	
Gorgonocephalus caryi	basketstar
Family Ophiactidae	
Ophiopholis aculeata	
Class Echinoidea	
Family Strongylocentrotidae	
Strongylocentrotus drobachiensis	
Strongylocentrotus sp.[2/]	Unidentified sea urchin
Family Echinarachniidae	
Echinarachnius parma	Sand dollar
Class Holothuroidea	
Family Cucumariidae	
Cucumaria sp.[2/]	
Cucumaria caleigera	
Family Stichopodidae	
Stichopus sp.[2/]	
Parastichopus sp.[2/]	
Family Chiridotidae	
Chirodota pellacida	
Family Psolidae	
Psolus japonicus	

Family Myriotrochidae
Myriotrochus rinkii

Phylum CHORDATA (TUNICATA)	ASCIDIANS
Class Ascidiacea Phlebobranchia	
Family Pyuridae	
Boltenia ovifera	Sea onion
Boltenia echinata	
Halocynthia aurantium	Sea potato
Family Stylelidae	
Pelonaia corrugata	
Family Rhodosomatidae	
Chelysoma sp.2/	
Chelysoma columbianum	
Styela macrenteron	

1/ Nomenclature primarily according to Pavlovskii (1955) and identification, unless otherwise noted, by University of Alaska, Institute of Marine Science staff.

2/ Unknown number of species.

3/ Identification by R. MacIntosh, NMFS, NWAFC, Kodiak Facility.

and subarea in Norton Sound, the southeastern Chukchi Sea and adjacent waters (BLM/OCS survey, 1976).

Species	Subarea	Number of Fish Measured Male	Female	Unsexed	Total	Number of Observation Sets
Yellowfin sole	1N	0	0	0	0	
	1S	24	44	0	68	7
	2I	55	79	0	134	6
	2Ø	13	15	0	28	4
	3W	2	4	0	6	3
	3E	69	170	0	239	7
	4Ø	1,184	1,275	0	2,459	52
	4I	231	246	0	477	12
	TOTAL	1,578	1,833	0	3,411	91
Starry flounder	1N	2	7	0	9	1
	1S	5	19	21	45	6
	2I	0	2	0	2	1
	2Ø	2	0	0	2	2
	3E	52	29	0	81	6
	4Ø	239	226	0	465	45
	4I	19	9	0	28	9
	TOTAL	319	292	21	632	70
Pacific herring	1N	50	74	0	124	5
	1S	95	96	0	191	9
	2I	3	5	0	8	2
	2Ø	337	349	0	686	17
	3W	25	20	0	45	4
	3E	122	109	0	231	9
	4Ø	180	131	96	407	26
	4I	2	0	0	2	1
	TOTAL	814	784	96	1,694	73
Arctic cod	1N	373	273	590	1,236	25
	1S	124	81	0	205	7
	2I	13	15	0	28	3
	2Ø	103	113	30	246	13
	3W	115	119	169	403	21
	3E	96	63	66	225	12
	4Ø	665	674	4	1,343	41
	4I	60	58	0	118	15
	TOTAL	1,549	1,396	859	3,084	137
Saffron cod Adult	1N	10	8	0	18	5
	1S	119	38	0	157	11
	2I	13	20	0	33	2
	2Ø	161	156	0	317	11
	3W	9	51	0	60	8
	3E	522	548	0	1,070	13
	4Ø	5,081	3,621	42	8,744	58
	4I	564	372	0	936	17
	TOTAL	6,479	4,814	42	11,335	125
Pollock	1N	9	5	0	14	2
	1S	35	16	0	51	3
	3W	31	18	36	85	7
	3E	7	37	21	48	6
	4Ø	12	8	89	109	11
	4I	0	0	0	0	0
	TOTAL	94	84	146	324	29

Table VIII-5. -- (cont'd)

Toothed smelt	1N	95	64	0	159	7
	1S	43	24	13	80	8
	2I	29	23	0	52	5
	2Ø	311	183	20	514	18
	3W	30	35	0	65	5
	3E	464	280	177	921	12
	4Ø	837	577	103	1,517	48
	4I	98	82	0	180	10
	TOTAL	1,907	1,268	313	3,488	113
Alaska plaice	1N	15	3	0	18	3
	1S	60	28	0	88	8
	2I	31	19	0	50	5
	2Ø	57	28	0	85	10
	3W	10	18	0	28	6
	3E	88	68	0	156	7
	4Ø	332	327	0	659	50
	4I	216	105	0	321	15
	TOTAL	809	596	0	1,405	104
Capelin	1N	0	0	121	121	3
	1S	0	0	46	46	3
	2Ø	0	0	47	47	1
	3W	37	55	217	309	10
	3E	0	0	98	98	2
	4Ø	0	1	0	1	1
	4I	9	16	0	25	3
	TOTAL	46	72	529	647	23
Longhead dab	1S	2	3	0	5	1
	2Ø	9	16	0	25	3
	3E	18	43	0	61	4
	4Ø	85	178	0	263	14
	4I	1	0	0	1	1
	TOTAL	115	240	0	355	23
Bering flounder	1N	34	68	0	102	19
	1S	1	4	0	5	3
	2Ø	16	14	0	30	6
	TOTAL	51	86	0	137	28
Arctic flounder	1N	0	1	0	1	1
	1S	0	1	0	1	1
	2I	9	14	0	23	1
	2Ø	4	2	0	6	1
	4Ø	2	42	0	44	9
	4I	0	1	0	1	1
	TOTAL	15	61	0	76	14
Saffron cod Juvenile	1N	0	0	344	344	6
	1S	0	0	424	424	8
	2I	0	0	182	182	3
	2Ø	0	0	304	304	7
	3W	0	0	85	85	4
	3E	0	0	372	372	10
	4Ø	164	0	2,778	2,942	47
	4I	0	0	368	368	12
	TOTAL	164	0	4,857	5,021	97
TOTAL, ALL SPECIES		31,609				

Table VIII-6.--Number of readable age structures collected by species, sex, and otolith area in Norton Sound, the southeastern Chukchi Sea, and adjacent waters (BLM/OCS survey, 1976).

Species	Sex	Otolith Area: North Southeastern Chukchi Sea and Kotzebue Sound	Otolith Area: South Norton Sound and Northern Bering Sea	Areas Combined
Arctic cod	Male	66	57	123
	Female	68	73	141
Alaska plaice	Male	52	93	145
	Female	33	118	151
Bering flounder	Male	13	2	15
	Female	40	2	42
Pacific herring	Male	85	66	151
	Female	65	58	123
Saffron cod	Male	130	136	266
	Female	135	160	295
Starry flounder	Male	--	61	61
	Female	--	24	24
Toothed smelt	Male	53	76	129
	Female	45	74	119
Yellowfin sole	Male	39	93	132
	Female	78	110	188

Table VIII-7.--Number of weight-at-length observations by species, sex, and otolith area in Norton Sound, the southeastern Chukchi Sea, and adjacent waters (BLM/OCS survey, 1976).

Species	Sex	Otolith Area: North Southeastern Chukchi Sea and Kotzebue Sound	Otolith Area: South Norton Sound and Northern Bering Sea	Areas Combined
Arctic cod	Male	70	67	137
	Female	74	70	144
Alaska plaice	Male	48	93	141
	Female	33	121	154
Bering flounder	Male	17	1	18
	Female	38	1	39
Pacific herring	Male	38	24	62
	Female	38	42	80
Saffron cod	Male	122	128	250
	Female	141	152	293
Starry flounder	Male	1	77	78
	Female	6	31	37
Toothed smelt	Male	49	100	149
	Female	31	89	120
Yellowfin sole	Male	38	92	130
	Female	80	108	188

Table VIII-8.--Number of carapace measurements by species, sex, and subarea in Norton Sound, the southeastern Chukchi Sea, and adjacent waters (BLM/OCS survey, 1976).

Species	Subarea	Number of crab measured Male	Female	Total	Number of observation sets
Red king crab	2Ø	7	0	7	3
	3W	10	2	12	3
	4Ø	1,277	151	1,431	47
	4I	36	27	63	13
Total		1,330	180	1,513	66
Blue king crab	3W	100	77	177	19
	3E	2	1	3	2
Total		102	78	180	21
Tanner crab	1N	1,955	992	2,947	27
	1S	898	426	1,324	16
	2I	103	103	206	6
	2Ø	1,019	480	1,499	18
	3W	1,717	662	2,379	32
	3E	143	39	182	8
	4Ø	123	91	214	19
	4I	1	0	1	1
Total		5,959	2,793	8,752	127
TOTAL, ALL SPECIES	10,445				

Table VIII-9.--Numbers of shell measurements for snails by species, sex, and subareas in Norton Sound, the southeastern Chukchi Sea, and adjacent waters (BLM/OCS survey, 1976).

Species	Subarea	Number of snails measured Male	Female	Total	Number of observation sets
Neptunea borealis	1N	16	21	37	13
	1S	5	5	10	4
	2I	2	0	2	2
	3W	19	14	33	11
	3E	3	1	4	3
	4Ø	5	15	20	4
	4I	3	2	5	4
Total		53	58	111	41
Neptunea heros	1N	250	218	468	22
	1S	168	117	285	10
	2I	95	82	177	7
	2Ø	15	13	28	5
	3W	391	327	718	27
	3E	161	105	266	11
	4Ø	218	230	448	29
	4I	176	160	336	14
Total		1,474	1,252	2,726	125
Neptunea ventricosa	1N	44	80	124	16
	1S	28	36	64	7
	2I	7	14	21	7
	2Ø	7	9	16	5
	3W	105	134	239	24
	3E	64	107	171	11
	4Ø	27	44	71	24
	4I	18	23	41	12
Total		300	447	747	106
Beringius beringii	1N	15	17	32	14
	1S	9	11	20	7
	2I	6	16	22	5
	2Ø	15	9	24	10
	3W	20	30	50	13
	3E	17	16	33	3
	4Ø	62	84	146	24
	4I	22	17	39	11
Total		166	200	366	87
Volutopsius fragilis	1N	15	12	27	9
	1S	1	3	4	1
	2I	12	3	15	5
	3W	0	3	3	3
	3E	5	2	7	2
	4Ø	3	5	8	2
Total		36	28	64	22
Pyrulofusos deformis	1N	15	2	17	2
	2I	5	7	12	4
	2Ø	1	2	3	1
	3W	21	28	49	11
	3E	14	18	32	2
	4Ø	9	9	18	10
	4I	0	2	2	2
Total		65	68	133	32
TOTAL, ALL SPECIES	4,147				

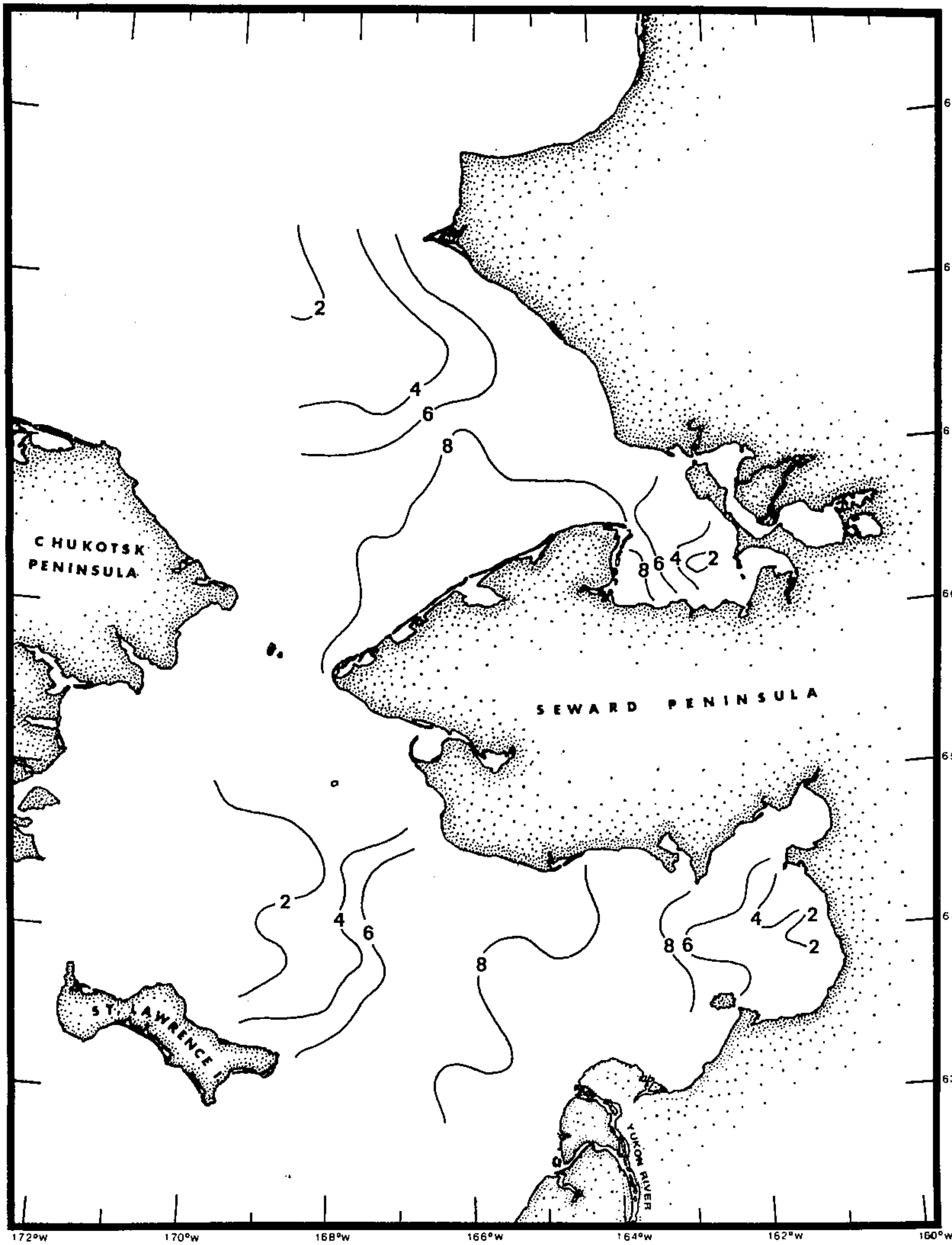


Figure VIII-8.--Bottom temperature isotherms in Norton Sound, the south-eastern Chukchi Sea and adjacent waters for September-October as determined from 1976 Baseline survey.

Total Biomass

The total apparent biomass of all fish and invertebrates in the survey area was estimated at about 340 thousand mt (Table VIII-10). Of this, approximately 38% was located in regions north of Bering Strait (subareas 1 and 2) and 62% to the south (subareas 3 and 4).

In terms of relative abundance, the average catch rate for all taxa combined was highest in Norton Sound (subarea 4, 57.5 kg/km) (Table VIII-11 and Figures VIII-9 and 10). The other three regions, the southeastern Chukchi Sea (subarea 1), Kotzebue Sound (subarea 2), and northern Bering Sea (subarea 3), all had similar catch rates (39.3, 42.9, and 37.1 kg/km, respectively) with the lowest occurring in the latter region. Average catch rate for the entire survey area was approximately 43.2 kg/km trawled.

Relative Importance of Major Taxonomic Groups

For the entire survey area, fish fauna were estimated at over 47,000 mt but accounted for only 14% of the total biomass for the region surveyed. The proportion of biomass varied greatly by subarea, ranging from 42.6% in subarea 4 to 8.4% in subarea 2. Most of the fish biomass (over 77%) occurred south of Bering Strait (Table VIII-10).

By subarea, fish contributed from 7 to 19% of total catch rates. Their catch rate was highest in subarea 4 (10.9 kg/km), lower in subareas 2 and 3 (5.4 and 6.0 kg/km, respectively), and lowest in subarea 1 (2.7 kg/km) (Table VIII-11 and Figures VIII-11 and 12). Average total fish catch rate for the entire survey area was 6.1 kg/km trawled.

Overall, invertebrates accounted for 86% of the total demersal biomass; their biomass was estimated at about 290,000 mt. Nearly 60% of the invertebrate biomass was located in subareas 3 and 4 (Table VIII-10), south of Bering Strait; however, this proportion was almost identical to the proportion of area surveyed south of Bering Strait.

By subarea, invertebrate fauna contributed from 81 to 93% of the total catch rates. The average catch rate for total invertebrates was highest in subarea 4 (46.6 kg/km), decreased in subareas 1 and 2 (36.6 and 37.4 kg/km, respectively) and was lowest in subarea 3 (31.1 kg/km) Table VIII-9 and Figures VIII-13 and 14). Average total invertebrate catch rate for the entire survey area was 37.1 kg/km trawled.

Fish Groups

Fishes accounted for only a relatively small proportion of the overall demersal biomass determined for the 1976 survey region. Five fish families, Gadidae, Pleuronectidae, Cottidae, Clupeidae, and Osmeridae, provided over 95% of the estimated total fish biomass. Of these, the most

Table VIII-10. -- Apparent biomass by major taxonomic groups by subarea estimated from the BLM/OCS survey in Norton Sound and the southeastern Chukchi Sea, September-October, 1976.

Taxa	Biomass for 1/ total survey area (mt)	Proportion of total biomass 1/	Biomass by subarea				Proportion of taxa biomass by subarea			
			1	2	3	4	1	2	3	4
Gadidae	22,692	.067	1,447	1,027	7,674	12,544	.063	.045	.338	.553
Pleuronectidae	10,509	.031	2,783	399	1,999	5,328	.264	.038	.190	.507
Cottidae	6,699	.020	695	101	4,547	1,356	.104	.015	.679	.202
Clupeidae	2,878	.009	637	1,607	453	181	.221	.558	.157	.063
Osmeridae	2,463	.007	320	740	1,035	368	.130	.300	.420	.149
Zoarcidae	888	.003	250	65	387	186	.282	.073	.436	.209
Cyclopteridae	574	.002	333	7	224	10	.580	.012	.390	.017
Stichaeidae	222	.001	45	24	23	130	.203	.108	.104	.586
Agonidae	248	.001	83	8	79	78	.335	.032	.319	.315
Other fish	271	.001	8	2	211	50	.029	.007	.779	.186
Total fish	47,444	.140	6,601	3,980	16,632	20,231	.139	.084	.351	.426
Gastropod molluscs	19,341	.057	8,649	1,253	6,368	3,071	.447	.064	.329	.159
Pelecypod molluscs	632	.002	191	40	99	302	.302	.063	.157	.478
Shrimp	2,904	.009	1,171	175	936	622	.403	.060	.322	.214
<u>Chionoecetes</u> sp.	8,741	.026	3,879	3,597	1,210	55	.444	.412	.138	.006
<u>Paralithodes</u> sp.	5,192	.015	76	13	1,515	3,588	.014	.003	.292	.691
<u>Telemessus</u> sp.	2,769	.008	1,199	217	330	1,023	.433	.078	.119	.480
Total commercially important invertebrates	39,579	.117	15,165	5,295	10,458	8,661	.398	.134	.264	.219
Starfish	161,251	.478	38,842	17,252	34,264	70,893	.24	.107	.212	.440
Other echinoderms	27,010	.080	4,221	42	22,626	121	.156	.002	.838	.006
Other invertebrates 3/	62,395	.185	31,337	4,804	19,243	7,011	.502	.077	.308	.146
Total invertebrates	290,235	.859	89,565	27,393	86,591	86,686	.309	.094	.298	.299
TOTAL CATCH 4/	337,679		96,166	31,373	103,223	106,917	.285	.093	.306	.317

1/ Apparent estimated biomass susceptible to the trawl.
2/ Total biomass for all fish and invertebrate taxa.
3/ Primarily includes coelenterates, pagurid crabs and ascidians.
4/ Total catch of all fish and invertebrate taxa.

Table VIII-11. --Average catch per unit effort of major taxonomic groups by subarea estimated from the BLM/OCS survey in Norton Sound and the southeastern Chukchi Sea, September-October, 1976.

Taxa	CPUE for total survey area	Proportion of total CPUE 1/	CPUE by subarea				Proportion of total CPUE by subarea			
			1	2	3	4	1	2	3	4
Gadidae	2.90	.067	0.59	1.40	2.75	6.74	.015	033	.074	.117
Pleuronectidae	1.34	.031	1.14	0.55	0.72	2.86	.029	.013	.019	.050
Cottidae	0.86	.020	0.28	0.14	1.63	0.73	.007	.003	.044	.013
Clupeidae	0.37	.009	0.26	2.20	0.16	0.10	.007	.051	.004	.002
Osmeridae	0.31	.007	0.13	1.01	0.37	0.20	.003	.024	.010	.003
Zoarcidae	0.11	.003	0.10	0.09	0.14	0.10	.003	.002	.004	.002
Cyclopteridae	0.07	.002	0.14	0.01	0.08	0.01	.004	3/	.002	3/
Sticheidae	0.03	.001	0.01	0.03	0.01	0.07	3/	.001	3/	.001
Agonidae	0.03	.001	0.03	0.01	0.03	0.04	.001	3/	.001	.001
Other fish	0.04	.001	0.02	—	0.09	0.02	.001	3/	.002	3/
Total fish	6.06	.140	2.70	5.44	5.97	10.87	.069	.127	.161	.189
Gastropod molluscs	2.47	.057	3.54	1.71	2.29	1.65	.090	.040	.062	.029
Pelecypod molluscs	0.08	.002	0.08	0.06	0.04	0.16	.002	.001	.001	.003
Shrimp	0.37	.009	0.48	0.24	0.34	0.33	.012	.006	.009	.006
Chionoecetes sp.	1.12	.026	1.59	4.91	0.43	0.03	.040	.115	.012	.001
Paralithodes sp.	0.66	.015	0.03	0.02	0.54	1.93	.001	3/	.015	.034
Telemessus sp.	0.35	.008	0.49	0.30	0.12	0.55	.012	.007	.003	.010
Total commercially important invertebrates	5.05	.117	6.20	7.24	3.75	4.65	.158	.169	.101	.081
Starfish	20.61	.478	15.89	23.57	12.30	38.10	.404	.550	.332	.663
Other echinoderms	3.45	.080	1.73	0.06	8.12	0.06	.044	.001	.219	.001
Other invertebrates 2/	7.99	.185	12.81	6.56	6.90	3.78	.326	.153	.186	.066
Total invertebrates	37.10	.860	36.63	37.43	31.08	46.58	.931	.873	.839	.811
TOTAL CATCH 4/	43.16		39.33	42.87	37.05	57.46				

1/ Catch per unit effort (kg/km) for all fish and invertebrate taxa combined.
2/ Primarily includes coelenterates, pagurid crabs and ascidians.
3/ Proportion less than .0005.
4/ Total catch for all fish and invertebrate taxa.

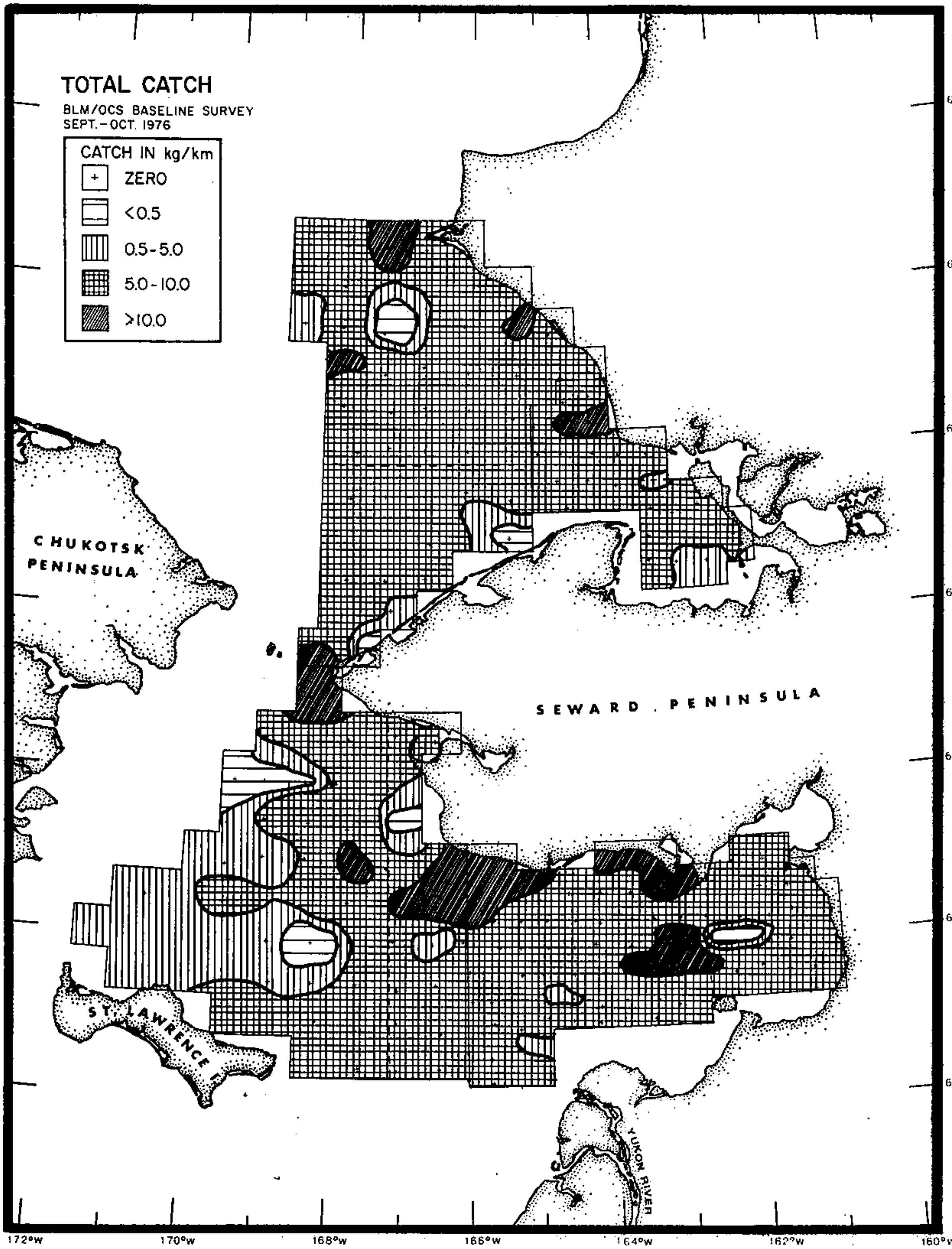


Figure VIII-9.--Distribution and relative abundance by weight of total fish and invertebrates in Norton Sound, the southeastern Chukchi Sea and adjacent waters (BLM/OCS survey, 1976).

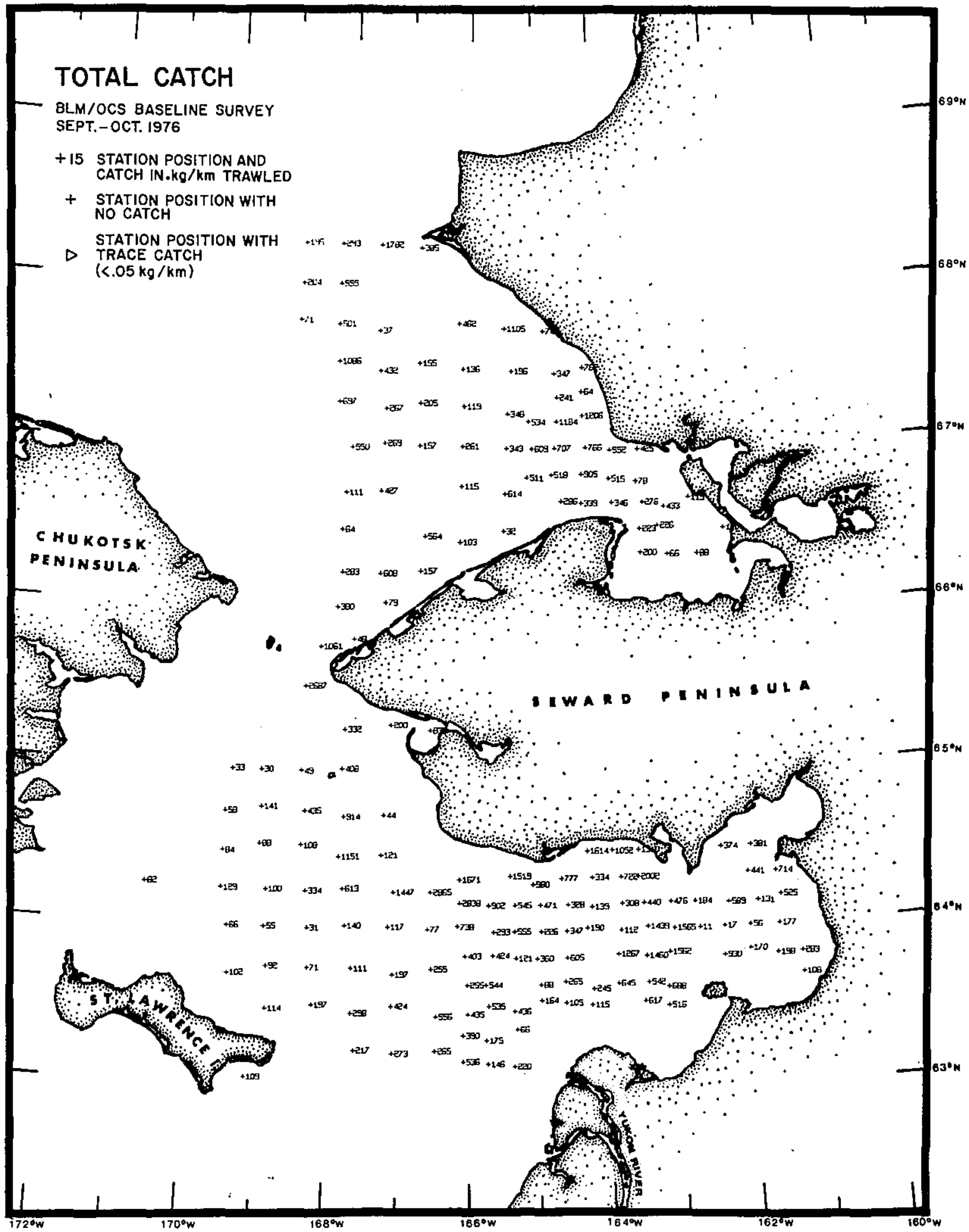


Figure VIII-10.--Distribution of catch rates by weight by total fish and invertebrates in Norton Sound, the southeastern Chukchi Sea and adjacent waters (BLM/OCS survey, 1976).

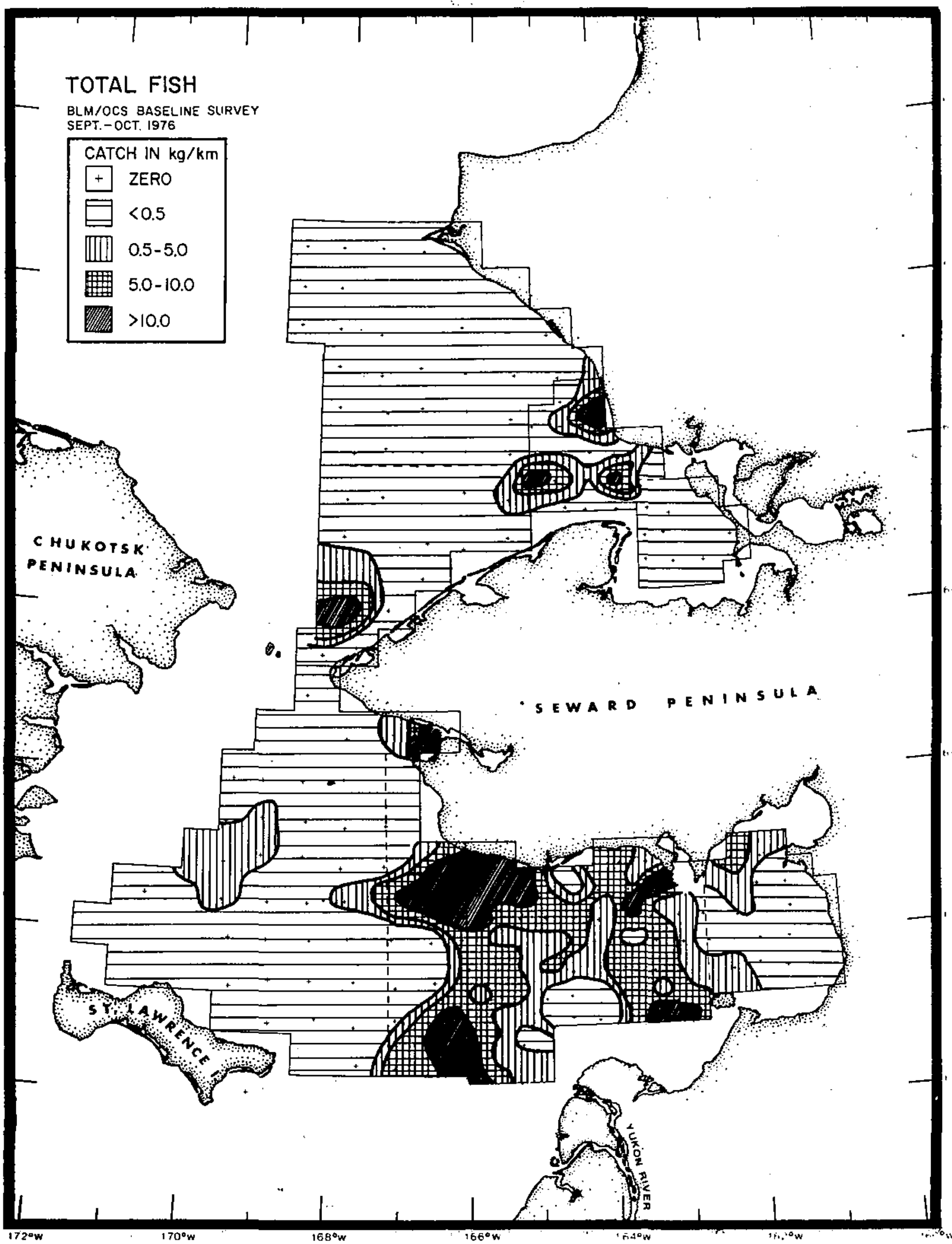


Figure VIII-11.--Distribution and relative abundance by weight of total fish in Norton Sound, the southeastern Chukchi Sea and adjacent waters (BLM/OCS survey, 1976).

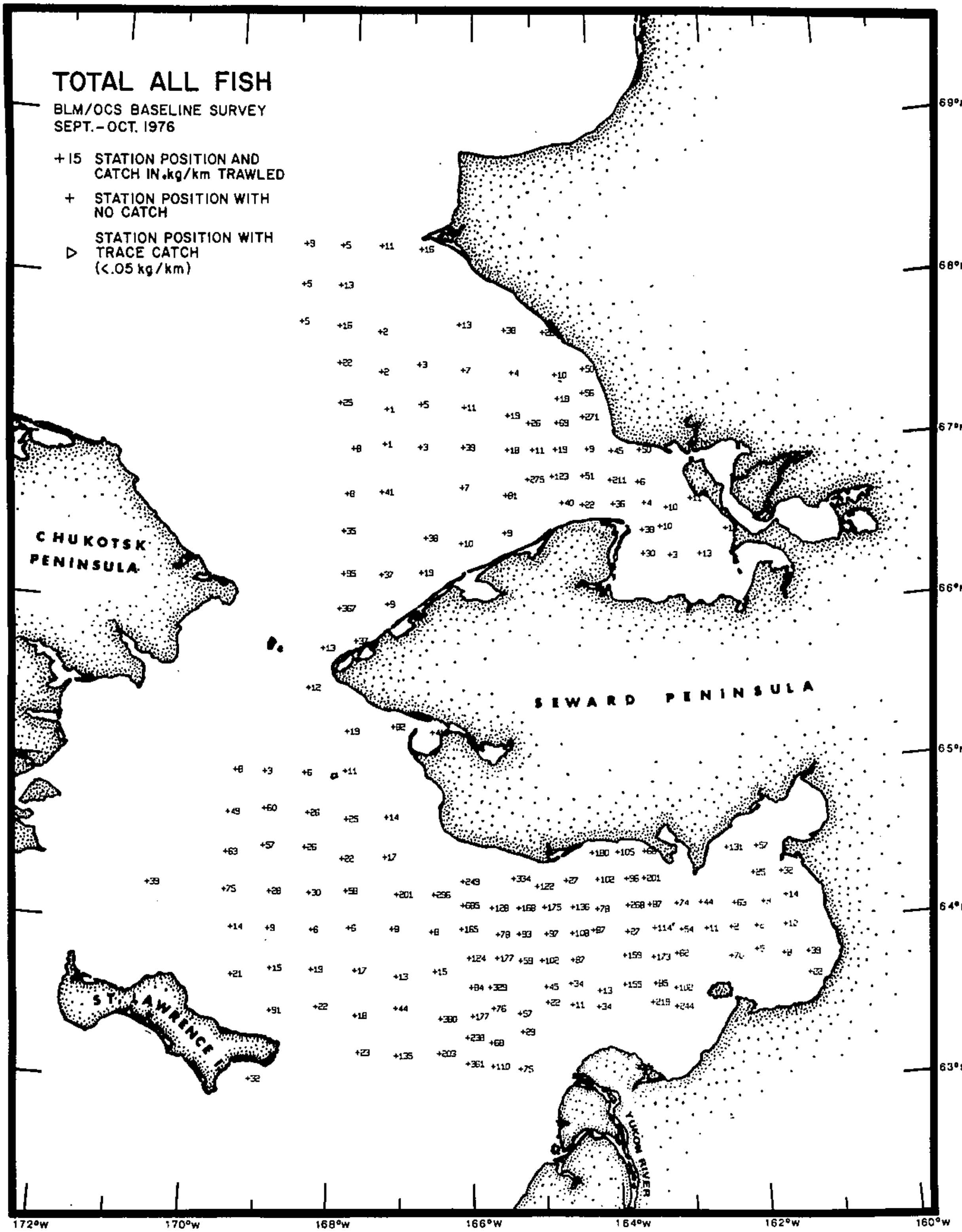


Figure VIII-12.--Distribution of catch rates by weight of total fish in Norton Sound, the southeastern Chukchi Sea and adjacent waters (BLM/OCS survey, 1976).

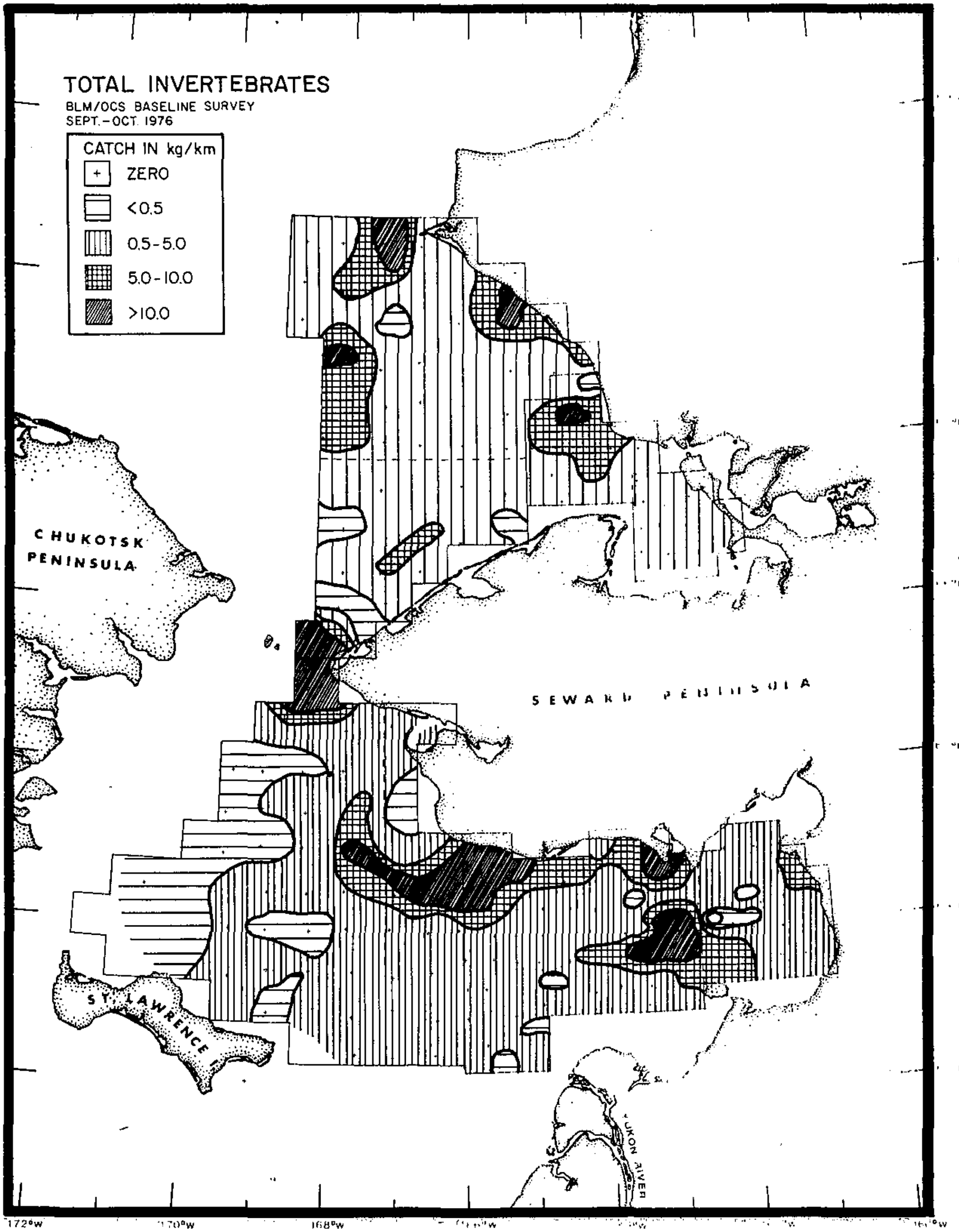


Figure VIII-13.--Distribution and relative abundance by weight of total invertebrates in Norton Sound, the southeastern Chukchi Sea and adjacent waters (BLM/OCS survey, 1976).

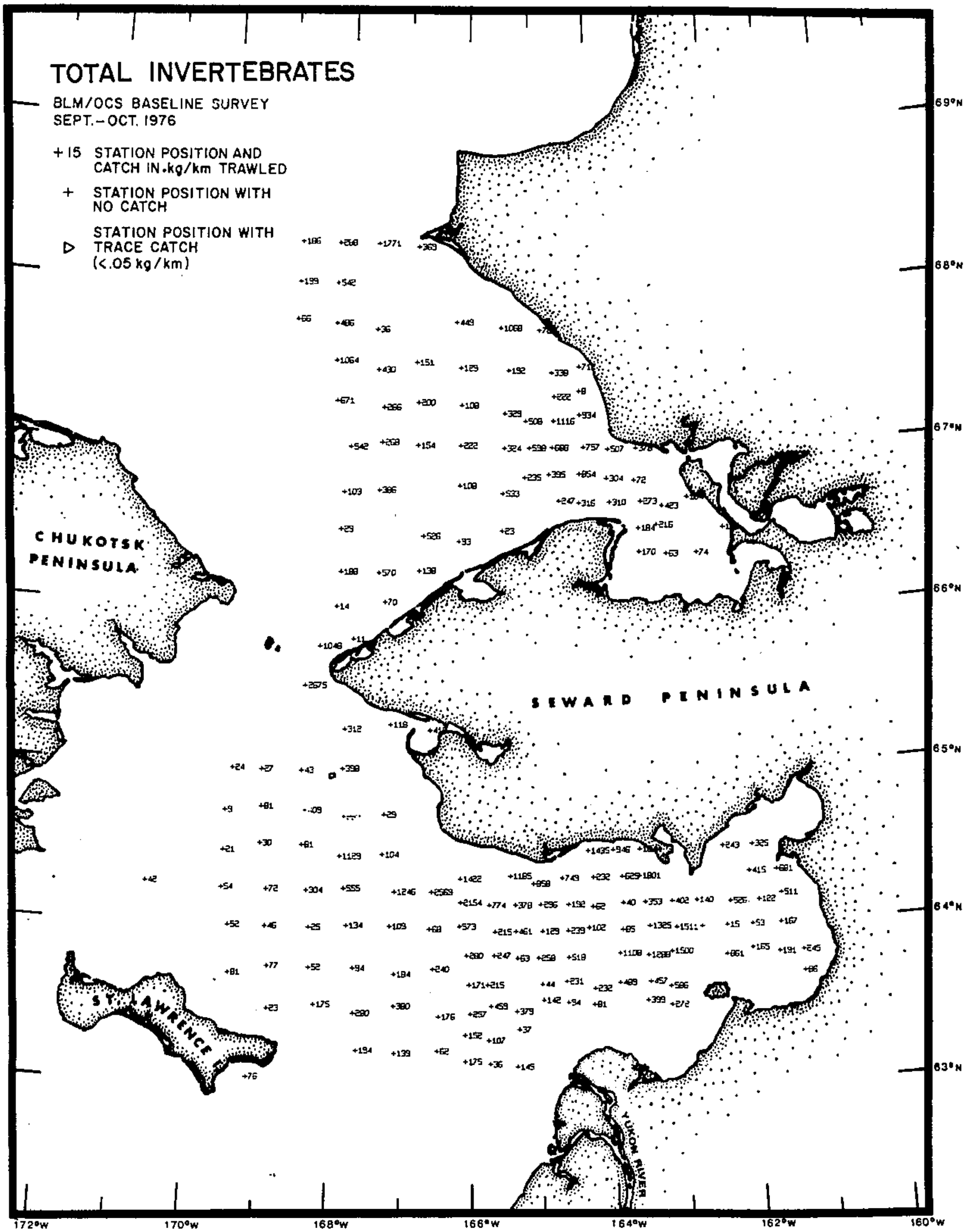


Figure VIII-14.--Distribution of catch rates by weight of total invertebrates in Norton Sound, the southeastern Chukchi Sea and adjacent waters (BLM/OCS survey, 1976).

abundant families were Gadidae and Pleuronectidae, accounting for 70% of the fish biomass with this proportion varying from 36% in subarea 2 to 89% in subarea 4. Families Cottidae, Clupeidae, and Osmeridae, combined, contributed an additional 25% to total fish biomass. Of these three families, cottids were most abundant in the offshore subarea 3 while clupeids and osmerids were found in greatest concentration in the northern inshore subarea 2. Three other families, Zoarcidae, Stichaeidae, and Agonidae comprised most of the remaining 5% of the total fish biomass. Greatest abundance of these families occurred in the offshore subareas 1 and 3.

Gadidae (saffron cod and Arctic cod)

Gadids were represented by four species (Table VIII-3), with an estimated total apparent biomass of nearly 23,000 mt (Table VIII-10). This family was the most abundant component of the fish community, its members occurring in all subareas and accounting for nearly 48% of the total fish biomass (7% of the total demersal biomass). Two gadids, saffron cod and Arctic cod, comprised 99% of the catch of this family; walleye pollock and Pacific cod were found only in trace amounts. Maximum contribution of the Gadidae to total catch rates occurred in subarea 4 (6.7 kg/km), where they accounted for 62% of the catch rate for all fish (12% of the total demersal fauna catch rate) (Figures VIII-15 and 16).

Pleuronectidae (flatfishes)

The pleuronectids were represented by 8 species and 7 genera, with an apparent total biomass estimated at 11,000 mt. This family ranked second only to the gadids in relative overall abundance, comprising 22% of the total fish biomass for the survey region (Table VIII-10). Three species, starry flounder, Alaska plaice, and yellowfin sole, accounted for nearly 88% of the pleuronectid biomass. Flatfish distribution and abundance varied considerably by subarea (Figures VIII-17 and 18), with the highest average catch rate occurring in subarea 4 (2.9 kg/km), decreasing in subareas 1 and 3 (1.1 and 0.7 kg/km, respectively) and lowest in subarea 2 (0.5 kg/km). Pleuronectidae was the most abundant fish family in subarea 1.

Cottidae (sculpins)

Sculpins were represented by 13 species and 10 genera, with an apparent biomass estimated at nearly 7,000 mt. This family accounted for over 14% of the total fish biomass (2% of total biomass) in the survey area and were distributed over the entire survey region (Figures VIII-19 and 20). Highest catch rates occurred in the offshore subarea 3 (1.6 kg/km), where 68% of the total cottid biomass was found. The average catch rate for cottids over the entire survey region was 0.9 kg/km trawled and three species, the shorthorn sculpin, plain sculpin, and Arctic staghorn sculpin, comprised 86% of this catch rate.

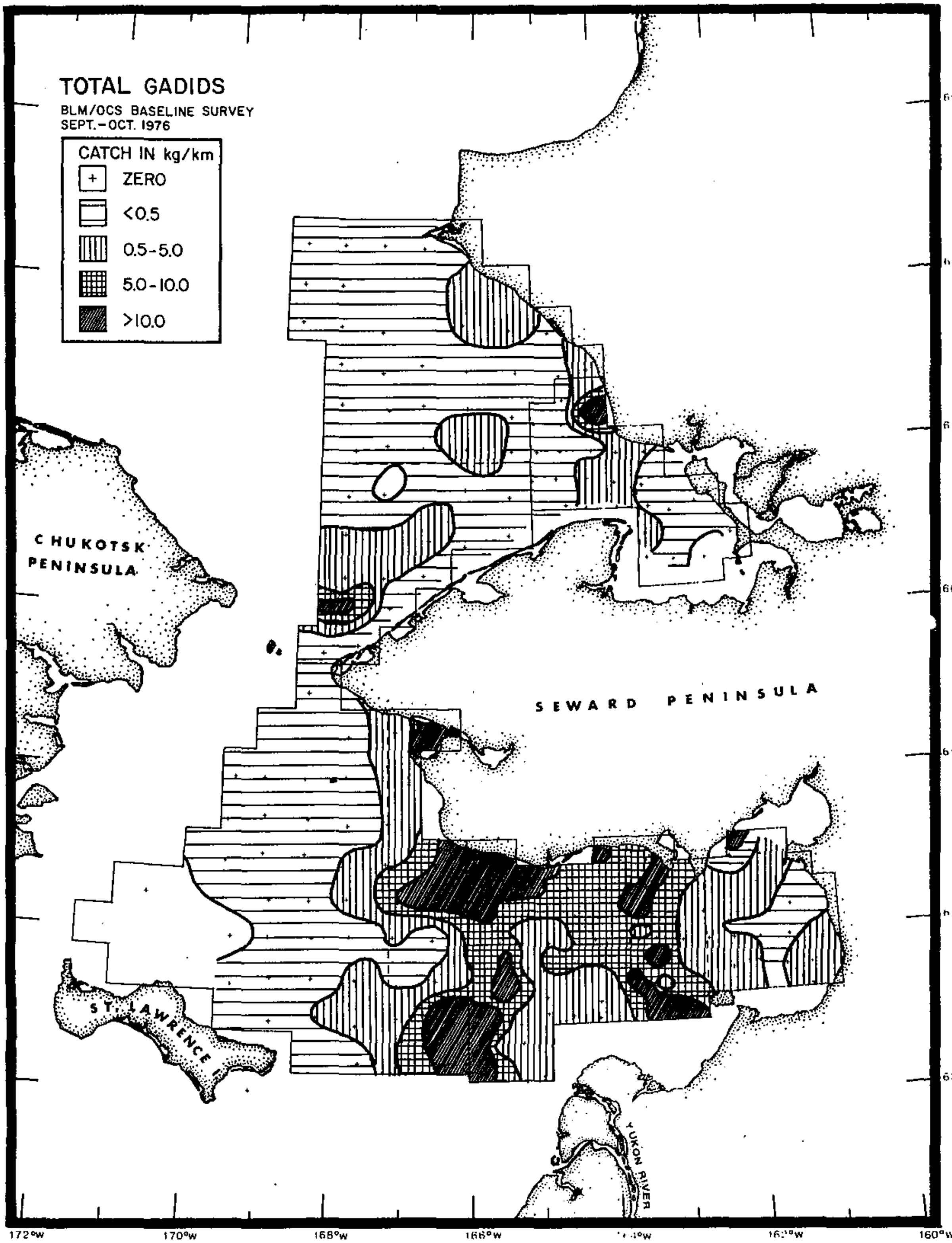


Figure VIII-15.--Distribution and abundance by weight of total gadids in Norton Sound, the southeastern Chukchi Sea and adjacent waters (BLM/OCS survey, 1976).

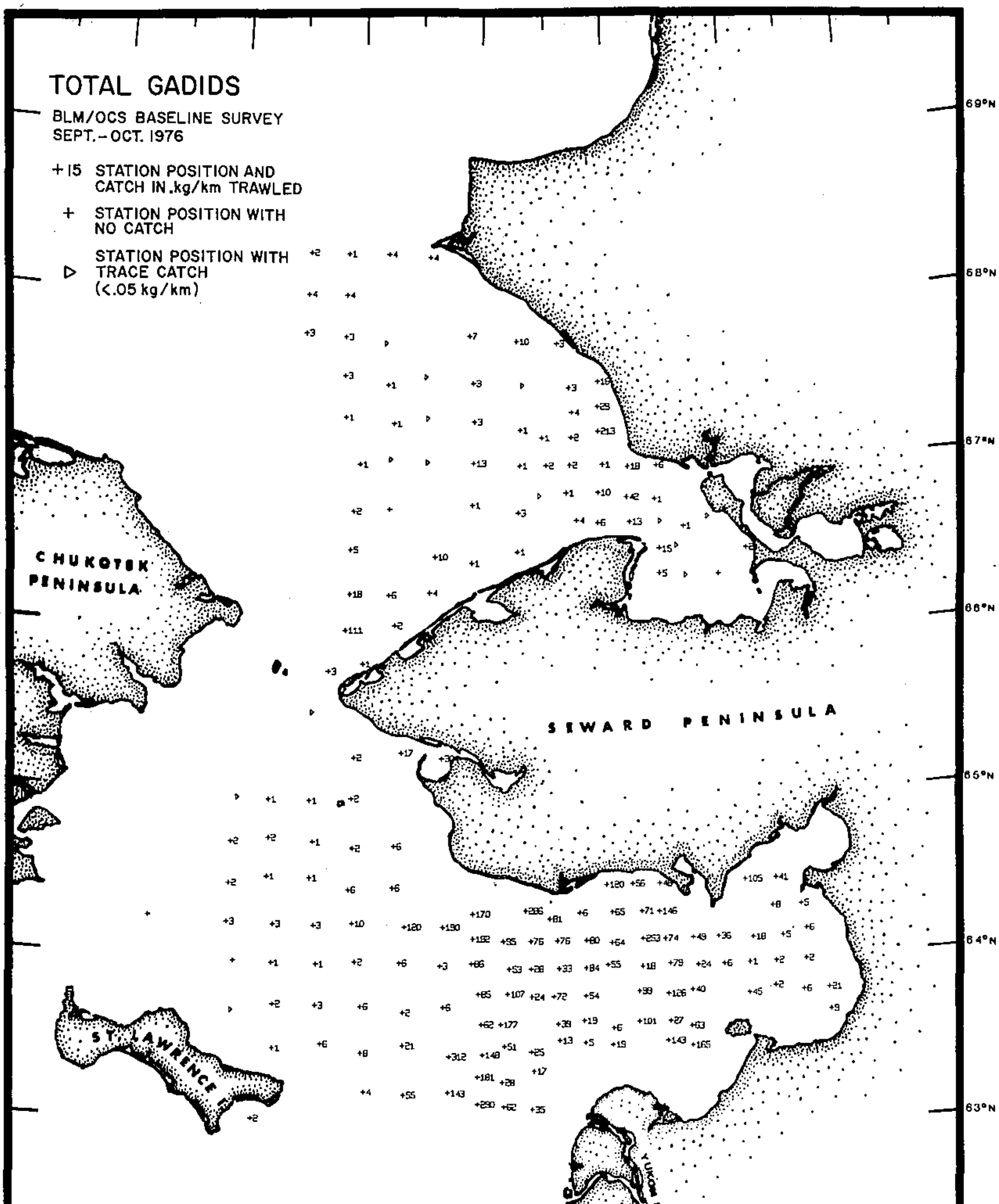


Figure VIII-16.--Distribution of catch rates by weight of total gadids in Norton Sound, the southeastern Chukchi Sea and adjacent waters (BLM/OCS survey, 1976).

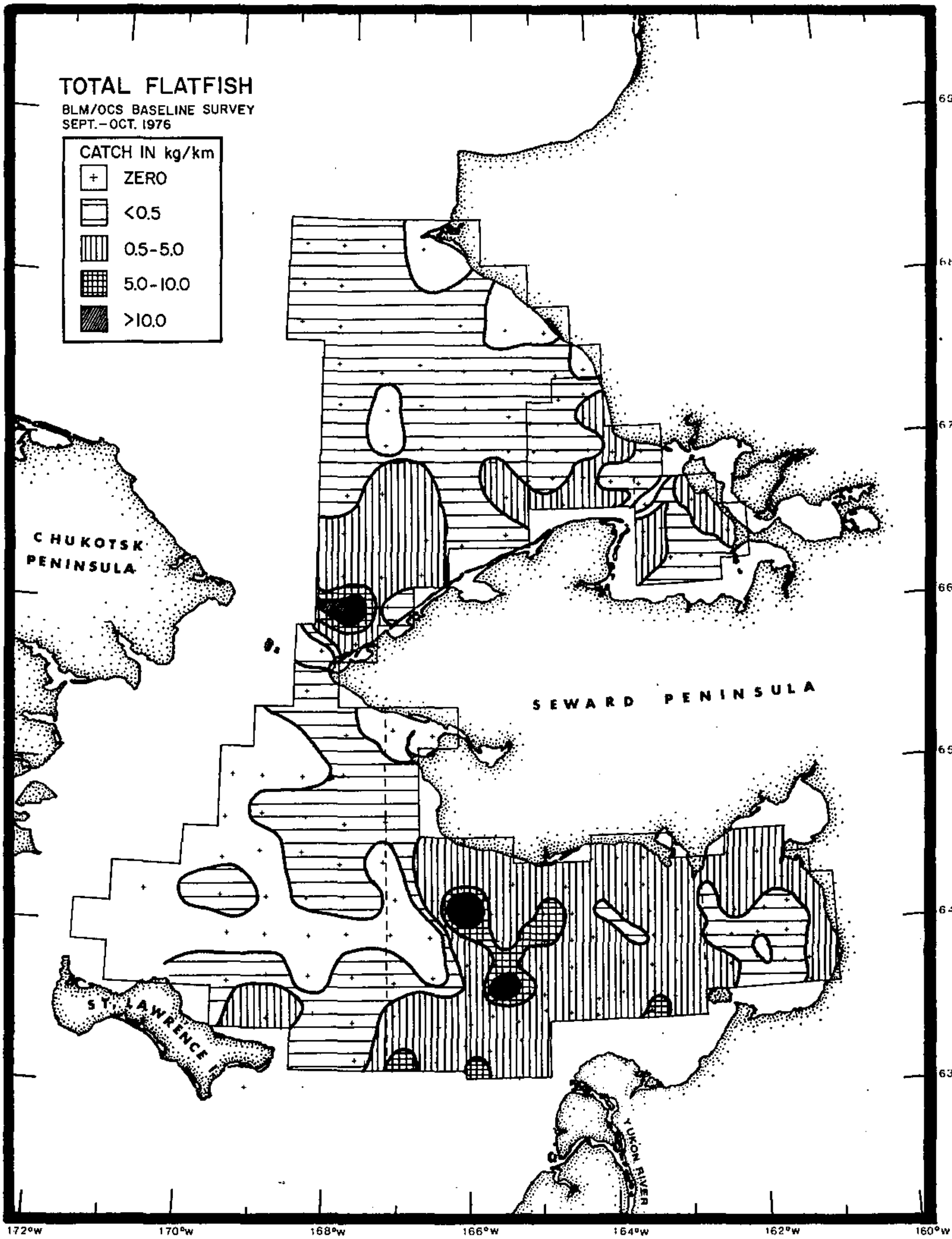


Figure VIII-17.--Distribution and relative abundance by weight of total flatfish in Norton Sound, the southeastern Chukchi Sea and adjacent waters (BLM/OCS survey, 1976).

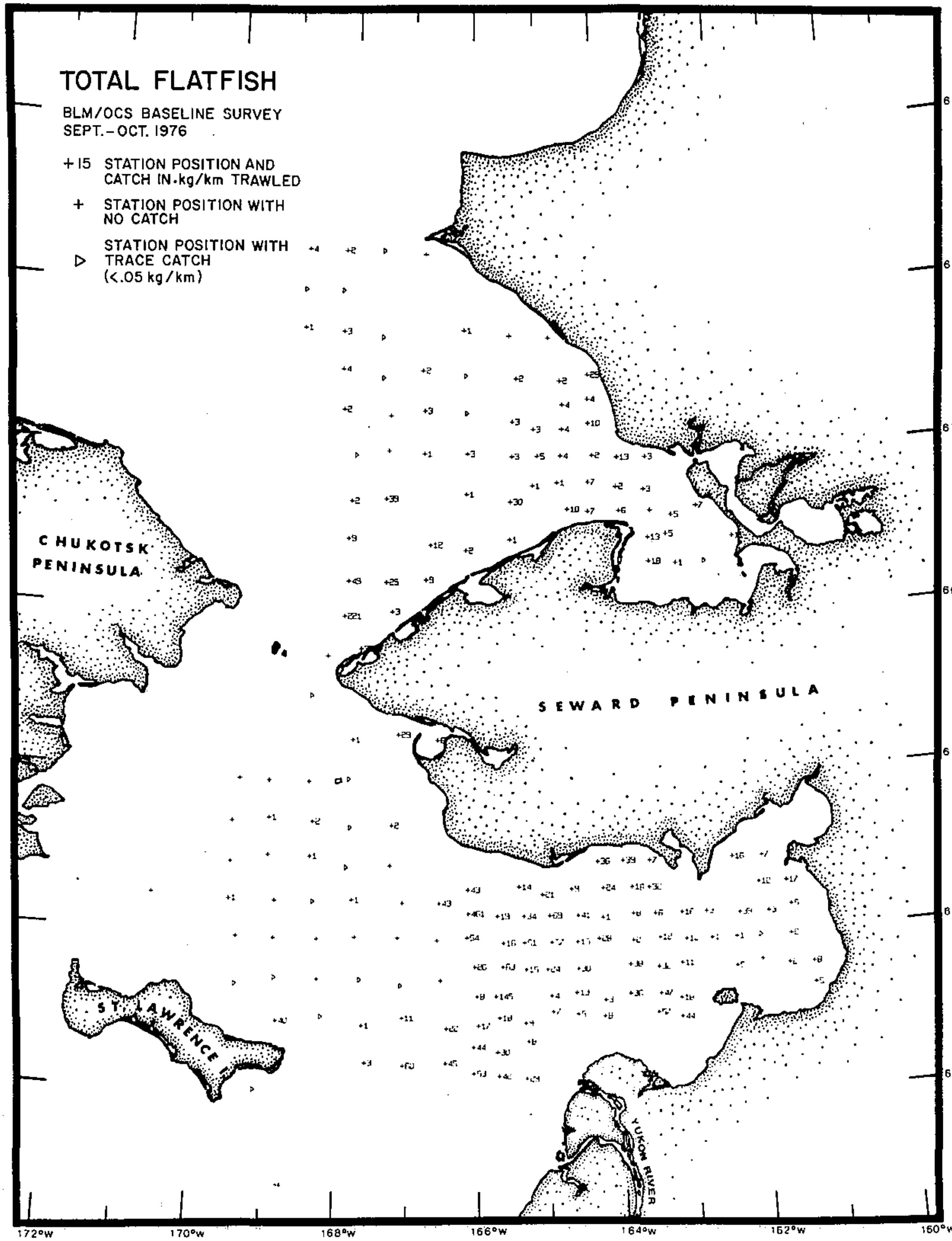


Figure VIII-18.--Distribution of catch rates by weight of total flatfish in Norton Sound, the southeastern Chukchi Sea and adjacent waters (BLM/OCS survey, 1976).

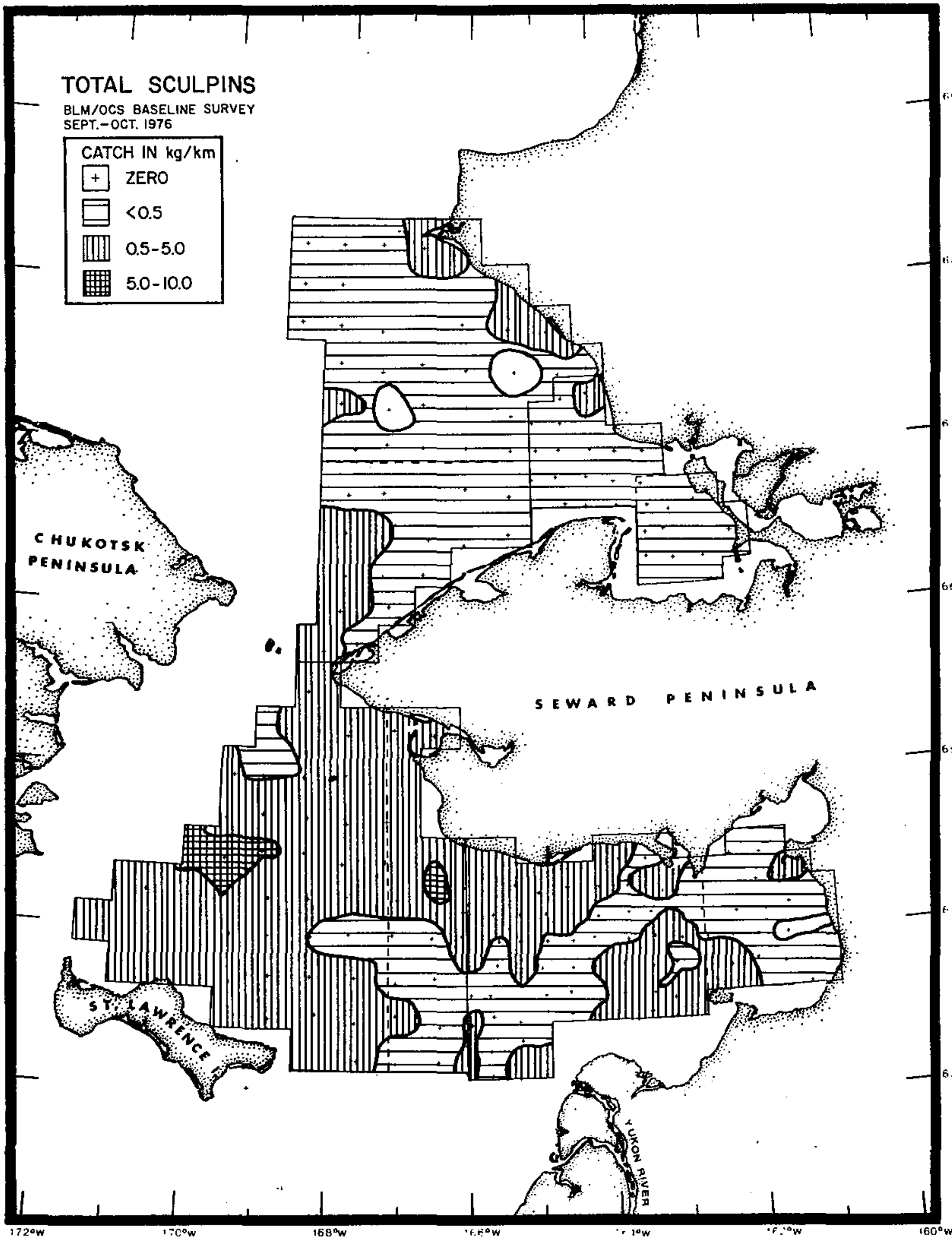


Figure VIII-19.--Distribution and relative abundance by weight of total sculpins in Norton Sound, the southeastern Chukchi Sea and adjacent waters (BLM/OCS survey, 1976).

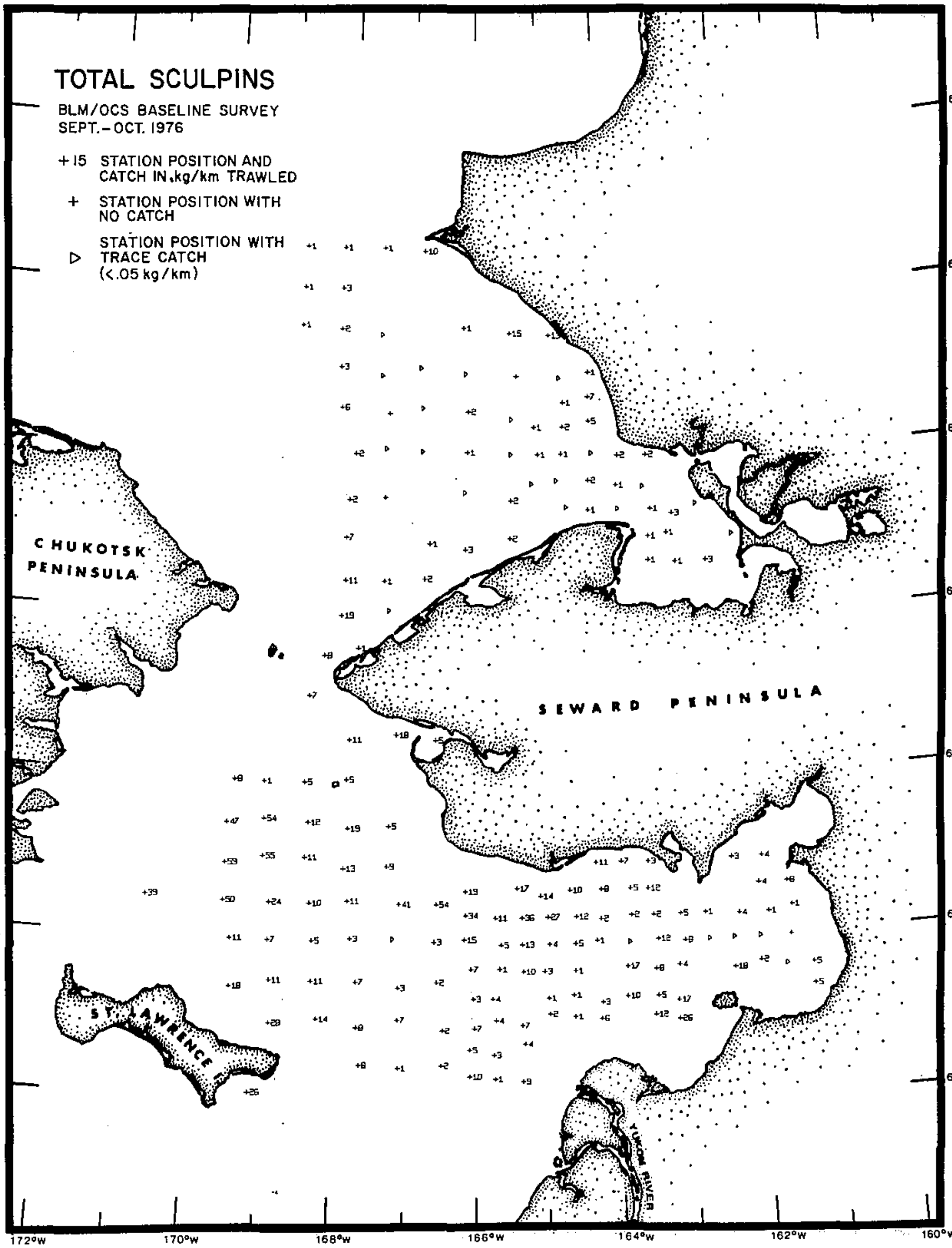


Figure VIII-20.--Distribution of catch rates by weight of total sculpins in Norton Sound, the southeastern Chukchi Sea and adjacent waters (BLM/OCS survey, 1976).

Clupeidae and Osmeridae (herring and smelt)

Clupeids and osmerids were represented by 4 species and genera and comprised about 11% of the total fish biomass or approximately 5,000 mt. Of this amount, 44% occurred in inshore subarea 2 with clupeids being the most abundant fish family in that subarea (Figures VIII-21 and 22). Average catch rates ranged from 3.2 kg/km in subarea 2 to 0.3 kg/km in subarea 4. The overall average catch rate for these families was 0.7 kg/km trawled with Pacific herring and toothed smelt accounting for 98% of this amount.

Zoarcidae, Cyclopteridae, Stichaeidae, and Agonidae (eelpouts, snailfish, pricklebacks, and sea poachers)

These four families were represented by 12 species from 9 genera and all were caught in trace amounts during the survey. Estimated total biomass for this fish group was about 2,000 mt with an overall average catch rate of 0.3 kg/km trawled. Centers of abundance varied by family with pricklebacks and sea poachers found in slightly greater amounts in subarea 4 (Figures VIII-23 and 24), snailfish in subarea 1 (Figure VIII-25), and eelpouts in subarea 3 (Figure VIII-26).

Invertebrate Groups

Since this study focused on invertebrates only of potential economic importance, this segment of the invertebrate fauna was the portion examined in detail. Another group, the echinoderms, were also examined because of their extremely high abundance relative to other survey region fauna.

The major component of the survey catch was echinoderms, accounting for 65% of the invertebrate catch and nearly 56% of the total demersal biomass. The proportion of catch and biomass varied over all subareas with 48 and 45%, respectively in subarea 1; and 82 and 60%,respectively,in subarea 4. Invertebrates of potential commercial importance included several types of crustaceans and molluscs and accounted for about 14% of the total invertebrate fauna. The crustacean group had their greatest biomass in subarea 2 while molluscs were most abundant in subarea 1. The remaining 22% of the invertebrate biomass primarily included coelenterates, pagurid crabs, and ascidians and were most abundant in the northern and western portions of the survey area, subareas 1 and 3.

Echinodermata (starfish, basketstars, and other echinoderms)

Echinodermata was represented by 24 species (Table VIII-4) with an estimated apparent biomass of over 180,000 mt (Table VIII-10). This phyla was by far the most abundant component of the demersal community in the survey area, occurring in large amounts in all subareas. Starfish

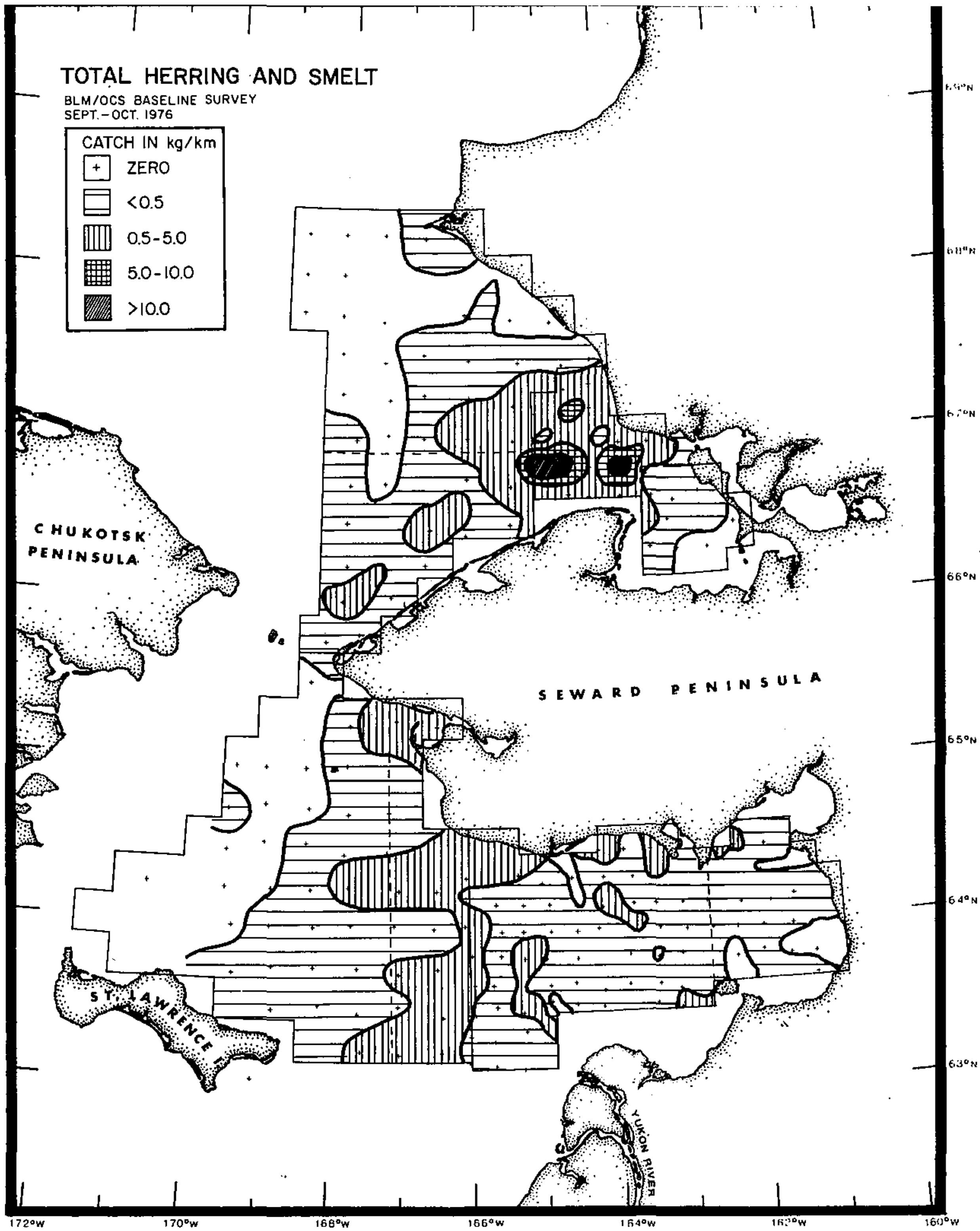


Figure VIII-21.--Distribution and relative abundance by weight of herring and smelt in Norton Sound, the southeastern Chukchi Sea and adjacent waters (BLM/OCS survey, 1976).

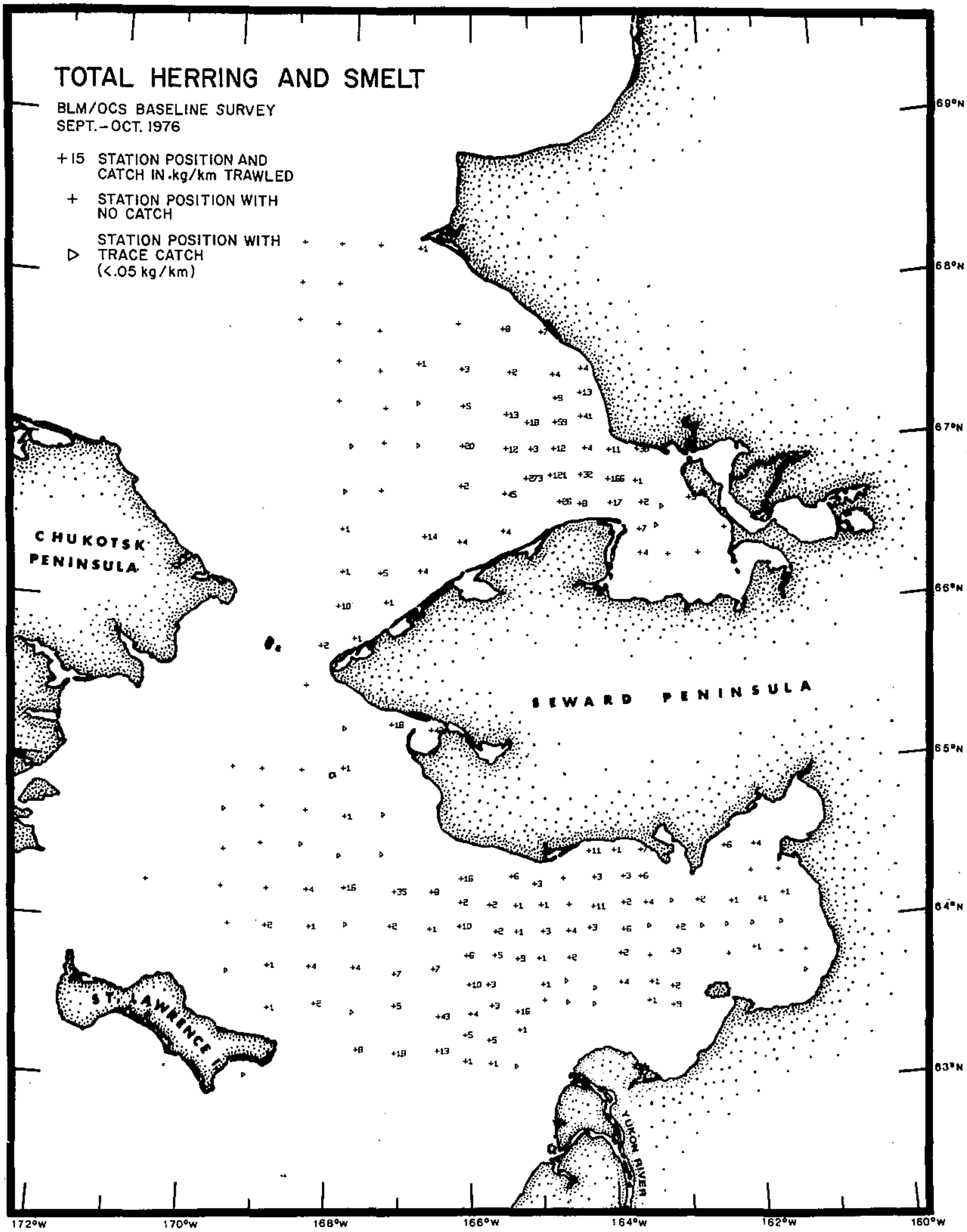


Figure VIII-22.--Distribution of catch rates by weight of herring and smelts in Norton Sound, the southeastern Chukchi Sea and adjacent waters (BLM/OCS survey, 1976).

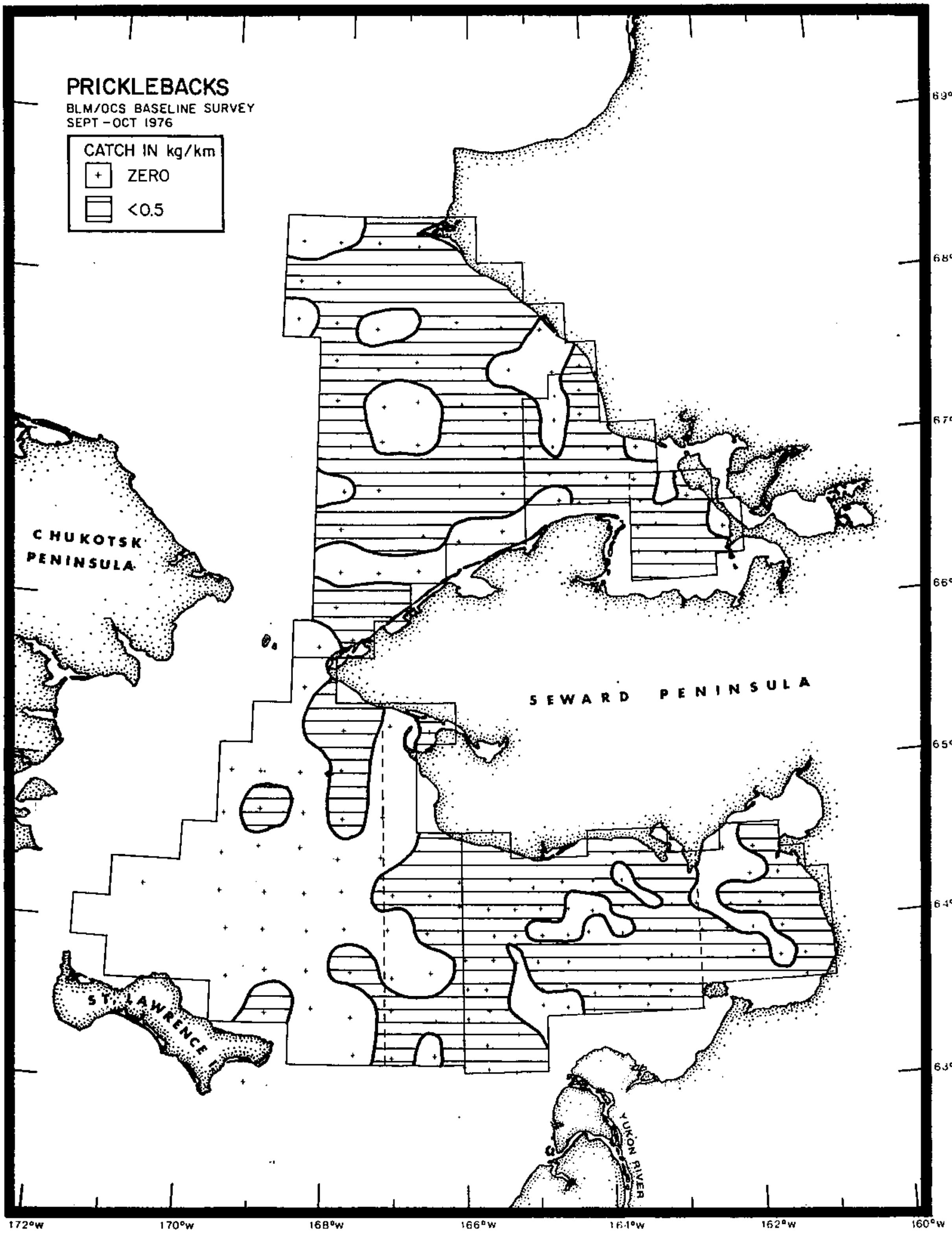


Figure VIII-23.--Distribution and relative abundance of pricklebacks in Norton Sound, the southeastern Chukchi Sea and adjacent waters (BLM/OCS survey, 1976).

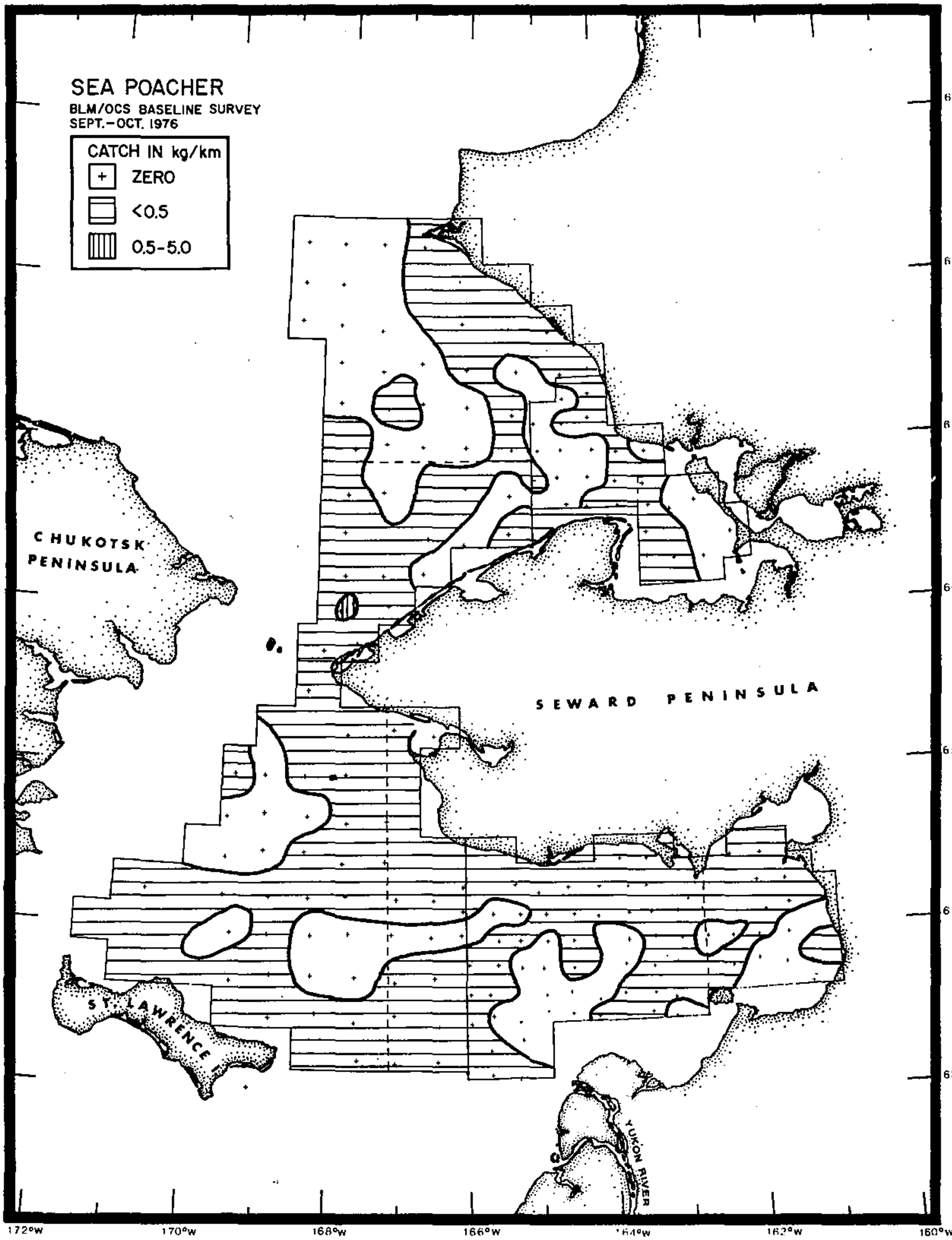


Figure VIII-24.--Distribution and relative abundance of sea poachers in Norton Sound, the southeastern Chukchi Sea and adjacent waters (BLM/OCS survey, 1976).

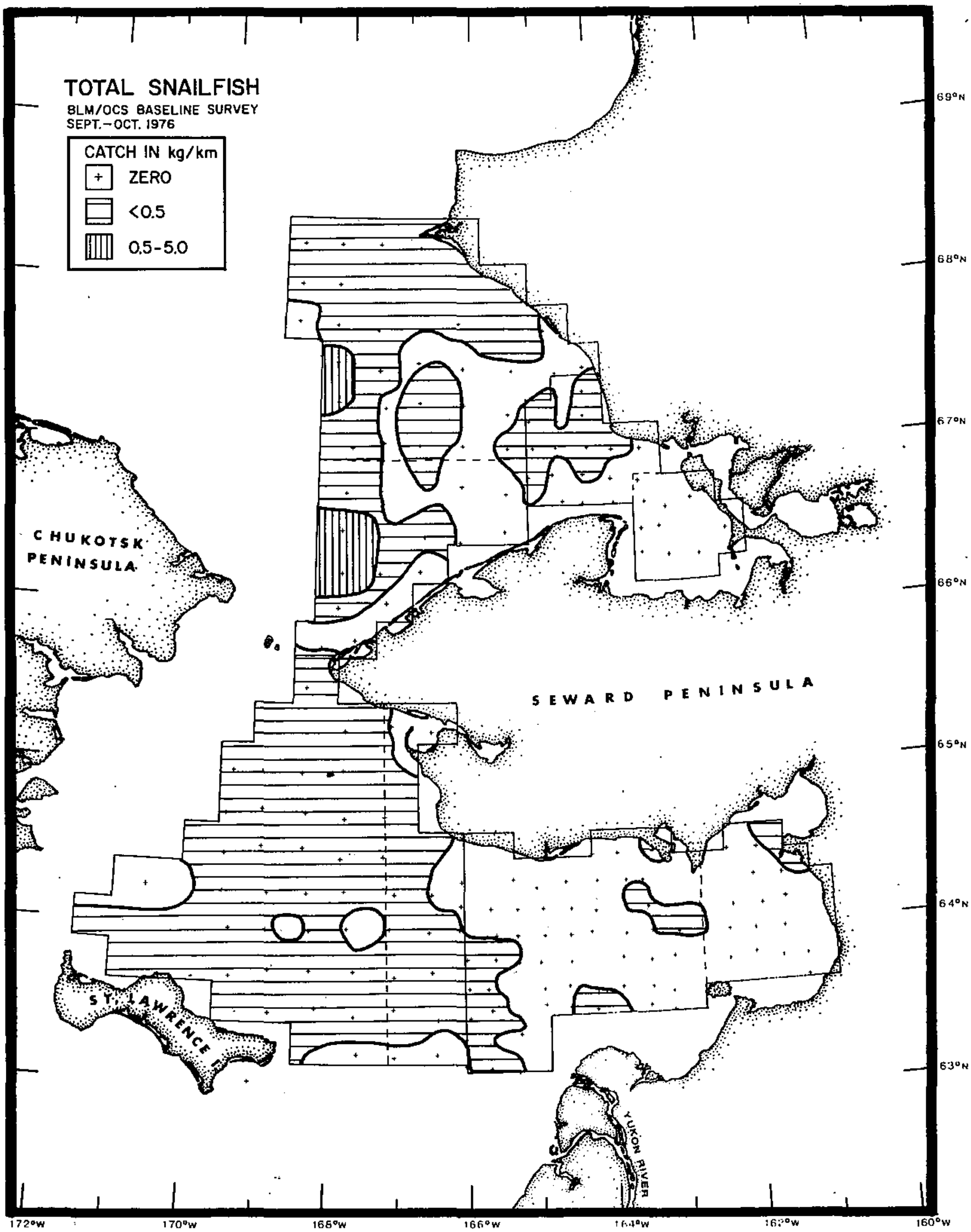


Figure VIII-25.--Distribution and relative abundance by weight of total snailfish in Norton Sound, the southeastern Chukchi Sea and adjacent waters (BLM/OCS survey, 1976).

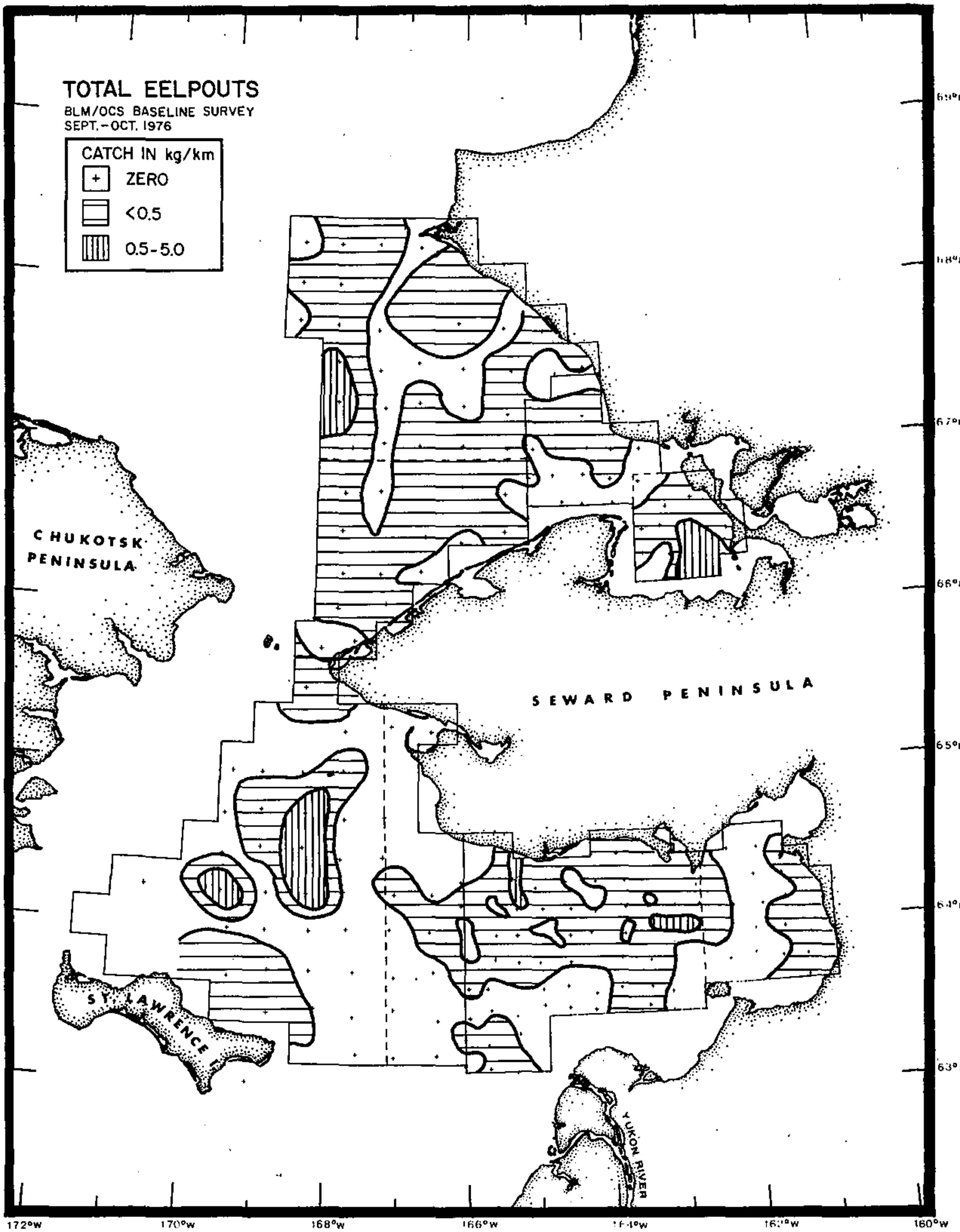


Figure VIII-26.--Distribution and relative abundance by weight of total eelpouts in Norton Sound, the southeastern Chukchi Sea and adjacent waters (BLM/OCS survey, 1976).

comprised most of the echinoderm catch and were most abundant in subarea 4 (Figures VIII-27 and 28). Members of the family Asteridae accounted for the major portion of the starfish biomass while the basketstar, Gorgonocephalus caryi, was the dominant element of the remaining echinoderm catch. Maximum contribution of Echinodermata to total catch rates occurred in the embayments of Norton Sound (subarea 4, 38.2 kg/km) and Kotzebue Sound (subarea 2, 23.5 kg/km) where they accounted for 66 and 55%, respectively, of the average catch rates of all species.

Crustacea (shrimp and crabs)

Crustaceans of possible economic importance were represented by 10 species of shrimp and 3 crab species, with an apparent total biomass estimated at about 19,000 mt. The abundance and relative importance of this component of the invertebrate fauna varied by subarea. Overall maximum abundance was in subarea 1 (Table VIII-10), but by groups, maximum relative abundance and catch rates were as follows: for shrimp, subarea 1 (0.5 kg/km, Figures VIII-29 and 30); Tanner crab, subarea 2 (4.9 kg/km, Figures VIII-31 and 32); and king crab, subareas 3 and 4 (.05 and 1.9 kg/km, respectively, Figures VIII-33 and 34).

Mollusca (snails and clams)

Gastropod and pelecypod molluscs were represented by 87 species, with an apparent biomass estimated at over 20,000 mt. Relative abundance was somewhat similar by subarea with slightly greater catch rates occurring in subareas 1 and 3 (3.6 and 2.3 kg/km, respectively). Gastropods (or snails) comprised the major portion of mollusc catches (97%) with centers of abundance again in subareas 1 and 3 (Figures VIII-35 and 36). Pelecypods (clams) were caught in small amounts throughout the study region with slightly larger catch rates occurring in subarea 4 (Figures VIII-37 and 38).

Other invertebrates (coelenterates, pagurid crabs, ascidians, and others)

Other invertebrates were represented by 41 species from 10 phyla, with an apparent total biomass estimated at over 62,000 mt, of which over 50% was found in subarea 1 (Table VIII-10). Overall catch rate for this group was 8.0 kg/km.

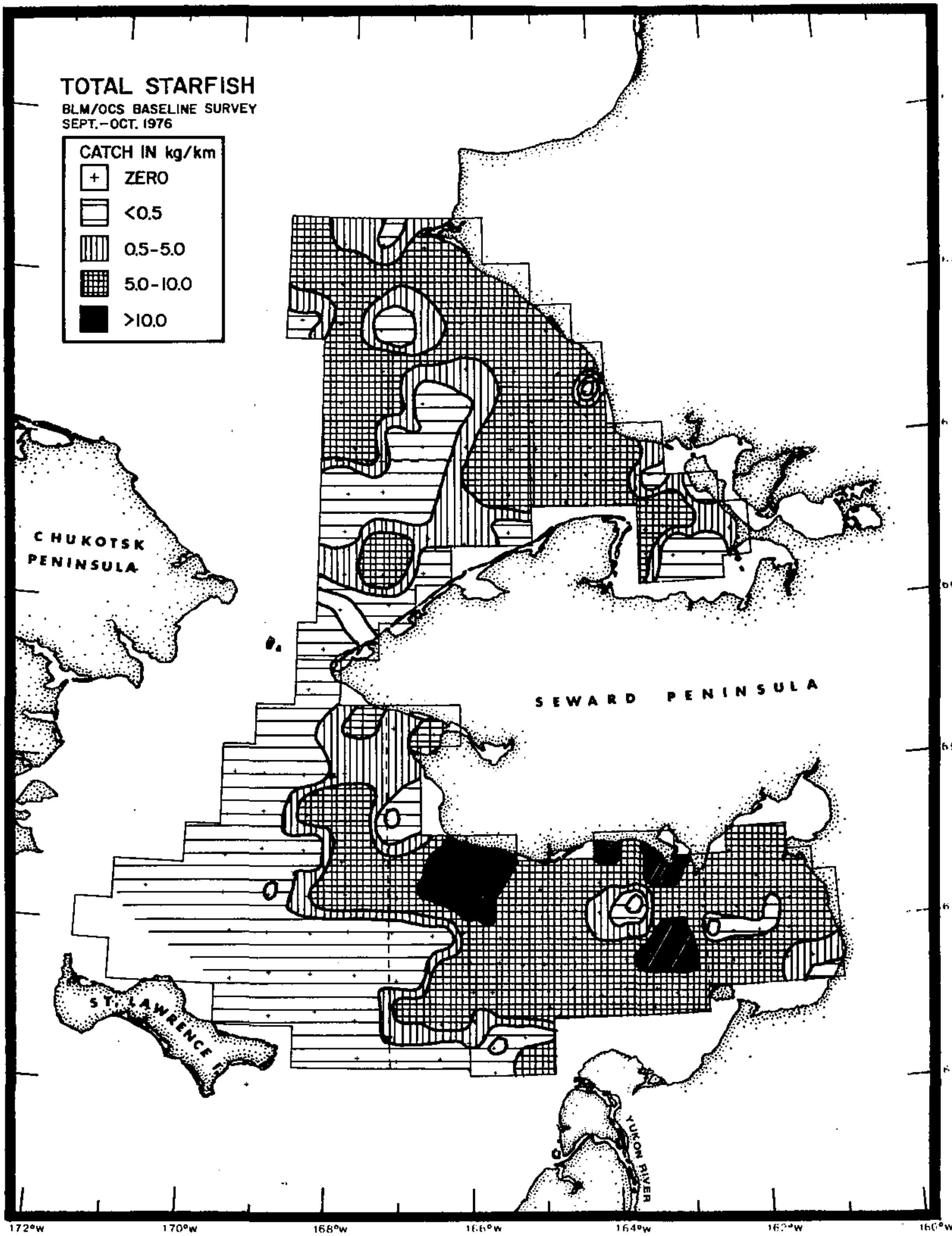


Figure VIII-27.--Distribution and relative abundance by weight of total starfish in Norton Sound, the southeastern Chukchi Sea and adjacent waters (BLM/OCS survey, 1976).

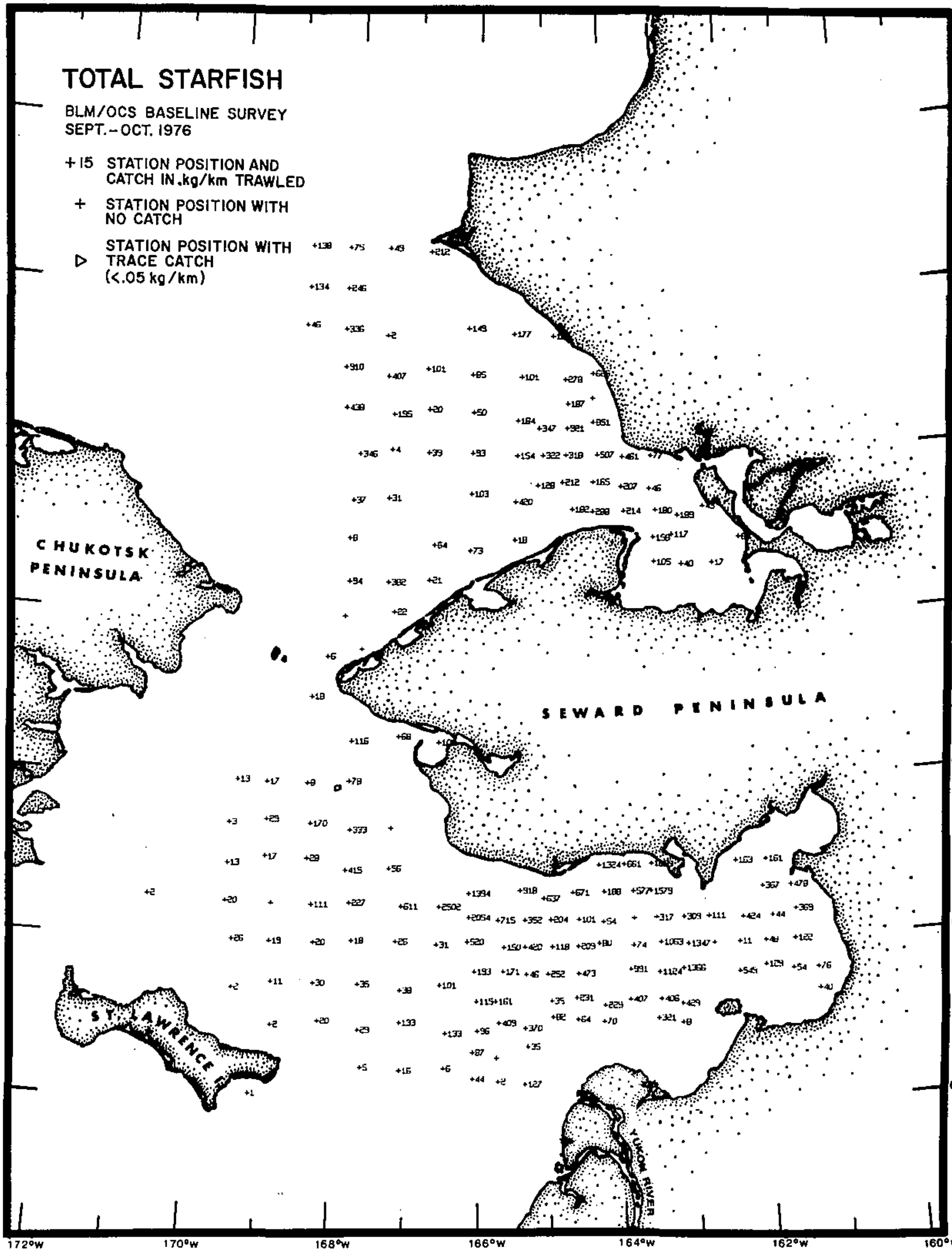


Figure VIII-28.--Distribution of catch rates by weight of total starfish in Norton Sound, the southeastern Chukchi Sea and adjacent waters (BLM/OCS survey, 1976).

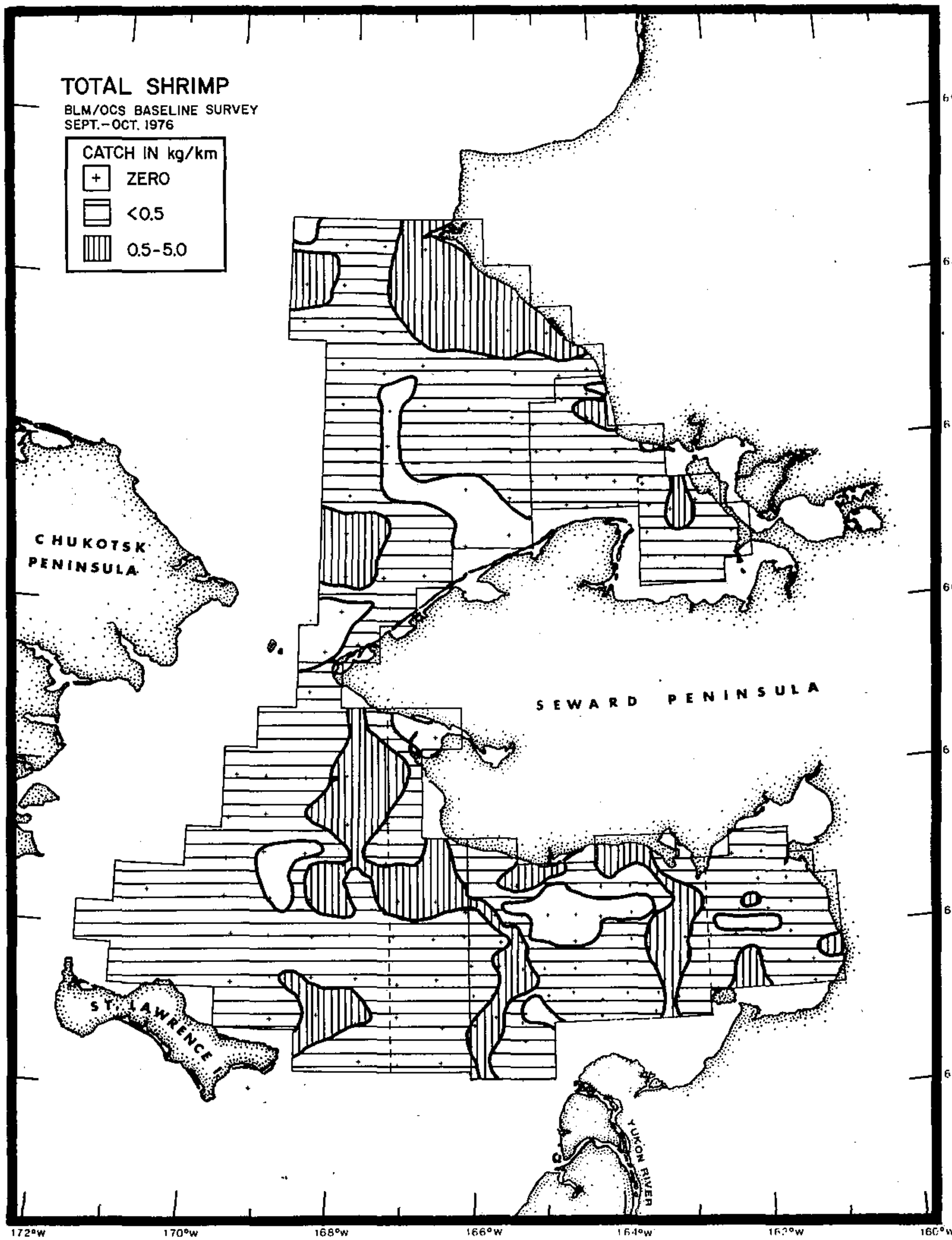


Figure VIII-29.--Distribution and relative abundance by weight of total shrimp in Norton Sound, the southeastern Chukchi Sea and adjacent waters (BLM/OCS survey, 1976).

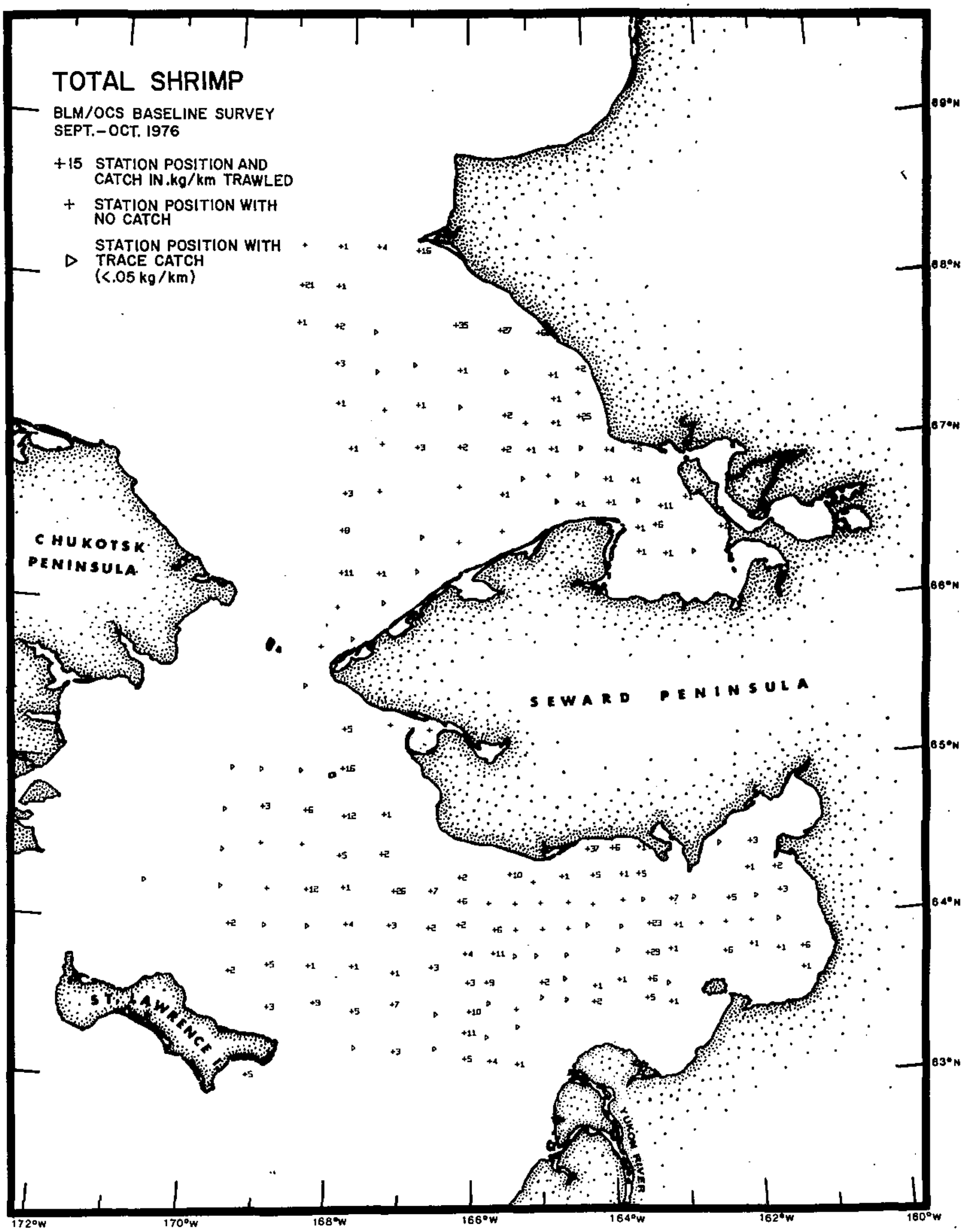


Figure VIII-30.--Distribution of catch rates by weight of total shrimp for Norton Sound, the southeastern Chukchi Sea and adjacent waters (BLM/OCS survey, 1976).

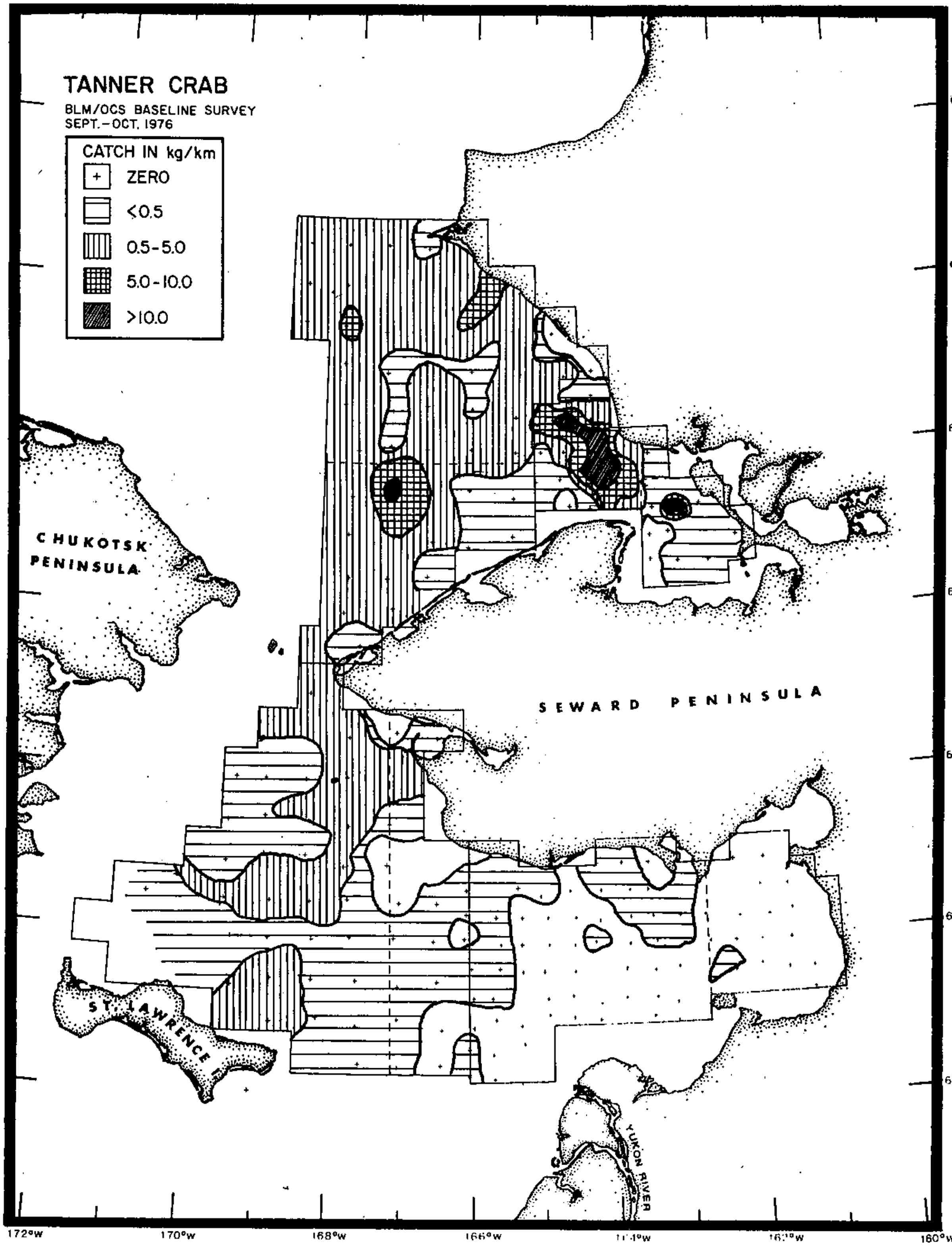


Figure VIII-31.--Distribution and relative abundance by weight of total Tanner crabs in Norton Sound, the southeastern Chukchi and adjacent waters (BLM/OCS survey, 1976).

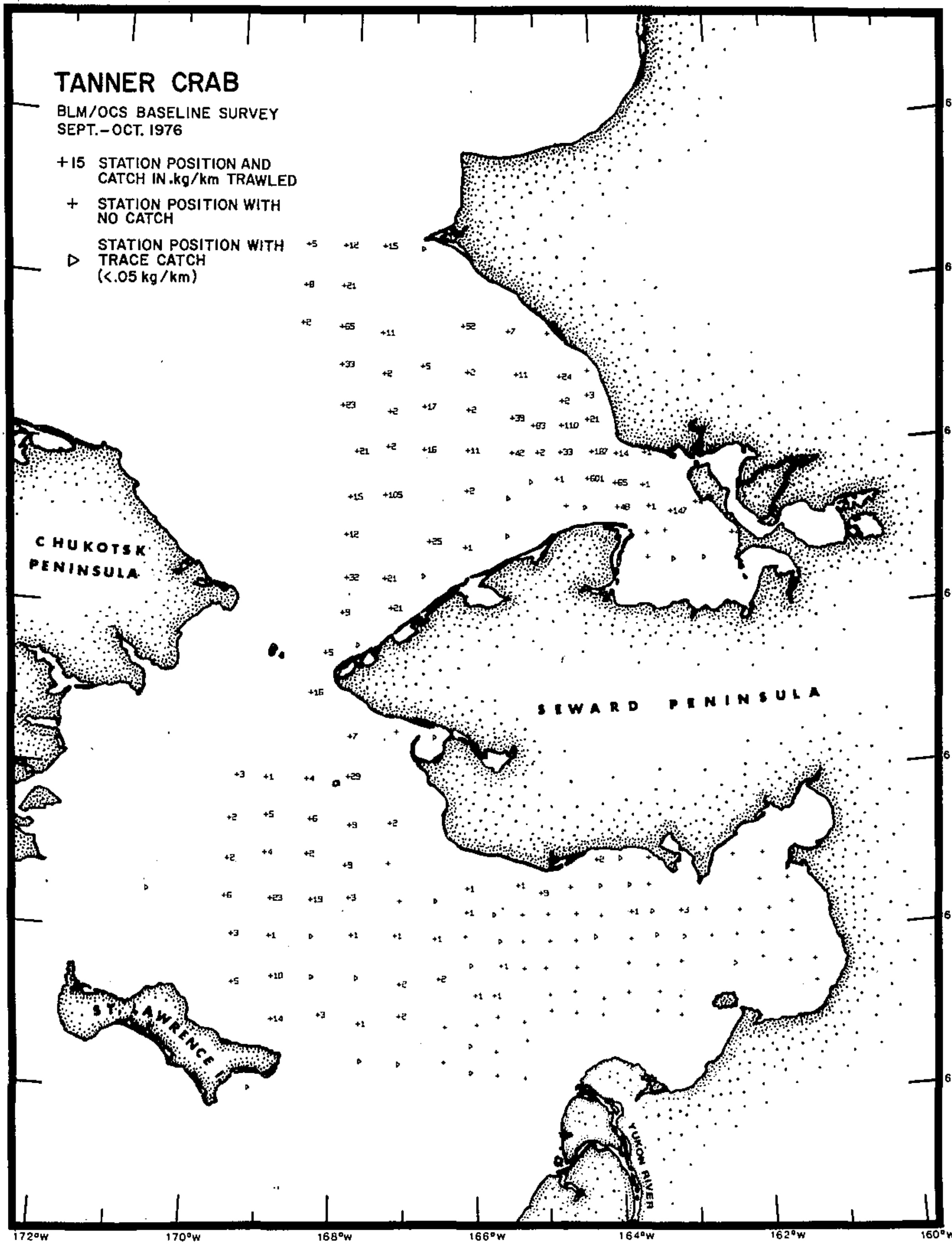


Figure VIII-32.--Distribution of catch rates by weight of total Tanner crab for Norton Sound, the southeastern Chukchi Sea and adjacent waters (BLM/OCS survey, 1976).

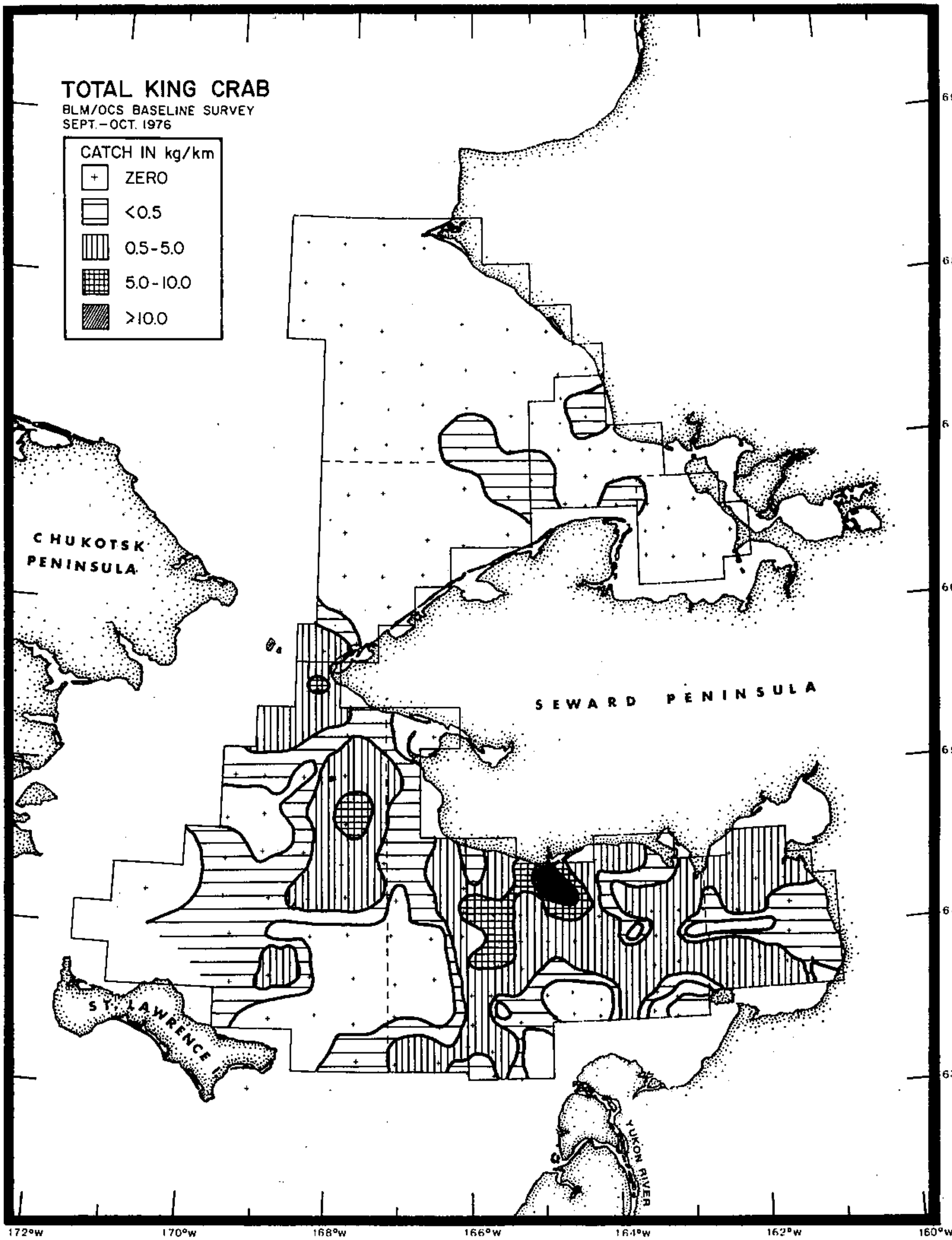


Figure VIII-33.--Distribution and relative abundance by weight of total king crabs in Norton Sound, the southeastern Chukchi Sea and adjacent waters (BLM/OCS survey, 1976).

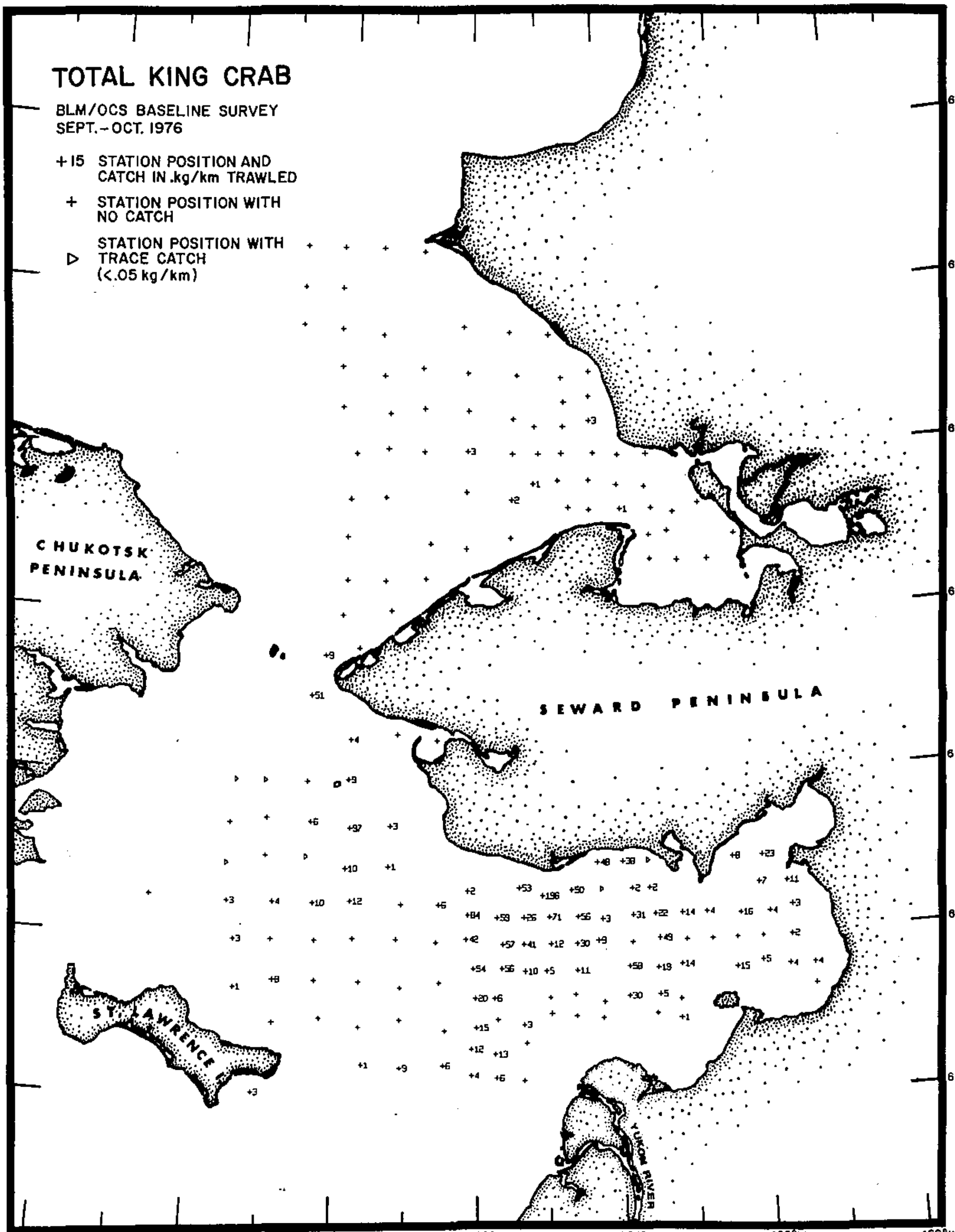


Figure VIII-34.--Distribution of catch rates by weight of total king crab of Norton Sound, the southeastern Chukchi Sea and adjacent waters (BLM/OCS survey, 1976).

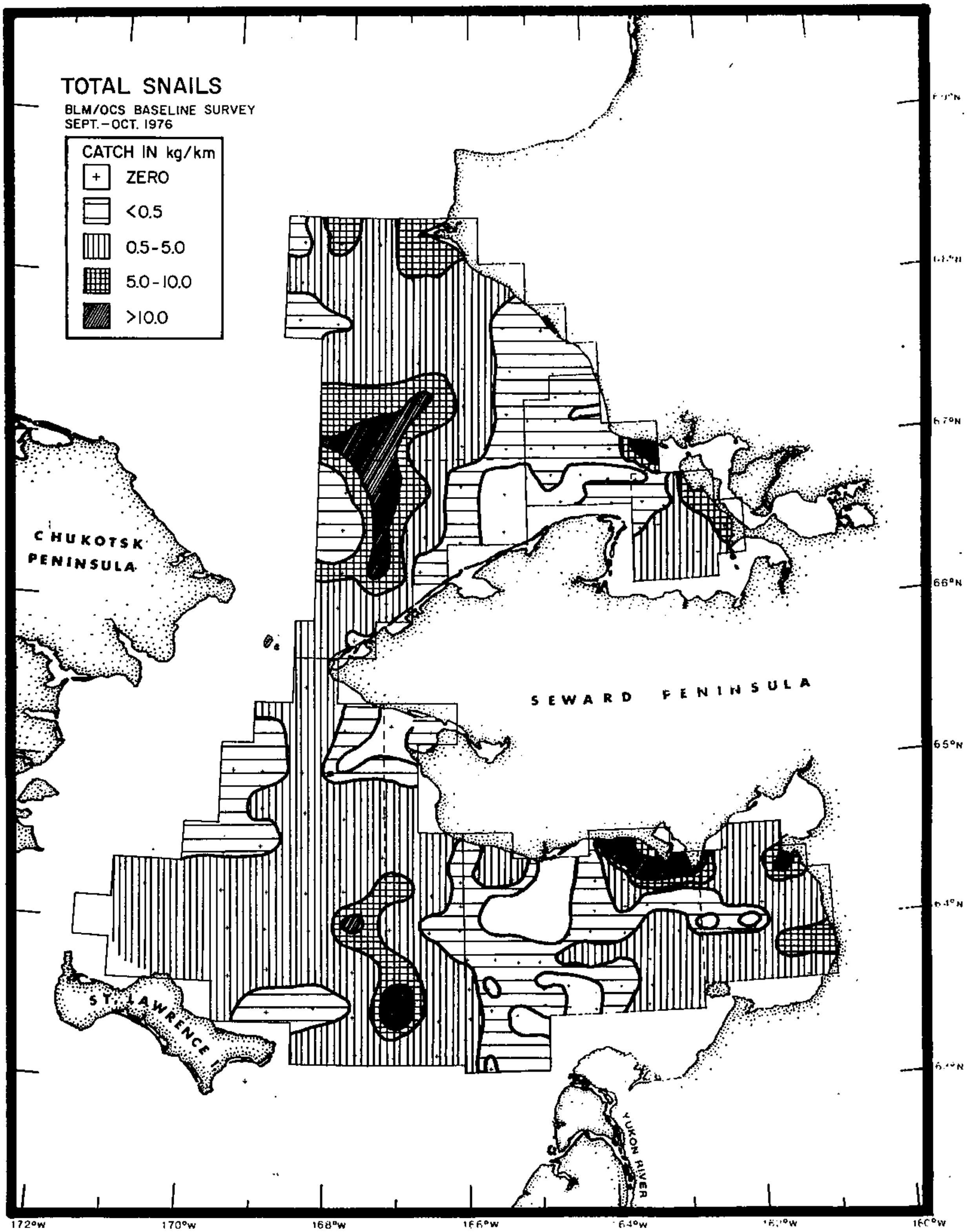


Figure VIII-35.--Distribution and relative abundance by weight of snails in Norton Sound, the southeastern Chukchi Sea and adjacent waters (BLM/OCS survey, 1976).

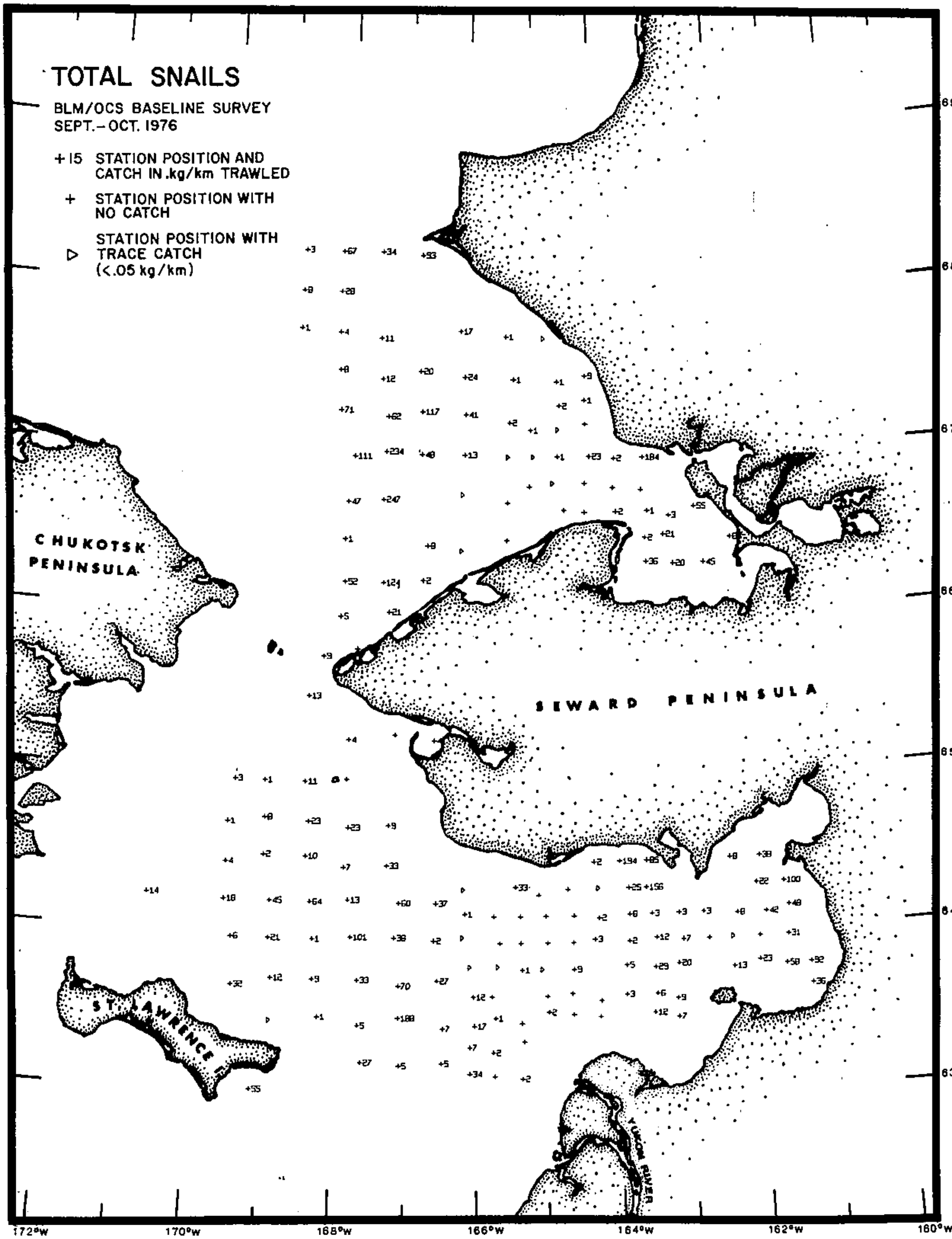


Figure VIII-36.--Distribution of catch rates by weight of total snails in Norton Sound, the southeastern Chukchi Sea and adjacent waters (BLM/OCS survey, 1976).

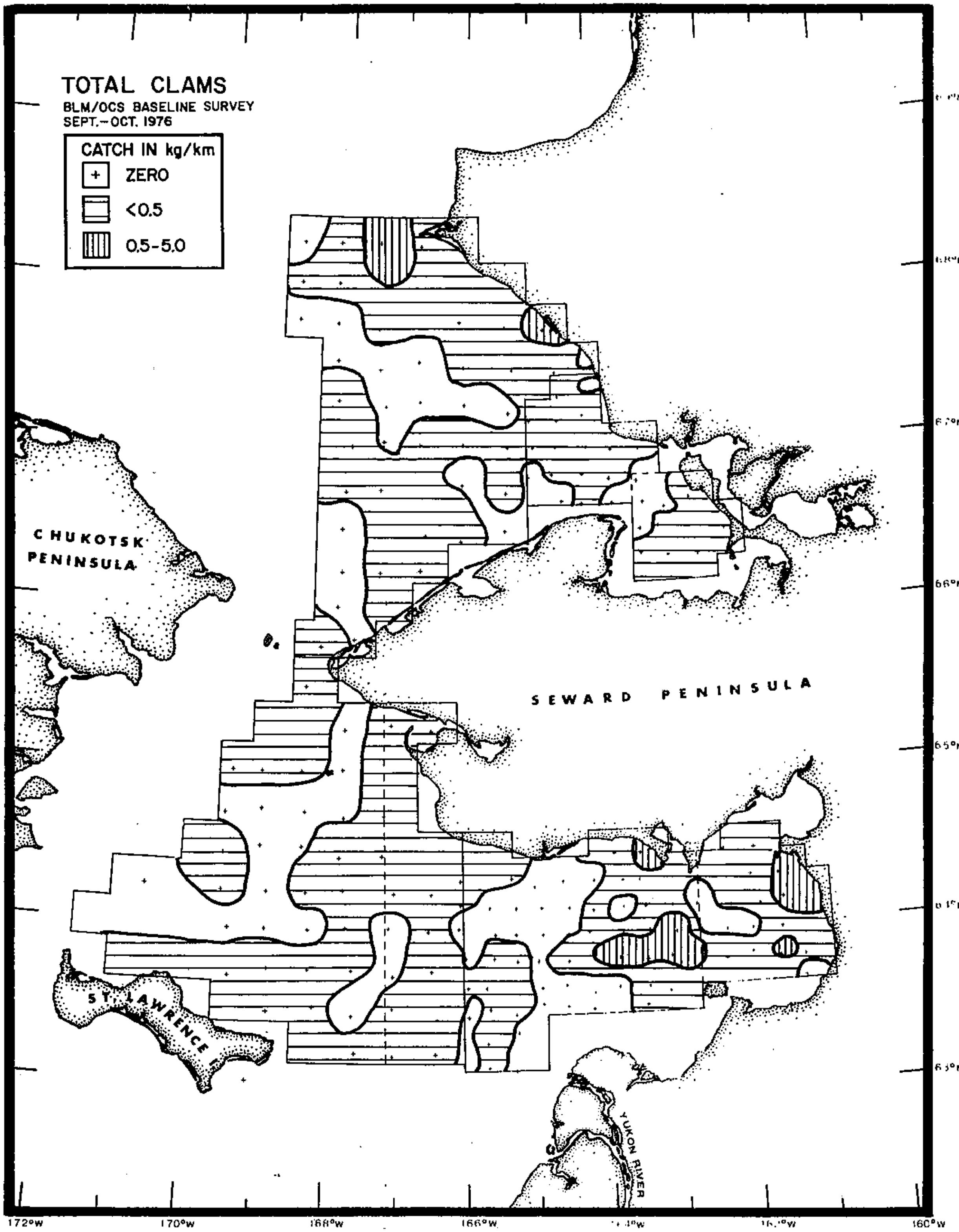


Figure VIII-37.--Distribution and relative abundance by weight of total clams in Norton Sound, the southeastern Chukchi Sea and adjacent waters (BLM/OCS survey, 1976).

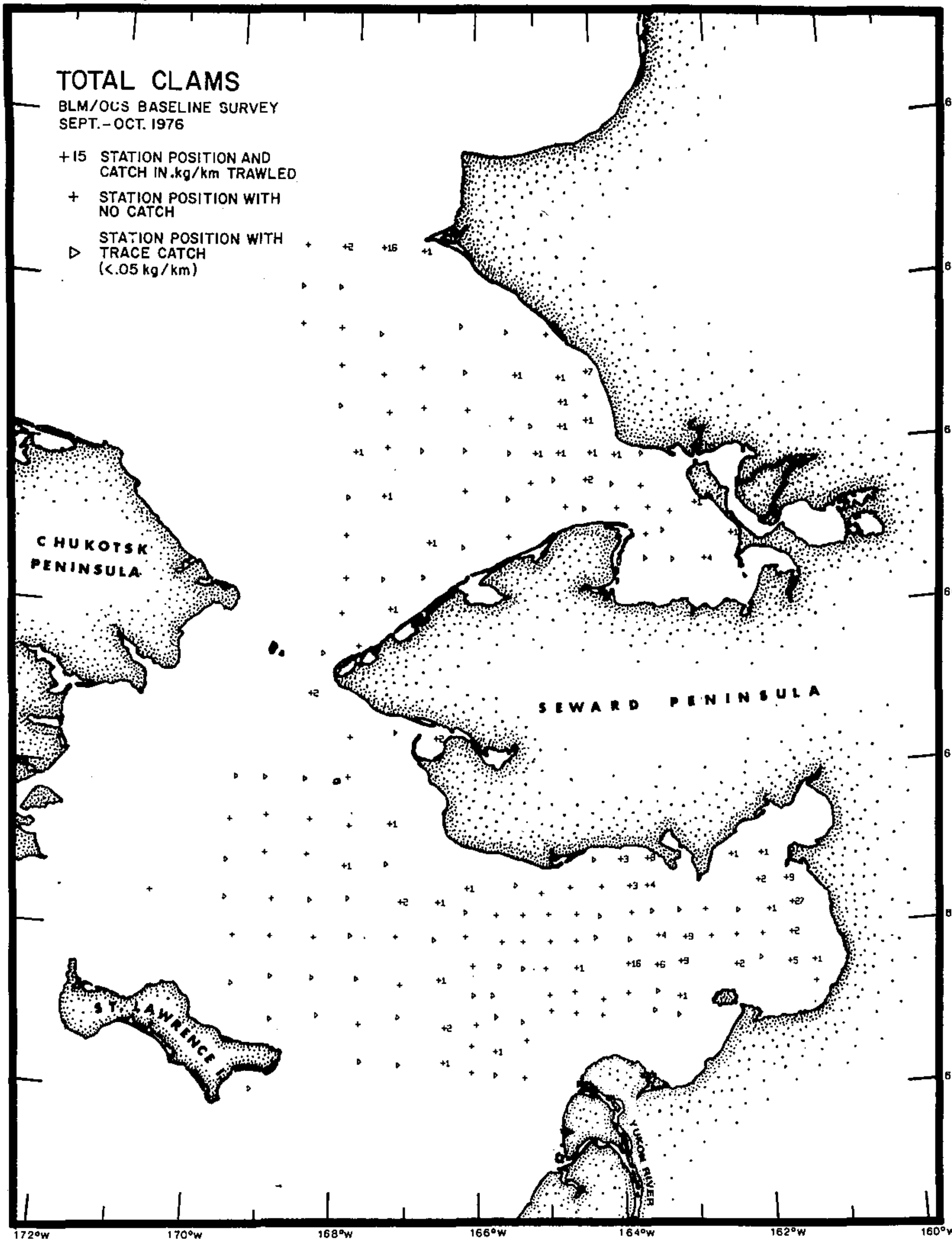


Figure VIII-38.--Distribution of catch rates by weight of total clams in Norton Sound, the southeastern Chukchi Sea and adjacent waters (BLM/OCS survey, 1976).

Relative Importance of Individual Species

Rank Order of Species by Frequency of Occurrence

Fish--Twelve species occurred at about 50% or more of the demersal stations occupied during the 1976 survey (Table VIII-12). The most frequently occurring species was Arctic cod, which was found at nearly 85% of all stations sampled. Other widely distributed species included saffron cod (78%), Arctic staghorn sculpin (75%), toothed smelt (67%), sturgeon poacher (62%), and yellowfin sole (56%).

The frequency of occurrence of species varied widely by subarea. Although Arctic cod and saffron cod were generally among the most common fish in all subareas, the percent occurrence of many other species showed large differences between subareas. Yellowfin sole occurred at 81% of the stations sampled in the embayments of Norton and Kotzebue sounds (subareas 4 and 2, respectively) and at only 28% of the more offshore regions surveyed in the southeastern Chukchi Sea and northern Bering Sea (subareas 1 and 3, respectively). Similar patterns were seen for Alaska plaice, toothed smelt, Pacific herring, and the slender eelblenny. Shorthorn sculpin, snailfish, and capelin showed the opposite pattern, occurring at a far greater percentage of stations in the offshore subareas as compared to subareas more nearshore. Other species exhibited large differences in percent occurrence between areas north and south of Bering Strait. Bering flounder were far more common in catches in the northern subareas while the plain sculpin displayed a greater frequency of occurrence in southern subareas, especially Norton Sound.

Invertebrates--In addition to starfish and the unidentified invertebrate groups, four shellfish species of potential economic importance occurred at over 50% of the 1976 survey stations (Table VIII-13). The most common of these species was *Argis* shrimp (*Argis* spp.) which was found at nearly 75% of the stations. The other species widely distributed over the survey area were Tanner crab (67%) and two neptunid whelks, *Neptunea heros* (64%) and *N. ventricosa* (56%). As with fish taxa, rank order of occurrence varied by subarea. Tanner crabs frequently occurred in catches in most regions but its incidence decreased substantially in Norton Sound (subarea 4). Blue and red king crabs were frequently encountered, but each only in one subarea, (3 and 4, respectively). Other species displayed marked changes in percentage occurrence between offshore and inshore regions. Basketstars and three neptunid whelks, *Neptunea heros*, *N. ventricosa*, and *N. borealis*, occurred at a far greater number of offshore stations (subareas 1 and 3) than inshore (subareas 2 and 4). The distribution of *Telemessus* crab displayed an opposite pattern, occurring more often inshore than offshore.

Rank Order by Relative Abundance

Fish--Two species, saffron cod and starry flounder, together accounted for over 57% of the total catch of all fish (Table VIII-14). In all

Table VIII-12.-Rank order by frequency of occurrence (percent) of the 20 most common fish taxa in Norton Sound, the southeastern Chukchi Sea and adjacent waters (BLM/OCS survey, 1976).

Rank	Taxon	All areas combined	Subarea 1	Subarea 2	Subarea 3	Subarea 4
1	Arctic cod	84.9	84	74	91	84
2	Saffron cod	78.1	50	89	63	100
3	Arctic staghorn sculpin	75.0	70	85	96	63
4	Toothed smelt	67.2	41	89	46	88
5	Alaska plaice	66.1	41	85	39	91
6	Sturgeon poacher	62.0	50	52	70	68
7	Yellowfin sole	56.3	27	55	28	91
8	Slender eelblenny	55.2	52	74	26	68
9	Shorthorn sculpin	55.2	52	37	96	39
10	Pacific herring	49.5	41	74	39	52
11	Starry flounder	47.4	25	37	17	83
12	Antlered sculpin	44.8	20	52	37	62
13	Unidentified snailfish	43.2	52	33	78	20
14	Polar eelpout	32.3	59	30	30	31
15	Plain sculpin	29.7	--	7	17	63
16	Ribbed sculpin	28.6	30	33	39	20
17	Walleye pollock	27.6	18	15	50	23
18	Wattled eelpout	27.1	34	44	2	32
19	Bering flounder	26.5	68	40	22	--
20	Capelin	24.4	39	11	48	6
Total fish species		48	34	32	36	36
Total number of hauls		192	44	27	46	75

Table VIII-13.--Rank order by frequency of occurrence (percent) of the most common invertebrate taxa in Norton Sound, the southeastern Chukchi Sea (BLM/OCS survey, 1976).

Rank	Taxon	All areas combined	Subarea 1	Subarea 2	Subarea 3	Subarea 4
1	Starfish	95.8	95	96	96	96
2	Other invertebrates	90.6	91	89	98	87
3	_Argis_ spp.	74.5	80	81	80	65
4	Tanner crab	67.2	95	85	89	31
5	_Neptunea heros_	64.1	70	41	85	56
6	_Neptunea ventricosa_	55.7	55	48	78	45
7	_Beringius beringii_	46.9	41	56	40	53
8	_Serripes groenlandicus_	44.3	30	56	43	49
9	Basketstars	37.5	50	22	65	19
10	_Telemessus_ crab	35.9	18	48	7	60
11	Red king crab	33.9	2	11	7	77
12	_Pandalus goniurus_	30.2	25	19	41	31
13	_Crangon dalli_	24.5	7	15	2	52
14	_Sclerocrangon boreas_	24.5	14	41	20	28
15	_Neptunea borealis_	21.9	41	7	43	11
16	_Pyrulofusus deformis_	17.2	5	11	30	19
17	_Clinocardium ciliatum_	16.1	18	48	4	11
18	_Volutopsius fragilis_	13.0	23	19	17	3
19	Blue king crab	12.0	5	—	46	—
20	_Buccinium angulossum_	11.5	16	7	20	5

Table VIII-14.--Rank order of abundance of the 20 most abundant fish taxa in Norton Sound and the southeastern Chukchi Sea, all areas combined (BLM/OCS survey, 1976).

Rank	Taxon	CPUE 1/ (kg/km)	Proportion of 2/ fish CPUE	Proportion of 3/ total CPUE	Cumulative proportion of fish CPUE
1	Saffron cod	2.70	0.446	0.063	0.446
2	Starry flounder	0.77	0.127	0.018	0.573
3	Shorthorn sculpin	0.54	0.089	0.013	0.662
4	Pacific herring	0.37	0.061	0.009	0.723
5	Toothed smelt	0.29	0.048	0.007	0.771
6	Alaska plaice	0.21	0.035	0.005	0.806
7	Yellowfin sole	0.19	0.031	0.004	0.837
8	Arctic cod	0.17	0.028	0.004	0.865
9	Plain sculpin	0.12	0.020	0.003	0.885
10	Pacific halibut	0.11	0.018	0.003	0.903
11	Arctic staghorn sculpin	0.09	0.015	0.002	0.918
12	Polar eelpout	0.09	0.015	0.002	0.933
13	Unidentified snailfish	0.07	0.012	0.002	0.945
14	Antlered sculpin	0.04	0.007	0.001	0.952
15	Walleye pollock	0.04	0.007	0.001	0.959
16	Belligerent sculpin	0.03	0.005	0.001	0.964
17	Sturgeon poacher	0.03	0.005	0.001	0.969
18	Bering flounder	0.03	0.005	0.001	0.974
19	Longhead dab	0.03	0.005	0.001	0.979
20	Wattled eelpout	0.03	0.005	0.001	0.984

1/ Overall catch per unit effort, kg/km trawled. Total effort = 620.7 km.

2/ Proportion of catch per unit effort, total fish only. Fish CPUE = 6.06 kg/km trawled.

3/ Proportion of total catch per unit effort, all fish and invertebrates combined. Total CPUE = 43.16 kg/km trawled.

subareas, these species and one or two others usually dominated, accounting for over 50% of the total fish catch (Tables VIII-15 through 18).

Invertebrates--Starfish, basketstars, and "other" invertebrates (not identified for this report) comprised over 85% of the total mean catch for all invertebrates combined (Table VIII-19). The remaining 15% consisted of several mollusc and crustacean species which may have potential for commercial utilization and were the primary invertebrate species of interest for our study. Of this group, the neptunid whelk, *Neptunea heros*, Tanner crab, and red king crab were dominant, representing 68% of the commercial invertebrate catch. As with fish taxa, two or three species usually dominated each subarea catch (Tables VIII-20 through 23).

Rank order by relative abundance for all taxa identified during the baseline study is given in Appendices E and F.

Table VIII-15.--Rank order of abundance of the 20 most abundant fish taxa in the southeastern Chukchi Sea (subarea 1, BLM/OCS survey, 1976).

Rank	Taxon	CPUE 1/ (kg/km)	Proportion of 2/ fish CPUE	Proportion of 3/ total CPUE	Cumulative proportion of fish CPUE
1	Starry flounder	0.53	0.205	.014	0.205
2	Pacific halibut 4/	0.32	0.118	.008	0.323
3	Saffron cod	0.31	0.114	.008	0.437
4	Pacific herring	0.26	0.096	.007	0.533
5	Arctic cod	0.20	0.076	.005	0.609
6	Shorthorn sculpin	0.18	0.067	.005	0.676
7	Alaska plaice	0.16	0.058	.004	0.733
8	Unidentified snailfish	0.14	0.050	.003	0.784
9	Toothed smelt	0.10	0.037	.003	0.821
10	Polar eelpout	0.08	0.031	.002	0.852
11	Walleye pollock	0.08	0.030	.002	0.881
12	Bering flounder	0.07	0.027	.002	0.908
13	Arctic staghorn sculpin	0.06	0.021	.001	0.929
14	Yellowfin sole	0.03	0.013	.001	0.942
15	Sturgeon poacher	0.03	0.012	.001	0.954
16	Capelin	0.03	0.012	.001	0.966
17	Antlered sculpin	0.02	0.008	.001	0.973
18	Wattled eelpout	0.02	0.007	5/	0.980
19	Belligerent sculpin	0.01	0.005	5/	0.985
20	Slender eelblenny	0.01	0.004	5/	0.989

1/ Overall catch per unit effort, kg/km trawled. Total effort = 139.2 km.

2/ Proportion of catch per unit effort, total fish only. Fish CPUE = 2.70 kg/km trawled.

3/ Proportion of total catch per unit effort, all fish and invertebrates combined. Total CPUE = 39.33 kg/km trawled.

4/ Total catch for this species = 1 large fish (44.2 kg).

5/ Proportion less than 0.0005.

Table VIII-16.--Rank order of abundance of the 20 most abundant fish taxa in Kotzebue Sound (subarea 2, BLM/OCS survey, 1976).

Rank	Taxon	CPUE 1/ (kg/km)	Proportion of 2/ fish CPUE	Proportion of 3/ total CPUE	Cumulative proportion of fish CPUE
1	Pacific herring	2.20	0.404	0.051	0.404
2	Saffron cod	1.28	0.235	0.030	0.640
3	Toothed smelt	1.00	0.184	0.023	0.824
4	Alaska plaice	0.20	0.037	0.005	0.861
5	Starry flounder	0.15	0.028	0.003	0.889
6	Yellowfin sole	0.13	0.023	0.003	0.912
7	Arctic cod	0.12	0.021	0.003	0.934
8	Polar eelpout	0.06	0.010	0.001	0.944
9	Arctic staghorn sculpin	0.05	0.009	0.001	0.953
10	Antlered sculpin	0.04	0.008	0.001	0.961
11	Bering flounder	0.04	0.008	0.001	0.969
12	Wattled eelpout	0.03	0.006	0.001	0.975
13	Slender eelblenny	0.03	0.006	0.001	0.981
14	Shorthorn sculpin	0.02	0.004	4/	0.985
15	Longhead dab	0.02	0.004	4/	0.989
16	Unidentified snailfish	0.01	0.002	4/	0.991
17	Ribbed sculpin	0.01	0.002	4/	0.993
18	Sturgeon poacher	0.01	0.002	4/	0.994
19	Capelin	0.01	0.001	4/	0.995
20	Belligerent sculpin	0.01	0.001	4/	0.996

1/ Overall catch per unit effort, kg/km trawled. Total effort = 86.6 km.

2/ Proportion of catch per unit effort, total fish only. Fish CPUE = 5.44 kg/km trawled.

3/ Proportion of total catch per unit effort, all fish and invertebrates combined. Total CPUE = 42.87 kg/km trawled.

4/ Proportion less than .0005.

Table VIII-17.--Rank order of abundance of the 20 most abundant fish taxa in the northern Bering Sea, north of St. Lawrence Island (subarea 3, BLM/OCS survey, 1976).

Rank	Taxon	CPUE 1/ (kg/km)	Proportion of 2/ fish CPUE	Proportion of 3/ total CPUE	Cumulative proportion of fish CPUE
1	Saffron cod	2.58	0.433	0.070	0.433
2	Shorthorn sculpin	1.23	0.205	0.033	0.638
3	Starry flounder	0.42	0.071	0.011	0.709
4	Toothed smelt	0.34	0.056	0.009	0.765
5	Pacific herring	0.16	0.027	0.004	0.793
6	Alaska plaice	0.16	0.026	0.004	0.819
7	Arctic staghorn sculpin	0.14	0.024	0.004	0.843
8	Arctic cod	0.14	0.024	0.004	0.866
9	Plain sculpin	0.13	0.022	0.004	0.888
10	Polar eelpout	0.12	0.020	0.003	0.908
11	Yellowfin sole	0.09	0.014	0.002	0.922
12	Unidentified snailfish	0.08	0.013	0.002	0.936
13	Belligerent sculpin	0.06	0.010	0.002	0.946
14	King salmon	0.04	0.007	0.001	0.953
15	Capelin	0.04	0.006	0.001	0.959
16	Antlered sculpin	0.03	0.006	0.001	0.965
17	Walleye pollock	0.03	0.005	0.001	0.970
18	Bering wolffish	0.03	0.005	0.001	0.975
19	Sturgeon poacher	0.03	0.004	0.001	0.979
20	Longhead dab	0.03	0.004	0.001	0.983

1/ Overall catch per unit effort, kg/km trawled. Total effort = 150.9 km.

2/ Proportion of catch per unit effort, total fish only. Fish CPUE = 5.97 kg/km trawled.

3/ Proportion of total catch per unit effort, all fish and invertebrates combined.

Table VIII-18.--Rank order of abundance of the 20 most abundant fish taxa in Norton Sound (subarea 4, BLM/OCS survey, 1976).

Rank	Taxon	CPUE 1/ (kg/km)	Proportion of 2/ fish CPUE	Proportion of 3/ total CPUE	Cumulative proportion of fish CPUE
1	Saffron cod	6.56	0.604	0.114	0.604
2	Starry flounder	1.83	0.168	0.032	0.772
3	Yellowfin sole	0.59	0.053	0.010	0.826
4	Alaska plaice	0.35	0.032	0.006	0.858
5	Plain sculpin	0.29	0.026	0.005	0.885
6	Toothed smelt	0.20	0.018	0.003	0.903
7	Arctic cod	0.17	0.016	0.003	0.918
8	Shorthorn sculpin	0.17	0.015	0.003	0.934
9	Pacific herring	0.10	0.009	0.002	0.943
10	Arctic staghorn sculpin	0.08	0.008	0.001	0.950
11	Fourhorn sculpin	0.08	0.007	0.001	0.957
12	Antlered sculpin	0.08	0.007	0.001	0.964
13	Polar eelpout	0.06	0.006	0.001	0.970
14	Longhead dab	0.06	0.006	0.001	0.976
15	Slender eelblenny	0.04	0.005	0.001	0.980
16	Sturgeon poacher	0.04	0.003	0.001	0.983
17	Wattled eelpout	0.04	0.003	0.001	0.986
18	Arctic flounder	0.04	0.003	0.001	0.990
19	Belligerent sculpin	0.03	0.003	0.001	0.992
20	*Lumpenus mackayi*	0.03	0.003	4/	0.995

1/ Overall catch per unit effort, kg/km trawled. Total effort = 243.9 km.

2/ Proportion of catch per unit effort, total fish only. Fish CPUE = 10.87 kg/km trawled.

3/ Proportion of total catch per unit effort, all fish and invertebrates combined. Total CPUE = 57.46 kg/km trawled.

4/ Proportion less than 0.0005.

Table VIII-19.--Rank order of abundance of the 20 most abundant invertebrate taxa of possible commercial importance in Norton Sound, the southeastern Chukchi Sea, and adjacent waters (BLM/OCS survey, 1976).

Rank	Taxon	CPUE 1/ (kg/km)	Proportion of 2/ commercially important invertebrate CPUE	Proportion 3/ of total CPUE	Cumulative proportion
1	Neptunea heros	1.85	0.366	0.043	0.366
2	Tanner crab	1.12	0.221	0.026	0.587
3	Red king crab	0.48	0.094	0.011	0.681
4	Telemessus crab	0.35	0.070	0.008	0.751
5	Neptunea ventricosa	0.35	0.068	0.008	0.820
6	Argis sp.	0.21	0.041	0.005	0.860
7	Blue king crab	0.19	0.037	0.004	0.897
8	Sclerocrangon boreas	0.12	0.023	0.003	0.921
9	Beringius beringii	0.09	0.019	0.002	0.939
10	Pyrulofusus deformis	0.08	0.015	0.002	0.954
11	Serripes groenlandicus	0.05	0.010	0.001	0.964
12	Volutopsius fragilis	0.02	0.004	0.001	0.968
13	Pandalus goniurus	0.02	0.003	4/	0.972
14	Crangonidae	0.02	0.003	4/	0.975
15	Volutopsius castaneus	0.01	0.003	4/	0.977
16	Cyclopecte randolphi	0.01	0.002	4/	0.979
17	Crangon dalli	0.01	0.002	4/	0.982
18	Buccinum polare	0.01	0.002	4/	0.984
19	Neptunea borealis	0.01	0.002	4/	0.986
20	Buccinum angulossum	0.01	0.001	4/	0.987

1/ Overall catch per unit effort, kg/km trawled. Total effort = 620.6 km.
2/ Proportion of catch per unit effort for invertebrates of possible commercial importance only; CPUE = 5.06 kg/km trawled.
3/ Proportion of total catch per unit effort, all fish and invertebrates combined. Total CPUE = 43.16 kg/km trawled.
4/ Proportion less than .0005.

Table VIII-20.--Rank order of abundance of the 20 most abundant invertebrate taxa of possible commercial importance in the southeastern Chukchi Sea (subarea 1, BLM/OCS survey, 1976).

Rank	Taxon	CPUE 1/ (kg/km)	Proportion of 2/ commercially important invertebrate CPUE	Proportion 3/ of total CPUE	Cumulative proportion
1	*Neptunea heros*	2.77	0.477	0.071	0.447
2	Tanner crab	1.59	0.256	0.040	0.703
3	*Telemessus* crab	0.49	0.079	0.012	0.782
4	*Neptunea ventricosa*	0.48	0.078	0.012	0.861
5	*Argis* sp.	0.26	0.041	0.007	0.902
6	*Sclerocrangon boreas*	0.21	0.034	0.005	0.936
7	*Beringius beringii*	0.07	0.011	0.002	0.947
8	*Volutopsius fragilis*	0.04	0.006	0.001	0.954
9	*Cyclopecte randolphi*	0.04	0.006	0.001	0.960
10	*Pyrulofusus deformis*	0.03	0.005	0.001	0.964
11	Blue king crab	0.03	0.004	0.001	0.969
12	*Buccinum polare*	0.02	0.004	0.001	0.973
13	*Volutopsius castaneus*	0.02	0.003	0.001	0.977
14	*Serripes groenlandicus*	0.02	0.003	0.001	0.980
15	*Neptune borealis*	0.02	0.003	0.001	0.983
16	*Natica clausa*	0.02	0.003	4/	0.986
17	*Buccinum angulossum*	0.01	0.002	4/	0.989
18	*Polinices pallida*	0.01	0.002	4/	0.990
19	*Pandalus goniurus*	0.01	0.001	4/	0.992
20	*Buccinum scalariforme*	0.01	0.001	4/	0.993

1/ Overall catch per unit effort, kg/km trawled. Total effort = 139.2 km.
2/ Proportion of catch per unit effort for invertebrates of possible commercial importance; CPUE = 6.20 kg/km trawled.
3/ Proportion of total catch per unit effort, all fish and invertebrates combined. Total CPUE = 39.33 kg/km trawled.
4/ Proportion less than .0005.

Table VIII-21.--Rank order of abundance of the 20 most abundant invertebrate taxa of possible commercial importance in Kotzebue Sound (subarea 2, BLM/OCS survey, 1976).

Rank	Taxon	CPUE 1/ (kg/km)	Proportion of 2/ commercially important invertebrate CPUE	Proportion 3/ of total CPUE	Cumulative proportion
1	Tanner crab	4.91	0.677	0.115	0.677
2	*Neptunea heros*	1.11	0.153	0.026	0.829
3	*Telemessus* crab	0.30	0.041	0.007	0.870
4	*Neptunea ventricosa*	0.27	0.037	0.006	0.907
5	*Argis* sp.	0.19	0.027	0.004	0.934
6	*Beringius beringii*	0.19	0.026	0.004	0.960
7	*Pyrulofusus deformis*	0.06	0.009	0.001	0.968
8	*Sclerocrangon boreas*	0.04	0.006	0.001	0.974
9	*Buccinum scalariforme*	0.03	0.004	0.001	0.978
10	*Volutopsius fragilis*	0.03	0.004	0.001	0.983
11	*Serripes groenlandicus*	0.02	0.003	4/	0.986
12	Red king crab	0.02	0.002	4/	0.988
13	*Astarte borealis*	0.01	0.002	4/	0.990
14	*Buccinum angulossum*	0.01	0.001	4/	0.992
15	*Clinocardium ciliatum*	0.01	0.001	4/	0.993
16	*Neptunea lyrata*	5/	4/	4/	0.994
17	*Pandalus goniurus*	5/	4/	4/	0.994
18	*Clinocardium californienaus*	5/	4/	4/	0.995
19	*Crangon dalli*	5/	4/	4/	0.995
20	*Natica clausa*	5/	4/	4/	0.995

1/ Overall catch per unit effort, kg/km trawled. Total effort = 86.6 km.
2/ Proportion of catch per unit effort for invertebrates of possible commercial importance only; CPUE = 7.26 kg/km trawled.
3/ Proportion of total catch per unit effort, all fish and invertebrates combined. Total CPUE = 42.87 kg/km trawled.
4/ Proportion less than .0005.
5/ Proportion less than .005.

Table VIII-22.--Rank order of abundance of the 20 most abundant invertebrate taxa of possible commercial importance in the northern Bering Sea (subarea 3, BLM/OCS survey, 1976).

Rank	Taxon	CPUE 1/ (kg/km)	Proportion of 2/ commercially important invertebrate CPUE	Proportion 3/ of total CPUE	Cumulative proportion
1	*Neptunea heros*	1.55	0.412	0.042	0.412
2	Blue king crab	0.50	0.133	0.013	0.545
3	*Neptunea ventricosa*	0.41	0.110	0.011	0.655
4	*Argis* sp.	0.17	0.044	0.005	0.699
5	*Pyrulofusus deformis*	0.15	0.041	0.004	0.741
6	*Telemessus* crab	0.12	0.032	0.003	0.772
7	*Sclerocrangon boreas*	0.09	0.025	0.003	0.798
8	*Beringius beringii*	0.08	0.022	0.002	0.820
9	Red king crab	0.05	0.012	0.001	0.832
10	Crangonidae	0.04	0.012	0.001	0.844
11	*Pandalus goniurus*	0.03	0.007	0.001	0.852
12	*Serripes groenlandicus*	0.02	0.005	0.001	0.857
13	*Volutopsius castaneus*	0.02	0.004	4/	0.861
14	*Volutopsius fragilis*	0.02	0.004	4/	0.865
15	*Beringius fragili*	0.01	0.003	4/	0.868
16	*Neptunea borealis*	0.01	0.002	4/	0.870
17	*Buccinum polare*	0.01	0.002	4/	0.872
18	*Astarte borealis*	5/	0.001	4/	0.873
19	*Buccinum angulossum*	5/	0.001	4/	0.874
20	*Colus spitzbergensis*	5/	0.001	4/	0.875

1/ Overall catch per unit effort, kg/km trawled. Total effort = 150.9 km.
2/ Proportion of catch per unit effort for invertebrates of possible commercial importance only; CPUE = 3.75 kg/km trawled.
3/ Proportion of total catch per unit effort, all fish and invertebrates combined. Total CPUE = 37.05.
4/ Proportion less than .0005.
5/ Proportion less than .005.

Table VIII-23.--Rank order of abundance of the 20 most abundant invertebrate taxa of possible commercial importance in Norton Sound (subarea 4, BLM/OCS survey, 1976).

Rank	Taxon	CPUE 1/ (kg/km)	Proportion of 2/ commercially important invertebrate CPUE	Proportion 3/ of total CPUE	Cumulative proportion
1	Red king crab	1.93	0.415	0.034	0.415
2	*Neptunea heros*	1.39	0.299	0.024	0.714
3	*Telemessus* crab	0.55	0.118	0.010	0.832
4	*Argis* sp.	0.21	0.045	0.003	0.877
5	*Serripes groenlandicus*	0.14	0.031	0.003	0.908
6	*Beringius beringii*	0.10	0.022	0.002	0.931
7	*Neptunea ventricosa*	0.10	0.021	0.002	0.952
8	*Sclerocrangon boreas*	0.06	0.012	0.001	0.964
9	*Crangon dalli*	0.04	0.009	0.001	0.973
10	Tanner crab	0.03	0.006	0.001	0.979
11	Unidentified snails	0.02	0.005	4/	0.984
12	*Pyrulofusus deformis*	0.02	0.005	4/	0.988
13	*Pandalus goniurus*	0.02	0.004	4/	0.992
14	*Pandalus hypsinotus*	0.01	0.002	4/	0.994
15	*Clinocardium californianaus*	0.01	0.001	4/	0.996
16	*Volutopsius fragilis*	0.01	0.001	4	0.997
17	*Clinocardium ciliatum*	5/	0.001	4/	0.998
18	*Neptunea borealis*	5/	0.001	4/	0.998
19	*Musculus discors*	5/	0.001	4/	0.999
20	*Mytilus edulis*	5/	4/	4/	0.999

1/ Overall catch per unit effort, kg/km trawled. Total effort = 243.9 km.
2/ Proportion of catch per unit effort for invertebrates of possible commercial importance only; CPUE = 4.65 kg/km trawled.
3/ Proportion of total catch per unit effort, all fish and invertebrates combined. Total CPUE = 57.46 kg/km trawled.
4/ Proportion less than .0005.
5/ Proportion less than .005.

SPECIES ASSOCIATIONS

PROCEDURES

The relationships between demersal fish and numerous invertebrate taxa were initially examined by means of species assemblages, as determined through the recurrent group procedure described by Fager (1957, 1963) and Fager and Longhurst (1968). This analysis identifies species associations on the basis of co-occurrence of species within trawl samples and a dichotomy of grouping rules. The geometric mean of the proportion of co-occurrences, corrected for sample size, was used as an index of the affinity:

$$\frac{c}{\sqrt{ab}} - \frac{1}{2\sqrt{b}}$$

where _c_ is the number of joint occurrences, _a_ is the number of occurrences by species A, and _b_ is the number of occurrences by species B ($b \geq a$). Only those species pairs having indices above the specified value (0.60) were considered to have affinities.

Several criteria were used in the determination of valid groupings: each species in a group had to show an affinity with all other members of that group, the largest possible groups were formed, and no species could occur in more than one group. Species showing affinities with some but not all members of a group were considered associate members.

After recurrent groups were defined, intergroup relationships were determined as the ratio of the number of observed species - pair affinities between the groups to the maximum number of possible connections. The occurrence of groups (all group members present) among stations were also listed and plotted.

All catch data for positively identified fish and invertebrate taxa in the 192 successful demersal trawl hauls were included in the analysis. Saffron cod were classified as adults (> 10 cm) and juveniles (≤ 10 cm) because of their large numbers and relative importance. Invertebrate taxa included in the analysis were those groups mentioned earlier: starfish, basketstars, gastropod and pelecypod molluscs, shrimp, and Tanner, king, and _Telemessus_ crabs.

RESULTS

Twenty-three (23) taxa were identified through the recurrent grouping procedure as having one or more affinity values greater than 0.60 and were organized into five groups. The remaining taxa examined did not occur frequently enough to show affinity at the assigned level. Group compositions and intergroup relationships are shown in Figure VIII-39.

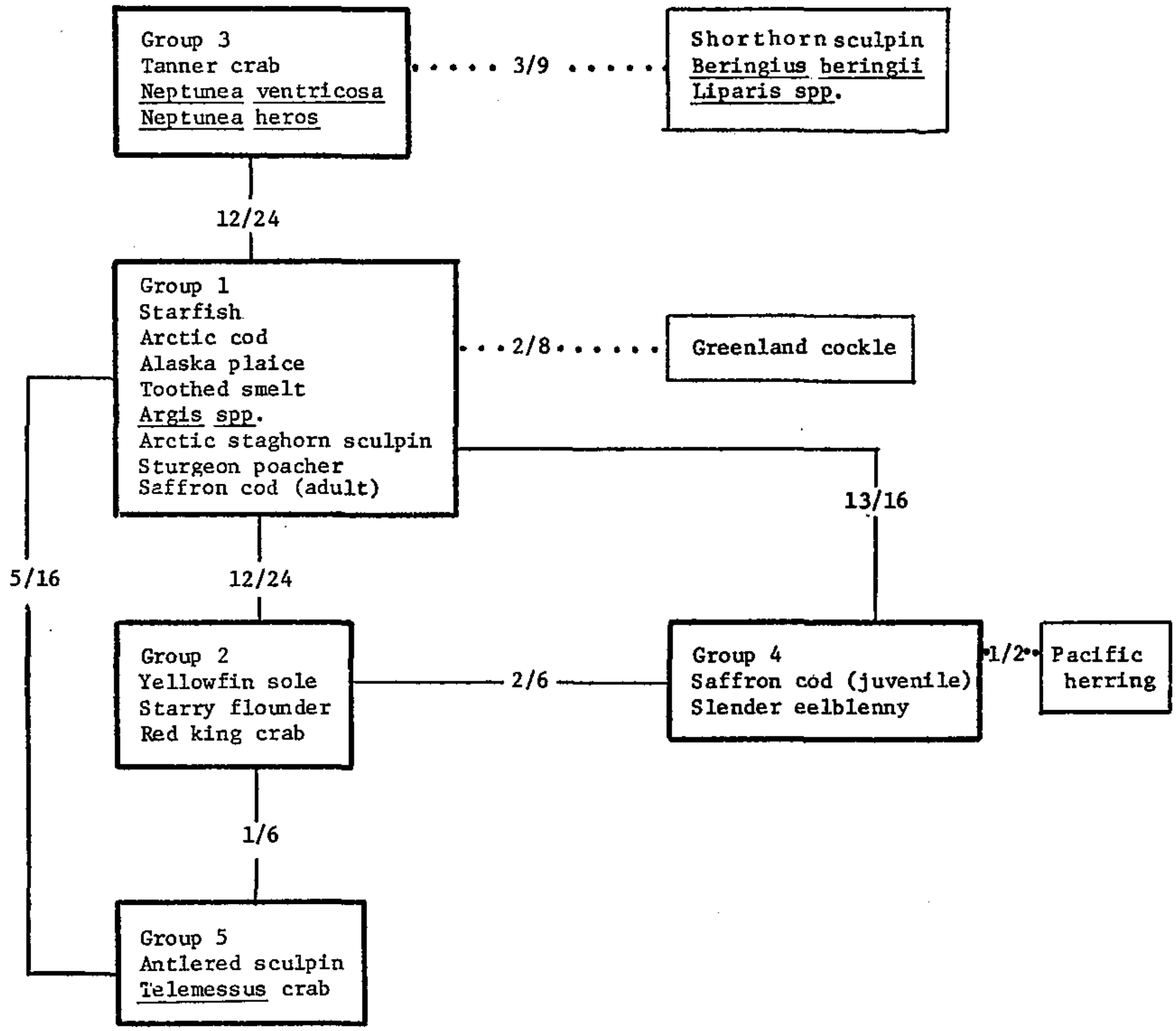


Figure VIII-39.--Recurrent species groups and their relationships in Norton Sound, the southeastern Chukchi Sea, and adjacent waters (BLM/OCS survey, 1976). Fractions indicate the ratio of the number of observed species-pair affinities between groups to the maximum numbers of possible connections (maximum possible connections for any two groups = product of number of species within both groups). Dotted lines indicate associated taxa showing affinity with some group numbers, but not all.

Although relatively few taxa were found to have significant relationships, the composition and distribution patterns of these recurrent species groups suggest that they characterize important features of the survey area environment: (1) the 23 taxa accounted for 71% of the total survey catch by weight, and (2) group occurrences were regional, with fairly limited geographical overlap.

Group 1 (total survey region group): Eight taxa formed this group which had the most widespread distribution throughout the survey area at all depths. This combination of species was also the most commonly encountered group, occurring at 79 trawl stations (Figure VIII-40) and included several taxa (starfish, adult saffron cod, and Arctic cod) which dominated the total survey catch. The Greenland cockle was associated with two group members, starfish and *Argis* shrimp.

Group 2 (Norton Sound shallow-water group): Two fish and one invertebrate species formed group 2 which was found at 52 stations, primarily at depths less than 25 m and almost exclusively in Norton Sound (Figure VIII-41). Although starry flounder and yellowfin sole were found together in several other areas of the survey region, the inclusion of red king crab into this group caused this group's highly defined regional distribution.

Group 3 (offshore group): Group 3 members (3 invertebrate species) and three associates occurred together at 62 stations, primarily in offshore regions of the survey area, in both the northern Bering and southeastern Chukchi seas (Figure VIII-42). When this group occurred in shallow water (< 25 m), their presence was generally associated with bottom waters colder than 6°C. The shorthorn sculpin and snailfish showed affinity with Tanner crab, while the whelk, *Beringius beringii*, was associated with another group member, the fat neptune whelk, *Neptunea ventricosa*.

Group 4 (all survey area shallow-water group): Group 4 members (two species and one associate) were frequently encountered throughout the survey region (72 stations) at water depths less than 25 m, and occasionally at slightly deeper depths (Figure VIII-43). Pacific herring showed affinity with juvenile saffron cod but not with the slender eelblenny.

Group 5 (nearshore shallow-water group): The two species of this group were encountered together at 52 stations in several nearshore sampling areas where water depths were less than 25 m. The heaviest concentration of occurrences of group 5 was encountered in inner Norton Sound (Figure VIII-44).

The results of these preliminary analyses provide evidence for recurrent features in the organization of demersal fauna for Norton Sound, the southeastern Chukchi Sea, and adjacent waters during late summer months in one year. A relatively small number of principal species appears to define much of the demersal community structure. These principal species were identified as members of five groups: one which occurred throughout much of the survey region at most depths, another group which appeared associated with deeper, colder water, and three combinations of taxa which occurred in shallow water but had specific distributional features which provided a means for separation.

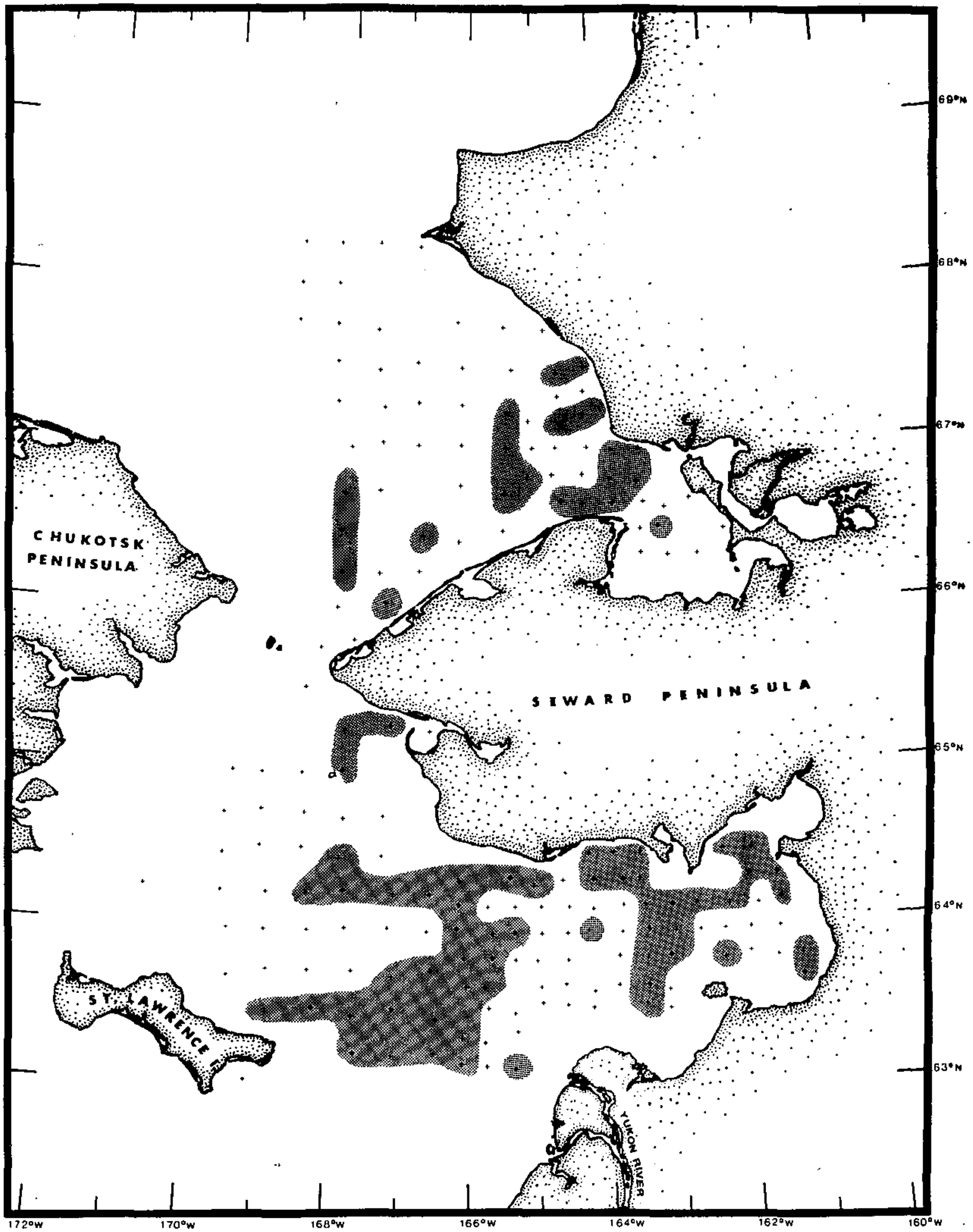


Figure VIII-40.--Occurrence of recurrent group 1 in Norton Sound, the southeastern Chukchi Sea and adjacent waters (BLM/OCS survey, 1976).

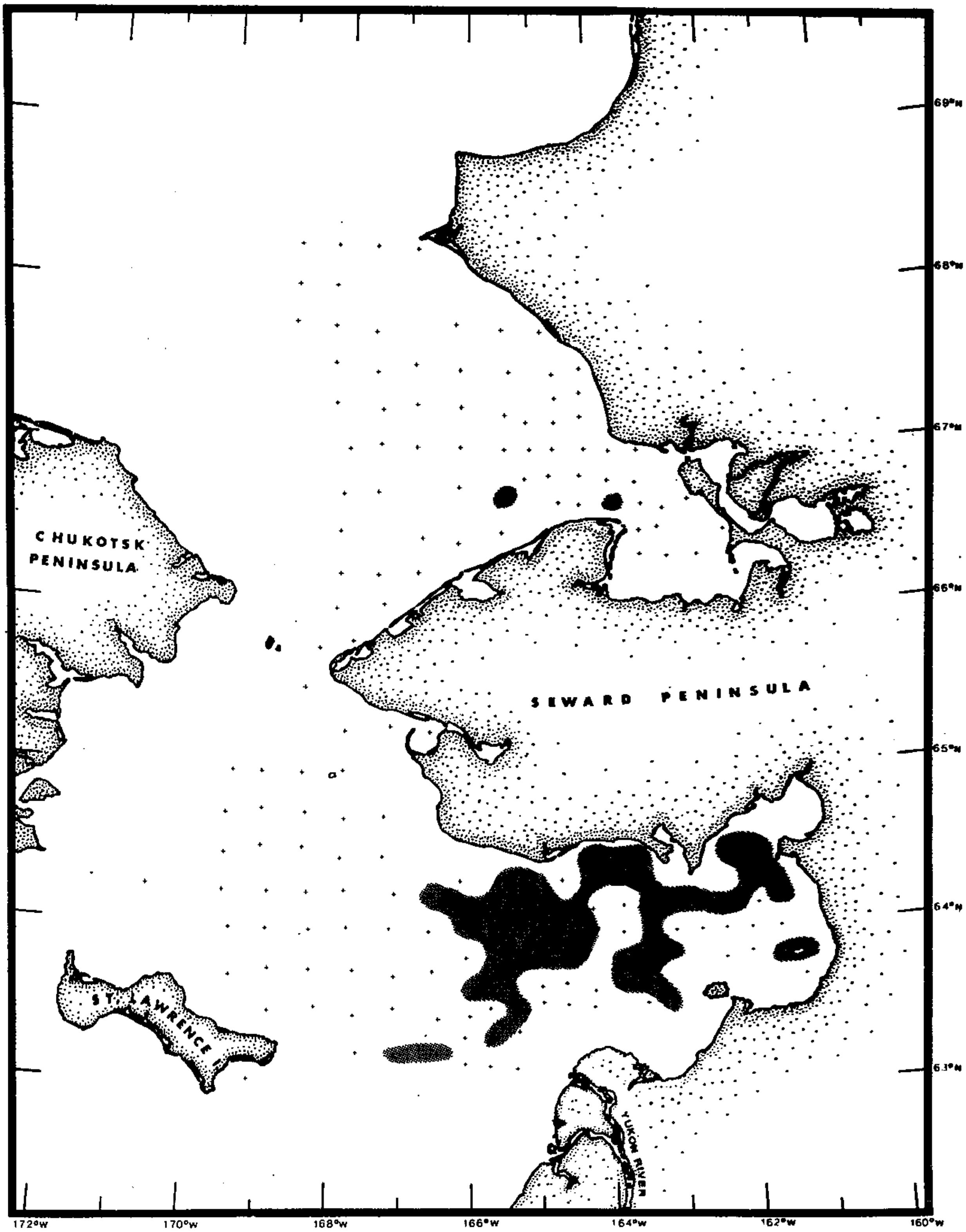


Figure VIII-41.--Occurrence of recurrent group 2 in Norton Sound, the southeastern Chukchi Sea and adjacent waters (BLM/OCS survey, 1976).

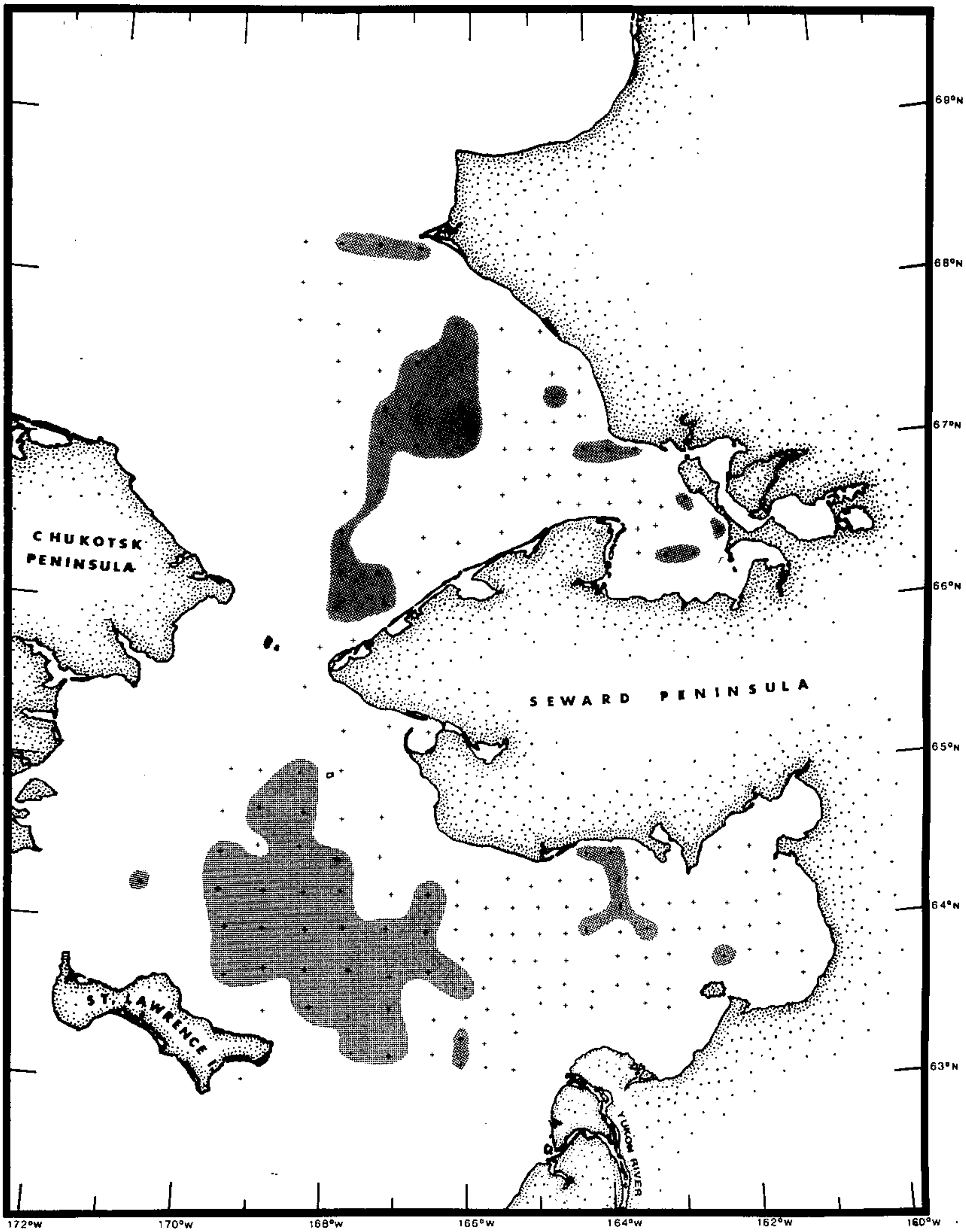


Figure VIII-42.--Occurrence of recurrent group 3 in Norton Sound, the southeastern Chukchi Sea and adjacent waters (BLM/OCS survey, 1976).

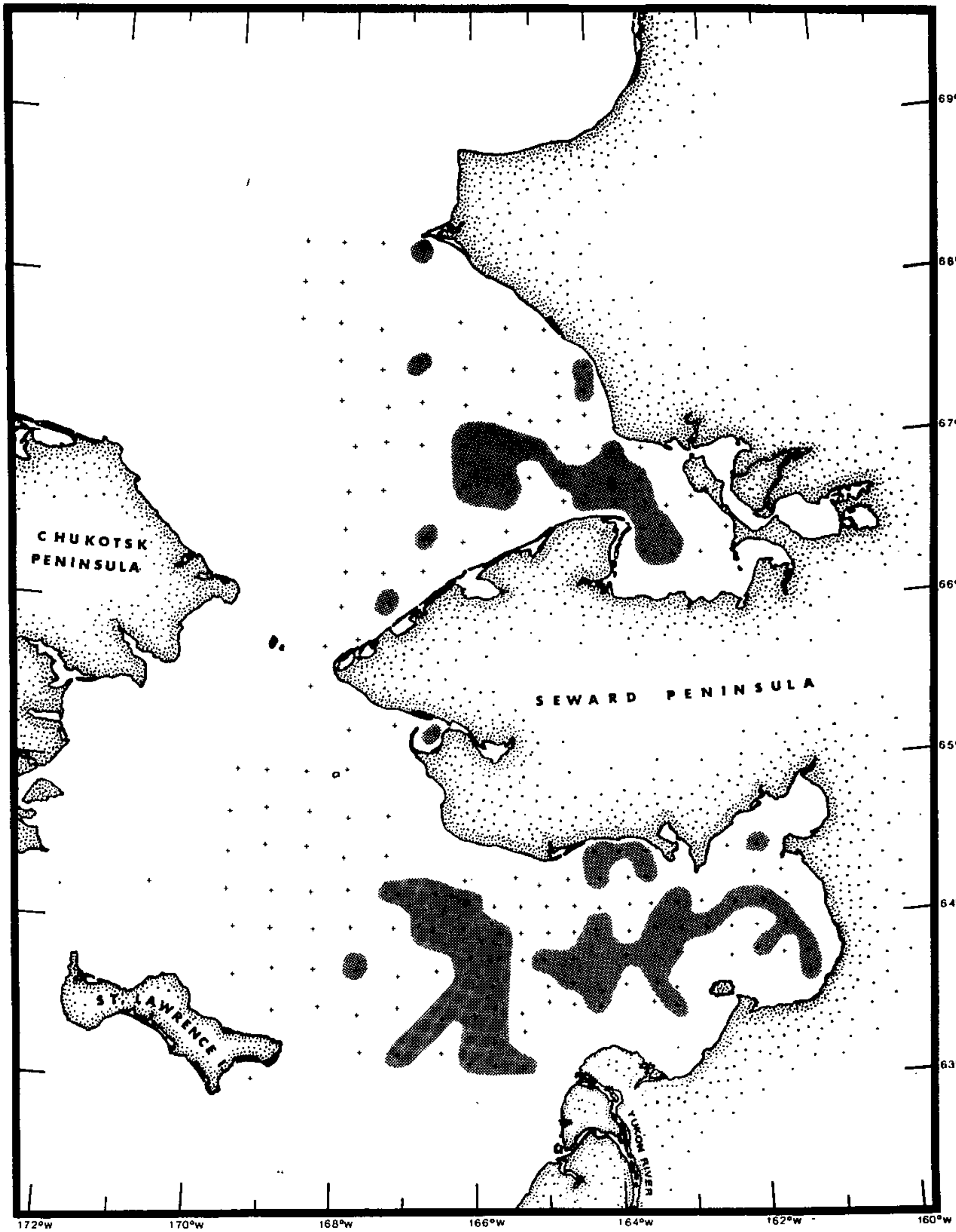


Figure VIII-43.--Occurrence of recurrent group 4 in Norton Sound, the southeastern Chukchi Sea and adjacent waters (BLM/OCS survey, 1976).

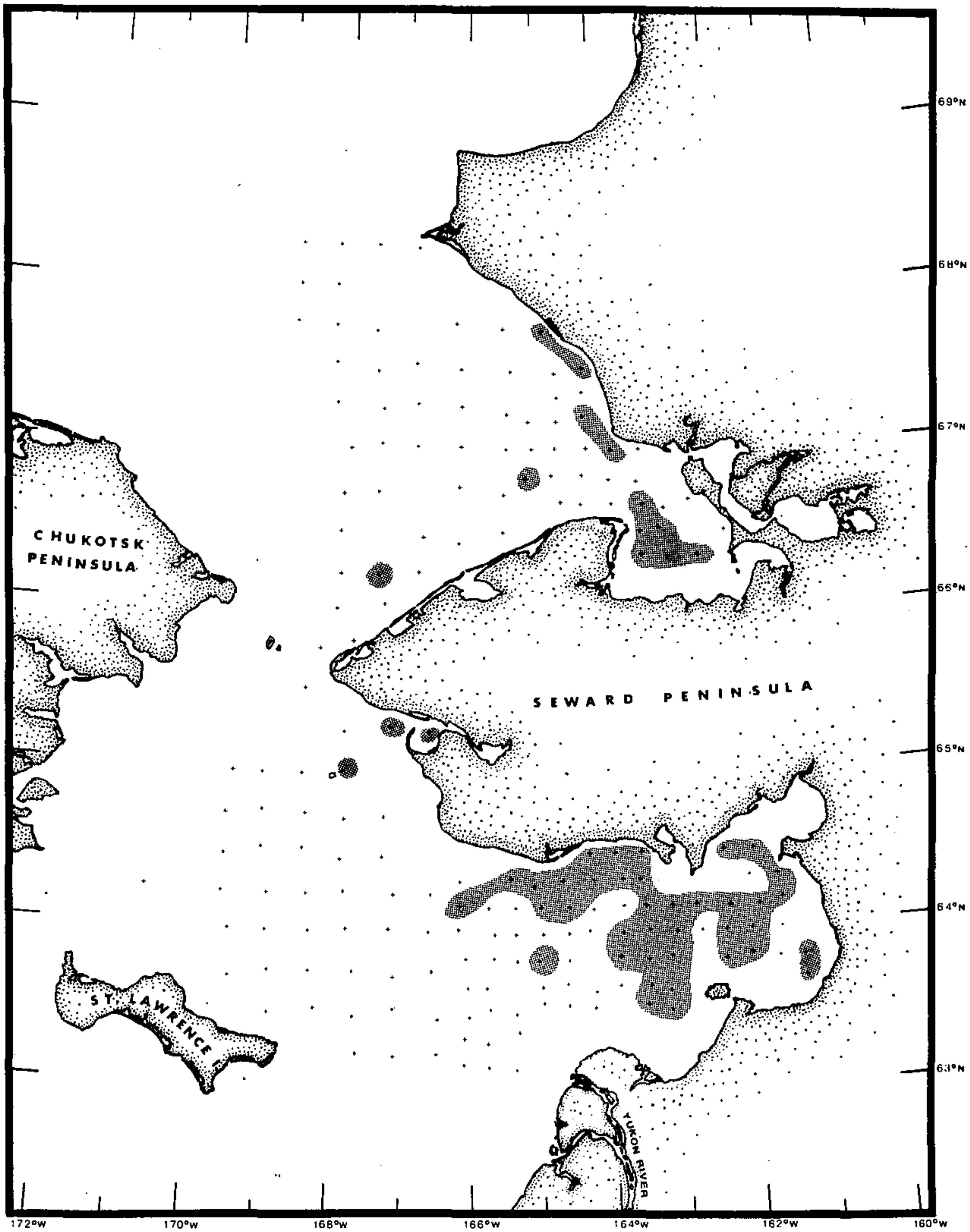


Figure VIII-44.--Occurrence of recurrent group 5 in Norton Sound, the southeastern Chukchi Sea and adjacent waters (BLM/OCS survey, 1976).

Distribution, Biomass, and Biological Features of Principal Species of Fish

Saffron cod

Distribution and abundance--Saffron cod was the most abundant fish species encountered in the survey area. It occurred at 78% of the demersal stations sampled (Table VIII-24) and accounted for 45% of the total apparent biomass for all fish species combined. Largest concentrations of saffron cod were located in the outer portion of Norton Sound and the eastern portion of the northern Bering Sea (strata 4Ø and 3E) (Figures VIII-45 and 46) where catches averaged 8.0 and 8.2 kg/km, respectively. Average catch rates decreased to about 1.8 kg/km in outer Kotzebue and inner Norton sounds (strata 2Ø and 4I) and further declined to between 0.1 and 0.7 kg/km in the remainder of the survey region. The overall mean catch rate for the entire survey area was about 2.2 kg/km trawled.

Table VIII-24.--Estimated biomass and population size of saffron cod in Norton Sound, the southeastern Chukchi Sea, and adjacent waters (BLM/OCS survey, 1976).

Stratum	Percent frequency of occurrence	Mean CPUE (kg/km)1/	Estimated biomass (mt)	Proportion of total estimated biomass	Estimated population ($\times 10^3$)	Proportion of total estimated population	Mean size per individual weight (kg)	Mean size per individual length (cm)
Southeastern Chukchi Sea and Kotzebue Sound								
1N	27.6	0.110	188	.010	43,660	.049	.004	7.74
1S	93.3	0.687	520	.028	31,948	.036	.016	8.92
2Ø	89.5	1.710	735	.040	43,802	.049	.017	10.38
2I	87.5	0.272	83	.005	6,937	.008	.012	8.25
Norton Sound and Northern Bering Sea								
3W	46.9	0.125	274	.015	5,332	.006	.051	19.07
3E	100.0	8.195	5,015	.273	158,797	.179	.032	15.02
4Ø	100.0	7.952	10,587	.576	550,172	.619	.019	11.50
4I	100.0	1.821	968	.053	48,737	.055	.020	12.07
All strata combined:	78.1 2/	2.192	18,370 3/		889,385		.020	11.51

1/ Mean catch per unit effort, kg/km trawled.
2/ Percent occurrence in 192 successful hauls.
3/ 95% confidence interval: 14,116-22,624 mt.

The apparent biomass of saffron cod in the entire survey area was estimated at 18,400 mt (95% confidence interval 14,100-22,600 mt). This is a minimum estimate for the survey region, since saffron cod are semi-pelagic and some unknown proportion of the population occupied the water

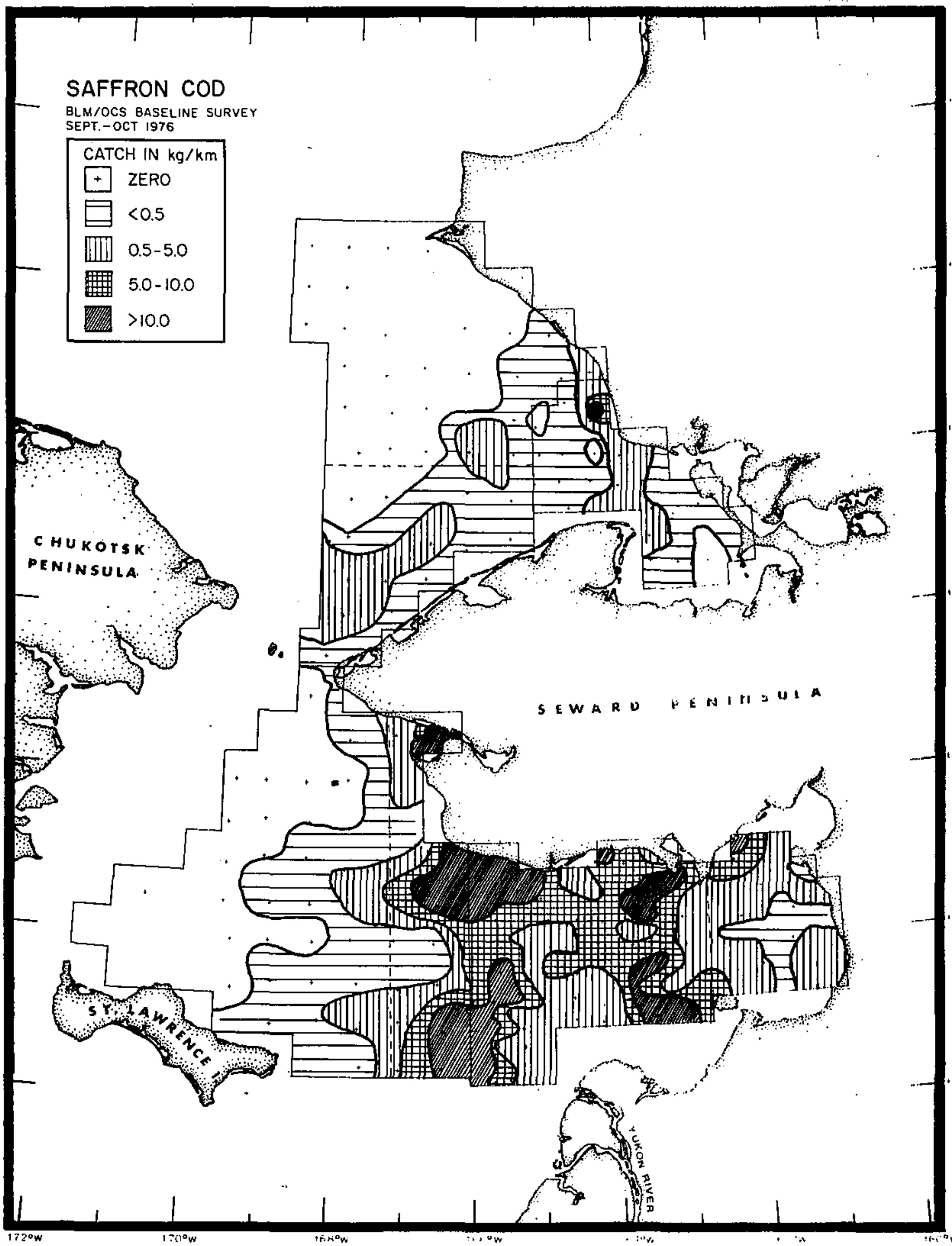


Figure VIII-45.--Distribution and relative abundance by weight of saffron cod in Norton Sound, the southeastern Chukchi Sea and adjacent waters (BLM/OCS survey, 1976).

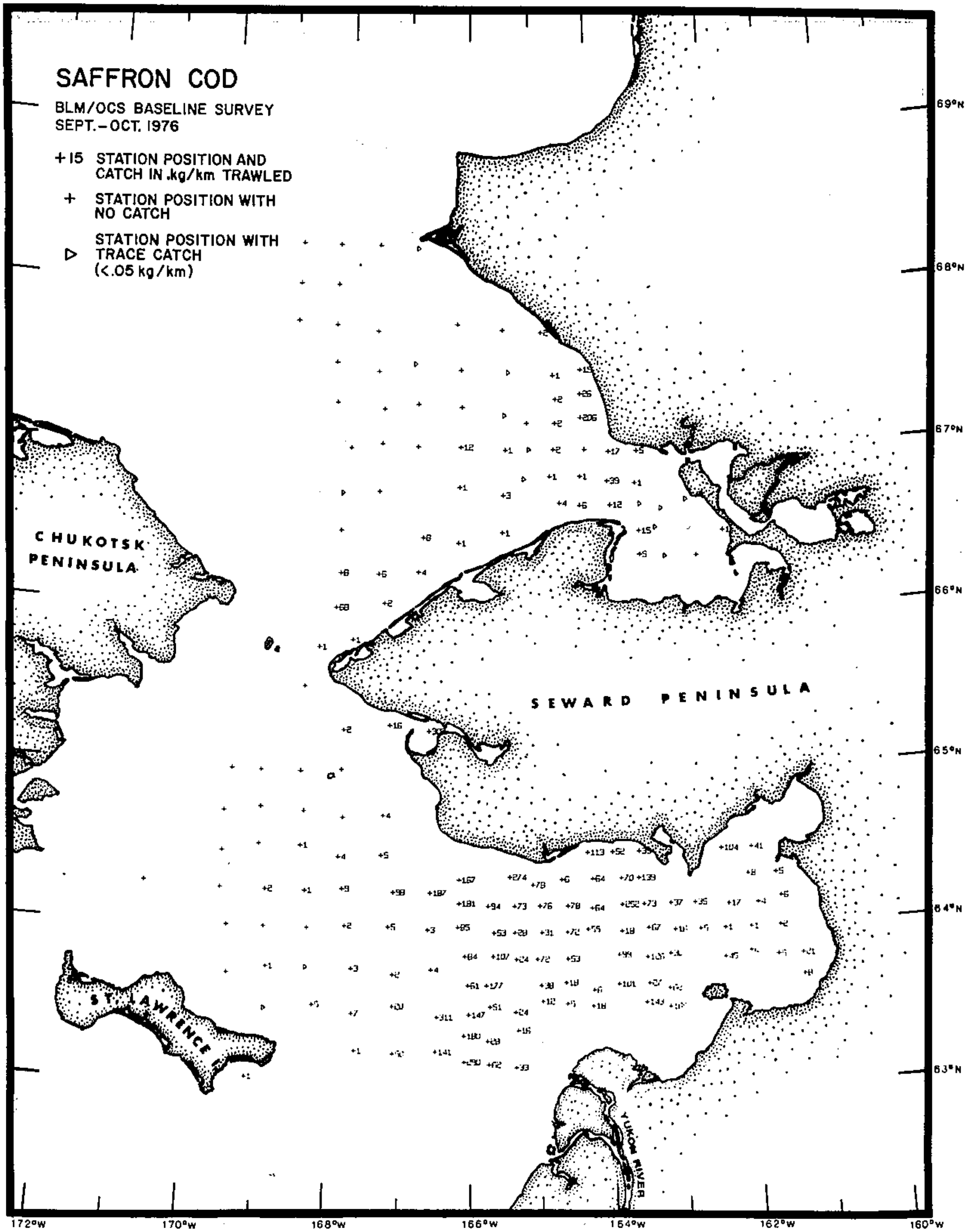


Figure VIII-46.--Distribution of catch rates by weight of saffron cod in Norton Sound, the southeastern Chukchi Sea and adjacent waters (BLM/OCS survey 1976).

column above the demersal trawl, thus being unavailable to the sampling gear. In addition, saffron cod concentrations may have existed beyond the southern boundary of the survey region. Some of the largest catches of this species occurred near the southern limit of strata 3E and 4Ø; earlier Japanese trawl surveys in 1968-1970 indicated catches of saffron cod of up to 1000 kg/30 minute trawl hauls off Cape Romanzof, 50 km south of the survey boundary.

For the saffron cod population sampled, the major portion of the biomass (approximately 85%) was located in strata 3W and 4Ø. Of the remaining biomass, 5% was located in stratum 4I, 4% in stratum 2I, and 1-3% in all other strata.

The relative distribution of estimated numbers of fish differed somewhat from that of apparent biomass. In the southeastern Chukchi Sea, the offshore stratum 1N had an estimated apparent biomass of only 188 mt while in the more nearshore strata 1S and 2Ø, the estimated biomasses were 520 and 735 mt, respectively. Population estimates for these strata, however, were 44 million fish in 1N, 32 million in 1S, and 44 million in 2Ø. While biomass estimates for stratum 1N were only 1/4 to 1/3 that for strata 1S and 2Ø, its estimated population equalled or exceeded that for the other strata.

As with biomass, most of the estimated population of saffron cod occurred in strata 3E and 4Ø. These strata accounted for about 75% of the total population estimate of nearly 900 million fish.

Size composition--Saffron cod ranged in length from 5 to 35 cm. Females were generally larger than males, averaging 19.5 compared to 17.9 cm for all strata combined (Figure VIII-47). Length-frequency distributions for saffron cod included juvenile fish of undetermined sex. The inclusion of these unsexed fish in the calculation of mean size for both sexes combined in all strata caused mean lengths to be considerably less than those for individual sexes.

Most saffron cod found north of Bering Strait were small. Nearly all fish in strata 1N and 1S were less than 10 cm in length, while a few fish as large as 23 cm occurred in stratum 2Ø. In strata south of Bering Strait, fish smaller than 10 cm were still present in appreciable numbers; however, saffron cod as large as 25 cm were far more abundant. In stratum 4Ø, fish from 13 to 25 cm comprised about 25% of the total estimated population.

A general description of the distribution of saffron cod by size in relation to geographic areas shows small (< 10 cm) fish occured throughout the survey region. A few larger fish (10-20 cm) were found in outer Kotzebue Sound and inner Norton Sound, while most large fish (> 20 cm) occurred in outer Norton Sound and in Port Clarence.

Age composition--In terms of estimated numbers of fish, age groups 0-2 predominated (Table VIII-25), comprising over 96% of the estimated standing stock in numbers for the entire survey area. Age group 0 fish alone comprised 67% of the total, with most of these fish occurring in

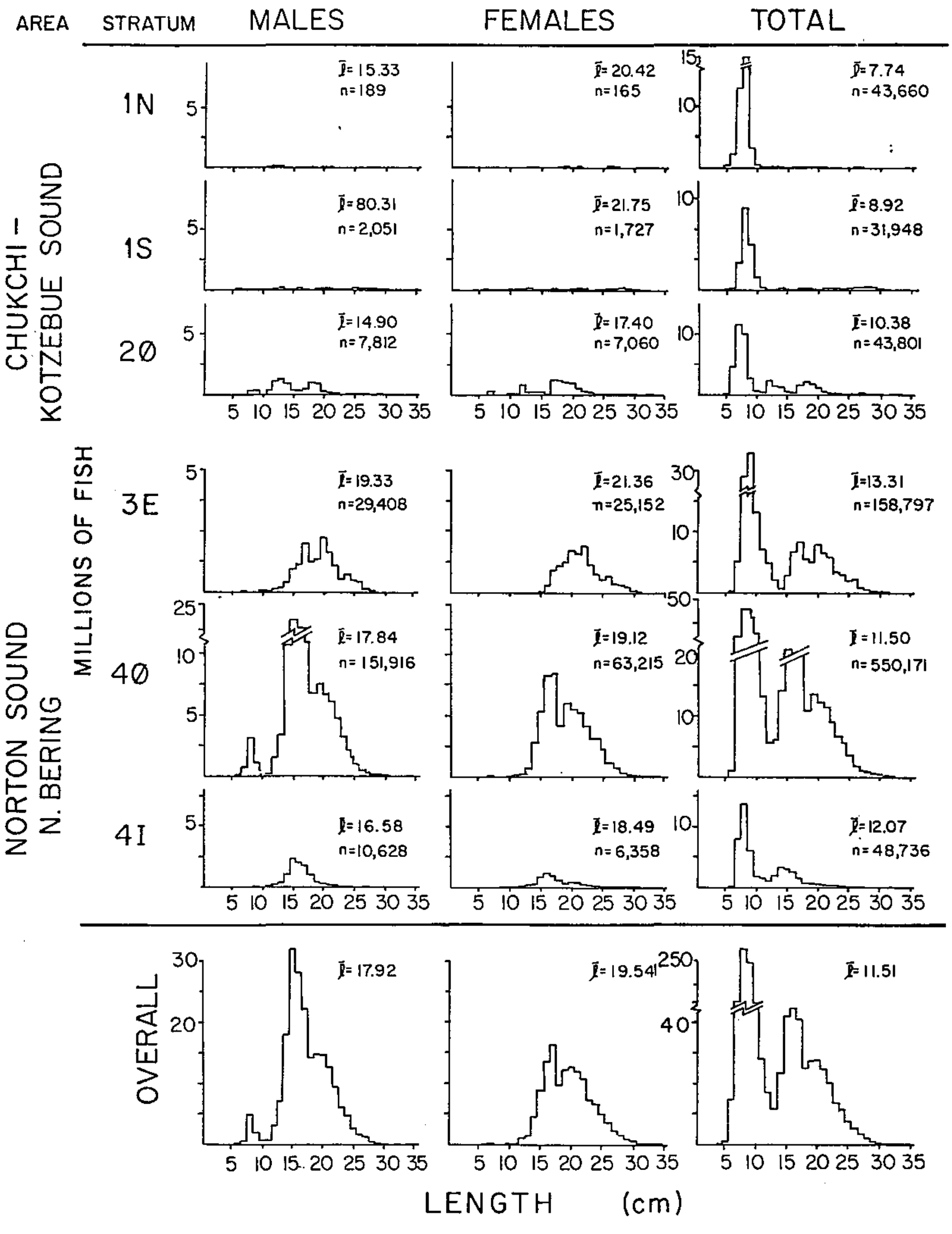


Figure VIII-47.--Size composition of saffron cod by sex and stratum in Norton Sound, the southeastern Chukchi Sea, and adjacent waters (BLM/OCS survey, 1976).

strata 3E and 4Ø. Age groups 1 and 2, accounting for nearly 25% of the total population, also were most abundant in strata 3E and 4Ø. All other age groups were present in relatively small amounts throughout the survey region.

Table VIII-25.--Population numbers ($x10^5$) and sex ratios (number of males/ number of females) of saffron cod by age group and stratum (BLM/OCS survey, 1976).

Age group Year class	0 1976	1 1975	2 1974	3 1973	4 1972	5 1971	6 1970	7 1969	8 1968	9 1967	10 1966	>10 ≤1965	All ages combined
Stratum													
Southeastern Chukchi Sea and Kotzebue Sound													
1N	426.1 --	3.7 (2.45)	1.6 (1.17)	0.1 (0.50)	0.4 (2/)	0.1 (2/)	--	--	--	--	--	--	432.0 (1.13)
1S	275.9 (2.16)	8.5 (2.45)	10.5 (2.04)	6.0 (148.00)	10.4 (20.58)	0.7 (2/)	3.6 (1/)	--	0.3 (1/)	0.3 (1/)	--	--	316.0 (4.79)
2Ø	290.1 (1.93)	57.2 (3.47)	82.7 (0.55)	3.6 (8.97)	3.0 (0.27)	0.6 (0.33)	--	0.1 (2/)	--	--	--	--	437.0 (1.11)
2I	61.0 --	1.7 (1.05)	3.7 (0.57)	0.6 (2.73)	0.4 (0.26)	0.1 (2/)	0.1 (2/)	--	--	--	--	--	67.6 (0.66)
Norton Sound and Northern Bering Sea													
3W	27.0 --	0.3 (1/)	13.3 (0.18)	6.7 (0.25)	2.8 (0.19)	0.8 (2/)	0.1 (2/)	--	--	--	--	--	51.0 (1.20)
3E	891.6 (1/)	200.6 (5.26)	385.9 (0.95)	85.8 (1.01)	20.1 (0.75)	0.4 (2/)	0.1 (2/)	--	--	--	--	--	1,584.4 (1.17)
4Ø	3,741.1 (1.15)	817.2 (1.98)	764.1 (1.18)	144.0 (1.01)	27.1 (1.11)	1.2 (0.22)	0.6 (2/)	--	--	--	--	--	5,495.4 (1.40)
4I	296.0 (0.71)	111.2 (2.65)	67.6 (1.23)	9.5 (0.57)	3.0 (0.55)	0.1 (2/)	0.1 (2/)	--	--	--	--	--	487.4 (1.67)
All strata combined	6008.9 (1.64)	1200.3 (2.28)	1329.3 (1.05)	256.1 (1.03)	67.0 (1.09)	4.1 (0.10)	4.4 (3.41)	0.1 (2/)	0.3 (1/)	0.3 (1/)	--	--	8,870.7 (1.34)
Proportion of total population	.677	.135	.150	.029	.008	.001	.001	T	T	T	--	--	

1/ Only males in estimate.
2/ Only females in estimate.

Differences in relative age composition between sexes do not appear significant (Figure VIII-48).

Sex ratio--Estimated sex ratios (number of males/number of females) by stratum and age group are presented in Table VIII-25. Males were more abundant than females in nearly all strata although this trend was not consistent among all age classes, especially for those older than 2 years.

Age-length relationship and growth--Age and length data collected for saffron cod were as follows:

Sex	Otolith areas	Number of readable otoliths	Range in age (years)	Range in length (cm)
Male	North	130	0-9	6-35
	South	136	0-5	8-34
Female	North	135	0-7	6-34
	South	160	0-6	7-34

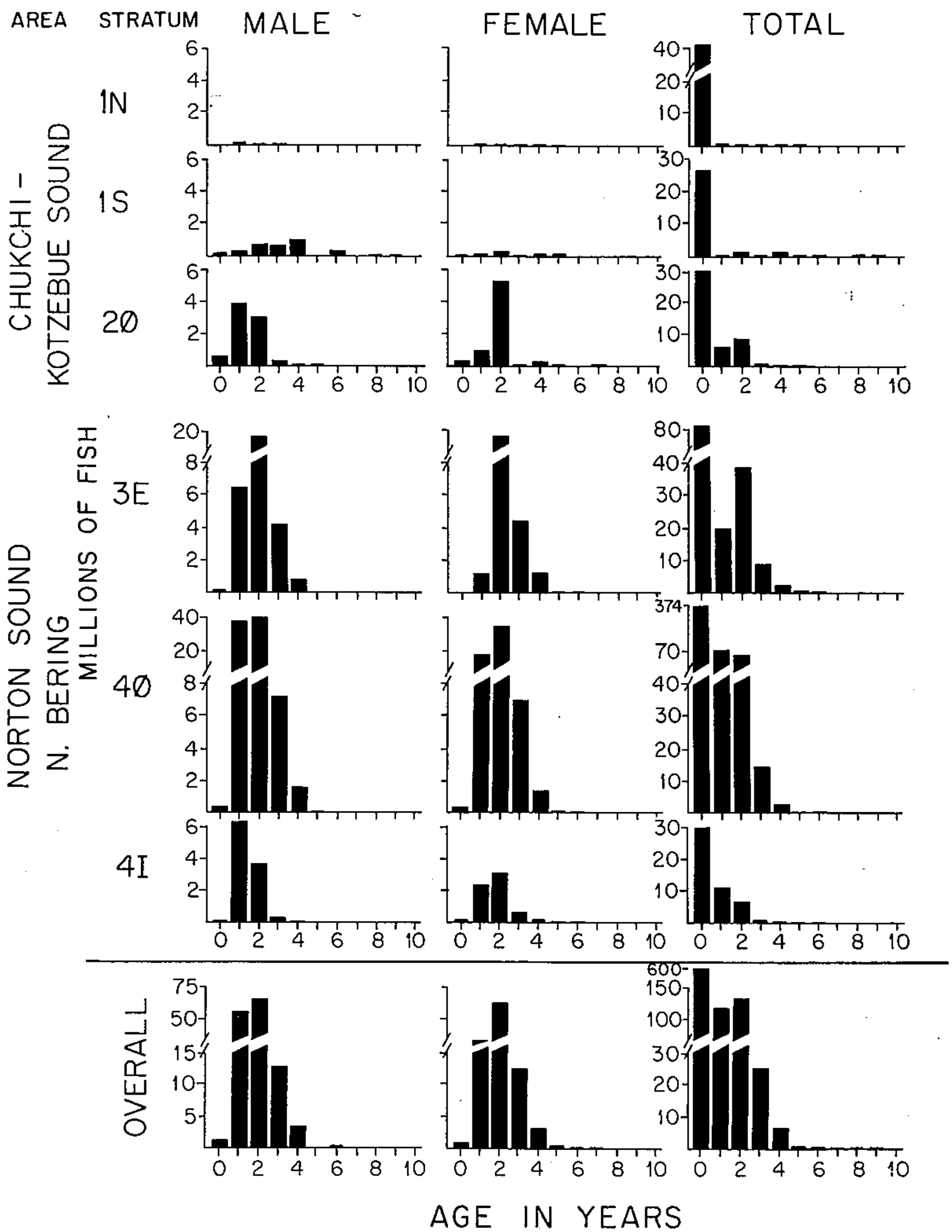


Figure VIII-48.--Age composition of saffron cod by sex and stratum in Norton Sound, the southeastern Chukchi Sea, and adjacent waters (BLM/OCS survey, 1976).

These data are summarized in Figure VIII-49 by plots of mean-lengths-at-age by sex and otolith area. Age-length keys for these data groupings are presented in Appendix I and growth parameters based on this information are given in Table VIII-26.

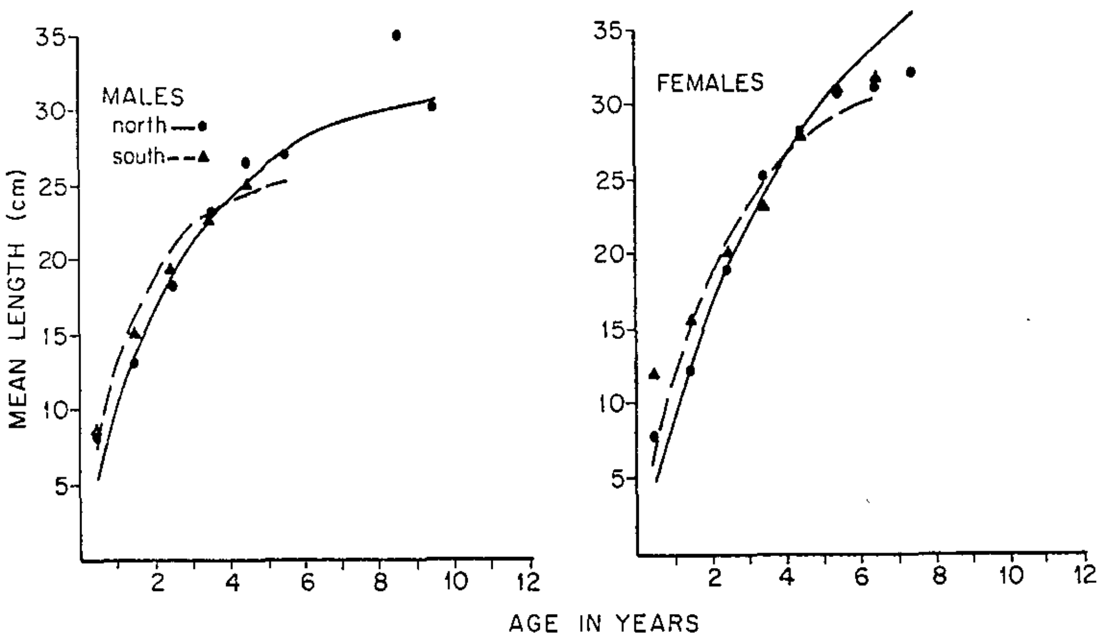


Figure VIII-49.--Mean lengths-at-age and growth curves fit to the origin for saffron cod by sex and otolith area in Norton Sound, the southeastern Chukchi Sea, and adjacent waters (BLM/OCS survey, 1976).

Table VIII-26.--Parameters for von Bertalanffy growth curves for saffron cod in Norton Sound, the southeastern Chukchi Sea, and adjacent waters (BLM/OCS survey, 1976).

Otolith areas	Sex	Range in age and length of analyzed data: age (yr)	length (cm)	Original data set: δ	L_∞	K	t_0	Selected data: δ	L_∞	K	t_0	Selected data with origin: δ	L_∞	K	t_0
North	Males	0.5-9.5 (1.5-5.5)	(10-32)	2.08	35.83	-0.27	-0.35	0.87	30.35	-0.42	0.18	0.79	31.57	-0.36	-0.01
	Females	0.5-7.5 (1.5-4.5)	(10-32)	1.51	37.32	-0.26	-0.32	0.99	36.26	-0.36	0.34	0.95	43.61	-0.23	-0.01
South	Males	0.5-5.5 (0.5-4.5)	(8-30)	2.35	-618.18	0.01	-1.13	0.15	30.86	-0.34	-0.47	1.27	25.76	-0.63	-0.02
	Females	0.5-6.5 (1.5-4.5)	(11-33)	1.10	46.18	-0.14	-1.58	0.77	102.93	-0.05	-1.71	1.29	32.16	-0.42	0.02

Since young of the year (age group 0) were present in all sets of saffron cod age data, adjustments to ages were necessary to provide reasonable growth curve fits for both the original data and for the selected sets which included values at the origin of the curve (age and length = 0). Age plus 0.5 years was used as the adjustment, since it is reasonable to assume that at least half of a year's growth had been completed by the September-October survey date. 1/

In most cases, there was a reduction in the residual root mean square deviations by using selected data and fitting the curve to the origin. This was especially evident in fits for data from the north otolith area. The selected sets also improved fits for the southern area data where meaningless parameters ($\underline{K} > 0$ and $\underline{L}_\infty < 0$) were estimated before selection.

Sex and area effects were observed within the selected data for the parameters $\underline{K}$ and $\underline{L}_\infty$. Males appeared to have substantially higher growth completion rates ($\underline{K}$) than females and estimates of this parameter for either sex were considerably higher (42-45%) in the south otolith area than in the north. Additionally, values of $\underline{L}_\infty$ by sex were 18-26% greater in the north otolith area than in the south. Mean length-at-age for both sexes in the south were greater than those for fish of similar ages in the north otolith area but this relationship was observed only up to age 2.5 years. Beyond that age the reverse was usually observed with larger sizes at age in the north than south.

Overall, age-length data for saffron cod suggest that males achieved maximum size more rapidly than females while total growth was greatest for females. By area, both sexes of saffron cod grew more in the survey region north of Bering Strait, although at ages less than 3.5 years, fish of either sex in the south had larger sizes at age than in the north.

Curves describing the growth equation for selected data with a fit to the origin are presented with observed mean lengths-at-age by area and sex in Figure VIII-49.

<u>Length-weight relationship</u>--Table VIII-27 summarizes the length-weight observations taken for saffron cod by sex and area and gives coefficients of the regression fit to these data. Data points representing all length-weight observations collected for this species during the survey are shown graphically in Figure VIII-50.

Analysis of covariance for between-area and between-sex differences in the relationship between length and weight indicated significant levels of variation ($p < .05$) in all treatments of the data. On the basis of weights predicted by the regression coefficients, males generally weighed slightly more at-length than females, and fish of either sex from the

1/ Andriyashev (1954) indicated that saffron cod spawn during early winter in the Asian side of Bering Strait and growth into adult forms occurs by July.

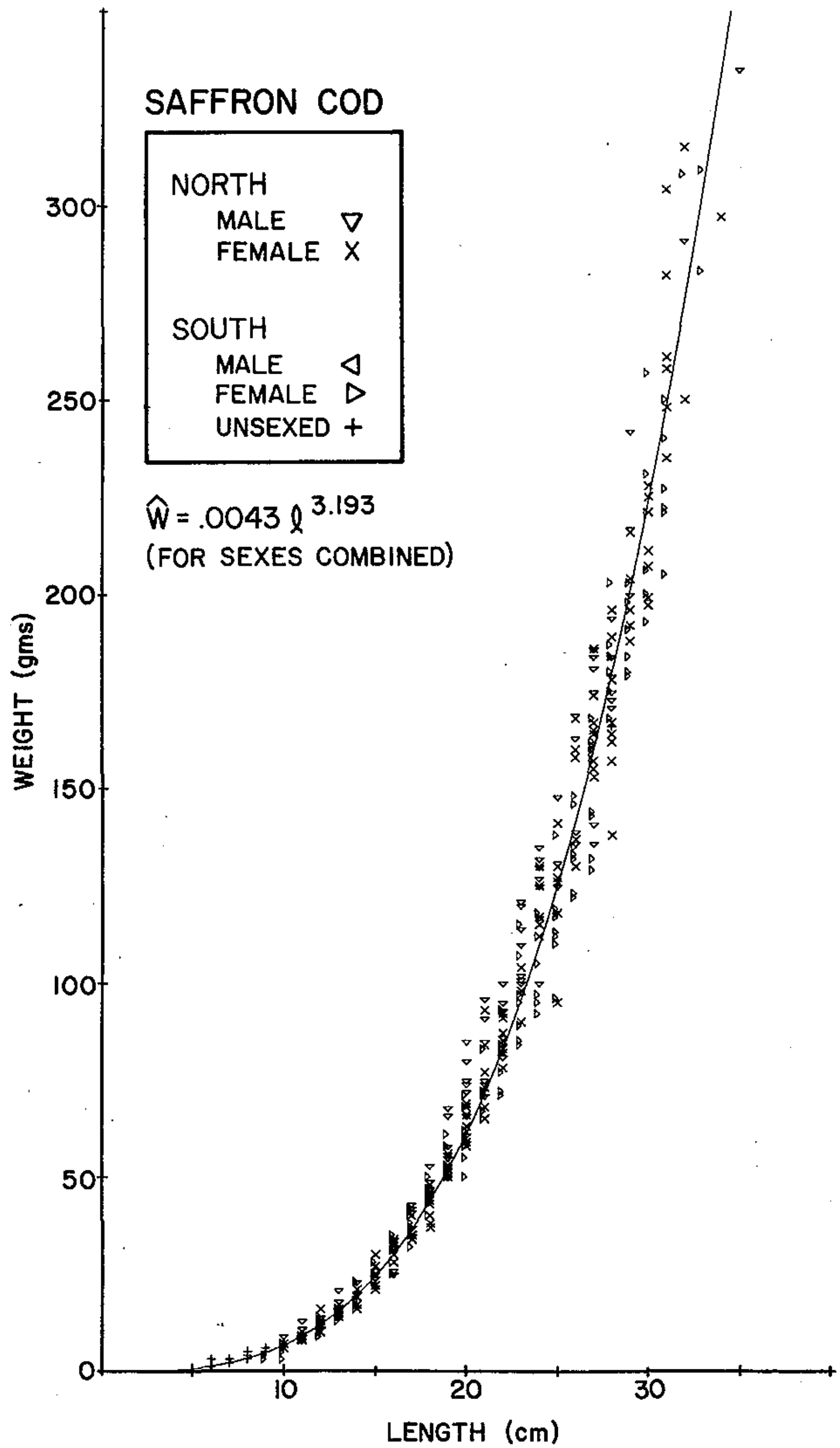


Figure VIII-50.--Weight-at-length observations for saffron cod by sex and otolith area in Norton Sound, the southeastern Chukchi Sea and adjacent waters (BLM/OCS survey, 1976).

north otolith area were heavier at-length than fish of corresponding length and sex from the south. These data suggest differing stocks of saffron cod north and south of Bering Strait. Differences in weight-at-length, however, were on the order of 3-5%; thus, an overall length-weight relationship for saffron cod in the survey area could be described by the equation:

$$\hat{w} = 0.0043\ell^{3.1926}$$

where $\hat{w}$ equals the predicted weight in grams of a fish ℓ cm in length. The relationship described by this equation is shown as a solid line in Figure VIII-50.

Table VIII-27. --Parameters for the length-weight relationship (weight (g) = a · lenght^{b}) for saffron cod and results from the analysis of covariance for between-area and between-sex differences in this relationship (BLM/OCS survey, 1976).

Sex	Otolith Area	Number of Fish Measured	Range in Length (cm)	Parameters a	Parameters b
Males	North	122	10-35	.0033	3.3018
	South	128	8-30	.0045	3.1765
Females	North	141	10-34	.0041	3.2071
	South	151	9-32	.0032	3.2750

Differences between-	F slope df	F slope F	F intercept df	F intercept F	H_b 1/	H_a 1/	Pooled regression a	Pooled regression b
Areas for males	1;246	5.20*	1;247	6.18*	+	+	.0038	3.2425
Areas for females	1;288	2.91	1;289	11.50**	-	+	.0036	3.2478
Areas for sexes combined 2/	1;561	17.1**	1;562	6.52*	+	+	.0043	3.1926
Sexes for south area	1;275	4.11*	1;276	7.69**	+	+	.0039	3.2218
Sexes for north area	1;259	4.58*	1;260	10.10**	+	+	.0038	3.2399
Sexes for areas combined	1;538	.03	1;539	17.5**	-	+	.0038	3.2355

* Significant at the .05 level.

** Significant at the .01 level.

1/ Plus (+) indicates that the common slope (H_b) hypothesis or common intercept (H_a) hypothesis cannot be rejected on the basis of the values of F obtained.

2/ Includes unsexed fish.

Starry flounder

Distribution and abundance--Starry flounder was the second-most abundant fish species, by weight, in the survey region. It accounted for 13% of the total fish biomass and occurred at 47% of the stations sampled (Table VIII-28). Largest concentrations were located in outer Norton Sound (stratum 4Ø), the eastern portion of the northern Bering Sea (stratum 3E), and in the southern portion of the Chukchi Sea (stratum 1S) (Figures VIII-51 and 52) where catch rates averaged 2.3, 1.4, and 1.5 kg/km, respectively. Average catch rates were substantially lower in outer Kotzebue Sound (stratum 2Ø) and inner Norton Sound (stratum 4I), while no catches occurred offshore in both the southeastern Chukchi Sea (stratum 1N) and northern Bering Sea (stratum 3W). Overall the mean catch rate for the entire survey area was 0.6 kg/km trawled.

Table VIII-28.--Estimated biomass and population size of starry flounder in Norton Sound, the southeastern Chukchi Sea and adjacent waters (BLM/OCS survey, 1976).

Stratum	Percent frequency of occurrence	Mean CPUE (kg/km)1/	Estimated biomass (mt)	Proportion of total estimated biomass	Estimated population ($x 10^3$)	Proportion of total estimated population	Mean size per individual weight (kg)	Mean size per individual length (cm)
Southeastern Chukchi Sea and Kotzebue Sound								
1N	3.4	0.049	84	.016	167	.023	.504	32.66
1S	66.7	1.528	1,156	.214	1,185	.163	.976	40.64
2Ø	42.1	0.128	55	.010	96	.013	.575	--
2I	25.0	0.204	62	.012	68	.009	.908	38.50
Norton Sound and northern Bering Sea								
3W	--	--	--	--	--	--	--	--
3E	57.1	1.396	854	.158	1,217	.168	.703	34.85
4Ø	87.9	2.304	3,068	.569	4,067	.560	.755	35.68
4I	64.7	0.209	111	.021	460	.063	.242	24.86
All strata combined:	47.4 2/	0.643	5,390 3/		7,260		.745	35.67

1/ Mean catch per unit effort, kg/km trawled.
2/ Percent occurrence in 192 successful hauls.
3/ 95% confidence interval: 2,957-7,823 mt.

Starry flounder biomass in the entire survey area was estimated at about 5,400 mt (95% confidence interval 2,957-7,823 mt). This survey region estimate is probably fairly good, even though relatively high catch rates occurred along the southern boundary of the study region, indicating the probable presence of relatively large starry flounder concentrations south of the survey boundary. This species is known to primarily inhabit shallow

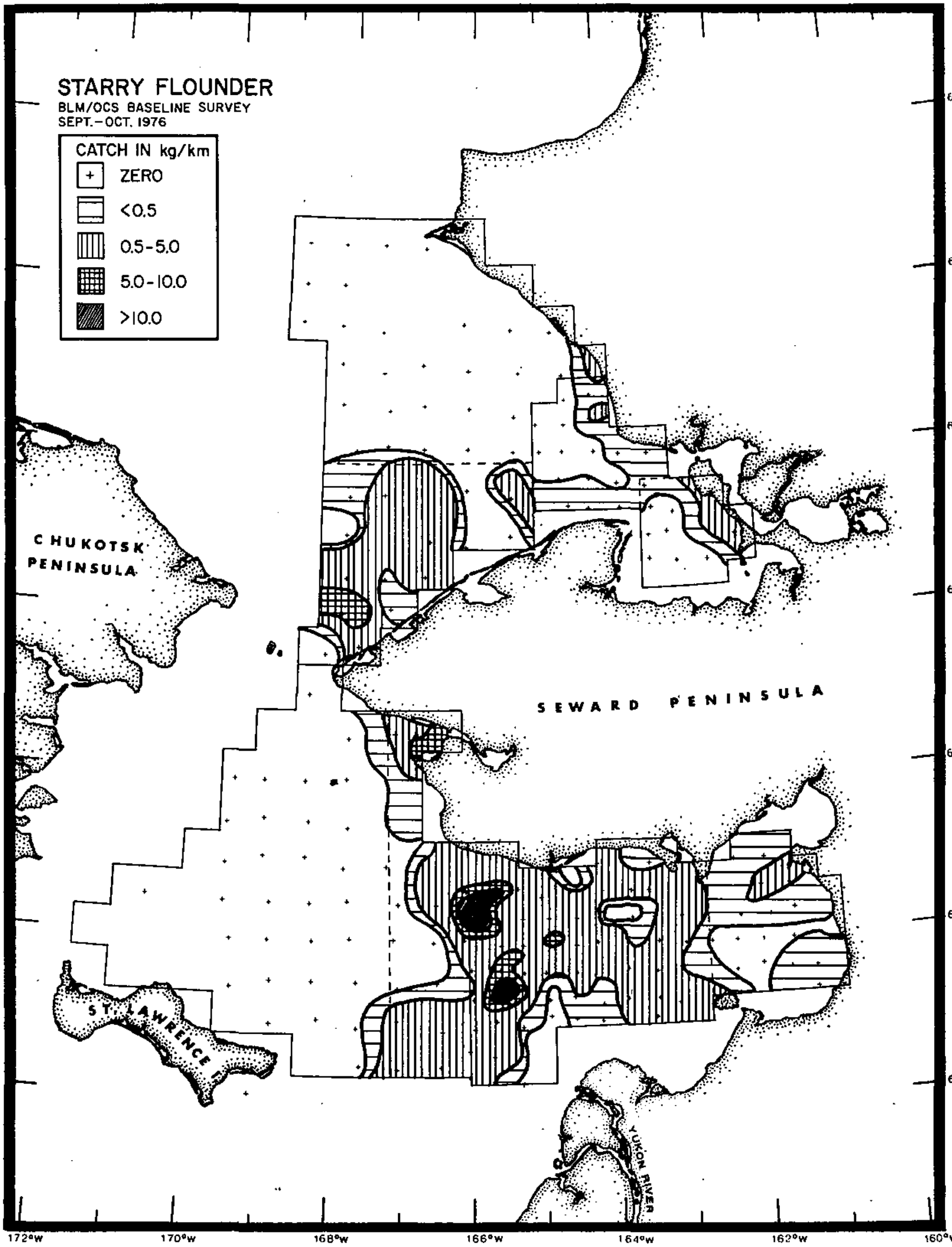


Figure VIII-51.--Distribution and relative abundance by weight of starry flounder in Norton Sound, the southeastern Chukchi Sea and adjacent waters (BLM/OCS survey, 1976).

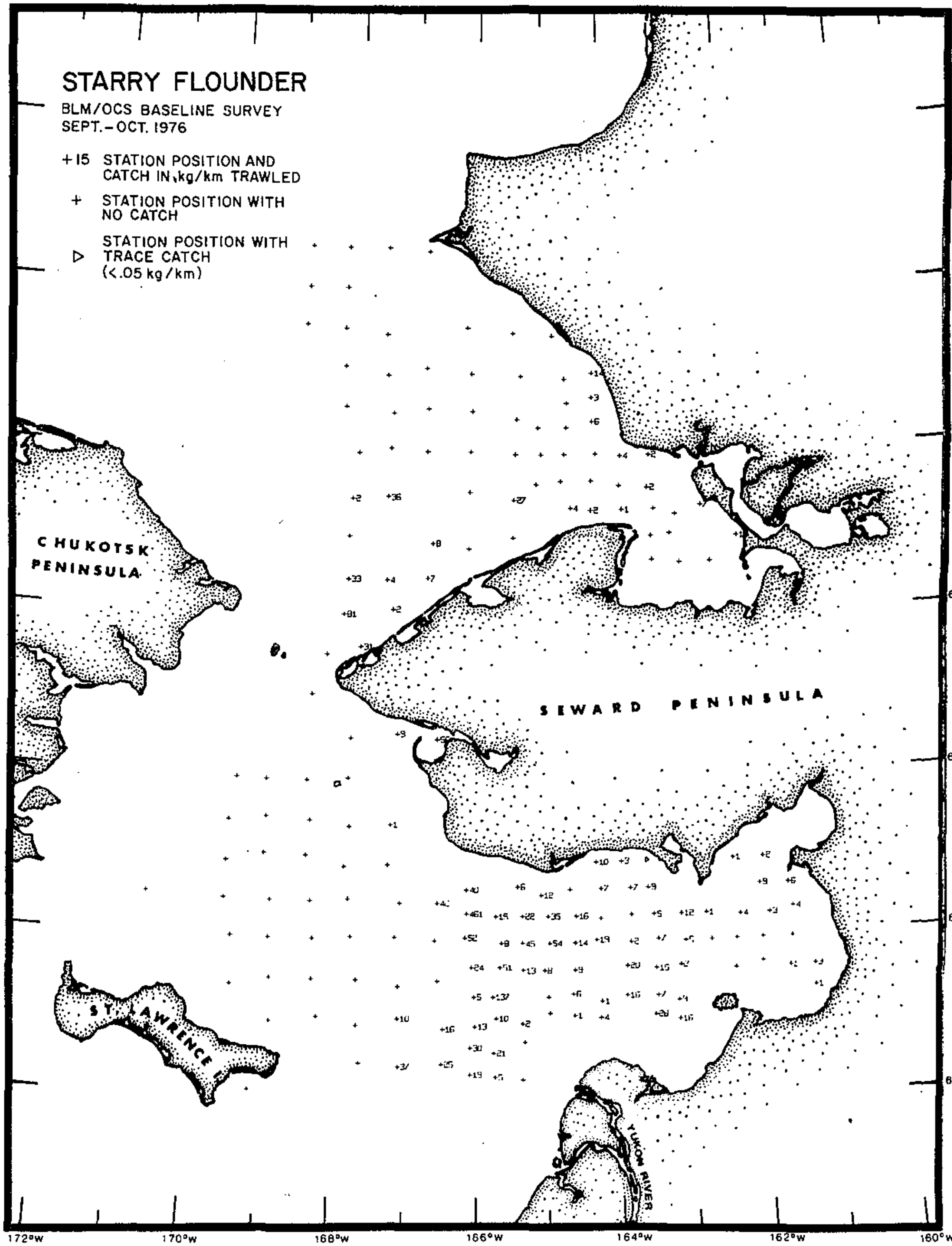


Figure VIII-52.--Distribution of catch rates by weight of starry flounder in Norton Sound, the southeastern Chukchi Sea and adjacent waters (BLM/OCS survey, 1976).

water regions during fall months (Andriyashev, 1937 and 1954), thus depths trawled within the survey region provided adequate depth coverage for September-October. Of the starry flounder population in the survey area, the greatest portion of apparent biomass (approximately 57%) was located in stratum 4Ø, with another 37% in strata 1S and 3E, combined. Most of the remaining 6% of the estimated biomass was found in the nearshore strata 2Ø, 2I, and 4I.

The relative distribution of estimated numbers did not substantially differ from apparent biomass. Strata 4Ø, 3E and 1S together contained an estimated 6.4 million fish or about 89% of the total survey area population estimate. Stratum 4I contained a further 6% of the total population estimate which was slightly less than 7.3 million fish for all subareas combined.

Size composition, mean length and weight--Starry flounder caught during the survey ranged in length from 15 to 63 cm. Females were substantially larger than males, averaging 39.3 cm compared to 31.4 cm for all strata combined, (Figure VIII-53).

Length-frequency distributions for starry flounder suggest that average size and differences in size composition by sex varied within the survey region. In stratum 4I, the only inshore area where relatively substantial numbers were encountered, mean size by sex was very similar and the overall average length was 24.9 cm. The average size of fish exceeded 32 cm in all other strata and differences in size between sexes were quite large.

In general, starry flounder larger than 40 cm were found mostly in strata 1S and 4Ø in the southern portion of the Chukchi Sea and in outer Norton Sound. Intermediate-size fish (30-40 cm) were located in stratum 4Ø and adjacent stratum 3E while fish smaller than 30 cm were present in the shallow, more nearshore strata 4Ø and 4I.

The average weight of starry flounder was 0.75 kg, largest for any of the fish species encountered during the survey. Although several other fish species had estimated population numbers which greatly exceeded that for starry flounder, the large weight and size of this species provided an estimated biomass which was far greater than that for other more numerous fish.

Age composition--Differences in relative age composition by sex and stratum are shown in Figure VIII-54. Ages ranged 5 to 21 years. In terms of absolute numbers, age groups 14 and 15 somewhat predominated (Table VIII-29).

Few young fish were found north of Bering Strait. In strata 1N, 1S, 2Ø, and 2I, only about 11% of the estimated starry flounder population was less than 12 years of age. South of Bering Strait, the proportion of younger fish was much higher. For strata 3E and 4Ø, 24% of the standing stock estimate was younger than age 12, while in stratum 4I, these younger fish comprised over 42% of the apparent population.

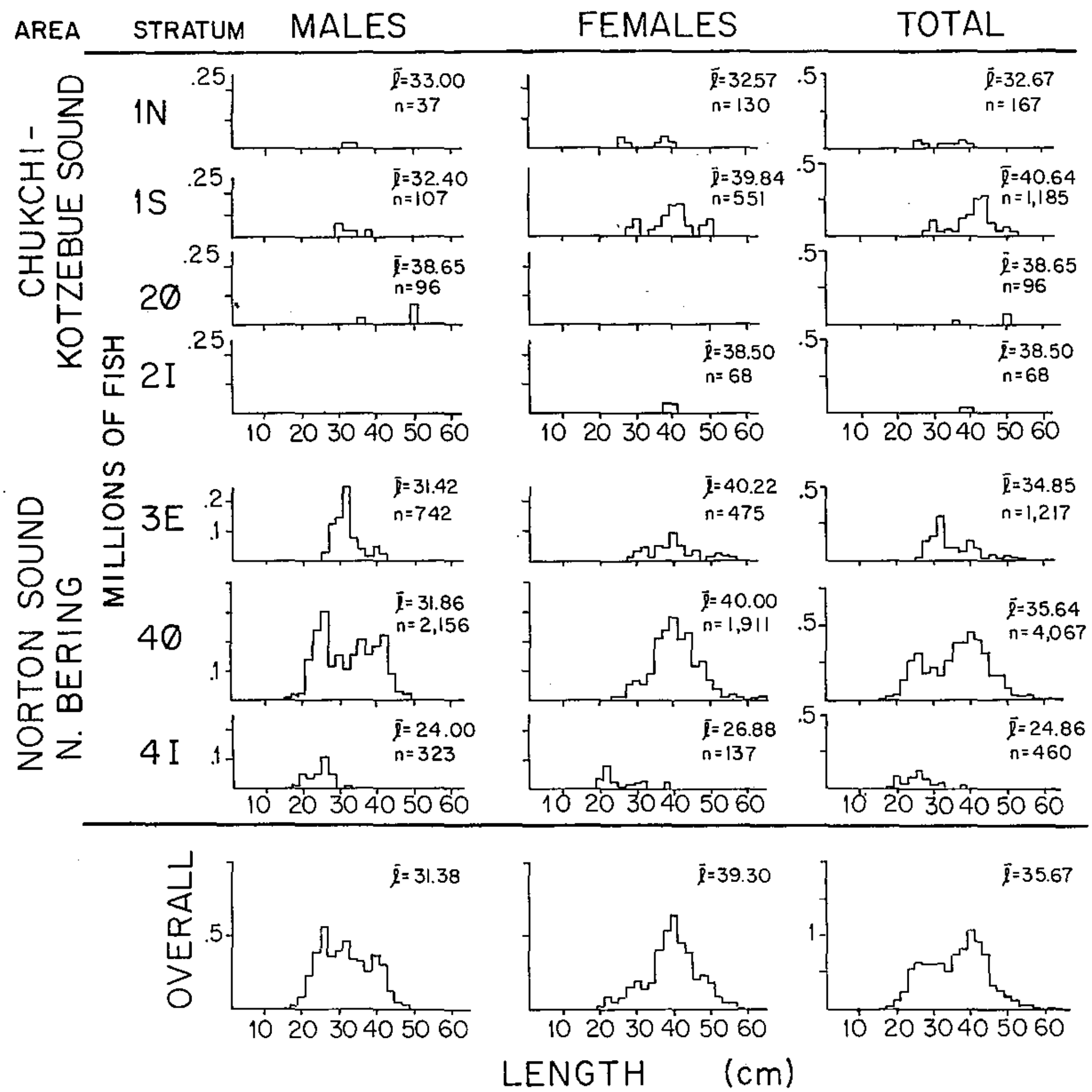


Figure VIII-53.--Size composition of starry flounder by sex and stratum in Norton Sound, the southeastern Chukchi Sea, and adjacent waters (BLM/OCS survey, 1976).

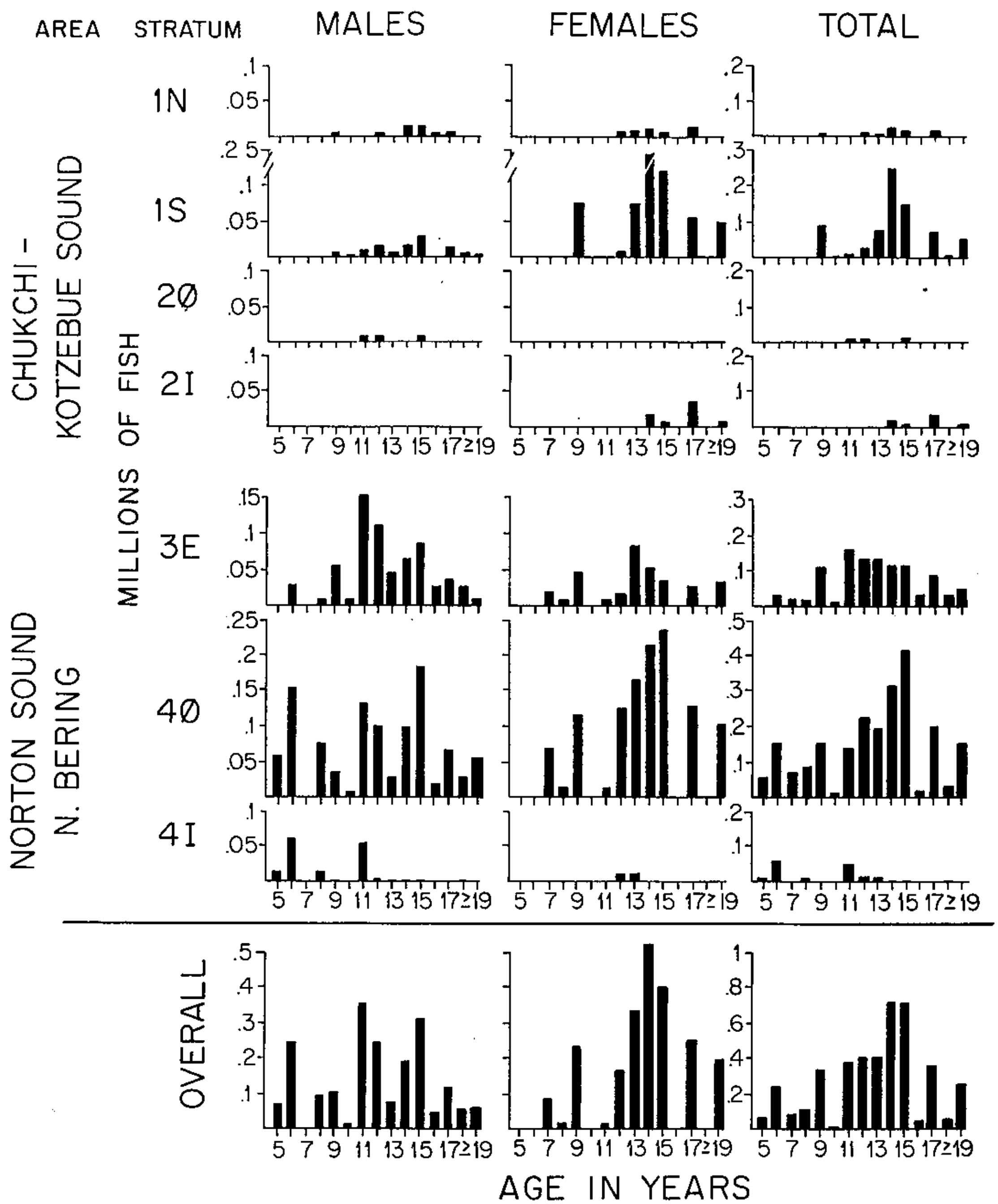


Figure VIII-54.--Age composition of starry flounder by sex and stratum in Norton Sound, the southeastern Chukchi Sea, and adjacent waters (BLM/OCS survey, 1976).

Table VIII-29.--Population numbers ($x10^4$) and sex ratios of starry flounder by age group and stratum (BLM/OCS survey, 1976).

Age group Year class	5 1971	6 1970	7 1969	8 1968	9 1967	10 1966	11 1965	12 1964	13 1963	14 1962	15 1961	16 1960	17 1959	18 1958	>18 ≤1957	All ages combined
Stratum																
Southeastern Chukchi Sea and Kotzebue Sound																
1N	--	--	--	--	0.3 (1/)	--	--	0.9 (0.50)	0.6 (2/)	2.2 (1.20)	1.8 (2.00)	-- (1/)	1.5 (0.50)	--	--	7.6 (1.00)
1S	--	--	--	--	8.3 (0.11)	0.2 (1/)	1.0 (1/)	2.5 (1.78)	7.8 (0.08)	24.6 (0.06)	14.9 (0.24)	--	6.4 (0.23)	0.4 (1/)	5.0 (0.04)	7.11 (0.17)
2Ø	--	--	--	--	--	--	0.9 (1/)	0.9 (1/)	--	--	0.9 (1/)	--	--	--	--	2.7 (1/)
2I	--	--	--	--	--	--	--	--	--	1.7 (2/)	0.9 (2/)	--	3.4 (2/)	--	0.9 (2/)	6.9 (2/)
Norton Sound and Northern Bering Sea																
3W	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
3E	--	2.9 (1/)	1.9 (2/)	1.7 (0.89)	10.1 (1.24)	0.9 (1/)	15.6 (17.33)	12.7 (6.94)	12.7 (0.53)	11.4 (1.24)	11.4 (2.56)	2.5 (1/)	6.3 (1.33)	2.6 (1/)	4.1 (0.28)	97.7 (2.02)
4Ø	5.7 (1/)	15.4 (1/)	6.7 (2/)	8.5 (6.73)	14.9 (0.28)	0.8 (1/)	14.0 (11.91)	22.4 (0.81)	19.2 (0.16)	31.4 (0.45)	41.5 (0.78)	1.9 (1/)	19.2 (0.51)	2.9 (1/)	15.4 (0.52)	220.1 (0.88)
4I	1.6 (1/)	6.0 (1/)	--	1.6 (1/)	0.2 (1/)	--	5.2 (1/)	1.4 (0.27)	1.3 (0.18)	0.1 (1/)	0.1 (1/)	--	--	0.1 (1/)	--	17.6 (7.00)
All strata combined	7.3 (1/)	24.3 (1/)	8.6 (2/)	11.8 (4.90)	33.8 (0.43)	1.9 (1/)	37.8 (17.9)	40.8 (1.46)	41.6 (0.23)	71.4 (0.36)	71.5 (0.79)	4.7 (1/)	36.8 (0.47)	6.0 (1/)	25.4 (0.34)	423.7 (0.90)
Proportion of total population	.017	.057	.020	.028	.080	.004	.089	.096	.098	.169	.169	.011	.087	.014	.060	

1/Only males in estimate.
2/Only females in estimate.

Sex ratio--Estimated sex ratios (number of males/number of females) by stratum and age group are presented in Table VIII-29. There appeared to be more females than males in the area of greatest abundance (stratum 4Ø) although this situation was not consistent for age groups younger than 11 years. For all strata combined, males were generally more abundant than females for age groups younger than 12 years while in older age groups, the opposite was observed.

Age-length relationship and growth--Age-length data collected for starry flounder were as follows:

Sex	Number of readable otoliths	Range in age (years)	Range in length (cm)
Male	61	5-20	24-44
Female	24	7-21	25-53

No age-length information was obtained from the north otolith area for this species. Plots of mean lengths-at-age by sex are presented in Figure VIII-55 and age-length keys for the data groupings are given in Appendix I. Growth parameters by sex are presented in Table VIII-30.

Since few age-length samples were obtained for starry flounder, only two growth curves were fitted: one to the original data and the other with the original data fit to the origin. Fitting curves to the origin did not reduce the root mean square deviations (δ) or change $\underline{L}_\infty$ from values obtained from the original data sets, but the parameters $\underline{K}$ and $\underline{t}_o$ were reduced to more realistic values.

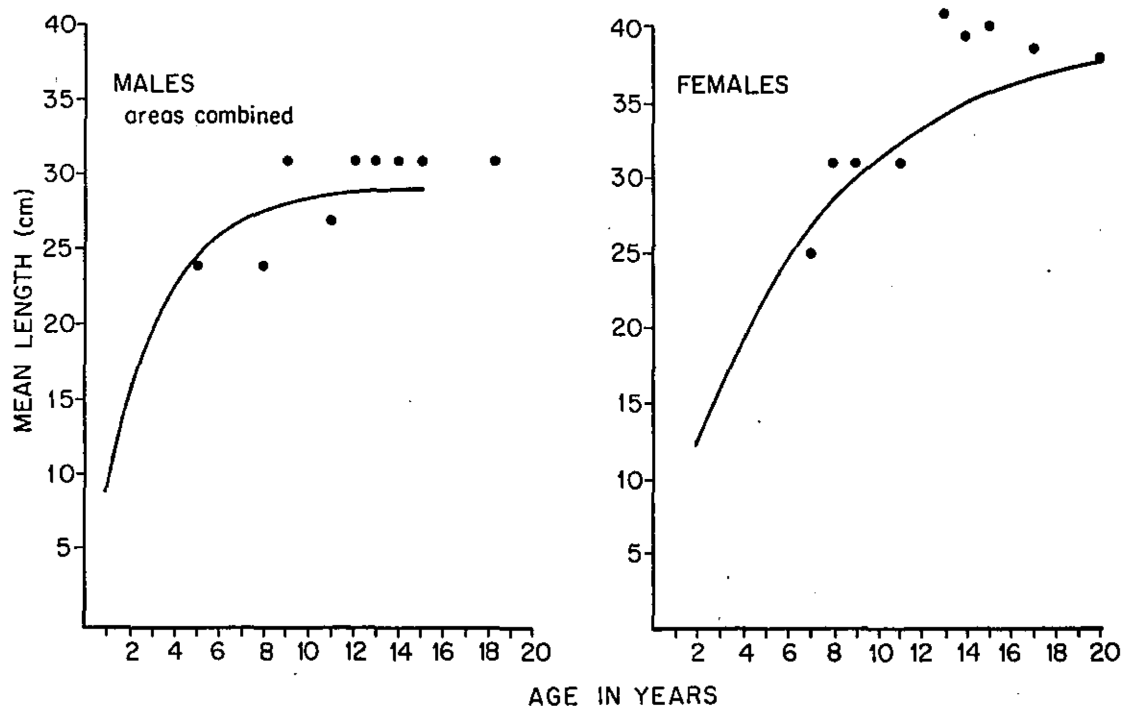


Figure VIII-55.--Mean lengths-at-age and growth curves fit to the origin for starry flounder in Norton Sound, the southeastern Chukchi Sea, and adjacent waters (BLM/OCS survey, 1976).

Table VIII-30. --Parameters for von Bertalanffy growth curves for starry flounder in Norton Sound, the southeastern Chukchi Sea and adjacent waters (BLM/OCS survey, 1976).

	Original data set				Original data with origin			
Sex	δ	L_∞	K	t_o	δ	L_∞	K	t_o
Males	2.70	29.34	-1.15	3.61	2.35	29.25	-0.37	0.02
Females	2.88	38.21	-0.39	4.29	3.69	39.42	-0.15	-0.45

Male starry flounder appear to have a more rapid growth than females and achieve maximum size at an earlier age. The value of $\underline{K}$ for males was more than twice that of females while $\underline{L}_\infty$ differed between sexes by about 25%.

Length-weight relationship--Table VIII-31 summarizes the length-weight relationships, along with corresponding regression coefficients, for starry flounder by sex. Data points representing all length-weight observations are shown graphically in Figure VIII-56.

Table VIII-31.--Parameters for the length-weight relationship (weight (g) = a · length^{b}) for starry flounder and results of the analysis of covariance for between-sex differences in this relationship (BLM/OCS survey, 1976).

Sex	Otolith Area	Number of Fish Measured	Range in Length (cm)	Parameters a	Parameters b
Males	North	1	25	------	------
	South	77	24-44	0.0094	3.0981
Females	North	6	32-48	------	------
	South	31	31-52	0.0037	3.3700

Differences between-	F slope df	F slope F	F intercept df	F intercept F	H_b 1/	H_a 1/	Pooled regression a	Pooled regression b
Sexes for areas combined	1;111	2.30	1;112	2.09	-	-	0.0045	3.3149

1/ Plus (+) indicates that the common slope (H_b) hypothesis or common intercept (H_a) hypothesis cannot be rejected on the basis of the values of F obtained.

Since few length-weight observations were obtained for starry flounder in the north otolith area, between-area differences were not tested and an analysis of covariance for between-sex differences failed to indicate significant levels of variation ($p < .05$). The overall length-weight relationship for starry flounder, sexes combined, was described by the equation:

$$\hat{w} = 0.0045\ell^{3.3149}$$

where $\hat{w}$ equals the predicted weight in grams of a fish ℓ cm in length. The relationship described by this equation is shown as a solid line in Figure VIII-56.

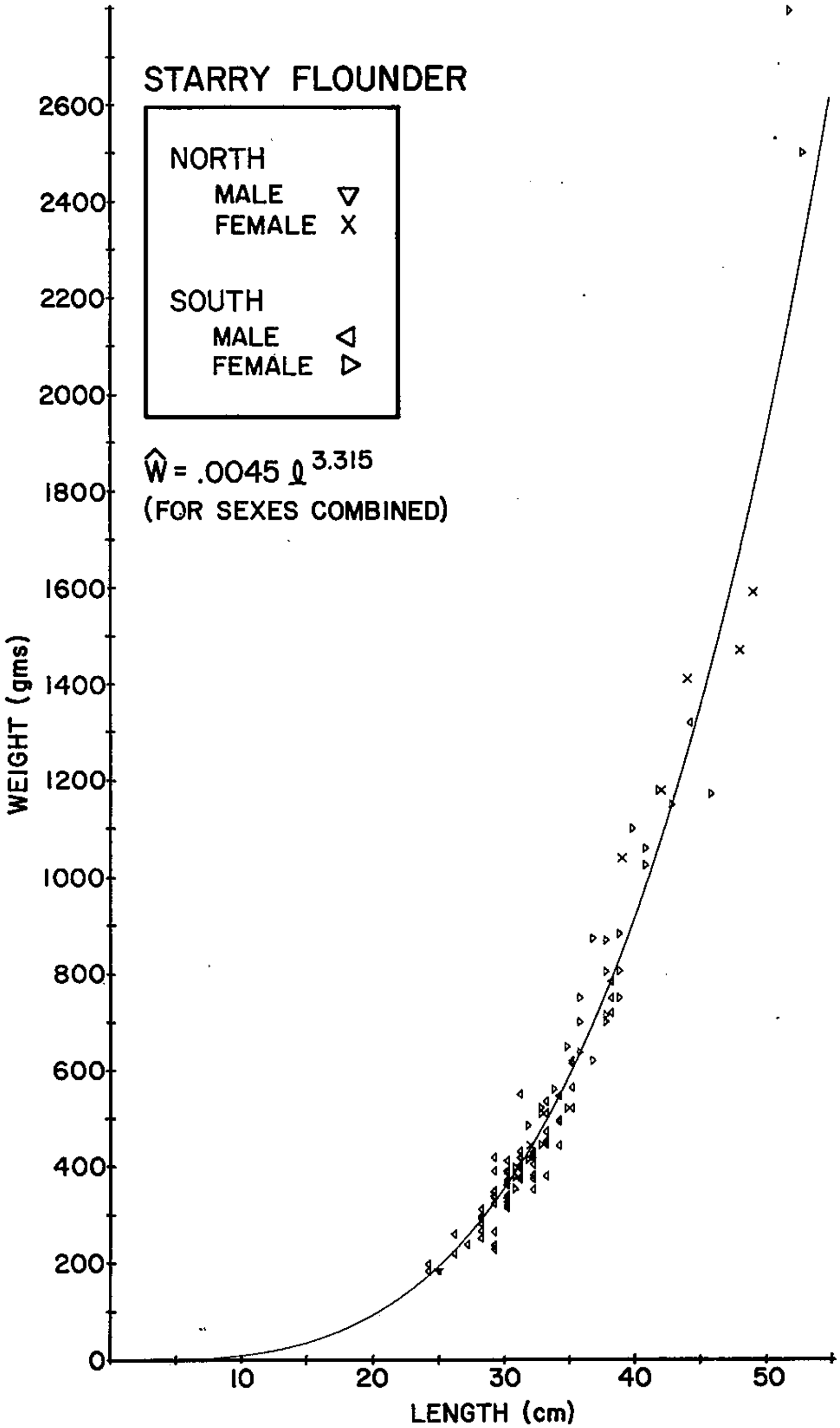


Figure VIII-56.--Weight-at-length observations for starry flounder by sex and otolith area in Norton Sound, the southeastern Chukchi Sea and adjacent waters (BLM/OCS survey, 1976).

Shorthorn sculpin

Distribution and abundance--Although not identified as one of the principal demersal species in the survey region, shorthorn sculpin was the third-most abundant fish species encountered. It comprised 9% of the total fish biomass and occurred at over 55% of all stations sampled (Table VIII-32). Largest concentrations of shorthorn sculpin were located in the northern Bering Sea (strata 3W and 3E), where stratum catch rates averaged 1.5 and 0.6 kg/km (Figures VIII-57 and 58). Other regions where concentrations occurred included the northwest portion of outer Norton Sound (a portion of stratum 4Ø) and the southeastern Chukchi Sea (stratum 1S) slightly north of Bering Strait, where depths exceeded 25 m. Average catch rates decreased markedly in inner Norton Sound (stratum 4I), Kotzebue Sound (strata 2I and 2Ø), and in the northern portion of the southeastern Chukchi Sea (stratum 1N). The overall mean catch rate for the entire survey area was 0.5 kg/km trawled.

Table VIII-32.--Estimated biomass and population size of shorthorn sculpin in Norton Sound, the southeastern Chukchi Sea, and adjacent waters (BLM/OCS survey, 1976).

Stratum	Percent frequency of occurrence	Mean CPUE (kg/km)1/	Estimated biomass (mt)	Proportion of total estimated biomass	Estimated population ($\times 10^3$)	Proportion of total estimated population	Mean size per individual weight (kg)	Mean size per individual length (cm)
Southeastern Chukchi Sea and Kotzebue Sound								
1N	44.8	0.115	196	.045	10,462	.317	.019	—
1S	66.7	0.304	230	.053	6,317	.191	.036	—
2Ø	47.4	0.034	15	.003	288	.009	.051	—
2I	12.5	0.001	t	t	11	t	—	—
Norton Sound and northern Bering Sea								
3W	96.9	1.511	3,289	.752	10,945	.331	.301	—
3E	92.9	0.574	352	.080	3,372	.102	.104	—
4Ø	48.3	0.215	287	.066	1,625	.049	.177	—
4I	5.9	0.002	1	t	6	t	—	
All strata combined:	55.2 2/	0.522	4,371 3/		33,025		.133	—

1/ Mean catch per unit effort, kg/km trawled.
2/ Percent occurrence in 192 successful hauls.
3/ 95% confidence interval: 2,922-5,819 mt.

The apparent biomass of shorthorn sculpin in the 1976 baseline survey area was estimated at about 4,300 mt (95% confidence interval 2,922 - 5,819 mt). Little is known concerning the extent of vertical distribution of this species, but in general, cottids are described as bottom-dwelling species (Hart, 1973), thus indicating that the biomass estimate was fairly

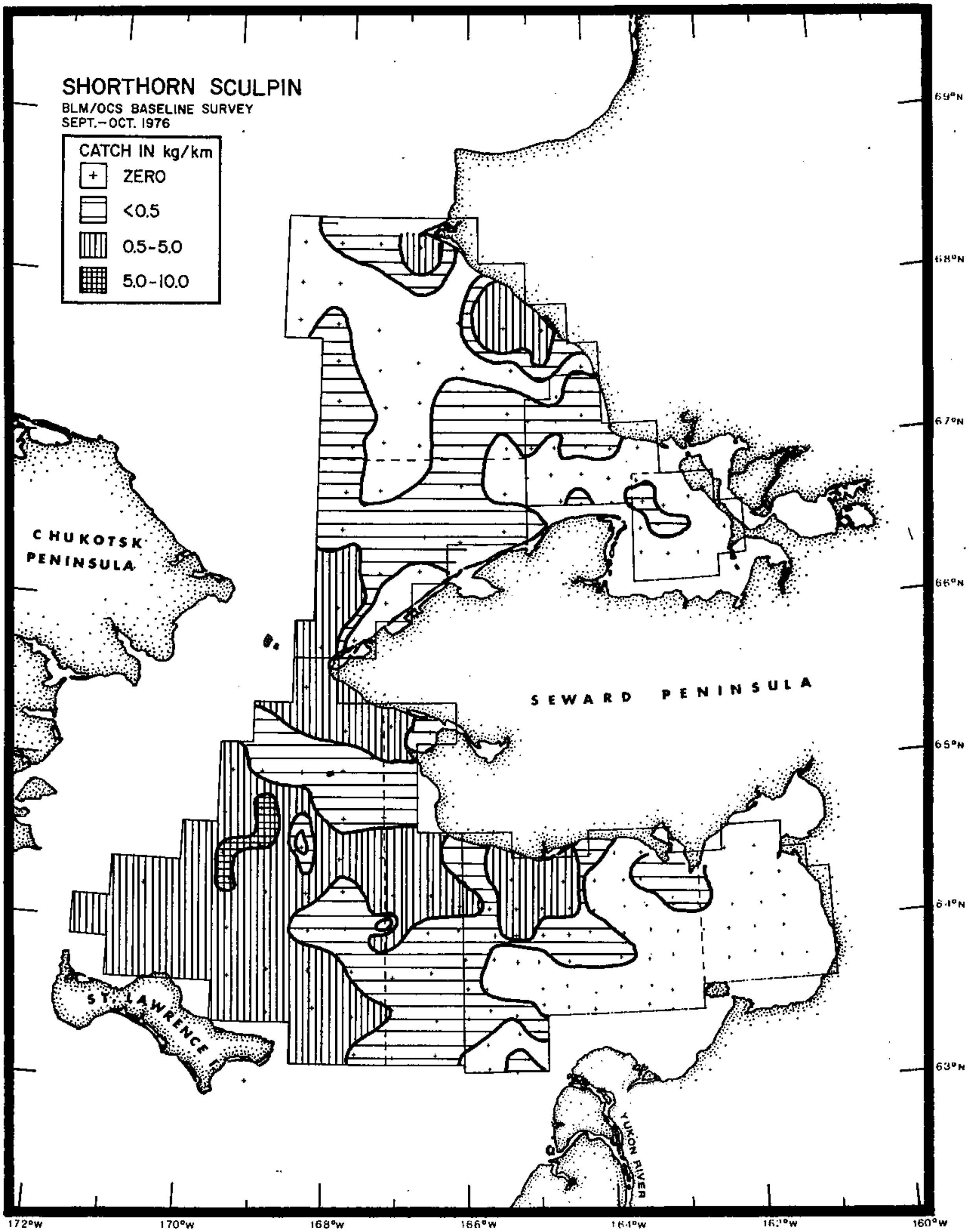


Figure VIII-57.--Distribution and relative abundance by weight of shorthorn sculpin in Norton Sound, the southeastern Chukchi Sea and adjacent waters (BLM/OCS survey, 1976).

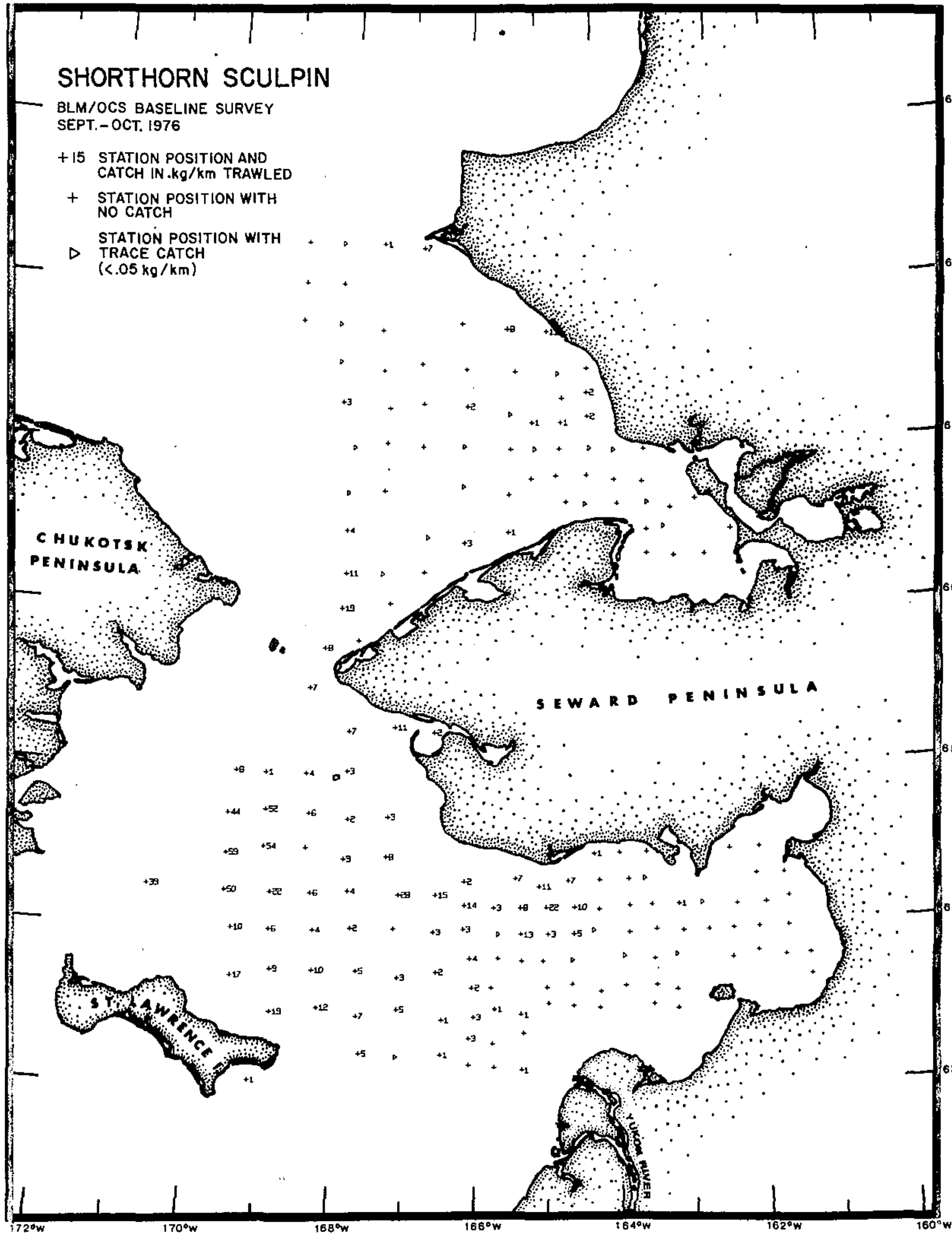


Figure VIII-58.--Distribution of catch rates by weight of shorthorn sculpin in Norton Sound, the southeastern Chukchi Sea and adjacent waters (BLM/OCS survey, 1976).

good for the survey area. A problem concerning biomass, however, might result from the fact that this species showed a definite preference for deeper waters (>25m), especially in the northern Bering Sea portion of the survey area. Much of the westernmost part of stratum 3W was deeper than 25m but had rough untrawlable bottom and catches could not be obtained from most of the stations in this region.

For the population encountered, over 75% of the apparent biomass of shorthorn sculpin was located in stratum 3W. A further 15% was located in adjacent stratum 3E and stratum 4Ø, while nearly 10% occurred in strata 1N and 1S combined. Only trace amounts were found in strata 2Ø, 2I, and 4I where bottom depths were quite shallow (<25 m).

Relative distribution of estimated numbers differed from apparent biomass. Strata 1N and 1S in the southeastern Chukchi Sea together contained only 10% of the estimated biomass; however, over 50% of the survey population estimate occurred in this region. Most of the remaining portion of estimated population (43%) was located in strata 3E and 3W where the greatest biomass occurred. Bering Strait appeared to separate the shorthorn sculpin population by weight. The average weight of fish north of Bering Strait was only 25 gm, while to the south the average weight per individual exceeded 246 gm. The overall average weight of shorthorn sculpin was 133 gm.

Pacific herring

Distribution and relative abundance--Pacific herring occurred at 50% of the stations sampled (Table VIII-33) and accounted for about 6% of the apparent biomass for all fish combined. The main concentration of this species was found in outer Kotzebue Sound (stratum 2Ø) (Figures VIII-59 and 60) where the average catch rate was 3.1 kg/km trawled. Average catch rates decreased to about 0.5 kg/km along the northern shore of the Seward Peninsula (stratum 1S) and in the eastern portion of the northern Bering Sea (stratum 3E). In the remaining strata, catch rates were very low, especially in the inner portions of Norton and Kotzebue sounds (strata 4I and 2I) and in the western portion of the northern Bering Sea (stratum 3W). The overall mean catch rate for the entire survey area was 0.3 kg/km trawled.

Table VIII-33.--Estimated biomass and population size of Pacific herring in Norton Sound, the southeastern Chukchi Sea, and adjacent waters (BLM/OCS survey, 1976).

Stratum	Percent frequency of occurrence	Mean CPUE (kg/km)1/	Estimated biomass (mt)	Proportion of total estimated biomass	Estimated population ($x 10^3$)	Proportion of total estimated population	Mean size per individual weight (kg)	length (cm)
Southeastern Chukchi Sea and Kotzebue Sound								
1N	24.1	0.150	255	.102	2,832	.093	.090	19.02
1S	73.3	0.472	357	.143	4,376	.144	.082	18.66
2Ø	94.7	3.099	1,331	.534	14,902	.489	.089	18.88
2I	25.0	0.048	15	.006	133	.004	.111	19.43
Norton Sound and northern Bering Sea								
3W	21.9	0.048	105	.042	1,125	.037	.093	19.25
3E	78.6	0.424	259	.104	3,549	.117	.073	17.72
4Ø	60.3	0.123	164	.066	3,468	.114	.047	15.05
4I	23.5	0.008	4	.002	74	.002	.060	--
All strata combined:	49.5 2/	0.297	2,491 3/		30,458		.080	18.31

1/ Mean catch per unit effort, kg/km trawled.
2/ Percent occurrence in 192 successful hauls.
3/ 95% confidence limits: 1,072-3,910.

The apparent biomass of Pacific herring in the survey region was estimated at 2,500 mt (95% confidence interval 1,000-3,900 mt), which is a minimum estimate for the entire survey area. Pacific herring are primarily pelagic and substantial portions of the population probably occupied the water column above the sampling gear. Thus, the demersal trawl gear only sampled some portion of the population. Additionally, dense concentrations of this species have been known to occur in Norton Sound during late spring. For

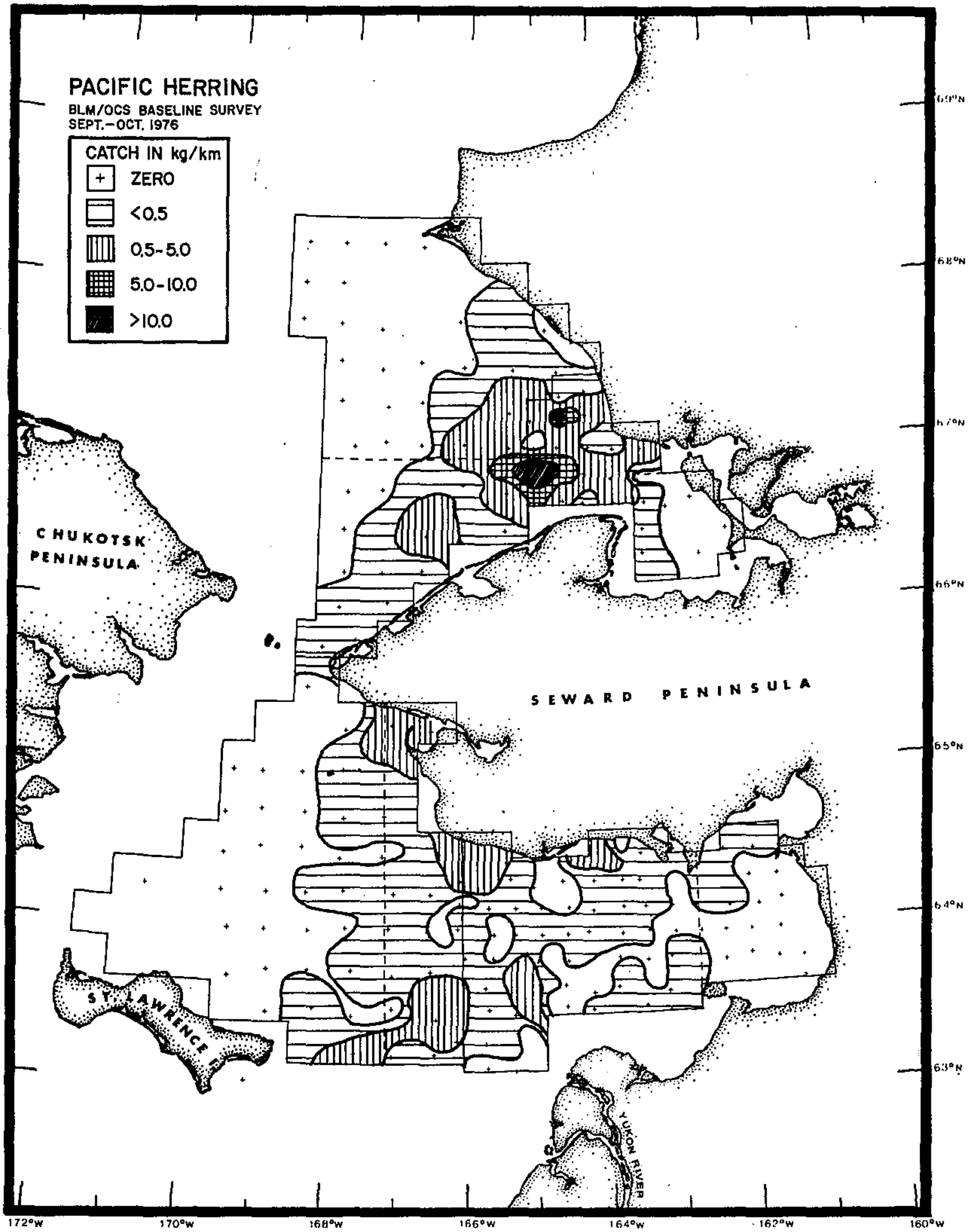


Figure VIII-59.--Distribution and relative abundance by weight of Pacific herring in Norton Sound, the southeastern Chukchi Sea and adjacent waters (BLM/OCS survey, 1976).

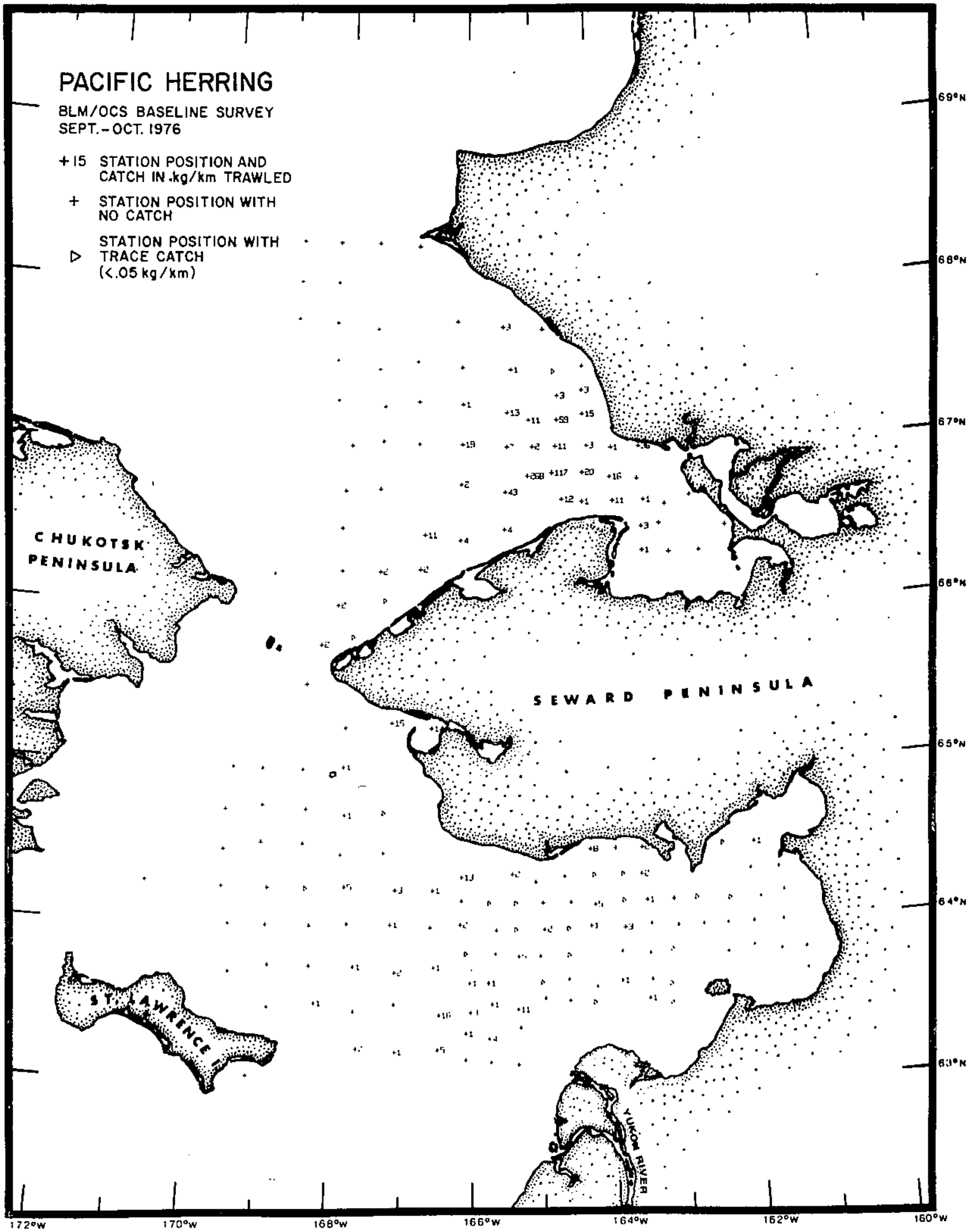


Figure VIII-60.--Distribution of catch rates by weight of Pacific herring in Norton Sound, the southeastern Chukchi Sea and adjacent waters (BLM/OCS survey, 1976).

several years, Japanese gillnet fleets fished this region after the spring breakup when herring formed dense spawning schools. A survey of this region during an earlier time of the year may have produced substantially different population estimates.

For the Pacific herring population sampled, over half (53%) of the estimated biomass was located in stratum 2Ø. Most of the remaining biomass was fairly evenly distributed throughout most of the remaining survey region in strata 1S, 1N, 3W, 3E, and 4Ø. The shallow inshore waters of strata 2I and 4I contained only trace amounts of Pacific herring.

Relative distribution of estimated numbers did not appreciably differ from apparent biomass. Stratum 2Ø contained 15 million fish or approximately 50% of the total survey area estimate of 30 million Pacific herring. Strata 1N, 1S, 3W, and 4Ø each contained from 9 to 11% of the total estimate while strata 2I and 4I together accounted for less than 1% of the estimated standing stock in numbers.

Size composition, mean length and weight--Pacific herring caught during the survey ranged in length from 5 to 28 cm. Females generally were slightly larger than males, averaging 18.7 cm compared to 18.5 cm for all strata combined (Figure VIII-61). Length-frequency distributions for Pacific herring included observations on juvenile fish(which were not sexed) in the distributions for sexes combined. The inclusion of these unsexed fish in the calculation of mean size for sexes combined in stratum 4Ø caused the overall mean length in this stratum to be noticeably less than those for individual sexes. Small fish (< 11 cm) were found only in stratum 4Ø where they comprised 30% of the total fish estimated. Overall, fish less than 11 cm accounted for only 3% of the population estimate in numbers, 12-20 cm fish accounted for 83%, and fish larger than 20 cm comprised 14% of the estimated population.

Overall, mean weight of Pacific herring was 80 gm in the entire survey region. Fish in those strata north of Bering Strait averaged between 82 and 111 gms. Fish in 3W and 3E in the northern Bering Sea averaged 93 and 73 gms, respectively, while Pacific herring in Norton Sound had the smallest average weights. Fish in strata 4Ø and 4I (Norton Sound) averaged 47 and 60 gm, respectively.

Age composition--Differences in relative age composition by sex and stratum are shown in Figure VIII-62. In terms of absolute numbers, age groups 2 through 4 predominated (Table VIII-34). These age groups were prevalent in nearly all strata with older-aged fish more numerous in the strata north of Bering Strait and younger ages to the south. Stratum 4Ø was the only region where age group 0 fish occurred.

Sex ratio--Estimated sex ratios (number of males/number of females) by stratum and age group are presented in Table VIII-34. There appeared to be more females than males in strata north of Bering Strait, while to the south, males were more abundant than females. This trend, however, was not consistent for all age classes.

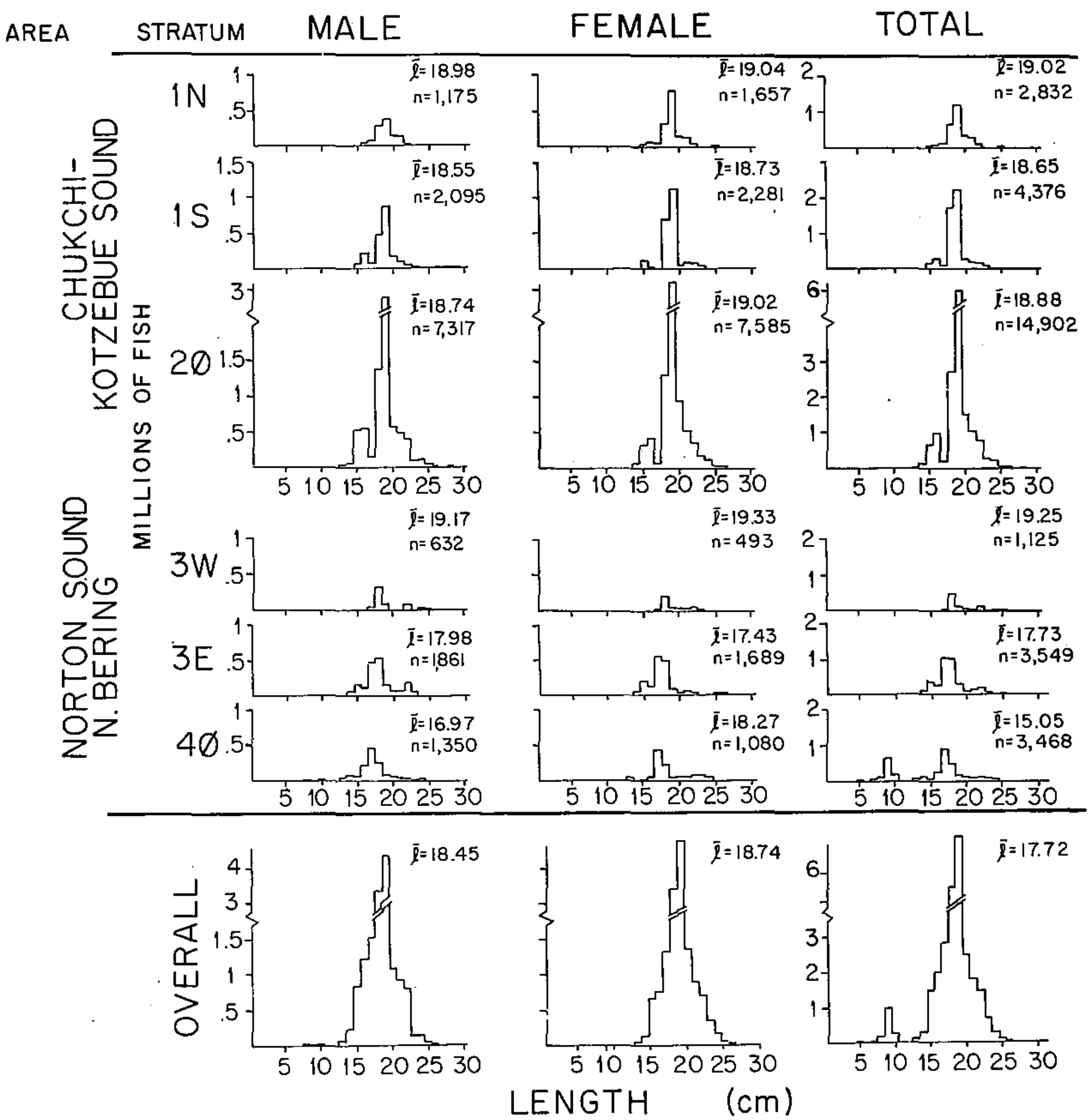


Figure VIII-61.--Size composition of Pacific herring by sex and stratum in Norton Sound, the southeastern Chukchi Sea, and adjacent waters (BLM/OCS survey, 1976).

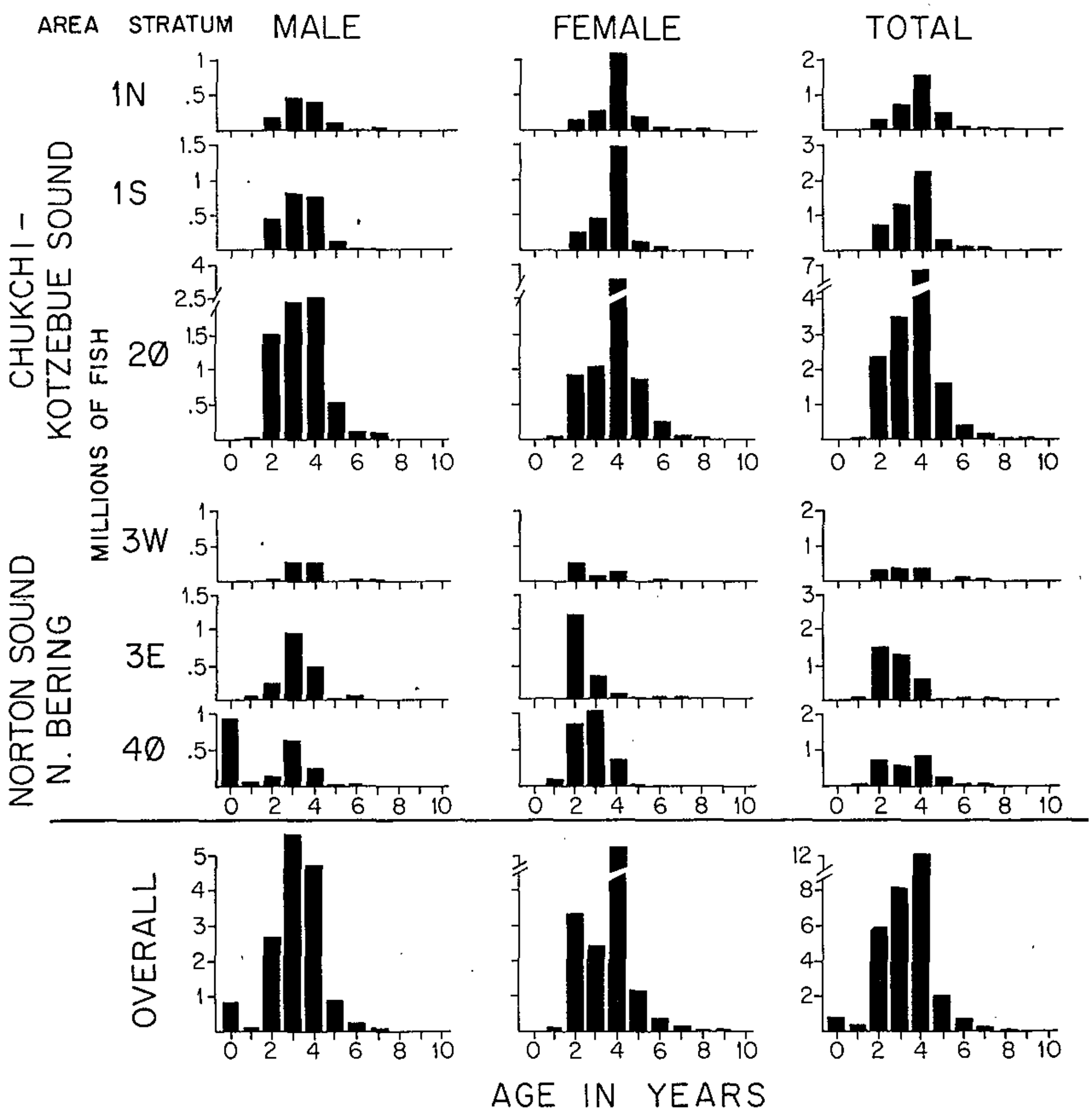


Figure VIII-62.--Age composition of Pacific herring by sex and stratum in Norton Sound, the southeastern Chukchi Sea and adjacent waters (BLM/OCS survey, 1976).

Table VIII-34.--Population numbers ($x10^4$) and sex ratio of Pacific herring by age group and stratum (BLM/OCS survey, 1976).

Age group Year class	0 1976	1 1975	2 1974	3 1973	4 1972	5 1971	6 1970	7 1969	8 1968	9 1967	10 1966	>10 ≤1965	All ages combined
Stratum													
Southeastern Chukchi Sea and Kotzebue Sound													
1N	--	--	26.9 (1.56)	69.1 (1.66)	152.4 (0.42)	29.7 (0.73)	3.2 (0.07)	1.4 (0.17)	0.6 2/	--	--	--	283.3 (0.71)
1S	--	--	65.5 (1.85)	123.2 (1.73)	217.7 (0.53)	24.3 (0.83)	6.1 (0.20)	1.0 (1/)	--	--	--	--	437.8 (0.92)
2Ø	--	10.5 (0.46)	240.1 (1.58)	345.3 (2.39)	683.5 (0.59)	151.4 (0.69)	39.3 (0.49)	15.6 (1.84)	4.5 (2/)	--	--	--	1,490.2 (0.96)
2I	--	--	2.3 (10.50)	1.4 (0.27)	7.1 (0.22)	2.4 (1.00)	0.2 (1/)	0.2 (1/)	--	--	--	--	13.6 (0.64)
Norton Sound and Northern Bering Sea													
3W	--	--	32.6 (0.15)	36.3 (3.43)	37.1 (2.17)	--	4.3 (3.78)	2.2 (1/)	--	--	--	--	112.5 (1.29)
3E	--	5.6 (1/)	148.2 (0.22)	129.7 (2.74)	59.1 (5.29)	2.4 (7.00)	8.1 (6.36)	1.6 (2/)	--	--	--	--	354.7 (1.10)
4Ø	84.5 (1/)	29.0 (4.47)	84.8 (0.42)	104.4 (2.75)	39.6 (1.15)	1.3 (1/)	3.0 3.14	--	--	--	--	--	346.6 (1.25)
4I	--	--	--	1.0 (1/)	5.5 (1/)	--	1.0 (1/)	--	--	--	--	--	7.5 (1/)
All strata combined	84.5 (1/)	45.1 (1.91)	600.4 (0.79)	810.4 (2.31)	1,202.0 (0.66)	211.5 (0.74)	65.2 (0.76)	22.0 (1.65)	5.1 (2/)	--	--	--	3,046.2 (0.98)
Proportion of total population	0.63	.033	.197	.266	.395	.069	.021	.007	.004	--	--	--	

1/ Only males in estimate.
2/ Only females in estimate.

Age-length relationship and growth--Age and length data collected for Pacific herring were as follows:

Sex	Otolith area	Number of readable otoliths	Range in age (years)	Range in length (cm)
Male	North	85	1-7	13-28
	South	66	0-7	8-29
Female	North	65	1-8	14-26
	South	58	0-7	9-26

These data are summarized in Figure VIII-63 by plots of mean lengths-at-age by sex and otolith area with estimated growth curves for each data group. Age-length keys for these data groupings are presented in Appendix I and growth parameters based on this information are given in Table VIII-35.

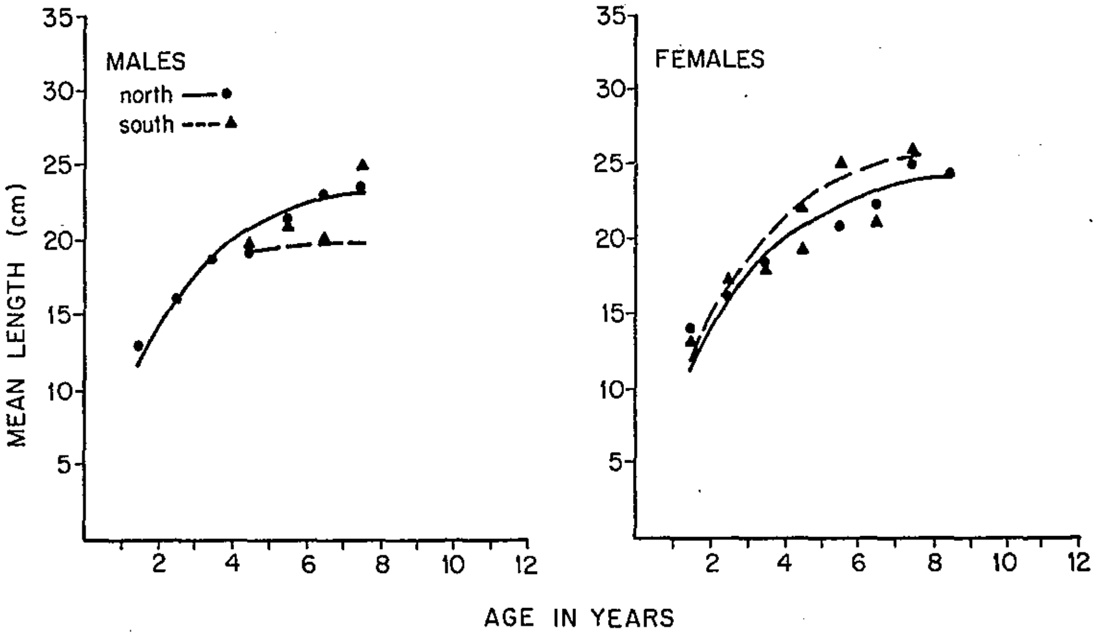


Figure VIII-63.--Mean lengths-at-age and growth curves fit to the origin for Pacific herring by sex and otolith area in Norton Sound, the southeastern Chukchi Sea, and adjacent waters (BLM/OCS survey, 1976).

Table VIII-35.--Parameters for von Bertalanffy growth curves for Pacific herring in Norton Sound, the southeastern Chukchi Sea, and adjacent waters (values in parenthese are ranges for selected ages and lengths) (BLM/OCS survey, 1976).

Otolith areas	Sex	Range in age and length of analyzed data: age (yr)	Range in age and length of analyzed data: length (cm)	Original data set: δ	Original data set: L_∞	Original data set: K	Original data set: t_o	Selected data: δ	Selected data: L_∞	Selected data: K	Selected data: t_o	Selected data with origin: δ	Selected data with origin: L_∞	Selected data with origin: K	Selected data with origin: t_o
North	Males	1.5-7.5 (2.5-7.5)	(14-28)	0.63	25.58	-0.29	-0.91	0.67	26.49	-0.24	-1.45	0.89	23.93	-0.45	0.02
	Females	1.5-8.5 (2.5-8.5)	(15-25)	0.86	27.76	-0.19	-2.04	0.99	26.42	-0.25	-1.07	1.18	24.59	-0.41	0.02
South	Males	0.5-7.5 (2.5-4.5)	(14-29)	1.55	22.77	-0.45	-0.47	1/	1/	1/	1/	1.01	19.66	-0.78	0.01
	Females	0.5-7.5 (2.5-4.5, 7.5)	(14-26)	2.38	23.94	-0.62	0.37	1.61	31.80	-0.17	-1.88	1.67	26.95	-0.40	0.04

1/ Insufficient data points for calculating parameters.

Since young of the year (age group 0) were present in some of the Pacific herring age data sets, adjustments to ages were necessary to provide reasonable fits for both the original data and for the selected sets which included values for the origin of the curve (age and length = 0). Age plus 0.5 years was used as the adjustment since it is reasonable to assume that at least half of a year's growth had been achieved by the September-October survey date.

Selection of data to eliminate age groups with few (< 5) observations and fitting the curve to the origin did not greatly reduce the root mean square deviations (δ) or substantially change values for $\underline{L}_\infty$. However, it did greatly affect estimates of $\underline{K}$ and $\underline{t}_0$, resulting in reasonable values for these parameters. Differences in all growth curve parameters between the data sets usually were small. Large differences in $\underline{K}$ and $\underline{L}_\infty$ were observed in one instance, but the extremely high growth completion rate ($\underline{K}$) for south males (0.78 compared to 0.40-0.45 for all other sets) and relatively low $\underline{L}_\infty$ probably resulted from an insufficient set of data points for proper fitting of the curve (Figure VIII-63). Overall, differences in growth between areas and sexes did not appear to be significant.

Length-weight relationship--Table VIII-36 summarizes the length-weight observations taken for Pacific herring by sex and otolith area and gives coefficients of regression lines fit to these data. Data points representing all length-weight observations collected for this species during the survey are shown graphically in Figure VIII-64.

Analysis of covariance for between-area or between-sex differences in the relationship between length and weight indicated significant levels of variation ($p < .05$) in three treatments of the data: the comparison of between-sex in the south otolith area, between sexes for areas combined, and between areas for sexes combined.

Significant differences between sexes for the combined otolith areas probably resulted from length-weight differences for males and females in the south otolith area. South area differences may have been influenced by observations of only females at lengths less than 13 cm.

On the basis of weights predicted by the regression coefficients, male Pacific herring generally weighed more at-length than females; however, in the south otolith area this relationship was true only up to lengths of about 21 cm. Above that length females weighed more than males. Between- sex differences in length-weight were quite large ($> 10\%$) for fish less than 15 cm in length, especially in the south otolith area, but differences for fish larger than 15 cm were usually on the order of 0-5% (fish larger than 15 cm comprised most of the entire estimated population). In general, an overall length-weight relationship for Pacific herring in the survey region was described by the equation:

$$\hat{w} = 0.0110\ell^{\,3.0256}$$

where $\underline{\hat{w}}$ equals the predicted weight in grams of a fish $\underline{\ell}$ cm in length. The relationship described by this equation is shown as a solid line in Figure VIII-64.

Table VIII-36. --Parameters for the length-weight relationship (weight (g) = a · length^b) for Pacific herring and results from the analysis of covariance for between-area and between-sex differences in this relationship (BLM/OCS survey, 1976).

Sex	Otolith Area	of Fish Measured	Range in Length (cm)	Parameters	
				a	b
Males	North	38	12-26	.01630	2.9033
	South	77	13-25	.01297	2.9719
Females	North	38	15-25	.0255	2.7410
	South	42	9-23	.0053	3.2669

Differences between-	F slope		F intercept		H_a 1/	H_b 1/	Pooled regression	
	df	F	df	F			a	b
Areas for males	1;184	.28	1;185	1.99	-	-	.0135	2.9611
Areas for females	1;163	14.9**	1;164	.95	+	-	.0081	3.1240
Areas for sexes combined 2/	1;355	8.09**	1;356	2.08	+	-	.0110	3.0256
Sexes for south area	1;181	7.97**	1;182	5.63	+	+	.0084	3.1148
Sexes for north area	1;166	1.03	1;167	3.72	-	-	.0207	2.8173
Sexes for areas combined	1;351	3.48	1;352	10.1**	-	+	.0107	3.0356

* Significant at the .05 level.

** Significant at the .01 level.

1/ Plus (+) indicates that the common slope (H_b) hypothesis or common intercept (H_a) hypothesis cannot be rejected on the basis of the values of F obtained.

2/ Includes unsexed fish.

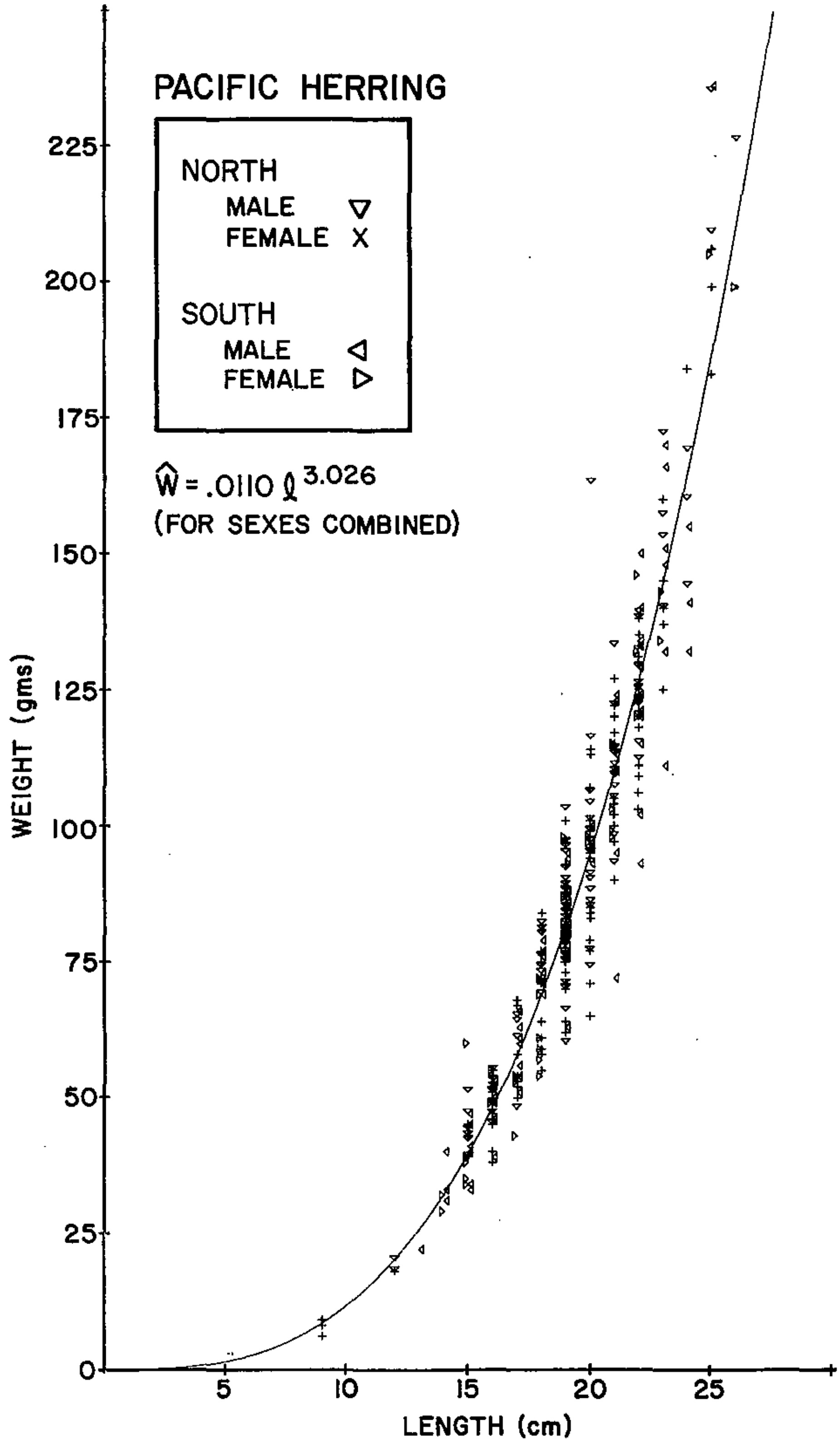


Figure VIII-64.--Weight-at-length observations for Pacific herring by sex and otolith area in Norton Sound, the southeastern Chukchi Sea and adjacent waters (BLM/OCS survey, 1976).

Toothed (rainbow) smelt

Distribution and abundance--Toothed smelt was the fifth-most abundant fish species encountered in the survey area and occurred at over 67% of all stations sampled (Table VIII-37). It accounted for slightly less than 5% of the total apparent biomass for all fish fauna combined. Two concentrations of this species were located in the survey region, in outer Kotzebue Sound (stratum 2Ø) and in the northern Bering Sea (stratum 3E) (Figures VIII-65 and 66) where average catch rates were 1.4 and 1.0 kg/km, respectively. Average catch rates decreased in outer Norton Sound (stratum 4Ø), along the north coast of the Seward Peninsula (stratum 1S), and in inner Kotzebue Sound (stratum 2I), to between 0.1 and 0.2 kg/km. Catch rates were very low in inner Norton Sound (stratum 4I) and in the offshore deeper-water portions of the southeastern Chukchi Sea and northern Bering Sea (strata 1N and 3W, respectively). The overall mean catch rate for the survey was 0.2 kg/km trawled.

Table VIII-37.--Estimated biomass and population size of toothed smelt in Norton Sound, the southeastern Chukchi Sea and adjacent waters (BLM/OCS survey, 1976).

Stratum	Percent frequency of occurrence	Mean CPUE (kg/km)1/	Estimated biomass (mt)	Proportion of total estimated biomass	Estimated population (x 10^3)	Proportion of total estimated population	Mean size per individual weight (kg)	Mean size per individual length (cm)
Southeastern Chukchi Sea and Kotzebue Sound								
1N	24.1	0.085	145	.075	3,540	.047	.041	16.87
1S	73.3	0.127	96	.050	1,699	.023	---	16.12
2Ø	100.0	1.375	591	.305	25,762	.344	.023	13.77
2I	62.5	0.123	37	.019	1,082	.014	---	15.13
Norton Sound and northern Bering Sea								
3W	28.1	0.053	117	.060	3,533	.047	.033	17.71
3E	85.7	0.981	601	.310	23,915	.319	.025	16.80
4Ø	93.1	0.227	303	.156	13,001	.174	.023	14.11
4I	70.6	0.090	48	.025	2,340	.031	.021	13.40
All strata combined:	67.2 2/	0.231	1,938 3/		74,874		.026	15.12

1/ Mean catch per unit effort, kg/km trawled.
2/ Percent occurrence in 192 successful hauls.
3/ 95% confidence interval: 1,134-2,742 mt.

The apparent biomass of toothed smelt in our survey region was estimated at slightly less than 2,000 mt (95% confidence interval 1,134-2,742 mt). This is probably a minimum estimate for the survey region, since this species is pelagic and some unknown proportion of the population occupied

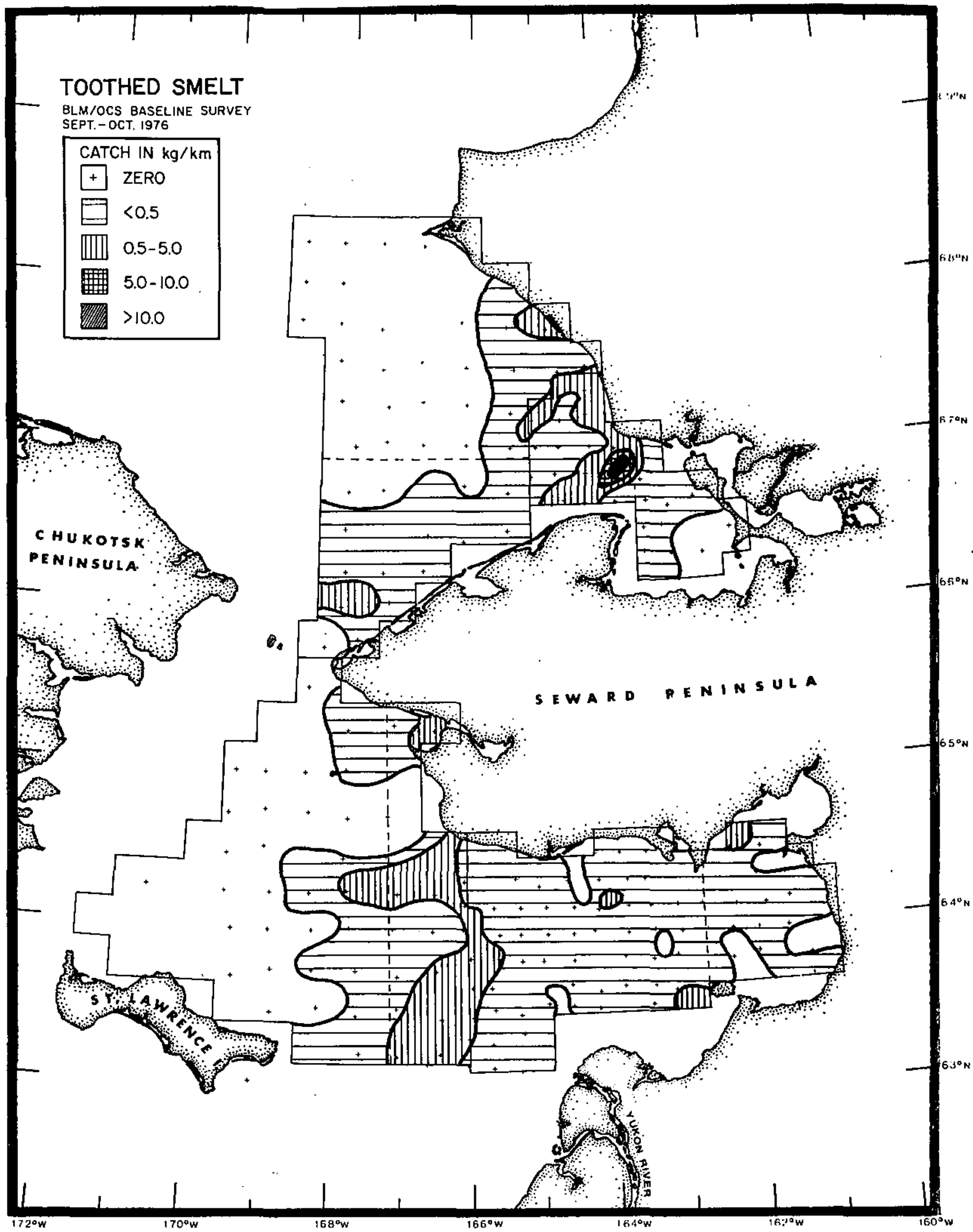


Figure VIII-65.--Distribution and relative abundance by weight of toothed smelt in Norton Sound, the southeastern Chukchi Sea and adjacent waters (BLM/OCS survey, 1976).

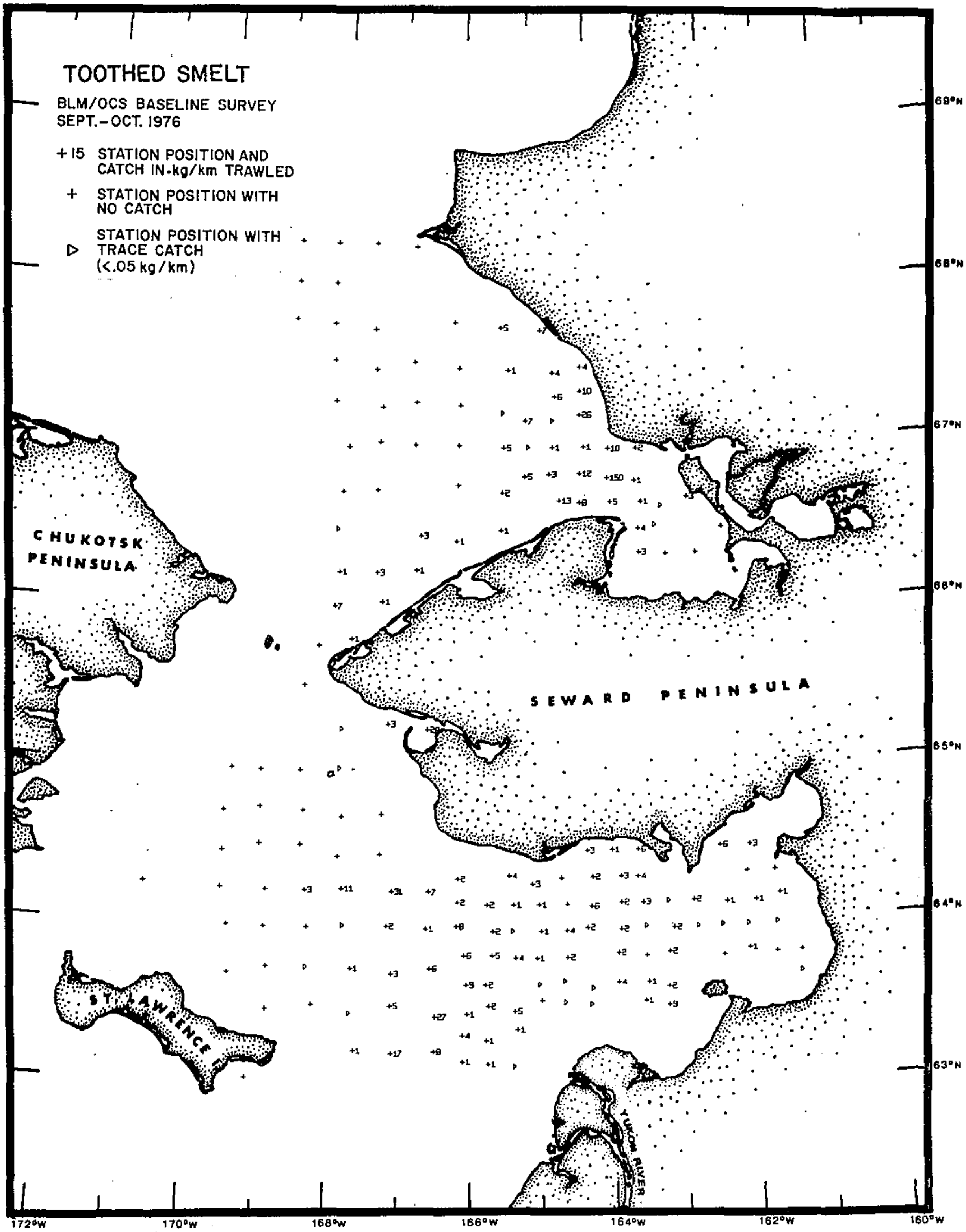


Figure VIII-66.--Distribution of catch rates by weight of toothed smelt in Norton Sound, the southeastern Chukchi Sea and adjacent waters (BLM/OCS survey, 1976).

the water column above the sampling gear, thus being unavailable to the trawl. In addition, toothed smelt are anadromous, spawning in rivers from February to June (McAlister, 1963). Some other proportion of the population may have been located in the more nearshore estuarine and freshwater regions than covered by the survey. For the population sampled, however, the major portion of the estimated biomass (approximately 78%) was located in strata 2Ø, 3E, and 4Ø, mainly between the 20 and 30 m isobaths. Of the remaining amount, 8% of the total was located in stratum 1N, 6% in stratum 3W, and 5% in stratum 1S. The estimated biomass for strata 2I and 4I together comprised less than 5% of the total.

The relative distribution of estimated numbers of fish did not substantially differ from apparent biomass. Strata 2Ø, 3E, and 4Ø combined contained an estimated 62.7 million fish which was about 84% of the total population estimate for the entire survey area. Another 5% occurred in strata 1N and 3W. The total population estimate for all strata combined was slightly less than 75 million fish.

Size composition, mean length and weight--Toothed smelt caught during the survey ranged in length from 7 to 36 cm. Females generally were larger than males, averaging 15.7 cm compared to 14.7 cm for all strata combined (Figure VIII-67).

Length frequency distributions did not indicate major differences in relative size composition between sexes for any of the strata. Fish less than 20 cm comprised nearly the entire population in most strata, although appreciable numbers of large (> 20 cm) individuals occurred in stratum 3E. Large fish accounted for 20% of the population in stratum 3E and 6% of the overall population estimate. Generally, the average size of toothed smelt was less in the shallow and near-shore strata than in deeper offshore regions.

Age composition--Differences in relative age composition by sex and subarea are shown in Figure VIII-68. In terms of absolute numbers, age groups 4 and 5 predominated (Table VIII-38) with these age groups representing about 64% of the total estimated population. Age groups 3, 6, and 7 were also present in substantial numbers, together accounting for most of the remaining population. Although age groups 4 and 5 were main components of age composition in nearly all strata, 5 and 6 year-old fish comprised much of the toothed smelt populations in the offshore strata (1N and 3W) and age group 3 fish were the dominant segment of fish present in outer Kotzebue Sound (stratum 2Ø).

Sex ratio--Estimated sex ratios (number of males/number of females) by stratum and age group are presented in Table VIII-38. Males appeared to be more abundant than females in nearly all strata and age groups except in stratum 3W where the opposite was observed. Overall, males outnumbered females by nearly 70%.

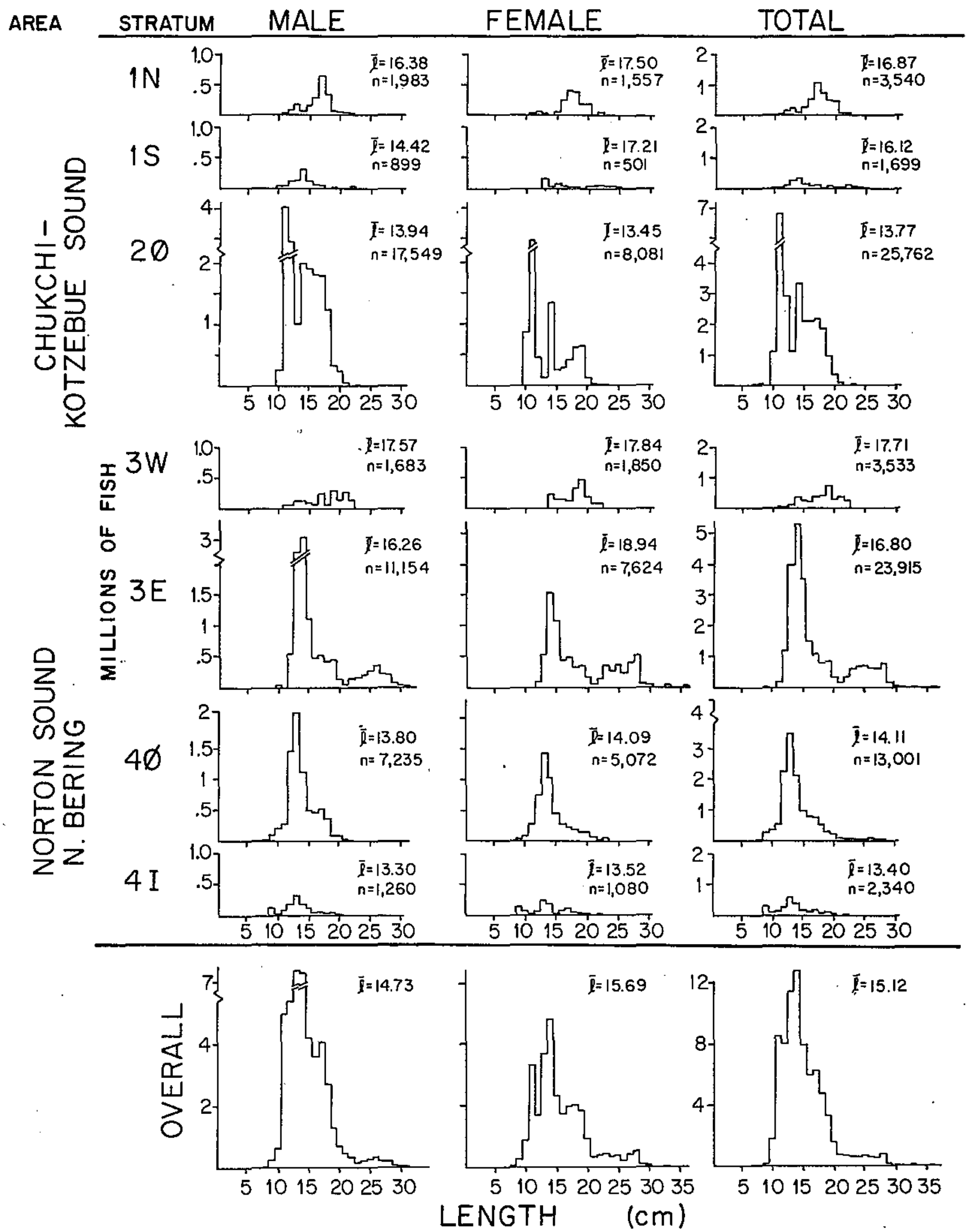


Figure VIII-67.--Size composition of toothed smelt by sex and stratum in Norton Sound, the southeastern Chukchi Sea, and adjacent waters (BLM/OCS survey, 1976).

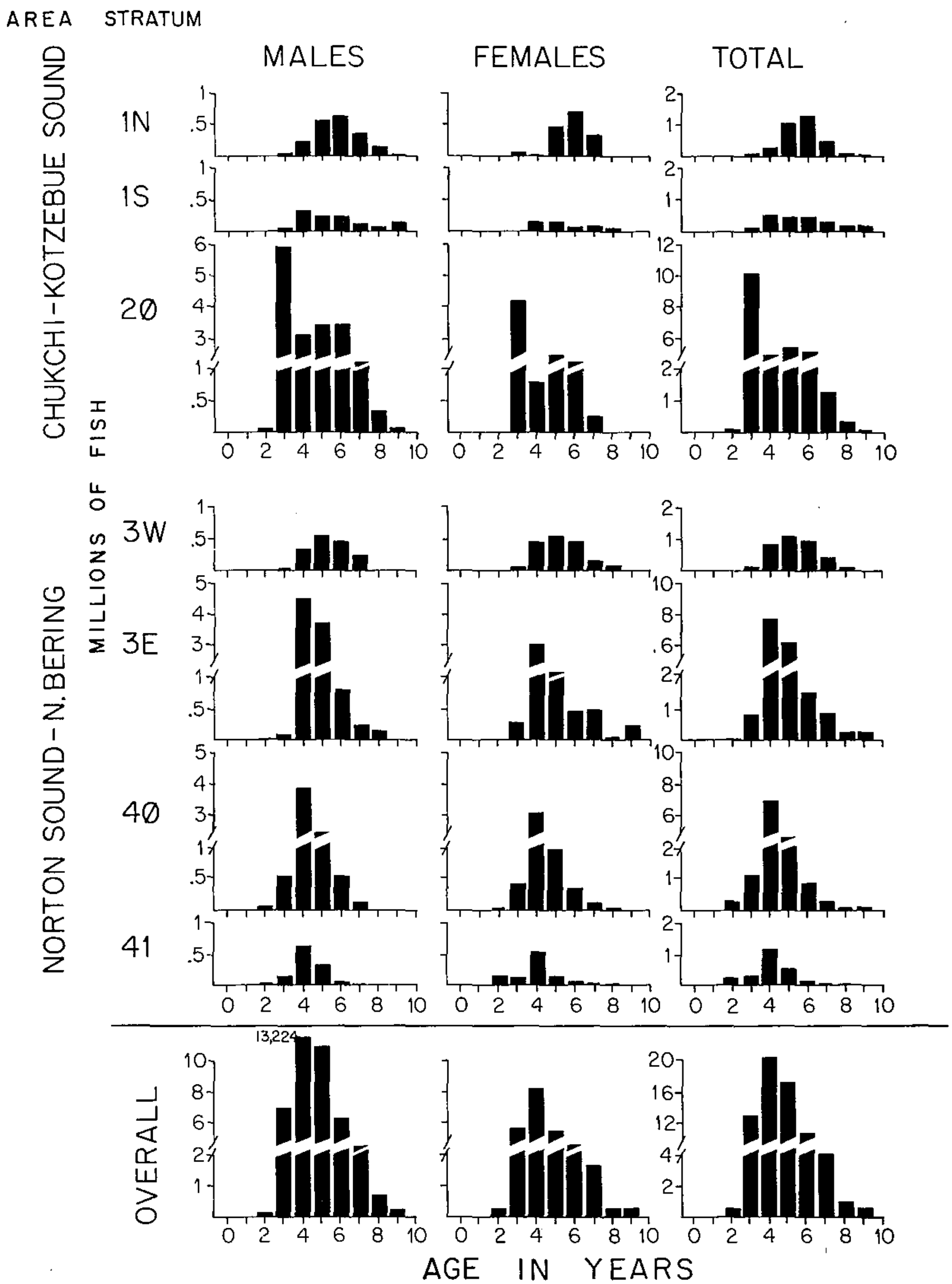


Figure VIII-68.--Age composition of toothed smelt by sex and stratum in Norton Sound, the southeastern Chukchi Sea, and adjacent waters (BLM/OCS survey, 1976).

Table VIII-38.--Population numbers ($x10^5$) and sex ratios of toothed smelt by age group and stratum (BLM/OCS survey, 1976).

Age group Year class	0 1976	1 1975	2 1974	3 1973	4 1972	5 1971	6 1970	7 1969	8 1968	9 1967	10 1966	>10 ≤1965	All ages combined
Stratum													
Southeastern Chukchi Sea and Kotzebue Sound													
1N	--	--	--	1.3 (1.10)	2.3 (11.26)	10.3 (1.27)	13.2 (0.88)	6.9 (1.10)	1.2 (1/)	0.4 (1/)	--	--	35.4 (1.27)
1S	--	--	--	1.0 (1/)	4.9 (1.96)	4.2 (1.97)	4.2 (3.62)	2.7 (1.15)	1.3 (1.25)	1.6 (1/)	--	--	17.0 (2.39)
2D	--	--	1.3 (1/)	102.2 (1.42)	39.6 (3.89)	49.0 (2.43)	46.9 (2.77)	15.6 (2.96)	3.7 (1/)	0.7 (1/)	--	--	257.5 (2.19)
2I	--	--	0.8 (2/)	1.1 (1.59)	1.0 (2.06)	3.3 (1.14)	3.2 (1.32)	1.0 (1.76)	0.4 (1/)	--	--	--	10.8 (1.24)
Norton Sound and Northern Bering Sea													
3W	--	--	--	1.2 (0.86)	8.1 (0.71)	11.4 (0.98)	9.7 (0.99)	4.0 (1.54)	1.0 (2/)	--	--	--	35.3 (0.91)
3E	--	--	0.1 (1/)	8.8 (0.33)	103.2 (1.50)	63.1 (3.23)	15.8 (1.73)	8.9 (0.55)	2.8 (1.98)	2.5 (2/)	--	--	155.4 (1.67)
4D	--	--	2.1 (3.88)	11.6 (1.40)	70.8 (1.25)	30.3 (2.04)	9.1 (1.56)	2.4 (1.05)	0.5 (2/)	1.0	--	--	122.7 (1.44)
4I	--	--	2.1 (0.15)	3.1 (1.58)	11.7 (1.18)	5.0 (1.18)	1.3 (1.49)	0.2 (0.82)	0.1 (2/)	--	--	--	23.4 (1.17)
All strata combined	--	--	6.4 (0.69)	130.2 (1.37)	241.6 (1.61)	176.6 (2.20)	103.3 (1.82)	41.7 (1.44)	11.0 (2.67)	6.1 (0.91)	--	--	657.8 (1.69)
Proportion of total population	--	--	.010	.198	.367	.268	.157	.063	.017	.009	--	--	

1/ Only males in estimate.
2/ Only females in estimate.

Age-length relationship and growth--Age and length data collected for toothed smelt were as follows:

Sex	Otolith area	Number of readable otoliths	Range in age (years)	Range in length (cm)
Male	North	53	3-9	10-23
	South	76	2-8	8-23
Female	North	45	2-8	8-25
	South	74	2-9	9-26

These data are summarized in Figure VIII-69 by plots of mean lengths-at-age by sex and otolith area with estimated growth curves for each data group. Age-length keys for these data groupings are presented in Appendix I and growth parameters based on this information are given in Table VIII-39.

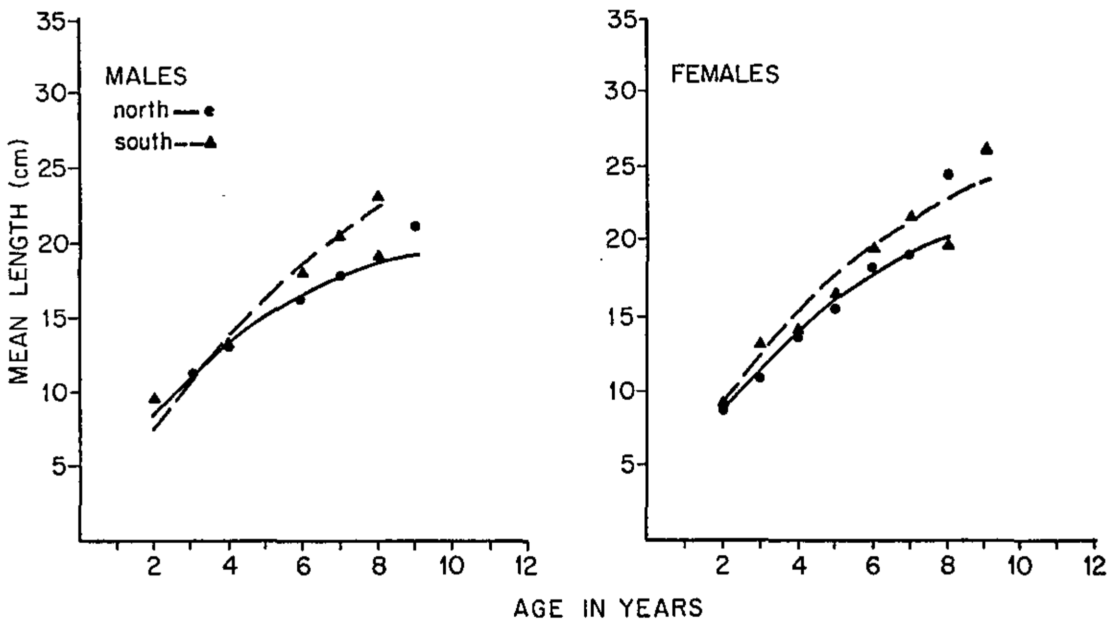


Figure VIII-69.--Mean lengths-at-age and growth curves fit to the origin for toothed smelt by sex and otolith area in Norton Sound, the southeastern Chukchi Sea and adjacent waters (BLM/OCS survey, 1976).

Table VIII-39.--Parameters for von Bertalanffy growth curves for toothed smelt in Norton Sound, the southeastern Chukchi Sea, and adjacent waters (BLM/OCS survey, 1976).

Otolith areas	Sex	Range in age and length of analyzed data: age (yr)	length (cm)	Original data set: δ	L_∞	K	t_o	Selected data: δ	L_∞	K	t_o	Selected data with origin: δ	L_∞	K	t_o
North	Males	3-9 (3-7)	(10-20)	0.49	43.05	-0.06	-1.84	0.44	22.28	-0.22	-0.15	0.36	21.60	-0.24	0.01
	Females	2-8 (2-7)	(8-23)	1.09	-12.72	0.09	-3.50	0.48	29.45	-0.14	-0.50	0.50	24.66	-0.21	0.04
South	Males	2-8 (3-7)	(9-22)	0.32	-13.21	0.08	-5.00	0.25	-57.06	0.03	-2.31	0.56	37.92	-0.11	0.08
	Females	2-9 (2-7)	(9-23)	1.92	33.36	-0.15	0.15	0.89	37.61	-0.11	-0.44	0.96	29.61	-0.18	0.06

Selection of data to eliminate age groups with few (< 5) observations and fitting the curve to the origin reduced the root mean square deviations(δ),especially for female groupings in both otolith areas. The selected sets also improved curve fits for south males and north females, where meaningless parameters ($\underline{K} > 0$ and $\underline{L}_\infty < 0$) were determined in the original data sets. Sex effects varied by area. In the north otolith area, the estimates of $\underline{L}_\infty$ for females was higher than for males but in the south otolith region, the opposite was observed. Estimates of $\underline{K}$ varied as well. Female toothed smelt in the south otolith area had a higher growth completion rate ($\underline{K}$) than males, but in the north, again the reverse was observed.

In general, growth of toothed smelt appears to differ significantly by area. For both sexes, largest mean lengths-at-age, highest estimates for $\underline{L}_\infty$ and lowest values for $\underline{K}$ occurred in the south otolith area. This suggests that toothed smelt south of Bering Strait achieve their maximum size at a slower rate than fish to the north although the maximum size in the south exceeds that for fish in the north.

Length-weight relationships--Table VIII-40 summarizes length-weight observations taken for toothed smelt by sex and otolith area and gives coefficients of the regression lines fit to these data. Data points representing all length-weight observations from these data are shown graphically in Figure VIII-70.

Table VIII-40.--Parameters for the length-weight relationship (weight (g) = a · lenght^{b}) for toothed smelt and results from the analysis of covariance for between-area and between-sex differences in this relationship (BLM/OCS survey, 1976).

Sex	Otolith Area	Number of Fish Measured	Range in Length (cm)	Parameters a	Parameters b
Males	North	49	11-22	.0015	3.5460
	South	100	8-23	.0007	3.8543
Females	North	31	14-21	.0054	3.0925
	South	89	4-26	.0006	3.8761

Differences between-	F slope df	F slope F	F intercept df	F intercept F	H_b 1/	H_a 1/	Pooled regression a	Pooled regression b
Areas for males	1;145	4.07*	1;146	1.64	+	-	.0008	3.7996
Areas for females	1;116	7.59**	1;117	.18	+	-	.0007	3.8314
Areas for sexes combined	1;265	9.07**	1;266	.85	+	-	.0008	3.7933
Sexes for south area	1;185	.06	1;186	7.60**	-	+	.0007	3.8396
Sexes for north area	1;76	3.84	1;77	.47	-	-	.0020	3.4424
Sexes for areas combined	1;265	.16	1;266	7.78**	-	+	.0008	3.7933

* Significant at the .05 level.

** Significant at the .01 level.

1/ Plus (+) indicates that the common slope (H_b) hypothesis or common intercept (H_a) hypothesis cannot be rejected on the basis of the values of F obtained.

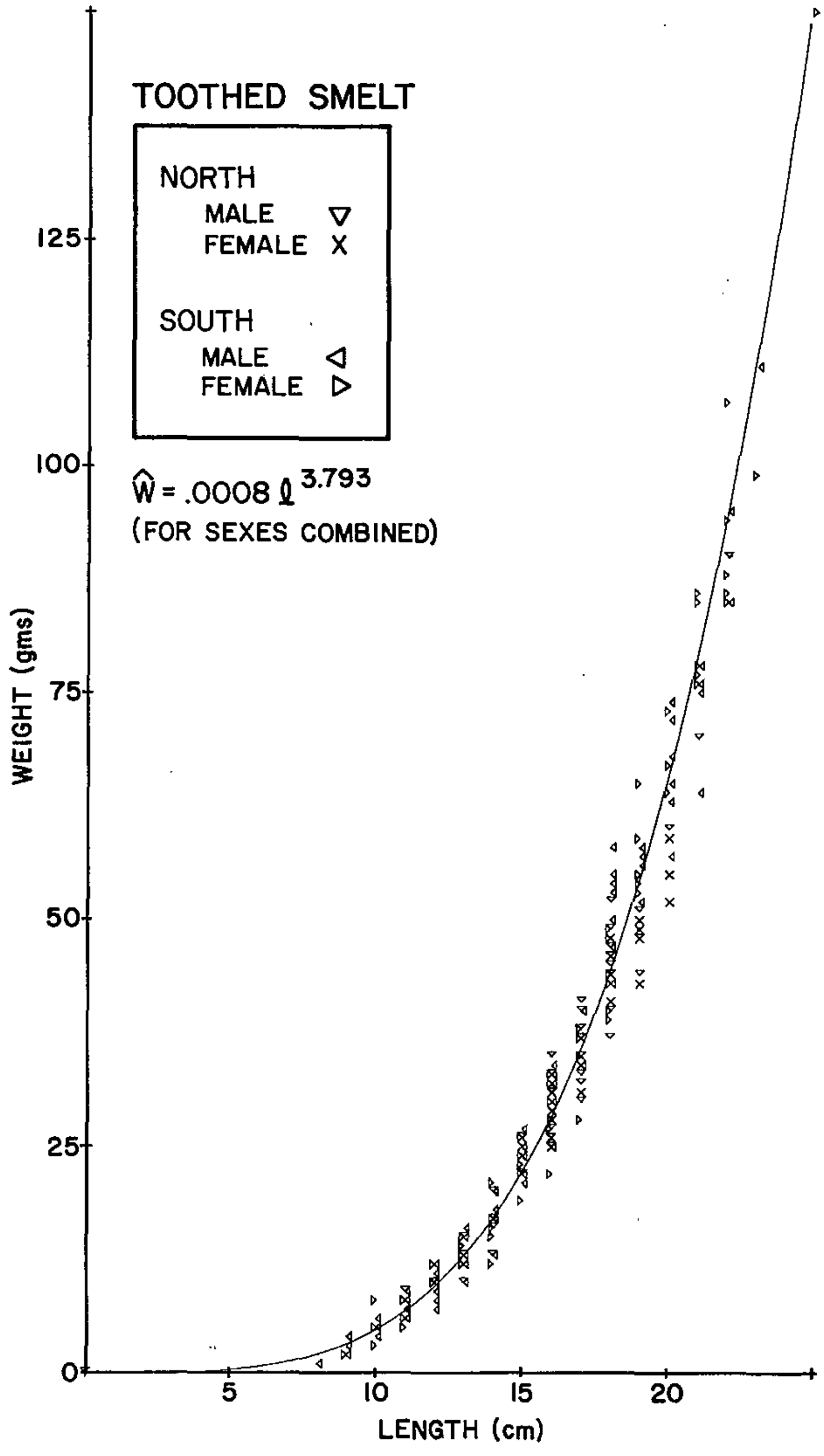


Figure VIII-70.--Weight-at-length observations for toothed smelt by sex and otolith area in Norton Sound, the southeastern Chukchi Sea and adjacent waters (BLM/OCS survey, 1976).

Analysis of covariance for between-area or between-sex differences in the relationships between length and weight indicated significant levels of variation ($p < .05$) in all treatments of the data, with the exception of between-sex differences in the north otolith area. On the basis of weights predicted by the regression coefficients, males were slightly heavier at-length than females in both otolith areas. Fish of either sex from the north otolith area weighed more at-length than fish of a corresponding length and sex in the south otolith area, but only up to lengths of about 15 cm. Above that size, fish from the south area were heavier than fish from the north. For sizes less than about 11 cm and greater than 20 cm, length-weight differences between sexes and areas were quite large (> 10%). Differences for the 11-20 cm size range were on the order of 3-7%. Although toothed smelt from the two otolith areas appeared to have different weights-at-length, a general overall relationship for the entire survey region was described by the equation:

$$\hat{w} = 0.0008\,\ell^{3.7933}$$

where $\hat{w}$ equals the predicted weight in grams of a fish ℓ cm in length. The relationship described by this equation is shown as a solid line in Figure VIII-70.

Alaska plaice

Distribution and abundance--Alaska plaice occurred at over 66% of the stations sampled (Table VIII-41) and accounted for about 3.5% of the total apparent fish biomass. No large large concentrations of this species were found in the survey area (Figures VIII-71 and 72); however, highest average catch rates occurred along the north coast of the Seward Peninsula (stratum 1S) and in outer Norton Sound (stratum 4Ø) where Alaska plaice were caught at the average rates of 0.3 and 0.4 kg/km, respectively. Average catch rates for all other strata ranged from 0.1 to 0.2 kg/km and the overall mean catch rate for the entire survey region was slightly less than 0.2 kg/km trawled.

Table VIII-41.--Estimated biomass and population size of Alaska plaice in Norton Sound, the southeastern Chukchi Sea, and adjacent waters (BLM/OCS survey, 1976).

Stratum	Percent frequency of occurrence	Mean CPUE (kg/km)1/	Estimated biomass (mt)	Proportion of total estimated biomass	Estimated population (x 10^3)	Proportion of total estimated population	Mean size per individual weight (kg)	length (cm)
Southeastern Chukchi Sea and Kotzebue Sound								
1N	17.2	0.069	118	.075	365	.025	0.323	22.17
1S	86.7	0.322	244	.155	2,117	.143	0.115	20.68
2Ø	84.2	0.181	78	.050	589	.040	0.133	18.01
2I	87.5	0.242	74	.047	786	.053	0.094	17.81
Norton Sound and northern Bering Sea								
3W	34.4	0.134	293	.186	817	.055	0.359	27.64
3E	50.0	0.209	128	.082	2,111	.143	0.061	16.20
4Ø	91.4	0.394	525	.334	4,925	.333	0.107	17.98
4I	88.2	0.211	112	.071	3,068	.208	0.037	13.96
All strata combined:	66.1 2/	0.188	1,572 3/		14,777		0.106	17.91

1/ Mean catch per unit effort, kg/km trawled.
2/ Percent occurrence in 192 successful hauls.
3/ 95% confidence interval: 994-2,200 mt.

The apparent Alaska plaice biomass for the entire survey area was estimated at about 1,600 mt (95% confidence interval 994-2,200 mt). This estimate is probably quite representative for the survey region even though some of the relatively larger catches occurred at stations along the southern border of the survey area. These catches along the survey

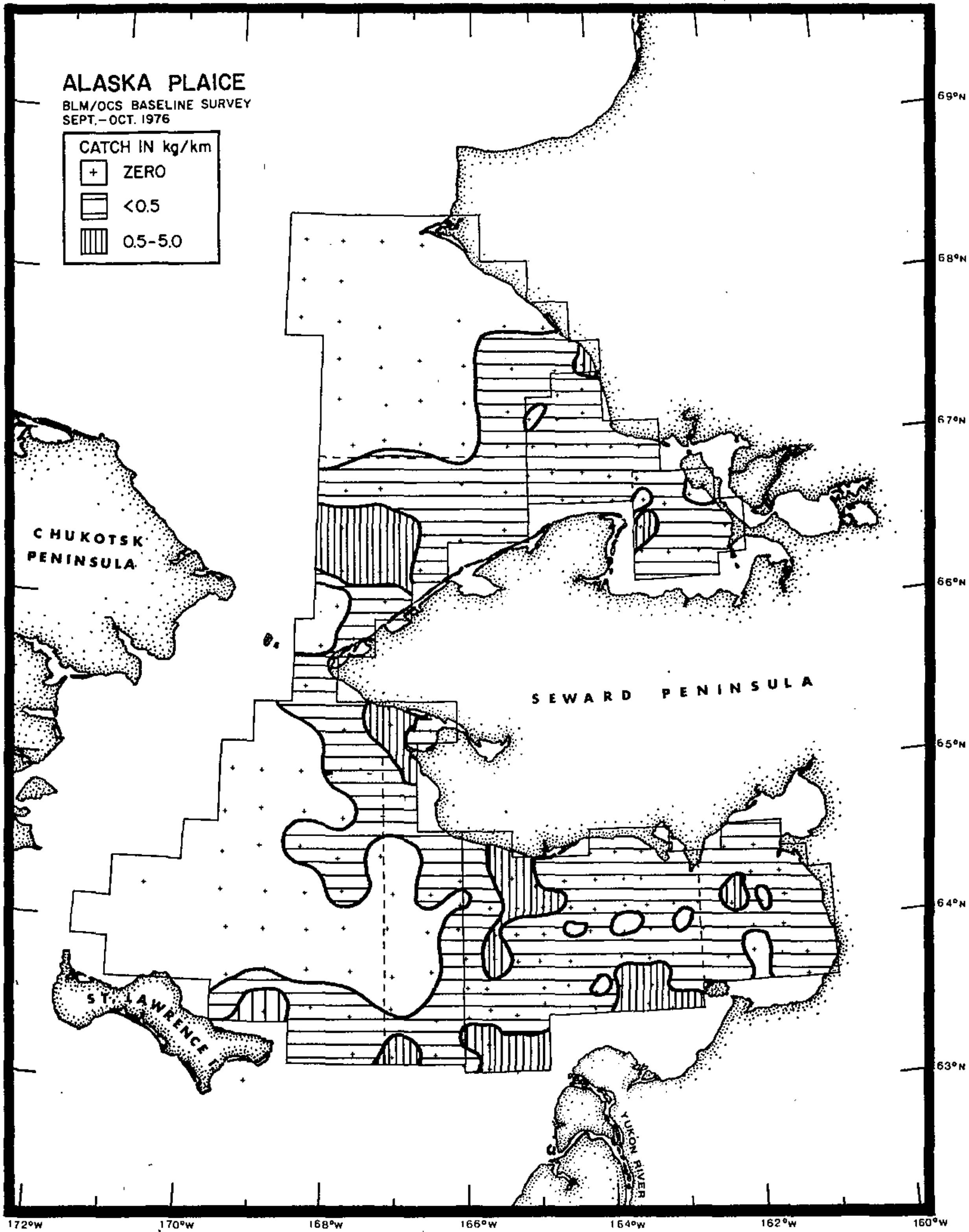
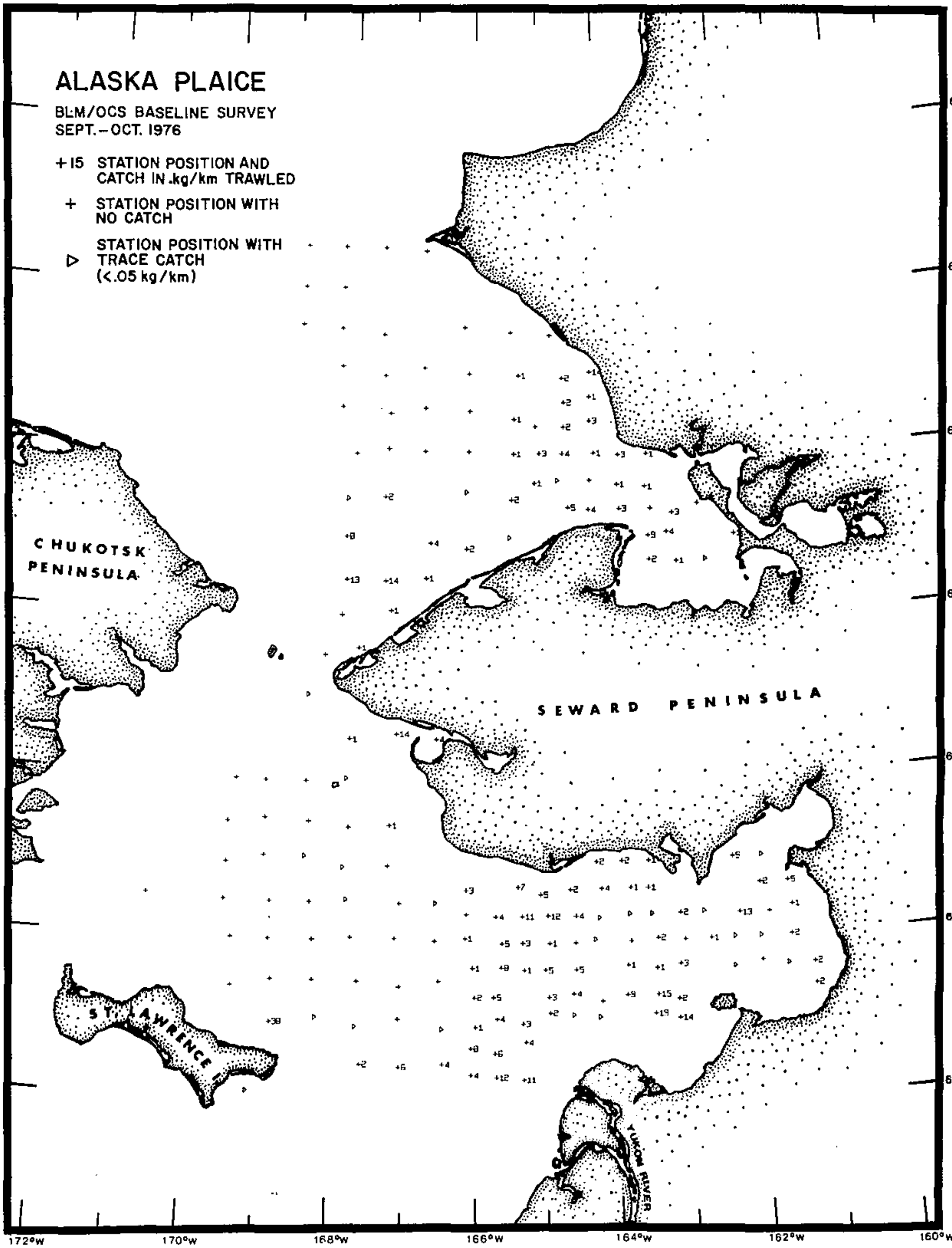


Figure VIII-71.--Distribution and relative abundance by weight of Alaska plaice in Norton Sound, the southeastern Chukchi Sea and adjacent waters (BLM/OCS survey, 1976).



Figuve VIII-72.--Distribution of catch rates by weight of Alaska plaice in Norton Sound, the southeastern Chukchi Sea and adjacent waters (BLM/OCS survey, 1976).

boundary indicate a likely presence of Alaska plaice to the south of the survey region. It is unknown to what degree any fish outside the survey area might influence survey area populations; however, since Alaska plaice had a fairly uniform low distribution throughout the survey region, it seems doubtful that any extensive concentrations were located in close proximity to our survey region. For the population estimated in the survey region, about half (49%) of the apparent biomass was located in strata 1S and 4Ø. Another 19% occurred in stratum 3W but this amount was heavily influenced by one relatively large catch northeast of St. Lawrence Island. Apparent biomass within each of the other strata ranged from 5 to 8% of the overall total. In general, most of the Alaska plaice biomass in the survey area was found in shallow-water regions where depths were less than 25 m.

The relative distribution of estimated numbers differed somewhat from apparent biomass. Although only 7% of the apparent biomass occurred in stratum 4I, the population estimate in numbers for this region was over 3 million fish or about 21% of the total survey estimate. The opposite situation occurred in stratum 3W where the estimated biomass comprised 19% of the total while numbers of fish present was less than 6% of the survey total. The overall estimate for the entire survey region was 14.8 million fish.

Size composition, mean length and weight--Alaska plaice captured during the survey ranged from 6 to 42 cm. Females were considerably larger than males, averaging 20.3 cm compared to 16.1 cm for all strata combined (Figure VIII-73). A variation in size composition by area was evident, with a greater proportion of smaller fish associated with strata 4Ø and 4I.

Mean weight per individual varied by strata. Largest average weights occurred in the offshore deeper-water strata, 1N and 3W, where weights averaged 323 and 359 gm, respectively. Shallower near-shore strata contained Alaska plaice with much smaller average weights, especially in stratum 4I where individuals averaged only 37 gm. The overall mean weight per individual for the entire survey region was 106 gm.

Age composition--Relative age composition by sex and stratum for Alaska plaice is shown in Figure VIII-74. In terms of estimated numbers of fish (Table VIII-42), age groups 4 through 7 predominated, accounting for over 71% of the total estimated population. Differences in age composition occurred by region. In all strata north of Bering Strait and in the offshore waters of the northern Bering Sea (stratum 3W), nearly all fish (99%) were five years old or older. In Norton Sound and the eastern portion of the northern Bering Sea (strata 4Ø, 4I, and 3E) fish in age groups 5 and older comprised a majority of the population; however age groups 2 through 4 constituted 38% of the estimated population.

Sex ratio--Estimated sex ratios (number of males/number of females) by stratum and age group are presented in Table VIII-42. Males were more numerous than females in age groups 6 and younger, while in age groups 7 and older the opposite was observed. This trend was consistent for most strata. Additionally, for all ages combined, males were more numerous than females in every strata except stratum 3W.

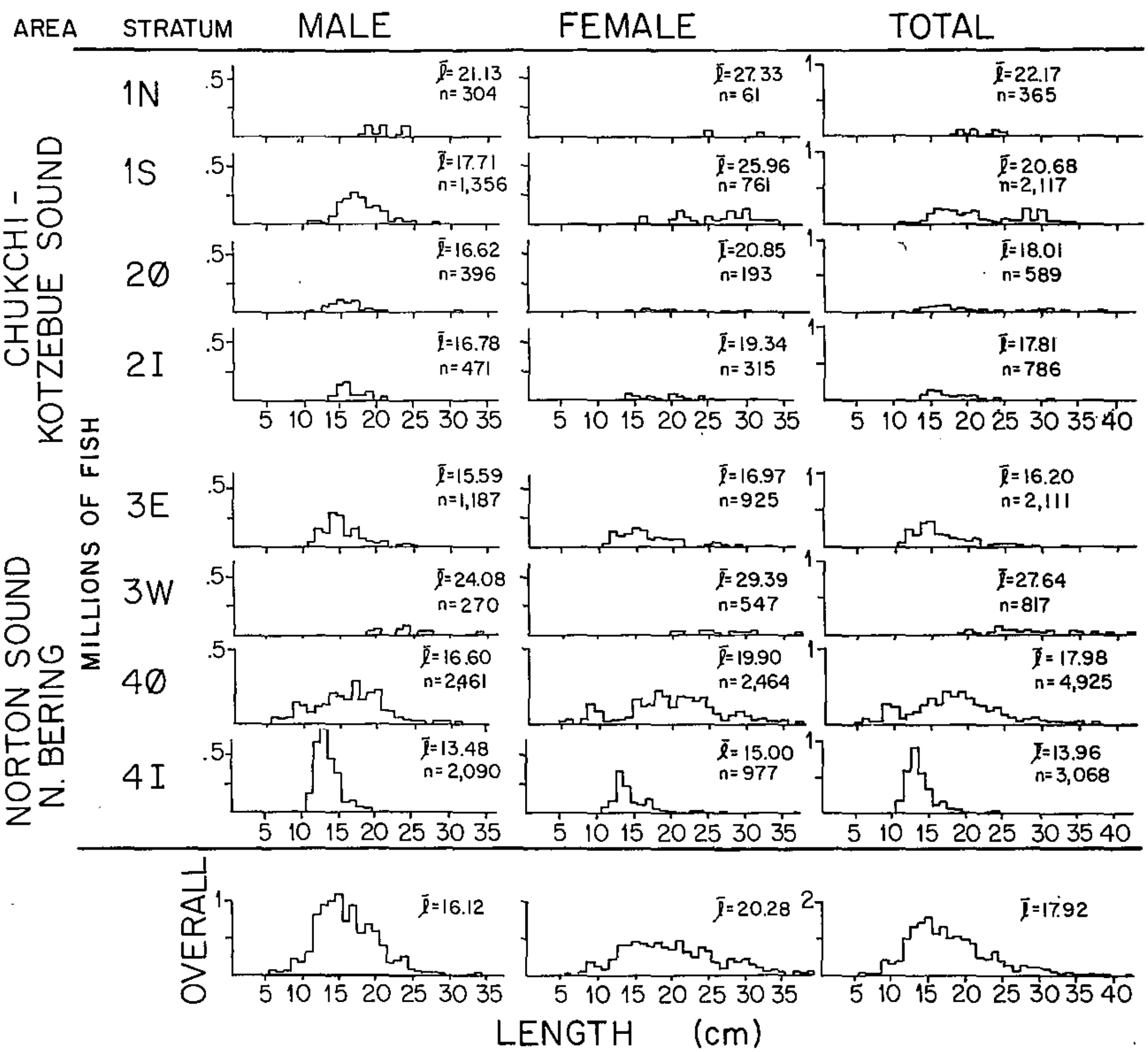


Figure VIII-73.--Size composition of Alaska plaice by sex and stratum in Norton Sound, the southeastern Chukchi Sea, and adjacent waters (BLM/OCS survey, 1976).

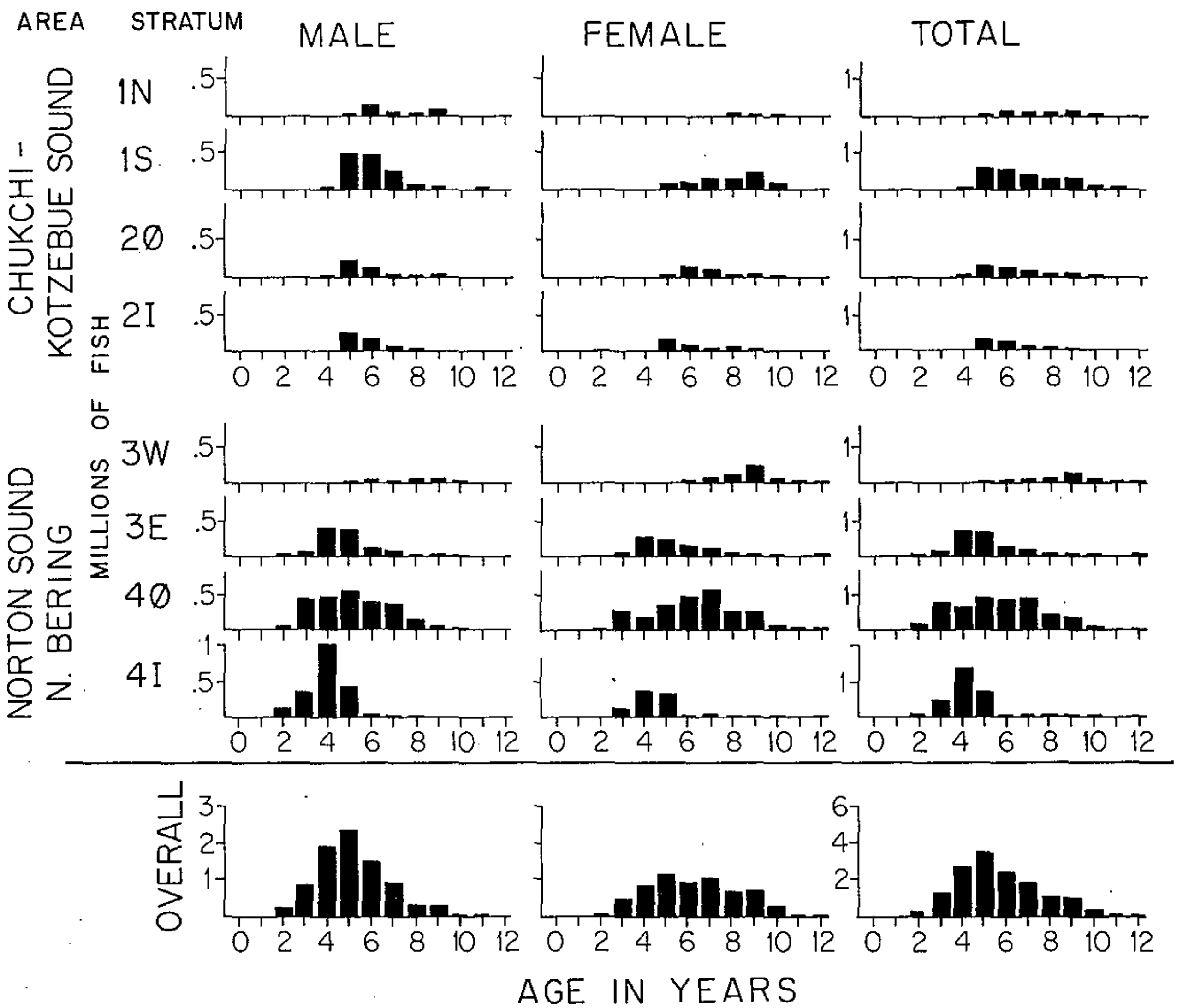


Figure VIII-74.--Age composition of Alaska plaice by sex and stratum in Norton Sound, the southeastern Chukchi Sea, and adjacent waters (BLM/OCS survey, 1976).

Table VIII-42.--Population numbers (x10^4) and sex ratios of Alaska plaice by age group and stratum (BLM/OCS survey, 1976).

Age group Year class	0 1976	1 1975	2 1974	3 1973	4 1972	5 1971	6 1970	7 1969	8 1968	9 1967	10 1966	>10 ≤1965	All ages combined
Stratum													
Southeastern Chukchi Sea and Kotzebue Sound													
1N	--	--	--	--	--	0.4 (1/)	14.7 (1/)	6.2 (1/)	4.8 (0.20)	9.1 (8.10)	1.0 (2/)	--	36.2 (5.33)
1S	--	--	--	--	3.5 (1/)	54.8 (7.43)	55.5 (6.50)	36.5 (1.83)	22.1 (0.55)	23.6 (0.09)	8.2 (2/)	2.0 (1/)	246.2 (1.22)
2O	--	--	--	--	0.7 (1/)	26.7 (7.09)	24.5 (0.75)	12.3 (0.23)	2.5 (0.67)	3.8 (0.81)	0.5 (2/)	--	71.0 (1.26)
2I	--	--	--	--	--	36.2 (1.68)	25.2 (2.00)	9.2 (1.63)	6.1 (0.42)	1.8 (2/)	--	--	81.0 (1.38)
Norton Sound and Northern Bering Sea													
3W	--	--	--	--	--	0.5 (1/)	8.8 (1.93)	10.7 (0.32)	16.3 (0.75)	29.2 (0.32)	11.8 (0.55)	4.4 (2/)	81.7 (0.50)
3E	--	--	4.3 (1/)	15.5 (1.07)	66.7 (1.49)	62.4 (1.55)	22.9 (0.97)	20.1 (0.90)	9.0 (0.80)	6.7 (0.91)	2.5 (0.19)	0.8 (2/)	210.9 (1.28)
4O	--	--	11.6 (3.14)	69.8 (1.54)	59.6 (2.37)	91.6 (1.48)	81.9 (0.90)	89.4 (0.63)	40.5 (0.49)	32.7 (0.34)	12.5 (0.44)	3.3 (2/)	492.9 (1.00)
4I	--	--	13.3 (1/)	46.5 (3.01)	139.1 (2.71)	75.0 (1.22)	7.7 (1.33)	9.5 (0.61)	4.0 (0.43)	1.6 (2/)	1.0 (2/)	0.3 (2/)	298.0 (2.05)
All strata combined	--	--	29.2 (8.80)	131.8 (1.83)	269.6 (2.29)	347.6 (1.98)	241.2 (1.65)	193.9 (0.83)	105.3 (0.54)	108.5 (0.39)	37.5 (0.29)	10.0 (0.23)	1,475.4 (1.34)
Proportion of total population	--	--	.020	.089	.183	.236	.163	.131	.071	.074	.025	.007	

1/ Only males in estimate.
2/ Only females in estimate.

Age-length relationship and growth--Age and length data collected for Alaska plaice were as follows:

Sex	Otoliths areas	Number of readable otoliths	Range in age (years)	Range in length (cm)
Male	North	52	4-11	11-33
	South	93	2-10	6-34
Female	North	33	5-10	14-34
	South	118	2-12	5-42

These data are summarized in Figure VIII-75 by plots of mean lengths-at-age by sex and otolith area with estimated growth curves for each data group. Age-length keys for these data groupings are presented in Appendix I and growth parameters based on this information are given in Table VIII-43.

Selection of data to eliminate age groups with few (<5) observations and fitting the curve to the origin resulted in reductions in the residual root mean square deviations ($\underline{\delta}$), as well as providing more realistic

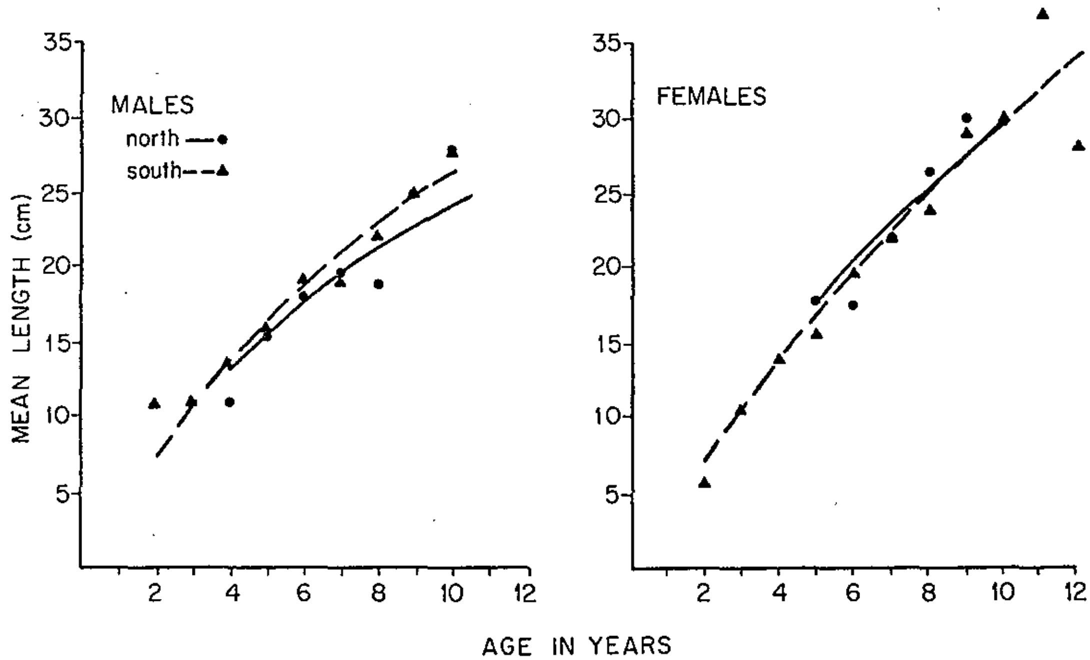


Figure VIII-75.--Mean lengths-at-age and growth curves fit to the origin for Alaska plaice by sex and otolith area in Norton Sound, the southeastern Chukchi Sea and adjacent waters (BLM/OCS survey, 1976).

Table VIII-43.--Parameters for von Bertalanffy growth curves for Alaska plaice in Norton Sound, the southeastern Chukchi Sea, and adjacent waters (BLM/OCS survey, 1976).

		Range in age and length of analyzed data		Original data set				Selected data				Selected data with origin			
Otolith areas	Sex	age (yr)	length (cm)	δ	L_∞	K	t_0	δ	L_∞	K	t_0	δ	L_∞	K	t_0
North	Males	4-8 (5-7)	(12-25)	2.04	33.32	-0.19	2.08	1/	1/	1/	1/	0.74	34.45	-0.12	-0.06
	Females	5-10 (5-10)	(14-32)	2.48	42.20	-0.13	1.06	2.48	42.20	-0.13	1.06	2.20	50.69	-0.09	0.08
South	Males	2-10 (3-9)	(7-29)	0.92	36.83	0.04	-4.97	0.90	88.52	-0.03	-0.96	0.99	41.34	-0.10	0.15
	Females	2-12 (3-10)	(8-37)	3.81	30.40	-0.27	1.43	1.05	70.32	-0.06	0.12	0.97	71.75	-0.05	0.07

1/ Insufficient data points for calculating parameters.

values for t_o (theoretically equal to zero). Sex and area effects were observed for the parameters L_∞ and K in selected data with the origin. Females appeared to have substantially greater L_∞ values than males and estimates of this parameter by sex were considerably larger in the south otolith area than in the north. Values for K differed only slightly between sexes and otolith areas, but a trend was apparent. Males had larger estimates of the growth completion rate (K) than females and, by area, values of this parameter by sex were larger in the north otolith area than in the south. This information suggests that growth differed by sex. Also, the rate of growth completion for both sexes in the survey area south of Bering Strait appears slower than to the north, but largest maximum size was achieved for Alaska plaice south of Bering Strait.

Length-weight relationship--Table VIII-44 summarizes the length-weight observations taken for Alaska plaice by sex and otolith area and gives coefficients of the regression lines fit to these data. Data points representing all length-weight observations collected for this species during the survey are shown graphically in Figure VIII-76.

Table VIII-44.--Parameters for the length-weight relationship (weight (g) = a · length^b) for Alaska plaice and results from the analysis of covariance for between-area and between-sex differences in this relationship (BLM/OCS survey, 1976).

Sex	Otolith Area	Number of Fish Measured	Range in Length (cm)	Parameters a	Parameters b
Males	North	48	11-28	.0053	3.3058
	South	93	9-28	.0057	3.2660
Females	North	33	17-32	.0059	3.2826
	South	121	11-34	.0042	3.3746

Differences between-	F slope df	F slope F	F intercept df	F intercept F	H_b 1/	H_a 1/	Pooled regression a	Pooled regression b
Areas for males	1;137	.18	1;138	6.60*	-	+	.0056	3.2775
Areas for females	1;150	.71	1;151	2.76	-	-	.0042	3.3759
Areas for sexes combined	1;291	.80	1;292	8.09**	-	+	.0046	3.3493
Sexes for south area	1;210	3.38	1;211	1.28	-	-	.0045	3.3497
Sexes for north area	1;77	.04	1;78	1.14	-	-	.0049	3.3336
Sexes for areas combined	1;291	3.64	1;292	.76	-	-	.0046	3.3493

* Significant at the .05 level.

** Significant at the .01 level.

1/ Plus (+) indicates that the common slope (H_b) hypothesis or common intercept (H_a) hypothesis cannot be rejected on the basis of the values of F obtained.

Analysis of covariance for between-area and between-sex differences in the relationship between length and weight indicated significant levels of variation ($p < .05$) in two treatments of the data; the comparisons between areas for males and between areas for sexes combined. The significant difference for the comparison between areas for sexes combined probably resulted from the between-area differences for males. Inasmuch as these differences were identified only in tests for the intercepts and not for the slopes, the variations between areas could have resulted from limited samples of small-sized males in the north otolith area. Despite the differences, one length-weight relationship was used for all Alaska plaice in the survey area, as described by the equation:

$$\hat{w} = 0.0056\ell^{3.0645}$$

where $\hat{w}$ equals the predicted weight in grams for a fish ℓ cm in length. The relationship described by this equation is shown as a solid line in Figure VIII-76.

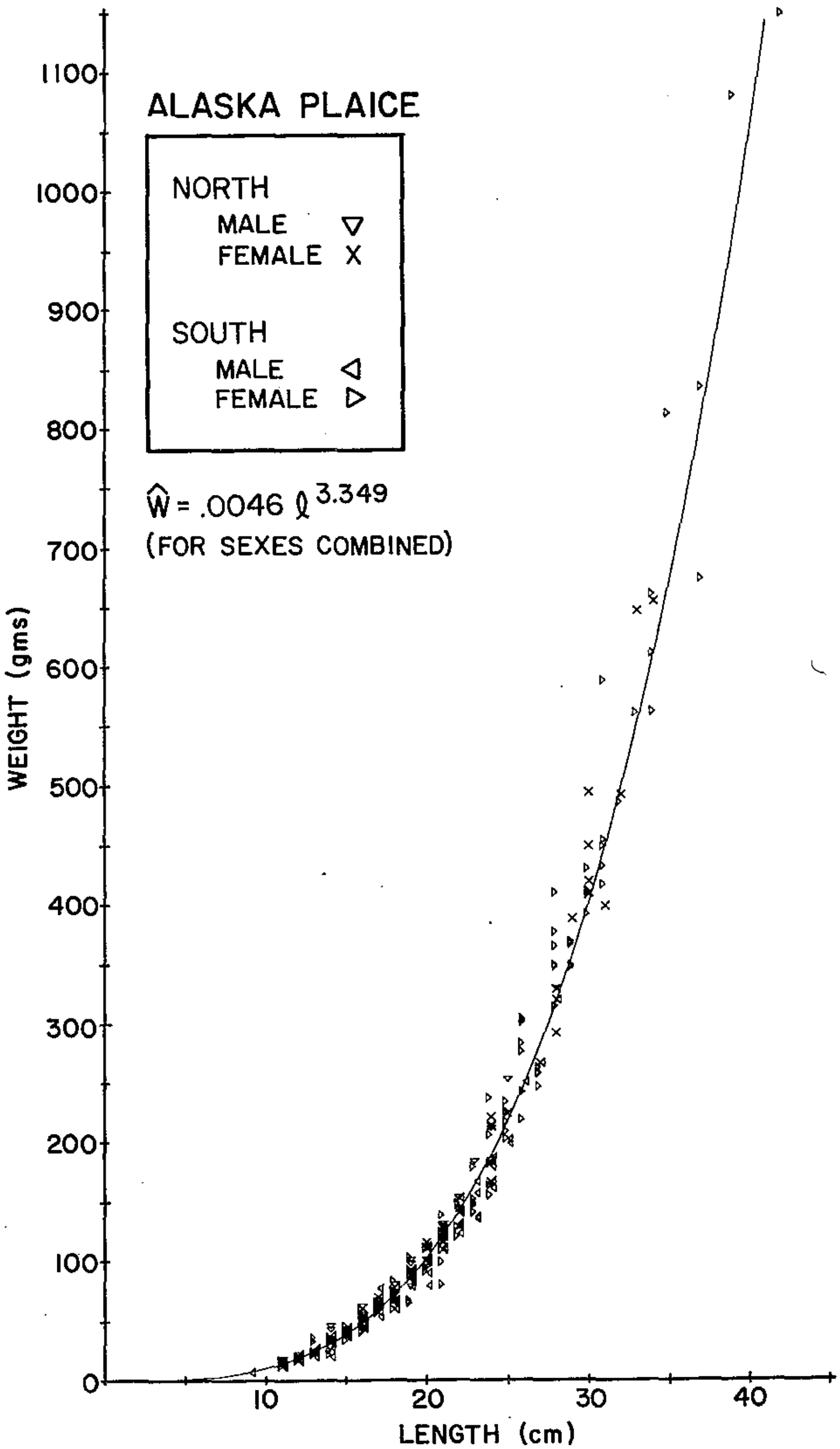


Figure VIII-76.--Weight-at-length observations for Alaska plaice by sex and otolith area in Norton Sound, the southeastern Chukchi Sea and adjacent waters (BLM/OCS survey, 1976).

Yellowfin sole

Distribution and abundance--Yellowfin sole occurred at 56% of the stations sampled (Table VIII-45) and accounted for about 3% of the total apparent fish biomass. The largest concentration was located in outer Norton Sound (strata 4Ø) (Figures VIII-77 and 78) where catch rates averaged 0.7 kg/km. Average catch rates decreased to about 0.3 kg/km in inner Norton Sound, the eastern portion of the northern Bering Sea, and in inner Kotzebue Sound (strata 4I, 3W, and 2I, respectively). Only trace amounts of yellowfin sole were taken in the southern section of the southeastern Chukchi Sea, outer Kotzebue Sound, and the western portion of the northern Bering Sea (strata 1S, 2Ø, and 3W, respectively). No catches of this species occurred in stratum 1N in the southeastern Chukchi Sea. The overall mean catch rate for the entire survey area was less than 0.2 kg/km trawled.

Table VIII-45.--Estimated biomass and population size of yellowfin sole in Norton Sound, the southeastern Chukchi Sea, and adjacent waters (BLM/OCS survey, 1976).

Stratum	Percent frequency of occurrence	Mean CPUE (kg/km)1/	Estimated biomass (mt)	Proportion of total estimated biomass	Estimated population (x 10^3)	Proportion of total estimated population	Mean size per individual weight (kg)	Mean size per individual length (cm)
Southeastern Chukchi Sea and Kotzebue Sound								
1N	—	—	—	—	—	—	—	—
1S	80.0	0.099	75	.053	1,415	.039	.053	15.78
2Ø	42.1	0.060	26	.018	361	.010	.071	16.74
2I	87.5	0.284	86	.061	3,728	.103	.023	12.07
Norton Sound and northern Bering Sea								
3W	15.6	0.013	29	.020	173	.005	.166	22.55
3E	57.1	0.252	155	.109	3,658	.101	.042	15.80
4Ø	94.8	0.665	886	.623	20,440	.564	.043	14.94
4I	76.5	0.311	165	.116	6,452	.178	.026	13.29
All strata combined:	56.3 2/	0.170	1,422 3/		36,228		.040	14.60

1/ Mean catch per unit effort, kg/km trawled.
2/ Percent occurrence in 192 successful hauls.
3/ 95% confidence interval: 1,068-1,776 mt.

The apparent yellowfin sole biomass in our survey area was estimated at about 1,400 mt (95% confidence interval 1,068-1,776 mt). This is probably a good estimate for this species in our survey region even though some larger catches occurred along the southern border of the survey area. Concentrations of fish along the southern limit of the survey re-

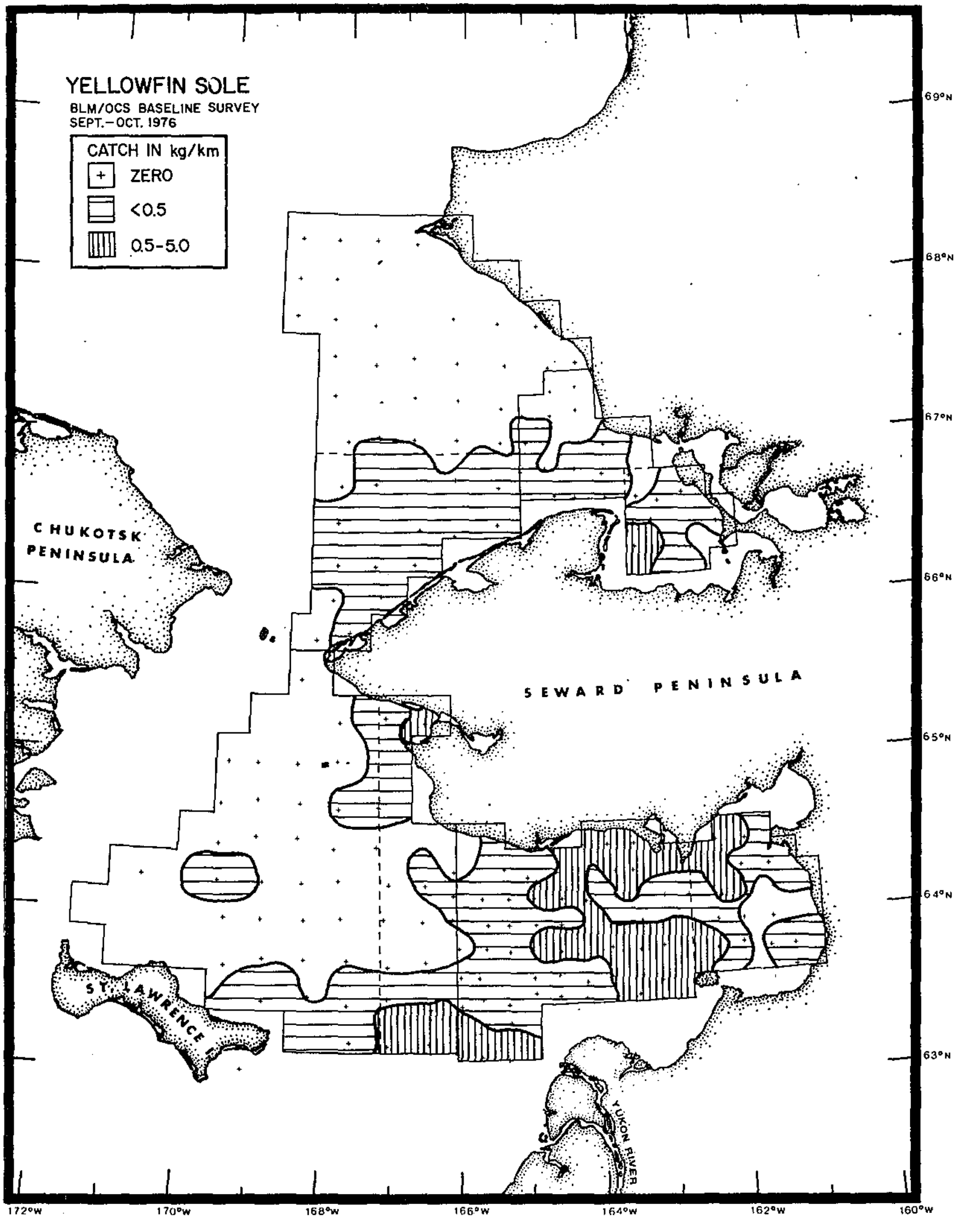


Figure VIII-77.--Distribution and relative abundance by weight of yellowfin sole in Norton Sound, the southeastern Chukchi Sea and adjacent waters (BLM/OCS survey, 1976).

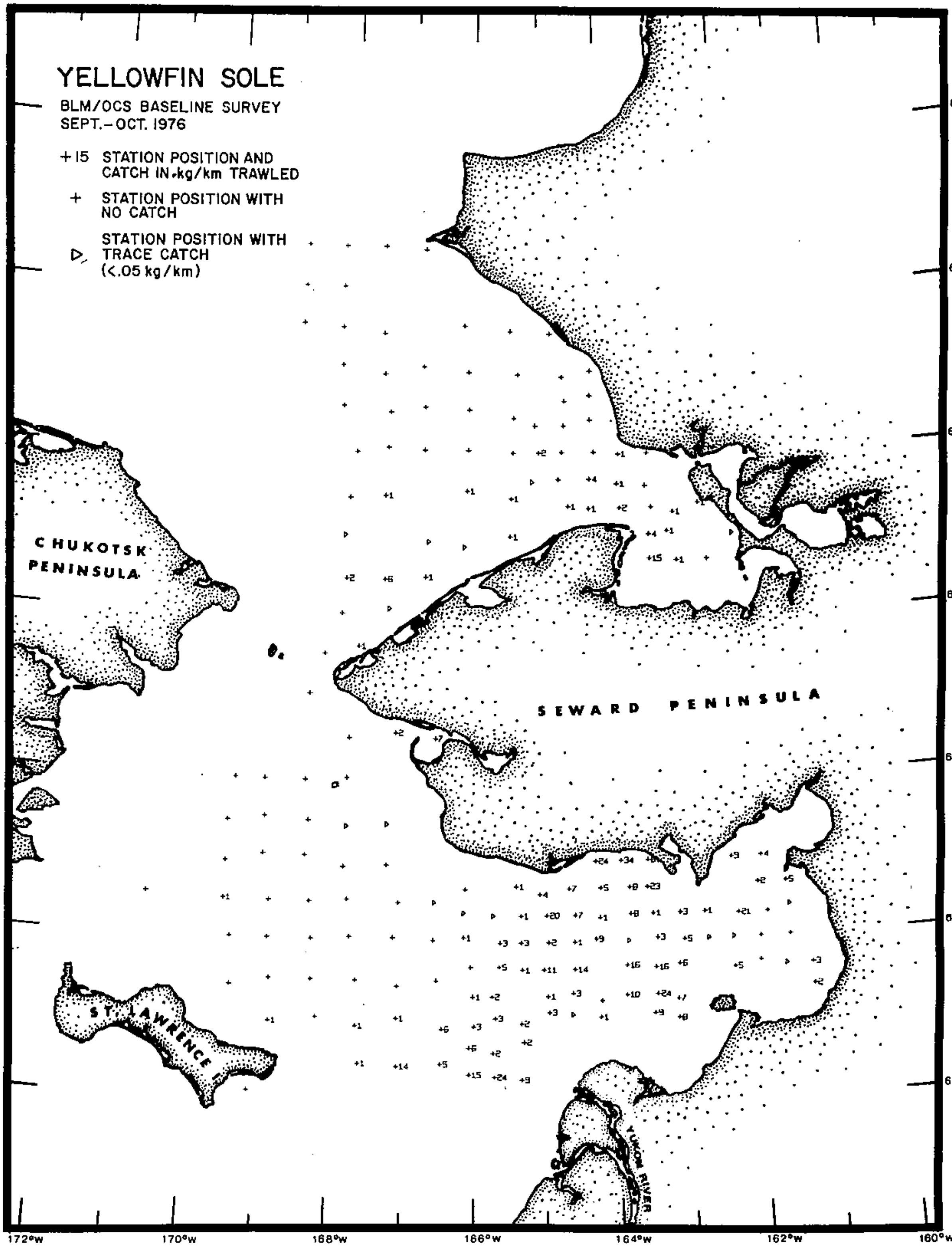


Figure VIII-78.--Distribution of catch rates by weight of yellowfin sole in Norton Sound, the southeastern Chukchi Sea and adjacent waters (BLM/OCS survey, 1976).

gion indicated a probable presence of fish to the south of the survey area, but the extent of movements of fish between the survey region and areas to the south are unknown. For the population sampled, the greatest proportion of apparent biomass (approximately 74%) was located in strata 4Ø and 4I combined, while a further 11% occurred in adjacent stratum 3E. All other strata accounted for 0-6% of the total biomass estimated. No yellowfin sole were found in stratum 1N, the northern portion of the southeastern Chukchi Sea.

Relative distribution of estimated numbers of yellowfin sole did not significantly differ from apparent biomass. The total population estimate for all strata combined was about 36 million fish.

Size composition, mean length and weight--Yellowfin sole caught during the survey ranged in length from 4 to 33 cm. Females were generally larger than males, averaging 15.6 cm compared to 13.5 cm for all strata combined (Figure VIII-79).

Length-frequency distributions of yellowfin sole indicated differences in relative size composition by area and between sexes within strata. Smallest average sizes by strata occurred in the shallow inner portions of both Kotzebue and Norton Sounds (strata 2I and 4I). Mean size increased with deeper and more offshore strata. This trend was especially evident in the set of strata south of Bering Strait where average size increased from 13.3 cm in stratum 4I to 14.9 cm in 4Ø, 15.8 in 3E, and 22.6 cm in stratum 3W. Differences in relative size compositions between sexes appeared in strata 1S and 2Ø. Average length of females in these strata was about 4 cm larger than for males.

Age composition--Differences in relative age composition by sex and stratum are shown in Figure VIII-80. Overall, age groups 4-7 accounted for 76% of the estimated standing stock in numbers of yellowfin sole in the survey area (Table VIII-46) and occurred in relatively substantial numbers in most strata. Young fish (< age 4) comprised 8% of the total and were primarily found in strata 4Ø and 4I while older fish (> age 7) accounted for the remaining 16% of the population estimate and occurred in all strata in the survey region.

Sex ratio--Estimated sex ratios (number of males/number of females) by stratum and age group are presented in Table VIII-46. There appeared to be more females than males in areas of low relative abundance and in all strata north of Bering Strait. In areas of highest relative abundance, males and females occurred in equal amounts.

Age-length relationship and growth--Age and length data collected for yellowfin sole were as follows:

Sex	Otolith areas	Number of readable otoliths	Range in age (years)	Range in length (cm)
Male	North	39	2-10	7-23
	South	93	1-10	4-26
Female	North	78	4-12	8-24
	South	110	2-14	5-34

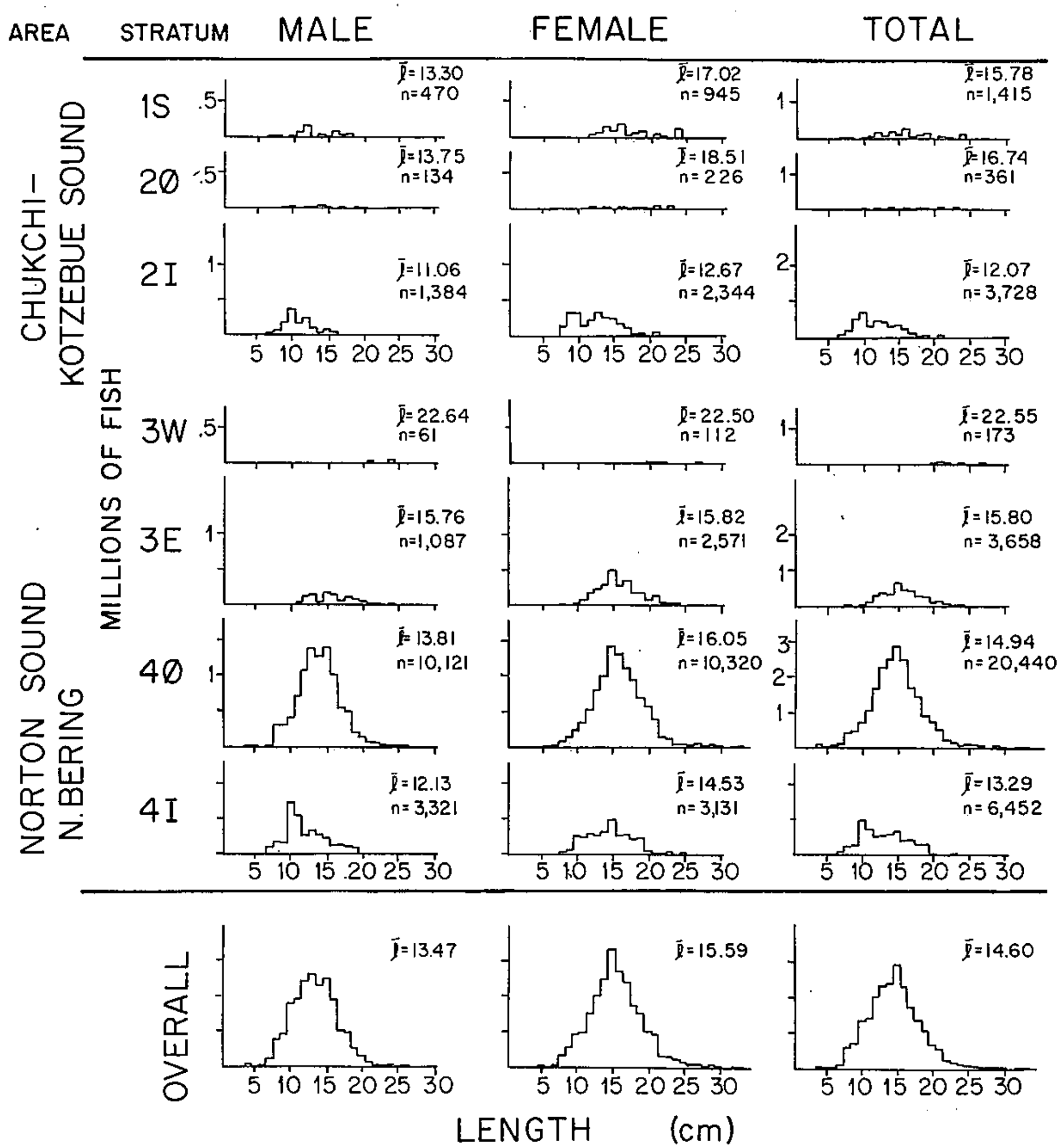


Figure VIII-79.--Size composition by sex and stratum for yellowfin sole in Norton Sound, the southeastern Chukchi Sea, and adjacent waters (BLM/OCS survey, 1976).

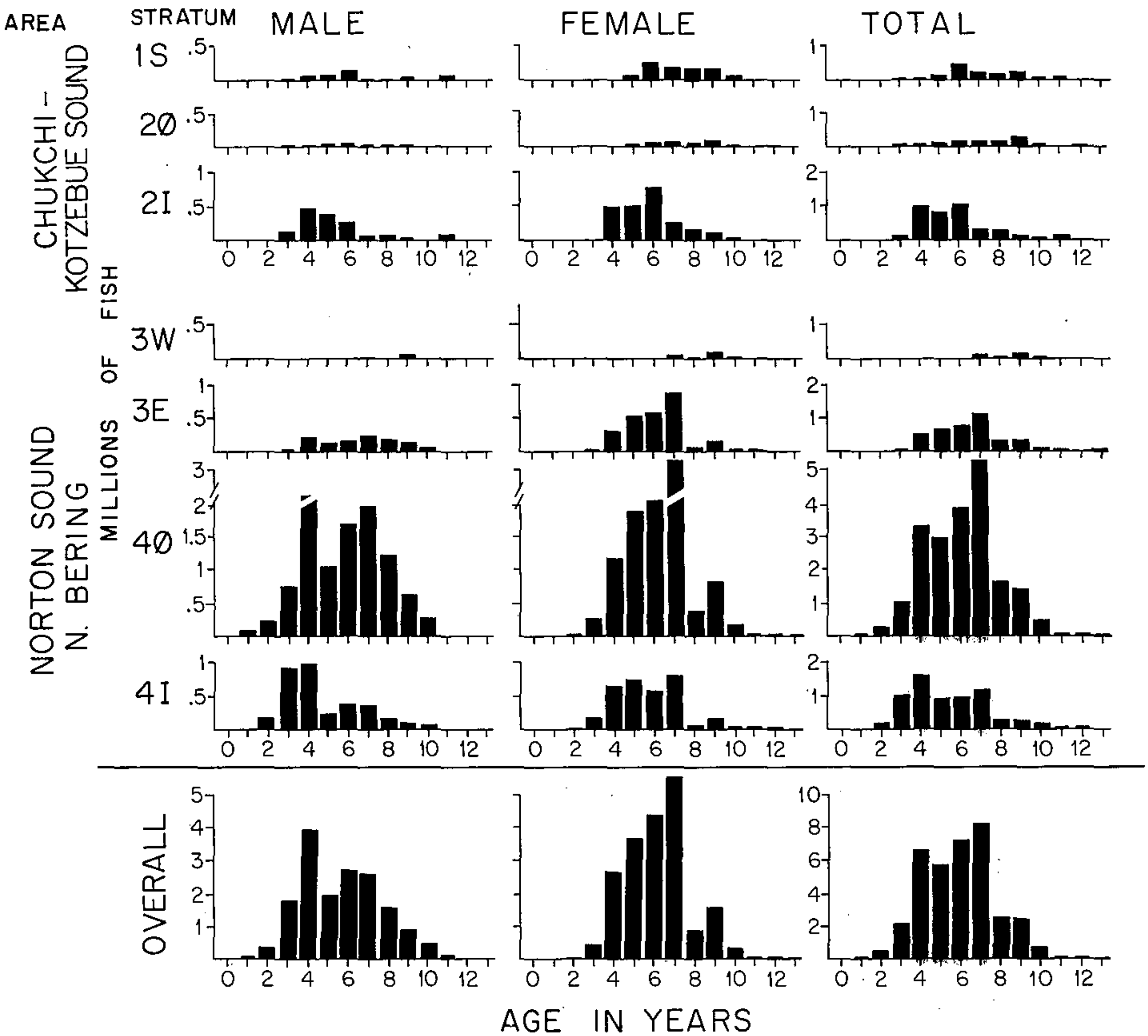


Figure VIII-80.--Age composition of yellowfin sole by sex and stratum in Norton Sound, the southeastern Chukchi Sea, and adjacent waters (BLM/OCS survey, 1976).

Table VIII-46.--Population numbers ($x10^4$) and sex ratios of yellowfin sole by age group and stratum (BLM/OCS survey, 1976).

Age group Year class	0 1976	1 1975	2 1974	3 1973	4 1972	5 1971	6 1970	7 1969	8 1968	9 1967	10 1966	>10 ≤1965	All ages combined
Stratum													
Southeastern Chukchi Sea and Kotzebue Sound													
1N	--	--	--	--	--	--	--	--	--	--	--	--	--
1S	--	--	--	0.5 (1/)	6.9 (1/)	14.1 (1.56)	44.7 (0.66)	22.1 (0.13)	17.0 (0.03)	20.6 (0.11)	7.5 (2/)	8.3 (1/)	141.7 (0.50)
2d	--	--	--	0.6 (1/)	1.6 (1/)	3.6 (1.40)	7.9 (1.19)	4.4 (0.42)	5.0 (0.19)	11.0 (0.17)	0.5 (2/)	0.3 (2/)	34.3 (0.52)
2I	--	--	--	10.8 (1/)	9.73 (0.96)	89.6 (0.76)	105.6 (0.33)	27.9 (0.09)	21.2 (0.29)	12.0 (0.22)	2.8 (2/)	5.9 (1/)	373.1 (0.59)
Norton Sound and Northern Bering Sea													
3W	--	--	--	--	--	--	--	5.7 (0.46)	1.8 (0.64)	9.5 (0.61)	0.4 (2/)	--	17.4 (0.54)
3E	--	--	--	4.6 (1.19)	50.7 (0.69)	63.5 (0.24)	76.3 (0.29)	109.8 (6.26)	23.5 (2.41)	29.1 (0.66)	8.0 (2.08)	1.3 (2/)	336.0 0.42
4d	--	8.5 (1/)	25.3 (6.23)	102.8 (2.56)	338.0 (1.88)	293.8 (0.55)	382.4 (0.82)	531.2 (0.58)	161.2 (3.19)	145.7 (0.76)	47.2 (1.73)	7.1 (2/)	2,044.0 0.98
4I	--	--	18.7 (16.00)	106.1 (5.89)	161.6 (1.60)	95.1 (0.32)	95.3 (0.60)	115.6 (0.45)	22.2 (2.26)	20.0 (0.65)	9.0 (2.75)	1.7 (2/)	645.3 (1.06)
All strata combined	--	8.5 (1/)	44.0 (8.57)	225.4 (3.86)	656.1 (1.53)	559.7 (0.51)	712.2 (0.62)	816.7 (0.47)	251.9 (1.79)	247.9 (0.59)	75.4 (1.25)	13.8 (1.48)	3,612.9 (0.84)
Proportion of total population	--	.002	.012	.062	.182	.155	.197	.226	.070	.069	.021	.007	

1/ Only males in estimate.
2/ Only females in estimate.

These data are summarized in Figure VIII-81 by plots of mean lengths-at-age by sex and otolith area with estimated growth curves for each data group. Age-length keys for these data groupings are presented in Appendix I and growth parameters based on this information are given in Table VIII-47.

Fitting the selected data to the origin failed to substantially reduce the root mean square deviation and actually increased δ for age groupings in the north otolith area. Increased δ was most noticeable for the north area females. Original data for this group suggested almost linear growth (Figure VIII-81) with t_o estimated at about age 2 years ($t_o = 2.04$). The selected data with the origin, however, did improve values for $\underline{L}\infty$, $\underline{K}$, and t_o, especially for area south females where meaningless parameters ($\underline{L}\infty < 0$ and $\underline{K} > 0$) were obtained before selection.

An area effect was observed for both sexes for the parameters $\underline{L}\infty$ and $\underline{K}$ in the selected data with the origin. For males and females, estimates of $\underline{L}\infty$ in the south otolith area were larger than estimates in the north by 28% and 14%, respectively. Also, lower estimated growth completion rates ($\underline{K}$) by sex were indicated for the south otolith area than for the north area.

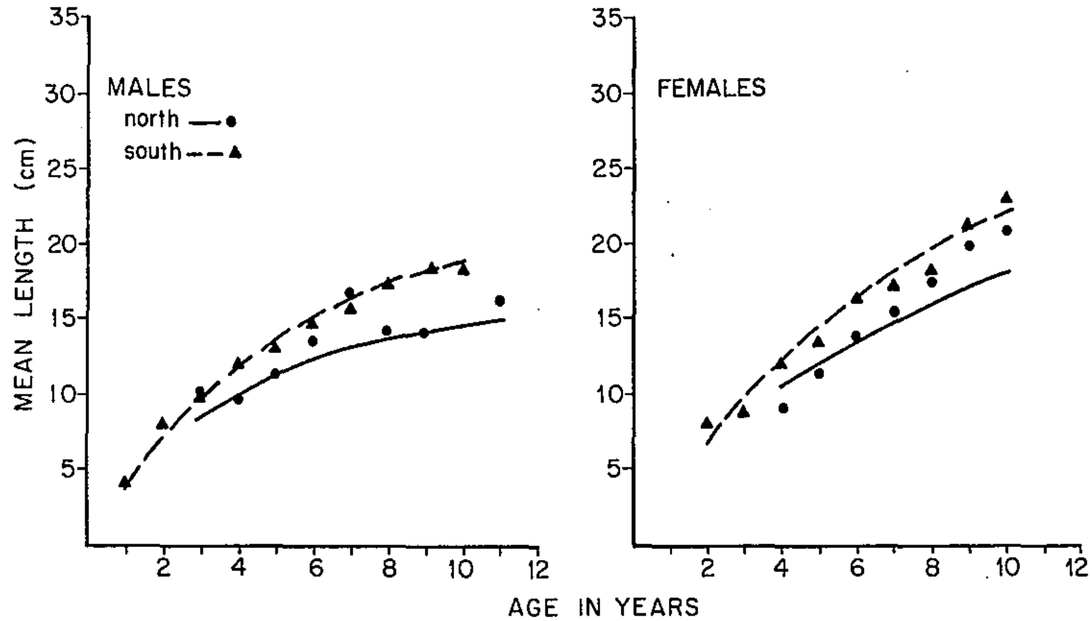


Figure VIII-81.--Mean lengths-at-age and growth curves fit to the origin for yellowfin sole by sex and otolith area in Norton Sound, the southeastern Chukchi Sea and adjacent waters (BLM/OCS survey, 1976).

Table VIII-47.--Parameters for von Bertalanffy growth curves for yellowfin sole in Norton Sound, the southeastern Chukchi Sea, and adjacent waters (values in parentheses are ranges for selected ages and lengths) (BLM/OCS survey, 1976).

Otolith areas	Sex	Range in age and length of analyzed data: age (yr)	length (cm)	Original data set: δ	L_∞	K	t_o	Selected data: δ	L_∞	K	t_o	Selected data with origin: δ	L_∞	K	t_o
North	Males	3-11 (4-9)	(7-14)	1.65	15.81	-0.34	0.59	1.60	14.47	-0.91	2.95	1.97	15.94	-0.23	-0.19
	Females	4-12 (4-12)	(8-24)	1.12	21.35	-0.28	2.04	1.12	21.35	-0.28	2.04	2.03	24.54	-0.12	-0.51
South	Males	1-10 (4-9)	(9-26)	0.53	20.40	-0.22	-0.00	0.26	62.94	-0.03	-3.87	0.50	22.23	-0.19	0.08
	Females	2-13 (2-11)	(9-29)	1.65	-38.01	0.10	-8.83	0.85	41.73	-0.07	-1.08	1.08	28.64	-0.15	0.20

These data suggest a possible difference in growth for yellowfin sole found north and south of Bering Strait. Maximum size of this species appears to be substantially smaller for stocks north of Bering Strait than for fish to the south and the rate at which maximum size is achieved also differs between these regions. Mean lengths-at-age were smaller by sex north of Bering Strait than for yellowfin sole south of that strait.

Length-weight relationship--Table VIII-48 summarizes the length-weight observations taken for yellowfin sole by sex and otolith area and gives coefficients of regression lines fit to these data. Data points representing all length-weight observations collected for this species during the survey are shown graphically in Figure VIII-82.

Table VIII-48.--Parameters for the length-weight relationship (weight (g) = a · length^{b}) for yellowfin sole and results from the analysis of covariance for between-area and between-sex differences in this relationship (BLM/OCS survey, 1976).

Sex	Otolith Area	Number of Fish Measured	Range in Length (cm)	Parameters a	Parameters b
Male	North	38	9-25	.0072	3.1696
	South	92	7-24	.0081	3.1100
Female	North	80	10-24	.0067	3.2091
	South	108	9-34	.0083	3.1225

Differences between-	F slope df	F slope F	F intercept df	F intercept F	H_b 1/	H_a 1/	Pooled regression a	Pooled regression b
Areas for males	1;126	.14	1;127	.59	-	-	.0082	3.1072
Areas for females	1;184	1.32	1;185	.82	-	-	.0079	3.1438
Areas for sexes combined	1;314	1.74	1;315	2.96	-	-	.0076	3.1507
Sexes for south area	1;196	.03	1;197	7.14**	-	+	.0079	3.1340
Sexes for north area	1;114	.08	1;115	1.01	-	-	.0064	3.2235
Sexes for areas combined	1;314	.35	1;315	10.3**	-	+	.0076	3.1507

* Significant at the .05 level.

** Significant at the .01 level.

1/ Plus (+) indicates that the common slope (H_b) hypothesis or common intercept (H_a) hypothesis cannot be rejected on the basis of the values of F obtained.

Analysis of covariance for between-area or between-sex differences in the length-weight relationship indicated a significant difference in two treatments of the data, the comparisons of between-sex differences in the south otolith area and for areas combined (F= 7.14 and 10.3, respectively, p <.01). A significant difference for the area-combined comparison between sexes probably resulted from differences between sexes in the south otolith area. Since significance was determined only for tests of the treatment intercepts and not the slopes, the two treatment differences may have been due to limited observations of small-sized fish of either sex. Despite the differences, one length-weight relationship was used for all yellowfin sole in the survey area, as described by the equation:

$$\hat{w} = 0.0076\ell^{3.1507}$$

where $\hat{w}$ equals the predicted weight in grams of a fish ℓ cm in length. The relationship described by this equation is shown as a solid line in Figure VIII-82.

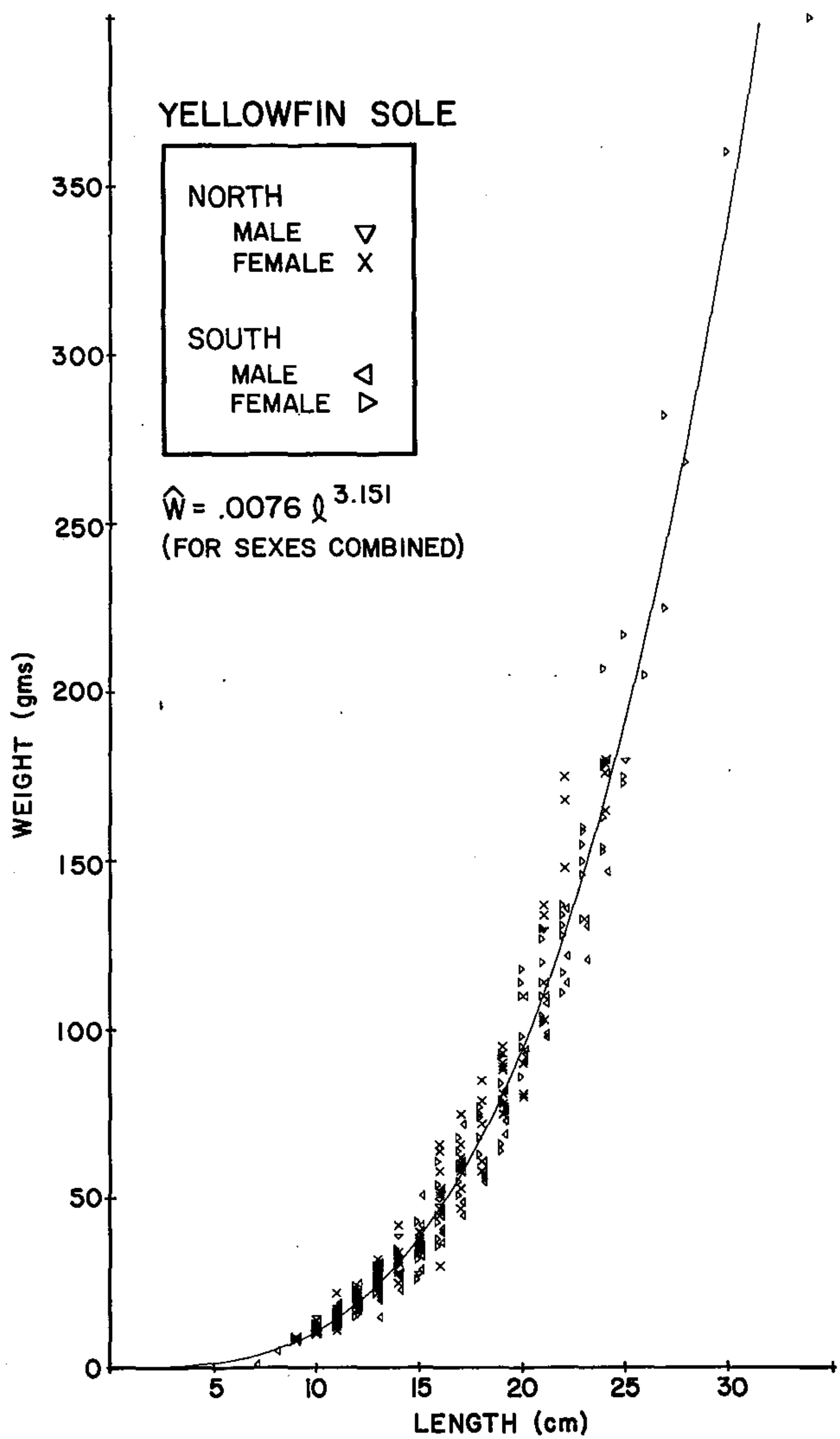


Figure VIII-82.--Weight-at-length observation for yellowfin sole by sex and otolith area in Norton Sound, the southeastern Chukchi Sea and adjacent waters (BLM/OCS survey, 1976).

Arctic cod

Distribution and abundance--Arctic cod was the most frequently encountered species, occurring at nearly 85% of all stations sampled (Table VIII-49); however, it accounted for less than 3% of the total apparent fish biomass. Small concentrations were found throughout the survey region (Figures VIII-83 and 84), with the southeastern Chukchi Sea, outer Kotzebue Sound, outer Norton Sound, and the eastern portion of the northern Bering Sea (strata 1N, 1S, 2Ø, 4Ø, and 3E) all having catch rates of about 0.2 kg/km. Catch rates were even lower in the inshore portions of Norton and Kotzebue sounds (2I and 4I) where only trace amounts of Arctic cod were encountered. The overall mean catch rate for the entire survey area was slightly more than 0.1 kg/km trawled.

Table VIII-49.--Estimated biomass and population size of Arctic cod in Norton Sound, the southeastern Chukchi Sea, and adjacent waters (BLM/OCS survey, 1976).

Stratum	Percent frequency of occurrence	Mean CPUE (kg/km)1/	Estimated biomass (mt)	Proportion of total estimated biomass	Estimated population ($\times 10^3$)	Proportion of total estimated population	Mean size per individual weight (kg)	Mean size per individual length (cm)
Southeastern Chukchi Sea and Kotzebue Sound								
1N	96.6	0.208	353	.286	25,270	.330	.014	10.41
1S	66.7	0.197	149	.121	8,774	.115	.017	12.53
2Ø	89.5	0.155	67	.054	3,149	.041	.021	12.65
2I	37.5	0.018	6	.005	344	.004	—	12.25
Norton Sound and northern Bering Sea								
3W	90.6	0.099	217	.176	18,544	.242	.012	8.63
3E	92.9	0.233	143	.116	4,959	.065	.029	14.13
4Ø	82.8	0.208	278	.225	14,410	.188	.019	13.38
4I	88.2	0.041	22	.018	1,065	.014	.021	12.99
All strata combined:	84.9 2/	0.147	1,234 3/		76,516		.016	11.32

1/ Mean catch per unit effort, kg/km trawled.
2/ Percent occurrence in 192 successful hauls.
3/ 95% confidence interval: 918-1,550 mt.

The Arctic cod biomass for the entire survey area was estimated at just over 1,200 mt (95% confidence interval 912-1,550 mt). This is a minimum estimate for the region, since Arctic cod are considered semi-pelagic. Quast (1974) indicated this species was by far the most abundant taken in midwater sampling during an earlier study in the Chukchi Sea. Some unknown proportion of the population, therefore, occupied the water column above

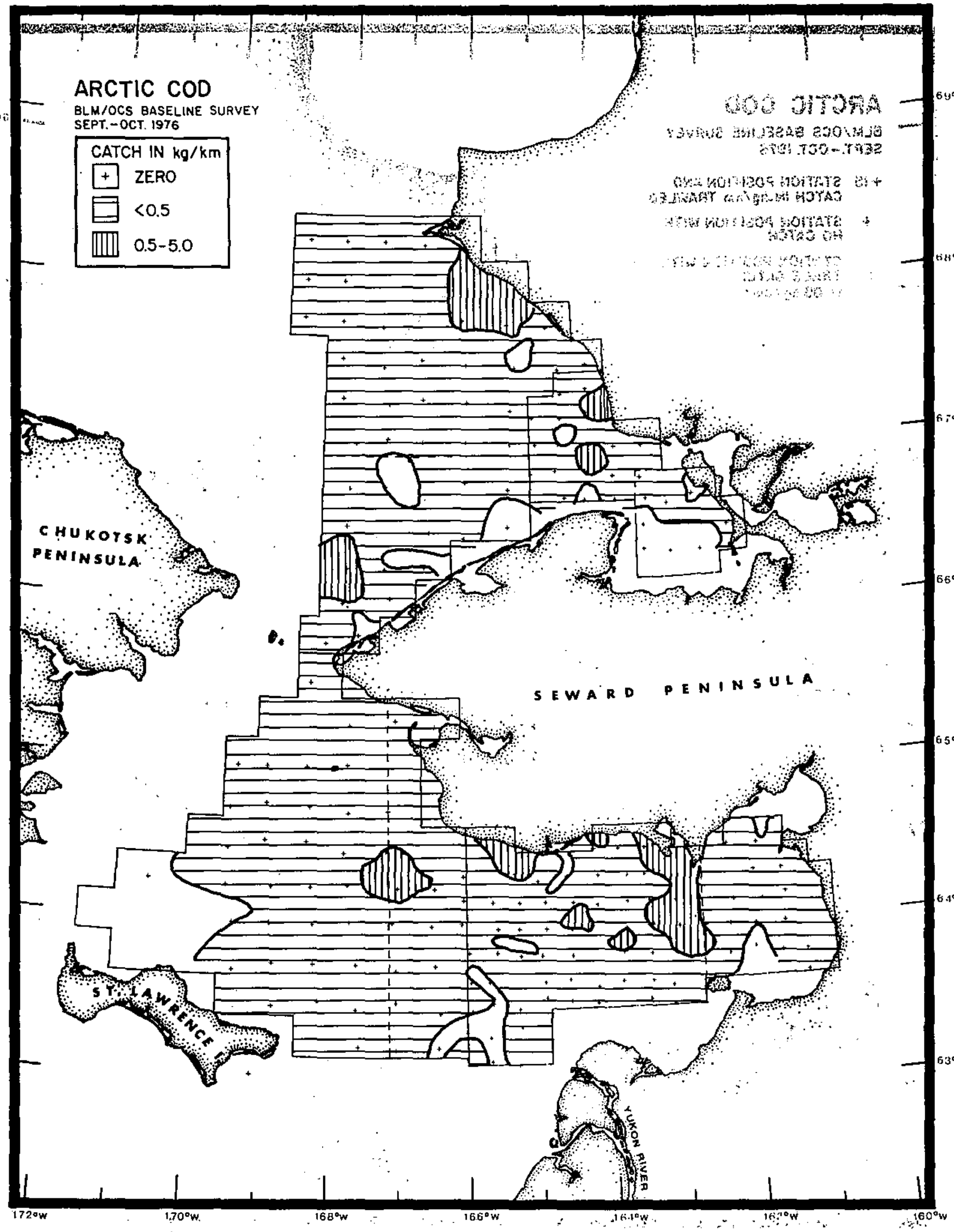


Figure VIII-83.--Distribution and relative abundance by weight of Arctic cod in Norton Sound, the southeastern Chukchi Sea and adjacent waters (BLM/OCS survey, 1976).

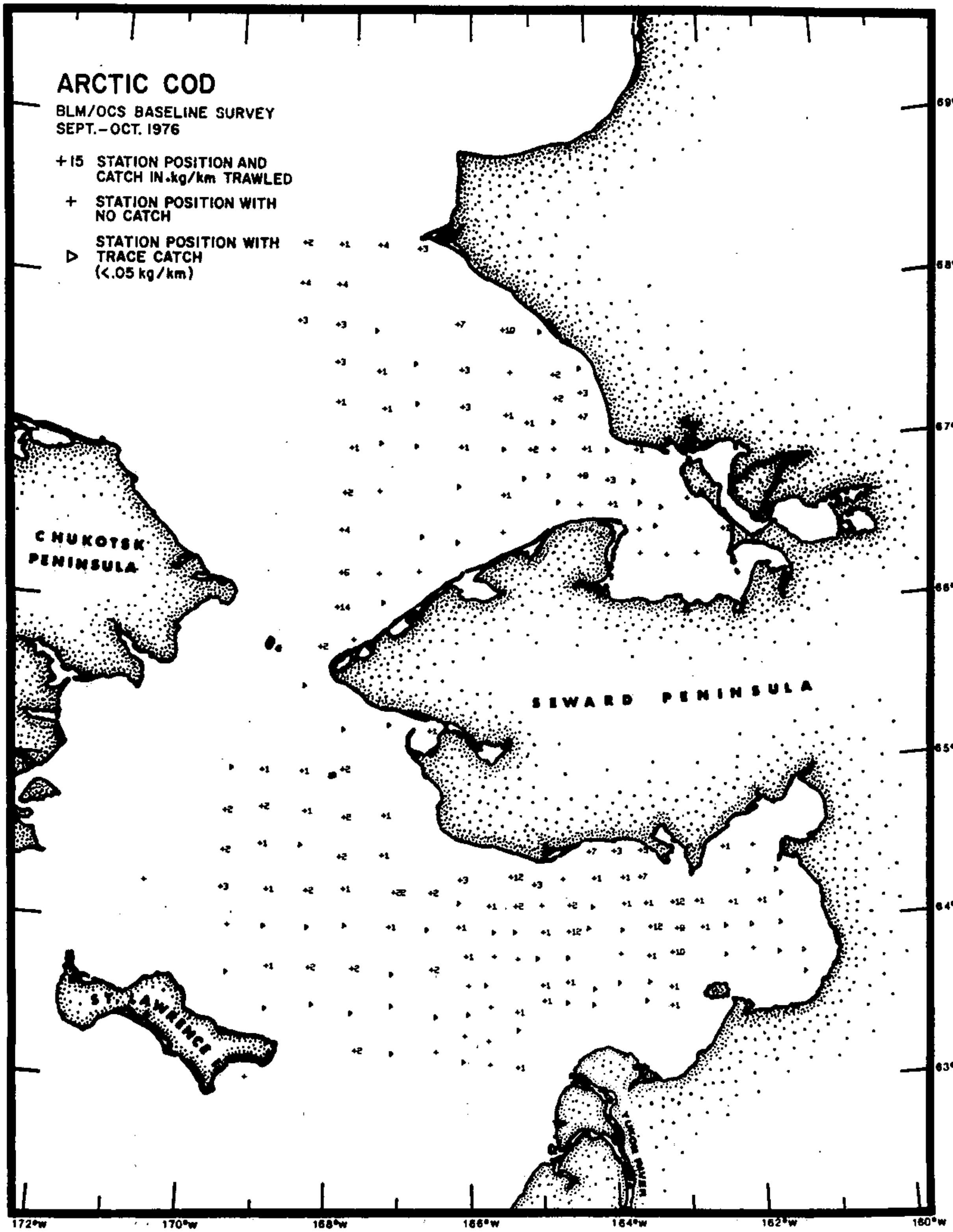


Figure VIII-84.--Distribution of catch rates by weight of Arctic cod in Norton Sound, the southeastern Chukchi Sea and adjacent waters (BLM/OCS survey, 1976).

the sampling gear and was unavailable to the trawl. Also, concentrations may have existed north of the survey region. Earlier work by Alverson and Wilimovsky (1966) mentioned relatively large catches of Arctic cod slightly north of Pt. Hope. The degree to which these peripheral stocks may influence the survey area population is unknown. Additionally, this species exhibits a preference for colder waters (Svetovidov, 1968) and the relatively warm water temperatures measured during the survey may have had still another effect on Arctic cod distribution and abundance.

For the Arctic cod population sampled, over 40% of the estimated population occurred in strata 1N and 1S combined. Of the remaining biomass, 29% occurred in strata 3W and 3E combined, 22% in stratum 4Ø, and less than 2% each in strata 2I and 4I.

The relative distribution of the estimated number of fish did not appreciably differ from the apparent biomass. The total population estimate for the entire survey area was about 76.5 million fish.

Size composition, mean length and weight--Arctic cod caught during the survey ranged in size from 4 to 26 cm. Males were slightly larger than females, averaging 13.6 cm compared to 13.5 cm for all strata combined (Figure VIII-85). Length frequency distributions for Arctic cod include juvenile fish for which sex was not determined. The inclusion of these unsexed fish in the calculation of mean size for sexes combined caused the mean length in most strata to be considerably less than for individual sexes.

Small fish (< 8 cm) were almost entirely located in the offshore deeper water strata 1N and 3W. Larger Arctic cod (> 8 cm) were found in all strata, but were most abundant in strata 1N, 1S, and 4Ø.

Highest mean weight for Arctic cod (29 gm) was observed in stratum 3E where catches of small fish were not encountered. Overall mean weight per individual for the entire survey region was only 16 gm.

Age composition--Differences in relative age composition between sexes was not significant (Figure VIII-86). In terms of estimated numbers of fish (Table VIII-50), age groups 0 and 2 predominated, accounting for over 72% of the total estimated population. Most of the remaining estimated population consisted of 3 and 4 year-old fish. It is most interesting that age 1 fish appeared very low in estimated abundance, comprising less than 2% of the total estimate. No obvious reason could be identified for this low abundance.

Sex ratio--Estimated sex ratios (number of males/number of females) by stratum and age group are presented in Table VIII-50. Overall, males were slightly more numerous than females, but females predominated in age groups 4 and older.

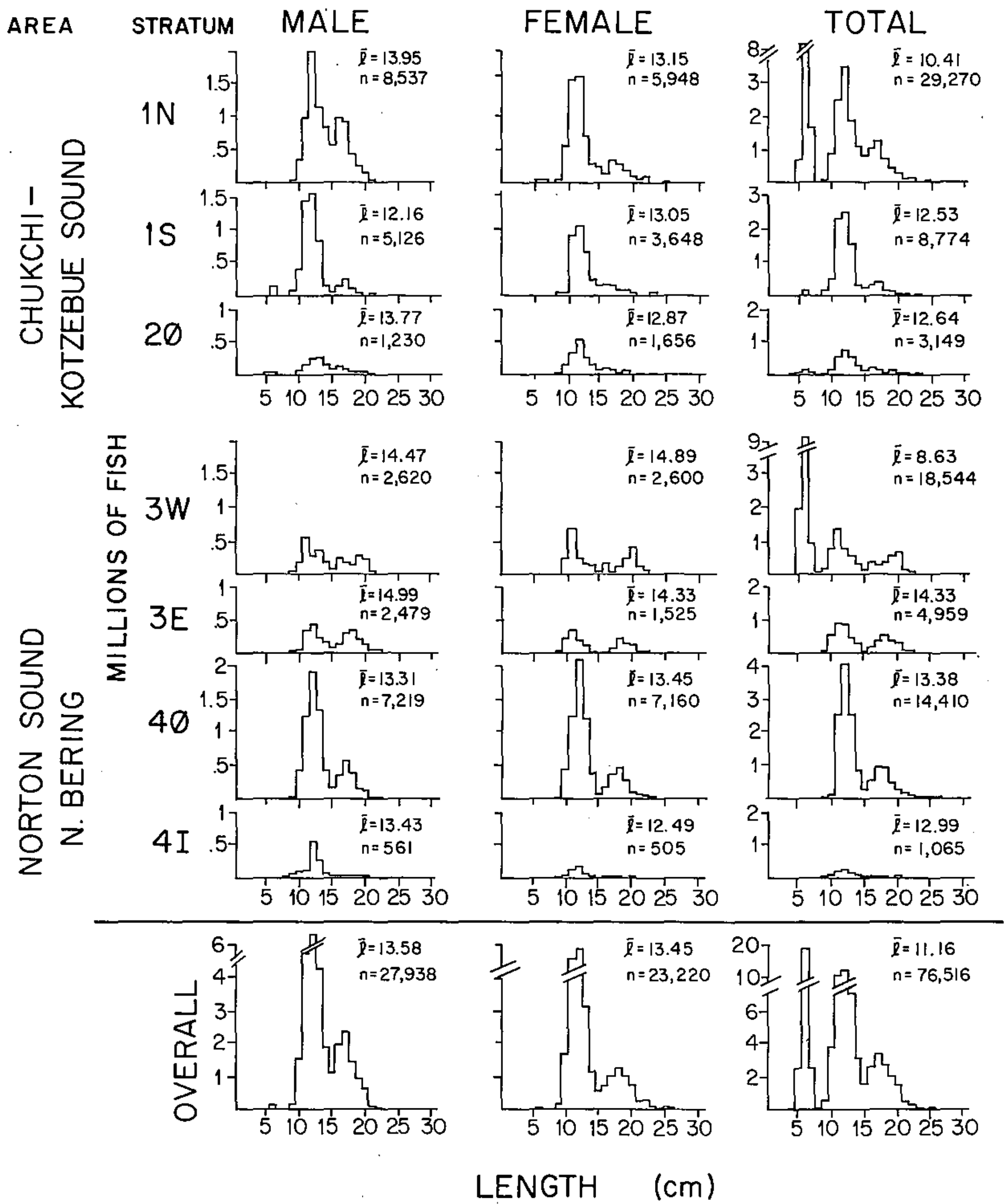


Figure VIII-85.--Size composition of Arctic cod by sex and stratum in Norton Sound, the southeastern Chukchi Sea and adjacent waters (BLM/OCS survey, 1976).

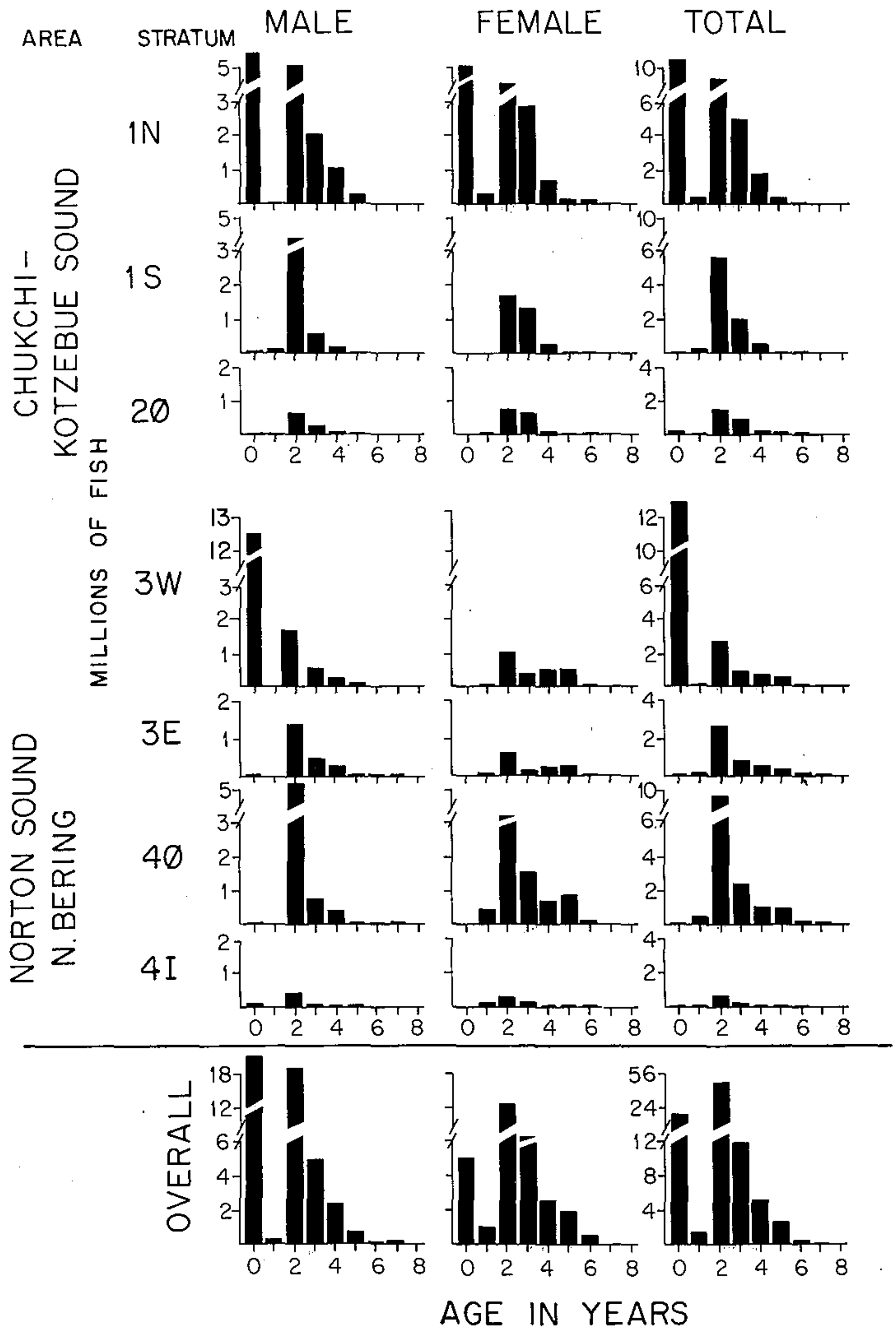


Figure VIII-86.--Age composition of Arctic cod by sex and stratum in Norton Sound, the southeastern Chukchi Sea and adjcent waters (BLM/OCS survey, 1976).

Table VIII-50.--Population numbers ($x10^5$) and sex ratios for Arctic cod by age group and stratum (BLM/OCS survey, 1976).

Age group Year class	0 1976	1 1975	2 1974	3 1973	4 1972	5 1971	6 1970	7 1969	8 1968	9 1967	10 1966	>10 ≤1965	All ages combined
Stratum													
Southeastern Chukchi Sea and Kotzebue Sound													
1N	108.4 (1.88)	4.2 (0.22)	94.4 (1.14)	49.3 (0.71)	17.4 (1.52)	4.8 (2.35)	1.0 (2/)	--	--	--	--	--	279.6 (0.99)
1S	1.4 (1/)	1.9 (4.46)	57.1 (2.21)	20.1 (0.45)	5.3 (0.71)	0.8 (2.42)	0.7 (2/)	--	--	--	--	--	85.0 (1.43)
4Ø	2.7 (1/)	0.8 (0.14)	15.2 (0.91)	9.3 (0.47)	2.5 (1.08)	0.7 (4.15)	0.2 (2/)	--	--	--	--	--	31.2 (0.74)
2I	--	0.2 (0.50)	2.0 (0.87)	0.6 (1.76)	0.3 (3.83)	0.1 (2.50)	T (2/)	--	--	--	--	--	3.1 (1.08)
Norton Sound and Northern Bering Sea													
3W	124.9 (1/)	1.4 (2/)	34.9 (1.69)	8.9 (1.21)	7.7 (0.51)	6.6 (0.20)	0.8 (2/)	0.2 (1/)	--	--	--	--	185.4 (1.01)
3E	0.2 (1/)	1.0 (2/)	29.2 (2.11)	8.3 (4.00)	5.8 (1.33)	3.8 (0.19)	1.0 (0.51)	0.4 (1/)	--	--	--	--	49.7 (1.62)
4Ø	0.3 (1/)	4.6 (2/)	93.4 (1.74)	24.1 (0.50)	10.9 (0.59)	9.2 (0.08)	1.7 (0.04)	0.1 (1/)	--	--	--	--	144.2 (1.01)
4I	0.1 (1/)	0.5 (2/)	7.5 (1.51)	1.6 (0.62)	0.7 (0.89)	0.3 (0.26)	T (2/)	--	--	--	--	--	10.6 (1.11)
All strata combined	232.9 (4.71)	14.6 (0.23)	333.5 (1.54)	122.2 (0.69)	50.7 (0.94)	26.2 (0.36)	5.4 (0.08)	0.7 (1/)	--	--	--	--	785.7 (1.08)
Proportion of total population	.296	.019	.424	.156	.064	.033	.007	.001	--	--	--	--	

1/ Only males in estimate.
2/ Only females in estimate.

Age-length relationship and growth--Age and length data collected for Arctic cod were as follows:

Sex	Otolith area	Number of readable otoliths	Range in age (years)	Range in length (cm)
Male	North	66	0-5	5-21
	South	57	0-7	9-23
Female	North	68	0-6	6-25
	South	73	1-6	9-26
Unsexed	North	5	0	4-8
	South	--	--	--

These data (except unsexed) are summarized in Figure VIII-87 by plots of mean lengths-at-age by sex and otolith area with estimated growth curves for each data group. Age-length keys for these data groupings are presented in Appendix I and growth parameters based on this information are given in Table VIII-51.

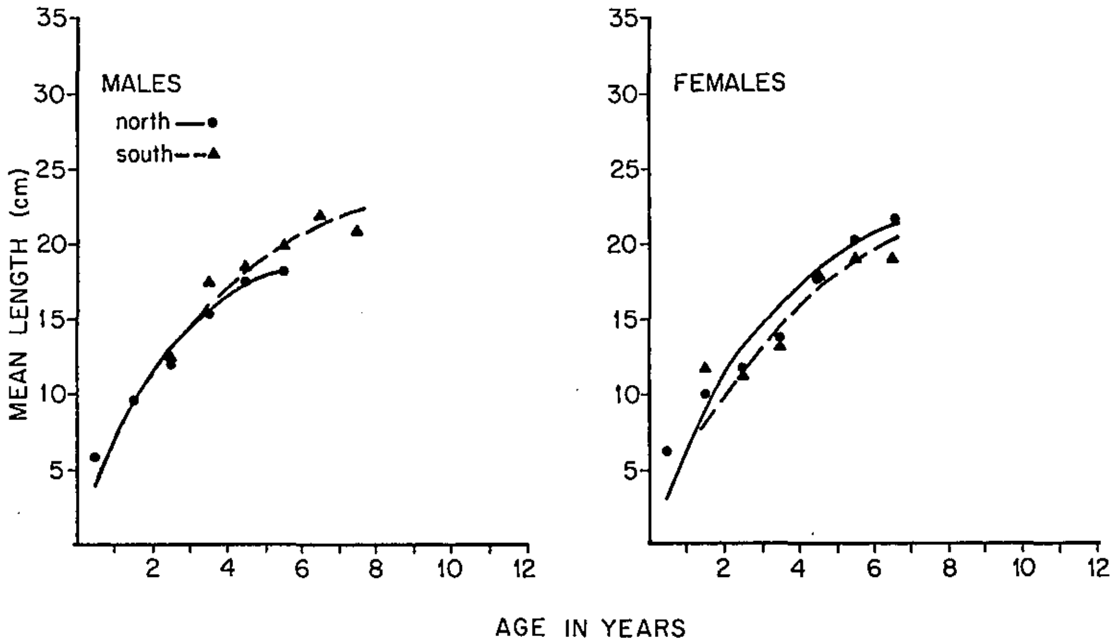


Figure VIII-87.--Mean lengths-at-age and growth curves fit to the origin for Arctic cod by sex and otolith area in Norton Sound, the southeastern Chukchi Sea and adjacent waters (BLM/OCS survey, 1976).

Table VIII-51.--Parameters for von Bertalanffy growth curves for Arctic cod in Norton Sound, the southeastern Chukchi Sea, and adjacent waters (values in parentheses are ranges for selected ages and lengths) (BLM/OCS survey, 1976).

Otolith areas	Sex	Range in age and length of analyzed data: age (yr)	length (cm)	Original data set: δ	L_∞	K	t_0	Selected data: δ	L_∞	K	t_0	Selected data with origin: δ	L_∞	K	t_0
North	Males	0.5-5.5 (1.5-5.5)	(9-20)	0.45	25.97	-0.20	-0.78	0.66	23.08	-0.26	-0.54	0.64	20.40	-0.41	0.01
	Females	0.5-6.5 (1.5-6.5)	(10-25)	1.01	34.27	-0.13	-1.07	1.13	77.15	-0.04	-2.06	1.60	24.59	-0.31	0.08
South	Males	2.5-7.5 (2.5-5.5)	(10-20)	0.99	21.10	-0.83	1.44	0.86	19.80	-1.15	1.65	1.19	25.13	-0.29	-0.04
	Females	1.5-6.5 (2.5-5.5)	(10-23)	1.96	23.98	-0.19	-1.92	1.43	20.30	-0.48	0.84	1.23	25.58	-0.24	0.02

Since young of the year (age group 0) were present in nearly all sets of Arctic cod age data, adjustments to ages were necessary to provide reasonable growth curve fits for both the original data and for the selected sets, with values at the origin of the curve (age and length = 0). Age plus 0.5 years was used as the adjustment, since it is reasonable to assume that at least half of a year's growth had been completed by the September-October survey date.[1/]

Selection of data to eliminate age groups not fully recruited to the gear or with few (<5) observations and fitting the curve to the origin resulted in slight increases in the root mean square deviations (δ). The selected data fitted to the origin, however, did improve estimates of $\underline{K}$ and provided more realistic values for $\underline{t}_o$.

Sex and area effects were observed for the parameters $\underline{L}_\infty$ and $\underline{K}$ within the selected Arctic cod data. Females appeared to have slightly greater $\underline{L}_\infty$ values than males and estimates of this parameter by sex were larger in the south otolith area than in the north. Values of the growth completion rate ($\underline{K}$) substantially differed by sex and otolith areas. Male groups had higher $\underline{K}$ values than females, and, by area, estimates of this parameter were higher in the north otolith area than for south area groups. This information suggests that growth may differ by sex and that the rate of growth completion for both sexes of Arctic cod in that part of the survey region south of Bering Strait is slightly slower than to the north. Greatest maximum size within the survey region, however, is achieved by fish occurring south of Bering Strait.

Length-weight relationship--Table VIII-52 summarizes length-weight observations taken for Arctic cod by sex and otolith area and gives coefficients of the regression lines fit to these data. Data points representing all length-weight observations collected for this species from the survey are shown graphically in Figure VIII-88.

Analysis of covariance for between-area and between-sex differences indicated significant differences for most treatments of the data. Interesting trends resulted from consideration of weights predicted by the regression coefficients. Overall, males weighed more at-length than females, and these differences in weight-at-length increased with size. Additionally, males from the north otolith area were heavier at-length than fish of corresponding sex and size in the south, but only up to a length of about 18 cm. Above that size, south area males were heavier. A similar situation was observed for females, although the change to south area females weighing more than north fish did not occur until a length of 33 cm was attained. This is considerably larger than the size of Arctic cod encountered during the survey. The between-area differences suggest that Arctic cod stocks north and south of Bering Strait grow at differing rates

1/ Rass (1968) indicated that Arctic cod spawn during January-February and transition from the larval to juvenile form occurs in August at a size of 3-5 cm.

and more than one localized population may occur in the survey region. Absolute differences in the length-weight relationships for both areas and both sexes, however, were on an order of 3-7% and an overall length-weight relationship could be used to describe the entire population in the survey region. This overall relationship was described by the equation:

$$\hat{w} = 0.0057\ell^{3.0645}$$

where $\hat{w}$ equals the predicted weight in grams of a fish ℓ cm in length. The relationship described by this equation is shown as a solid line in Figure VIII-88.

Table VIII-52.--Parameters for the length-weight relationship (weight (g) = a · length^{b}) for Arctic cod and results from the analysis of covariance for between-area and between-sex differences in this relationship (BLM/OCS survey, 1976).

Sex	Otolith Area	Number of Fish Measured	Range in Length (cm)	Parameters a	Parameters b
Males	North	70	9-21	.0081	2.9509
	South	66	9-23	.0029	3.2991
Females	North	70	6-25	.0067	3.0084
	South	70	10-25	.0051	3.0876

Differences between-	F slope df	F slope F	F intercept df	F intercept F	H_b 1/	H_a 1/	Pooled regression a	Pooled regression b
Areas for males	1;131	12.00**	1;132	10.60**	+	+	.0050	3.1200
Areas for females	1;136	.98	1;137	8.57**	-	+	.0061	3.0317
Areas for sexes combined	1;271	9.09**	1;272	19.50**	+	+	.0057	3.0645
Sexes for south area	1;131	4.34*	1;132	1.55	+	-	.0040	3.1766
Sexes for north area	1;136	.53	1;137	3.96**	-	+	.0072	2.9850
Sexes for areas combined	1;271	1.74	1;272	4.34**	-	+	.0057	3.0645

* Significant at the .05 level.

** Significant at the .01 level.

1/ Plus (+) indicates that the common slope (H_b) hypothesis or common intercept (H_a) hypothesis cannot be rejected on the basis of the values of F obtained.

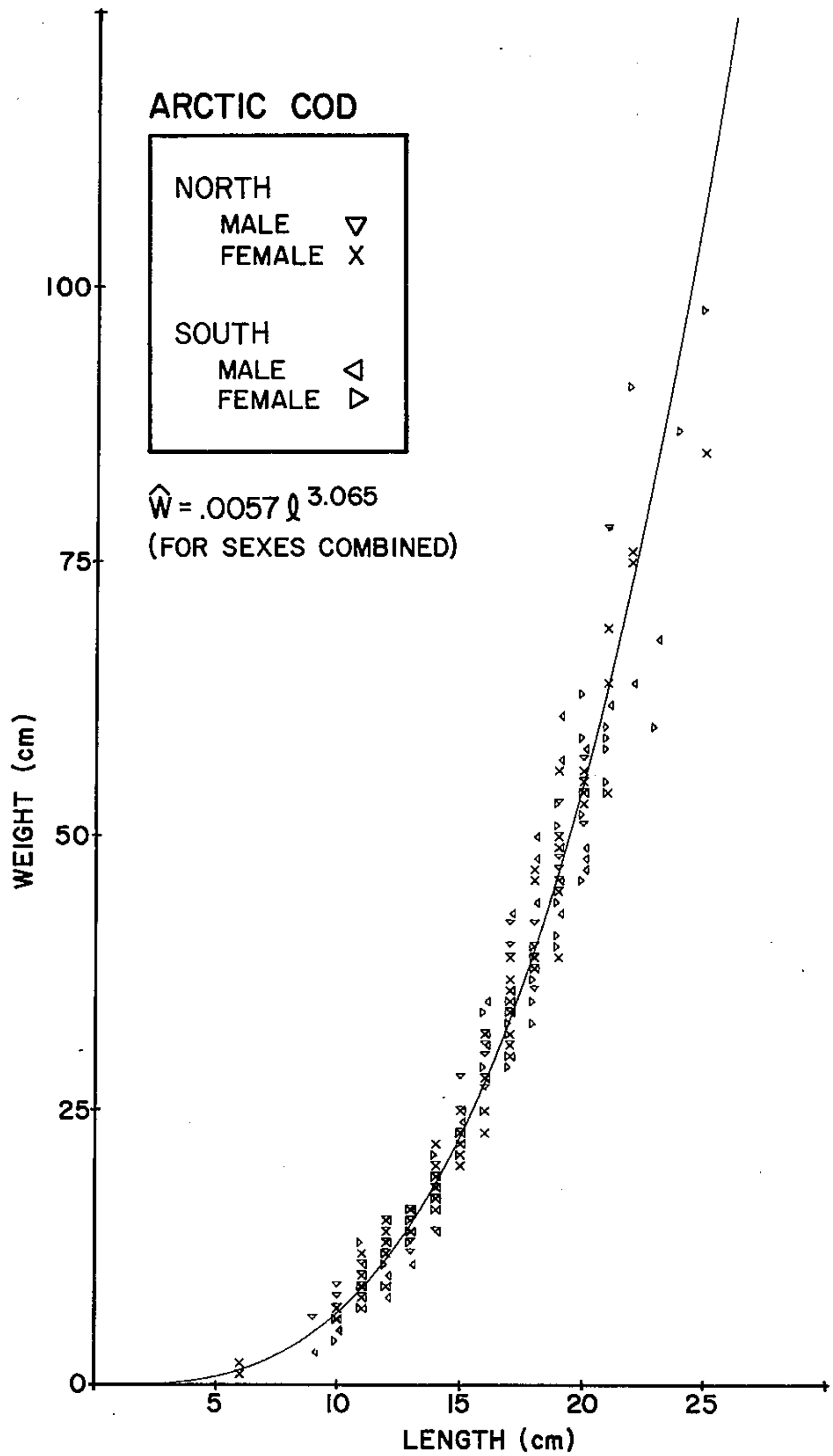


Figure VIII-88.--Weight-at-length observations for Arctic cod by sex and otolith area in Norton Sound, the southeastern Chukchi Sea and adjacent waters (BLM/OCS survey, 1976).

Other fish species

During the demersal survey, several other fish species were encountered, but limited biological information was obtained for them. The following are brief descriptions of the distributions and abundances for these other species with a presentation of biological information when available.

Walleye pollock was the other member of family Gadidae which occurred in the survey region.[1/] Their distribution (Figure VIII-89) was primarily limited to offshore waters in the northern Bering Sea and southeastern Chukchi Sea (strata 3W, 3E, and 1S), where only trace amounts were encountered. The apparent total biomass of this species in the survey region was about 267 mt (95% confidence interval 0-579 mt) (Table VIII-53). All pollock encountered were small (< 20 cm), age 1 juveniles (Figure VIII-90). Catches in the southeastern Chukchi Sea during our survey appear to be the first record of pollock occurring north of Bering Strait.

Table VIII-53.--Estimated biomass and population size of walleye pollock in Norton Sound, the southeastern Chukchi Sea, and adjacent waters (BLM/OCS survey, 1976).

Stratum	Percent frequency of occurrence	Mean CPUE (kg/km)[1/]	Estimated biomass (mt)	Proportion of total estimated biomass	Estimated population (x 10^3)	Proportion of total estimated population	Mean size per individual weight (kg)	Mean size per individual length (cm)
Southeastern Chukchi Sea and Kotzebue Sound								
1N	6.9	0.003	5	.021	279	.017	—	12.48
1S	40.0	0.227	172	.643	804	.649	.016	14.32
2Ø	15.8	0.002	1	.003	25	.001	—	—
2I	12.5	0.005	2	.006	36	.002	—	—
Norton Sound and northern Bering Sea								
3W	50.0	0.015	34	.128	2,110	.127	.016	10.82
3E	57.1	0.066	40	.151	2,548	.153	.016	12.90
4Ø	29.3	0.009	13	.047	845	.051	.015	12.17
All strata combined:	27.6[2/]	0.032	267[3/]		16,646		.016	13.44

1/ Mean catch per unit effort, kg/km trawled.
2/ Percent occurrence in 192 successful hauls.
3/ 95% confidence interval: 0-579 mt.

1/ One specimen of Pacific cod (Gadus morhua macrocephalus) was captured in the southernmost trawl haul of the survey, southeast of St. Lawrence Island.

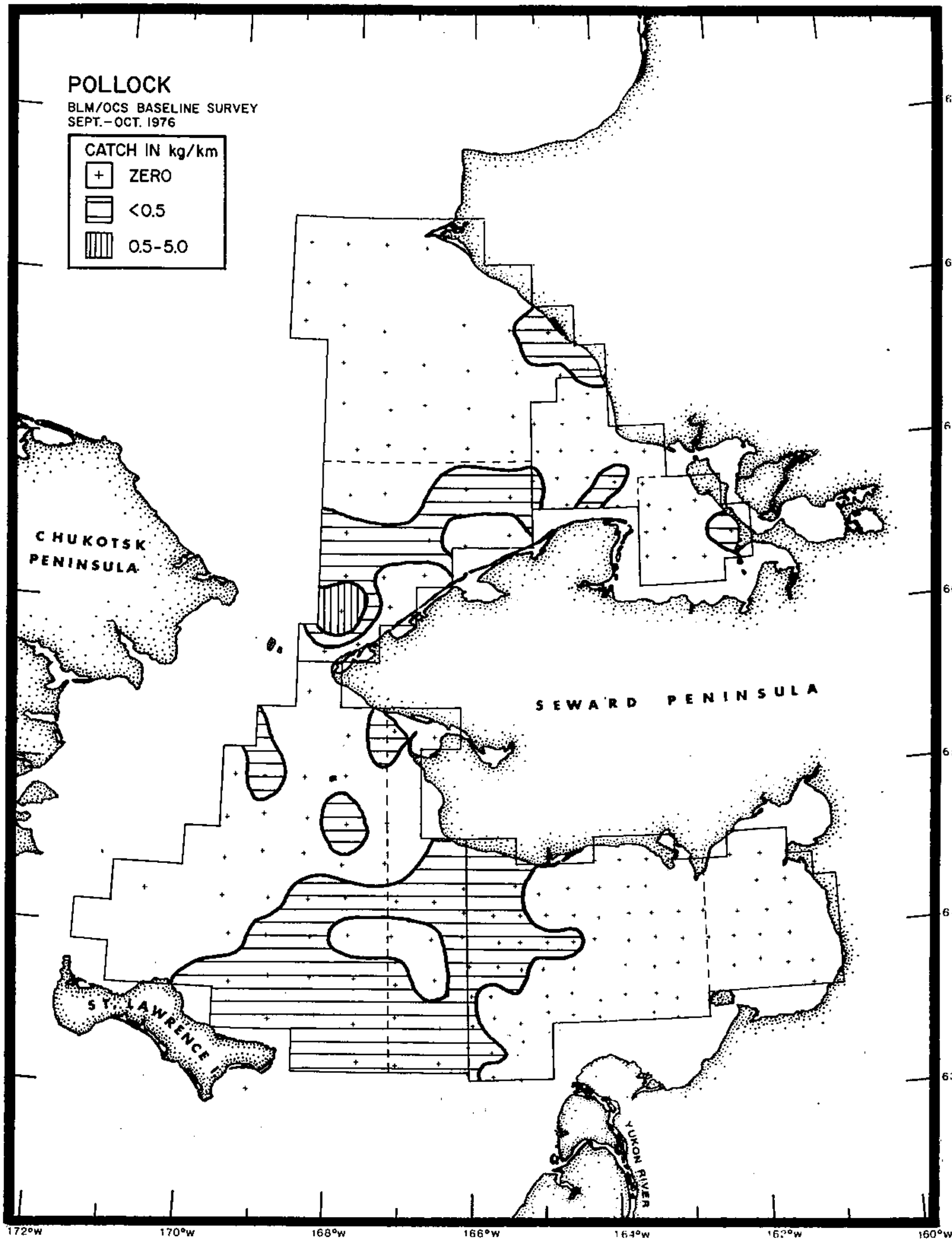


Figure VIII-89.--Distribution and relative abundance by weight of walleye pollock in Norton Sound, the southeastern Chukchi Sea and adjacent waters (BLM/OCS survey, 1976).

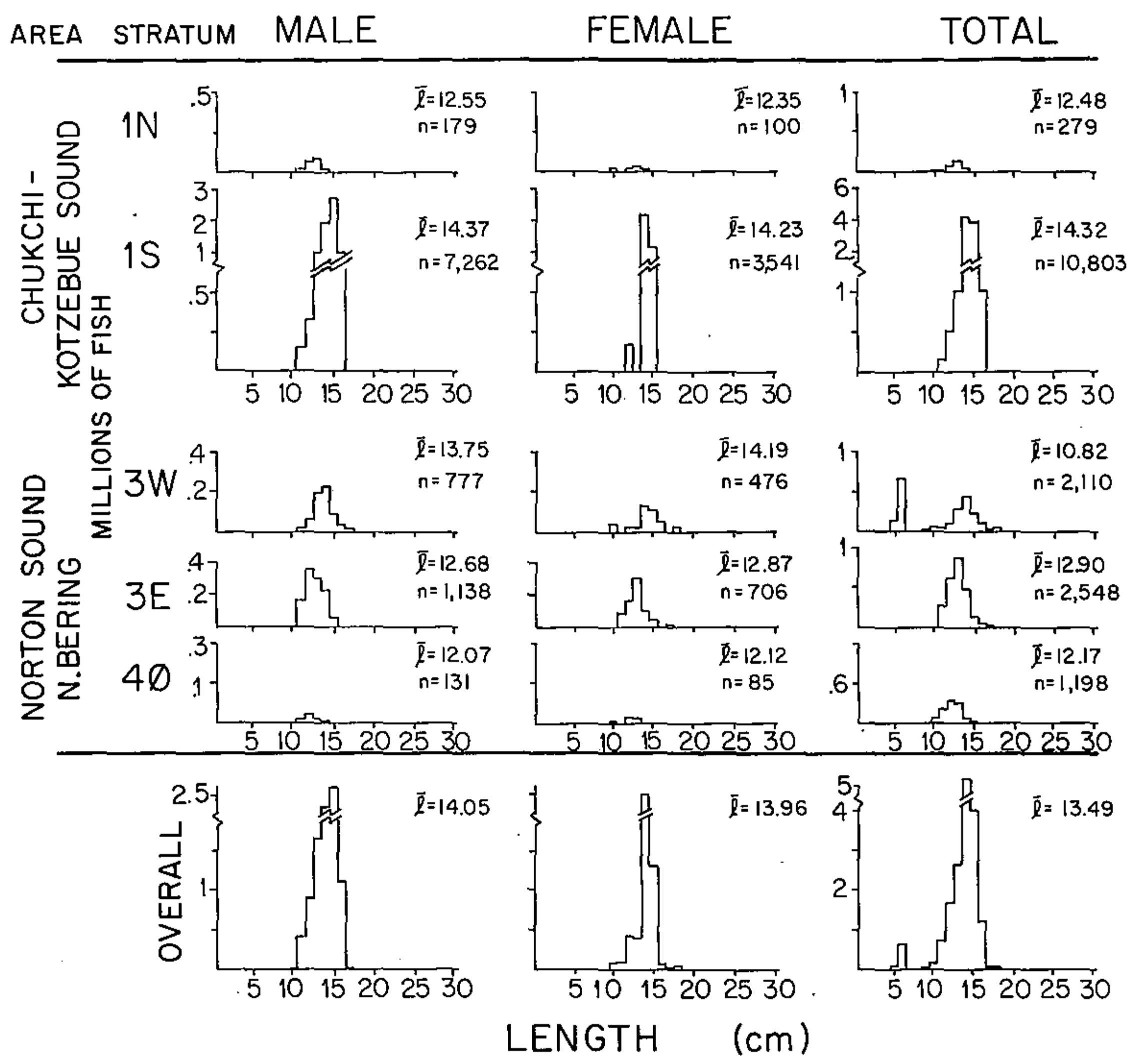


Figure VIII-90.--Size composition of walleye pollock by sex and stratum in Norton Sound, the southeastern Chukchi Sea and adjacent waters (BLM/OCS survey, 1976).

Bering flounder, longhead dab, Arctic flounder, and Pacific halibut were the other members of family Pleuronectidae encountered during the 1976 baseline survey. Bering flounder were found in trace amounts throughout much of the survey region (Figure VIII-91) but were absent from Norton Sound (strata 4Ø and 4I) and inner Kotzebue Sound (stratum 2I). Total apparent biomass for this flatfish species was 232 mt (95% confidence interval 150-315 mt) for the entire survey region (Table VIII-54) and nearly 75% of this amount was found in stratum 1N in the southeastern Chukchi Sea. For the limited samples obtained, size distribution ranged from 8 to 25 cm (Figure VIII-92) and predominant ages were 5 year olds for males and 5 and 9 year olds for females (Figure VIII-93).

Table VIII-54.--Estimated biomass and population size of Bering flounder in Norton Sound, the southeastern Chukchi Sea, and adjacent waters (BLM/OCS survey, 1976).

Stratum	Percent frequency of occurrence	Mean CPUE (kg/km)1/	Estimated biomass (mt)	Proportion of total estimated biomass	Estimated population (x 10^3)	Proportion of total estimated population	Mean size per individual weight (kg)	length (cm)
Southeastern Chukchi Sea and Kotzebue Sound								
1N	79.3	0.102	173	.744	2,077	.741	.083	17.23
1S	46.7	0.014	11	.048	193	.069	—	19.97
2Ø	57.9	0.058	25	.108	307	.109	.082	17.85
2I	—	—	—	—	—	—	—	—
Norton Sound and northern Bering Sea								
3W	25.0	0.010	22	.094	198	.071	.110	—
3E	14.3	0.002	1	.006	29	.010	—	—
4Ø	—	—	—	—	—	—	—	—
4I	—	—	—	—	—	—	—	—
All strata combined:	26.6 2/	0.028	232 3/		2,803		.083	17.51

1/ Mean catch per unit effort, kg/km trawled.
2/ Percent occurrence in 192 successful hauls.
3/ 95% confidence interval: 150-315 mt.

Longhead dab was found in most shallow water areas of the survey region with slightly higher concentrations occurring in outer Norton Sound (Figure VIII-94). Estimated biomass of longhead dab in the survey region was 172 mt (95% confidence interval 63-282 mt) with 60% of this amount occurring in stratum 4Ø (Table VIII-55).

Arctic flounder had a very limited distribution, occurring in very shallow waters of the survey region off the Yukon River, in Norton Bay, Port Clarence, and in Kotzebue Sound (Figure VIII-95). The total apparent biomass for this species was only 69 mt (95% confidence interval 21-118 mt) with nearly 83% of this amount found in stratum 4Ø (Table VIII-56).

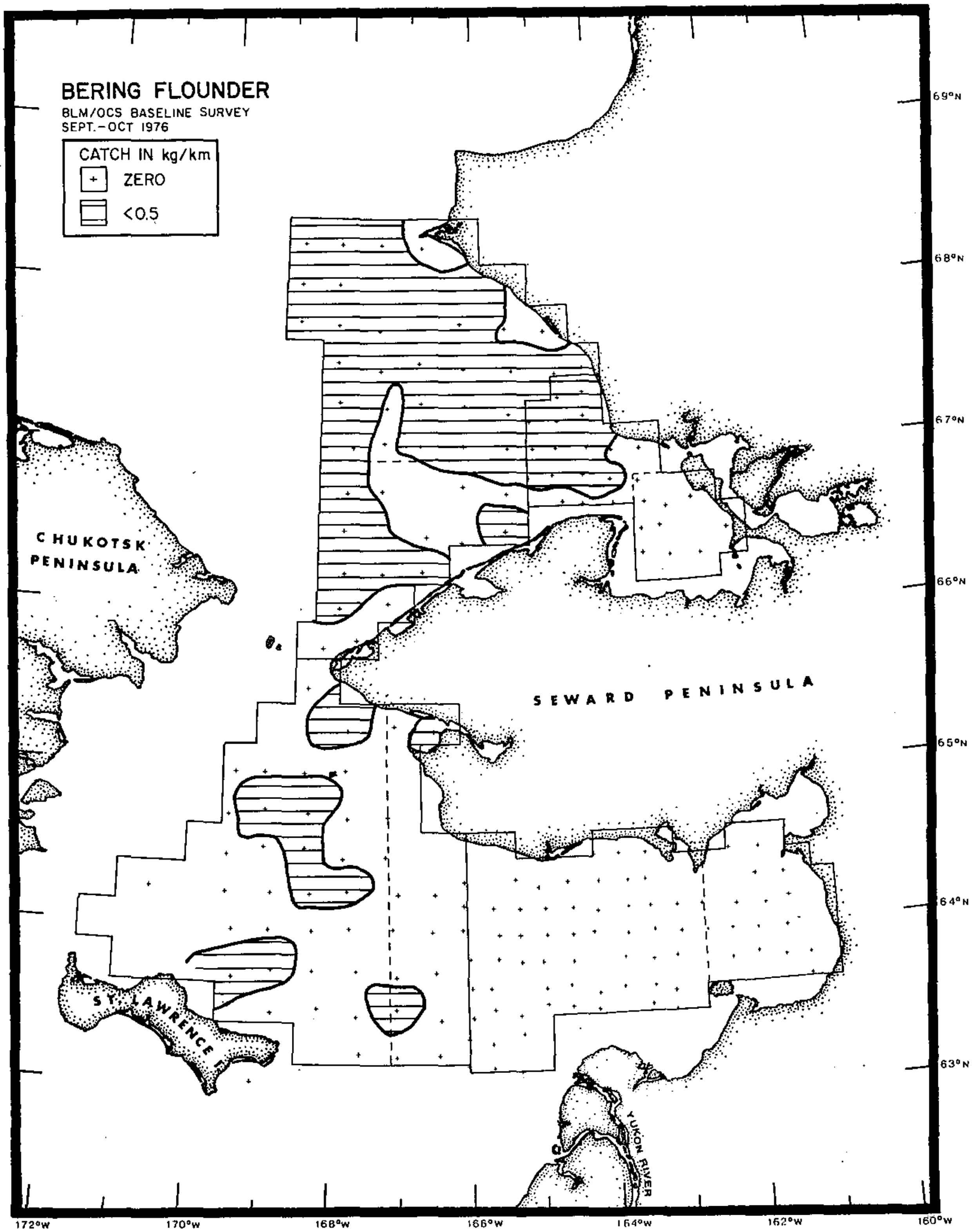


Figure VIII-91.--Distribution and relative abundance by weight of Bering flounder in Norton Sound, the southeastern Chukchi Sea and adjacent waters (BLM/OCS survey, 1976).

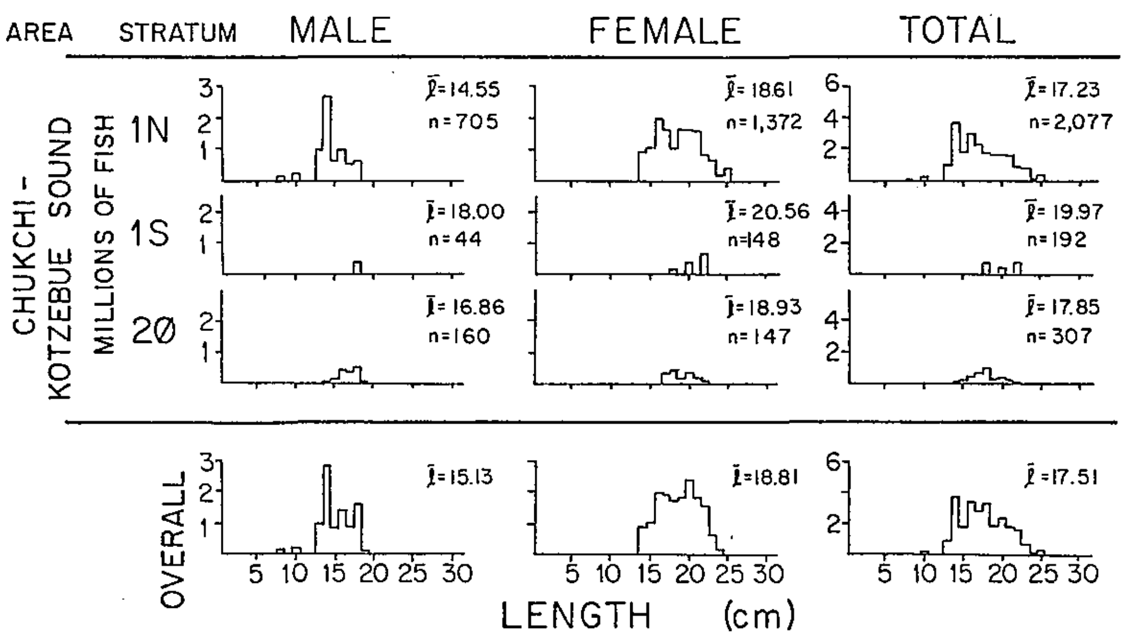


Figure VIII-92.--Size composition of Bering flounder by sex and stratum in Norton Sound, the southeastern Chukchi Sea and adjacent waters (BLM/OCS survey, 1976).

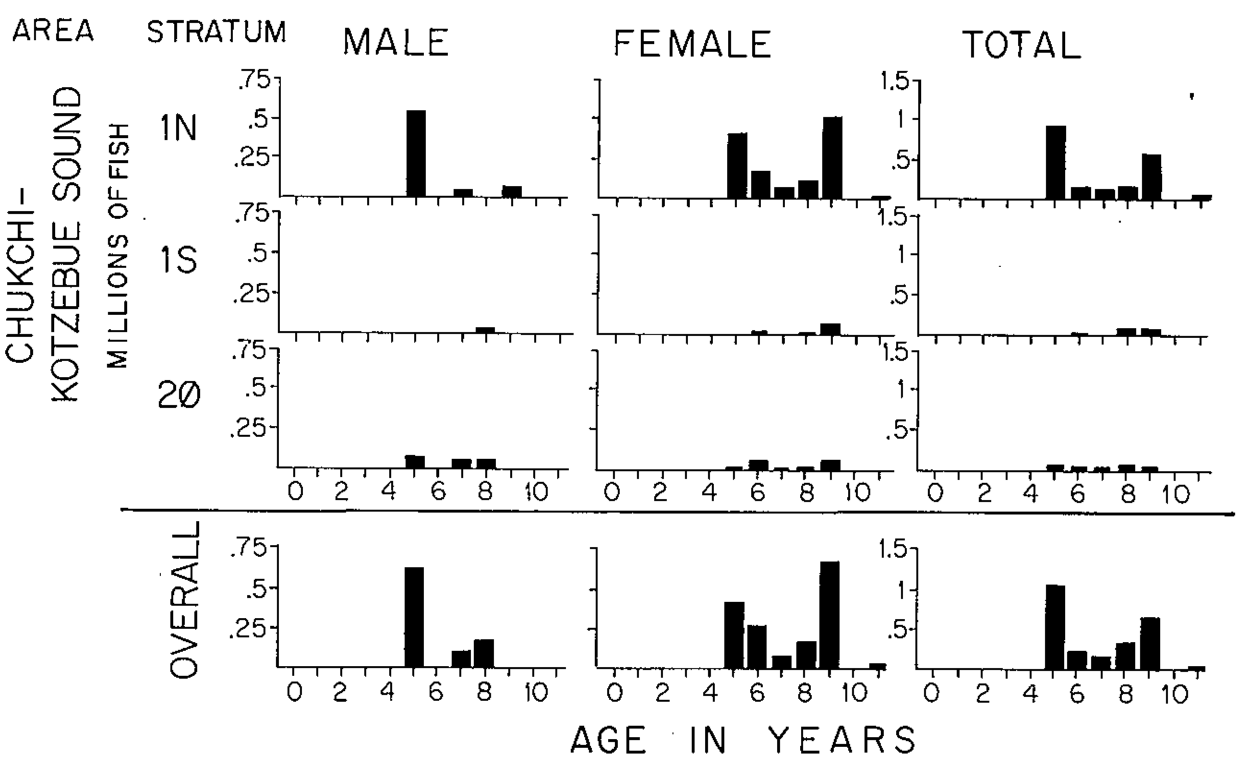


Figure VIII-93.--Age composition of Bering flounder by sex and stratum in Norton Sound, the southeastern chukchi Sea and adjacent waters (BLM/OCS survey, 1976).

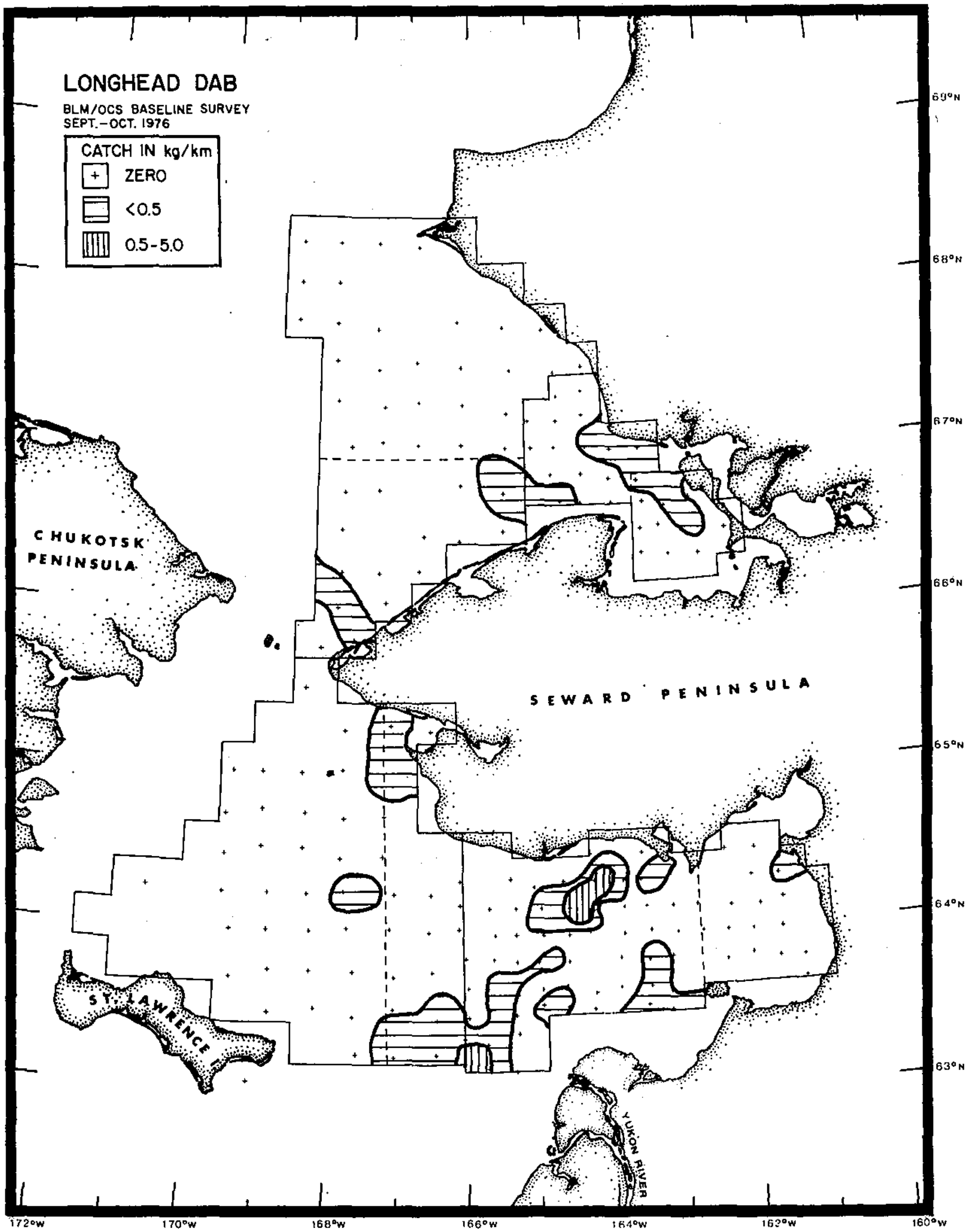


Figure VIII-94.--Distribution and relative abundance by weight of longhead dab in Norton Sound, the southeastern Chukchi Sea and adjacent waters (BLM/OCS survey, 1976).

Table VIII-55.--Estimated biomass and population size of longhead dab in Norton Sound, the southeastern Chukchi Sea, and adjacent waters (BLM/OCS survey, 1976).

Stratum	Percent frequency of occurrence	Mean CPUE (kg/km)1/	Estimated biomass (mt)	Proportion of total estimated biomass	Estimated population (x 10^3)	Proportion of total estimated population	Mean size per individual weight (kg)	Mean size per individual length (cm)
Southeastern Chukchi Sea and Kotzebue Sound								
1N	—	—	—	—	—	—	—	—
1S	20.0	.011	8	.049	220	.065	.039	—
2Ø	26.3	.024	10	.061	176	.052	.060	—
2I	12.5	.013	4	.023	29	.009	.136	—
Norton Sound and northern Bering Sea								
3W	3.1	t	2	.010	19	.006	.091	—
3E	28.6	.072	44	.257	900	.267	.049	16.49
4Ø	27.6	.077	103	.598	2,012	.598	.051	16.30
4I	5.9	t	t	.002	8	.003	.045	—
All strata combined:	16.1 2/	.021	172 3/		3,364		.051	16.21

1/ Mean catch per unit effort, kg/km trawled.
2/ Percent occurrence in 192 successful hauls.
3/ 95% confidence interval: 63-282 mt.

Table VIII-56.--Estimated biomass and population size of Arctic flounder in Norton Sound, the southeastern Chukchi Sea, and adjacent waters (BLM/OCS survey, 1976).

Stratum	Percent frequency of occurrence	Mean CPUE (kg/km)1/	Estimated biomass (mt)	Proportion of total estimated biomass	Estimated population (x 10^3)	Proportion of total estimated population	Mean size per individual weight (kg)	Mean size per individual length (cm)
Southeastern Chukchi Sea and Kotzebue Sound								
1N	3.4	t	1	.012	19	.022	—	—
1S	13.3	.001	1	.017	27	.032	—	—
2Ø	5.3	.002	1	.017	39	.047	.030	13.17
2I	25.0	.011	4	.052	325	.394	.011	10.30
Norton Sound and northern Bering Sea								
3W	—	—	—	—	—	—	—	—
3E	7.1	t	1	.009	13	.016	—	—
4Ø	19.0	.043	57	.827	370	.448	.155	20.83
4I	11.8	.001	5	.066	34	.041	—	—
All strata combined:	10.4 2/	.008	69 3/		826		.095	16.78

1/ Mean catch per unit effort, kg/km trawled.
2/ Percent occurrence in 192 successful hauls.
3/ 95% confidence interval: 21-118 mt.

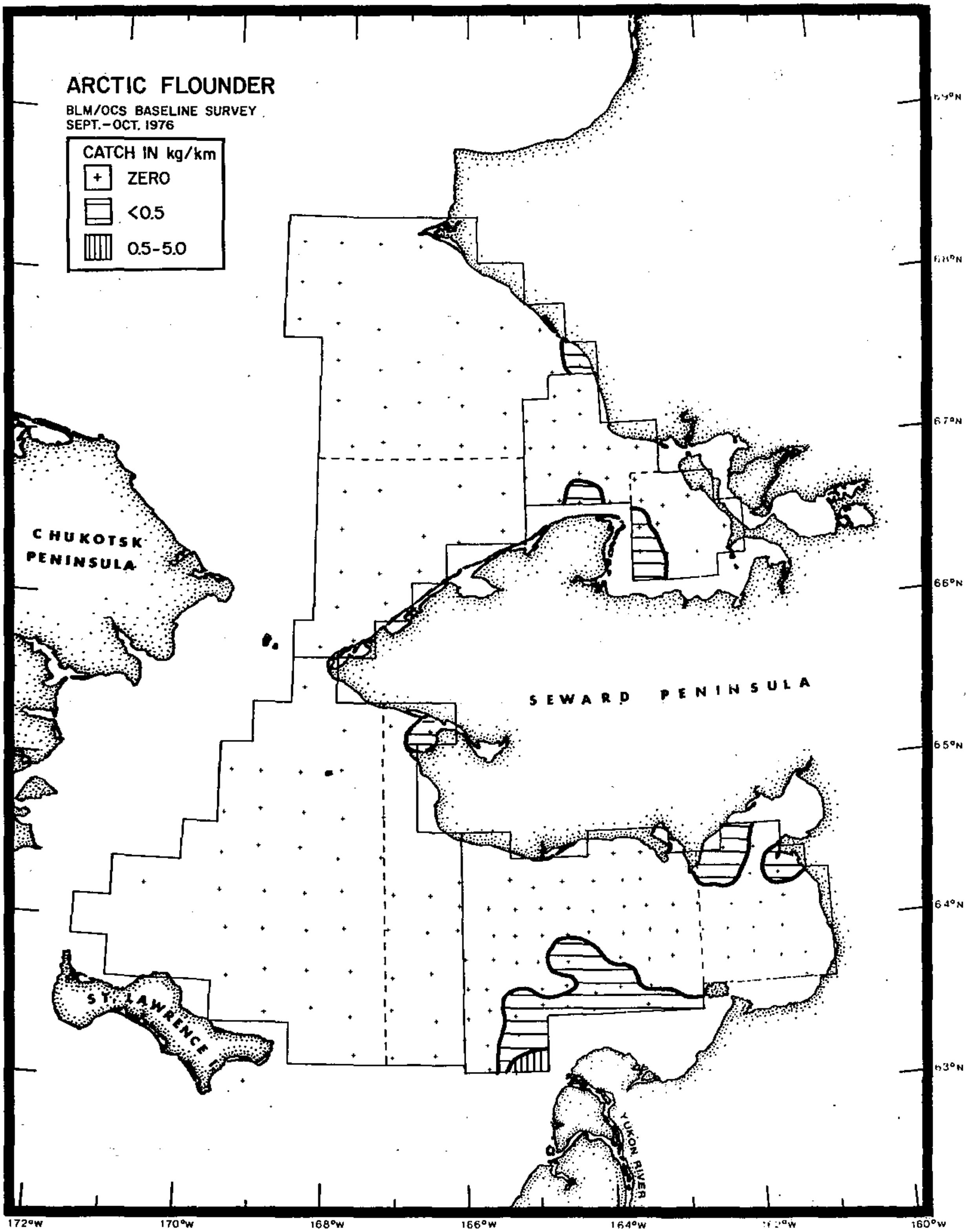


Figure VIII-95.--Distribution and relative abundance by weight of Arctic flounder in Norton Sound, the southeastern Chukchi Sea and adjacent waters (BLM/OCS survey, 1976).

Two Pacific halibut were captured during the survey, one in Norton Sound and the other at the northern end of Bering Strait. The specimen caught in Bering Strait was a 150 cm female and is the northernmost record for distribution of this species.

Capelin was thought to be very abundant in our survey region, but only trace amounts were encountered, mostly in offshore and deeper waters (Figure VIII-96). Total estimated biomass for this species was 190 mt (95% confidence interval 99-281 mt) with over 52% of this amount occurring in offshore stratum 3W and an additional 34% in stratum 1N in the southeastern Chukchi Sea (Table VIII-57). Sizes encountered ranged from 6 to 21 cm (Figure VIII-97). Capelin larger than 17 cm occurred only in stratum 3W.

Table VIII-57.--Estimated biomass and population size of capelin in Norton Sound, the southeastern Chukchi Sea, and adjacent waters (BLM/OCS survey, 1976).

Stratum	Percent frequency of occurrence	Mean CPUE (kg/km)1/	Estimated biomass (mt)	Proportion of total estimated biomass	Estimated population (x 10^3)	Proportion of total estimated population	Mean size per individual weight (kg)	Mean size per individual length (cm)
Southeastern Chukchi Sea and Kotzebue Sound								
1N	34.5	0.037	64	.337	3,206	.189	.020	13.78
1S	46.7	0.017	13	.071	706	.042	.019	17.96
2Ø	15.8	0.008	4	.020	344	.020	.011	10.89
2I	—	—	—	—	—	—	—	—
Norton Sound and northern Bering Sea								
3W	56.3	0.045	99	.521	11,168	.659	.009	11.36
3E	28.6	0.011	7	.039	1,490	.088	.005	9.03
4Ø	8.6	0.001	2	.013	41	.002	—	—
4I	—	—	—	—	—	—	—	—
All strata combined:	24.5 2/	0.023	190 3/		16,955		.011	11.88

1/ Mean catch per unit effort, kg/km trawled.
2/ Percent occurrence in 192 successful hauls.
3/ 95% confidence interval: 99-281 mt.

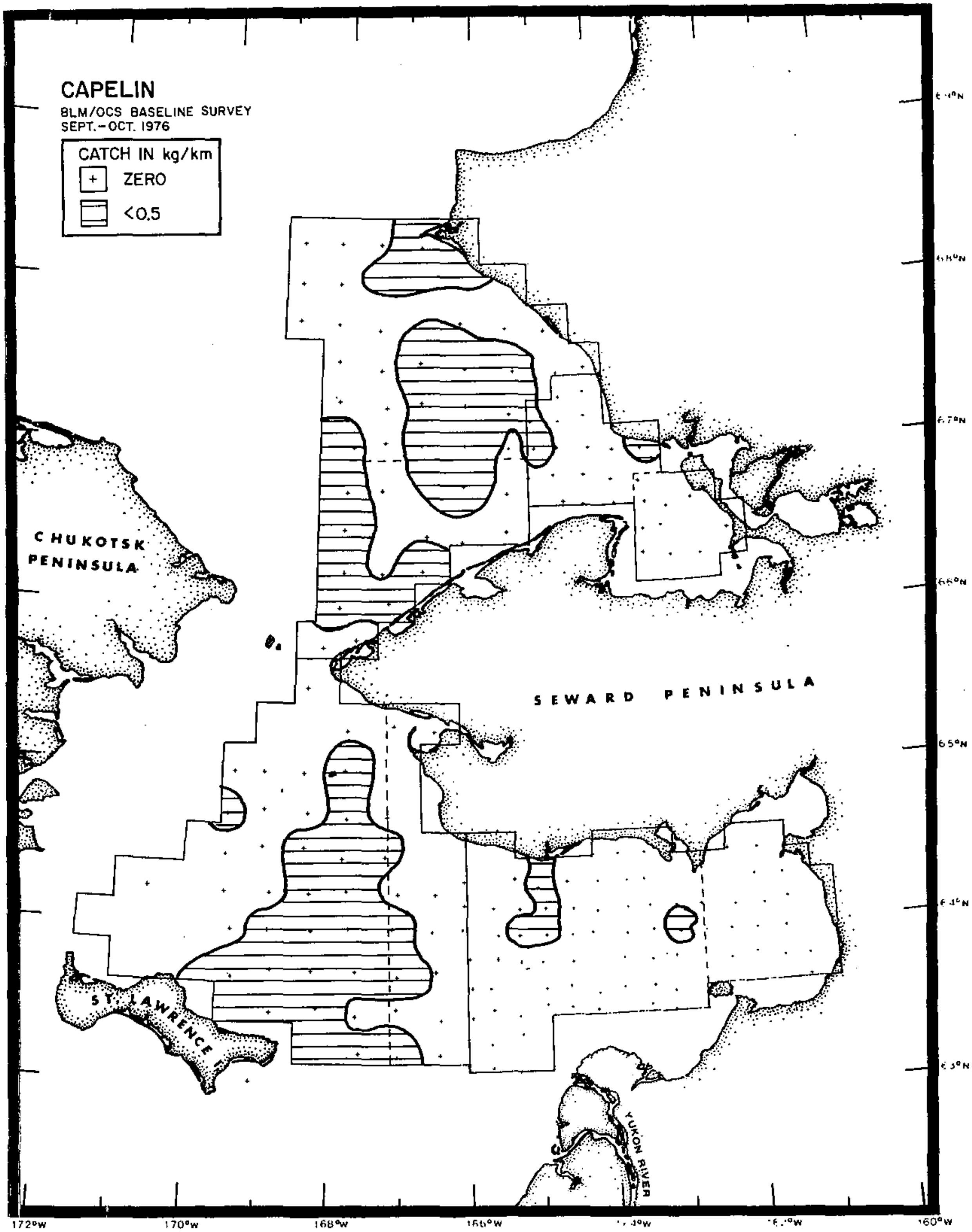


Figure VIII-96.--Distribution and relative abundance by weight of capelin in Norton Sound, the southeastern Chukchi Sea and adjacent waters (BLM/OCS survey, 1976).

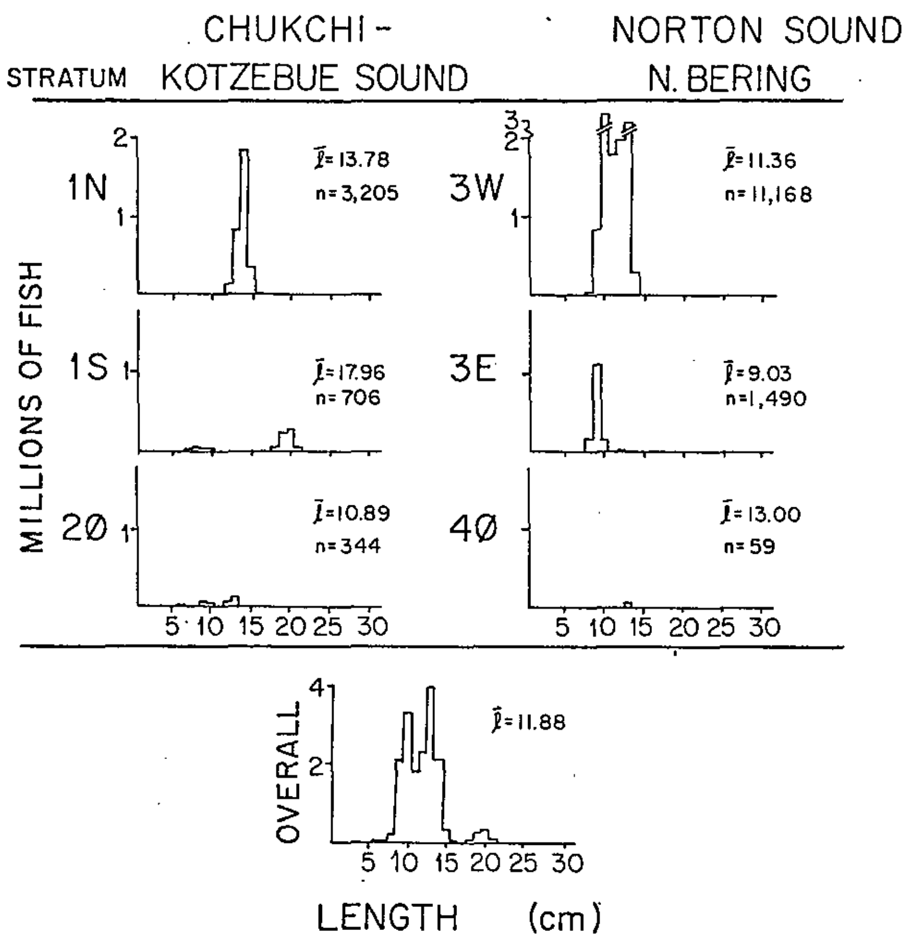


Figure VIII-97.--Size composition of capelin by sex and stratum in Norton Sound, the southeastern Chukchi Sea and adjacent waters (BLM/OCS survey, 1976).

Distribution, Abundance, and Biological Features of Principal Species of Crabs

In this section the distribution, abundance, and size composition of king crab and Tanner crab are presented from results of the 1976 baseline survey. In addition, shell age composition and egg clutch size are examined to provide some baseline information on crab growth and to identify the relative size of mature or maturing females.

Shell age is an important index of crab growth since it reflects the frequency of molting which, taken with the increase in size per molt, determines the absolute rate of growth for individual crabs. An examination of a time series of data on shell age composition is necessary to establish any trends in growth of crabs. The baseline survey data provide only one interval in a time series and thus cannot describe crab growth by itself. The baseline data, however, do provide a set of information to which future data may be compared.

Red king crab

Distribution and abundance--Red king crab were found at only 34% of the trawl stations sampled, but were concentrated in Norton Sound (Figures VIII-98 and 99) where their frequency of occurrence exceeded 76% (Table VIII-58). Outer Norton Sound (stratum 4Ø) had the highest average catch rate of all strata, averaging 2.3 kg/km. Mean catch rate decreased to 0.6 kg/km in inner Norton Sound (stratum 4I) and further dropped to only trace levels in the eastern part of the northern Bering Sea (stratum 3E) and in the vicinity of outer Kotzebue Sound (strata 1S and 2Ø). Red king crab were not found at any of the stations in the western portion of the northern Bering Sea (stratum 3W) or in the southeastern Chukchi Sea (stratum 1N) where deeper and colder waters occurred.

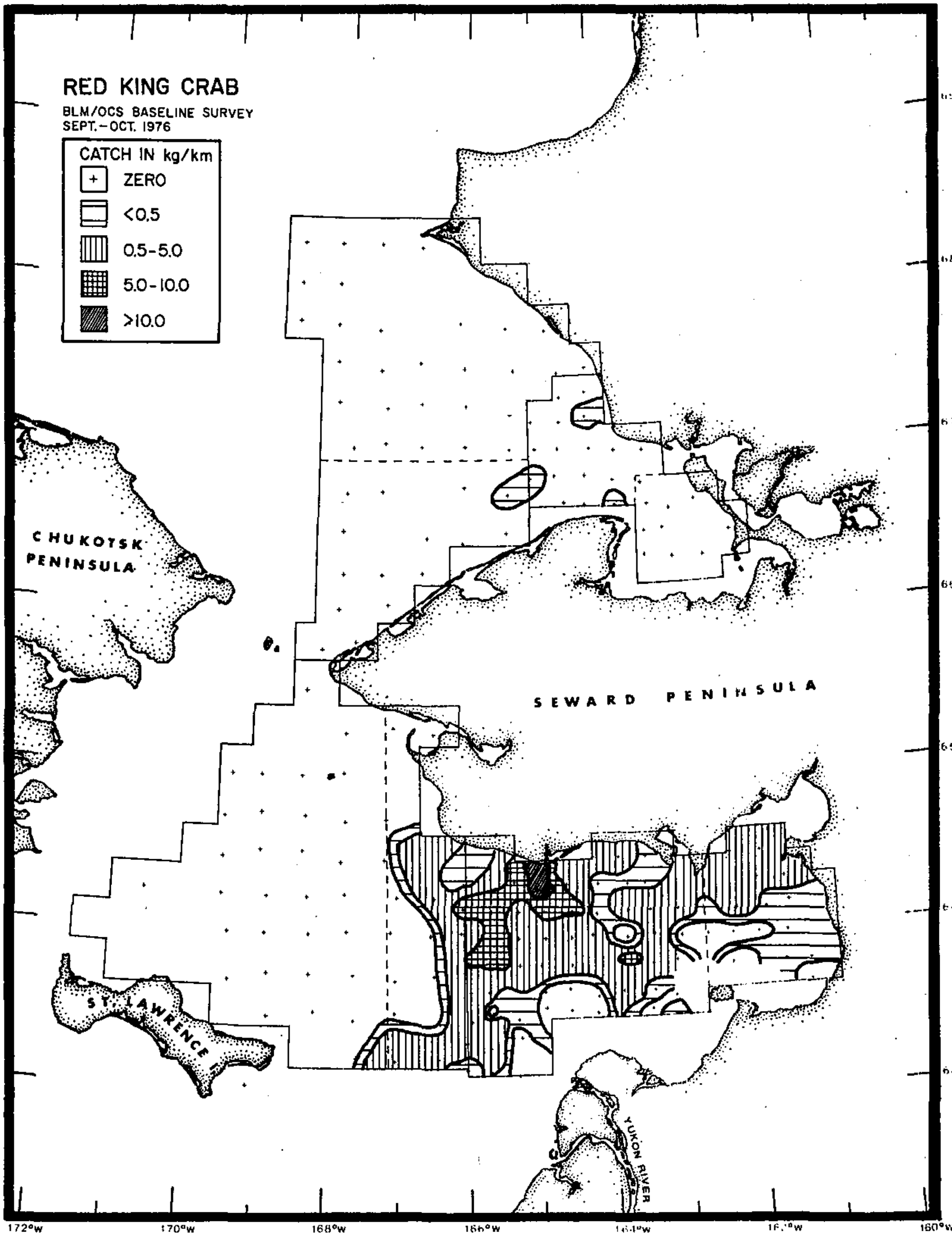


Figure VIII-98.--Distribution and relative abundance by weight of red king crab in Norton Sound, the southeastern Chukchi Sea and adjacent waters (BLM/OCS survey, 1976).

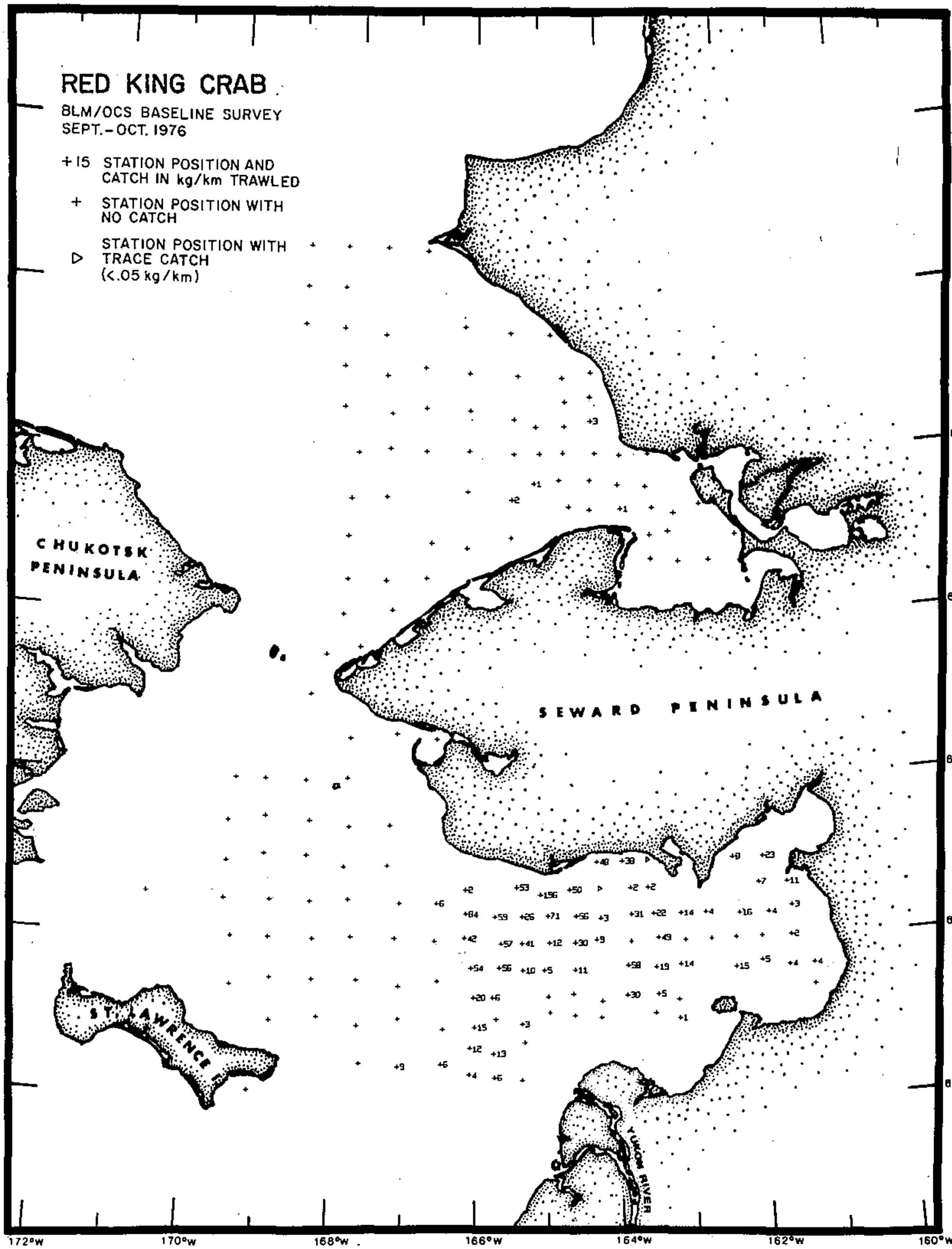


Figure VIII-99.--Distribution of catch rates by weight of red king crab in Norton Sound, the southeastern Chukchi Sea, and adjacent waters (BLM/OCS survey, 1976).

Table VIII-58.--Estimated biomass and population size of red king crab in Norton Sound, the southeastern Chukchi Sea, and adjacent waters (BLM/OCS survey, 1976).

Strata	Percent frequency of occurrence	Mean CPUE (kg/km)1/	Estimated biomass (mt)	Proportion of total estimated biomass	Estimated population (X10³)	Proportion of total estimated population	Mean weight per individual (kg)
Southeastern Chukchi Sea and Kotzebue Sound							
1N	-	-	-	-	-	-	-
1S	6.7	0.011	9	.003	19	.004	.454
2Ø	15.8	0.025	11	.003	21	.004	.506
2I	-	-	-	-	-	-	-
Norton Sound and Northern Bering Sea							
3W	-	-	-	-	-	-	-
3E	21.4	0.152	93	.027	112	.022	.836
4Ø	77.6	2.311	3,077	.874	4,291	.858	.718
4I	76.5	0.619	329	.094	557	.111	.591
All strata combined:	33.9 2/	0.420	3,519 3/		5,000 3/		.707

1/ Mean catch per unit effort, kg/km trawled.
2/ Percent occurrence in 192 successful hauls.
3/ 95% confidence interval: biomass--2,369 - 4,670 mt; population--3,245,000 - 6,756,000.

The apparent red king crab biomass for the entire survey area was estimated at over 3,500 mt (95% confidence interval 2,369-4,670 mt). Several catches of this species occurred at stations along the southern border of the survey area indicating a likely presence of red king crab south of the survey region. It is unknown to what degree crab south of the survey limit might interact with stocks within the survey region. The highest concentrations of red king crab encountered, however, were well within the survey boundaries and our estimate should be quite good for the survey region. For the population sampled, the major portion of the biomass (approximately 87%) was located in outer Norton Sound in stratum 4Ø, and much of this amount was found near the community of Nome. Of the remaining biomass, nearly 10% of the total was located in stratum 4I and 3% in stratum 3E.

The relative distribution of the estimated number of red king crab was very similar to apparent biomass. Strata 4Ø and 4I accounted for nearly

97% of the total population estimate of 5 million crabs (95% confidence interval 3.2-6.8 million crabs).[1/]

Size composition--Size composition data for red king crab by sex and stratum are presented in Figure VIII-100. Sizes ranged from 15 to 165 mm carapace length and females exhibited a smaller size range (15-100 mm) than males (15-165 mm). Only one mode in size composition was observed per sex at about 105-110 mm for males and 75-80 mm for females.

Population estimates by size groups, strata, and sexes are presented in Table VIII-59. Intermediate sized males (100-125 mm) were the most abundant group in most regions where red king crabs were found. They represented over 69% of the estimated male population and 60% of the overall apparent population. Large females (> 70 mm) comprised 85% of the estimated female population (11% of total numbers estimated). No females were observed north of Bering Strait, and for males present in this region, no large crabs (> 125mm) were encountered. Overall, males comprised the vast majority of the estimated population, outnumbering females by a factor of nearly 7.5 to 1.

Mean size for male red king crab was larger than for females in all strata (Figure VIII-100). Average size of males varied only slightly by stratum with males in stratum 4I having the smallest mean size. Differences in female mean size by stratum were slightly greater with smallest average size occurring in stratum 3E, increasing in stratum 4Ø, and largest in stratum 4I.

1/ Another population estimate for red king crab was determined by the computer program SIZEPOP to obtain population estimates by size and sex for size composition analysis. Program SIZEPOP utilized the 192 standard survey trawl hauls as well as the 44 trawl hauls performed during the day-night catch comparisons. For this population estimate, an estimated station population was obtained by analyzing catch rates for all trawl hauls at a station. This means that at five stations both a standard survey tow and several other trawl hauls were examined. The total red king crab population estimate obtained through this procedure was about 9.8 million crabs (95% confidence interval 4.8-14.8 million crabs), substantially higher than the estimate determined solely from the standard survey tows. The marked difference between the two population estimates was the result of catches at one station in stratum 4Ø. At this station, the standard survey tow produced a catch rate (in numbers) of 6.7 crabs/km. Catch rates for the eight day-night comparative tows at this station (fished about 1 month after the standard survey tow) ranged from 10.2 to 86.4 crabs/km. When both the standard tow and comparative tows were combined, the overall station catch rate had jumped to 30.5 crabs/km or 4.5 times that obtained solely from the standard tow. Since these catches were the largest encountered during the entire survey and because nearly all of the survey's red king crab population occurred in stratum 4Ø, the catch rate for this one station had a dramatic effect on the total population estimate. Differences between standard and comparative tow catch rates were substantially less for all other stations where both types of trawl hauls occurred. Additionally, major differences between standard survey/comparative tow catch rates did not occur for other fish and crab species examined.

Table VIII-59.--Estimated population ($x10^3$) of red king crab by stratum, sex and size groups[1/] in Norton Sound, the southeastern Chukchi Sea, and adjacent waters (BLM/OCS survey, 1976).

	MALES				FEMALES			
Stratum	<100mm	100-125mm	>125mm	All sizes	<70mm	≥70mm	All sizes	Sexes combined
Southeastern Chukchi Sea and Kotzebue Sound								
1N	--	--	--	--	--	--	--	--
1S	4.4	15.0	--	19.4	--	--	--	19.4
2Ø	4.7	16.4	--	21.1	--	--	--	21.1
2I	--	--	--	--	--	--	--	--
Norton Sound and northern Bering Sea								
3W	--	--	--	--	--	--	--	--
3E	28.1	62.5	7.4	98.0	7.0	7.0	14.0	112.0
4Ø	1,035.8	2,715.4	127.7	3878.9	79.2	333.0	412.2	4,291.1
4I	107.3	198.3	8.5	314.1	8.5	234.7	243.2	557.3

1/ Carapace length (mm).

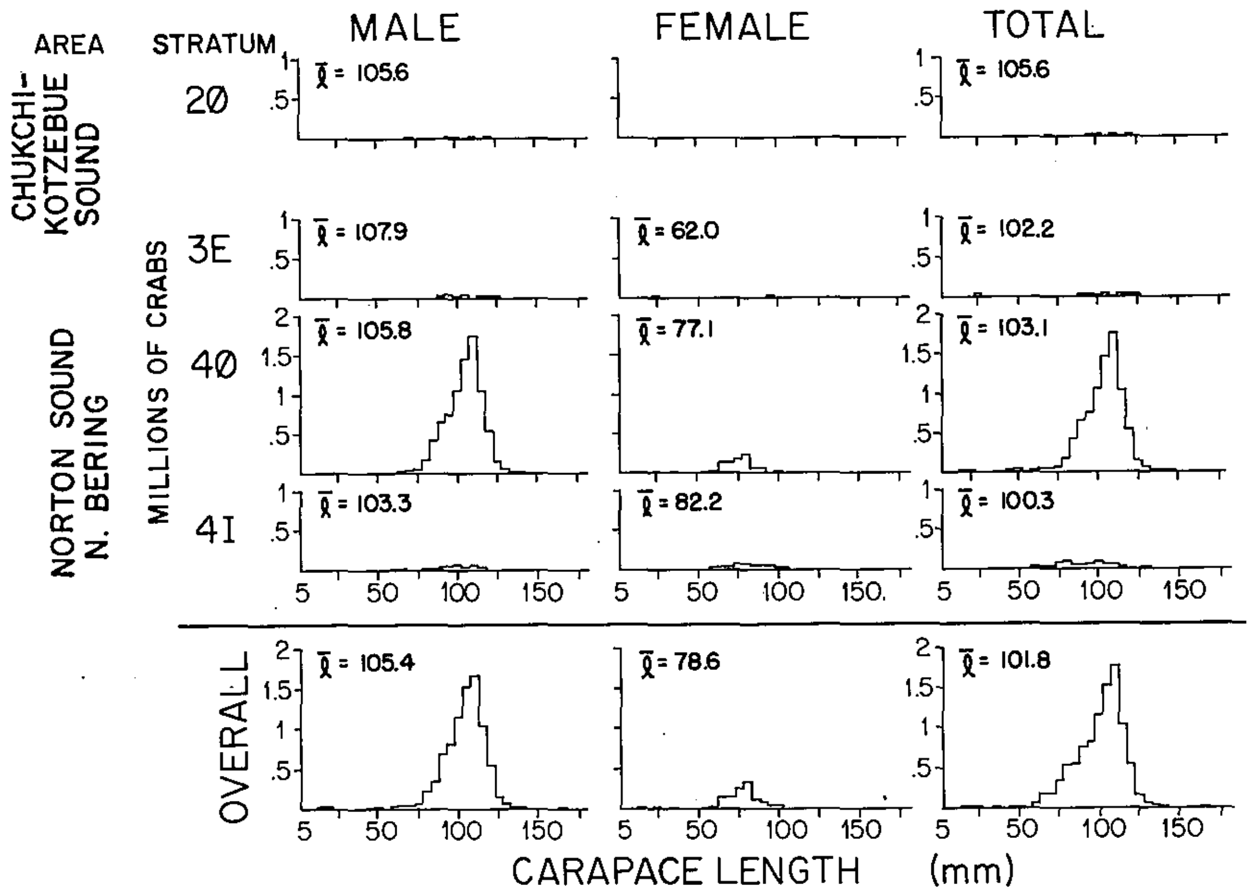


Figure VIII-100.--Size composition of red king crab by sex and stratum in Norton Sound, the southeastern Chukchi Sea and adjacent waters (BLM/OCS survey, 1976).

Shell condition--Shell age composition by region and sex for red king crab and other crab species is presented in Table VIII-60. In the southeastern Chukchi Sea and Kotzebue Sound, all red king crab encountered were new-shell crabs. In the northern Bering Sea and Norton Sound, new-shell crabs still were predominant but relatively large proportions of both sexes were old-shell crabs, indicating one or more skip molts. Overall, new-shell crabs accounted for 67% of the total estimated male population and over 75% of the female red king crabs while old-shell crab comprised 26% and 15% of the population of males and females, respectively.

Egg clutch size--Size of egg clutch and the proportion of females with eggs by length groups is shown in Table VIII-61. The smallest carapace length with egg clutches present were 60-64 mm. Several barren females (no egg clutch) were present in the sample at sizes up to 70-74 mm; however, from these limited data, in general it appeared that 70 mm was the approximate minimum size at which over half the female red king crab of the survey area were gravid.

Table VIII-60.--Shell age composition for king and Tanner crab (percent by sex) by subareas and total survey area for Norton Sound, the southeastern Chukchi Sea and adjacent waters (BLM/OCS survey, 1976).

	Southeastern Chukchi Sea (strata 1N and 1S)	Kotzebue Sound (strata 2Ø and 2I)	Northern Bering Sea (strata 3W and 3E)	Norton Sound (strata 4Ø and 4I)	Percent overall
Red king crab					
Males					
Molting	--	--	--	0.2	0.1
Soft	--	--	25.0	6.5	6.5
New	100.0	100.0	75.0	65.8	66.8
Old	--	--	--	27.6	26.5
Females					
Molting	--	--	--	--	--
Soft		--	--	0.7	9.3
New	100	--	100.0	83.1	76.2
Old	--	--	--	16.2	14.6
Blue king crab					
Males					
Molting	--	--	--	--	--
Soft	--	--	7.0	--	7.0
New	--	--	86.0	--	86.0
Old	--	--	7.0	--	7.0
Females					
Molting	--	--	--	--	--
Soft	--	--	3.9	--	3.9
New	--	--	90.8	--	90.8
Old	--	--	5.3	--	5.3
Tanner crab (Opilio)					
Males					
Molting	--	--	--	--	--
Soft	--	--	1.0	--	0.1
New	99.7	99.9	97.3	100.0	99.5
Old	0.3	0.1	1.7	--	0.4
Females					
Molting	--	--	--	--	--
Soft	--	0.1	1.2	--	0.1
New	99.3	99.9	98.1	100.0	99.5
Old	0.7	--	0.7	--	0.4

Table VIII-61.--Numbers of female red king crab by size of egg clutch and carapace length and poportion of gravid females by size group (BLM/OCS survey, 1976).

Carapace length (mm)	No eggs	Trace-1/8 full	1/4 full	1/2 full	3/4 full	full	Proportion with eggs
15-54	2	--	--	--	--	--	--
55-59	1	--	--	--	--	--	--
60-64	2	--	--	--	1	1	0.50
65-69	6	--	--	4	1	3	0.57
70-74	4	--	--	4	3	2	0.69
75-79	1	--	--	9	8	13	0.97
80-84	1	--	4	7	8	14	0.97
85-89	2	1	--	3	4	4	0.86
90-94	--	--	--	2	5	7	1.00
95-99	--	--	--	--	--	1	1.00
100-104	--	--	--	--	1	1	1.00

Blue king crab

Distribution and abundance--Blue king crab occurred in only 12% of all stations sampled, having a highly localized distribution. They occurred in over 59% of the stations surveyed in northern Bering Sea waters in stratum 3W (Table VIII-62), where two concentrations occurred; one south of Bering Strait and the other southwest of Port Clarence (Figures VIII-101 and 102). Average catch rate for stratum 3W was by far the highest of all strata, averaging over 0.7 kg/km, while in the southeastern Chukchi Sea (strata 1N and 1S) and the eastern portion of the northern Bering Sea (stratum 3E), only trace amounts were encountered. Blue king crab were not found at any of the stations fished in Kotzebue Sound (strata 2Ø and 2I) and Norton Sound (strata 4Ø and 4I). The distribution of blue king crab appeared to be associated with areas where depths exceeded 25 m and bottom temperatures were less than 4°C.

Table VIII-62.--Estimated biomass and population size of blue king crab in Norton Sound, the southeastern Chukchi Sea, and adjacent waters (BLM/OCS survey, 1976).

Strata	Percent frequency of occurrence	Mean CPUE (kg/km)1/	Estimated biomass (mt)	Proportion of total estimated biomass	Estimated population (X10³)	Proportion of total estimated population	Mean weight per individual (kg)
Southeastern Chukchi Sea and Kotzebue Sound							
1N	3.4	0.011	19	.012	33	.009	.568
1S	6.7	0.057	43	.027	130	.036	.336
2Ø	--	--	--	--	--	--	--
2I	--	--	--	--	--	--	--
Norton Sound and Northern Bering Sea							
3W	59.4	0.702	1,529	.950	3,379	.943	.453
3E	14.3	0.028	18	.011	40	.011	.438
4Ø	--	--	--	--	--	--	--
4I	--	--	--	--	--	--	--
All strata combined:	12.0 2/	0.192	1,608 3/		3,582 3/		.449

1/ Mean catch per unit effort, kg/km trawled.
2/ Percent occurrence in 192 successful hauls.
3/ 95% confidence intervals: biomass--125 - 3,092 mt; population--401,000 - 6,762,000.

The apparent blue king crab biomass for the entire survey region was estimated at over 1,600 mt (95% confidence interval 125-3,092 mt). Since catches occurred along the western boundary of the survey area, it seems likely that blue king crab stocks extended westward across the US-USSR convention line toward the Chukotsk Peninsula. The extent of this westward distribution is unknown, but since only relatively low catch rates occurred along most of the survey's western boundary, our biomass estimate

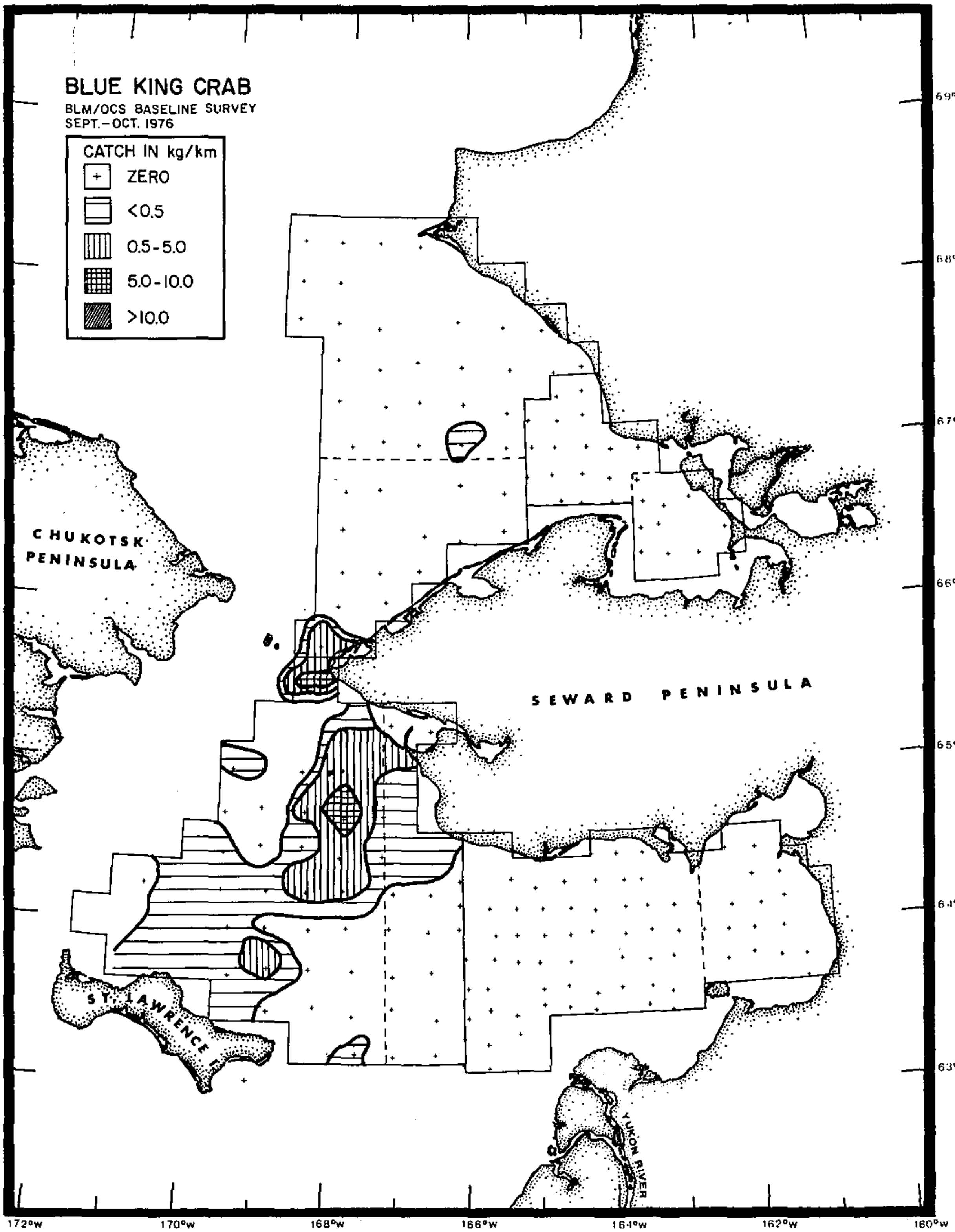


Figure VIII-101.--Distribution and relative abundance by weight of blue king crab in Norton Sound, the southeastern Chukchi Sea and adjacent waters (BLM/OCS survey, 1976).

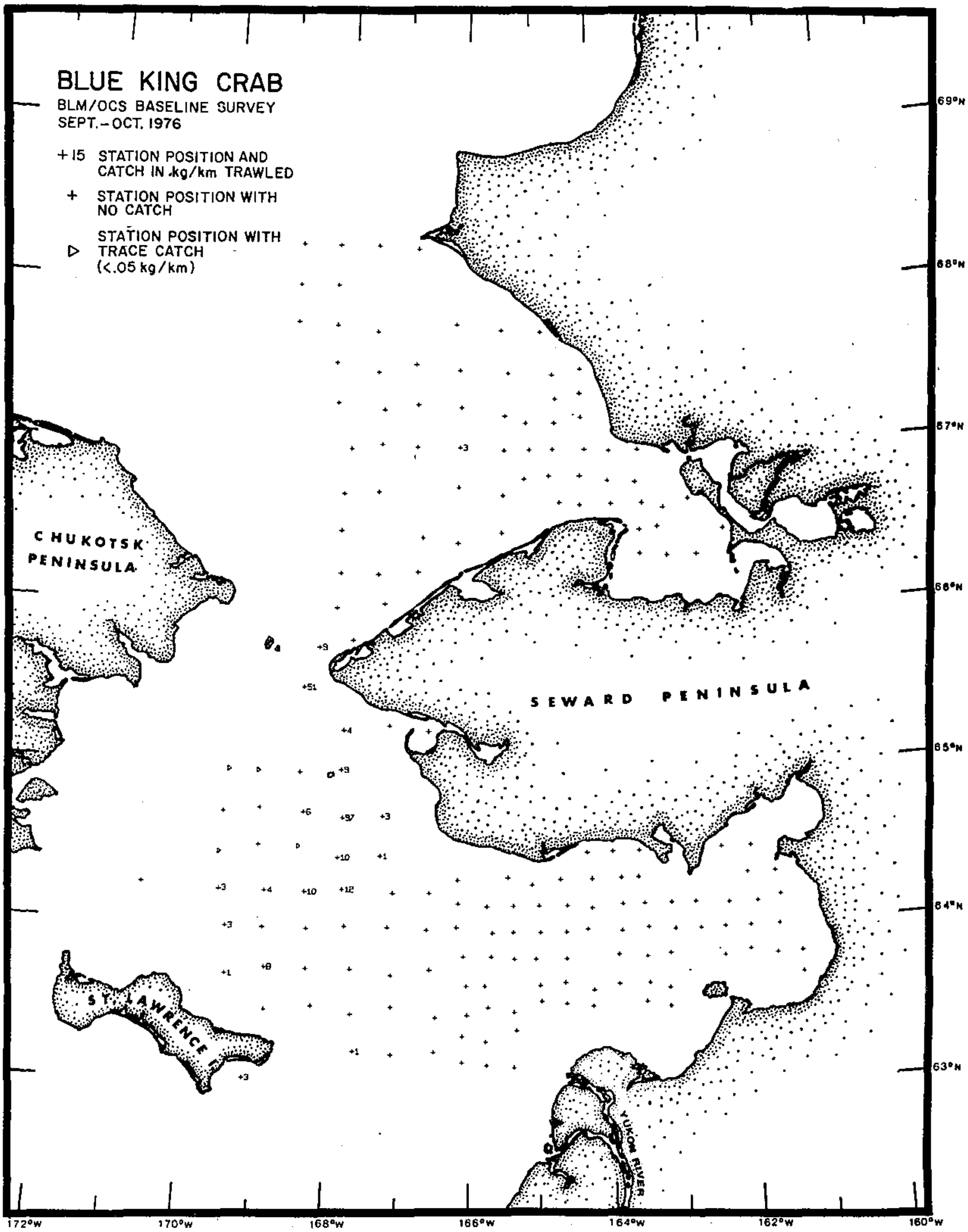


Figure VIII-102.--Distribution of catch rates by weight of blue king crab in Norton Sound the southeastern Chukchi Sea and adjacent waters (BLM/OCS survey, 1976).

for the survey region should be fairly good. For the population sampled, 95% of the estimated biomass was found in stratum 3W. Of the remaining portion, 3% was located in stratum 1S, all of which occurred near Bering Strait.

The distribution of the estimated number of blue king crab was nearly identical to apparent biomass. The total population estimate for the entire survey region was about 3.6 million crabs (95% confidence interval 401 thousand-6.8 million crabs).

Size composition--Size composition data for blue king crab by sex and stratum are shown in Figure VIII-103. Sizes ranged from 25 to 135 mm carapace length, with females displaying a smaller mean size than males, 72.8 mm and 85.6 mm, respectively. There appeared to be two modes for males at about 75 and 100 mm and only one major mode for females at about 75 mm.

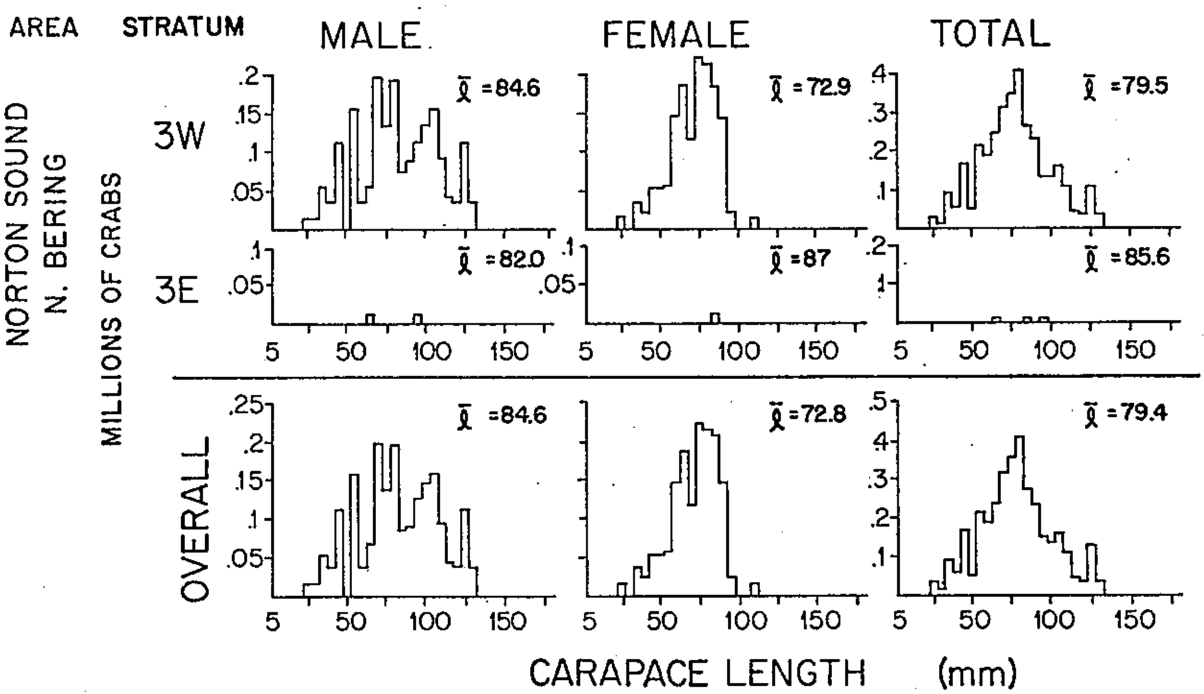
Population estimates by size groups, strata, and sexes are presented in Table VIII-63. Small-sized males (< 100 mm) comprised the majority of the estimated population, accounting for 68% of all males and 38% of the entire number estimate. Large females (> 70 mm) were the next most abundant size group, comprising 27% of the total estimated population while intermediate sized males (100-125 mm) and small females (< 70 mm) accounted for a further 14 and 15%, respectively. Small-sized males and large females were present in all strata where blue king crab occurred. Intermediate and large males were found only in stratum 3W. Overall, males were slightly more numerous than females and accounted for 56% of the total population estimate.

Table VIII-63.--Estimated population ($x10^3$) of blue king crab by stratum, sex and size groups[1/] in Norton Sound, the southeastern Chukchi Sea, and adjacent waters (BLM/OCS survey, 1976).

	MALES				FEMALES			
Stratum	<100mm	100-125mm	>125mm	All sizes	<70mm	≥70mm	All sizes	Sexes combined
Southeastern Chukchi Sea and Kotzebue Sound								
1N	16.6	--	--	16.6	--	16.6	16.6	33.2
1S	64.8	--	--	64.8	38.9	25.9	64.8	129.6
2∅	--	--	--	--	--	--	--	--
2I	--	--	--	--	--	--	--	--
Norton Sound and northern Bering Sea								
3W	1;261.4	487.7	154.5	1,903.6	554.5	920.7	1,475.2	3,378.8
3E	27.3	--	--	27.3	--	12.8	12.8	40.1
4∅	--	--	--	--	--	--	--	--
4I	--	--	--	--	--	--	--	--

1/ Carapace length (mm).

Figure VIII-103.--Size composition of blue king crab by sex and stratum in Norton Sound, the southeastern Chukchi Sea, and adjacent waters (BLM/OCS survey, 1976).



Shell condition--New-shell crabs constituted the major portion of both the male and female components of the blue king crab population (Table VIII-60), comprising 86 and 91%, respectively. No molting blue king crabs were observed.

Egg clutch size--Since few females were caught during the entire survey, information on blue king crab clutch size was quite limited. Of the 70 females examined, only 2 individuals in the 85-89 mm size group possessed egg clutches (Table VIII-64).

Table VIII-64.--Number of female blue king crab by size of egg clutch and carapace length and proportion of gravid females by size group (BLM/OCS survey, 1976).

Carapace length (mm)	No. eggs	Trace-1/8 full	1/4 Full	1/2 Full	3/4 Full	Full	Proportion with eggs
0-84	57	--	--	--	--	--	0.00
85-89	7	--	--	--	1	1	0.22
90-94	1	--	--	--	--	--	0.00
95-99	1	--	--	--	--	--	0.00
100-104	1	--	--	--	--	--	0.00
105-109	--	--	--	--	--	--	--
110-114	1	--	--	--	--	--	0.00

Tanner crab (C. opilio)

Distribution and abundance--Tanner crab was the most abundant crab species encountered, comprising 52% of the total biomass of commercially important crabs and occurring at over 67% of the stations sampled (Table VIII-65). The largest concentration of Tanner crab occurred in outer Kotzebue Sound (stratum 2Ø) (Figures VIII-104 and 105) where catch rates averaged 6.1 kg/km. Catch rates decreased to between 1.5 and 1.9 kg/km in the remaining strata north of Bering Strait (strata 1N, 1S, and 2I), and further dropped to 0.6 kg/km in the western portion of the northern Bering Sea (stratum 3W). In the remainder of the survey region, Tanner crab were caught only in trace amounts. The overall mean catch rate for the entire survey area was 1.1 kg/km trawled.

Table-65.--Estimated biomass and population size of Tanner crab (C. opilio) in Norton Sound, the southeastern Chukchi Sea, and adjacent waters (BLM/OCS survey, 1976).

Stratum	Percent frequency of occurrence	Mean CPUE (kg/km)1/	Estimated biomass (mt)	Proportion of total estimated biomass	Estimated population (x 10³)	Proportion of total estimated population	Mean weight per individual (kg)
Southeastern Chukchi Sea and Kotzebue Sound							
1N	93.1	1.549	2.619	.308	110,911	.365	.024
1S	100.0	1.658	1,254	.148	51,220	.168	.024
2Ø	94.7	6.169	2,649	.312	74,114	.244	.036
2I	62.5	1.932	586	.069	15,476	.051	.038
Norton Sound and northern Bering Sea							
3W	100.0	0.594	1,253	.152	49,262	.162	.026
3E	64.3	0.069	42	.009	1,379	.005	.031
4Ø	32.9	0.032	50	.006	1,627	.009	.031
4I	5.9	T	.4	T	8	T	.046
All strata combined	67.2 2/	1.088	8,493 3/		303,997 3/		.028

1/ Mean catch per unit effort, kg/km trawled.
2/ Percent occurrence in 192 successful hauls.
3/ 95% confidence interval: biomass--5,067-11,922 mt; population--208,259,000-399,736,000.

The apparent total biomass for the entire survey region was estimated at about 8,500 mt (95% confidence interval 5,067-11,922 mt). This estimate may be somewhat suspect because of the possible influence of Tanner crab in regions adjacent to the survey area. Relatively large catches of this species occurred along the entire outer boundary of the survey area in the southeastern Chukchi Sea. This suggests a continuation of Tanner crab stocks into other waters, but an estimate of the size of this

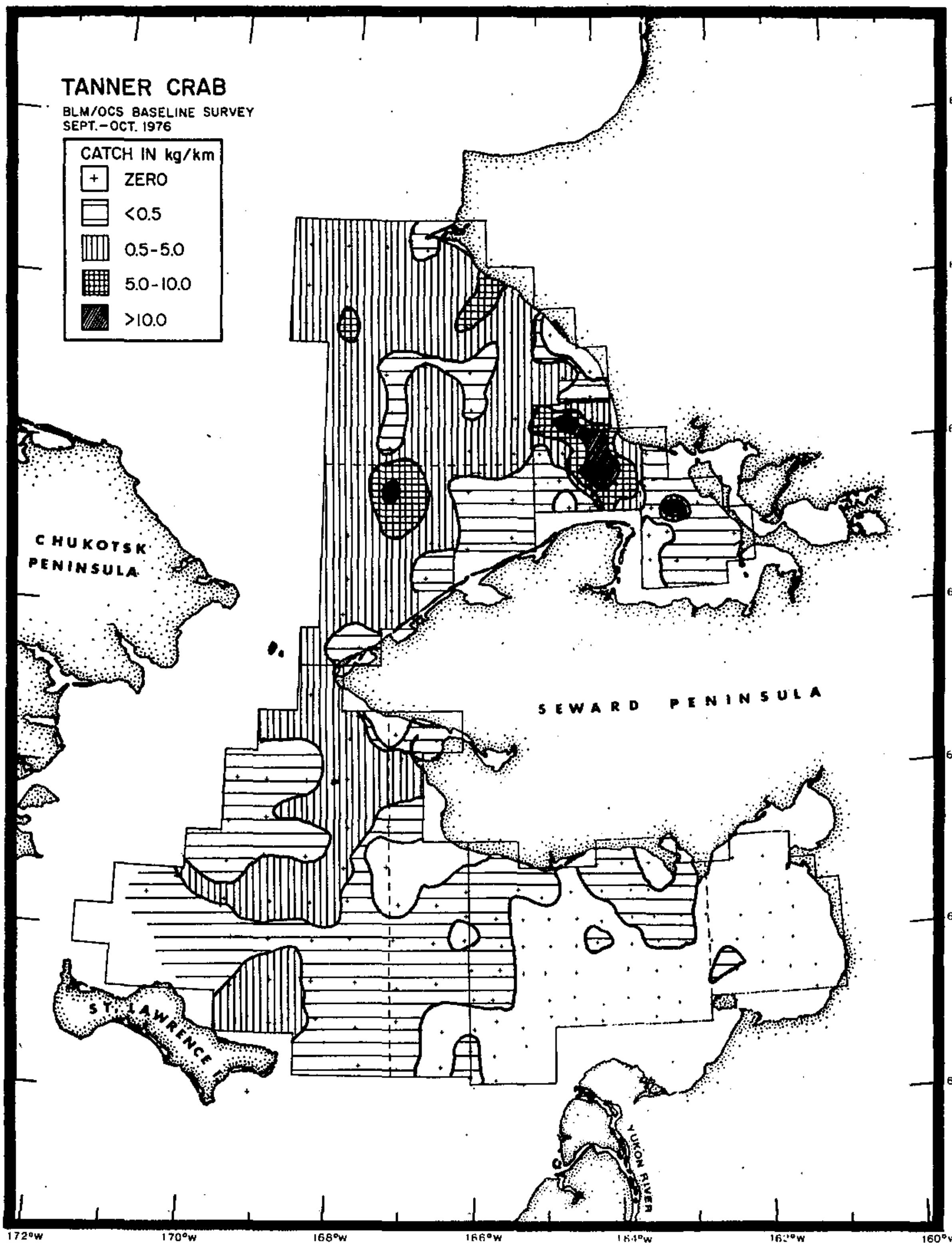


Figure VIII-104.--Distribution and relative abundance of Tanner crab (C. opilio) in Norton Sound, the southeastern Chukchi Sea, and adjacent waters (BLM/OCS survey, 1976).

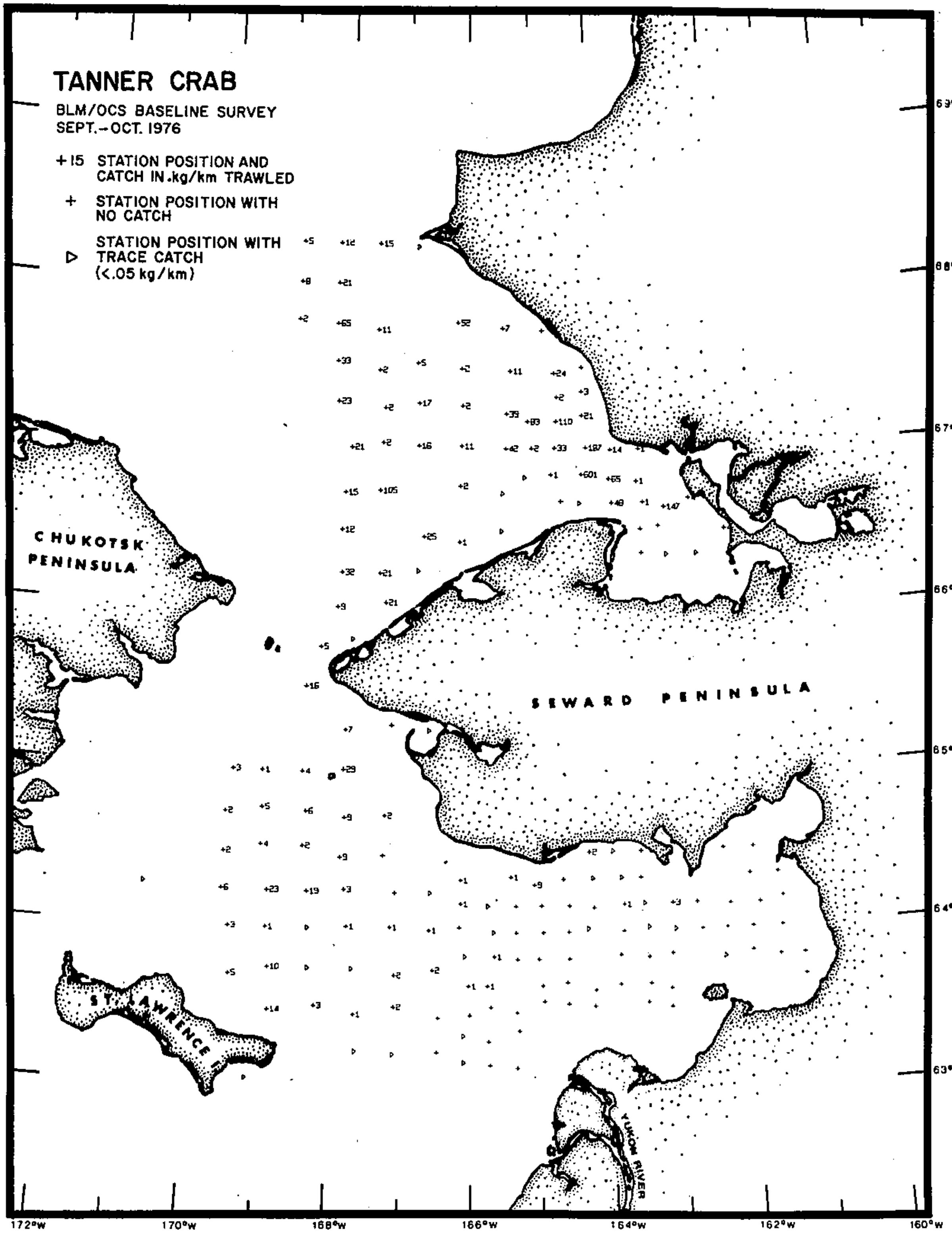


Figure VIII-105.--Distribution of catch rates by weight of Tanner crab (C. opilio) in Norton Sound, the southeastern Chukchi Sea, and adjacent waters (BLM/OCS survey, 1976).

unsampled portion of the population is unknown. Of the population within the survey area, over 62% of the estimated biomass was located in strata 1N and 2Ø combined. Another 30% occurred in strata 1S with most of the remaining portion located in stratum 2I.

The relative distribution of the estimated number of Tanner crab was very similar to apparent biomass. Strata 1N, 1S, and 2Ø north of Bering Strait accounted for nearly 78% of the total population estimate, or over 236 million crabs. Stratum 3W was the only region south of Bering Strait where sizeable numbers of Tanner crab were present. The apparent population in this stratum comprised 16% of the total population estimate of 304 million crabs for the entire survey region (95% confidence interval 208.3 million-399.7 million crabs).

Size composition--Size composition data for Tanner crab by sex and stratum are presented in Figure VIII-106. Sizes ranged from 3 to 98 mm carapace width and females exhibited a larger size range (3-98 mm) than males (7-87 mm). Two modes in size composition were observed per sex. A major mode in female size occurred at about 45-49 mm and for males at 40-49 mm while minor modes for both sexes were observed at about 15-19 mm.

Mean size of Tanner crab varied slightly by sex and strata (Figure VIII-106). Largest average size for both sexes occurred in strata 2Ø and 2I, areas where few very small crab ($\leq$ 25 mm) were encountered. Overall, females were slightly larger (40.0 mm) than males (38.5 mm) based on data for all strata combined.

Population estimates by size group, strata, and sex are presented in Table VIII-66. Small-sized males (25-64 mm) were the most abundant size group found in the survey region. They represented 85% of the estimated male population, and over 50% of the overall apparent stock. Similar size females were the next most abundant group, comprising 86% of all females and 28% of the overall total. Very small males and females (< 25 mm) together accounted for the majority of the remaining population, while individuals of both sexes larger than 65 mm were found in only trace amounts. Overall, males were more abundant than females, accounting for about 67% of the total number of Tanner crab estimated for the entire survey region.

Shell Condition--Shell age composition by region and sex for Tanner crab and other crab species is presented in Table VIII-60. Overall, new shell crabs comprised nearly the entire population, accounting for over 99% of the total. Skip molt and soft shell individuals were present, but in very small amounts, and no molting crabs were encountered.

Egg clutch size--Size of egg clutch and the proportion of gravid females by carapace width are presented in Table VIII-67. Females without eggs were present throughout nearly the entire range of sizes while the smallest size group of Tanner crab which had egg clutches present was at 35-39 mm. The proportion of gravid females per size group remained very low for all sizes between 35-54 mm and increased to about 8% for

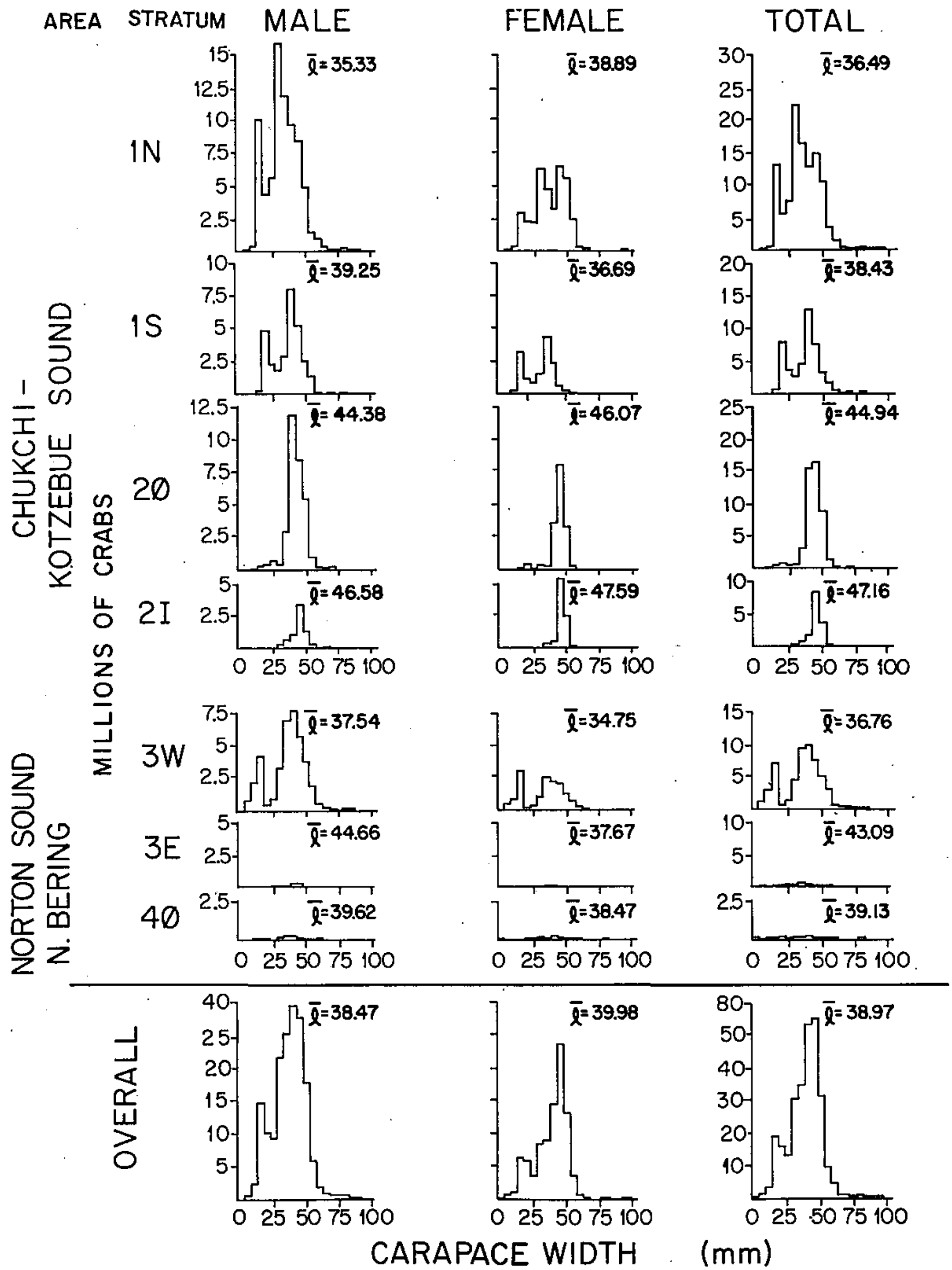


Figure VIII-106.--Size composition of Tanner crab (C. opilio) by sex and stratum in Norton Sound, the southeastern Chukchi Sea, and adjacent waters (BLM/OCS survey, 1976).

individuals in the 55-59 mm size range. Gravid females comprised the majority of individuals larger than 59 mm; however, only a few of the larger specimens were encountered during the survey.

No gravid female Tanner crab were captured in either Norton or Kotzebue sounds.

Table VIII-66.--Estimated population ($x10^6$) of Tanner crab (Chionoecetes opilio) by stratum, sex and size group[1/] in Norton Sound, the south-eastern Chukchi Sea, and adjacent waters (BLM/OCS survey, 1976).

	MALES				FEMALES				
Stratum	<25mm	25-64mm	>65mm	All sizes	<25mm	25-64mm	>65mm	All sizes	Sexes combined
Southeastern Chukchi Sea and Kotzebue Sound									
1N	14.9	59.9	0.8	74.8	5.4	30.8	T	36.2	111.0
1S	5.9	28.5	0.4	34.8	3.8	12.6	—	16.4	51.2
2Ø	1.3	48.0	0.3	49.6	0.6	23.9	—	24.5	74.1
2I	—	6.4	0.1	6.5	—	8.9	—	8.9	15.4
Norton Sound and northern Bering Sea									
3W	6.8	28.8	—	35.9	4.0	9.4	T	13.4	49.3
3E	T	1.1	—	1.1	T	0.3	—	0.3	1.4
4Ø	0.1	0.9	—	1.0	0.1	0.6	—	0.7	1.7
4I	—	T	—	T	—	—	—	—	T

1/ Carapace width (mm).

Table VIII-67.--Number of female Tanner crab by size of egg clutch and carapace width and the proportion of gravid females by size group (BLM/OCS survey, 1976).

Carapace width (mm)	No eggs	Trace-1/8 Full	1/4 Full	1/2 Full	3/4 Full	Full	Proportion with eggs
0-34	1,532	—	—	—	—	—	0
35-39	498	—	—	—	—	1	<0.01
40-44	1,437	—	—	—	—	13	0.01
45-49	2,246	—	1	3	2	101	0.05
50-54	1,134	—	—	4	5	11	0.02
55-59	208	—	3	3	1	11	0.08
60-64	4	—	—	1	2	6	0.69
65-69	1	—	—	—	—	2	0.67
70-74	—	—	—	—	—	—	—
75-79	—	—	—	—	—	—	—
80-84	1	—	—	—	—	—	0
85-89	—	—	—	—	—	—	—
90-94	—	—	—	—	—	—	—
95-98	—	—	—	—	—	—	1.00

Distribution, Abundance, and Biological Features of Principal Species of Snails

Nearly 50 species of snails were collected during the 1976 baseline study of the Norton Sound-southeastern Chukchi Sea region. Of these species, a few occurred in relatively substantial amounts. In this section are descriptions of the distribution, abundance, and size composition of the four most abundant snail species (by weight) encountered during the survey. These species together comprised over 95% of the total estimated snail biomass.

Neptunea heros

Distribution and abundance--*Neptunea heros* was by far the most abundant snail species encountered. It occurred at over 61% of the demersal stations sampled (Table VIII-68) and accounted for 75% of the total apparent biomass of all snail species combined (5% of the entire invertebrate biomass). Largest concentrations of *N. heros* were found in the southeastern Chukchi Sea (strata 1N and 1S) and in inner Norton Sound (stratum 4I) (Figures VIII-107 and 108) where catch rates averaged about 2.8 kg/km. Mean catch rates decreased to about 2.3 kg/km in inner Kotzebue Sound and the eastern portion of the northern Bering Sea (strata 2I and 3E, respectively) and further dropped to between 0.6-1.0 kg/km in the remainder of the survey region. Overall, the mean catch rate for the entire survey area was over 1.7 kg/km trawled.

Table VIII-68.--Estimated biomass and population size of *Neptunea heros* in Norton Sound, the southeastern Chukchi Sea, and adjacent waters (BLM/OCS survey, 1976).

Strata	Percent frequency of occurrence	Mean CPUE (kg/km)1/	Estimated biomass (mt)	Proportion of total estimated biomass	Estimated population ($X10^3$)	Proportion of total estimated population	Mean weight per individual (kg)
Southeastern Chukchi Sea and Kotzebue Sound							
1N	75.9	2.802	4,739	.325	47,200	.347	.100
1S	60.0	2.719	2,056	.141	21,906	.161	.094
2Ø	26.3	0.654	281	.019	2,683	.020	.105
2I	75.0	2.183	662	.045	8,589	.063	.077
Norton Sound and Northern Bering Sea							
3W	84.4	1.201	2,616	.180	23,719	.174	.110
3E	85.7	2.330	1,426	.098	9,859	.072	.145
4Ø	48.3	0.986	1,313	.090	8,709	.064	.151
4I	82.4	2.777	1,475	.101	13,358	.098	.111
All strata combined:	64.1 2/	1.739	14,568 3/		136,023 3/		.108

1/ Mean catch per unit effort, kg/km trawled.
2/ Percent occurrence in 192 successful hauls.
3/ 95% confidence interval: biomass-- 9,992 - 19,144mt; population--92,242,000 - 179,807,000.

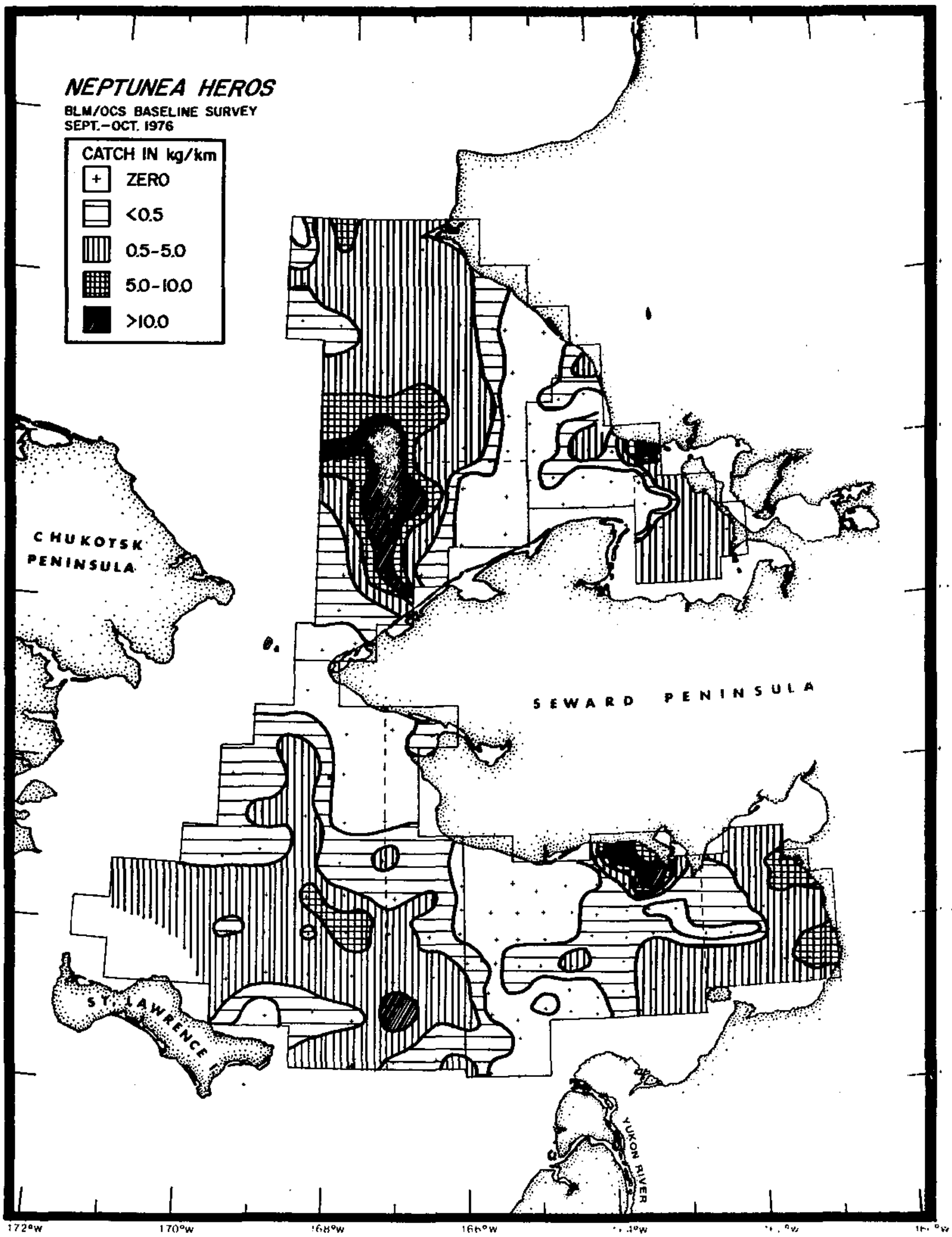


Figure VIII-107.--Distribution and relative abundance by weight of <u>Neptunea heros</u> in Norton Sound, the southeastern Chukchi Sea and adjacent waters (BLM/OCS survey, 1976).

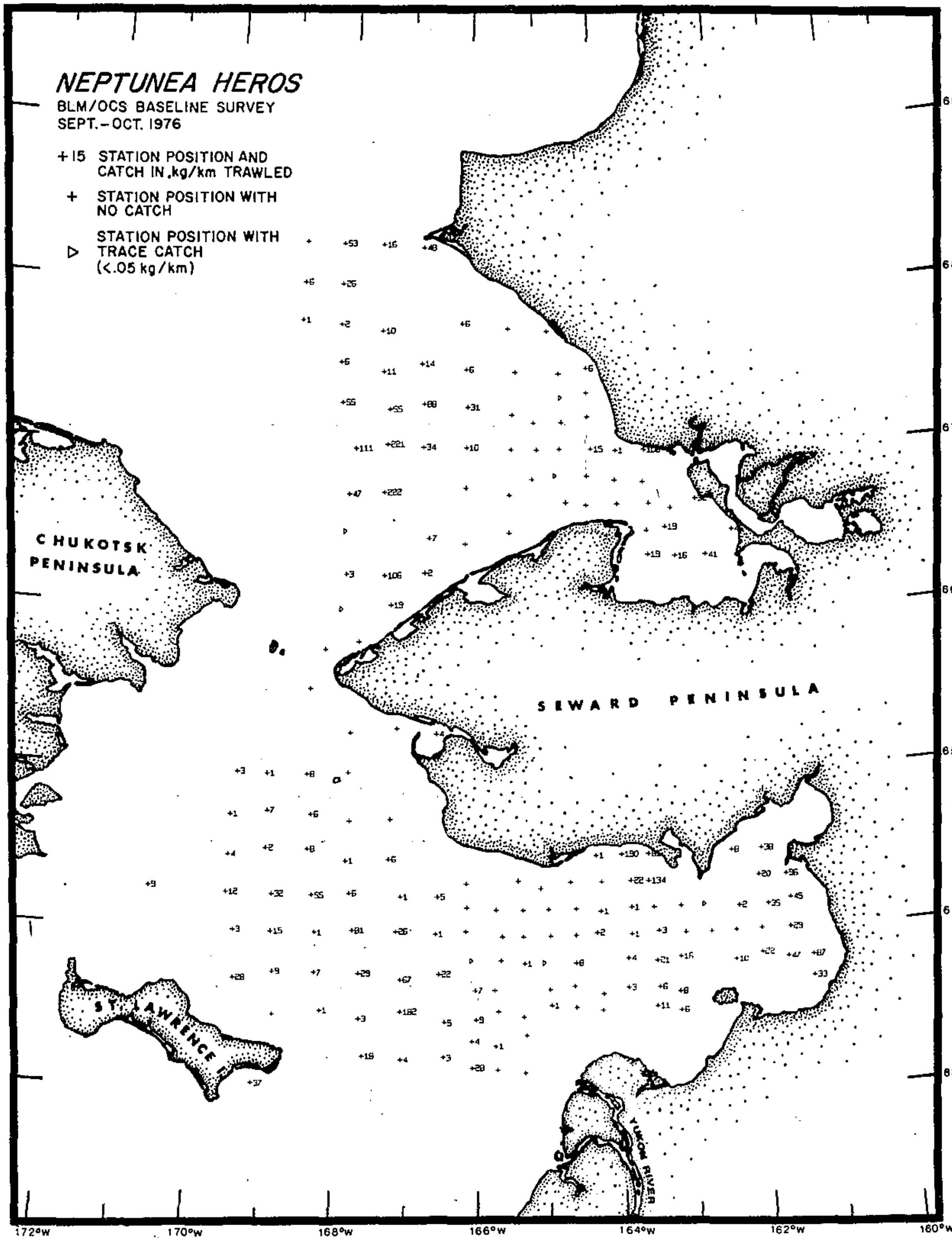


Figure VIII-108.--Distribution of catch rates by weight of Neptunea heros in Norton Sound, the southeastern Chukchi Sea and adjacent waters (BLM/OCS survey, 1976).

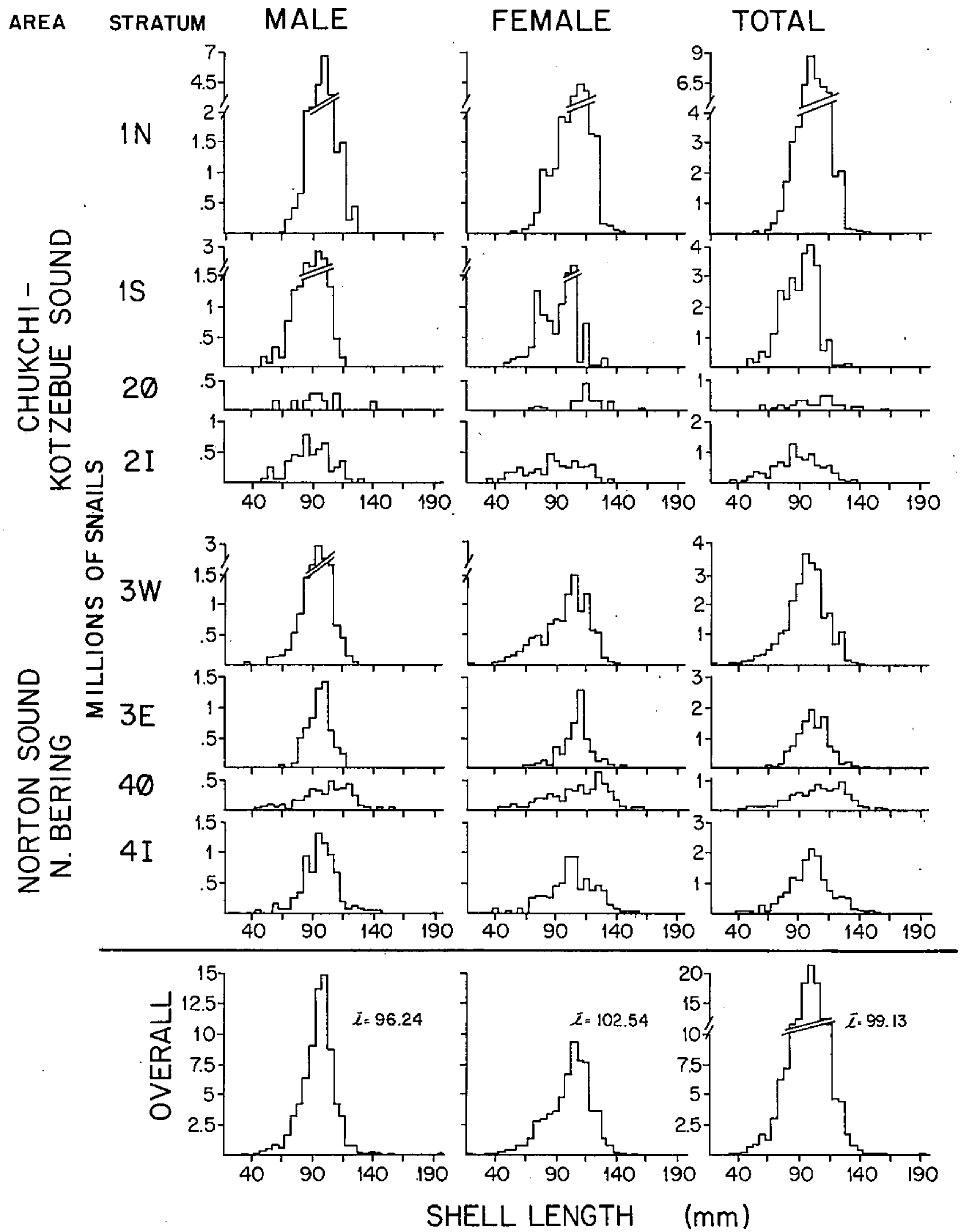


Figure VIII-109.--Size composition by sex and stratum for Neptunea heros in Norton Sound, the southeastern Chukchi Sea and adjacent waters (BLM/OCS survey, 1976).

The apparent biomass of N. heros in the entire survey area was estimated at about 14,500 mt (95% confidence interval 9,992-19,144 mt). This is a minimum estimate for the survey region, since snails are burrowing animals and some unknown portion of the population may have occurred slightly below the sea bed surface, thus being unavailable to the trawl. Additionally, relatively large catches of this species occurred along the outer boundary of the survey area in the southeastern Chukchi Sea. This suggests a continuation of N. heros stocks into non-survey waters. Of the population within the survey area, over half of the total estimated biomass was found in strata 1N and 3W, offshore and where depths generally exceeded 25 m. A further 9-14% occurred in strata 1S, 3E, 4Ø, and 4I. Nearly the entire biomass estimated for stratum 4Ø (outer Norton Sound) was located in a small portion of the northeast section of this region. Only about 6% of the total estimated biomass occurred in strata 2Ø and 2I combined.

The relative distribution of estimated numbers of N. heros did not differ greatly from apparent biomass. Strata 1N and 3W together contained 52% of the total population, or an estimated 71 million snails. An additional 16% was estimated present in stratum 1S while all other strata contained between 2-10%. The total overall population estimated for the survey region was about 136 million snails.

Size composition, mean length and weight--N. heros collected during the survey ranged in shell length from 22-197 mm. Females generally were larger than males, averaging 102.5 mm compared to 96.2 mm for all strata combined (Figure VIII-109). Intermediately-sized (90-115 mm) males and females were the most abundant groups in nearly all strata (Table VIII-69) and represented over 60% of the overall apparent population. Small N. heros (< 90 mm) were the next most abundant size group and were found mostly in the northern and westernmost areas of the survey region in strata 1N, 1S, and 3W.

Table VIII-69.--Estimated population ($x10^6$) of Neptunea heros by stratum, sex and size group[1/] in Norton Sound, the southeastern Chukchi Sea, and adjacent waters (BLM/OCS survey, 1976).

	MALES				FEMALES				
Stratum	<90mm	90-115mm	>115mm	Total	<90mm	90-115mm	>115mm	Total	Sexes combined
Southeastern Chukchi Sea and Kotzebue Sound									
1N	3.4	18.3	2.3	24.1	2.6	12.5	7.4	22.5	46.5
1S	6.3	8.9	0.2	15.3	3.8	6.2	0.9	10.0	25.4
2Ø	0.4	1.0	0.1	1.5	T	0.3	0.8	1.1	2.7
2I	2.4	2.0	0.4	4.8	1.8	1.5	0.7	3.8	8.7
Norton Sound and northern Bering Sea									
3W	3.4	9.4	0.6	13.4	2.7	5.0	2.5	10.2	23.5
3E	1.3	4.5	0.2	6.0	0.3	3.0	1.0	4.3	10.3
4Ø	0.9	1.7	1.2	3.9	1.0	1.5	2.3	4.8	8.7
4I	1.8	4.8	0.5	7.1	1.2	3.1	2.0	6.3	13.4

1/ Shell length (mm).

Mean weight per individual was noticeably higher in all strata south of Bering Strait than to the north. Average weights of N. heros in strata 3W, 3E, 4Ø, and 4I were about 129 gm while in strata 1N, 1S, 2Ø, and 2I individual weights averaged 94 gm. The overall average weight of N. heros was about 108 gm.

Neptunea ventricosa

Distribution and abundance--Neptunea ventricosa was the second-most abundant snail species encountered, occurring at nearly 56% of all stations sampled (Table VIII-70) and comprising about 14% of the total snail biomass. Dense concentrations of this snail species were not encountered in the survey region, although highest average catch rates of about 0.6 kg/km occurred in the southern portion of the southern Chukchi Sea and the eastern part of the northern Bering Sea (strata 1S and 3E, respectively) (Figure VIII-110 and 111). Average catch rates dropped to between 0.2-0.4 kg/km in the remaining portion of the southeastern Chukchi and northern Bering seas and in Kotzebue Sound (strata 1N, 3E, 2Ø, and 2I) and further decreased to 0.1 kg/km in Norton Sound (strata 4Ø and 4I). The overall mean catch rate for the entire survey area was 0.3 kg/km trawled.

Table VIII-70.--Estimated biomass and population size of Neptunea ventricosa in Norton Sound, the southeastern Chukchi Sea, and adjacent waters (BLM/OCS survey, 1976).

Strata	Percent frequency of occurrence	Mean CPUE (kg/km)1/	Estimated biomass (mt)	Proportion of total estimated biomass	Estimated population ($X10^3$)	Proportion of total estimated population	Mean weight per individual (kg)
Southeastern Chukchi Sea and Kotzekue Sound							
1N	55.2	0.424	717	.271	10,815	.319	.066
1S	53.3	0.599	453	.171	5,714	.168	.079
2Ø	26.3	0.274	118	.044	1,394	.041	.085
2I	100.0	0.252	76	.029	1,048	.031	.073
Norton Sound and Northern Bering Sea							
3W	75.0	0.340	741	.280	8,008	.236	.093
3E	85.7	0.576	353	.133	4,099	.121	.086
4Ø	39.7	0.083	111	.042	1,209	.036	.092
4I	64.7	0.148	79	.030	1,636	.048	.048
All strata combined:	55.72/	0.316	2,6483/		33,9233/		.078

1/ Mean catch per unit effort, kg/km trawled.
2/ Percent occurrence in 192 successful hauls.
3/ 95% confidence interval: biomass--1,811 - 3,485 mt; population--21,511,000 - 46,335,000.

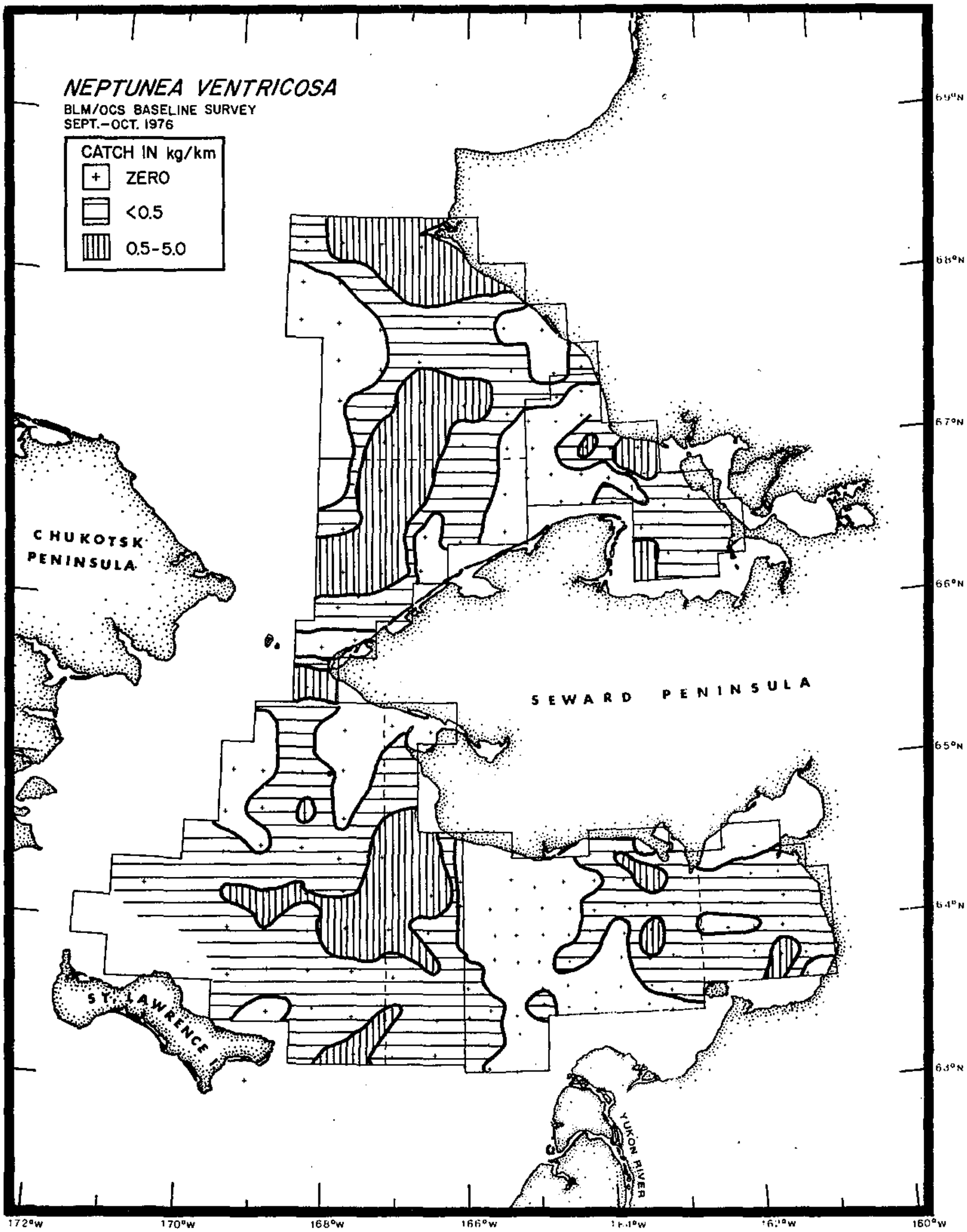


Figure VIII-110.--Distribution and relative abundance by weight of Neptunea ventricosa in Norton Sound, the southeastern Chukchi Sea and adjacent waters (BLM/OCS survey, 1976).

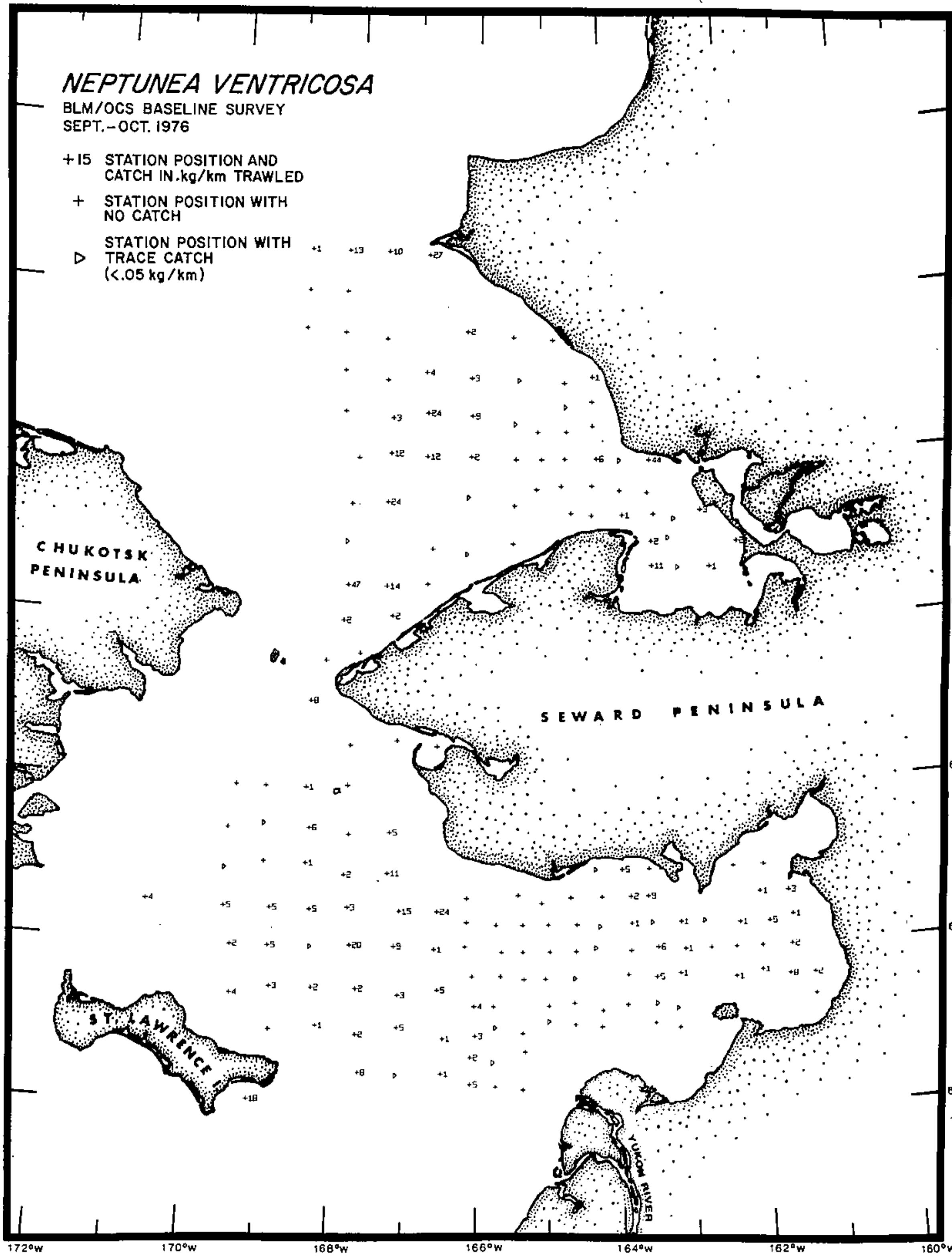


Figure VIII-111.--Distribution of catch rates by weight of Neptunea ventricosa in Norton Sound, the southeastern Chukchi Sea and adjacent waters (BLM/OCS survey, 1976).

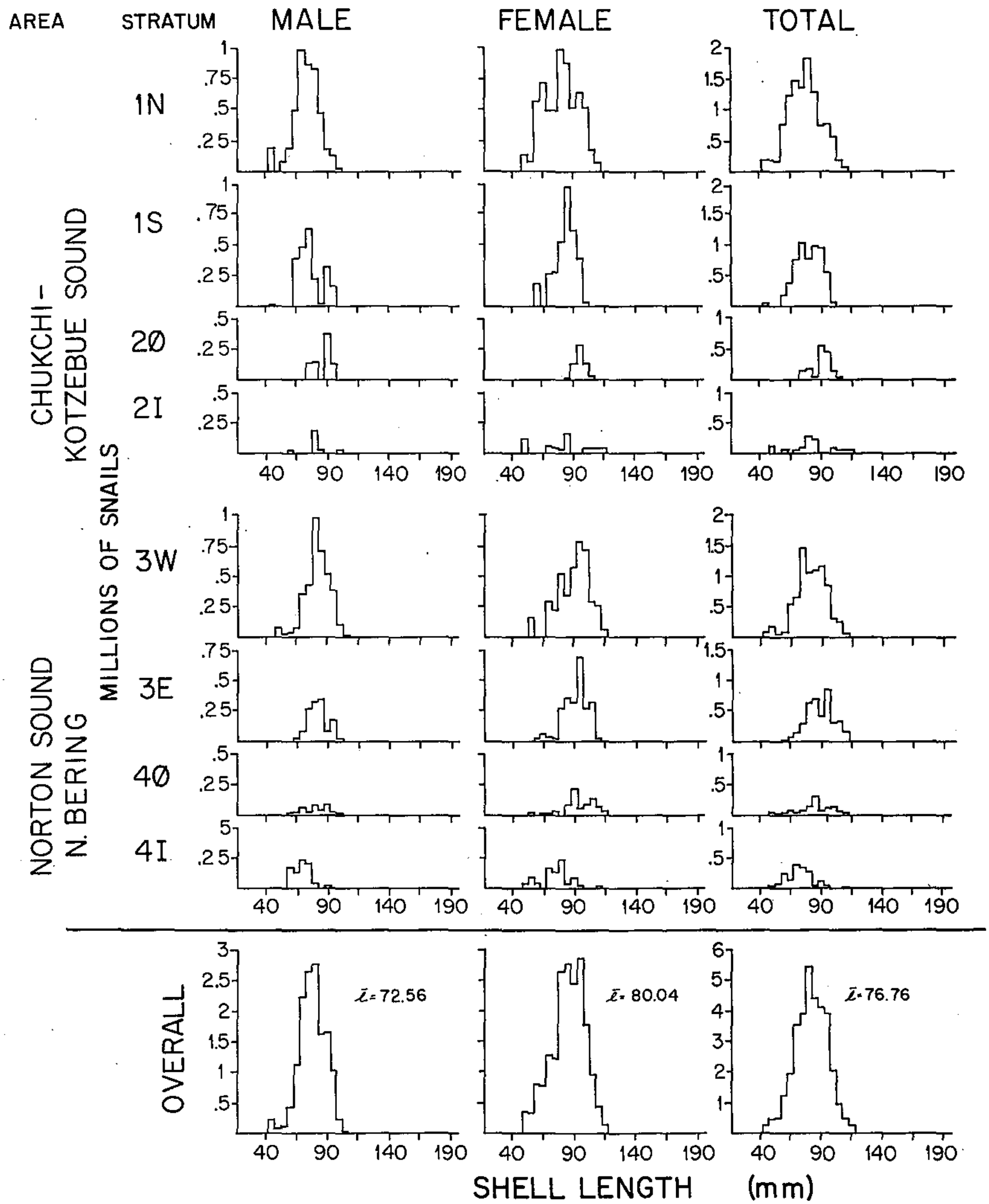


Figure VIII-112.--Size composition by sex and stratum for Neptunea ventricosa in Norton Sound, the southeastern Chukchi Sea and adjacent waters (BLM/OCS survey, 1976).

The apparent biomass of *N. ventricosa* in the entire survey region was estimated at over 2,600 mt (95% confidence interval 1,811-3,485 mt). Nearly 86% of this amount was located in strata 1N, 1S, 3W, and 3E combined, where depths generally exceeded 25 m. The remaining portion of the estimated biomass was almost equally distributed among all other strata which were more inshore and had depths generally less than 25 m.

No substantial difference was observed between the distribution of apparent biomass and estimated numbers. Approximately 84% of the estimated population of *N. ventricosa* was found in strata 1N, 1S, 3E, and 3W. The total population estimated for the entire survey region was about 34 million snails.

Size composition, mean length and weight--*N. ventricosa* collected during the survey ranged from 47 to 117 mm in shell length (Figure VIII-112). Females usually were larger than males, averaging 80.0 mm compared to 72.6 mm. Nearly the entire observed population were small or intermediate-sized snails (< 115 mm). The largest portion of small individuals (< 90 mm) was found north of Bering Strait in strata 1N and 1S (Table VIII-71) while the greatest numbers of intermediate-sized individuals (90-115 mm) were located south of Bering Strait in strata 3W and 3E.

Mean weights per individual were fairly consistent throughout the survey region and averaged 78 gm.

Table VIII-71.--Estimated population ($x10^6$) of *Neptunea ventricosa* by stratum, sex and size group[1/] in Norton Sound, the southeastern Chukchi Sea, and adjacent waters (BLM/OCS survey, 1976).

	MALES				FEMALES				
Stratum	<90mm	90-115mm	>115mm	Total	<90mm	90-115mm	>115mm	Total	Sexes combined
Southeastern Chukchi Sea and Kotzebue Sound									
1N	4.1	0.4	--	4.5	4.3	1.9	--	6.2	10.7
1S	1.9	0.5	--	2.3	2.2	1.0	--	3.2	5.5
2Ø	0.3	0.5	--	0.8	T	0.6	--	0.6	1.4
2I	0.2	0.1	--	0.3	0.5	0.2	T	0.7	1.0
Norton Sound and northern Bering Sea									
3W	2.7	1.0	--	3.7	1.5	2.6	0.1	4.2	7.9
3E	1.1	0.3	--	1.4	0.8	1.6	--	2.4	3.7
4Ø	0.3	0.1	--	0.4	0.1	0.6	T	0.7	1.1
4I	0.8	T	--	0.8	0.7	0.2	--	0.8	1.7

1/ Shell length (mm).

Beringius beringii

Distribution and abundance--Beringius beringii was frequently encountered during the survey, occurring at nearly 47% of all stations (Table VII-72), but comprised less than 4% of the total apparent snail biomass. Moderate concentrations were found in small isolated locations throughout the survey area (Figures VIII-113 and 114) at depths usually less than 25 m. Largest catches occurred in inner Kotzebue Sound (stratum 2I) where catch rates averaged nearly 0.3 kg/km. Mean catch rates dropped to about 0.2 kg/km in outer Kotzebue Sound (stratum 2Ø) and further declined to 0.1 kg/km in the eastern portion of the northern Bering Sea (stratum 3E) and in Norton Sound (strata 4Ø and 4I). Only trace amounts were found in the remainder of the survey region. Overall, the mean catch rate for the entire survey area was about 0.1 kg/km trawled.

Table VIII-72.--Estimated biomass and population size of Beringius beringii in Norton Sound, the southeastern Chukchi Sea, and adjacent waters (BLM/OCS survey, 1976).

Strata	Percent frequency of occurrence	Mean CPUE (kg/km)1/	Estimated biomass (mt)	Proportion of total estimated biomass	Estimated population ($X10^3$)	Proportion of total estimated population	Mean weight per individual (kg)
Southeastern Chukchi Sea and Kotzebue Sound							
1N	51.7	0.079	134	.183	1,399	.155	.096
1S	20.0	0.047	36	.049	354	.039	.102
2Ø	52.6	0.155	67	.092	829	.092	.081
2I	62.5	0.271	82	.113	1,113	.123	.074
Norton Sound and Northern Bering Sea							
3W	40.6	0.061	133	.182	2,093	.232	.064
3E	28.6	0.135	83	.114	830	.092	.100
4Ø	50.0	0.101	136	.185	1,465	.162	.093
4I	64.7	0.114	61	.083	938	.104	.065
All strata combined:	46.9 2/	0.087	732 3/		9,021 3/		.082

1/ Mean catch per unit effort, kg/km trawled.
2/ Percent occurrence in 192 successful hauls.
3/ 95% confidence intervals: biomass--485 - 977 mt; population--6,183,000 - 11,863,000.

The apparent biomass of B. beringii for the entire survey region was estimated at about 730 mt (95% confidence interval 485-977 mt). This estimated biomass was fairly evenly distributed throughout most of the survey region. Of the estimated biomass, 18% was located in each of three strata, 1N, 3W, and 4Ø; 11% each in strata 2I and 3E; and 8-9% in strata 2Ø and 4I. Less than 5% of the total estimated biomass occurred in stratum 1S.

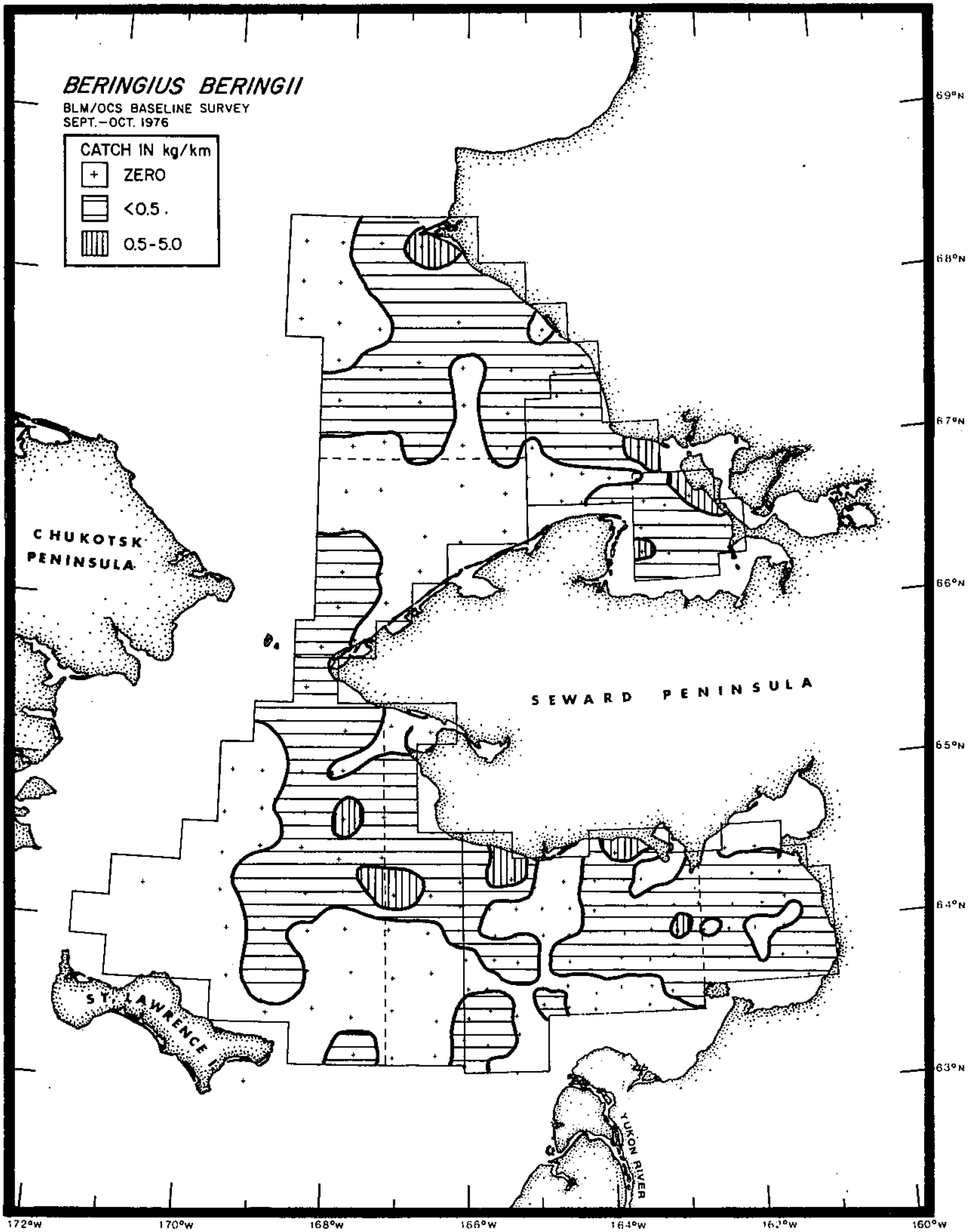


Figure VIII-113.--Distribution and relative abundance by weight of <u>Beringius beringii</u> in Norton Sound, the southeastern Chukchi Sea and adjacent waters (BLM/OCS survey, 1976).

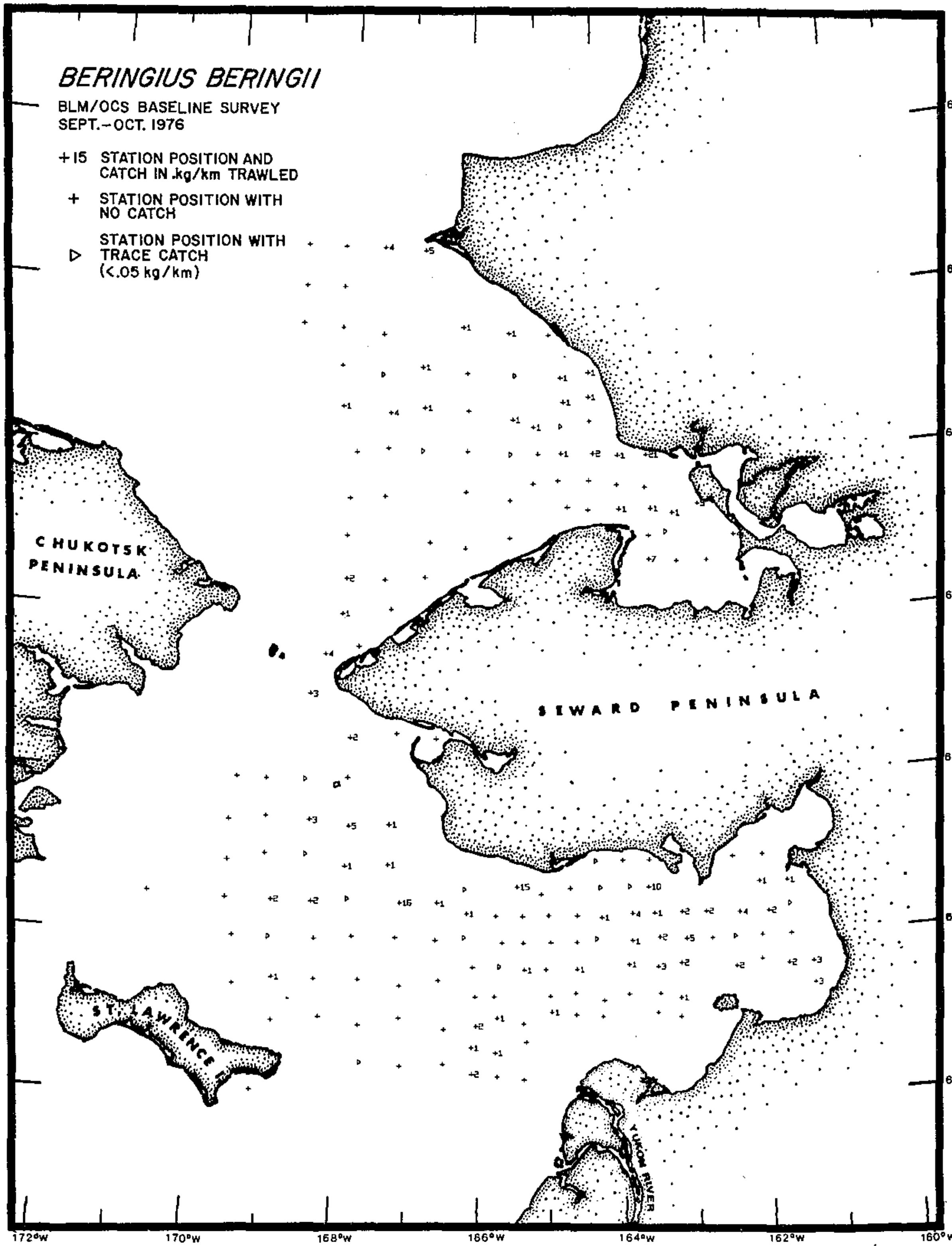


Figure VIII-114.--Distribution of catch rates by weight of <u>Beringius beringii</u> in Norton Sound, the southeastern Chukchi Sea and adjacent waters (BLM/OCS survey, 1976).

The relative distribution of estimated numbers of B. beringii generally was similar to apparent biomass. The total population estimated for the entire survey region was 9 million snails.

Size composition, mean length and weight--B. beringii collected during the survey ranged in shell length from 47-147 mm. Females appeared to be larger than males, averaging 107.9 mm compared to 94.5 mm (Figure VIII-115). Intermediate-sized males and females (90-115 mm) were the most abundant groups in most strata (Table VIII-73). They represented nearly 60% of the overall apparent population. Small-sized (< 90 mm) and large (> 115 mm) snails comprised about equal proportions of the remaining number estimated. For all strata combined, small males outnumbered similar sized females and for the intermediate and large size groups, females were more numerous than males.

Overall, the average weight of B. beringii was 82 gm.

Table VIII-73.--Estimated population ($x10^5$) of Beringius beringii by stratum, sex and size group1/ in Norton Sound, the southeastern Chukchi Sea, and adjacent waters (BLM/OCS survey, 1976).

	MALES				FEMALES				
Stratum	<90 mm	90-115mm	>115mm	Total	<90mm	90-115mm	>115mm	Total	Sexes combined
Southeastern Chukchi Sea and Kotzebue Sound									
1N	1.3	4.4	0.2	5.9	0.6	2.3	4.4	7.4	13.2
1S	0.1	1.7	0.3	2.0	--	0.7	0.7	1.4	3.4
2Ø	0.1	6.0	0.1	6.2	--	1.5	0.5	2.0	8.1
2I	1.2	2.3	--	3.5	1.7	6.1	3.5	8.7	12.3
Norton Sound and northern Bering Sea									
3W	5.2	1.8	0.4	7.4	2.7	9.7	1.8	14.2	21.6
3E	0.7	1.9	1.6	4.2	0.6	1.8	1.8	4.2	8.5
4Ø	1.6	3.8	0.1	5.4	1.0	5.0	2.7	8.7	14.1
4I	3.3	1.2	--	4.5	1.5	2.2	0.7	4.5	9.0

1/ Shell length (mm).

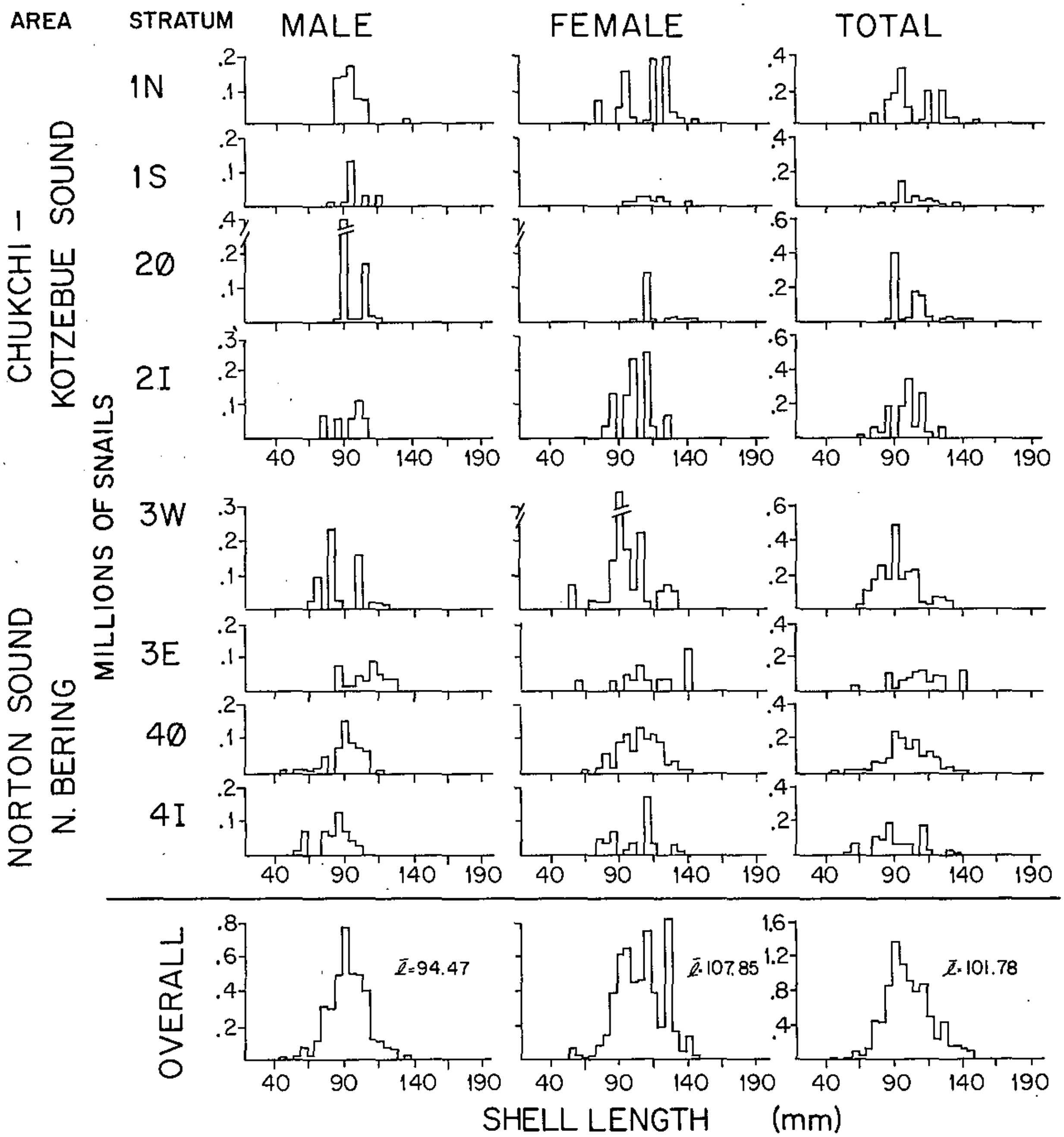


Figure VIII-115.--Size composition by sex and stratum for Beringius beringii in Norton Sound, the southeastern Chukchi Sea and adjacent waters (BLM/OCS survey, 1976).

Pyrulofusus deformis

Distribution and abundance--*P. deformis* was infrequently encountered during the survey, occurring at only 17% of the stations sampled (Table VIII-74) and accounting for less than 3% of the total snail biomass. Its distribution was fairly localized (Figures VIII-116 and 117) with highest catch rates occurring in the northern Bering Sea (strata 3E and 3W). Only trace amounts were encountered in most of the remaining survey area with no catches obtained in the southern portion of the Chukchi Sea (stratum 1S). Overall, the average catch rate for the entire survey area was less than 0.1 kg/km trawled.

The apparent biomass of *P. deformis* was estimated at 526 mt (95% confidence interval 211-913 mt) for the entire survey area. Most (70%) of this amount was located in strata 3W and 3E combined. These strata also contained the majority (65%) of the total population estimate of about 3.4 million snails.

Table VIII-74.--Estimated biomass and population size of *Pyrulofusus deformis* in Norton Sound, the southeastern Chukchi Sea, and adjacent waters (BLM/OCS survey, 1976).

Strata	Percent frequency of occurrence	Mean CPUE (kg/km)1/	Estimated biomass (mt)	Proportion of total estimated biomass	Estimated population (X10³)	Proportion of total estimated population	Mean weight per individual (kg)
Southeastern Chukchi Sea and Kotzebue Sound							
1N	6.9	0.048	82	.145	863	.164	.095
1S	--	--	--	--	--	--	--
2Ø	5.3	0.056	24	.043	427	.081	.057
2I	25.0	0.074	23	.040	287	.055	.078
Norton Sound and Northern Bering Sea							
3W	34.4	0.108	237	.422	2,255	.430	.105
3E	21.4	0.258	158	.282	1,141	.218	.139
4Ø	20.7	0.024	33	.059	238	.045	.139
4I	11.8	0.008	5	.008	33	.006	.145
All strata combined:	17.2 2/	0.067	562 3/		5,244 3/		.108

1/ Mean catch per unit effort, kg/km trawled
2/ Percent occurrence in 192 successful hauls.
3/ 95% confidence interval: biomass--211 - 913 mt; population--2,115,000 - 8,373,000.

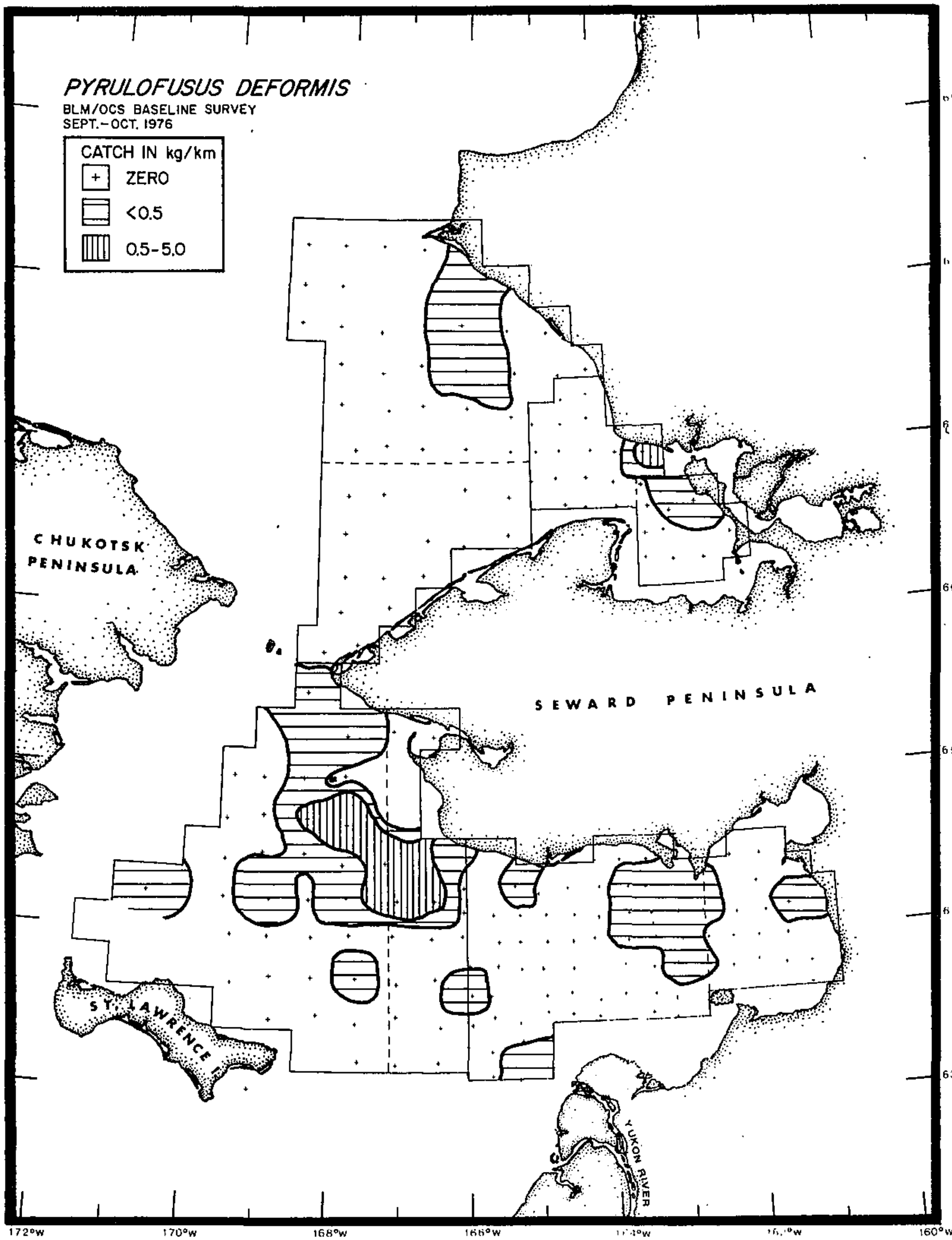


Figure VIII-116.--Distribution and relative abundance by weight of *Pyrulofusus deformis* in Norton Sound, the southeastern Chukchi Sea and adjacent waters (BLM/OCS survey, 1976).

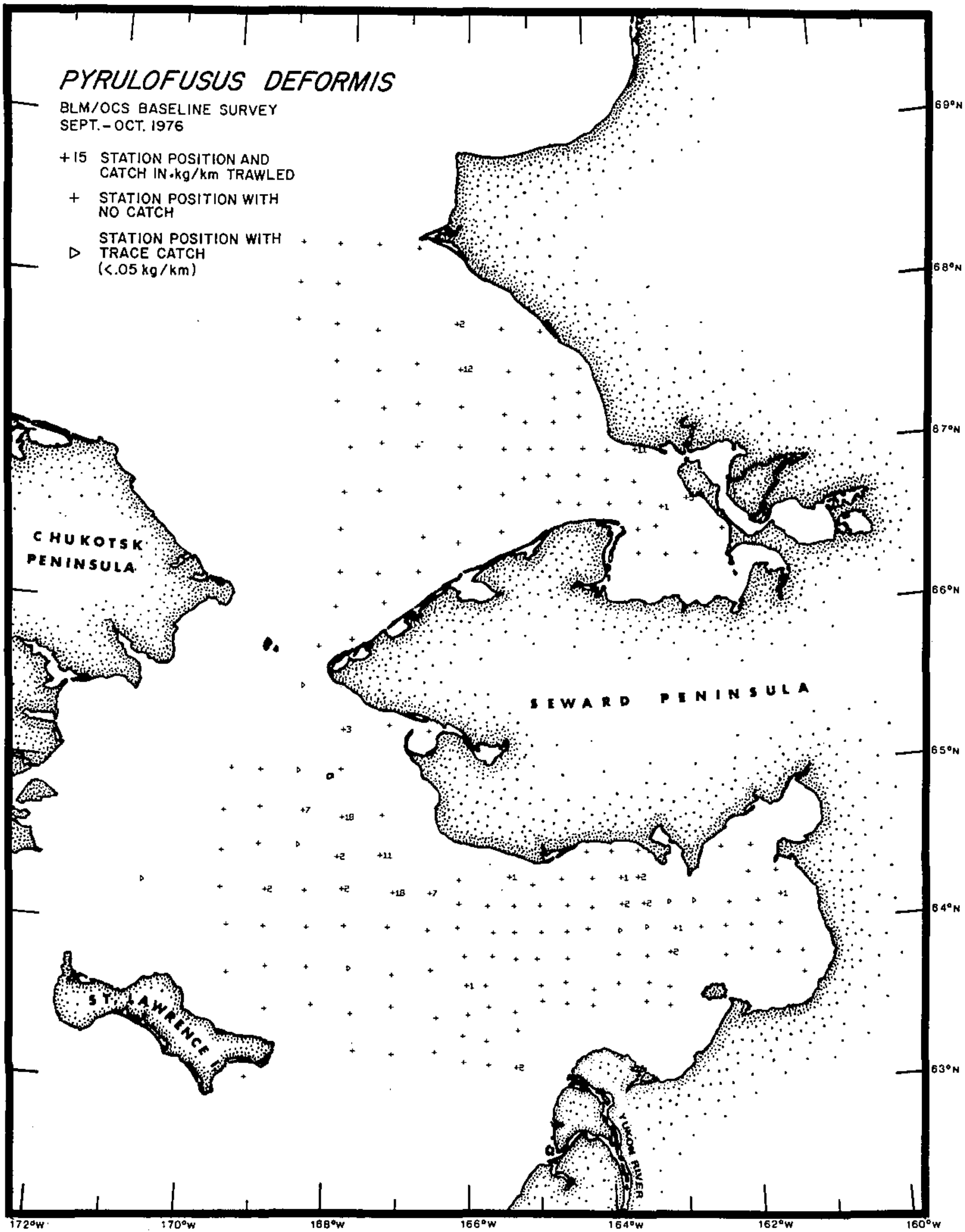


Figure VIII-117.--Distribution of catch rates by weight of Pyrulofusus deformis in Norton Sound, the southeastern Chukchi Sea and adjacent waters (BLM/OCS survey, 1976).

Size composition, mean length and weight--P. deformis collected during the survey ranged from 52-157 mm in shell length. Females were slightly larger than males, averaging 109.5 mm compared to 102.5 mm (Figure VIII-118). By size groups, intermediate - sized males and females (90-115 mm) were the most abundant groups in the survey area, together comprising 82% of the total estimated population (Table VIII-75).

The average size of P. deformis was markedly different north and south of Bering Strait. In strata 1N, 1S, 2I, and 2Ø, average shell length ranged from 78-98 mm and the average weight was about 77 gm. South of Bering Strait in strata 3W, 3E, 4Ø, and 4I, mean shell sizes ranged from 108-122 mm and individuals were much heavier, weighing an average of 132 gm.

Table VIII-75.--Estimated population ($x10^5$) of Pyrulofusus deformis by stratum, sex and size group[1/] in Norton Sound, the southeastern Chukchi Sea, and adjacent waters (BLM/OCS survey, 1976).

	MALES				FEMALES				
Stratum	<90mm	90-115mm	>115mm	Total	<90mm	90-115mm	>115mm	Total	Sexes combined
Southeastern Chukchi Sea and Kotzebue Sound									
1N	1.0	6.1	--	7.0	--	1.2	--	1.2	8.2
1S	--	--	--	--	--	--	--	--	--
2Ø	--	1.4	--	1.4	2.8	--	--	2.8	4.2
2I	2.7	--	--	2.7	1.6	1.4	0.5	3.4	6.1
Norton Sound and northern Bering Sea									
3W	0.9	7.9	0.2	9.0	0.2	6.1	4.8	11.0	20.1
3E	0.5	1.0	2.2	3.6	0.2	1.7	2.7	4.6	8.2
4Ø	0.3	0.6	0.1	1.0	--	0.3	0.5	0.9	1.9
4I	--	--	--	--	--	0.3	T	0.3	0.3

1/ Shell length (mm).

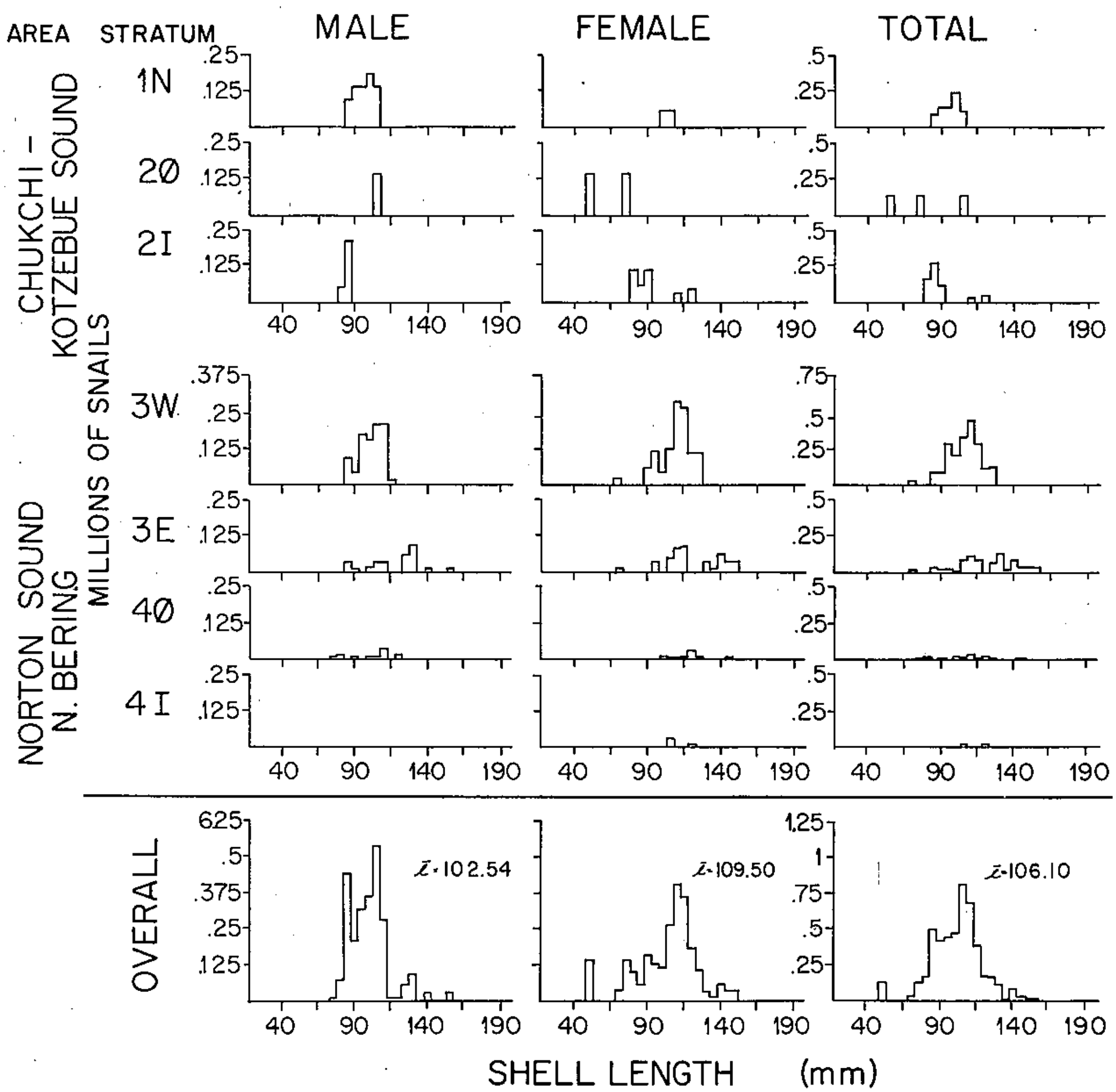


Figure VIII-118.--Size composition by sex and stratum for Pyrulofusus deformis in Norton Sound, the southeastern Chukchi Sea and adjacent waters (BLM/OCS survey, 1976).

RESULTS OF THE GILLNET SURVEY

A total of 33 gillnet stations were completed during the survey. These included 22 stations located throughout the survey region (Figure VIII-119) to qualitatively determine the general distribution of common near-surface fish species. The remaining 11 were made in an attempt to determine the relative catchability of the gillnets by day and night as well as establish whether 2, 4, or 8 hour soak-times were the most effective means of obtaining (and retaining) fish.

Analysis of day-night and variable-time gillnet sets was not performed because extremely small catches were obtained during those sets.

All gillnet operations proved most unproductive. Catches were small, ranging from approximately 70 fish to no catch. Individual gillnet station catches are listed in Appendix C. Gillnet sets made in the shallower inshore areas of the survey region generally caught more fish than those made over deeper, offshore waters. All fish were taken in the smaller mesh sizes, i.e., 21-42 mm mesh. The 42 mm shackle caught the greatest amounts of all mesh sizes.

Of the 12 fish species obtained during gillnet operations (Table VIII-76), Pacific herring was by far the most abundant, occurring in 45% of all sets and comprising over 68% of all fish caught by gillnet. Largest catches occurred in Kotzebue Sound (Figure VIII-120).

Table VIII-76.--Numbers of fish by species taken by various mesh sizes during gillnet operations in Norton Sound, the southeastern Chukchi Sea, and adjacent waters (BLM/OCS survey, 1976).

SPECIES	STRETCHED MESH SIZE (mm)							Total
	21	35	42	64	83	114	113	
CLUPEIDAE								
Pacific herring	13	69	114					196
OSMERIDAE								
Toothed smelt	40	2	2					44
Pond smelt	1							1
SALMONIDAE								
King salmon		3	2					5
Chum salmon			1	1		2	2	6
Arctic char			8	1				9
Bering cisco					3			3
Pink salmon	1	6	1					8
PLEURONECTIDAE								
Starry flounder				1		1		2
COTTIDAE								
Arctic staghorn sculpin				1	1			2
Myoxocephalus spp.		2	2	1				5
GADIDAE								
Saffron cod		1	2	2				5
TOTAL	55	83	132	7	4	3	2	286

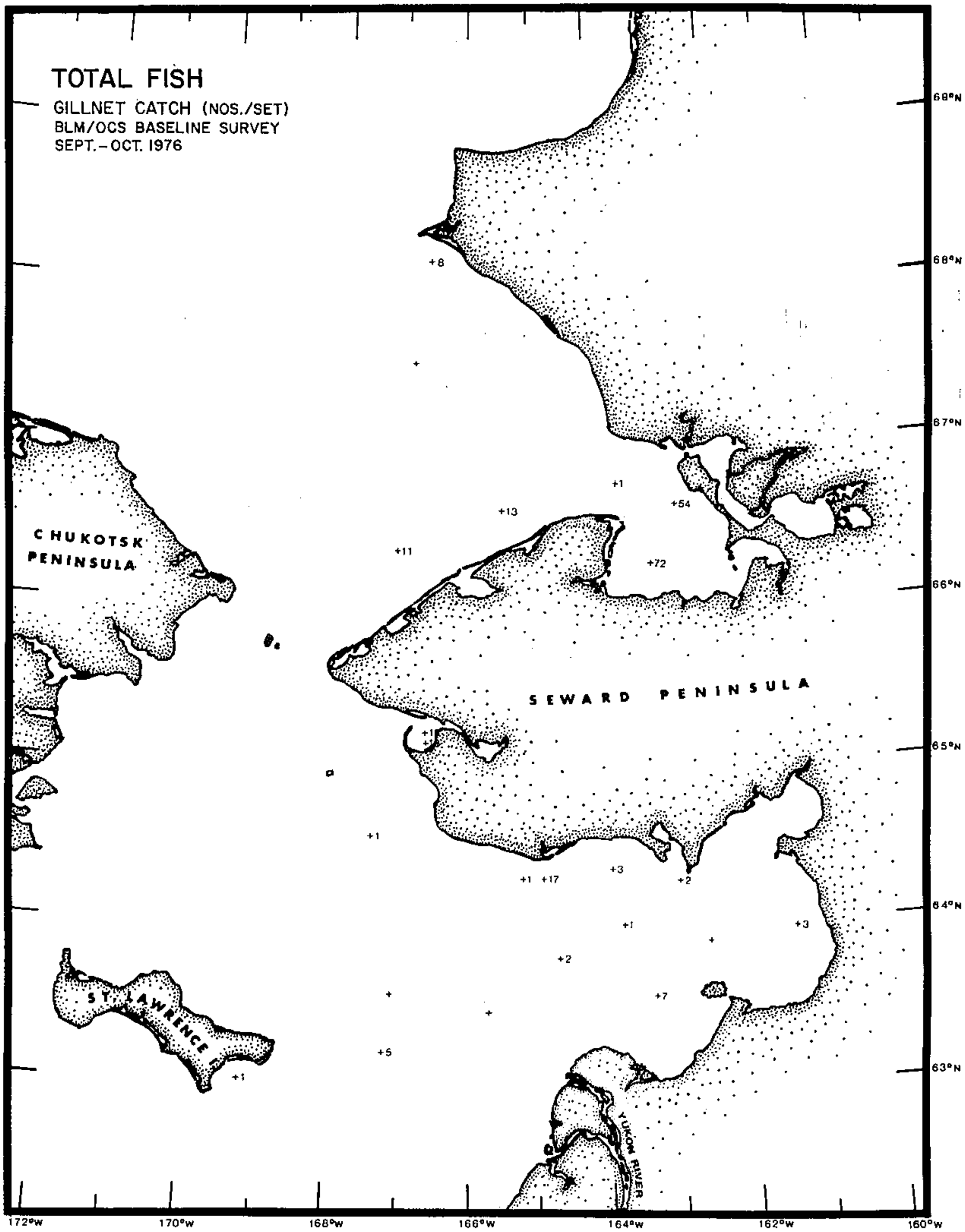


Figure VIII-119.--Gillnet sites (+) and total number of fish caught per site during 1976 BLM/OCS survey of Norton Sound, the southeastern Chukchi Sea and adjacent waters.

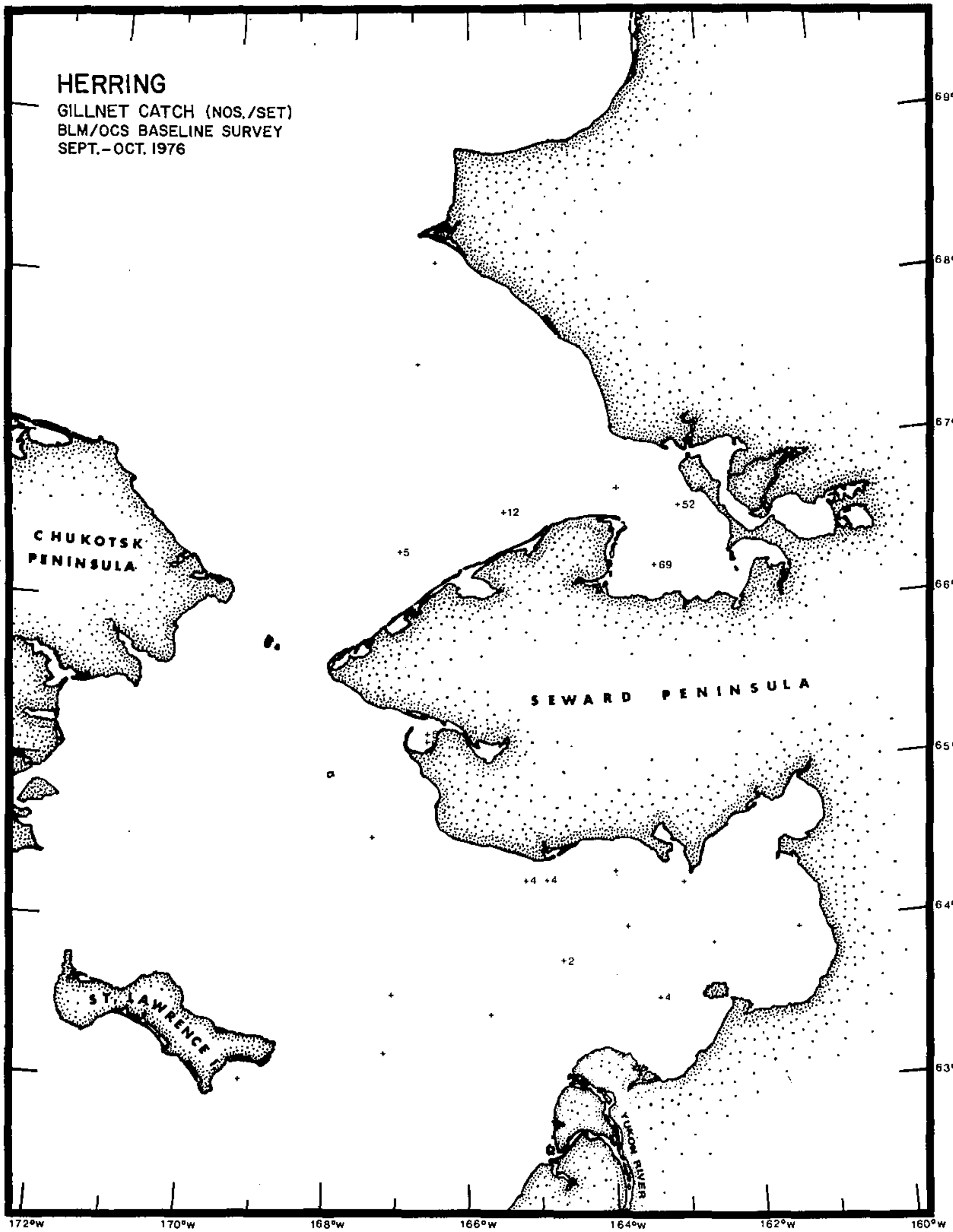


Figure VIII-120.--Numbers of Pacific herring caught at gillnet stations in Norton Sound, the southeastern Chukchi Sea and adjacent waters (BLM/OCS survey, 1976).

Size of Pacific herring captured varied, of course, by mesh size (Figure VIII-121). Pacific herring taken in the 21 mm shackle ranged in length from 9-18 cm and averaged about 13.8 cm. Fish caught with the 35 and 42 mm mesh nets had similar size ranges (15-24 cm and 16-24 cm, respectively), as well as average lengths (18.8 cm and 20.3 cm, respectively). Overall, the mean size of Pacific herring caught in the gillnets was about 19.4 cm, over 1.5 cm larger than the average size caught in the demersal trawls.

Toothed smelt was the second-most abundant species encountered in the gillnets. It occurred in 27% of the sets, mostly in more nearshore areas (Figure VIII-122), and accounted for about 15% of all fish caught. Again, all individuals were captured with the three smallest-sized meshes (Table VIII-76) with the 21 mm shackle accounting for over 90% of all fish caught. Overall, sizes ranged from 12 to 24 cm and averaged nearly 15.7 cm (Figure VIII-121), slightly more than trawl-caught fish.

Arctic char and pink, chum, and king salmon, four members of the family Salmonidae, were the third through sixth-most abundant species encountered during the gillnet operations. None of these species, however, had a total survey catch exceeding nine individuals. The length, weight, sex, and age (when available) for each salmonid caught during the survey are presented in Table VIII-77. Gillnet set catches are indicated in Figure VIII-123.

Other species caught during gillnetting included pond smelt, Bering cisco, starry flounder, Arctic staghorn sculpin, shorthorn sculpin, and saffron cod.

In general, Pacific herring appeared to be the most abundant fish species occurring near the sea-surface in the survey region. The relative abundance of salmon may have been low since nearly the entire adult population had already completed their spawning migration into the river systems around the survey region. Information from the gillnet commercial fishery (Louis Barton, ADF&G, personal communication) suggests that gillnet surveys performed earlier in the season probably would have encountered substantial numbers of adult salmon (and char).

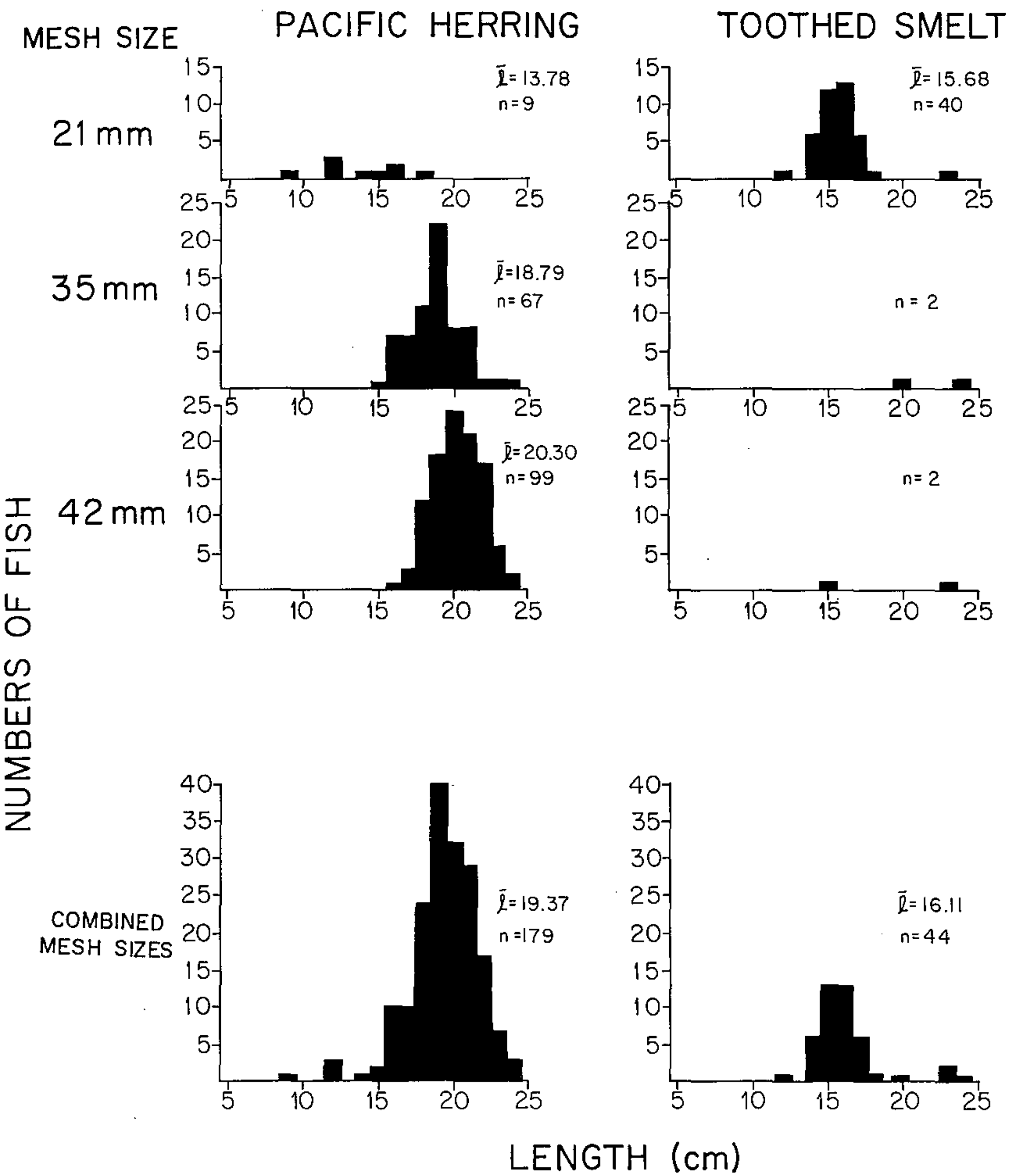


Figure VIII-121.--Size composition by mesh size for Pacific herring and toothed smelt caught by gillnets in Norton Sound, the southeastern Chukchi Sea and adjacent waters (BLM/OCS survey, 1976).

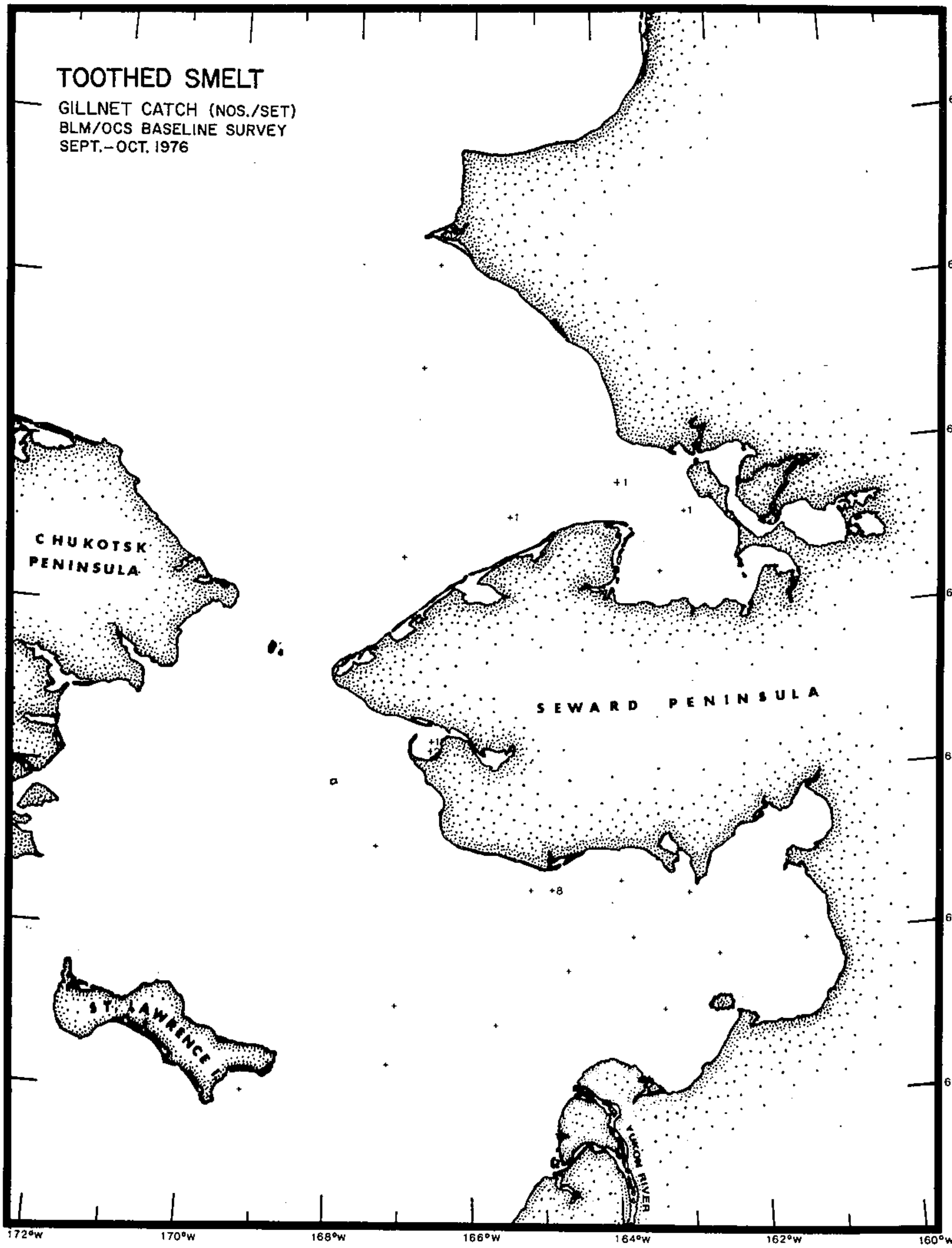


Figure VIII-122.--Numbers of toothed smelt caught at gillnet stations in Norton Sound, the southeastern Chukchi Sea and adjacent waters (BLM/OCS survey, 1976).

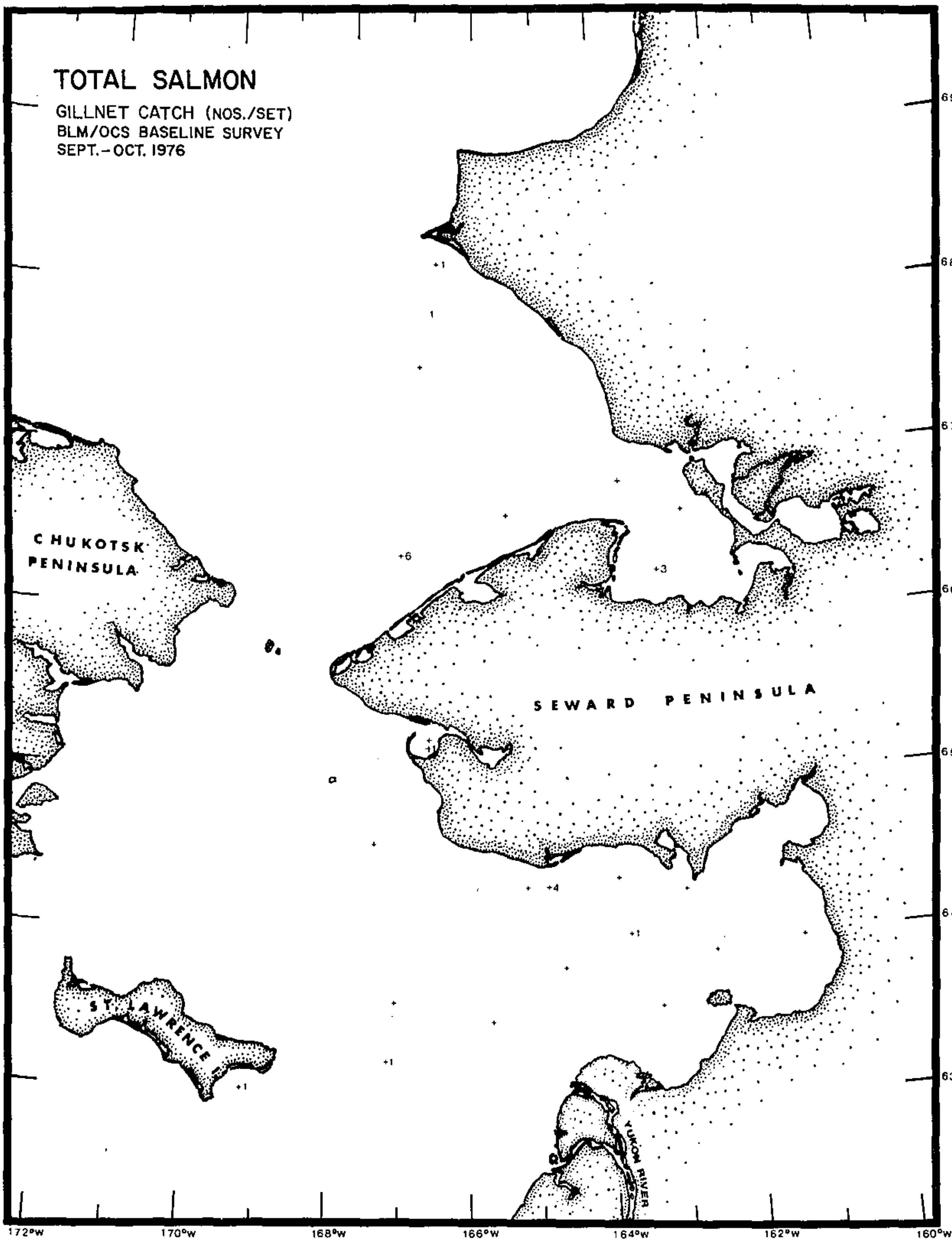


Figure VIII-123.--Numbers of salmon (all species combined) caught at gillnet stations in Norton Sound, the southeastern Chukchi Sea and adjacent waters (BLM/OCS survey, 1976).

Table VIII-77.--Age, length, and weight by sex of members of family Salmonidae captured by gillnets in Norton Sound and the southeastern Chukchi Sea (BLM/OCS survey, 1976).[1/]

Species	Sex	Length (cm)	Weight (kg)	Age
Chum salmon	Female	56.0	2.800	0.2[2/]
"	"	60.5	3.550	0.3
"	"	61.0	3.600	0.3
"	Male	61.0	3.600	0.3
"	"	63.6	4.200	0.4
"	Juvenile	17.8	0.053	0.0
King salmon	Juvenile	22.1	0.133	1.0
"	"	18.3	0.053	1.0
"	"	22.6	0.121	2.0
"	Female[3/]	77.9	6.700	1.3
Pink salmon	Juvenile	16.8	0.056	0.0
"	"	22.5	0.121	—
Bering cisco	Female	35.3	0.505	—
"	"	37.0	0.607	—
"	Male	34.6	0.531	—
Arctic char	Female	25.3	0.177	—
"	"	25.3	0.150	—
"	Male	24.2	0.116	—
"	"	24.2	0.116	—
"	"	25.9	0.180	—
"	"	24.5	0.157	—
"	"	24.6	0.155	—
"	"	25.9	0.185	—
"	"	25.5	0.163	—

1/ Small juveniles of some species were unmeasurable because they were damaged when removed from the gillnet.

2/ Freshwater annuli • Ocean annuli.

3/ Trawl caught.

RESULTS OF THE PELAGIC SURVEY

Hydroacoustical sounding revealed no extensive off-bottom fish concentrations. Time limitations and equipment malfunctions restricted pelagic trawl operations and resulted in only 8 sets (Figure VIII-124) for the entire survey.

Catches were extremely small and provided limited qualitative information. The largest pelagic trawl catch (15 fish) occurred near the entrance to Kotzebue Sound and included toothed smelt, saffron cod, Arctic char, and juvenile pink salmon.

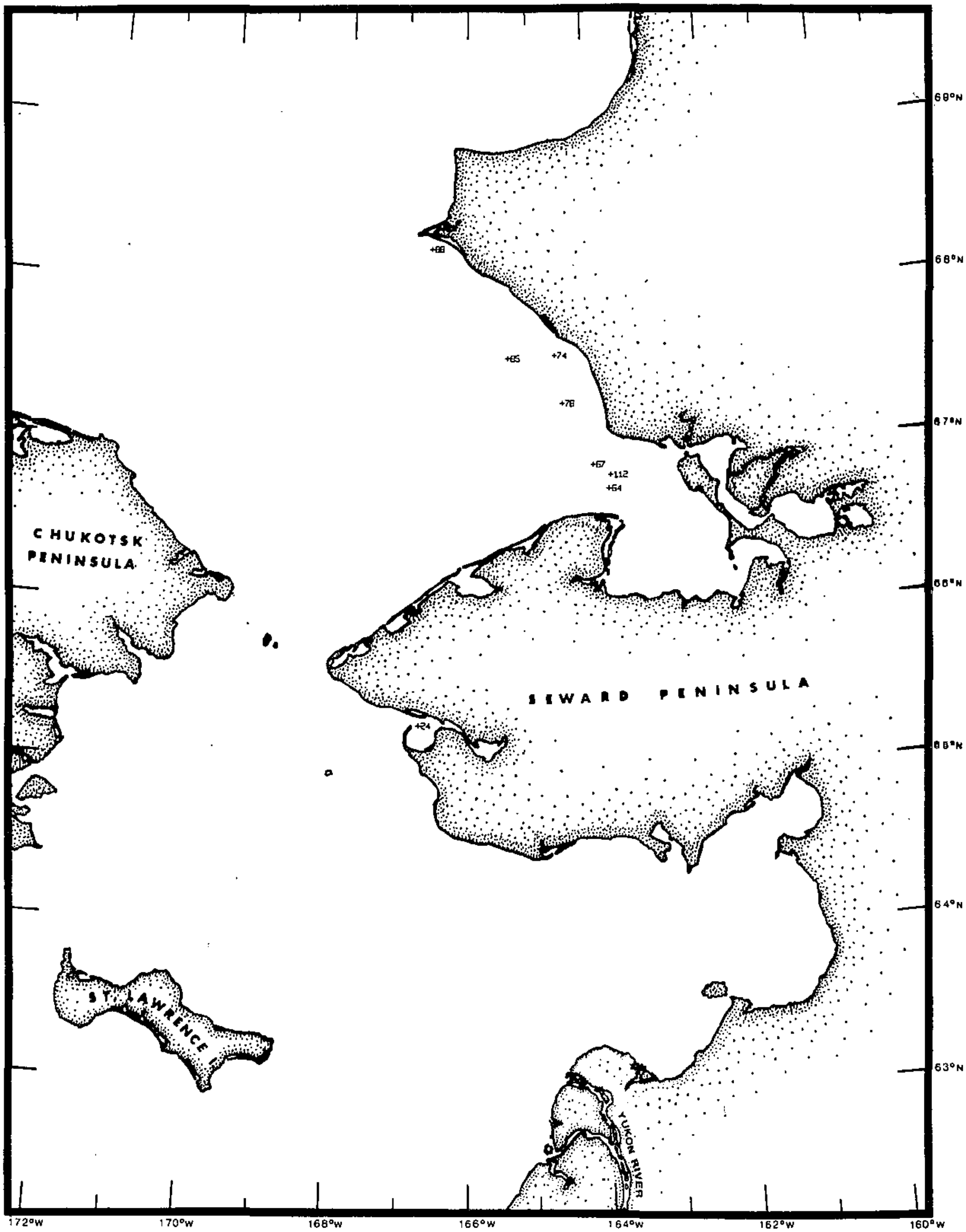


Figure VIII-124.--Pelagic trawl stations in Norton Sound, the southeastern Chukchi Sea and adjacent waters (BLM/OCS survey, 1976).

IX

FISH AND SHELLFISH RESOURCE INFORMATION FROM HISTORICAL SURVEYS

Prior to the 1976 survey, only three investigations were made which provided information on the distribution and abundance of fish and/or shellfish in or near the 1976 BLM/OCS study area. These were: an exploratory fishing survey by the Soviet Union in Siberian waters of the Bering and Chukchi Seas in 1933-34 (Andriyashev, 1937); an exploratory fishing survey by the U.S. Fish and Wildlife Service in Norton Sound and north of St. Lawrence Island in 1948-49 (Ellson et al., 1950); and, AEC sponsored studies (Project Chariot) of the Cape Thompson region in 1959 (Wilimovsky, 1966). Data from the 1933-34 and 1948-49 investigations were too general to be of use as baseline material, while the AEC studies provided a considerable amount of earlier information on marine fish and invertebrates for Alaskan waters north of the Bering Sea. Sparks and Pereyra (1966) and Abbott (1966) described the invertebrate fauna from the AEC survey, and studies of the marine fish community were documented by Alverson and Wilimovsky (1966). Although the quantity of fish taken during the AEC study was quite limited (less than 200 kg), a relatively substantial amount of abundance, distribution, and size composition information was obtained. Unfortunately, little or no detailed abundance and size composition data were reported for the invertebrates. Additionally, much of the area examined during the AEC work was located north of our 1976 survey region. In as much as the AEC data provides about the only detailed assemblage of information on marine fish stocks of the far northern waters off Alaska, a review of these data should provide valuable comparisons with results from the 1976 BLM/OCS survey.

This section of our report presents a brief summary of information from the AEC Project Chariot studies on the distribution, abundance, and size and age composition for those fish species examined in detail during the 1976 survey.

Catches from the 1959 AEC work were recorded in numbers caught per trawl haul and very little age data were obtained. To provide some comparability between 1959 catch data and our study results, overall species catch rates were converted to kg/km trawled. This conversion to kg/km was performed by multiplying the overall average number caught by a mean weight per individual from the 1976 data and assuming a standard trawling distance of 2.5 nautical miles or 4.6 km/hr.

Approximations of the relative abundance of age groups were determined by applying age-length keys from the 1976 data to numbers of fish per size interval in the 1959 length-frequency samples. The assumptions used in converting the earlier data into a format comparable to the 1976 information are quite broad. It is felt however, that these conversions should provide reasonable estimates of general conditions observed during the AEC study.

Rank Order of Abundance of Fish and Invertebrates

Analysis of the demersal trawl and bottom dredge data from the AEC survey indicate that over 220 invertebrate and 40 marine fish species were encountered in the southeastern Chukchi Sea during July–August 1959.

Decapod crustaceans were the most abundant and frequently encountered invertebrate taxa in the region (Table IX-1). Representatives of this group were present in all but one of the demersal sites sampled and comprised an estimated 23% of all invertebrates captured. Dominant forms included crangonid and hippolytid shrimp and hermit and Tanner (C. opilio) crabs. Other components of the invertebrate community which were encountered at over half the stations sampled included: starfish, gastropod and pelecypod molluscs, amphipod crustaceans, ophiuroideans, annelid worms, anthozoan coelenterates, and ascidians. These other components accounted for an additional 58% of the total number of invertebrates caught.

Only three fish species, Arctic cod, Arctic staghorn sculpin, and Bering flounder were present in over half of the demersal trawl catches (Table IX-2). Other fish taxa encountered in several trawl catches (32 to 45%) included ribbed sculpin, unidentified eelpouts, and two cottid species from the genera Artidellus and Myoxocephalus. Of the twenty fish taxa most frequently encountered during the 1959 AEC study, seven were representatives of family Cottidae.

Distribution and Biological Features of Certain Fish Species

Arctic cod--Arctic cod was the most frequently encountered and by far the most abundant fish species captured during the 1959 trawl survey. It occurred in nearly 72% of the demersal trawl stations and comprised 59% of the total number of fish taken. Relatively high abundance (> 100 individuals/hour trawled) was found throughout a wide area from south of Pt. Hope to north of Cape Lisburne (Figures IX-1 and 2) with maximum catch rates approaching 2000 fish/hour. Relative abundance was fairly low with the southern portion of the area surveyed (Cape Thompson to the Seward Peninsula) having trawl catches never exceeding 50 fish/hour trawled. Overall, the average catch rate for the entire 1959 survey was slightly less than 59 fish/hour or, in terms of weight per distance, an estimated 0.20 kg/km trawled.

Size composition information from the AEC study indicated Arctic cod found in the southeastern Chukchi Sea during the summer of 1959 ranged in length from 9 to 31 cm and averaged 15.9 cm (Figure IX-3). Two modes were observed in the length frequency samples, at 10-13 cm and 15-20 cm. The latter mode included nearly 70% of all fish measured.

Comparisons of the 1959 size data with the 1976 survey north otolith area age-length key suggest that 1 to 6 year old Arctic cod were present in the AEC study area and age groups 2-4 were dominant. The dominant age groups comprised an estimated 87% of all individuals examined. Only 4% of the fish subsampled from the AEC catches appeared to be 1 year olds and no age group 0 Arctic cod were thought to be present.

Table IX-1.--Rank order by frequency of occurrence and relative abundance of the 20 most common invertebrate taxa in the southeastern Chukchi Sea (AEC survey, 1959). (Adapted from Sparks and Pereyra, 1966).

Rank	Taxon	Percent frequency of occurrence 1/	Relative abundance index 2/
1	Decapod crustaceans	98.6	5882.5
2	Starfish	77.0	2253.4
3	Gastropod molluscs	70.3	1064.5
4	Amphipod crustaceans	67.6	1039.0
5	Pelecypod molluscs	63.5	1422.5
6	Omphiuroidean echinoderms	62.2	2797.5
7	Annelid worms	56.8	2048.0
8	Anthozoan collenterates	56.8	1267.1
9	Ascidians	55.4	2715.0
10	Holothuroidean echinoderms	41.9	1354.0
11	Echinoidean echinoderms	32.4	922.5
12	Cirripedia crustaceans	32.4	625.0
13	Scyphozoa coelenterates	29.7	485.0
14	Bryzoans	27.0	377.7
15	Sponges	23.0	664.0
16	Hydrazoan coelentrates	21.6	286.4
17	Sipunculoidea (coelomate worms)	20.3	59.1
18	Nemertian worms	18.9	47.5
19	Isopod crustaceans	13.5	25.0
20	Amphineura molluscs	10.8	51.4

1/ Number of sampling stations (trawls or trawls and dredge): 74.

2/ Total number of animals present in all samples adapted from rank key presented by Sparks and Pereyra (1966).

Table IX-2.--Rank order by catch rate (numbers/trawl) and frequency of occurrence (percent) of the 20 most common fish taxa in the southeastern Chukchi Sea (AEC survey, 1959) (adapted from Alverson and Wilimovsky, 1966).

Rank	Taxon	CPUE 1/ (No./trawl)	Proportion of total CPUE 2/	Percent frequency of occurrence
1	Arctic cod	58.98	0.586	71.9
2	Arctic staghorn sculpin	10.58	0.105	68.4
3	Bering flounder	4.30	0.043	61.4
4	Capelin	4.04	0.040	22.8
5	*Artediellus* sp.	3.68	0.037	43.9
6	Ribbed sculpin	2.11	0.021	45.6
7	Toothed smelt	1.96	0.019	22.8
8	*Myoxocephalus* sp.	1.35	0.013	33.3
9	Saffron cod	1.32	0.013	24.6
10	Unidentified eelpouts	1.18	0.012	43.9
11	Unidentified snailfish	1.05	0.010	31.6
12	Sturgeon poacher	0.89	0.009	24.6
13	Leister sculpin	0.63	0.006	22.8
14	Slender eelblenny	0.60	0.006	24.6
15	Stout eelblenny	0.58	0.006	22.8
16	Yellowfin sole	0.54	0.005	14.0
17	*Triglops* sp.	0.53	0.005	14.0
18	Pacific herring	0.49	0.005	14.0
19	Unidentified sea poachers	0.46	0.005	28.1
20	Eyeshade sculpin	0.19	0.002	14.0

1/ Overall catch per unit effort, no./trawl. Total effort = 57 trawls.

2/ Proportion of total catch per unit effort, fish only. Total CPUE = 100.63 fish/1 hr. trawl haul.

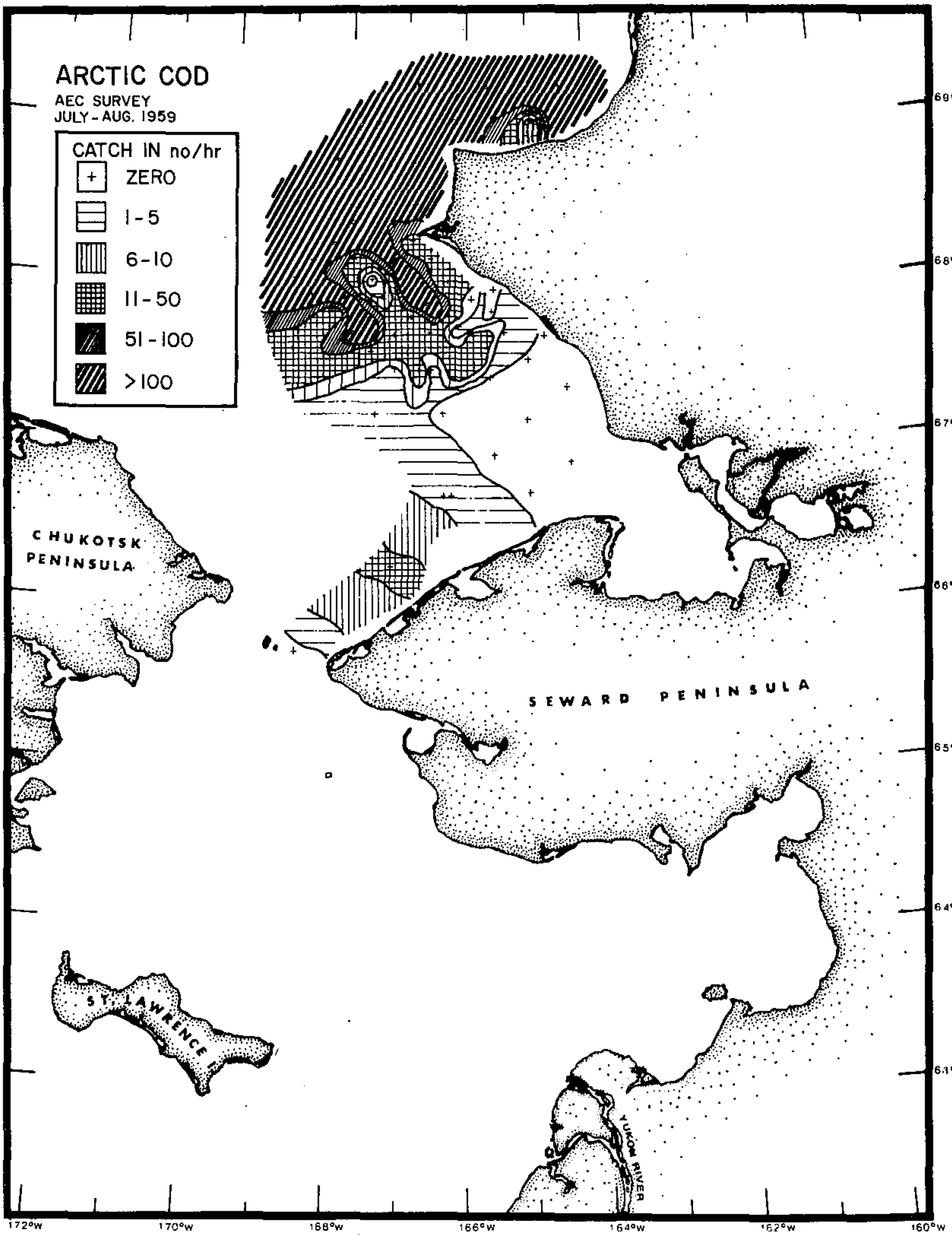


Figure IX-1.--Distribution and relative abundance by numbers of Arctic cod in the southeastern Chukchi Sea during 1959.

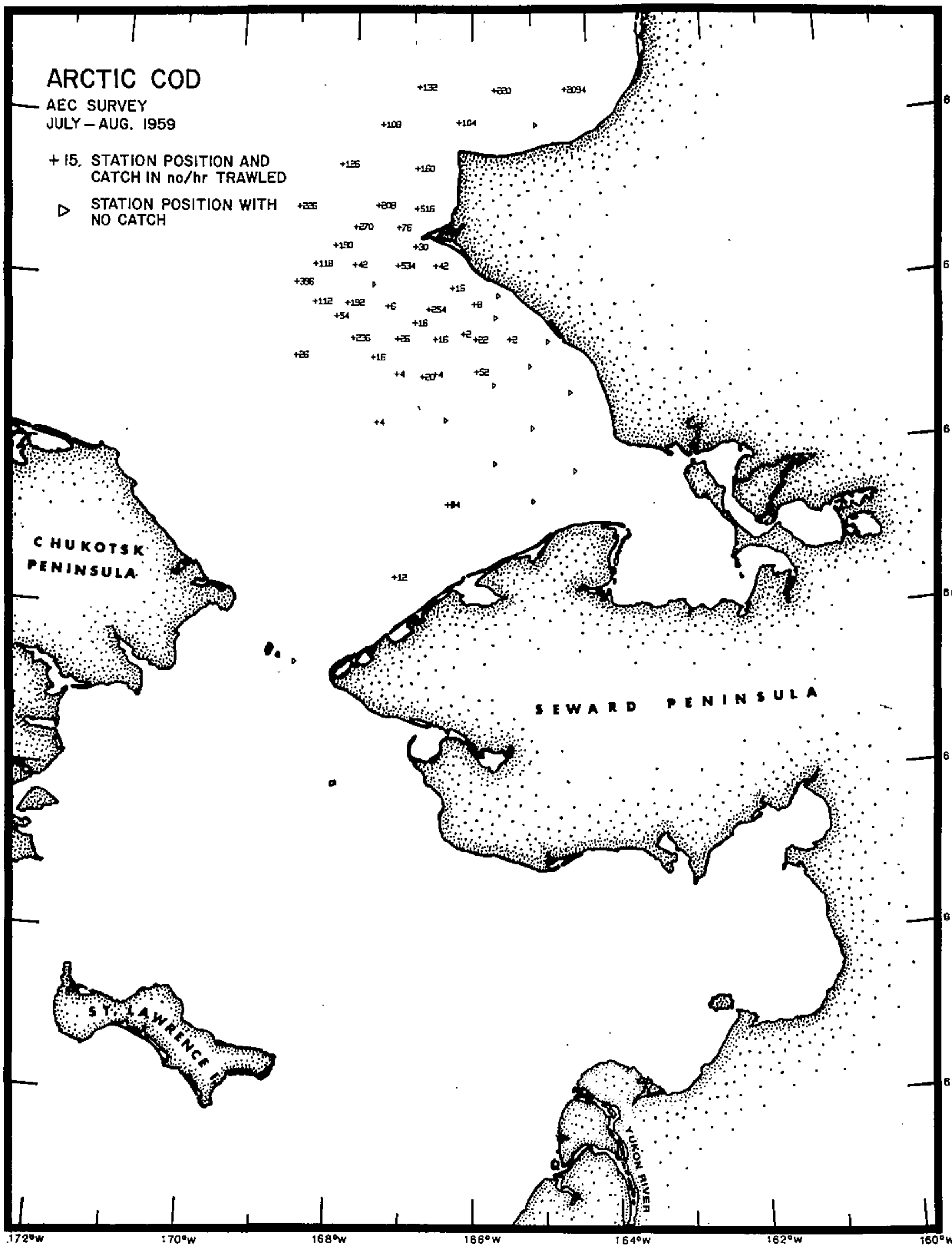


Figure IX-2.--Distribution of catch rates by numbers of Arctic cod in the southeastern Chukchi Sea during 1959.

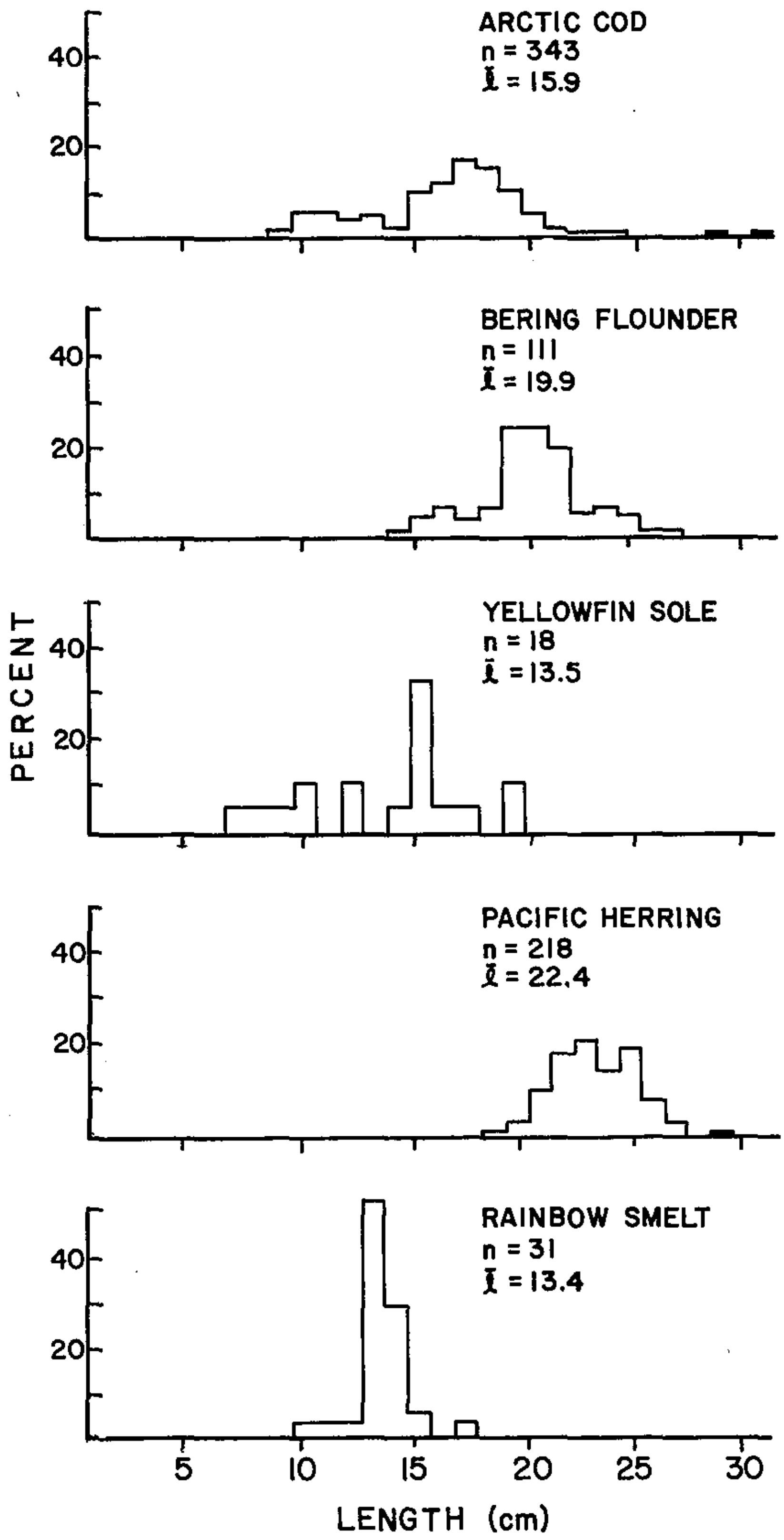


Figure IX-3.--Size composition and mean size for five fish species encountered during the 1959 AEC survey of the southeastern Chukchi Sea. (Adapted from Alverson and Wilimovsky, 1966).

Bering flounder--This pleuronectid was the third-most abundant fish species encountered in 1959, and occurred at over 61% of all stations sampled. Even though only two other species were captured in greater total numbers, the entire Bering flounder catch during the AEC survey was merely 252 fish, or 4% of the total number caught. Highest relative abundance was located off Pt. Hope (Figures IX-4 and 5). Overall, the average catch rate for this species was only 4.3 fish/hour trawled or, in terms of weight caught per distance, 0.08 kg/km. Pruter and Alverson (1962) indicated that during the 1959 study, most Bering flounder catches were associated with areas of relatively low temperature (2.6-3.6°C) and depths greater than 44 m.

Bering flounder measured during the 1959 survey of the southeastern Chukchi Sea ranged between 14 and 26 cm in length and averaged 19.9 cm (Figure IX-3). Most fish (64%) were in the 19-21 cm size range. Pruter and Alverson (1962) indicated an overall range in age of 6 to 13 years for Bering flounder in the AEC catches with individuals in the 19-21 cm size interval being mostly 8 and 9 year olds. Additionally, nearly all specimens were mature. This seems to contradict statements made earlier by Andriyashev (1937) regarding Bering flounder obtained during 1933-34 Soviet surveys of the Chukchi Sea. All specimens obtained during the Soviet studies were juveniles and ranged in length from 6 to 16 cm. Differences between the samples obtained during the AEC work and Soviet investigations probably were due to differing survey areas. The very early data described by Andriyashev (1937) came from Asian waters of the Chukchi Sea, a region known to possess colder water temperatures than those found off the coast of Alaska.

Toothed smelt--Very few toothed smelt were taken in the southeastern Chukchi Sea during the 1959 trawl survey. Of those fish encountered, all were found in the shallow nearshore stations and highest relative abundance occurred off the entrance to Kotzebue Sound (Figure IX-6). Size of toothed smelt in the AEC catches ranged only from 10-17 cm with an average length of 13.4 cm (Figure IX-3). Based on a comparison of the 1959 size data with 1976 age length keys, toothed smelt captured during the AEC study probably ranged in age from 3 to 7 years and an estimated 84% of all fish examined were age groups 4 and 5.

Saffron cod--Only 75 specimens of saffron cod were encountered during the entire AEC survey, and no size composition information was obtained. Of those fish taken, nearly all were found in shallow nearshore areas with highest concentrations located between Cape Lisburne and Pt. Hope, north of Kotzebue Sound (Figure IX-7). Fish were rarely encountered at trawl stations where depths exceeded 25 m. Since no length frequency data was obtained, no inference can be made regarding size and age composition.

Pacific herring--Very small catches of Pacific herring were encountered during the 1959 trawl survey. Highest relative abundance occurred nearshore, especially off Cape Thompson (Figure IX-8), but catch rates never exceeded 30 fish/hour trawled. Although demersal trawl catches were quite limited, a gillnet station, also near Cape Thompson, yielded an estimated 1000 herring, the largest catch taken by any of the survey gears.

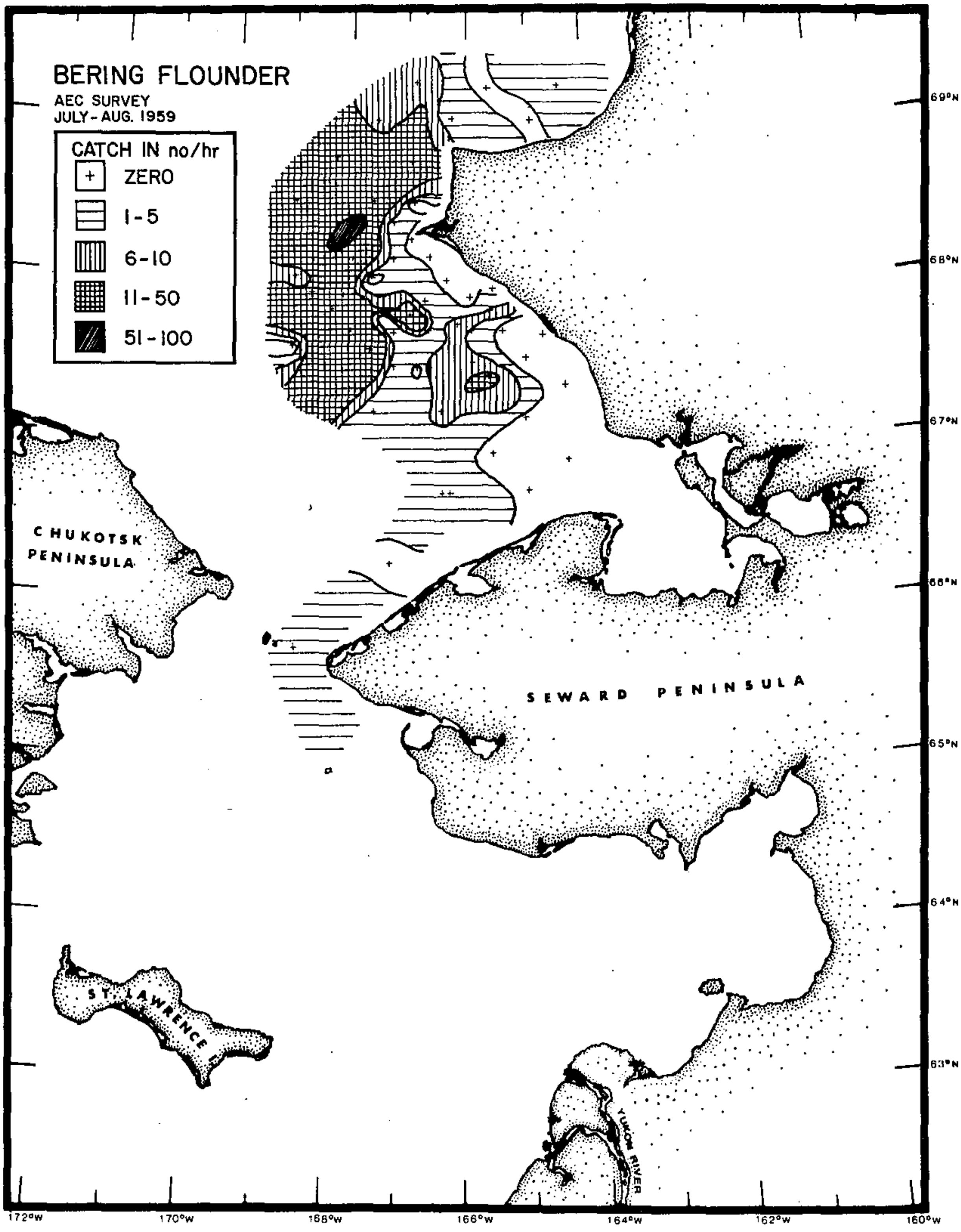


Figure IX-4.--Distribution and relative abundance by numbers of Bering flounder in the southeastern Chukchi Sea during 1959.

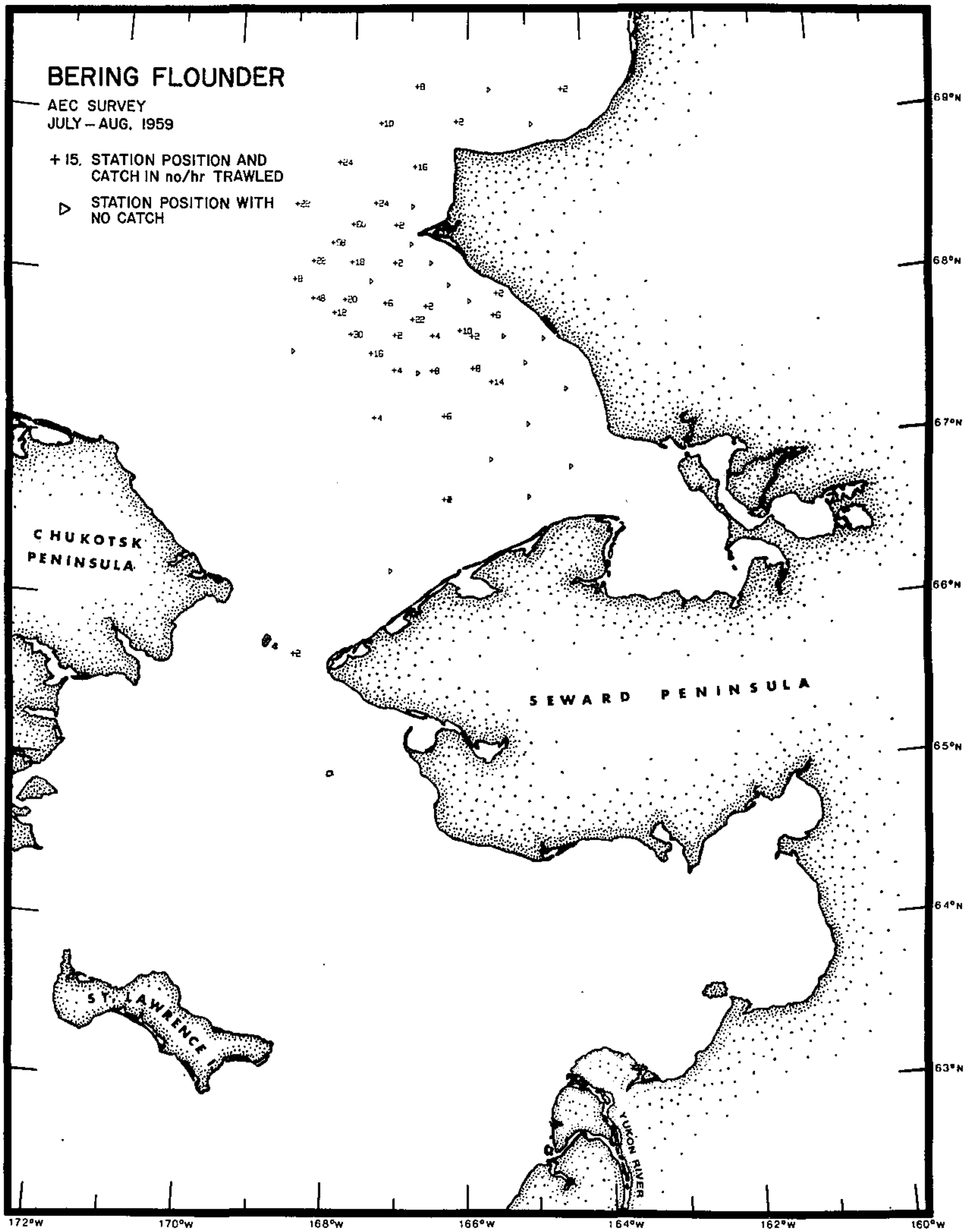


Figure IX-5.--Distribution of catch rates by numbers of Bering flounder in the southeastern Chukchi Sea during 1959.

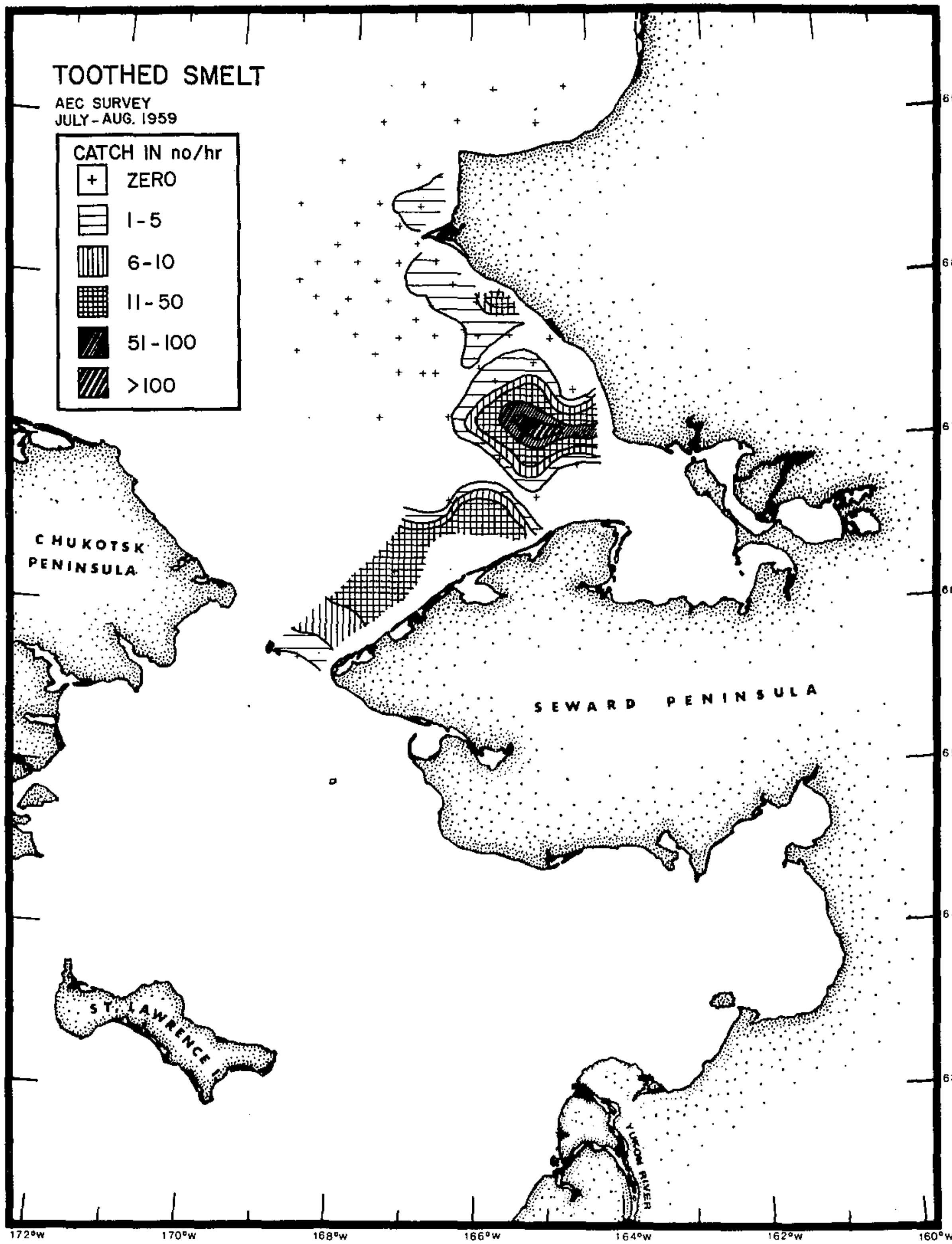


Figure IX-6.--Distribution and relative abundance by numbers of toothed smelt in the southeastern Chukchi Sea during 1959.

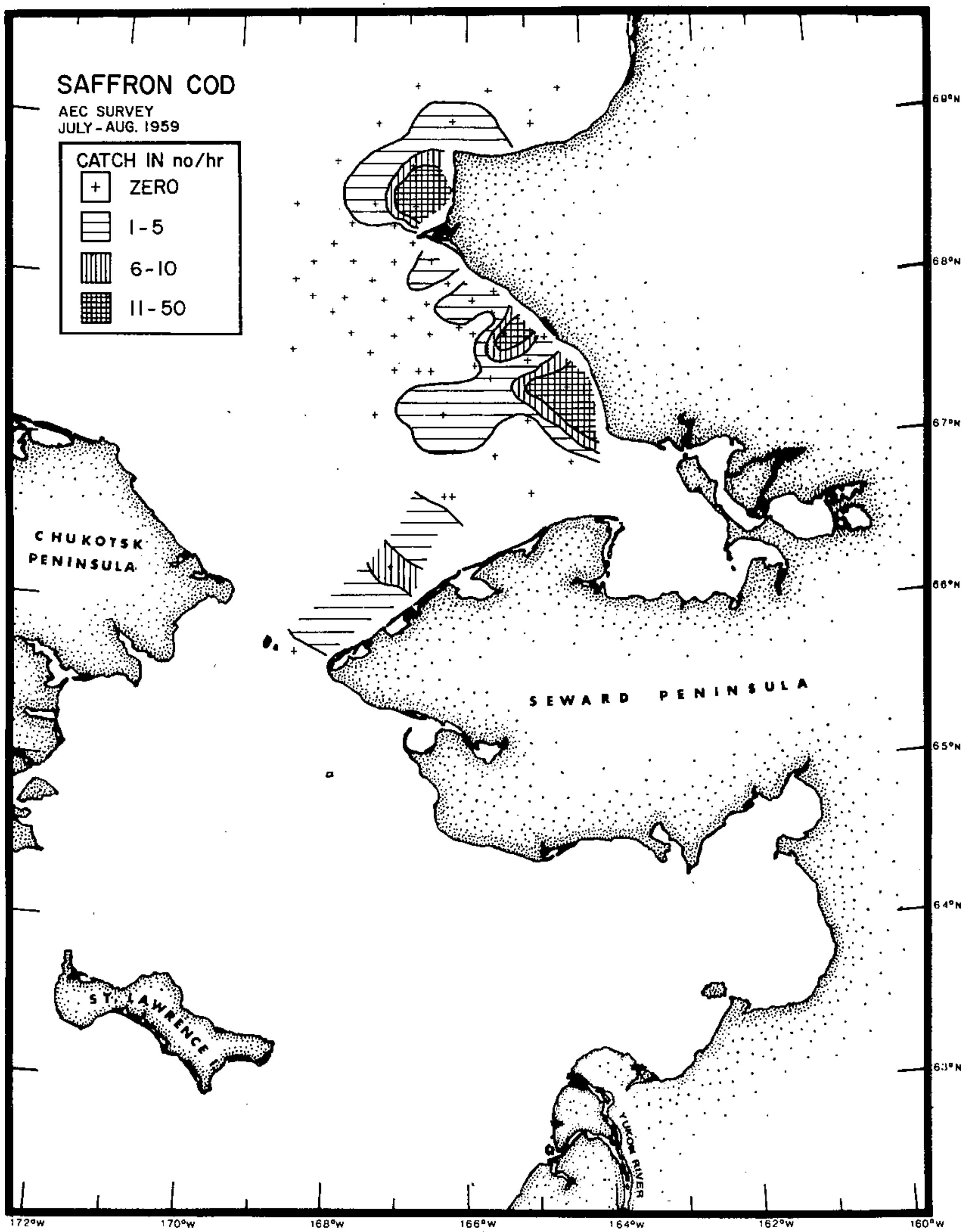


Figure IX-7.--Distribution and relative abundance by numbers of saffron cod in the southeastern Chukchi Sea during 1959.

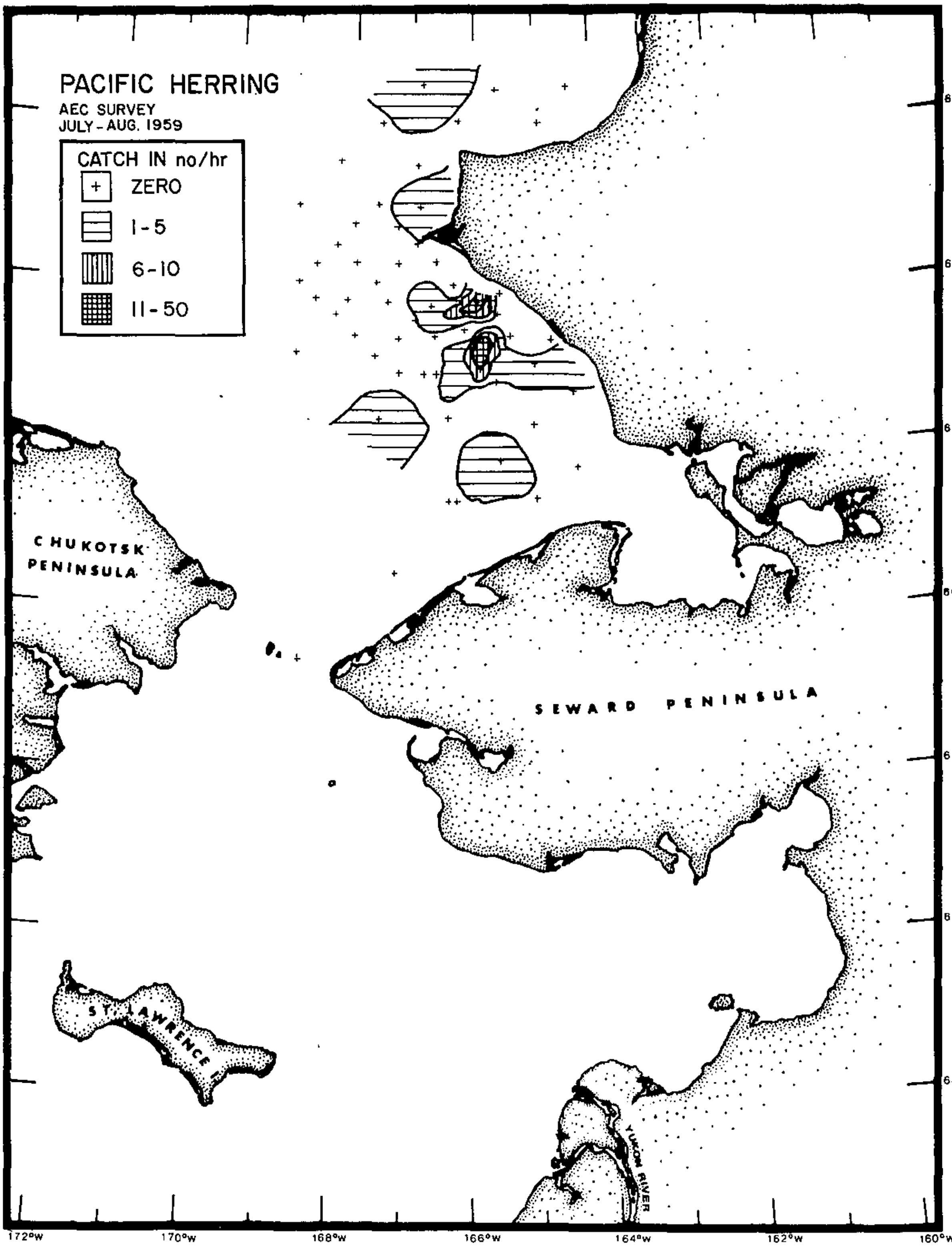


Figure IX-8.--Distribution and relative abundance by numbers of Pacific herring in the southeastern Chukchi Sea during 1959.

Sizes of trawl and gillnet caught fish, combined, ranged from 18 to 28 cm and averaged about 22 cm (Figure IX-3). A 1976 survey age-length key applied to the AEC samples suggests that ages ranged from 2 to 8 years with age groups 4-6 dominating.

Yellowfin sole--Only 31 individuals were taken during the AEC study. Most yellowfin sole were encountered in shallow, nearshore, warmer-water areas. Pruter and Alverson (1962) stated that during the 1959 study over 80% of all specimens were found at stations where depths ranged from 18 to 26 m and bottom temperatures exceeded 7°C.

Fish taken from the southeastern Chukchi Sea during 1959 were small, ranging from 7 to 19 cm in length and averaged about 13 cm (Figure IX-3). Age structures were obtained from 11 specimens and indicated a range in ages from 1 to 6 years.

SUMMARY

The 1976 BLM/OCS baseline demersal survey indicated a combined fish and invertebrate biomass of nearly 338,000 mt for the waters of Norton Sound, the southeastern Chukchi Sea, and adjacent areas. This amount seems quite substantial but in comparison to biomass estimates for other regions of the Alaska continental shelf, it is actually quite small. Results from the 1975 BLM/OCS survey of the eastern Bering Sea indicated a biomass approaching 5.9 million mt for that region (Kaimmer et. al., 1976). On a weight per area basis, the eastern Bering Sea demersal fish and invertebrate biomass averaged nearly 11.9 mt/km^2 while the biomass estimate for the Norton Sound-Chukchi Sea region averaged only 2.6 mt/km^2.

Biomass differences between our survey region and the eastern Bering Sea are even greater when specific components of the demersal community are compared. The primary purpose of both the 1975 and 1976 surveys was to intensively examine demersal fishes and shellfish of current or potential economic importance. These faunal elements comprised over 90% of the apparent biomass of the eastern Bering Sea (Figure X-1) but less than 25% of that estimated for our survey region, a nearly 60-fold difference in the magnitude of demersal fish and shellfish resources for the two continental shelf areas.

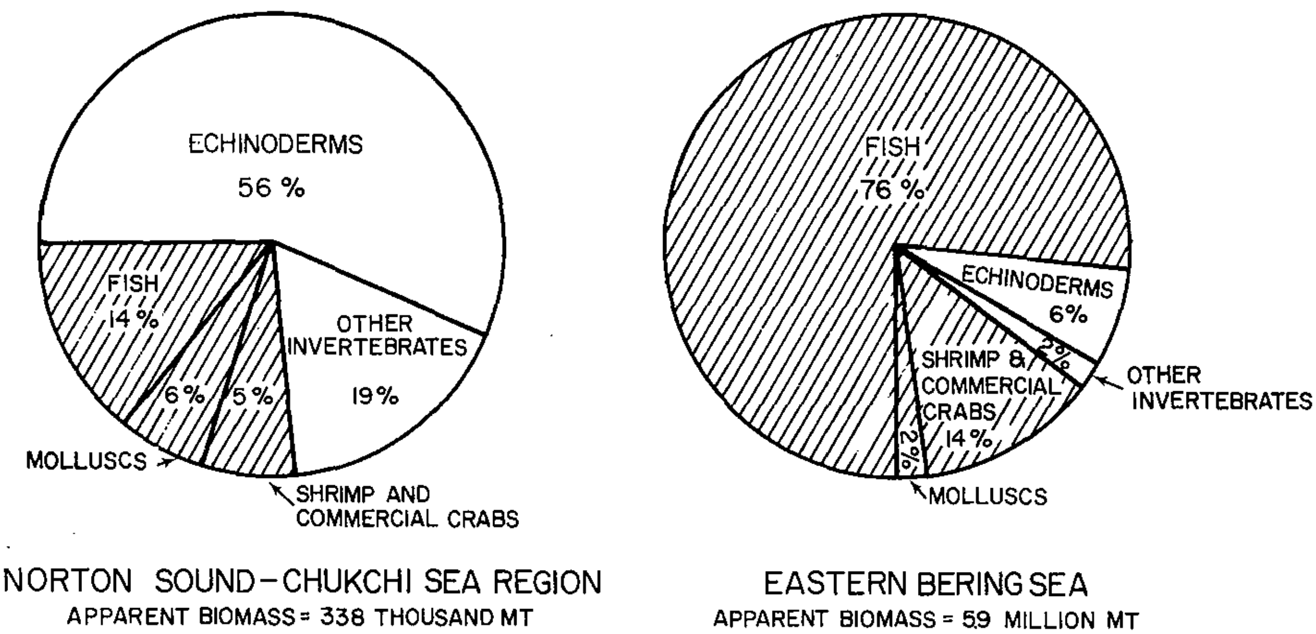


Figure X-1.--Relative importance of demersal species groups in the Norton Sound-Chukchi Sea and eastern Bering Sea regions in terms of apparent biomass. Biomass estimates are from results of the 1976 BLM/OCS baseline survey of Norton Sound and the southeastern Chukchi Sea and from Alton (1976).

Even though the demersal resources present in the Norton Sound-Chukchi Sea region do not approach quantities present elsewhere, information concerning these northern stocks is essential to enlarge our knowledge of the biota in all areas of the Alaska continental shelf. A summary of the major findings from the survey follows:

1) Results of the 1976 BLM/OCS demersal survey of Norton Sound, the southeastern Chukchi Sea, and adjacent waters indicate that highest relative abundance for nearly all fish and invertebrates occurred south of Bering Strait, especially in Norton Sound.

2) Starfish and other invertebrates of little or no potential economic importance had an estimated biomass of over 250,000 mt. This amount comprised 74% of the entire biomass estimated for the survey region.

3) Gadidae and Pleuronectidae were the dominant fish families encountered during the survey and had a combined estimated biomass of over 33,000 mt. This amount accounted for 70% of the total fish biomass estimated for the survey area. Cottidae, Osmeridae, and Clupeidae accounted for an additional 25% of the total fish biomass.

4) The eight most abundant fish species in the survey region, by rank order of estimated biomass were: saffron cod, starry flounder, shorthorn sculpin, Pacific herring, toothed smelt, Alaska plaice, yellowfin sole, and Arctic cod.

5) Most of the dominant fish species were found in highest relative abundance in areas south of Bering Strait and where bottom waters were warmer than 4°C and shallower than 30 m (Figure X-2).

6) Arctic cod was an exception to relative abundance trends for the dominant fish species. Relatively high abundance of this species occurred at nearly all bottom temperatures and at depths greater than 20 m.

7) Almost no fish species was encountered in either sufficient size of quantity to be considered as potential for commercial harvest. Pacific herring is the only non-salmonid species presently taken in a commercial fishery in the survey region. Recent harvests have been very small and attempts to greatly expand harvest levels do not appear likely.

8) Survey information on age-length and length-weight relationships indicate age and growth differences north and south of Bering Strait for several fish species. Pacific herring, toothed smelt, yellowfin sole, and Alaska plaice all displayed greater lengths-at-age and maximum sizes south of Bering Strait than to the north, while saffron cod data suggested the opposite--largest size and lengths-at-age in the north. Definite reasons for growth differences by area are not provided by our data; however, differences were identified and seem to suggest some stock segregation within the survey region.

9) Little is known about spawning and nursery areas in the survey region. An examination of catch rates by stratum for the youngest two age groups

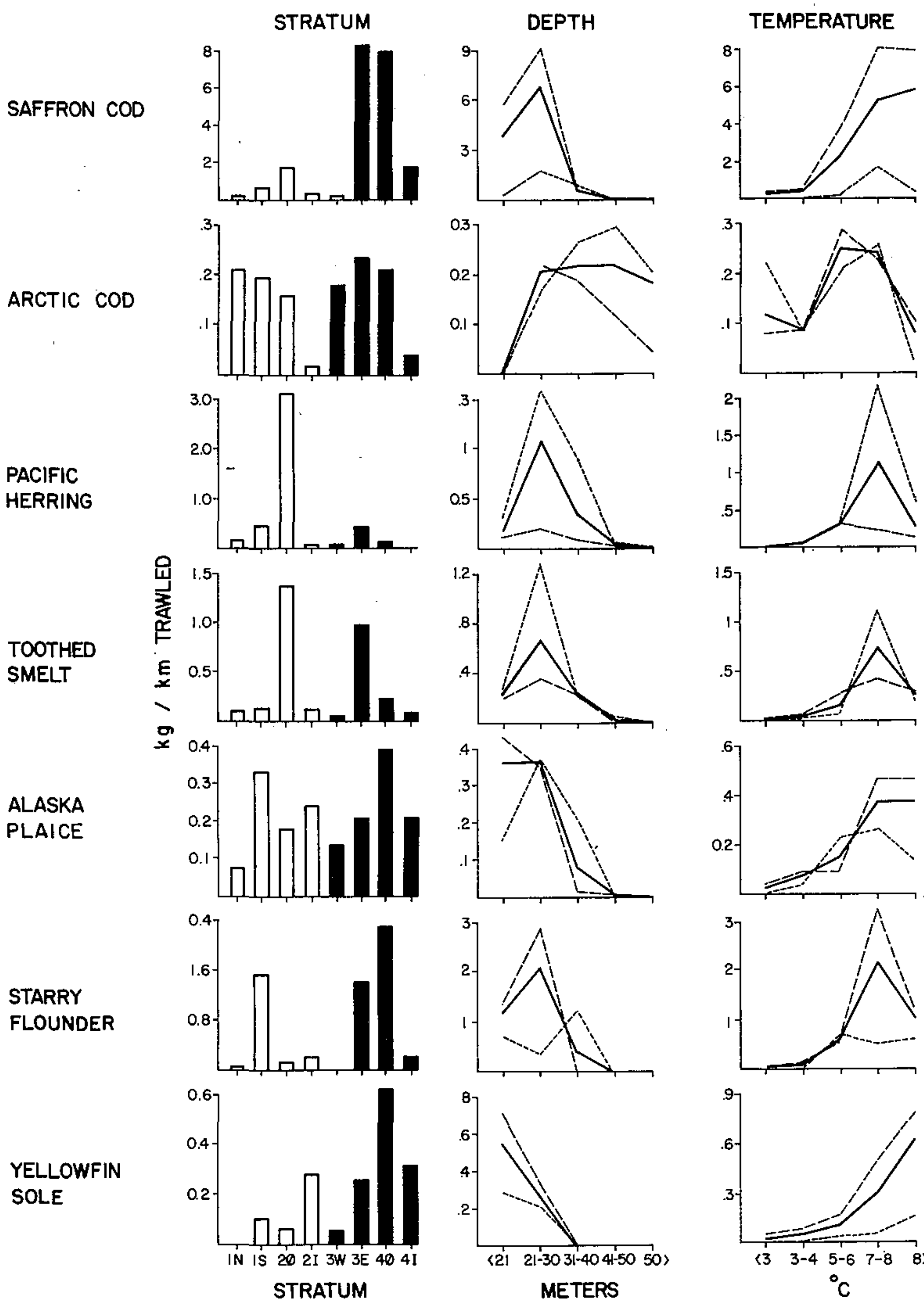


Figure X-2.--Average catch rates for dominant fish species by stratum, depth, and temperature, BLM/OCS survey, 1976. (Shaded bars and broken lines represent strata south of Bering Strait. Unshaded bars and dotted lines represent strata north of Bering Strait).

of each dominant fish species provides some insight as to possible locations of spawning areas and nursery grounds. Highest relative abundance for young saffron cod, Pacific herring, starry founder, Alaska plaice, and yellowfin sole was found in Norton Sound (Figure X-3). For species with more arctic distributions, Arctic cod and toothed smelt, either cold-deep waters or regions north of Bering Strait provided the areas of highest density of young fish.

10) About 2/3 of the area surveyed during the 1959 AEC work in the southeastern Chukchi Sea coincided with portions of our 1976 survey region (primarily stratum 1N). A general comparison of species composition and relative species abundances between the 1959 and 1976 data for this overlapping region suggests that no major changes have occurred in the fish community of the southeastern Chukchi Sea since that earlier study.

11) Three crab species of economic importance in other Alaskan waters, red and blue king crabs and Tanner crab (C. opilio), were encountered in the study region during the 1976 survey. Biomass estimates for all three species were quite low and all individuals encountered were very small.

12) Less than 1% of the estimated population of 5 million red king crabs were larger than the minimum size (135 mm carapace length) for commercial harvests in any region of Alaska. None of the blue king crabs or Tanner crabs were of sufficient size to be harvested under present size restrictions in any king or Tanner crab fishery.

13) A moderate snail biomass of 19,000 mt was estimated present in the survey region. Shell sizes of several species are similar to those taken in the Japanese harvest of snails in the eastern Bering Sea.

14) The clam population in the survey region appears to be large. One species, the greenland cockle, was encountered in almost half of our demersal catches. A trawl is a very ineffective means of sampling infauna; however, catches of this pelecypod species occasionally approached 150 individuals per trawl haul.

15) The gillnet and pelagic trawling portions of the 1976 survey offered little information on mid-water or near-surface fish populations in the study area. Pacific herring was the most commonly encountered fish species in the very sparse off-bottom sampling.

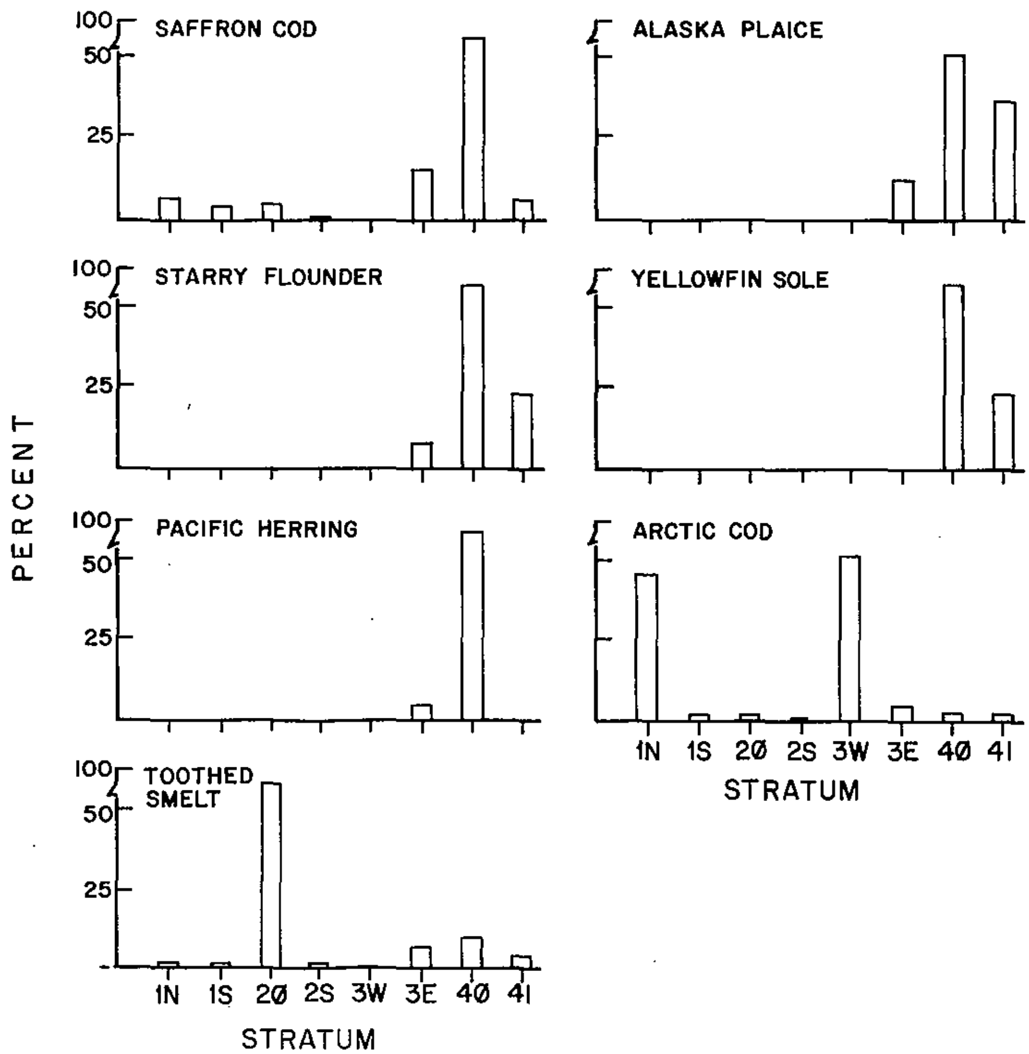


Figure X-3.--The proportion of total average catch rate by stratum of the youngest two age groups of each dominant fish species taken during the 1976 BLM/OCS survey of Norton Sound, the southeastern Chukchi Sea, and adjacent waters. (Numbers in parentheses indicate the age groups for which a catch rate was determined).

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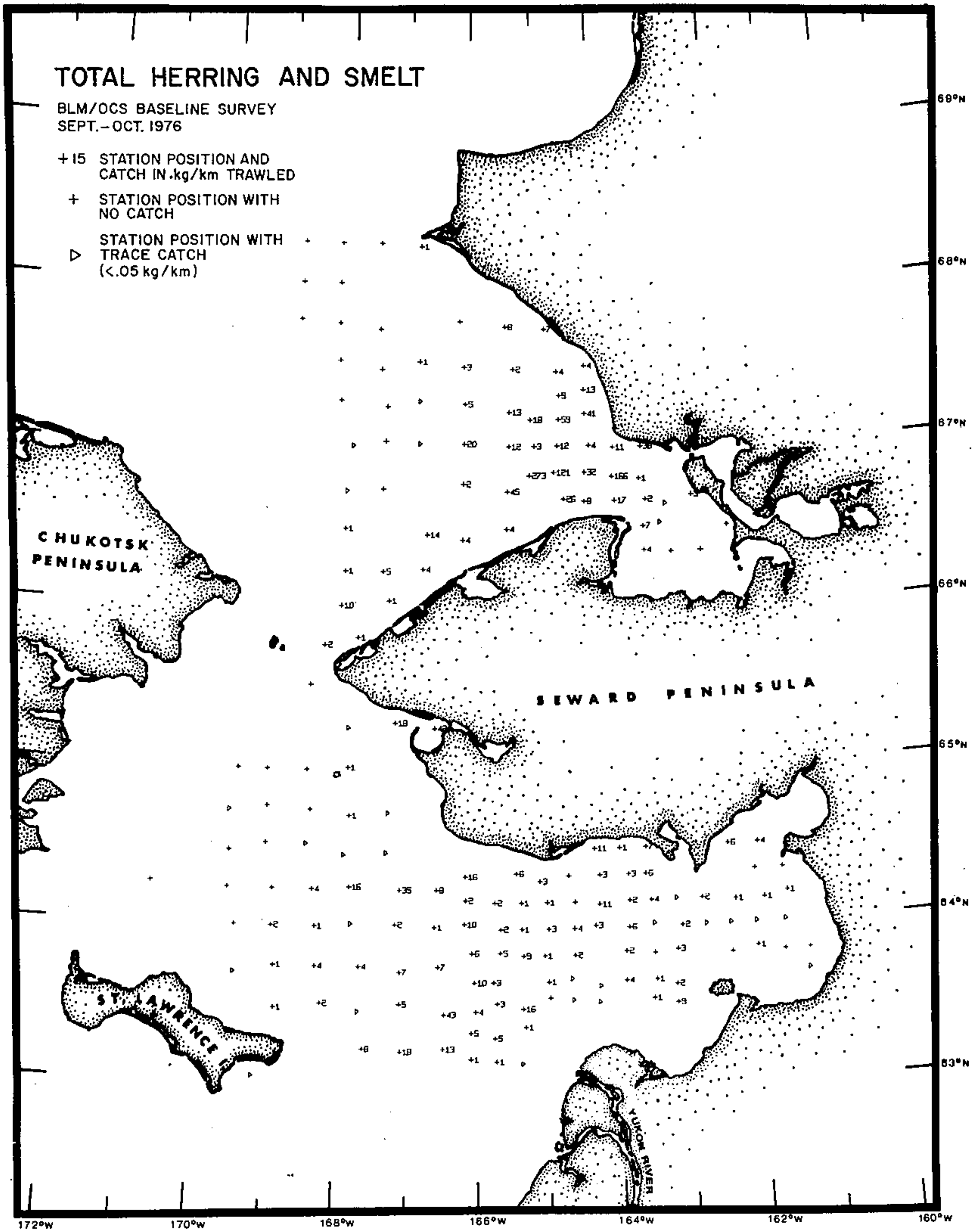

Figure VIII-22.--Distribution of catch rates by weight of herring and smelts in Norton Sound, the southeastern Chukchi Sea and adjacent waters (BLM/OCS survey, 1976).