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Outer Continental Shelf Environmental Assessment Program

Final Reports of Principal Investigators

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ENVIRONMENTAL ASSESSMENT PROGRAM

FINAL REPORTS OF PRINCIPAL INVESTIGATORS

VOLUME 32

JUNE 1985

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NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
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OFFICE OF OCEANOGRAPHY AND MARINE ASSESSMENT
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Outer Continental Shelf Environmental Assessment Program

Final Reports of Principal Investigators

VOLUME 32 JUNE 1985

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INFAUNA OF THE NORTHEASTERN BERING AND SOUTHEASTERN CHUKCHI SEAS

by

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Final Report
Outer Continental Shelf Environmental Assessment Program
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I. SUMMARY OF OBJECTIVES, CONCLUSIONS, AND IMPLICATIONS WITH RESPECT TO OCS OIL AND GAS DEVELOPMENT

The objectives of this study were: (1) a quantitative inventory of dominant infaunal invertebrates (inclusive of small, slow-moving epifaunal species) at selected stations in the study areas, (2) a description of spatial distribution patterns of species in the designated study areas, and (3) limited observations of biological interrelationships, emphasizing trophic interactions, between selected segments of the benthic biota.

A total of 47 widely dispersed stations for quantitative grab sampling were established in the eastern Bering and southeastern Chukchi Seas and were analyzed for this report. The stations were primarily located within or adjacent to the sites of four oil lease areas: the Zhemchug Basin, the Navarin Basin, the St. Matthew Basin, and the Hope Basin. Stations were also occupied within and near the Chirikov Basin.

Six hundred and forty-seven taxa were identified. It is probable that all taxa with numerical and biomass importance have been collected in the areas of investigation and that only rare taxa will be added in future sampling.

Criteria established for Biologically Important Taxa (BIT) delineated 128 taxa, with 62 of these identified as important in biomass at one or more stations.

Multivariate techniques were employed to examine groupings of stations and taxa in the study areas. In order to use multivariate techniques, a significant reduction in the number of taxa to be used in the analyses was necessary. Only those taxa identified to at least the generic level, occurring at three or more stations, and designated as BIT, were included in the numerical analyses; 189 such taxa were included.

The combined use of the multivariate techniques of cluster and principal coordinate analyses led to generalizations concerning station groups and species assemblages in the study areas:

1. A normal cluster analysis of transformed density data produced eleven station groups at the 21% similarity level. Three large station groups

(A', B, and D) were identified within and adjacent to the Navarin Basin lease area. One major station group (B) and two minor single-station groups (Station 74 [Group F] and Station 73 [Group C]) made up the Zhemchug Basin lease area. One small station group (Group E) described the St. Matthew Basin lease area. Two small station groups (Groups C and H) were identified within and adjacent to the Hope Basin lease area. A distinctive station (Group I; Station 31) occurred north of Etolin Strait and Nunivak Island. Two small station groups occurred adjacent to Cape Nome (Group A") and north of St. Lawrence Island (Group J). One station (Group G; Station 56) characterized Bering Strait, and a small station group (Group F) was located just north of the strait.

2. Forty-two species groups were identified by an inverse cluster analysis of tranformed density data at the 23% similarity level. The distribution of twenty of these groups showed a good association with the major station groups.

3. A normal cluster analysis of untransformed density data produced ten station groups at the 22% similarity level. This analysis, which places emphasis on the dominant species, resulted in one major station group (A'1) encompassing most of the Navarin Basin and Zhemchug Basin lease areas; all of the stations in these lease areas deeper than 100 m were included in this group. The status of none of the other station groups changed with this analysis.

The percent frequency of occurrence of motility and feeding classes in station groups that were formed by cluster analysis of *ln*-transformed density was calculated. The most frequent type of motility in each station group was of taxa that were motile. Deposit-feeding organisms dominated the feeding classes in all station groups.

Knowledge of species composition within the station groups in the eastern Bering and southeastern Chukchi Seas made it possible to make a preliminary assessment of the ecological consequences of damage to or loss of any of the known or prospective food species within the stations or station groups. Many of the more common deposit-feeding infaunal species in the Zhemchug and Navarin Basin lease areas were actual or potential food resources for bottom-feeding species (e.g., Tanner crab and bottom fishes), and loss of any or all of these food organisms could disrupt the trophic system involving these species. The dense populations of infaunal species in the vicinity of the St. Matthew Basin lease area comprised many organisms commonly taken by benthic predators elsewhere in the Bering Sea, and damage to large numbers of these organisms could negatively affect as yet unknown biological interactions in the region. In addition, the large numbers of tubes of the polychaete *Myriochele oculata* in the area just north of Etolin Strait and Nunivak Island (and adjacent to the St. Matthew Basin lease area) stabilize the bottom sediments there. Loss of or damage to a large segment of this polychaete population could destabilize the bottom sediments, resulting in the establishment of a new complement of dominant species. Obvious ecological changes might be expected if such damage occurred. A similar major ecological alteration of the bottom could occur in the Chirikov Basin, where large populations of tube-dwelling ampeliscid amphipods occurred. The latter problem could be compounded if recovery of the amphipod population did not take place prior to the annual summer feeding migration of gray whales (*Eschrichtius robustus*) to the area. The amphipods are a major food of the whales at this time, so depletion of the resource could be detrimental to these mammals. The Chirikov Basin and the region in the vicinity of St. Lawrence Island also contain dense populations of bivalve mollusks and other benthic food species that are used intensively at various periods of the year by bearded seals (*Erignathus barbatus*) and walruses (*Odobenus rosmarus divergens*). Contamination or loss of these food items would negatively affect a sizable percent of the populations of these mammals. The high benthic biomass characteristically observed in the Bering Strait and the southeastern Chukchi Sea in the vicinity of the Hope Basin lease area represents both a reservoir of food used by bottom-feeding fishes in warm years and a year-round food resource for the Tanner crabs (*Chionoecetes opilio*) resident in this region. The latter area is relatively shallow and could be easily contaminated by petroleum. Damage or loss of the high standing stocks of benthic food organisms could be critical to the predatory species that frequent the region, some of which (e.g., Tanner crab and flatfishes) are near the northern limits of their range.

Initial assessment of all data for the study areas suggests that: (1) sufficient station group uniqueness exists to permit development of monitoring programs based on taxon composition within the groups, using grab sampling, multivariate analysis, and selected statistical techniques; and (2) adequate numbers of biologically relatively well-known, abundant, and/or large species are available to permit nomination of likely monitoring candidates for the areas if oil-related activity is initiated.

II. INTRODUCTION

General Nature and Scope of Study

The operations connected with oil exploration, production, and transportation in the Bering and Chukchi Seas present a wide spectrum of potential dangers to the marine environment (see Olson and Burgess, 1967, for general discussion of marine pollution problems). Adverse effects on the marine environment of these areas cannot be quantitatively assessed, or even predicted, unless background data are acquired prior to industrial development.

Insufficient long-term information about an environment, and the basic biology and recruitment of species in that environment, can lead to erroneous interpretations of changes in types and density of species that might occur if the area becomes altered (see Pearson, 1971, 1972, 1975; Nelson-Smith, 1973; Rosenberg, 1973; and Pearson and Rosenberg, 1978, for general discussions of benthic biological investigations in industrialized marine areas). Populations of marine species fluctuate over a time span of a few to 30 years (Lewis, 1970; personal communication). Such fluctuations are typically unexplainable because of absence of long-term data on physical and chemical environmental parameters in association with biological information on the species involved (Lewis, 1970; personal communication).

Benthic organisms (primarily the infauna, but also the sessile and slow-moving epifauna) are particularly useful as indicator species for a disturbed area because they tend to remain in place, typically react to long-range environmental changes, and, by their presence, generally reflect the nature of the substratum. Consequently, the organisms of the infaunal benthos have frequently been chosen to monitor long-term pollution effects and are believed to reflect the biological health of a marine area (see Pearson, 1971, 1972, 1975; Rosenberg, 1973; and Pearson and Rosenberg, 1978, for discussion on long-term usage of benthic organisms for monitoring the effects of pollution).

The presence of large numbers of benthic epifaunal species of actual or potential commercial importance (crabs, shrimps, snails, finfishes) in the Bering Sea further dictates the necessity of understanding benthic communities, since many commercial species feed on infaunal and small epifaunal residents of the benthos (see Zenkevitch, 1963; Feder *et al.*, 1980a, b; and Feder and Jewett, 1981a, for discussions of the interaction of commercial species and the benthos). Any drastic changes in density of the food benthos could affect the health and numbers of these commercially important species.

Experience in pollution-prone areas of England (Smith, 1968), Scotland (Pearson, 1972, 1975; Pearson and Rosenberg, 1978), and California (Straughan, 1971) suggests that, at the completion of an initial exploratory study, selected stations should be examined regularly on a long-term basis to determine whether any post-development changes in species content, diversity, density, and/or biomass have taken place. Such long-term data acquisition should make it possible to differentiate between normal ecosystem variation and pollutant-induced biological alteration. Intensive investigations of the benthos of the Bering and Chukchi Seas are also essential for an understanding of both the trophic interactions involved in these areas and of the potential changes that could take place once oil-related activities are initiated. The benthic macrofauna of the Bering and Chukchi Seas is relatively well known taxonomically, and some data on distribution, density, general biology, and feeding mechanisms are reported in the literature (Feder and Mueller, 1977; Feder *et al.*, 1978; Stoker, 1978; Feder and Jewett, 1978, 1980). The relationship of specific infaunal feeding types with certain substrate conditions has been documented (although in a limited fashion) as well (Haflinger, 1978; Feder *et al.*, 1980b). However, detailed information on the temporal and spatial variability of the benthic fauna is sparse, and the relationship of benthic species with the overlying seasonal ice cover is not known. Some of the macrofaunal benthic species may be negatively affected by oil-related activities. An understanding of these benthic species and their interactions with each other and with various aspects of the abiotic features of their environment are essential to the development of environmental predictive capabilities for the Bering and Chukchi Seas.

The benthic biological program in the northeastern Bering Sea and the southeastern Chukchi Sea during this project emphasized development of an inventory of species as part of the overall examination of the biological, physical, and chemical components of those portions of the shelf slated for oil exploration and drilling activity. In addition, computer programs developed for use with data collected in the northeast Gulf of Alaska, and designed to quantitatively assess assemblages of benthic species on the shelf there, were applicable to this study (Feder and Matheke, 1980). The resultant computer analysis expands the understanding of distribution patterns of species in the study area.

The research program was designed to survey the benthic fauna on the northeastern Bering Sea and southeastern Chukchi Sea shelf in regions of offshore oil and gas concentrations. During the first phases of research, emphasis was placed on the collection of data on faunal composition and abundance of shelf infauna to develop baselines to which potential future changes could be compared. Future development of long-term studies on life histories and trophic interactions should clarify which components of the various species groups are vulnerable to environmental damage, and should ultimately help to determine the rates at which damaged environments can recover.

Specific Objectives

1. To quantitatively inventory of dominant infaunal invertebrates at selected stations in the study areas.
2. To describe spatial distribution patterns of species in the designated study areas.
3. To make limited observations of biological interrelationships, emphasizing trophic interactions, among selected segments of the benthic biota.

Relevance to Problems of Petroleum Development

The effects of oil pollution on subtidal benthic organisms have been seriously neglected, although a few studies, conducted after serious oil spills, have been published (see Boesch *et al.*, 1974, for a review of these papers). Thus, lack of a broad data base elsewhere makes it difficult at present to adequately predict the effects of oil-related activity on the subtidal benthos of the Bering and Chukchi Seas. However, research activities in Alaska OCSEAP areas should ultimately enable us to point with some confidence to certain species or regions that might bear closer scrutiny once industrial activity is initiated. It must be emphasized that a considerable time frame is needed to understand long-term fluctuations in density of marine benthic species. Thus, it cannot be expected that short-term research programs will result in predictive capabilities: assessment of the environment must be conducted on a continuing basis.

As indicated previously, infaunal benthic organisms tend to remain in place and, consequently, have been useful as an indicator species for disturbed areas. Thus, close examination of stations with substantial complements of infaunal species is warranted. Changes in the environment at stations with relatively large numbers of species might be reflected in a decrease in species diversity, with increased dominance of a few (see Nelson-Smith, 1973, for further discussion of oil-related changes in diversity). Likewise, stations with substantial numbers of epifaunal species should be assessed on a continuing basis (Feder and Jewett, 1978, 1980). The potential effects of loss of specific species to the overall trophic structure in the Bering and Chukchi Seas cannot be fully assessed at this time, but the problem can probably be better addressed using preliminary information on benthic food studies now available in Feder and Jewett (1978, 1980, 1981a), Smith *et al.* (1978) and Jewett and Feder (1980).

Data indicating the effect of oil on subtidal benthic invertebrates are fragmentary; however, echinoderms are "notoriously sensitive" to any reduction in water quality (Nelson-Smith, 1973). Echinoderms (ophiuroids, asteroids, and holothuroids) are conspicuous members of the benthos of the Bering and Chukchi Seas (Feder and Jewett, 1978, 1980; Jewett and Feder, 1981), and could be affected by oil activities there. Asteroids (sea stars) and ophiuroids (brittle stars) are often important components of the diet of large crabs (for example, the king crab feeds on sea stars and brittle stars: Feder and Jewett, 1981a, b; Jewett and Feder, in press) and demersal fishes (Jewett and Feder, 1980; Feder, unpubl. data). The Tanner or snow crab (*Chionoecetes opilio*) is a conspicuous member of the shallow shelf of the Bering and Chukchi Seas. Laboratory experiments with *C. bairdi* have shown that postmolt individuals lose most of their legs after exposure to Prudhoe Bay crude oil (Karinen and Rice, 1974); obviously, this aspect of the biology of the snow crab must be considered in the continuing assessment of this species. Little other direct data based on laboratory experiments are available for subtidal benthic species (Nelson-Smith, 1973).

A direct relationship between trophic structure (feeding type) and bottom stability has been demonstrated by Rhoads (1974). A diesel-fuel oil spill resulted in oil becoming adsorbed on sediment particles, with the resultant mortality of many deposit-feeders living on sublittoral muds. Bottom stability was altered with the death of these organisms, and a new complex of species became established in the altered substrate. The most common members of the infauna of the eastern Bering and southeastern Chukchi Seas are deposit-feeders (data of present report); thus, oil-related mortality of these species could result in a changed near-bottom sedimentary regime, with subsequent alteration of species composition.

As suggested above, upon completion of initial baseline studies in pollution prone areas, selected stations should be examined regularly on a long-term basis. Cluster analysis techniques discussed below, supplemented by principal coordinate analysis, should provide information useful for selection of stations to be used for continuous monitoring of infauna. In addition, these techniques should provide insight into normal ecosystem variation (Williams and Stephenson, 1973; Stephenson *et al.*, 1974; Clifford and Stephenson, 1975). Also, future examination of the biology (e.g., age, growth, condition, reproduction, recruitment, and feeding habits) of selected species should offer clues to possible effects of environmental alteration.

III. CURRENT STATE OF KNOWLEDGE

Data on distribution, density, and feeding mechanisms for infaunal species from the Bering and Chukchi Seas are reported in the literature (Neiman, 1960; Filatova and Barsanova, 1964; Kuznetsov, 1964; Rowland, 1973; Stoker, 1973; Feder and Mueller, 1977; Stoker, 1978; Feder and Jewett, 1980). The relationship of specific infaunal feeding types with certain hydrographic and sediment conditions has been documented (Neiman, 1960, 1963; Stoker, 1973, 1978). However, the direct relationship of these feeding types with the overlying winter ice cover and its contained algal material and with primary productivity in the water column is not known. Preliminary insights into the mechanisms that might integrate the water column and the benthos of the southeastern Bering Sea are included in Alexander and Cooney (1979) and Alexander and Niebauer (1981).

Neiman (1963) discussed the distribution of the benthic biomass in the Bering Sea. She found that the biomass was highest in the western and northern parts of the shelf, reaching a maximum average of 905 g/m^2 in the Chirikov Basin, north of St. Lawrence Island. The primary productivity of the Bering Sea is quite high, averaging 1.46 mg C/m^3-hr in Bristol Bay and 1.71 mg C/m^3-hr over the major part of the northern shelf in summer (Taniguchi, 1969). Summer productivity in the Chirikov Basin be even higher, with 18.2 mg C/m^3-hr recorded at one station sampled (McRoy *et al.*, 1972). This productivity compares favorably with the highest values encountered in the world's oceans (Stoker, 1978).

The biomass and productivity of microscopic sediment-dwelling bacteria, diatoms, microfauna, and meiofauna have not been determined for the Bering and Chukchi Seas, and their roles should ultimately be clarified. It is probable that these organisms are important agents for recycling nutrients and energy from sediment to the overlying water mass (see Fenchel, 1969, for a general review).

Until the initiation of OCSEAP investigations, the epifauna of the eastern Bering and Chukchi Seas had been little studied since the trawling activities of the Harriman Alaska Expedition (Merriam, 1904). Limited information can be obtained from the report of the pre-World War II king crab investigations (Anonymous, 1942) and from the report of the *Pacific Explorer* fishing and processing operations in 1948 (Wigutoff and Carlson, 1950). Some information on species found in areas is included in reports of the U.S. Fish and Wildlife Service Alaska exploratory fishing expedition to the northern Bering Sea in 1949 (Ellson *et al.*, 1949). Neiman (1960) has published a quantitative report on the molluscan communities in the eastern Bering Sea. A phase of the research program conducted by the King Crab Investigation of the Bureau of Commercial Fisheries (now known as National Marine Fisheries Service) for the International North Pacific Fisheries Commission included an ecological study of the eastern Bering Sea during the summers of 1958 and 1959 (McLaughlin, 1963). Sparks and Pereyra (1966) have presented a partial checklist and general discussion of the benthic fauna encountered during a marine survey of the southeastern Chukchi Sea during the summer of 1959. Their marine survey was carried out in the southeastern Chukchi Sea from Bering Strait to just north of Cape Lisburne and west to 169°W longitude. Some species described by them in the Chukchi Sea extend into the Bering Sea and are important there. An intensive survey of the epifauna of the northeastern Bering Sea and southeastern Chukchi Sea is reported in Feder and Jewett (1978) and Jewett and Feder (1981). Epifauna collected by them is described in terms of numbers and biomass trawled. They also include data on the food of several species of benthic invertebrates and fishes.

Crabs and bottom-feeding fishes of the Bering and Chukchi Seas exploit a variety of food types, with benthic invertebrates most important (see Feder and Jewett, 1980; Feder and Jewett, 1981a). Some marine mammals of the Bering Sea also feed on benthic species (Lowry and Burns, 1976; Lowry *et al.*, 1979, in press; Frost and Lowry, 1981; Lowry and Frost, 1981). Walruses and bearded seals feed predominantly on what appear to be slow-growing species of mollusks, but most species of seals prefer the more rapidly growing crustaceans and fishes in their diets (Fay *et al.*, 1977; Lowry and Frost, 1981). Gray whales primarily eat amphipod crustaceans, many of them infaunal species; they are also reported to eat a variety of other benthic organisms. Marine mammals, although showing food preferences, are opportunistic feeders. As a consequence of the broad spectrum of foods utilized and the exploitation of secondary and tertiary consumers, marine mammals are difficult to place in a trophic scheme and to assess in terms of energy cycling. Intensive trawling and oil-related activities on the Bering Sea shelf may have important ecological effects on infaunal and epifaunal organisms used as food by marine mammals. If benthic trophic relationships are altered by these industrial activities, the food regimes of marine mammals may be altered.

Bibliographies of northern marine waters, emphasizing the Bering Sea, are included in Feder and Mueller (1977), Feder and Jewett (1978), Feder *et al.* (1980b), and Jewett and Feder (1981).

IV. STUDY AREAS

A series of van Veen grab stations were occupied in or near four prospective OCS petroleum lease areas in the northeastern Bering Sea and southeastern Chukchi Sea: Navarin Basin, Zhemchug Basin, St. Matthew Basin, and Hope Basin; stations were also occupied in the Chirikov Basin (Fig. 1; Table I).

V. SOURCES, METHODS, AND RATIONALE OF DATA COLLECTION

Field and Laboratory

Benthic infauna were collected on two cruises on the USCGC *Polar Star*, one in 1979 and the other in 1980. The April 1979 cruise occurred in the northeastern Bering and southeastern Chukchi Seas. A total of 18 stations were sampled during this cruise. The 1980 cruise consisted of two segments (legs). The first leg (2-29 May 1980) yielded collections from 33 stations, 25 in the top-priority Navarin Basin lease area and 8 in the St. Matthew Basin lease area. Leg II took place between 1 and 26 June 1980. Samples came from 12 stations between St. Lawrence Island and Bering Strait (Chirikov Basin), 7 stations in or near the Hope Basin, and 7 stations in or near the Zhemchug Basin. An additional 14 benthic stations were occupied for Mary Nerini, National Marine Fisheries Service, Seattle, in the Chirikov Basin; her data will be reported elsewhere.

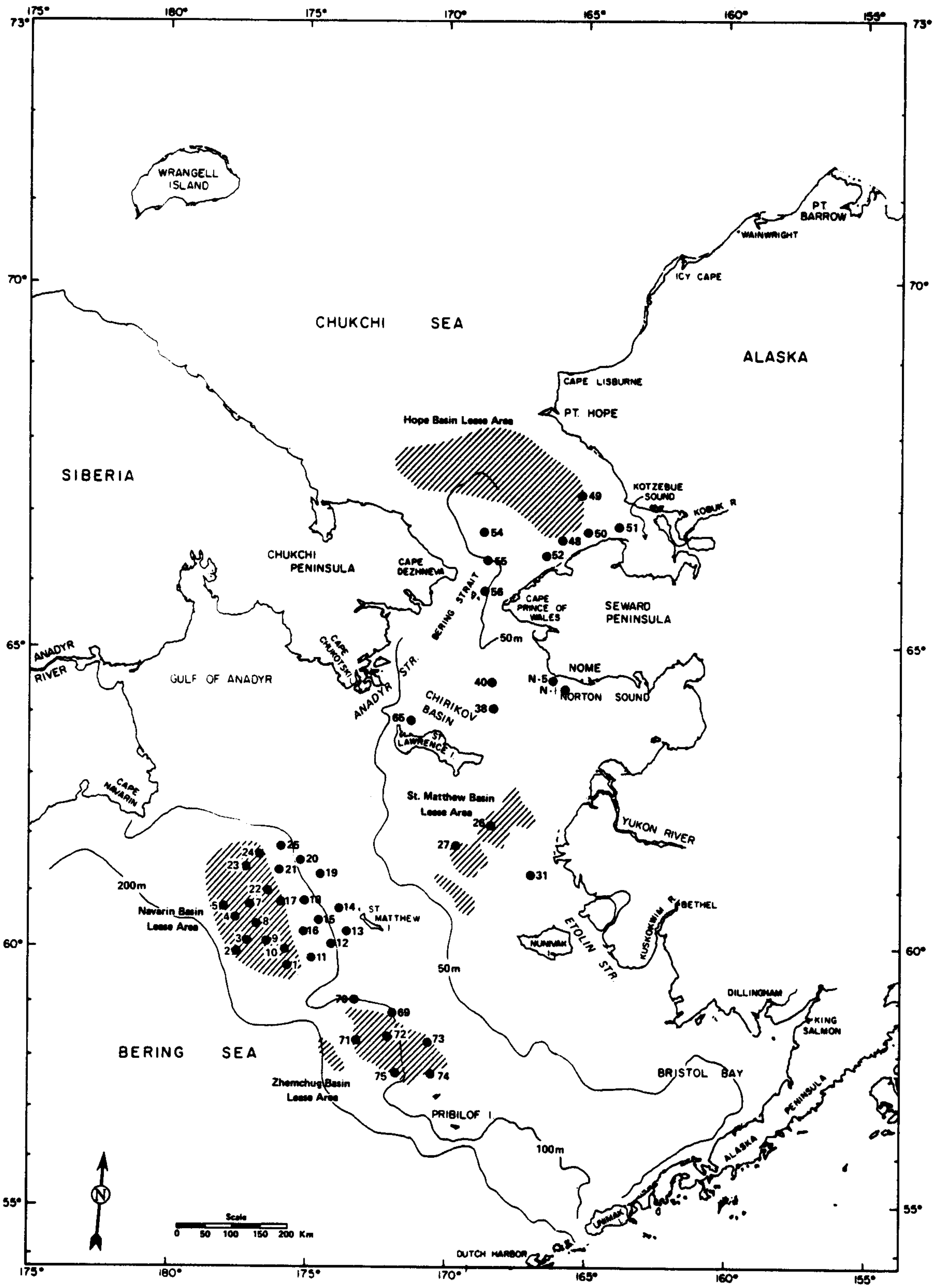

Figure 1. Map showing the location of stations occupied in this study.

TABLE I

BENTHIC STATIONS ANALYZED FROM THE NORTHEASTERN BERING SEA AND THE SOUTHEASTERN CHUKCHI SEA, APRIL 1979 AND MAY-JUNE 1980

Station No.	Date	Total Grab Vol.[a] (ℓ)	Depth[b] (m)	Coordinates[c] Latitude	Longitude
Navarin Basin					
1	4 May 1980	73	135.6	59°31.6'N	176°08.9'W
2	5 May 1980	36	162.6	59°44.2'N	177°49.2'W
3	5 May 1980	64	136.4	60°00.1'N	177°30.8'W
4	6 May 1980	35	165.6	60°26.6'N	178°17.6'W
5	6 May 1980	32	193.8	60°38.6'N	178°41.1'W
7	8 May 1980	69	144.2	60°43.5'N	177°38.3'W
8	8 May 1980	71	147.0	60°25.8'N	177°16.5'W
9	9 May 1980	73	141.8	60°01.8'N	176°55.2'W
10	9 May 1980	69	140.8	59°47.2'N	176°11.6'W
11	10 May 1980	66	122.6	59°43.7'N	175°01.2'W
12	10 May 1980	69	103.0	59°58.5'N	174°11.7'W
13	11 May 1980	36	78.2	60°14.6'N	173°44.3'W
14	11 May 1980	95	85.2	60°42.8'N	174°06.0'W
15	12 May 1980	80	102.6	60°30.2'N	174°45.1'W
16	12 May 1980	73	117.8	60°13.3'N	175°28.0'W
17	13 May 1980	74	116.0	60°49.5'N	176°16.3'W
18	13 May 1980	75	101.8	60°59.4'N	175°30.1'W
19	14 May 1980	76	81.4	61°29.8'N	174°44.4'W
20	14 May 1980	85	90.8	61°42.9'N	175°34.3'W
21	15 May 1980	83	103.2	61°31.9'N	176°15.5'W
22	15 May 1980	65	121.4	61°01.9'N	177°03.5'W
23	16 May 1980	62	124.4	61°30.2'N	177°27.7'W
24	16 May 1980	73	115.0	61°48.1'N	177°07.3'W
25	17 May 1980	77	102.4	62°00.2'N	176°22.3'W
St. Matthew Basin					
26	22 May 1980	18	34.6	62°10.4'N	168°59.1'W
27	23 May 1980	49	46.4	61°44.8'N	170°22.3'W
31	25 May 1980	18	22.4	61°14.8'N	167°08.9'W
St. Lawrence Island to Bering Strait					
38	5 Jun 1980	39	34.0	64°01.6'N	168°31.4'W
40	6 Jun 1980	34	39.8	64°23.7'N	168°31.2'W
56	16 Jun 1980	9	51.6	65°46.0'N	168°35.0'W
65	18 Jun 1980	33	23.0	63°50.9'N	171°23.2'W
1	19 Apr 1979	-	22.0	64°17.4'N	165°56.3'W
5	21 Apr 1979	-	22.0	64°30.7'N	166°23.6'W

TABLE I

CONTINUED

Station No.	Date	Total Grab Vol.[a] (ℓ)	Depth[b] (m)	Coordinates[c] Latitude	Longitude
Hope Basin					
48	8 Jun 1980	12	18.6	66°35.5'N	165°58.9'W
49	9 Jun 1980	61	29.8	67°08.7'N	165°12.8'W
50	11 Jun 1980	55	22.8	66°48.1'N	165°00.0'W
51	12 Jun 1980	65	24.0	66°50.0'N	163°52.0'W
52	13 Jun 1980	13	12.8	66°21.2'N	166°36.0'W
54	15 Jun 1980	22	32.2	66°46.0'N	168°41.0'W
55	15 Jun 1980	39	53.2	66°19.2'N	168°35.0'W
Zhemchug Basin (N.W. of Pribilof Islands)					
69	21 Jun 1980	61	102.0	58°45.3'N	172°19.4'W
70	21 Jun 1980	40	134.4	58°50.8'N	173°55.5'W
71	22 Jun 1980	19	122.4	58°00.0'N	173°45.0'W
72	22 Jun 1980	56	103.4	58°16.4'N	172°21.3'W
73	23 Jun 1980	50	79.6	58°13.9'N	170°41.6'W
74	23 Jun 1980	20	72.2	57°29.6'N	170°28.3'W
75	24 Jun 1980	49	109.4	57°31.0'N	172°18.1'W

[a]Total volume from five grabs

[b]Mean depth of five grabs

[c]Mean coordinate of five grabs

Quantitative samples were taken with a 0.1 m^2 van Veen grab with bottom penetration facilitated by addition of 31.7 kg (70 pounds) of lead weight to each grab. Two 1.0 mm mesh screen doors on top of the grab served to decrease shock waves produced by bottom grabs (see Feder and Matheke, 1979, for discussion of grab operation and effectiveness of the van Veen grab). Five replicate grabs were typically taken at all stations on all cruises (see discussion of optimum number of replicates that should be taken in a grab-sampling program in Feder and Matheke, 1979). Material from each grab was washed on a 1.0 mm mesh stainless steel screen and preserved in 10% formalin buffered with hexamine. Samples were stored in plastic bags.

Forty-seven stations were analyzed in the laboratory (Institute of Marine Science, University of Alaska, Fairbanks). Time limitations necessitated a reduction in the number of stations examined. However, station selections were based on the need for adequate biological coverage in and adjacent to each of the OCS petroleum lease areas addressed by this report. Samples were rinsed to remove the last traces of sediment, spread on a tray, covered with water, and rough-sorted by hand. The biotic material was then transferred to fresh preservative (buffered 10% formalin), and identifications were made. All organisms were counted and wet-weighed after excess moisture was removed with absorbent towel.

Numerical Analysis

Criteria developed by Feder and Matheke (1980) to recognize Biologically Important Taxa (BIT) were applied to the data. By use of these criteria, each species was considered independently (items 1, 2, and 3 below), as well as in combination with other benthic species (items 4 and 5; adopted from Ellis, 1969). Each taxon classified as a BIT in this study meets at least one of the four conditions below:

1. It is distributed in 50% or more of the total stations sampled.

2. & 3. It comprises over 10% of either the composite population density or biomass collected at any one station.

4. Its population density is significant at any given station. The significance is determined by the following test:

a. A percentage of the total density of all taxa is calculated for each taxon, with the sum of percentages of the total population density of all taxa at each station equaling 100%.
b. These percentages are then ranked in descending order.
c. The percentages of the taxa are summed in descending order until a cut-off point of 50% is reached. The BIT are those taxa whose percentages are used to reach the 50% cut-off point. When the cut-off point of 50% is exceeded by the percentage of the last taxon added, this taxon is also included.

Station groups and species assemblages were identified using cluster analysis. Cluster analysis can be divided into three basic steps:

1. Calculation of a measure of similarity or dissimilarity between entities to be classified.
2. Sorting through a matrix of similarity coefficients to arrange the entities in a hierarchy or dendrogram.
3. Recognition of classes within the hierarchy.

Data reduction prior to calculation of similarity coefficients consisted of elimination of both taxa that could not be identified to genus and taxa that occurred at fewer than three stations. If a taxon was a Biologically Important Taxon (Appendix A), it was retained, however. Taxa which could be identified to genus but which may have included more than one species were also eliminated from the analysis. This treatment reduced the number of taxa to 189 (Table II).

The Czekanowski coefficient was used to calculate a similarity matrix for cluster analysis. The Czekanowski coefficient[1] is a quantitative modification of the Sørenson coefficient, which is based on the presence or absence of particular attributes.

Sørenson

$$Cs_{1,2} = \frac{2C}{A + B}$$

where A = total number of attributes of entity one
B = total number of attributes of entity two
C = total attributes shared by entities one and two

[1]The Czekanowski coefficient is synonymous with the Motyka (Mueller-Dombois and Ellenberg, 1974) and Bray-Curtis (Clifford and Stephenson, 1975) coefficients.

TABLE II

SPECIES SELECTED FOR NUMERICAL ANALYSIS OF GRAB DATA

Polychaeta

Antinoella sarsi
Arcteobea anticostiensis
Arcteobea spinelytris
Gattyana ciliata
Gattyana cirrosa
Gattyana treadwelli
Harmothoe imbricata
Hesperone complanata
Tenonia kitsapensis
Nemidia tamarae
Pholoe minuta
Anaitides groenlandica
Anaitides mucosa
Eteone longa
Typosyllis alternata
Eusyllis blomstrandi
Nephtys assimilis
Nephtys ciliata
Nephtys caeca
Nephtys punctata
Nephtys rickettsi
Nephtys longosetosa
Glycinde picta
Onuphis sp.
Onuphis conchylega
Onuphis geophiliformis
Onuphis iridescens
Drilonereis filum
Drilonereis falcata minor
Haploscoloplos elongatus
Scoloplos armiger
Aricidea lopezi
Aricidea minuta
Tauberia gracilis
Apistobranchus tullbergi
Laonice cirrata
Polydora socialis
Prionospio cirrifera
Prionospio steenstrupi
Spio filicornis
Spiophanes bombyx
Magelona pacifica
Spiochaetopterus typicus
Spiochaetopterus costarum
Tharyx secundus
Chaetozone setosa
Brada villosa

Polychaeta (continued)

Flabelligera mastigophora
Scalibregma inflatum
Ammotrypane aulogaster
Ophelia limacina
Travisia forbesii
Travisia pupa
Sternaspis scutata
Capitella capitata
Heteromastus filiformis
Heteromastus giganteus
Mediomastus capensis
Barantolla americana
Maldane sarsi
Maldane glebifex
Axiothella catenata
Praxillella gracilis
Praxillella praetermissa
Rhodine gracilior
Owenia fusiformis
Myriochele heeri
Myriochele oculata
Amphictene moorei
Cistenides granulata
Ampharete acutifrons
Ampharete finmarchica
Amphicteis gunneri
Lysippe labiata
Melinna cristata
Asabellides sibirica
Neoleprea spiralis
Pista cristata
Pista elongata
Pista brevibranchiata
Artacama conifera
Terebellides stroemi
Chone infundibuliformis
Chone cincta
Euchone analis
Euchone longifissurata
Potamilla neglecta
Laonome kroyeri
Aphrodita negligens

Aplacophora

Chaetoderma robusta

TABLE II

CONTINUED

Bivalvia

Nucula tenuis
Nuculana pernula
Nuculana fossa
Yoldia amygdalea
Yoldia hyperborea
Yoldia myalis
Yoldia thraciaeformis
Astarte borealis
Cyclocardia sp.
Cyclocardia crebricostata
Axinopsida serricata
Axinopsida viridis
Thyasira flexuosa
Diplodonta aleutica
Mysella tumida
Mysella aleutica
Odontogena borealis
Clinocardium ciliatum
Serripes groenlandicus
Liocyma sp.
Liocyma fluctuosa
Psephidia lordi
Macoma calcarea
Macoma brota
Hiatella arctica

Gastropoda

Lepeta caeca
Solariella obscura
Solariella varicosa
Tachyrhynchus erosus
Natica clausa
Polinices pallidus
Fusitriton oregonensis
Buccinum sp.
Neptunea lyrata
Oenopota excurvata
Retusa obtusa
Cylichna alba

Copepoda

Calanus plumchrus
Metridia lucens

Cirripedia

Balanus crenatus

Cumacea

Hemilamprops pectinata
Leucon nasica
Eudorella emarginata
Eudorella pacifica
Eudorella dentata
Eudorellopsis integra
Eudorellopsis deformis
Eudorellopsis uschakovi
Diastylis alaskensis
Diastylis bidentata
Diastylis paraspinulosa
Campylaspis umbensis

Isopoda

Synidotea bicuspida
Pleurogonium rubicundum
Pleurogonium spinosissimum

Amphipoda

Ampelisca macrocephala
Ampelisca birulai
Ampelisca eschrichti
Ampelisca furcigera
Byblis gaimardi
Corophium crassicornis
Ericthonius hunteri
Melita dentata
Melita quadrispinosa
Pontoporeia femorata
Urothoe sp.
Urothoe denticulata
Photis spasskii
Protomedeia fasciata
Protomedeia chelata
Anonyx nugax
Anonyx laticoxae
Anonyx sarsi
Opisa eschrichti
Bathymedon nanseni

TABLE II

CONTINUED

Amphipoda (continued)

Machaironyx muelleri
Paroediceros lynceus
Westwoodilla caecula
Nicippe tumida
Harpinia kobjakovae
Harpinia gurjanovae
Paraphoxus robustus
Paraphoxus oculatus
Tiron biocuLata

Decapoda

Argis lar
Pagurus trigonocheirus
Chionoecetes opilio

Sipunculida

Golfingia margaritacea

Echiuroidea

Echiurus echiurus alaskanus

Priapulida

Priapulus caudatus

Ectoprocta

Alcyonidium disciforme

Asteroidea

Ctenodiscus crispatus

Echinoidea

Echinarachnius parma

Ophiuroidea

Diamphiodia sp.
Diamphiodia craterodmeta
Ophiura sarsi

Holothuroidea

Cucumaria sp.

Teleostei

Ammodytes hexapterus

Czekanowski

$$Cs_{1,2} = \frac{2W}{A + B}$$ where A = the sum of the measures of attributes of entity one
B = the sum of the measures of attributes of entity two
W = the sum of the lesser measures of attributes shared by entities one and two

The Czekanowski coefficient has been used effectively in marine benthic studies by Field and MacFarlane (1968), Field (1969, 1970, and 1971), Day *et al.* (1971), Stephenson and Williams (1971), Stephenson *et al.* (1972) and Feder and Matheke (1980). This coefficient emphasizes the effect of dominant species on the classification, and is often used with some form of transformation. The Czekanowski coefficient was used to calculate similarity matrices for normal cluster analysis (with stations as the entities to be classified and species as their attributes) and inverse cluster analysis (with species as entities and stations as attributes), using both *ln*-transformed and untransformed density data (individuals/m^2). The natural logarithm transformation, $Y = ln(X+1)$, reduces the influence that dominant species have on the similarity determination. Dendrograms were constructed from the similarity matrices using a group-average agglomerative hierarchical cluster analysis (Lance and Williams, 1966).

As an aid in the interpretation of dendrograms formed by cluster analysis, two-way coincidence tables comparing site groups formed by normal analysis and species groups formed by inverse analysis were constructed (Stephenson *et al.*, 1972). In each table, the original species x station data matrix was rearranged (based on the results of both normal and inverse analysis) so the stations or species with the highest similarities were adjacent to each other. The two-way coincidence table was then divided into cells whose elements are the abundance of each of the species in a species group at each of the stations in a station group. The two-way coincidence tables were then reduced to create a table of average cell densities (Dc) by summing the values of all the elements (n) in each cell and dividing the resulting sums by the product of the number of species (Nsp) in the appropriate species group and the number of stations (Nst) in the appropriate station group, as in

$$Dc = \frac{\Sigma n}{(Nsp)\ (Nst)}$$

Principal coordinate analysis (Gower, 1967, 1969) was used as an aid in interpreting the results of the cluster analysis (Stephenson and Williams, 1971; Boesch, 1973) and in identifying misclassifications of stations by cluster analysis. Misclassifications in an agglomerative cluster analysis can occur by the early fusion of two stations and their subsequent incorporation into a group whose stations have a high similarity to only one member of the original pair (Boesch, 1973). In principal coordinate analysis, an interstation similarity matrix is generated as in normal cluster analysis. The similarity matrix generated can be conceived of as a multi-dimensional space in which the stations are arranged in such a way that they are separated from one another according to their similarities, with the most similar stations being closest. An ordination is then performed on the matrix to extract axes from this multidimensional space, so that stations' relationships can be depicted in two or three dimensions. The first axis extracted coincides with the longest axis and accounts for the largest amount of variation in the similarity matrix; subsequent axes account for successively smaller amounts of variation in the data. The Czekanowski coefficient was used to calculate the similarity matrices used in principal coordinate analysis.

Diversity

Species diversity can be thought of as a measurable attribute of a collection or a natural assemblage of species and consists of two components: the number of species, or "species richness", and the relative abundance of each species, or "evenness". The two most widely used measures of diversity that include species richness and evenness are the Brillouin (1962) and Shannon (Shannon and Weaver, 1963) information measures of diversity (Nybakken, 1978). There is still disagreement on the applicability of these indices, and results are often difficult to interpret (Sager and Hasler, 1969; Hurlbert, 1971; Fager, 1972; Peet, 1974; Pielou, 1966a, b). Pielou (1966a, b, 1977) has outlined some of the conditions under which these indices are appropriate.

The Shannon function

$$H' = -\sum_i p_i \log p_i$$

where $p_i = \frac{n_i}{N}$

n_i = number of individuals in the i^{th} species
N = total number of individuals

assumes that a random sample has been taken from an infinitely large population, whereas the Brillouin function

$$H = \frac{1}{N} \log \frac{N!}{n_1!n_2!\cdots n_s!}$$

is appropriate only if the entire population has been sampled. Thus, if we wish to estimate the diversity of the fauna at a station, the Shannon function is appropriate. The Brillouin function is merely a measure of the diversity of the five grab samples taken at each station and makes no predictions about the diversity of the benthic community from which the samples were drawn. The evenness of samples taken at each site can be calculated using the Brillouin measure of evenness, $J = H/H_{maximum}$, where H = Brillouin diversity function. $H_{maximum}$, the maximum possible diversity for a given number of species, occurs if all species are equally common and is calculated as:

$$H_{maximum} = \frac{1}{N} \log \frac{N!}{\{[N/s]!\}^{s-r}\{([N/s]+1)!\}^{r}}$$

where $[N/s]$ = the integer part of N/s
s = number of species in the censused community
$r = N - s[N/s]$

Theoretically, the evenness component of the Shannon function can be calculated from the following:

$$J' = \frac{H'}{\log s^*}$$

where H' = Shannon diversity function
s^* = the total number of species in the randomly sampled community

However, s*, the total number of species in a randomly sampled community, is seldom known for benthic infaunal communities. Therefore, the evenness component of the Shannon diversity index was not calculated (for a discussion, see Pielou, 1977). Both the Shannon and Brillouin diversity indices were calculated in a study by Feder and Matheke (1980), and they were closely correlated (r = 0.97), indicating that either index would be acceptable, as both Loya (1972) and Nybakken (1978) have suggested. Species richness (Margalef, 1958) was calculated as

$$SR = \frac{(S-1)}{\ln N}$$

where S = the number of species
N = the total number of individuals

The Simpson index (Simpson, 1949) was also calculated:

$$D = 1-\Sigma \frac{n_i(n_i-1)}{N(N-1)}$$

where N = total number of individuals
n_i = number of individuals in the i^{th} species

These indices were calculated for all stations sampled.

The Simpson Index is an indicator of dominance, since the maximum value, one, is obtained when there is a single species (complete dominance); values approaching zero are obtained when there are numerous species, each of which is a very small fraction of the total (no dominance). The Shannon and Brillouin indices are indicators of diversity in that, the higher the value, the greater the diversity and the less the community is dominated by one or a few kinds of species.

Trophic Structure

The trophic structure of each of the station groups formed by cluster analysis was determined by classifying the 50 most abundant species in each station group into five feeding classes: suspension-feeders, deposit-feeders, predators, scavengers, and unknown. All species used in the determination of trophic structure were assigned to feeding classes based on available literature (MacGinitie and MacGinitie, 1949; Morton, 1958; Fretter and Graham, 1962; Jørgensen, 1966; Day, 1967; Hyman, 1967; Mills, 1967;

Purchon, 1968; Stanley, 1970; Eltringham, 1971; Feder *et al.*, 1973; Abbott, 1974; Barnes, 1974; Feder and Mueller, 1975; Trueman, 1975; Yonge and Thompson, 1976; Jumars and Fauchald, 1977; Haflinger, 1978; Feder and Matheke, 1979; Fauchald and Jumars, 1979; Feder and Matheke, 1980; Feder *et al.*, 1981a) and personal observation. Since species are distributed along a continuum of feeding types and many organisms utilize several feeding modes, it is often difficult to place a species in a specific class. For example, protobranch mollusks, generally regarded as deposit-feeders, may also feed on particles in suspension (Stasek, 1965; Stanley, 1970). However, since these mollusks probably obtain most of their nutritional requirements from the sediment, they were classified as deposit feeders. Species whose feeding behavior was unknown or uncertain were classified as "unknown". The percentage of individuals belonging to each feeding classification was calculated for each station group. When a species was assigned to two roughly equal feeding classes, we arbitrarily assigned a value of one-half to each class. Species were also classified into three classes of motility: sessile, discretely motile (generally sessile but capable of movement to escape unfavorable environmental conditions (after Jumars and Fauchald, 1979), and motile. The percentage of individuals belonging to each motility class was also calculated for each station group.

VI. RESULTS

General

Benthic infaunal data were collected at 91 stations during the April 1979 and May-June 1980 cruises. A total of 47 stations was subsequently selected for analysis (Fig. 1; Table I).

Biologically Important Taxa (BIT)

From the 47 stations, 647 taxa were identified and the Biologically Important Taxa (according to Feder and Mueller, 1975 and Feder and Matheke, 1979) were designated (see Appendix A). The criteria for the Biologically Important Taxa (BIT) delineated 128 taxa (Appendix A). Sixty-two of the BIT were identified as important in terms of biomass at one or more stations.

Some of the latter taxa were widely distributed throughout the study area, for example *Heteromastus filiformis* (Polychaeta), *Maldane glebifex* (Polychaeta), *Myriochele oculata* (Polychaeta), *Nucula tenuis* (Pelecypoda), and *Ophiura sarsi* (Ophiuroidea).

Numerical Analysis: *ln*-Transformed Density Data

A normal cluster analysis of *ln*-transformed density data produced eleven station groups at the 23.5% similarity level; Stations 31 (Group I) and 56 (Group G) did not group with any of the other stations (Fig. 2a; Table IIIa). Station Group A, a major group, was further subdivided at the 26% similarity level into A' (stations within and adjacent to the Navarin Basin lease area) and A" (stations adjacent to Cape Nome) (Figs. 2, 3; Table III). Station Group B, another large group, consisted of two station clusters, one within the Zhemchug Basin lease area and the other within the northern tip and to the east of the Navarin Basin lease area. Station Group C consisted of two stations within Kotzebue Sound and one station in the Zhemchug Basin lease area. Station Group D consisted of six stations northeast of the Navarin Basin lease area. Station Group E was composed of two stations in the Saint Matthew Basin lease area. Station Group F consisted of two stations north of Bering Strait and one station in the Zhemchug Basin lease area. Station Group G was just north of Bering Strait. Station Group H was composed of three stations between the Hope Basin lease area and the Seward Peninsula. Station Group I was located north of Nunivak Island. Station Group J consisted of three stations north of St. Lawrence Island (Chirikov Basin).

An inverse cluster analysis identified 42 species groups at the 23% similarity level (Fig. 4; Table IV). A two-way coincidence table (Feder and Matheke, 1979, 1980), as well as a reduced two-way table of average cell densities (Table V), were used to determine the species and species groups which characterized and distinguished each of the station groups. A summary of the major species groups follows (refer to Tables IV-V and Appendix B):

<u>Species Group 1</u> - The 14 species in this group were most important in Station 56, Station Group G. The two most important species at Station 56

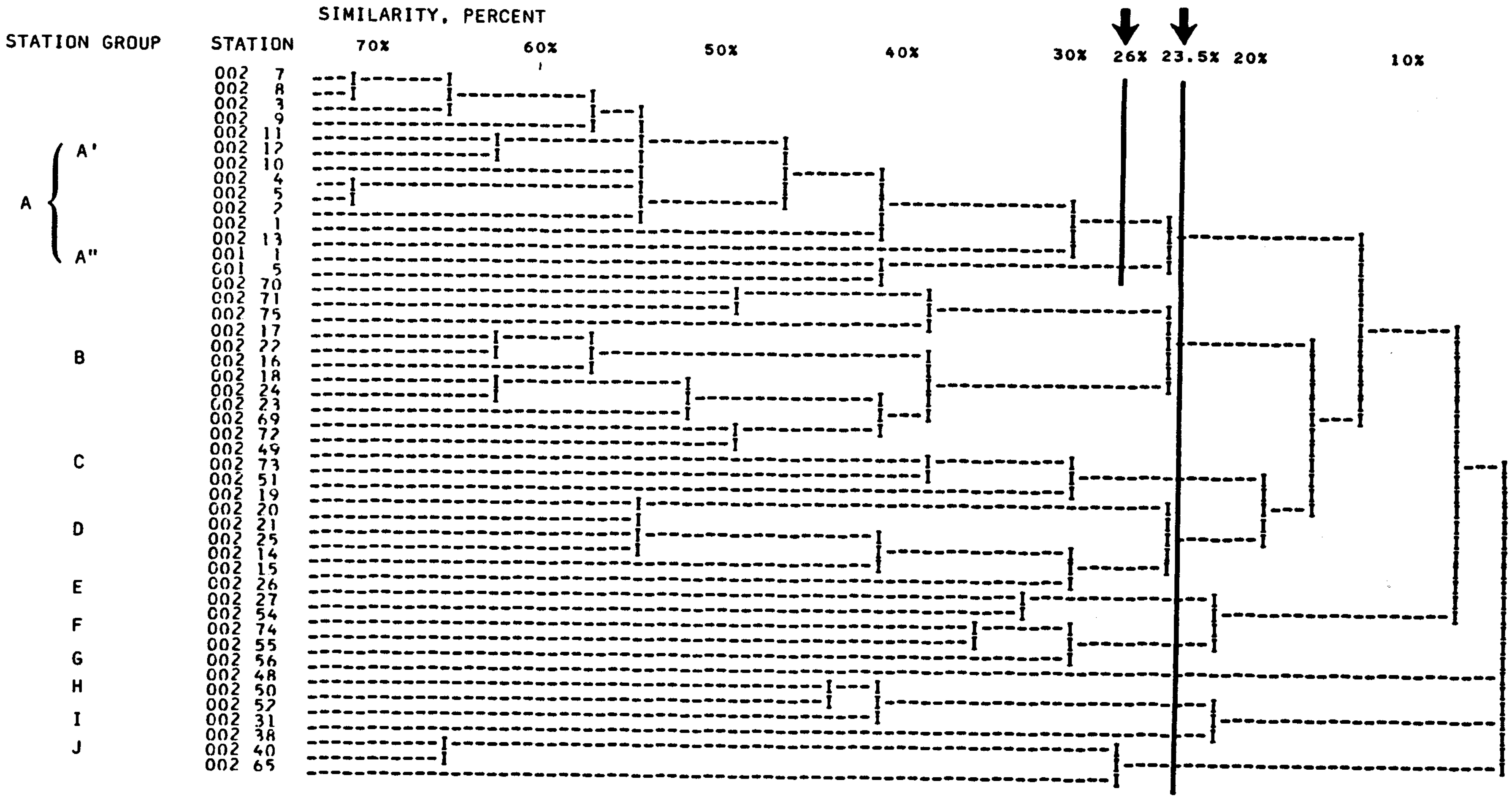

Figure 2a. Dendrogram produced by cluster analysis using *ln*-transformed density data (no. of individuals/m^2) collected in the Bering and southeast Chukchi Seas.

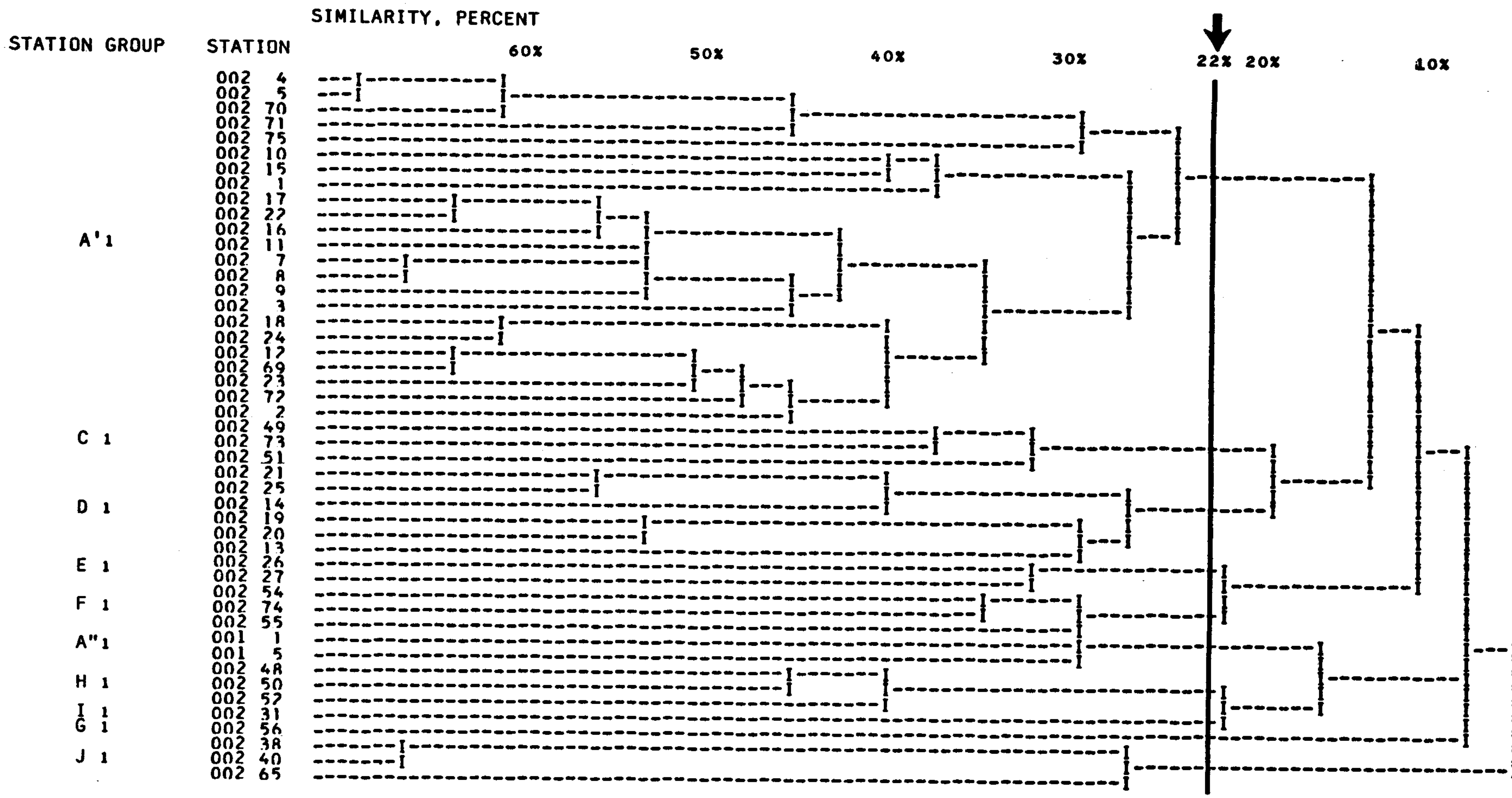

Figure 2b. Dendrogram produced by cluster analysis using untransformed density data (no. of individuals/m^2).

TABLE IIIa

STATION GROUPS FORMED BY CLUSTER ANALYSIS OF *ln*-TRANSFORMED AND UNTRANSFORMED DENSITY DATA (NUMBER OF INDIVIDUALS/M^2)

Station Group	Stations
	TRANSFORMED
A'	1, 2, 3, 4, 5, 7, 8, 9, 10, 11, 12, 13
A"	N1, N5
B	16, 17, 18, 22, 23, 24, 69, 70, 71, 72, 75
C	49, 51, 73
D	14, 15, 19, 20, 21, 25
E	26, 27
F	54, 55, 74
G	56
H	48, 50 52
I	31
J	38, 40, 65
	UNTRANSFORMED
A'1	1, 2, 3, 4, 5, 7, 8, 9, 10, 11, 12, 15, 16, 17, 18, 22, 23, 24, 69, 70, 71, 72, 75
A"1	N1, N5
C1	49, 51, 73
D1	13, 14, 19, 20, 21, 25
E1	26, 27
F1	54, 55, 74
G1	56
H1	48, 50, 52
I1	31
J1	38, 40, 65

TABLE IIIb

COMPARISON OF STATION GROUPS FORMED BY CLUSTER ANALYSIS OF UNTRANSFORMED AND *ln*-TRANSFORMED DENSITY DATA

	STATION GROUPS	
Station	Untransformed data	Transformed Data
N1	A"1	A"
N5	A"1	A"
1	A'1	A'
2	A'1	A'
3	A'1	A'
4	A'1	A'
5	A'1	A'
7	A'1	A'
8	A'1	A'
9	A'1	A'
10	A'1	A'
11	A'1	A'
12	A'1	A'
15	A'1	D
16	A'1	B
17	A'1	B
18	A'1	B
22	A'1	B
23	A'1	B
24	A'1	B
69	A'1	B
70	A'1	B
71	A'1	B
72	A'1	B
75	A'1	B
49	C1	C
51	C1	C
73	C1	C
13	D1	A'
14	D1	D
19	D1	D
20	D1	D
21	D1	D
25	D1	D
26	E1	E
27	E1	E
54	F1	F
55	F1	F
74	F1	F
56	G1	G
48	H1	H
50	H1	H
52	H1	H
31	I1	I
38	J1	J
40	J1	J
65	J1	J

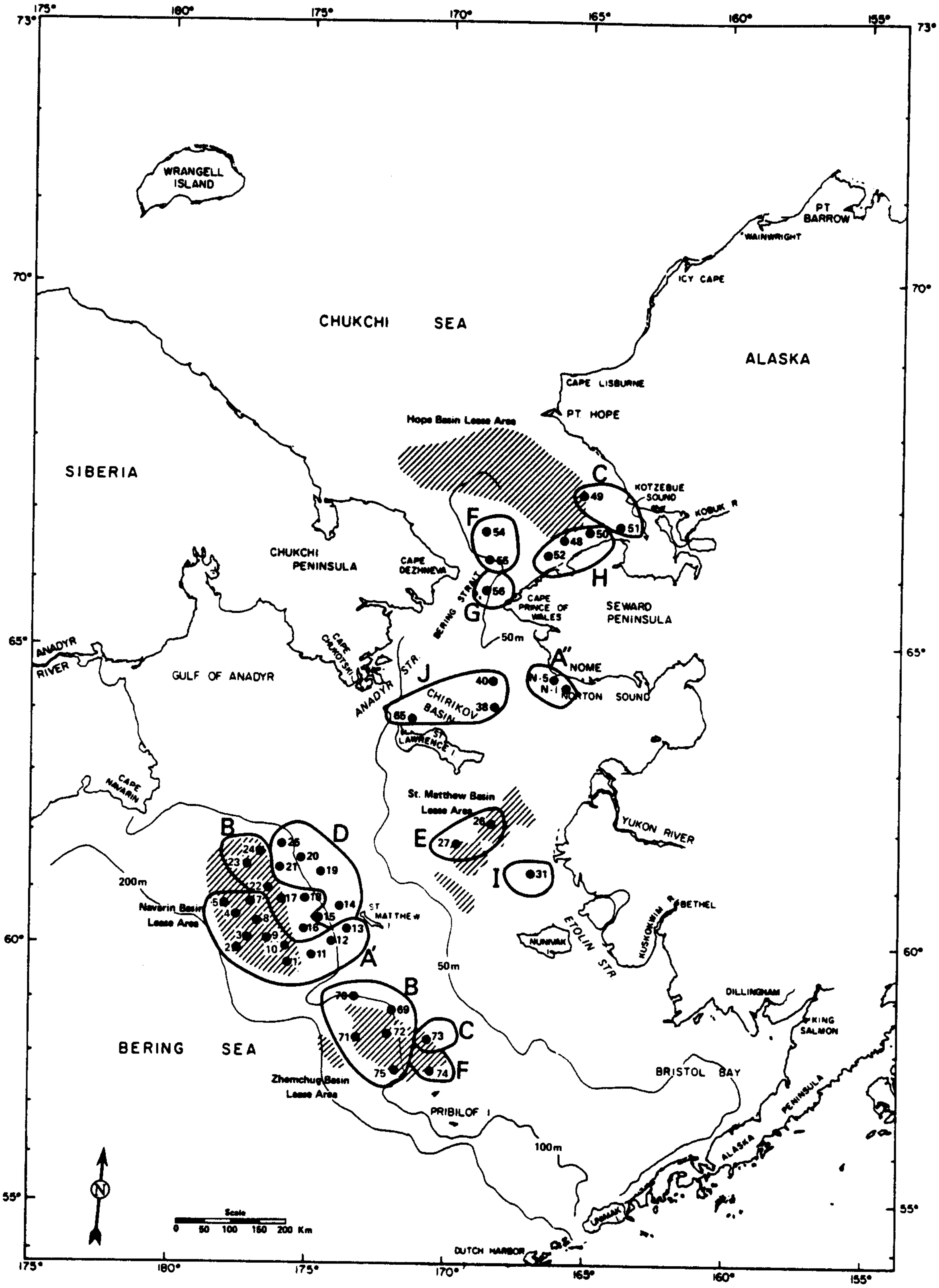

Figure 3a. Station groups formed by a cluster analysis of *ln*-transformed density data (number of individuals/m^2).

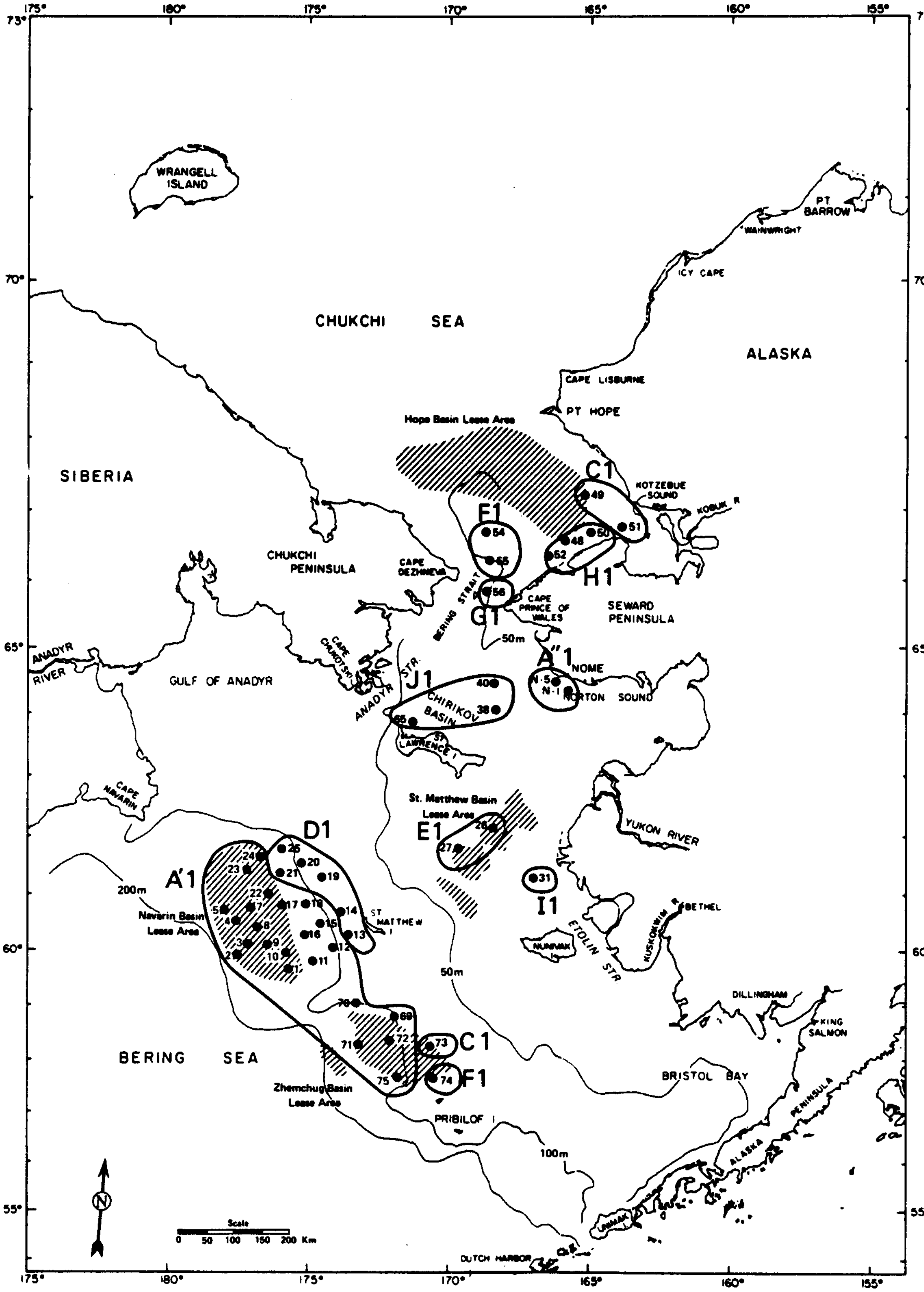

Figure 3b. Station groups formed by a cluster analysis of untransformed density data (number of individuals/m^2).

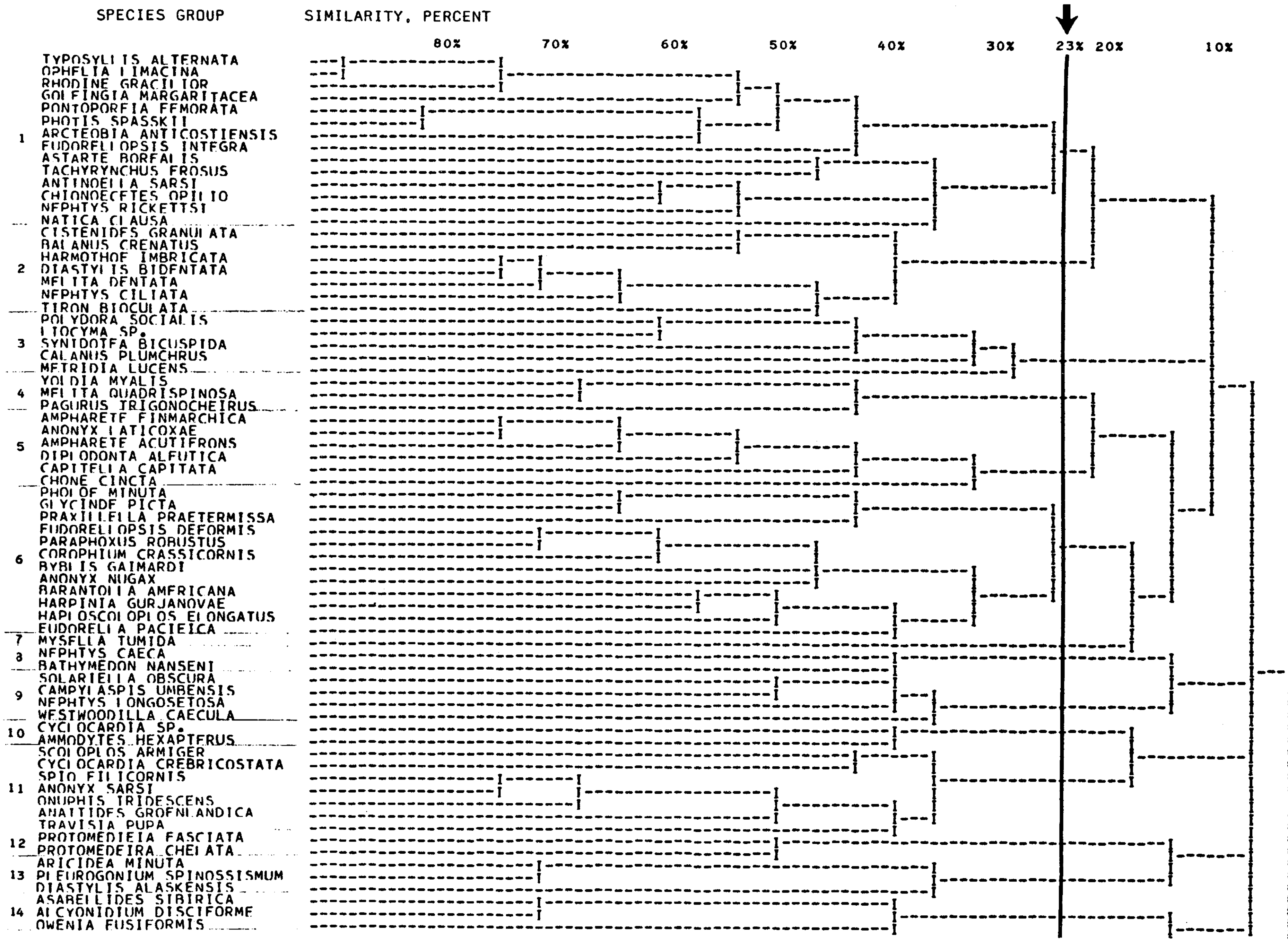

Figure 4. Species groups formed by an inverse cluster analysis in *ln*-transformed density data.

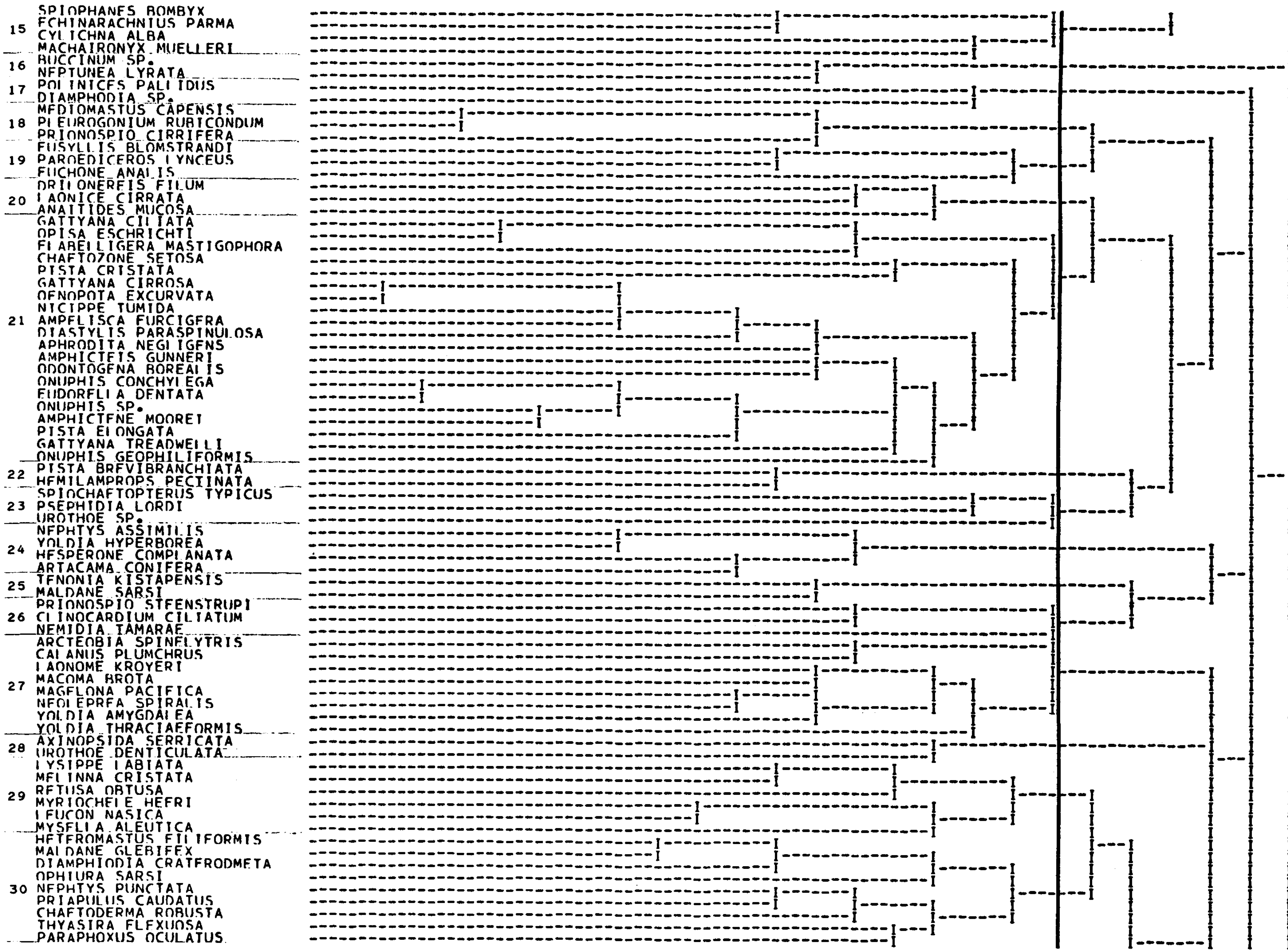

Figure 4. Continued.

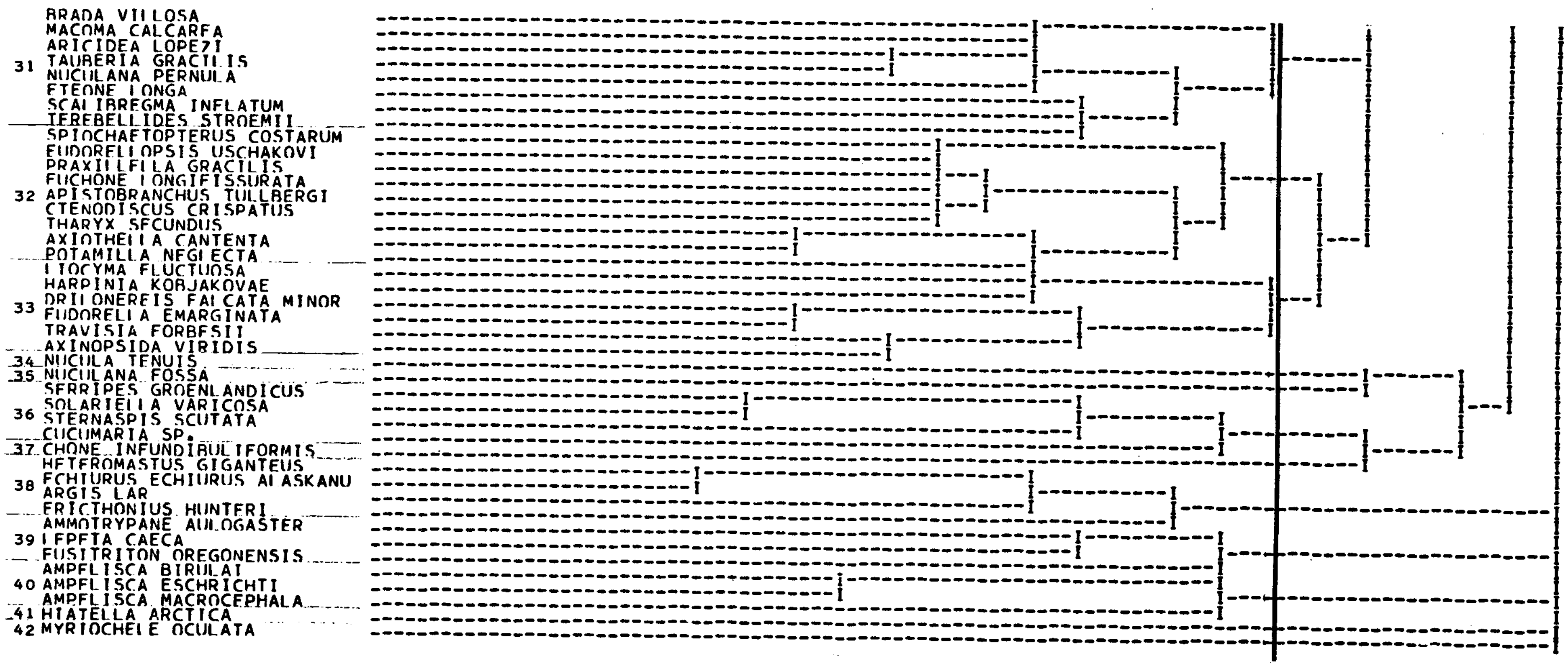

Figure 4. Continued.

TABLE IV

SPECIES GROUPS FORMED BY INVERSE CLUSTER ANALYSIS BASED ON DENSITY
Feeding type and motility from Haflinger (1978); Fauchald and Jumars (1979); Feder and Matheke (1979, 1980); and Feder *et al.* (1980b).

Group Number	Species Name	Feeding Type[1]	Motility Type[2]
1	*Typosyllis alternata*	P	M
	Ophelia limacina	DF	M
	Rhodine gracilior	DF	SE
	Golfingia margaritacea	DF	SE
	Pontoporeia femorata	SF	SE/DM
	Photis spasskii	DF	M
	Arcteobea anticostiensis	P/S	M
	Eudorellopsis integra	DF/S	M
	Astarte borealis	SF	DM
	Tachyrhynchus erosus	S/P	M
	Antinoella sarsi	DF/P	M
	Chionoecetes opilio	S/P	M
	Nephtys rickettsi	DF/P	M
	Natica clausa	P	M
2	*Cistenides granulata*	DF	M
	Balanus crenatus	SF	SE
	Harmothoe imbricata	S	M
	Diastylis bidentata	DF	M
	Melita dentata	DF	M
	Nephtys ciliata	DF/P	M
	Tiron bioculata	U	M
3	*Polydora socialis*	DF	DM
	Liocyma sp.	SF	SE
	Synidotea bicuspida	S	M
	Calanus plumchrus	SF	M
	Metridia lucens	SF	M
4	*Yoldia myalis*	DF	M
	Melita quadrispinosa	DF	M
	Pagurus trigonocheirus	S/P	M
5	*Ampharete finmarchica*	DF	S
	Anonyx laticoxa	S	M
	Ampharete acutifrons	DF	SE
	Diplodonta aleutica	SF/DF	SE/DM
	Capitella capitata	DF	M
	Chone cincta	SF	DM
6	*Pholoe minuta*	S/P	M
	Glycinde picta	DF/P	M
	Praxillella praetermissa	DF	SE
	Eudorellopsis deformis	DF	M
	Paraphoxus robustus	SF	M
	Corophium crassicornis	SF	SE
	Byblis gaimardi	SF	DM

TABLE IV

CONTINUED

Group Number	Species Name	Feeding Type[1]	Motility Type[2]
6	*Anonyx nugax*	S	M
	Barantolla americana	DF	M
	Harpinia gurjanovae	SF	M
	Haploscoloplos elongatus	DF	M
	Eudorella pacifica	DF	M
7	*Mysella tumida*	SF/DF	SE
8	*Nephtys caeca*	DF/P	M
	Bathymedon nanseni	DF/S	M
9	*Solariella obscura*	S/P	M
	Campylaspis umbensis	DF	M
	Nephtys longosetosa	DF/P	M
	Westwoodilla caecula	DF/S	M
10	*Cyclocardia* sp.	SF	SE
	Ammodytes hexapterus	P/S	M
11	*Scoloplos armiger*	DF	M
	Cyclocardia crebricostata	SF	SE
	Spio filicornis	DF	DM
	Anonyx sarsi	S	M
	Onuphis iridescens	DF	SE/DM
	Anaitides groenlandica	P/DF	M
	Travisia pupa	DF	M
12	*Protomedeia fasciata*	DF	M
	Protomedeia chaelata	DF	M
13	*Aricidea minuta*	DF	M
	Pleurogonium spinosissmum	S/DF	M
	Diastylis alaskensis	DF	M
14	*Asabellides sibirica*	DF	SE
	Alcyonidium disciforme	SF	SE
	Owenia fusiformis	SF/DF	M
15	*Spiophanes bombyx*	DF	DM
	Echinarachnius parma	DF	M
	Cylichna alba	P	M
	Machaironyx muelleri	DF/S	M
16	*Buccinum* sp.	P	M
	Neptunea lyrata	P	M
17	*Polinices pallidus*	P	M
	Diamphiodia sp.	DF	M
18	*Mediomastus capensis*	DF	M
	Pleurogonium rubicundum	S/DF	M
	Prionospio cirrifera	DF	DM
19	*Eusyllis blomstrandi*	P	M
	Paroediceros lynceus	S	M
	Euchone analis	SF	DM

TABLE IV

CONTINUED

Group Number	Species Name	Feeding Type[1]	Motility Type[2]
20	*Drilonereis filum*	DF	M
	Laonice cirrata	DF	DM
	Anaitides mucosa	P/DF	M
21	*Gattyana ciliata*	S	M
	Opisa eschrichti	U	U
	Flabelligera mastigophora	DF	M
	Chaetozone setosa	DF	DM
	Pista cristata	DF	SE
	Gattyana cirrosa	S	M
	Oenopota excurvata	P	M
	Nicippe tumida	SF	M
	Ampelisca furcigera	SF	SE/DM
	Diastylis paraspinulosa	DF	M
	Aphrodita negligens	DF	M
	Amphicteis gunneri	DF	SE
	Odontogena borealis	SF/DF	SE
	Onuphis conchylega	DF	M
	Eudorella dentata	DF	M
	Onuphis sp.	DF	M/SE/DM
	Amphictene moorei	DF	M
	Pista elongata	DF	SE
	Gattyana treadwelli	S	M
	Onuphis geophiliformis	DF	SE/DM
22	*Pista brevibranchiata*	DF	S
	Hemilamprops pectinata	DF	M
23	*Spiochaetopterus typicus*	SF	SE
	Psephidia lordi	SF	SE/DM
	Urothoe sp.	SF	M
24	*Nephtys assimilis*	DF/P	M
	Yoldia hyperborea	DF	M
	Hesperone complanata	S	M
	Artacama conifera	DF	DM
25	*Tenonia kitsapensis*	S/P	M
	Maldane sarsi	DF	SE
26	*Prionospio steenstrupi*	DF	DM
	Clinocardium ciliatum	SF	M
	Nemidia tamarae	S/P	M
27	*Arcteobea spinelytris*	S/P	M
	Calanus plumchrus	SF	M
	Laonome kroyeri	S/P	M
	Macoma brota	DF	SE
	Magelona pacifica	DF	M

TABLE IV

CONTINUED

Group Number	Species Name	Feeding Type[1]	Motility Type[2]
27	*Neoleprea spiralis*	DF	DM
	Yoldia amygdalea	DF	M
	Yoldia thraciaeformis	DF	M
28	*Axinopsida serricata*	SF/DF	SE
	Urothoe denticulata	SF	M
29	*Lysippe labiata*	DF	SE
	Melinna cristata	DF	SE
	Retusa obtusa	P	M
	Myriochele heeri	DF	SE
	Leucon nasica	DF	M
	Mysella aleutica	SF/DF	SE
30	*Heteromastus filiformis*	DF	M
	Maldane glebifex	DF	SE
	Diamphiodia craterodmeta	DF	M
	Ophiura sarsi	DF/P	M
	Nephtys punctata	DF/P	M
	Priapulus caudatus	P	M
	Chaetoderma robusta	DF/P	M
	Thyasira flexosa	SF/DF	SE
	Paraphoxus oculatus	SF	M
31	*Brada villosa*	DF	DM
	Macoma calcarea	DF	SE
	Aricidea lopezi	DF	M
	Tauberia gracilis	DF	M
	Nuculana pernula	DF	M
	Eteone longa	P	M
	Scalibregma inflatum	DF	M
	Terebellides stroemi	DF	SE
32	*Spiochaetopterus costarum*	SF/DF	SE
	Eudorellopsis uschakovi	DF	M
	Praxillella gracilis	DF	SE
	Euchone longifissurata	SF/DF	DM
	Apistobranchus tullbergi	DF	DM
	Ctenodiscus crispatus	DF	M
	Tharyx secundus	DF	DM
	Axiothella cantenata	DF	SE
	Potamilla neglecta	SF	SE
33	*Liocyma fluctuosa*	SF	SE
	Harpinia kobjakovae	SF	M
	Drilonereis falcata minor	DF	M
	Eudorella emarginata	DF	M
	Travisia forbesii	DF	M
	Axinopsida viridis	SF/DF	SE
34	*Nucula tenuis*	DF	M

TABLE IV

CONTINUED

Group Number	Species Name	Feeding Type[1]	Motility Type[2]
35	*Nuculana fossa*	DF	M
36	*Serripes groenlandicus*	SF	SE
	Solariella varicosa	S/P	M
	Sternaspis scutata	DF	M
	Cucumaria sp.	DF	SE
37	*Chone infundibuliformis*	SF	DM
38	*Heteromastus giganteus*	DF	M
	Echiurus echiurus alaskanus	DF	DM
	Argis lar	S/P	M
	Ericthonius hunteri	SF	DM
39	*Ammotrypane aulogaster*	DF	M
	Lepeta caeca	SF	M
	Fusitriton oregonensis	P	M
40	*Ampelisca birulai*	SF	DM
	Ampelisca eschrichti	SF	DM
	Ampelisca macrocephala	SF	DM
41	*Hiatella arctica*	SF	SE
42	*Myriochele oculata*	DF	SE

[1]Feeding types: P = predator, S = scavenger, DF = detrital feeder, SF = suspension feeder, U = unknown

[2]Motility types: M = motile, DM = discretely motile, SE = sessile, U = unknown

TABLE V

STATION GROUP/SPECIES GROUP COINCIDENCE TABLE SHOWING
AVERAGE CELL DENSITIES OF GROUPS FORMED BY A
CLUSTER ANALYSIS OF TRANSFORMED
DENSITY DATA

Taxon Groups	A'	A"	B	C	D	E	F	G	H	I	J
1	0.7	2.0	0.3	0.3	0.2	0.4	3.6	5.5	2.9	0.5	4.8
2	0.1	6.8	0.1	0.2	0.0	0.0	1.8	33.8	1.2	0.0	0.9
3	0.1	0.2	0.1	0.0	0.1	0.0	1.9	0.0	0.0	0.0	0.0
4	0.0	5.2	0.1	0.0	0.0	0.0	0.4	0.0	0.0	0.0	3.3
5	4.3	6.1	0.6	0.1	0.9	2.0	1.3	0.6	0.4	0.0	23.7
6	6.4	16.4	3.8	3.4	7.4	79.5	41.5	4.7	8.3	29.2	115.1
7	2.2	0.0	0.6	0.0	0.0	0.0	36.0	0.0	0.0	6.7	250.0
8	0.7	0.6	1.2	13.0	0.0	1.0	4.7	0.0	1.0	1.7	0.0
9	0.2	0.9	0.0	0.2	0.0	0.0	1.3	0.0	3.0	0.0	0.0
10	0.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	1.7	2.3
11	0.4	0.0	0.4	0.2	0.1	0.1	6.2	0.5	2.6	10.0	20.2
12	0.0	0.0	0.0	0.0	0.0	41.0	0.0	0.0	0.7	21.7	1.0
13	0.1	0.4	0.0	0.0	0.0	0.0	0.2	0.0	0.0	6.7	0.0
14	36.1	2.3	3.4	0.0	0.0	0.0	1.1	31.1	4.2	371.1	1.1
15	1.1	0.9	0.7	1.2	1.0	4.2	15.0	0.0	57.2	136.7	0.7
16	0.1	0.0	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
17	0.5	0.0	0.2	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
18	0.5	0.3	0.1	0.0	0.0	0.0	0.0	3.3	0.0	0.0	0.0
19	1.4	1.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
20	0.7	0.0	0.2	0.0	0.0	0.0	0.2	0.0	0.2	0.0	0.0
21	2.0	0.0	0.1	0.1	0.0	0.0	0.1	0.0	0.0	0.0	0.0
22	0.6	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
23	1.1	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
24	0.2	0.0	0.1	0.0	2.7	0.0	0.0	0.0	0.0	0.0	0.0
25	0.8	0.0	0.3	0.0	1.2	0.0	0.0	0.0	0.0	0.0	0.3
26	0.6	0.0	0.2	0.7	1.3	0.3	0.7	0.0	0.0	1.1	0.0
27	1.0	0.9	1.7	0.6	0.1	0.8	0.1	0.0	0.2	0.4	0.0
28	70.8	0.0	52.6	4.7	1.0	6.5	0.0	0.0	0.7	0.0	1.7
29	11.1	1.0	12.0	4.8	1.4	0.8	0.3	0.0	0.8	2.8	0.0
30	48.7	12.6	53.3	5.3	7.3	7.3	11.8	6.3	6.6	3.3	6.8
31	6.4	8.9	2.4	0.6	5.2	13.8	3.5	2.1	1.2	0.8	1.3
32	5.1	6.9	3.7	0.0	0.0	0.1	0.0	0.0	0.2	0.0	0.1
33	7.2	0.2	4.1	2.2	0.8	1.0	0.0	0.6	0.1	0.0	2.2
34	5.3	6.2	10.6	122.0	28.7	499.0	2.7	0.0	81.3	83.3	18.7
35	0.5	0.0	0.9	75.3	0.0	24.0	0.0	0.0	5.3	0.0	0.0
36	3.2	8.1	0.8	35.5	0.2	1.8	3.2	0.8	6.0	0.0	0.8
37	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.7	0.0	0.0
38	0.0	46.2	0.0	0.0	0.0	0.2	0.0	0.0	0.2	0.0	0.8
39	0.3	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2
40	1.7	3.0	0.7	0.0	0.0	0.0	15.8	0.0	9.6	1.1	6740.0
41	0.0	0.0	0.2	0.0	0.0	0.0	0.0	820.0	0.0	0.0	0.0
42	20.5	213.2	12.6	20.7	0.3	0.0	2.7	0.0	1476.7	25,053.0	2.7

were the sipunculid *Golfingia margaritacea* and the polychaete *Ophelia limacina*, which occurred in densities of 33 and 20 individuals/m^2, respectively. This species group was also important in Station Groups F and J.

Species Group 2 - The species in this group were most important in Station Group G. The polychaete *Cistenides granulata* and the barnacle *Balanus crenatus* dominated species density.

Species Group 5 - The species in this group were most important in Station Groups A', A", and J. The polychaetes *Ampharete finnmarchica, A. acutifrons*, and *Chone cincta* dominated species density in this species group.

Species Group 6 - Species in Species Group 6 were most important in Station Groups A", E, F, I, and J. Four species typically dominated in density: the amphipod *Harpinia gurjanovae*, the polychaetes *Haploscoloplos elongatus* and *Pholoe minuta* and the cumacean *Eudorella pacifica*.

Species Group 14 - This species group was most important in Station Group I. The polychaete *Asabellides sibirica* dominated in density (590 individuals/m^2) at Station Group I. This species group was also important at Station Groups A' and G.

Species Group 15 - These species were most important in Station Groups H and I. The echinoid *Echinarachnius parma* and the polychaete *Spiophanes bombyx* dominated the density of this species group, specifically at Station Group H.

Species Group 21 - These species were most important in Station Group A', and specifically at Stations 3, 4, and 5. Two polychaetes, *Chaetozone setosa* and *Pista cristata*, and the bivalve *Odontogena borealis* were most important in density.

Species Group 24 - Species in this group were most important in Station Group D. The protobranch clam *Yoldia hyperborea* had its highest density (16 individuals/m^2) at Station 20 in this station group.

Species Group 28 - The two species in this group were most important in Station Groups A' and B. The clam *Axinopsida serricata* dominated the species group, with 115 and 88 individuals/m^2 found at these two station groups, respectively.

Species Group 29 - These species were most important in Stations Groups A' and B. The gastropod *Retusa obtusa* and the polychaete *Myriochele heeri* were the dominant species in this species group.

Species Group 30 - This species group was most important in Station Groups A' and B. Important species, in terms of density, were the polychaete *Heteromastus filiformis* and the ophiuroid *Ophiura sarsi*.

Species Group 31 - The eight species in this group were most important in Station Groups A' and E. Station 27, in Station Group E, contained all of the species in Species Group 31. One or more of the species were absent in all other stations in the other station groups. The polychaete *Brada villosa* appeared to be the most dominant species at these two station groups. This species group was also important in Station Groups A' and D.

Species Group 32 - Species in this species group were most important in Station Groups A', A", and B. Station 16 in Station Group B contained all of the species in Species Group 32. All but two (*Eudorellopsis uschakovi* and *Ctenodiscus crispatus*) of the species in this group were polychaetes.

Species Group 33 - These species were most important in Station Groups A' and B. Stations 4 and 5 of Station Group A' contained high densities of this species group. The polychaete *Travisia forbesii* had a high density of 92 individuals/m^2 at Station 4.

Species Group 34 - The protobranch clam *Nucula tenuis*, the only member of this species group, was most important at Station Groups C, E, H, and I. The highest density occurred at Station 27 (Station Group E), with 994 individuals/m^2.

Species Group 35 - The protobranch clam *Nuculana fossa*, the only member of this species group, was most important at Station Groups C and E. Station 51 (Station Group C) contained a high density of 222 individuals/m^2.

Species Group 36 - These species were most important at Station Group C. Station 49 contained especially high densities of this species group. The sea cucumber *Cucumaria* sp. occurred in a density of 214 individuals/m^2 at this station.

Species Group 38 - These species were most important at Station Group A", specifically at Station N1. Two species dominated in density: the echiuroid worm *Echiurus echiurus alaskanus* and the amphipod *Ericthonius hunteri* occurred at Station N1 in densities of 165 and 168 individuals/m^2, respectively.

Species Group 40 - These species were important at Station Group J. Three amphipod species of the same genus (*Ampelisca*) occurred in this group. The amphipod *Ampelisca macrocephala* was the most common species present, with 14,408 individuals/m^2 found at Station 65.

Species Group 41 - The clam *Hiatella arctica*, the only member of this species group, was most important at Station Group G (Station 56), with a high density of 820 individuals/m^2 found here.

Species Group 42 - The polychaete *Myriochele oculata* was most important at Station Groups A", H, and I. The highest density occurred at Station 31 (Station Group I), with 25,053 individuals/m^2 found there.

A summary of the major station groups follows (refer to Figs. 2a and 2b, Table V, and the dominance-diversity curves in Appendix B).

When Group A in the Navarin Basin lease area (delineated at the 23.5% similarity level: Fig. 2a, transformed density data) was located on a map, it was apparent that Stations N1 and N5 of this station group were located approximately 1000 km north of the other stations in Group A. Furthermore, examination of the species groups within Station Group A revealed that stations N1 and N5 were distinct, in terms of species densities, from the other Group A stations. Thus, subdivision of Group A into Station Groups A' and A" was made at the 26% similarity level. When untransformed data (information that increases the importance of dominant species to the similarity coefficients) were utilized in the cluster analysis, Stations N1 and N5 (Station Group A"1) were well-separated from the stations in the Navarin Basin group (Station Group A'1) (Fig. 2b; Tables IIIa, b).

Station Group A' - This station group contained 132 species and was composed primarily of species in Species Groups 14, 28, 29, 30, and 42; members of Species Groups 5, 6, 31, 32, 33, 34, and 36 were also common, but to a lesser extent. At least small numbers of individuals of species in most of the species groups were present in this station group. Species that were found in all 12 stations in Station Group A' were *Haploscoloplos elongatus*, *Axinopsida serricata*, *Heteromastus filiformis*, *Nephtys punctata*, and *Priapulus caudatus*. The species dominant in density was *Heteromastus filiformis*, and the species dominant in biomass was *Ctenodiscus crispatus*.

Station Group A" - This station group was characterized by species in Species Groups 6, 30, 38, and 42. Species Groups 2, 4, 5, 31, 32, 34, and 36 were also important, but to a lesser extent. Species dominating by numbers in this station group were *Myriochele oculata*, *Haploscoloplos elongatus*, *Ericthonius hunteri*, and *Diamphiodia craterodmeta*, in decreasing order of density. The dominant species, in terms of biomass, were *Argis lar* and *Echiurus echiurus alaskanus*.

Station Group B - The fauna in this station group was composed of species mainly in Species Groups 28, 29, 30, 34, and 42. Species Groups 6, 14, 32, and 33 were of lesser importance. Species in common at all stations in Station Group B were *Axinopsida serricata* and *Heteromastus filiformis*. The leading species, in terms of density, were *H. filiformis*, *Ophiura sarsi*, *Maldane glebifex*, *Axinopsida serricata*, *Diamphiodia craterodmeta*, and *Priapulus caudatus*. Five of these six species (all but *A. serricata*) were members of Species Group 30. The leading species, in terms of biomass, were *O. sarsi*, *M. glebifex*, and *Ctenodiscus crispatus*.

Station Group C - This group was characterized by species in Species Groups 8, 34, 35, 36, and 42. Species groups 6, 28, 29, and 30 were of lesser importance. The dominant species in this group, in terms of density, were *Nucula tenuis*, *Nuculana fossa*, *Cucumaria* sp., *Sternaspis scutata*, and *Serripes groenlandicus*. The latter three species, dominant in biomass, were members of Species Group 36.

Station Group D - This group was characterized by species in Species Group 34, with Species Groups 6, 30, and 31 of lesser importance. Species in common with all stations in Station Group D were *Barantolla americana*, *Nephtys punctata*, and *Macoma calcarea*. The species in this group dominant in density and biomass, were the polychaete *B. americana* and the clam *Macoma calcarea*, respectively.

Station Group E - This group was characterized by Species Groups 6, 12, 31, 34, and 35. Species Groups 15, 28, and 30 were of lesser importance. The dominant species in this group, in terms of density and biomass, were the polychaete *Haploscoloplos elongatus* and the clam *Nucula tenuis*, respectively.

Station Group F - This group was characterized by species in Species Groups 6, 7, 11, 15, 30, and 40. Species Groups 1, 8, and 11 were of lesser importance. Species dominating in density at this station group were *Harpinia gurjanovae, Praxillella praetermissa, Glycinde picta, Haploscoloplos elongatus*, and *Barantolla americana*, all members of Species Group 6. *Echinarachnius parma* dominated in biomass.

Station Group G - This group was characterized by taxa in Species Groups 2, 14, and 41, with species groups 1, 6, 18, and 30 of lesser importance. Species dominating in density in this group were *Hiatella arctica, Asabellides sibirica, Balanus crenatus*, and *Cistenides granulata*, in decreasing order of density. The species dominating in biomass were *Hiatella arctica* and *Strongylocentrotus droebachiensis*.[1]

Station Group H - This group was characterized by Species Groups 15, 34, and 42, with Species Groups 6, 30, 36, and 40 of lesser importance. Taxa dominating in density were *Myriochele oculata, Echinarachnius parma*, and *Nucula tenuis*. The species dominating in biomass was *Macoma calcarea*.

Station Group I - This group was characterized by Species Groups 6, 11, 12, 14, 15, 34, and 42. Species Groups 7 and 13 were of lesser importance. The dominant species in this group (Station 31) were *Myriochele oculata, Asabellides sibirica, Alcyonidium disciforme*, and *Pholoe minuta*, in decreasing order of density. Foraminifera were also very important, occurring at a density of 3,753 individuals/m^2. The species dominating in biomass was *Alcyonidium disciforme*.

Station Group J - This group was characterized by Species Groups 1, 5, 6, 7, 11, 34, and 40. Species Groups 1 and 30 were of lesser importance. Species dominating in this group were *Ampelisca macrocephala, A. birulai*,

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[1]Specimens originally listed in the data printouts as unidentified Echinoidea were determined as *Strongylocentrotus droebachiensis* after all data were analyzed.

A. eschrichti, and *Mysella tumida*, in decreasing order of density. *Ampelisca macrocephala* also dominated the biomass.

A principal coordinate analysis using the Czekanowski coefficient with transformed density data (Fig. 5) revealed station groupings similar to those produced by cluster analysis (Fig. 2a). The greatest amount of group separation was attributed to Axis 1 (25.2%; Table VI). The amount of separation attributed to Axes 2 and 3 was 16.2% and 10.8%, respectively. Groups distinctly separated in Figure 5a were A", D, and G. Station groups that showed the least separation in Figure 5a were A' and B. Stations 73 and 74, which clustered with Station Groups C and F, respectively (Fig. 2), but were spatially separated from these groups by approximately 1,000 km (Fig. 3a), also grouped with Station Groups C and F in the principal coordinate analysis (Fig. 5).

Numerical Analysis: Untransformed Density Data

A normal cluster analysis of untransformed abundance data produced ten station groups at the 22% similarity level (Fig. 2b; Table IIIa, b). One major group, identified as Station Group A'1, consisted primarily of stations deeper than 100 m within and adjacent to the Navarin Basin and Zhemchug Basin lease areas. This station group (A'1) originally consisted of two station groups (A' and B) that were identified by the log-transformed data analysis, indicating a general similarity between these two station groups. The dominant species linking these two groups were *Asinopsida serricata*, *Heteromastus filiformis*, and *Myriochele oculata*. The other large group, identified as Group D1, consisted primarily of stations close to or shallower than 100 m, northeast of the Navarin Basin lease area. Group A"1 consisted of two stations adjacent to Cape Nome. The other station groups are identical to those delineated in the log-transformed cluster analysis (Figs. 2a and 3a).

Motility and Trophic Structure

The percent frequency of occurrences of motility and feeding classes in station groups formed by cluster analysis of transformed density data are presented in Table VII. The most frequent motility class in each station

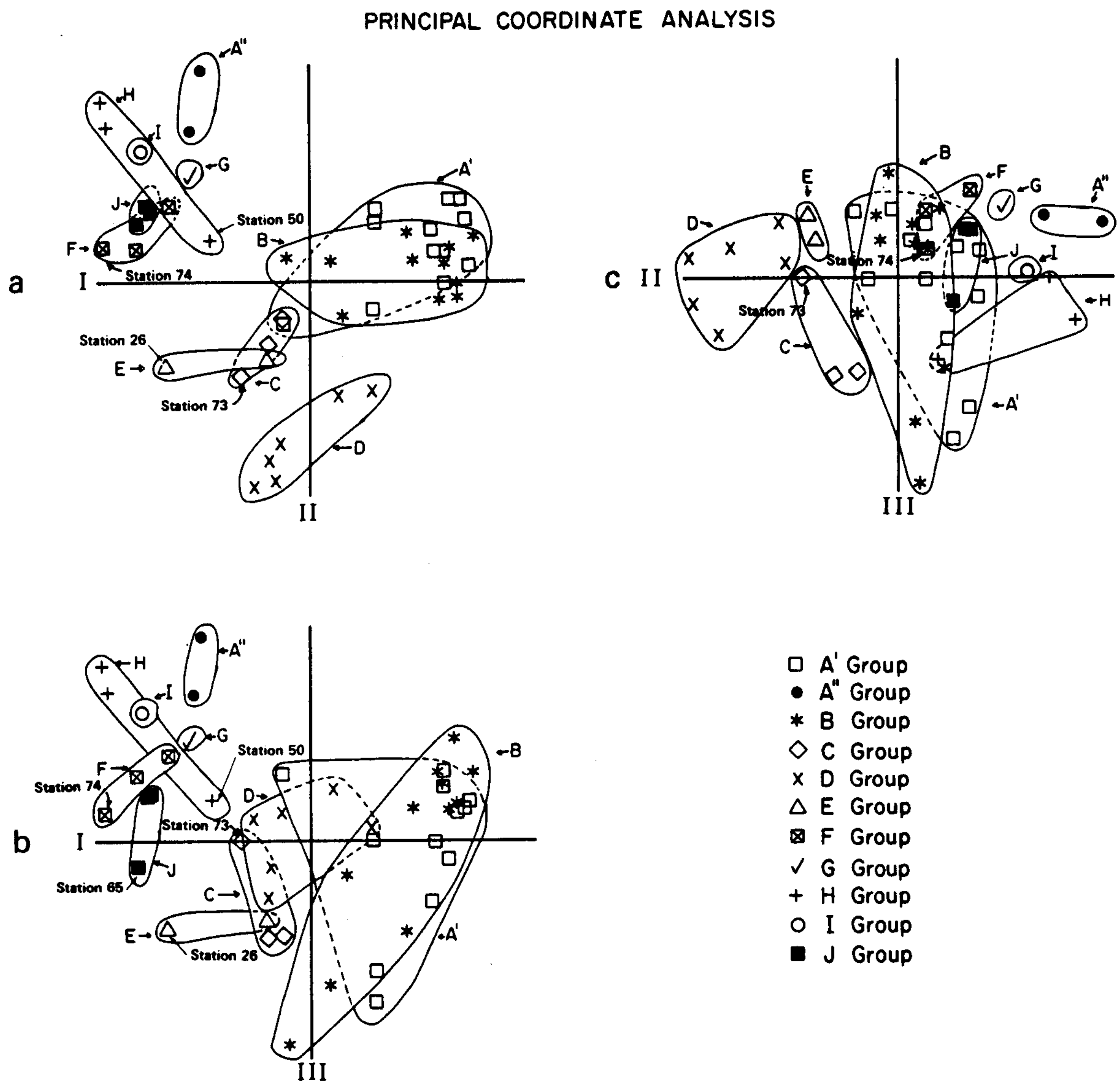

Figure 5. Plots of loadings on the first three coordinate axes extracted by principal coordinate analysis, using *ln*-transformed density data and the Czekanowski similarity coefficient.

group was of individuals that were motile. The percentage of motile individuals among station groups ranged from 55% (Group J) to 76% (Group C). Sessile and discretely motile organisms ranked second and third, respectively, in terms of percent frequency of occurrence. Deposit-feeding organisms dominated the feeding classes in all station groups, ranging from 51% (Group F) to 64% (Group D). Suspension feeders and predators were nearly equal at most station groups. Most station groups were composed of less than 12% scavengers.

Density, Biomass, and Diversity

Density, biomass, and diversity data arranged according to station groups delineated by cluster analysis of transformed density data are presented in Table VIII. Density values ranged from 148 individuals/m^2 at Station 21 (Station Group D) to 32,023 individuals/m^2 at Station 31 (Station Group I). The station groups with the lowest and highest mean density were Station Groups D and I, respectively (Table IX). Biomass values ranged from 14.2 g/m^2 at Station 71 (Station Group B) to 649.4 g/m^2 at Station 38

TABLE VI

AMOUNT OF BETWEEN-STATION-GROUP SEPARATION OF THE THREE DOMINANT AXES IN THE PRINCIPAL COORDINATE ANALYSIS OF *ln*-TRANSFORMED DENSITY DATA

Axis	Percent Separation of Station Groups	Cumulative percent
1	25.2	25.2
2	16.2	41.4
3	10.8	52.2

TABLE VII

DISTRIBUTION OF MOTILITY AND FEEDING CLASSES IN STATION GROUPS FORMED BY CLUSTER ANALYSIS OF *ln*-TRANSFORMED DENSITY DATA

N = number of species occurring in a station group, SE = sessile, DM = discretely motile, M = motile, DF = deposit feeder, SF = suspension feeder, P = predator, S = scavenger, U = unknown

Station Group	Motility Class %*				Feeding Class %*				
	M	DM	SE	U	DF	SF	P	S	U
A^{1} (N = 132)	60	15	24	1	57	20	13	9	1
A^{11} (N = 63)	65	14	21	0	56	16	13	14	1
B (N = 101)	60	12	28	0	61	17	16	6	0
C (N = 49)	76	4	20	0	53	17	22	8	0
D (N = 48)	67	7	26	0	64	11	19	6	0
E (N = 44)	75	6	19	0	63	12	20	5	0
F (N = 81)	63	15	22	0	51	19	17	12	1
G (N = 33)	70	3	27	0	57	15	17	8	3
H (N = 65)	63	11	26	0	55	20	16	9	0
I (N = 38)	66	8	26	0	55	20	18	7	0
J (N = 72)	55	15	30	0	55	26	11	8	0

*Percentages based on the number of each species occurring in the station group.

TABLE VIII

DENSITY, BIOMASS, AND DIVERSITY OF INDIVIDUAL BENTHIC SAMPLING STATIONS

Stations are arranged according to the station groups delineated by a cluster analysis of transformed density data

Station		Density	Biomass	No. of	Simpson	Shannon	Brillouin		Species
Group	Number	(No/m^2)	(g/m^2)	Taxa	Diversity	Diversity	Diversity	Evenness	Richness
A'	1	400	118.3	38	0.05	3.27	2.94	0.90	7.26
	2	1666	239.7	60	0.08	3.12	3.00	0.76	8.70
	3	3604	75.1	73	0.11	2.96	2.90	0.69	9.23
	4	2336	84.4	85	0.09	3.17	3.08	0.71	11.26
	5	2266	101.6	82	0.14	2.86	2.78	0.65	10.77
	7	2192	131.4	62	0.08	3.05	2.96	0.74	8.53
	8	2592	94.4	56	0.18	2.55	2.49	0.63	7.38
	9	1570	122.4	44	0.29	2.23	2.15	0.58	6.25
	10	868	27.2	40	0.06	3.18	3.03	0.86	6.30
	11	2186	144.4	62	0.08	3.20	3.10	0.77	8.58
	12	1596	173.2	50	0.08	3.05	2.97	0.78	6.90
	13	1086	21.8	39	0.07	3.04	2.87	0.83	6.41
A"	N1	2528	158.7	53	0.08	2.99	2.93	0.75	7.00
	N5	958	466.4	48	0.05	3.33	3.17	0.86	7.45
B	16	1954	90.7	54	0.10	2.95	2.88	0.74	7.27
	17	1950	167.3	41	0.17	2.41	2.34	0.65	5.75
	18	1618	46.3	53	0.08	3.08	2.95	0.77	7.87
	22	1702	215.9	36	0.16	2.51	2.42	0.70	5.23
	23	1826	130.3	45	0.08	2.94	2.84	0.77	6.52
	24	1348	92.4	39	0.06	3.02	2.91	0.82	5.88
	69	1784	122.6	45	0.13	2.73	2.67	0.72	6.08
	70	1718	155.8	48	0.17	2.52	2.45	0.65	6.65
	71	1018	14.2	29	0.26	2.00	1.93	0.59	4.30
	72	1006	325.9	32	0.19	2.33	2.23	0.67	4.95
	75	782	62.9	34	0.10	2.72	2.59	0.77	5.41
C	49	958	592.0	35	0.10	2.68	2.55	0.75	5.62
	51	796	68.4	26	0.24	2.00	1.92	0.61	3.98
	73	720	47.6	24	0.14	2.44	2.35	0.77	3.74
D	14	246	34.0	15	0.09	2.48	2.21	0.92	3.21
	15	890	156.8	32	0.07	2.96	2.79	0.85	5.43
	19	1152	157.0	39	0.09	2.85	2.75	0.78	5.78
	20	424	120.6	22	0.27	1.93	1.83	0.62	3.54
	21	148	20.8	11	0.30	1.61	1.44	0.66	2.23
	25	870	77.5	20	0.19	2.19	2.00	0.72	3.77
E	26	1352	32.5	26	0.40	1.53	1.48	0.46	3.62
	27	3036	266.4	45	0.19	2.35	2.31	0.62	5.58
F	54	3008	431.6	42	0.09	2.86	2.75	0.76	6.32
	55	9646	231.3	74	0.04	3.47	3.40	0.81	9.49
	74	1524	24.5	30	0.13	2.42	2.32	0.71	4.65
G	56	1933	634.6	43	0.30	2.17	2.12	0.57	5.73
H	48	4332	112.2	47	0.61	1.15	1.13	0.30	5.60
	50	1842	46.7	39	0.42	1.59	1.54	0.43	5.14
	52	2150	35.9	46	0.18	2.26	2.20	0.59	6.10
I	31	32023	145.0	36	0.68	0.90	0.89	0.25	3.67
J	38	15664	649.4	62	0.19	2.21	2.20	0.53	6.48
	40	9542	485.2	52	0.23	2.13	2.12	0.54	5.76
	65	21014	376.4	30	0.45	1.04	1.04	0.31	3.00

(Station Group J). The station group with the lowest and highest mean biomass were Station Groups H and G, respectively. The Shannon diversity ranged from 0.90 (Station 31:Station Group I) to 3.47 (Station 55:Station Group F) while the Brillouin diversity ranged from 0.89 at Station 31 to 3.40 at Station 55. Simpson diversity (a dominance index) ranged from 0.04 at Station 55 (74 taxa present) to 0.68 at Station 31 (36 taxa present). Brillouin evenness ranged from 0.25 at Station 31 (Station Group I) to 0.92 at Station 14 (Station Group D). Species richness ranged from 2.23 at Station 21 (Station Group D) to 11.26 at Station 4 (Station Group A').

VII. DISCUSSION

Biologically Important Taxa (BIT)

One hundred and twenty eight (128) taxa were delineated as BIT, with 62 important in terms of biomass at one or more stations. Since some of these taxa are distributed throughout the study area or are common within specific station groups, they probably have great influence on trophic and

TABLE IX

MEAN DENSITY AND BIOMASS VALUES FOR ALL STATION GROUPS DETERMINED BY CLUSTER ANALYSIS OF *ln*-TRANSFORMED DENSITY DATA

Station Group	Density (No/m^2)	Biomass (g/m^2)
A'	1,864.	111.2
A"	1,743.	312.6
B	1,519.	129.5
C	825.	236.0
D	622.	94.4
E	2,194.	149.4
F	4,726.	229.1
G	1,933.	634.6
H	2,775.	64.9
I	32,023.	145.0
J	15,407.	503.7

other interactions in their particular localities. Many of these taxa should have value as monitoring organisms if any of the lease areas are developed into producing oil fields.

Numerical Analysis

The numerical analysis of transformed abundance data delineated 11 station groups on or near four potential petroleum lease areas (Navarin Basin, Zhemchug Basin, St. Matthew Basin, and Hope Basin) and within the Chirikov Basin (Figs. 2a and 3a).

Three station groups (Station Groups B, C, and F) contained stations which were spatially disjunct (i.e., well separated geographically) (Fig. 3a). Station Group B consisted of two station clusters, one in the Navarin Basin lease area and the other in the Zhemchug Basin lease area. Although the six density-dominating species (*Heteromastus filiformis, Ophiura sarsi, Maldane glebifex, Axinopsida serricata, Diamphiodia craterodmeta*, and *Priapulus caudatus*) in Station Group B occurred in both clusters, only *O. sarsi* and *A. serricata* dominated those stations in the Zhemchug Basin lease area, while the remaining four species dominated in the Navarin Basin lease area (data summary submitted to NODC). Separation of these two station clusters in Station Group B was not evident in the principal coordinate analysis.

Station Group C consisted of three stations, one of which (Station 73) was located approximately 1000 km south of the other two members of the group (Figs. 2a and 3a). All three stations were linked primarily by *Nucula tenuis* (Station Group 34) and, to a lesser extent, by *Sternapsis scutata* (Species Group 36). Station 73, located in deeper water than Stations 49 and 51, was characterized by (1) a larger number of *Nucula tenuis* and *Sternaspis scutata* than occurred at Stations 49 and 51, and (2) by the absence of *Nuculana fossa* (Species Group 35), *Cucumaria* sp., and *Serripes groenlandicus* (both in Species Group 36). This separation of Station 73 from the other two stations in Group C is also apparent in the principal coordinate analysis (Fig. 5). Station 49 was the only station of the station group that contained all five of the density-dominating species (*N.*

tenuis, *N. fossa*, *Cucumaria* sp., *S. scutata*, and *S. groenlandicus*) of Station Group C. Station 51 contained high densities of *N. tenuis* and *N. fossa*.

Station Group F also consisted of three stations, one of which (Station 74) was located approximately 1000 km south of the other two members of the group (Figs. 2a and 3a). The three stations in the group were linked by *Pholoe minuta*, *Glycinda picta*, *Praxillella praetermissa*, *Harpinia gurjanovae*, *Haploscoloplos elongatus* (all in Species Group 6) and *Spiophanes bombyx* (Species Group 15). Stations 54 and 55, but not Station 74, were linked by *Westwoodilla caecula* (Species Group 9) and *Cyclocardia* sp. (Species Group 10). In addition, Station 74 was differentiated by the much lower density values (1524 individuals/m^2), one-third to one-sixth those of Stations 54 (3008 individuals/m^2) and 55 (9646 individuals/m^2), respectively. Furthermore, biomass estimates for Station 74 (24.5 g/m^2) were roughly six percent and ten percent of those at Stations 54 (431.6 g/m^2) and 55 (231.3 g/m^2), respectively. Among the six species (*Harpinia gurjanovae*, *Praxillella praetermissa*, *Glycinde picta*, *Haploscoloplos elongatus*, *Barantolla americana*, and *Paraphoxus oculatus*) that dominated in Group F, only two (*B. americana* and *P. oculatus*) did not occur at all three stations. When the principal coordinate analysis was examined, Station 74 was not obviously separated from the other two stations in Station Group F (Fig. 5), reaffirming the similarity of the stations in the group despite the considerable geographical separation of Station 74.

The Navarin Basin lease area consisted of three distinct station groups, A', B, and D. Most of the stations in Groups A' and B were located at depths between 100 m and 200 m. Similarities between the latter two groups exist in the importance of five dominant species groups (6, 28, 29, 30, 32) and in the dominance of three species: *Heteromastus filiformis*, *Axinopsida serricata*, and *Ophiura sarsi* (Figs. 1 and 5; Table V; Appendix B). The only station (Station 13) in Station Groups A' and B with few individuals of the above three species occurred in the relatively shallow water adjacent to St. Matthew Island; Station 13 was the last station to join Station Group A' in the cluster analysis of transformed density data (Fig. 2a), indicating its low affinity with Group A'. The principal coordinate analysis revealed the similarity of Groups A' and B: little separation between these groups was apparent (Fig. 5). Reduced numbers of species (in either of the station groups) in Species Groups 5, 6, 7, 14, 19, 21, 23, 31, 33, 34, 36, and 42 distinguished Station Group B from Group A'.

Three (Stations 14, 19, and 20) of the six stations in Station Group D were located in water depths between 80 and 90 m. This station group had the lowest mean density (622 individuals/m^2) and second-lowest mean biomass (94 g/m^2) of all of the station groups (Table IX). Station Group D was well separated from all of the other groups in the principal coordinate analysis (Fig. 5).

Station Group E included two stations (Stations 26 and 27) in the St. Matthew Basin lease area at water depths of 35 and 46 m, respectively. These stations were dominated by the polychaete *Haploscoloplos elongatus*, with densities of 612 (at Station 26) and 418 (at Station 27) individuals/m^2. No other stations examined in the present survey contained such high densities of *H. elongatus*. Station 27 also contained the highest density, of all stations, of the protobranch clam *Nucula tenuis* (994 individuals/m^2). The highest concentration of *N. tenuis* elsewhere was at Station 50 in Station Group H, adjacent to Kotzebue Sound, with 238 individuals/m^2. Station 27 in Station Group E showed a close affinity with Station Groups C and D on plots of the first and second axes and of the first and third axes of the principal coordinate plot (Fig. 5a, b). Station 26 in Group E is consistently separated from Station 27 on these plots, presumably the result of the high density of *N. tenuis* at the latter station.

Station Group A" consisted of two stations (N1 and N5, located close to Cape Nome) that were in only 22 m of water. These stations were dominated in density by the polychaetes *Myriochele oculata* (47 individuals/m^2) and *Haploscoloplos elongatus* (72 individuals/m^2) and in biomass by the shrimp *Argis lar* (17.6 g/m^2) and the echiuroid *Echiurus echiurus alaskanus* (9.2 g/m^2). Station Group A" was well-separated in the principal coordinate analyses from all other station groups (Fig. 5), although it showed affinities to Station Groups G (geographically close) and I (another shallow-water station group dominated by *M. oculata*).

Station Group G, represented by a single station (Station 56) located in Bering Strait, was dominated by a suspension-feeding clam (*Hiatella* *arctica*), a deposit-feeding polychaete (*Asabellides sibirica*), and a suspension-feeding barnacle (*Balanus crenatus*), with densities of 820, 93, and 83 individuals/m^2, respectively. No other stations approximated the densities of these species. Biomass values at this station were dominated by three species, two of which were also important in density: *Hiatella arctica* (265.8 g/m^2), *Balanus crenatus* (22.8 g/m^2), and *Strongylocentrotus droebachiensis*[1] (221.8 g/m^2). In the principal coordinate analysis, Station 56 showed some affinity with the two Chukchi Sea stations of Group F (Stations 54 and 55) just north of the Bering Strait (Fig. 5). Both density and biomass at Station 56 were relatively high, with estimates of 1933 individuals/m^2 and 635 g/m^2, respectively. Stoker (1981) also reported a high biomass at stations in the region of the Bering Strait. He related these high values to: (1) high productivity in spring, (2) an influx of detrital carbon from the Yukon River (as well as Norton Sound; Feder, unpub. data), and (3) the current structure in the vicinity of the Strait, such that the velocity of the northward flow, with its contained detritus, is greatly increased (data presented in this Final Report appear to reflect this by the high abundance of the suspension-feeding clam *Hiatella* and the sea urchin *Strongylocentrotus*) and consequently transports much organic carbon to either side of the strait.

The stations in Group H, consisting of three stations northeast of the Bering Strait and along the Seward Peninsula, were dominated by the surface-deposit-feeding polychaete *Myriochele oculata* and the suspension-feeding sand dollar *Echinarachnius parma*; tunicates also dominated at two of the stations (Stations 48 and 52) of the group closest to the Bering Strait. The surface-deposit-feeding (and probably also suspension-feeding) clam *Macoma calcarea* dominated in biomass here. The mean density and biomass of the stations in this group ranged from 1842 to 4332 individuals/m^2 and 36 to 112 g/m^2, respectively. In the principal coordinate analysis, Stations 48 and 52 of Station Group H were well separated from all other groups in the plots of the first and second axes and of the first and third axes

[1]Listed in data sheets as Echinoida and identified after data were analyzed (see Results).

(Fig. 5a, b). Station 50, the one station of the group located adjacent to Kotzebue Sound and closest to Station Group C, is always separated from the other two stations of Group H and shows affinities with Group C. The high densities of the dominant species, both surface-deposit- and suspension-feeders, presumably reflect the periodic availability of detrital materials passing from the Bering Strait eastward along the Seward Peninsula (see Discussion in Stoker, 1981).

Station Group I is represented by a single station (Station 31) located just north of Etolin Strait (between the mainland and Nunivak Island). Station 31 was dominated by Foraminifera, the deposit-feeding polychaetes *Myriochele oculata* and *Asabellides sibirica*, and the suspension-feeding ectoproct (bryozoan) *Alcyonidium disciforme*. The latter species dominated in biomass. In the principal coordinate analysis, Group I is separated from all other groups. The high density of 32,023 individuals/m^2 at this station is the highest observed at any station sampled in this investigation, and is primarily the result of large numbers of the tube-dewelling polychaete *M. oculata*. The water in Etolin Strait probably contains terrestrial detritus derived from the Kuskokwim River in the summer; this material presumably settles out on the bottom adjacent to Station 31 when current velocities are reduced there. The highest Simpson Index (a dominance index that approaches 1.0 when few species occur at a station) was recorded at this station, with a value of 0.68; the lowest Shannon Diversity Index, 0.90, also occurred here. The species at Station 31 are dominated by organisms that appear to be adapted to an environment where the bottom is periodically enriched by the influx of allochthanous carbon from the Kuskokwim River. The extremely high foraminiferan density further suggests an enriched, but well oxygenated, bottom.

Station Group J, consisting of three stations north of St. Lawrence Island (the Chirikov Basin), was distinguished by the dominance of amphipods in Species Groups 6 and 40. Within Station Group J, Station 65 (the station in the group closest to St. Lawrence Island) was the most dissimilar station in the group (Fig. 3a), due in part to the presence of over 14,000 *Ampelisca macrocephalus*/m^2 at that station. Also, at Station 65, the other two amphipod species of Species Group 40, *A. birulai* and *A. eschrichti*, were relatively unimportant. Conversely, Stations 38 and 40 had relatively high densities of all three of the amphipod species in Species Group 40. Station 65 joins the other two stations in Group J at a low similarity level (26%; Fig. 2a) in the *ln*-transformed cluster analysis. The area within and adjacent to Station Group J is a region where gray whales (*Eschrichtius robustus*) seasonally feed intensively on gammarid amphipods (Nerini *et al.*, 1980; personal communication), and where bearded seals (*Erignathus barbatus*) and walruses (*Odobenus rosmarus divergens*) also feed periodically on the bottom (Lowry and Frost, 1981). Although Station Group J shows strong affinities to Group F in the principal coordinate analysis (Fig. 5), these groups are not adjacent to each other geographically (Fig. 3a). However, the location of Station Group F north of the Chirikov Basin and the Bering Strait probably indicates settlement of larvae of species transported form the stations in Group J to the northern region. Group J is also relatively well separated geographically from all of the other station groups.

General Features of the Station Groups

An assessment of the biological data in this report indicates that most of the station groups, both within and adjacent to the basins considered, have features that separate them from all of the other groups. Characteristic species dominate in density and biomass in most of the groups, and can be used to describe these groups, thereby making it possible to plan viable monitoring programs for each of the petroleum lease areas. A description of some of the areas described in this report is also included in Stoker (1978), which complements and supplements some of the information presented here.

The station groups located primarily in the deeper waters of the Zhemchug and Navarin Basin lease areas (Station Groups A' and B) were composed mainly of deposit-feeding organisms characteristic of the muddy bottom present in these areas (see Feder *et al.*, 1980b). Two deposit-feeding species were common to this shelf area: the capitellid polychaete *Heteromastus filiformis* and the mud star *Ctenodiscus crispatus*.

The two stations (Stations 73 [Station Group C] and 74 [Station Group E]) within the Zhemchug Basin north of the Pribilof Islands are in waters shallower than are Station Groups A' and B and are also characterized by deposit-feeding species. These species are more characteristic of mid-shelf areas (see Feder *et al.*, 1980b), however: at Station 73, the deposit-feeding clams *Nucula tenuis* and *Nuculana fossa* dominated, and, at Station 74, the deposit-feeding polychaetes *Praxillella praetermissa* and *Glycinde picta* dominated. The substratum in the vicinity of the latter station is characteristically higher in sand fractions than are other regions around the Pribilof Islands (Feder *et al.*, 1980b). A dominance, in terms of biomass, of two suspension-feeding species at Station 74 appears to reflect this difference in substrate, with the sand dollar *Echinarachnius parma* (probably also using resuspended particulate matter) and the clam *Serripes groenlandicus* present.

Station Group D, east of the Navarin Basin, is also dominated by deposit-feeding species. Again, however, the species differ somewhat from other nearby stations within the Basin. The deposit-feeding clams *N. tenuis* and *Macoma calcarea* and the deposit-feeding polychaete *Maldane glebifex* are the most common species present. The importance, in biomass, of the sand dollar *E. parma* suggests an increase in sand fractions of the substrate in the Group D area.

The stations within the St. Matthew Basin (Group E) suggest an enriched depositing environment. Three deposit-feeding species dominated in density: the polychaetes *Haploscoloplos elongatus* and *Barantolla americana* and the clam *N. tenuis*. The dominance in biomass of deposit-feeding clams (*N. tenuis, M. calcarea, N. fossa,* and *Yoldia amygdalea*) further indicates the presence of an organically rich bottom, presumably representing a region at the periphery of the very rich area encompassed by Station 31 (Station Group I). It is in the latter region that the extraordinary high densities of the deposit-feeding polychaete *Myriochele oculata* occurs.

The shallow-water stations (23-40 m) of the Chirikov Basin are dominated by tube-dwelling amphipods, *Ampelisca* spp. These amphipods are generally considered suspension feeders (probably feeding primarily on resuspended sediments available after storms) and typically occur where high levels of particulate material settle to the bottom. Presumably, zooplankters funneled through the Anadyr Strait and detrital particles from the Yukon River and Norton Sound contribute to this particulate material (see Stoker, 1981).

The stations off Cape Nome (Station Group A") also reflect an environment where particulate material is settling to the bottom. The polychaete *M. oculata* is very common here, and the deposit-feeding clam *M. calcarea* dominates in biomass. The suspended materials of Norton Sound (derived from the Yukon River and other rivers within the Sound) presumably contribute much of the food available to the benthic species of Station Group A".

Station Group G (Station 56), located in Bering Strait, reflects the high-velocity currents and hard substrate present here, by the increase in dominance of suspension-feeding species: the clam *Hiatella arctica* and the barnacle *Balanus crenatus*. An increase in benthic biomass is typically apparent in the Bering Strait (Stoker, 1978, 1981).

The species that dominate Station Group H, northeast of Bering Strait, indicate the deposition (as a result of loss of current velocity) of materials funneled through the Strait and into Kotzebue Sound. The polychaete *M. oculata* and the deposit-feeding clams *N. tenuis* and *M. calcarea* are important here. The presence of the sand dollar *E. parma* also suggests an increase in sand fraction in the sediment here.

The stations south of the Hope Basin lease area (Stations 54 and 55) were dominated by deposit-feeding species feeding on particulate material funneled through Bering Strait and deposited in a region where water currents have decreased in velocity. The deposit-feeding polychaetes *P. praetermissa*, *G. picta*, and *H. elongatus* were common here. The suspension-feeding sand dollar *E. parma* dominated in biomass, suggesting that particulate material is still an important component of the water column in this region.

The shallow, muddy stations of Kotzebue Sound, east of the Hope Basin lease area, were dominated by deposit-feeding species characteristic of such an environment. The clams *N. tenuis*, *N. fossa*, the sea cucumber *Cucumaria* sp., and the polychaete *Sternaspis scutata* were common.

General Summary and Implications of Oil Development

In general, each of the station groups within or adjacent to the basin examined in this study had individual species and/or species groups that characterized and distinguished them from the other groups. In some cases, the similarities within groups occurred between stations that were widely separated geographically, e.g., the 1000 km separating stations of Station Groups C and F and the disjunct distribution of segments of Station Group B (Figs. 2a and 3a). Although the wide separation of stations within groups C and F implies ecological differences between these disjunct stations, in general, these station groups delineated by multivariate techniques appear to be distinctive enough to also be useful for monitoring purposes. Furthermore, knowledge of species composition within the station groups makes it possible to assess the ecological consequences of damage or loss of any of these species within the stations or station groups. Thus, the deposit-feeding species in the Zhemchug and Navarin Basins are actual or potential food resources for several bottom-feeding species (e.g., the Tanner crab *Chionoecetes opilio* and some species of bottomfishes), and loss of these food organisms could disrupt the trophic system involving these and other predatory species in the region of the lease areas (Feder and Jewett, 1981a; Jewett and Feder, 1981). The organically-enriched region of the St. Matthew Basin lease area sustains dense populations of numerous species of sessile, deposit-feeding organisms, many of which are of potential importance to bottom-feeding predators. No data are available on the epifaunal species composition or trophic interrelationship of species in the latter lease area. However, it is to be expected that such large concentrations of organisms as are found at Station 31 (Fig. 1; Table IX) must have ecological importance within the system, and alterations of the benthic biota would be expected if any of the species present were negatively affected by industrial activity. In addition, the high densities (25,000 individuals/m^2) of the tubes of the polychaete *Myriochele oculata* at Station 31 must stabilize the bottom sediments of the area to some extent. Loss of some or all of these sessile polychaetes could destabilize the bottom sediments, with subsequent alteration of the species composition, density, and/or biomass (e.g., see discussion in Rhoads, 1974). Similar destabilization of bottom sediments could also occur in the Chirikov Basin if severe damage was sustained by the tube-building ampeliscid amphipods (*Ampelisca* spp.) present in large numbers there, as well as the tube-dwelling polychaete *Myriochele oculata* within Station Group H (northeast of Bering Strait). In the case of the ampeliscids in the Chirikov Basin, gray whales depend on these crustaceans for food during the summer, and depletion of this resource would be critical for the whales at this time; they feed almost exclusively on their summering grounds (Frost and Lowry, 1981). Likewise, damage to the large bivalve mollusk populations present in the Chirikov Basin could negatively affect the bearded seals and walruses of the region (Stoker, 1978; Fay, 1981; Frost and Lowry, 1981; Lowry and Frost, 1981). The occasional importance of the northeastern Bering and southeastern Chukchi Seas to bottom-feeding fishes (Jewett and Feder, 1980; Feder and Jewett, 1981a) implies that the high standing stock of infauna (Stoker, 1978, 1981) is important to these organisms in those warm years when the fishes are able to migrate there to feed intensively. The continued presence of *Chionoecetes opilio*, a commercially-fished predator (in the southeastern Bering Sea) on infaunal organisms (Feder and Jewett, 1981a), in the latter regions also indicates the importance of sustaining healthy populations of infauna there.

VIII. CONCLUSIONS

Numerical analysis of van Veen grab samples collected in 1979 and 1980 in the eastern Bering and southeastern Chukchi Seas identified station groups (based on infaunal and slow-moving epifaunal species) on or near four potential petroleum lease areas — the Zhemchug Basin, Navarin Basin, St. Matthew Basin, and Hope Basin. A preliminary understanding of the Chirikov Basin, in conjunction with the data of Stoker (1978), also emerged from the present investigation. The present study, although based on collections made on one occasion at each station, makes it possible to develop a preliminary assessment of the infaunal composition in the vicinity of the above lease areas. As described in the introduction of the present report, organisms of the infaunal benthos are frequently chosen to monitor long-term pollution effects because they tend to remain in place, typically react to long-term environmental changes, and, by their presence, generally qualitatively reflect the nature of the substratum. Furthermore, the presence of epifaunal and finfish species of actual or potential commercial importance (crabs, shrimps, snails, bottomfishes), most of which feed on benthic organisms in the areas investigated, also emphasizes the necessity of understanding the benthic biota. Thus, changes in the availability of benthic food organisms (inclusive of many of the species addressed in this report) could indirectly affect these commercial species.

The data presented in this report, in conjunction with those of Haflinger (1978), Stoker (1978), Feder and Jewett (1978, 1980), and Feder *et al.* (1980b; in press), make it possible to understand the infaunal composition of each of the oil lease areas (each of which is separable biologically from the others) prior to initiation of industrial activity. Consequently, a benthic monitoring program can now be developed for each lease area, if required, with confidence that a reasonable data base is available to serve as the informational core of each program. However, it must be emphasized that most of the benthic biological data from the region considered in this report is distribution and abundance information only. Although limited life-history data are available for some bottom-living species (Feder and Jewett, 1978; Feder and Jewett, 1981a; Hood and Calder, 1981a, b; Feder *et al.*, in press), life-history information for the majority of these species is unavailable. Furthermore, a broad spectrum of physical and chemical environmental data, taken in conjunction with these benthic biological data, are virtually non-existent (but, see Haflinger, 1978; Stoker, 1978; relevant chapters in Hood and Calder, 1981a, b). Thus, although monitoring programs can be initiated, they can only be based on the available biological density and biomass data.

Generalizations, primarily based on multivariate analysis of *ln*-transformed density data, are presented below on the benthos in the vicinity of the petroleum lease areas investigated. A comparison of the summaries illustrates the uniqueness of most of the biological groups identified in the eastern Bering and southeastern Chukchi Seas. Each station group is considered briefly in terms of the major features that characterize it.

1. The infauna of the Zhemchug Basin lease area was segregated into three groups — Station Group B, Station 73, and Station 74 (Fig. 3a).
    a. Station Group B — the stations occurred at depths between 100 m and 200 m. Some stations in this station group also occur in the Navarin Basin lease area; these stations are considered when that group is presented. Most of the species in the group were deposit

feeders. The dominant species (in density) present were the polychaete *Heteromastus filiformis*, the brittle star *Ophiura sarsi*, the polychaete *Maldane glebifex*, the clam *Axinopsida serricata*, and the brittle star *Diamphiodia craterodmeta*, in decreasing order of importance. The leading species in biomass in this group were *O. sarsi, M. glebifex,* and the mud-consuming sea star *Ctenodiscus crispatus*, in decreasing order of importance.

b. Station 73 — located at 79.6 m, this station clustered with Station Group C, but is spatially separated by 1,000 km from the other stations in the group. Station Group C is considered below. The station was characterized in density by the deposit-feeding clam *Nucula tenuis* and the deposit-feeding polychaete *Sternaspis scutata*, in decreasing order of importance.

c. Station 74 — located at 72 m depth, just north of the Pribilof Islands. The station clustered with Station Group F, but was spatially separated by 1,000 km from the other stations in the group. Station Group F is considered separately below. The dominant species, by density, at this station were the amphipod *Harpinia gurjanovae* and the deposit-feeding polychaetes *Praxillella praetermissa* and *Glycinde picta*, in decreasing order of importance. Species dominant in biomass were *Nepthys caeca* (12.5 g/m^2), *Praxillella practermissa* (3.1 g/m^2), and unidentified Foraminifera (2.4 g/m^2).

2. The Navarin Basin lease area was composed of three relatively distinct station groups — Station Group A', B, and D (Fig. 3a).

   a. Station Group A' — most of the stations of this group occurred at depths between 100 m and 200 m. Station 12 of this group occurred at 103 m, and Station 13 was at 78 m; both of the latter stations were close to, and west of, St. Matthew Island. The dominant species present, in terms of density, was the deposit-feeding polychaete *Heteromastus filiformis*; the biomass dominant was the mud-consuming sea star *Ctenodiscus crispatus*. This group differed from Station Group B by differences in species groups (see Discussion and Table V).

b. Station Group B — although this station group is a disjunct one (i.e., separated by Station Group A'; Fig. 3a), its biological features are relatively similar throughout. See the description of this group under the Zhemchug Basin lease area above.

c. Station Group D — stations in this group occurred from 81 m to 103 m. This group had the lowest mean density (622 individuals/m^2) and the second lowest mean biomass (94 g/m^2) of all the station groups examined in this investigation. The dominant species, in terms of density and biomass, were the deposit-feeding polychaete *Barantolla americana* and the clam *Macoma calcarea*, respectively. Station 14, at 85 m and just northwest of St. Matthew Island, had a biomass of 34 g/m^2. Station 21, at 103 m, had the lowest biomass (21 g/m^2) of the entire station group.

3. The St. Matthew Basin lease area and vicinity consisted of two station groups — Station Groups E and I (Fig. 3a).

a. Station Group E — the two stations (Stations 26 and 27) in this group occurred at depths of 35 m and 46 m, respectively. The dominant species present, in terms of density and biomass, were the deposit-feeding polychaete *Haploscoloplos elongatus* and the deposit-feeding clam *Nucula tenuis*, respectively. No other station in any of the other station groups contained such high densities of *H. elongatus*.

b. Station Group H — the one station of this group, Station 31, occurred at 22 m, relatively close to the mainland and north of Etolin Strait. The dominant species, in density, was the polychaete *M. oculata*, with a density of 25,000 individuals/m^2. An ectoproct (bryozoan) *Alcyonidium disciforme*, dominated the biomass at this station. The high overall density at this station (32,023 individuals/m^2) was the highest value observed at any of the stations sampled in the investigation; this high density was primarily a reflection of the large numbers of the polychaete *M. oculata*. Large numbers of Foraminifera also characterized this station; the presence of such large numbers of these shelled protozoans was also unique to this station.

4. The Hope Basin lease area and vicinity consisted of three station groups — Station Groups C, F, and H (Fig. 3a).

   a. Station Group C — the two stations (Stations 49 and 51) in this group that is adjacent to the Hope Basin occurred at depths of 30 m and 24 m, respectively. The other station in the group, Station 73, was in the Zhemchug Basin lease area, and is discussed with the stations of that area. The species dominant in density (in decreasing order of importance) at Stations 49 and 51 were the deposit-feeding clams *Nucula tenuis* and *Nuculana fossa* and the sea cucumber *Cucumaria* sp., The species dominant in biomass were *Cucumaria* sp., the deposit-feeding polychaete *Sternaspis scutata*, and the large clam *Serripes groenlandicus*, in decreasing order of dominance.

   b. Station Group F — the two stations of this group are located south of the Hope Basin lease area and just north of Bering Strait; Stations 54 and 55 occurred at depths of 32 and 53 m, respectively. The other station in this group (Station 74) is in the Zhemchug Basin lease area and is discussed with the stations of that area. The dominant species, in decreasing order of density, were the amphipod *Harpinia gurjanovae* and the deposit-feeding polychaetes *Praxillella praetermissa* and *Glycinde picta*. The sand dollar *Echinarhachnius parma* dominated the biomass.

   c. Station Group H — The three stations of this group were northeast of Bering Strait, and occurred from depths of 13 m to 23 m. The dominant taxa (in decreasing order of density) were the polychaete *Myriochele oculata*, the sand dollar *E. parma*, and tunicates. The species dominating in biomass was the deposit-feeding clam *Macoma calcarea*.

5. Station groups from St. Lawrence Island through the Chirikov Basin to Bering Strait consisted of three station groups — Station Groups J, A", and G (Fig. 3a).

   a. Station Group J — the stations in this group are either adjacent to St. Lawrence Island or within the Chirikov Basin, and occurred at depths of 23-40 m. The dominant species (in decreasing order of density) were the tube-dwelling amphipods *Ampelisca macrocephala*, *A. birulai*, and *A. eschrichti*. *Ampelisca macrocephala* dominated in biomass. Station 65 of Group J was close to St. Lawrence Island (at 23 m), and differed from the other two stations of the group by having fewer *A. birulai* and *A. eschrichti*.

b. Station Group A" — the two stations of this group are adjacent to Cape Nome at a depth of 22 m. Species dominating in density were the polychaetes *M. oculata* and *Haploscoloplos elongatus* and the amphipod *Erichthonius hunteri*, in decreasing order of importance. The species dominant in biomass were the crangonid shrimp *Argis lar* and the deposit-feeding echiurid worm *Echiurus echiurus alaskanus*.

c. Station Group G — consists of a single station in Bering Strait at a depth of 52 m. Both the density and biomass at this station were relatively high, with values of 1,933 individuals/m^2 and 635 g/m^2, respectively. Species dominating in density were the boring clam *Hiatella arctica*, the sea urchin *Strongylocentrotus droebachiensis*, the deposit-feeding polychaete *Asabellides sibirica*, and the barnacle *Balanus crenatus*. This was the only station with high densities of *H. arctica* and *B. crenatus*. *Hiatella arctica* dominated the biomass.

Knowledge of species composition within the station groups delineated by this study makes it possible to make a preliminary assessment of the ecological consequences of damage to or loss of any of the food species within the stations or station groups. Many of the common, deposit-feeding infaunal species in the Zhemchug and Navarin Basin lease areas are actual or potential food resources for bottom-feeding species such as the Tanner crab (*Chionoecetes opilio*) and bottomfishes. Loss of any or all of the benthic food species as a result of industrial activity or petroleum contamination could seriously disrupt the trophic system involving these species. The dense populations of infaunal species in the vicinity of the St. Matthew Basin lease area consist of many species commonly taken as food by epibenthic predators elsewhere in the eastern Bering Sea, and damage to large segments of this food reserve could negatively affect as yet unknown biological interactions in the area. The dense masses of tubes of the polychaete *Myriochele oculata* in the area just north of Etolin Strait and Nunivak Island stabilize the bottom sediments of the area. Loss of, or damage to, a large segment of this polychaete population would destabilize the bottom sediments, consequently causing a new complement of species to be established. Obvious ecological changes would be expected in the latter area if such damage occurred. A similar change of the bottom structure would be expected in the Chirikov Basin if major mortality of, or damage to, the extensive ampeliscid amphipod populations present there occurred. In the latter situation, alteration of bottom structure with concomitant ecological changes are to be expected. However, a far more serious consequence of destruction of major portions of these amphipod beds would be manifested by the loss in food available to the large populations of gray whales (*Eschrictius robustus*) dependent on these crustaceans for a major component of their summer food. Damage to the bivalve populations in the Chirikov Basin via petroleum or other industrual development would affect an important seasonal food supply for bearded seals (*Erignathus barbatus*) and walruses (*Odobenus rosmarus*). The high benthic biomass located south and southeast of the Hope Basin lease area comprises a food reserve available to the resident Tanner crab and to transient populations of bottomfishes and marine mammals that periodically move into the region for summer feeding activity. The area is relatively shallow and could be readily contaminated by petroleum fractions. Damage to or loss of the high standing stocks of benthic food organisms in the Hope Basin lease area could be detrimental to the predatory species that frequent the region. It should be emphasized that both the Tanner crab and the transient bottomfish populations here are operating near the northern limits of their range, and alteration of any aspect of their environment could seriously affect their survival in the northeastern Bering and southeastern Chukchi Seas.

Availability of many readily-identifiable, biologically well-understood organisms is a preliminary to the development of monitoring programs. Sizeable biomasses of taxonomically well-known annelids, mollusks, crustaceans, and echinoderms were typical of most of the stations, and many of these taxa were sufficiently abundant to represent organisms potentially useful as monitoring tools. Some aspects of the feeding biology of these benthic organisms are known or can be surmised, based on a knowledge of the same or similar species elsewhere. However, other aspects of the biology of these organisms are poorly understood, although limited data are available for bivalve and gastropod growth as well as knowledge of reproduction and recruitment biology (see selected chapters in Hood and Calder, 1981a). Hopefully, future investigations in the study areas will clarify some of the more important aspects of the biology of the dominant benthic species; this information would increase the reliability of future monitoring programs for the eastern Bering and southeastern Chukchi Seas.

Initial assessment of all data for the study areas suggests that: (1) sufficient station group uniqueness exists to permit development of monitoring programs based on taxon composition within groups, using grab sampling and selected statistical techniques, and (2) adequate numbers of biologically relatively well-known, abundant, and/or large (in biomass) species are available to permit nomination of likely monitoring candidates for most of the Basins if oil-related activity is initiated.

IX. NEEDS FOR FURTHER STUDY

With respect to this study and to previous benthic studies in the Bering and Chukchi Seas, we feel that the following questions and comments need to be addressed in the future:

1. What is the seasonal variation in density and biomass of infauna in the areas examined?

2. With regard to the temporal variation referred to above, what are the life histories of the most important organisms (in terms of density, biomass, and/or act of promoting stability of the benthic environment) in each species group?

3. What are the most important species involved in trophic interactions with known and/or potential commercial fisheries species in the Bering and Chukchi Seas?

4. Are there specific stages in the life histories of the most important infaunal species that cause them to be very susceptible to effects of oil and/or industrial development?

5. Due to the extremely high species diversity (up to 85 taxa examined/station and an average of 44 taxa/grab overall), abundance (up to 32,000 individuals/station and an average of 1,660 individuals identified/station, yielding approximately 80,000 individuals identified overall), and biomass (173. g biomass/station), we were unable to analyze as many stations as we had originally planned, based on our best estimates of time available from earlier work in the southeastern Bering Sea and elsewhere (with attributes at most 60% of those discussed above). Hence, we analyzed all stations in the higher-priority (Navarin, Zhemchug, and Hope Basins) lease sale areas, but only analyzed selected stations in the lower-priority (St. Matthew and Chirikov basins) areas. Completion of analysis of samples in these latter areas would greatly improve our characterization of the infauna in these areas for future studies, thus allowing better monitoring of the infauna in these regions.

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APPENDIX A

LIST OF ALL TAXA IDENTIFIED FROM THE GRAB SAMPLES TAKEN APRIL 1979 AND MAY-JUNE 1980 IN THE EASTERN BERING AND CHUKCHI SEAS

Biologically important taxa (BIT) are shown by crosses (x) under the appropriate criteria

Criteria:

1. Taxon occur in 50 percent or more of stations
2. At least 10 percent of individuals at some stations
3. At least 10 percent of wet biomass at some stations
4. Abundant with respect to number of individuals at some stations
5. Abundant with respect to total biomass at some stations

TAXON NAME	CRIT1	CRIT2	CRIT3	CRIT4	CRIT5	STA OCC
SARCODINA RHIZOPODEA	X	X		X		24
PORIFERA						3
PORIFERA FRAGS						3
HYDROZOA						10
HYDROZOA COLONIES						6
SCYPHOZOA						1
ANTHOZOA			X	X		9
ALCYONACEA NEPHTHEIDAE						2
EUNEPHTHYA RUBIFORMIS				X		1
ACTINIARIA HALCAMPIDAE			X		X	2
TURBELLARIA						3
RHYNCHOCOELA	X		X			35
RHYNCHOCOELA FRAGS.						18
CEREBRATULUS SP.						13
NEMATODA	X			X		31
POLYCHAETA						4
POLYCHAETA FRAG.	X					42
POLYNOIDAE						14
POLYNOIDAE FRAGS.						3
NEMIDIA SP.						2
ANTINOELLA SARSI						5
ARCTEOBEA SP.						2
ARCTEOBIA ANTICOSTIENSIS						12
ARCTEOBIA SPINELYTRIS						7
ARCTONOE DP.						1
EUNOE SP.						1
EUNOE NODOSA						2
EUNOE OERSTEDI						2
GATTYANA SP.						4
GATTYANA CILIATA						3
GATTYANA CIRROSA						3
GATTYANA TREADWELLI						5
HARMOTHOE SP.						1
HARMOTHOE IMBRICATA						5
HARMOTHOE LUNULATA						2
POLYNOE CANADENSIS						1
POLYNOE GRACILIS						1
POLYEUNOA TUTA						1
HESPERONOE SP.						2
HESPERONE COMPLANATA						3
TENONIA KITSAPENSIS						0
TENONIA SP.						5
NEMIDIA TAMARAE						7
PSEUDOPOLYNOE SP.						2
PHOLOE SP.						2
PHLOE MINUTA	X					32
PHOLOE MINUTA FRAGS.						1
PHYLLODOCIDAE						3

TAXON NAME	CRIT1	CRIT2	CRIT3	CRIT4	CRIT5	STA OCC
PHYLLODOCIDAE FRAGS.						2
ANAITIDES SP.						9
ANAITIDES SP. FRAGMENT						1
ANAITIDES GROENLANDICA						10
ANAITIDES MUCOSA						7
ETEONE SP.						3
ETEONE SP. FRAGMENT						3
ETEONE PACIFICA						2
ETEONE LONGA	X					34
EULALIA SIGEFORMIS						2
HESIONIDAE						1
AMPHIDUROS SP.						1
SYLLIDAE				X		2
SYLLIDAE FRAGMENTS						1
AUTOLYTUS SP.						2
SYLLIS SP.						2
TYPOSYLLIS SP.						2
TYPOSYLLIS SP. FRAGS						1
TYPOSYLLIS ALTERNATA						3
TYPOSYLLIS FASCIATA						1
EUSGLLIS SP.						1
EUSYLLIS BLOMSTRANDI						5
EXOGONE SP						6
EXOGONE MOLESTA						1
NEREIS SP.						1
NEREIS PELAGICA						1
NEREIS PROCERA						1
NEREIS ZONATA						1
CERATOCEPHALE LOVENI						1
NEPHTYIDAE FRAGS						1
NEPHTYS SP.	X		X		X	30
NEPHTYS SP. FRAGS						6
NEPHTYS ASSIMILIS			X			1
NEPHTYS CILIATA						3
NEPHTYS CAECA			X		X	14
NEPHTYS PUNCTATA	X	X	X	X	X	38
NEPHTYS RICKETTSI			X		X	2
NEPHTYS LONGASETOSA						3
NEPHTYS PARADOXA						1
NEPHTYS CALIFORNIENSIS						1
SPHAERODOROPSIS OCULATA						1
COMMENSODORUM SP.						1
GONIADIDAE FRAGMENT						0
GLYCINDE SP.						1
GLYCINDE PICTA						19
GLYCINDE ARMIGERA						1
ONUPHIDAE						2
ONUPHIDAE FRAGMENT						3

TAXON NAME	CRIT1	CRIT2	CRIT3	CRIT4	CRIT5	STA OCC
ONUPHIS SP.						2
ONUPHIS CONCHYLEGA						3
ONUPHIS GEOPHILIFORMIS						1
ONUPHIS IRIDESCENS						1
ONUPHIS PARVA						3
ONUPHIS PARVA						17
LUMBRINERIDAE				X		4
LUMBRINERIDAE FRAGS						1
LUMBRINERIS SP.	X	X	X	X	X	32
LUMBRINERIS SP. FRAGS.						4
LUMBRINEREIS BICIRRATA						1
LUMBRINEREIS ZONATA						2
DRILONEREIS FALCATA MINOR						12
DORVILLEIDAE						3
DORVILLEA SP.						1
SCHISTOMERINGOS CAECA						2
ORBINIIDAE						1
ORBINIDAE FRAGS						2
HAPLOSCOLOPLOS SP.						1
HAPLOSCOLOPLOS PANAMENSIS						1
HAPLOSCOLOPLOS ELONGATUS	X	X	X	X	X	44
SCOLOPLOS ARMIGER						7
PHYLO FELIX						1
PARAONIDAE						1
AEDICIRA ANTENNATA						1
ARICIDEA SP.						4
ARICIDEA SUECICA						1
ARICIDEA LOPEZI	X					26
ARICIDEA MINUTA						3
TAUBERIA GRACILIS						18
APISTOBRANCHUS SP.						2
APISTOBRANCHUS TULLBERGI						12
SPIONIDAE						15
SPIONIDAE FRAGS						1
LAONICE SP.						2
LAONICE CIRRATA						4
POLYDORA SP.						4
POLYDORA SOCIALIS						3
POLYDORA CILIATA						1
POLYDORA LIMICOLA						1
PRIONOSPIO SP.						10
PRIONOSPIO MALMGRENI						2
PRIONOSPIO CIRRIFERA						5
PRIONOSPIO STEENSTRUPI						9
SPIO SP.						2
SPIO FILICORNIS						3
SPIO CIRRIFERA						1
BOCCARDIA SP.						3

TAXON NAME	CRIT1	CRIT2	CRIT3	CRIT4	CRIT5	STA OCC
BOCCARDIA CALIFORNICA						1
SPIOPHANES BOMBYX						7
PYGOSPIO ELEGANS						1
SCOLELEPIS SP.						1
MAGELONA SP.				X		8
MAGELONA SP. FRAGS.						3
MAGELONA PACIFICA						3
MAGELONA CERAE						2
SPIOCHAETOPTERUS SP.						7
SPIOCHAETOPTERUS TYPICUS						4
SPIOCHAETOPTERUS COSTARUM						4
CIRRATULIDAE	X	X		X		36
CIRRATULIDAE FRAGS						6
CIRRATULUS CIRRATUS						1
THARYX SP.				X		13
THARYX SECUNDUS						6
CHAETOZONE SETOSA						5
CIRROPHORUS BRANCHIATUS						1
FLABELLIGERIDAE						1
BRADA SP.						4
BRADA VILLOSA	X					24
BRADA INHABILIS						1
FLABELLIGERA AFFINIS						1
FLABELLIGERA MASTIGOPHORA					X	4
SCALIBREGMA INFLATUM						17
OPHELIIDAE						1
AMMOTRYPANE AULOGASTER						3
OPHELIA SP.						1
OPHELIA LIMACINA						4
TRAVESIA SP.						3
TRAVISIA FORBESII					X	9
TRAVISIA PUPA			X		X	2
OPHELINA GROENLANDICA						1
ANTIOBACTUM SP.						1
STERNASPIS SCUTATA			X	X	X	22
CAPITELLIDAE				X		3
CAPITELLIDAE FRAGS						6
CAPITELLA CAPITATA				X		21
HETEROMASTUS FILIFORMIS	X	X		X		39
HETEROMASTUS GIGANTEUS						2
NOTOMASTUS SP.						4
MEDIOMASTUS SP.						10
MEDIOMASTUS CAPENSIS						3
MEDIOMASTUS CALIFORNIENSIS						2
DECAMASTUS SP.						1
DECAMASTUS GRACILIS						1
BARANTOLLA SP.				X		1
BARANTOLLA AMERICANA	X	X		X		38

TAXON NAME	CRIT1	CRIT2	CRIT3	CRIT4	CRIT5	STA OCC
MALDANIDAE	X		X	X	X	34
MALDANIDAE FRAGS.	X					35
ASYCHIS SP.						1
ASYCHIS SIMILIS						1
MALDANE SP.						8
MALDANE SARSI						7
MALDANE GLEBIFEX	X	X	X	X	X	30
NICOMACHE LUMBRICALIS						1
PETALOPROCTUS TENUIS BOREALIS						1
PETALOPROCTUS TENUIS						2
AXIOTHELLA SP.						1
AXIOTHELLA SP. FRAG						1
AXIOTHELLA CANTENTA						7
PRAXILLELLA SP.						6
PRAXILLELLA GRACILIS						13
PRAXILLELLA GRACILIS FRAGS.						2
PRAXILLELLA PRAETERMISSA			X	X		16
PRAXILLELLA AFFINIS						1
RHODINE SP.				X		8
RHODINE SP. FRAGS.						7
RHODINE GRACILIOR						5
EUCLYMENE DELINEATA						1
CLYMENURA SP.		X		X		9
CLYMENURA SP. FRAGS						3
CLYMENURA BOREALIS						1
CLYMENURA POLARIS						1
LUMBRICLYMENE SP.						8
LUMBRICLYMENE SP. FRAGS						3
OWENIIDAE						2
OWENIDAE FRAGS						1
OWENIA FUSIFORMIS		X		X	X	14
MYRIOCHELE SP.						1
MYRIOCHELE SP. FRAGS						1
MYRIOCHELE HEERI				X		12
MYRIOCHELE OCCULATA	X	X	X	X	X	27
PECTINARIIDAE						2
AMPHICTENE MOOREI						5
AMPHICTENE JAPONICA						2
CISTENIDES GRANULATA				X		12
CISTENIDES HYPERBOREA						1
PECTINARIA GRANULATA						1
AMPHARETIDAE						17
AMPHARETIDAE FRAGS.						8
AMAGE SP.						1
AMPHARETE SP.				X		9
AMPHARETE REDUCTA						2
AMPHARETE GOESI						1
AMPHARETE ACUTIFRONS						9

TAXON NAME	CRIT1	CRIT2	CRIT3	CRIT4	CRIT5	STA OCC
AMPHARETE FINNARCHICA				X		7
AMPHARETE LINDSTROMI						1
AMPHECTEIS SP.						6
AMPHICTEIS GUNNERI						6
AMPHICTEIS SCAPHOBRANCHIATA						1
LYSIPPE LABIATA						7
MELINNA CRISTATA			X	X	X	11
ASABELLIDES SP.						1
ASABELLIDES SIBIRICA				X		12
TEREBELLIDAE					X	13
TEREBELLIDAE FRAGS.						9
AMPHRITITE SP.						1
LEAENA ABRANCHIATA						1
NEOLEPREA SPIRALIS			X		X	2
NICOLEA ZOSTERICOLA						1
PISTA SP.			X		X	7
PISTA SP. FRAG						1
PISTA CRISTATA						6
PISTA ELONGATA					X	3
PISTA BREVIBRANCHIATA						3
POLYCIRRUS SP.						1
POLYCIRRUS MEDUSA						2
ARTACAMA CONIFERI			X		X	5
ARTACAMA PROBOSCIDEA						1
LAPHANIS BOECKI						1
PROCLEA GRAFFII						1
STSCHAPOVELLA SP.						1
TEREBELLIDES STROEMII				X		18
TRICHOBRANCHUS GLACIALIS						2
SABELLIDAE			X	X	X	17
SABELLIDAE FRAGS.						3
CHONE SP.						7
CHONE INFUNDIBULIFORMIS			X		X	2
CHONE CINCTA				X		17
CHONE MAGNA						1
CHONE MOLLIS						1
EUCHONE SP.						2
EUCHONE ANALIS						3
EUCHONE PAPILLOSA						1
EUCHONE LONGIFISSURATA					X	8
MYXICOLA INFUNDIBULUM						1
POTAMILLA SP.						3
POTAMILLA NEGLECTA						8
POTAMILLA INTERMEDIA						1
POTAMILLA ABYSSICOLA						1
SABELLA SP.						2
FABRICIA CRENICOLIS						1
LAONOME SP.						1

TAXON NAME	CRIT1	CRIT2	CRIT3	CRIT4	CRIT5	STA OCC
LAONOME KROYERI						7
SERPULIDAE						2
SPIRORBIS SP.						3
APHRODITA CF. LONGIPALPA			X		X	1
APHRODITA NEGLIGENS			X		X	1
DISOMA SP.						1
DISOMA MULTISETOSUM						1
PECTONARIDAE FRAG						0
OLIGOCHAETA						5
MOLLUSCA						1
MOLLUSCA FRAG						2
CHAETODERMA ROBUSTA				X		21
POLYPLACOPHORA						1
ISCHNOCHITON ALBUS						1
PELECYPODA	X			X		32
PELECYPODA FRAGS.						3
ACILA CASTRENIS						1
NUCULA TENUIS	X	X	X	X	X	34
NUCULA BELLOTTI						1
NUCULANA SP.	X	X	X	X	X	27
NUCULANA PERNULA				X	X	13
NUCULANA FOSSA		X	X	X	X	7
TINDARIA SP.						2
YOLDIA SP.	X	X		X		32
YOLDIA AMYGDAIEA					X	7
YOLDIA HYPERBOREA			X		X	5
YOLDIA MYALIS						3
YOLDIA SCISSURATA						1
YOLDIA THRACIAEFORMIS			X		X	11
YOLDIELLA INTERMEDIA						1
CRENELLA DESSUCATA						1
CRENELLA LEANA						1
MEGACRENELLA COLUMBIANA						1
MUSCULUS SP.						1
MUSCULUS NIGER						1
MUSCULUS CORRUGATUS						2
MUSCULUS JAPONICA						1
MUSCULUS LAEVIGATUS						1
MODIOLUS MODIOLUS						2
ASARTE SP.						3
ASTARTE BOREALIS			X		X	6
CYCLOCARDIA SP.						0
CYCLOCARDIA CREBRICOSTATA			X		X	13
THYASIRIDAE						2
AXINOPSIDA SP.						4
AXINOPSIDA SERRICATA	X	X		X		32
AXINOPSIDA VIRIDIS						16
THYASIRA FLEXUOSA						23

TAXON NAME	CRIT1	CRIT2	CRIT3	CRIT4	CRIT5	STA OCC
THYASIRA DISJUNCTA						1
DIPLODONTA SP.						1
DIPLODONTA ALEUTICA						3
MYSELLA SP.						18
MYSELLA TUMIDA						11
MYSELLA ALEUTICA						3
ODONTOGENA BOREALIS						7
OROBITELLA				X		4
CLINOCARDIUM SP.						2
CLINOCARDIUM CILIATUM						9
SERRIPES GROENLANDICUS			X	X	X	14
LIOCYMA FLUCTUOSA						13
LIOCYMA VIRIDIS						0
PSEPHIDIA LORDI						5
SPISULA POLYNYMA						1
TELLINIDAE						4
MACOMA SP.	X	X		X		28
MACOMA CALCAREA		X	X	X	X	16
MACOMA BROTA			X		X	4
MACOMA MOESTA MOESTA						1
MACOMA CRASSULA						2
CRYPTOMYA CALIFORNICA						1
MYA ARENARIA						2
MYA PSEUDOARENARIA						1
HIATELLA ARCTICA		X	X	X	X	2
PENITELLA PENITA						1
LYONSIA SP.						1
LYONSIA ARENOSA						2
PERIPLOMA ALASKANA						1
ASTHENOTHAERUS ADAMSI						2
THRACIA SP.						4
THRACIA DEVEXA						1
CARDIOMYA SP.						2
CARDIOMYA PECTENATA						1
CARDIOMYA BERINGENSIS						1
LEPTONIDAE						4
NEAEROMYA SP.						5
GASTROPODA	X					25
LEPETA CAECA			X		X	1
TROCHIDAE						5
MARGARITES SP.			X			12
SOLARIELLA SP.						6
SOLARIELLA OBSCURA						4
SOLARIELLA VARICOSA						11
MOELLERIA COSTULATA						1
ALVINIA SP.						1
MICRANELLUM OREGONENSE						1
TACHYRYNCHUS EROSUS						7

TAXON NAME	CRIT1	CRIT2	CRIT3	CRIT4	CRIT5	STA OCC
BITTIUM MUNITUM			X		X	1
EPITONIUM GROENLANDICUM						1
CREPIDULA GRANDIS						1
TRICHOTROPIS KROYERI						2
NATICA SP.						2
NATICA CLAUSA						14
POLINICES SP.						7
NEVERITA NANUS						1
POLINICES PALLIDA					X	5
FUSITRITON OREGONENSIS						3
TROPHONOPSIS SP.						1
BUCCINIDAE						2
BUCCINUM PUCTRUM			X			1
COLUS SP.						1
NEPTUNEA SP.						1
NEPTUNEA LYRATA			X		X	3
NEPTUNEA COMMUNIS						1
ADMETE COUTHOUYI						1
SUAVODRILLIA KENNICOTTII						1
OENOPOTA SP.						17
OENOPOTA TURRICULA						1
OENOPOTA HARPA						1
OENOPOTA EXCURVATA						3
ODOSTOMIA SP.						6
ODOSTOMIA TENUISCULPTA						1
ODOSTOMIA SKIDEGATENSIS						1
ODOSTOMIA ARCTICA						1
RETUSA SP.						4
RETUSA OBTUSA	X			X		29
DIAPHANA MINUTA						1
PHILENE SP.						1
CYLICHNA ALBA	X					25
DORIDIDAE						1
AGLAJA DIOMEDEUM						1
OPISTOBRANCH						1
PYCNOGONIDA						1
NYMPHON SP.						1
NYMPHON BREVITARSE						1
ACHELIA SP.						1
CRUSTACEA						2
CRUSTACEA FRAGS.						6
POLYPHEMIDAE						1
PODOCOPA						2
COPEPODA						13
CALANOIDA						1
CALANOIDA FRAGS.						1
CALANUS SP.						1
CALANUS GLACIALIS						2

TAXON NAME	CRIT1	CRIT2	CRIT3	CRIT4	CRIT5	STA OCC
CALANUS PLUMCHRUS						4
CALANUS MARSHALLAE						2
AETIDEIDAE						2
METRIDIA LUCENS						4
BALANUS SP.		X	X	X	X	2
BALANUS SP. FRAGS						1
BALANUS CRENATUS				X		2
NEBALIA						2
MYSIS SP.						1
CUMACEA						13
CUMACEA FRAGS.						4
LAMPROPIDAE						1
LAMPROPS SP.						4
HEMILAMPROPS SP.						0
HEMILAMPROPS PECTINATA						4
LEUCONIDAE FRAGS.						5
LEUCON SP.		X				12
LEUCON NASICA	X					24
LEUCON NASICA FRAGS.						1
LEUCON NASICOIDES						2
EUDORELLA SP.						6
EUDORELLA EMARGINATA						17
EUDORELLA PACIFICA						12
EUDORELLA ARCTICA						1
EUDORELLA DENTATA						4
EUDORELLOPSIS SP.						9
EUDORELLOPSIS INTEGRA						11
EUDORELLOPSIS DEFORMIS						8
EUDORELLOPSIS USCHAKOVI						11
DIASTYLIS SP.						8
DIASTYLIS ALASKENSIS						3
DIASTYLIS BIDENTATA				X		5
DIASTYLIS KOREANA						1
DIASTYLIS PARASPINULOSA						3
DIASTYLIS NUCELLA						1
BRACHYDIASTYLIS SP.						1
BRACHYDIASTYLIS RESIMA						1
PETALOSARIA DECLIVIS						1
CAMPYLASPIS SP.						4
CAMPYLASPIS UMBENSIS						0
CAMPYLASPIS AFFINIS						1
TANAIDACEA						13
ISOPODA						1
ARCTURUS SP.						1
SYNIDOTEA SP.						4
SYNIDOTEA BICUSPIDA						3
TECTICEPS ALASCENSIS						1
MUNNIDAE						1

TAXON NAME	CRIT1	CRIT2	CRIT3	CRIT4	CRIT5	STA OCC
MONNA SP.						2
PLEUROGONIUM RUBICONDUM						3
CRYPTONISCIDAE						1
GNATHIA						1
AMPHIPODA		X		X		22
AMPHIPODA FRAGS						22
ACONTHONOTOZOMATIDAE FRAG.						1
ODIUS SP.						1
ODIUS CARINATUS						1
ODIUS CASSIGERUS						2
AMPELISCIDAE FRAGS						3
AMPELISCA SP.						4
AMPELISCA MACROCEPHALA		X	X	X	X	18
AMPELISCIDAE BIRULAI		X		X	X	4
AMPELISCIDA ESCHRICHTI		X	X	X	X	10
AMPELISCA FURCIGERA						3
BYBLIS SP.						18
BYBLIS SP. FRAG						1
BYBLIS GAIMARDI						13
HAPLOOPS SP.						4
LEMBOS ARCTICUS						2
ARGISSA HAMATIPES						2
ATYLIDAE						1
UROTHOE SP.						0
COROPHIUM SP. FRAG						1
COROPHIUM CRASSICORNE						7
ERICTHONIUS SP.						3
ERICTHONIUS HUNTERI				X		4
ERICHTHONIUS FOLLI						1
GUERNEA SP.						1
GAMMARIDAE						3
GOMMARIDAE FRAGS.						2
CERADOCUS TORELLI						1
MAERA DANAE						2
MAERA LOVENI						1
MELITA SP.						1
MELITA SP. FRAGS						1
MELITA DENTATA						3
MELITA QUADRISPINOSA				X		3
EOHAUSTORIAS EOUS						1
PONTOPOREIA SP.						1
PONTOPOREIA FEMORATA						7
PRISCILLINA ARMATA		X		X		1
UROTHOE SP. FRAG						1
UROTHOE DENTICULATA		X		X		8
ISAEIDAE						8
ISAEIDAE FRAG.						1
PHOTIS SP.						8

TAXON NAME	CRIT1	CRIT2	CRIT3	CRIT4	CRIT5	STA OCC
PHOTIS SPASSKII						8
PHOTIS FISCHMANNI						2
PROTOMEDIA SP.		X		X		15
PROTOMEDIEIA SP.						3
PROTOMEDIEIA FASCIATA						3
PROTOMEDEIRA FASCIATOIDES						1
PROTOMEDEIRA CHAELATA				X		3
PODOCEROPSIS SP.				X		6
PODOCEROPSIS NITIDA						1
ISCHYROCERIDAE						3
ISCHYROCERUS SP.	X			X		26
ISCHYROCERUS ANGUIPES						1
ISCHYROCERUS BRUSILOVI						1
ISCHYROCERUS ENIGMATICUS						1
JASSA SP.						1
LILLJEBORGIA FISSICORNIS						1
LYSIANASSIDAE						6
LYSIANASSIDAE FRAGS						1
ANONYX SP.						20
ANONYX NUGAX						7
ANONYX AFFINIS						1
ANONYX MINIMUS						2
ANONYX MAGNUS						0
ANONYX AVINAE						1
ANONYX RUBUSTUS						2
BOEKISIMUS SP.						4
BOECKOSIMUS KRASSINI						2
BOECKOSIMUS SIBIRICUS						1
HIPPOMEDON						9
HIPPOMEDON ABYSSI						2
HIPPOMEDON PROPINQUUS						1
HIPPOMEDON KURILIOUS						1
HIPPOMEDON GRANULOSA						1
LIPIDEPECREUM KUSATICA						1
LEPIDEPECREUM COMATUM						1
OPISA ESCHRICHTI						3
ORCHOMENE SP.						13
ORCHOMENE PACIFICA						1
MELPHIDIPPIDAE						3
OEDICEROTIDAE	X					26
OEDICEROTIDAE FRAGS						3
ACEROIDES SP.						1
ACEROIDES LATIPES						2
ARRHIS LUTHKEI						1
BATHYMEDON SP.						4
BATHYMEDON NANSENI						5
MONOCULODES CARINATUS						1
MONOCULODES SP.						13

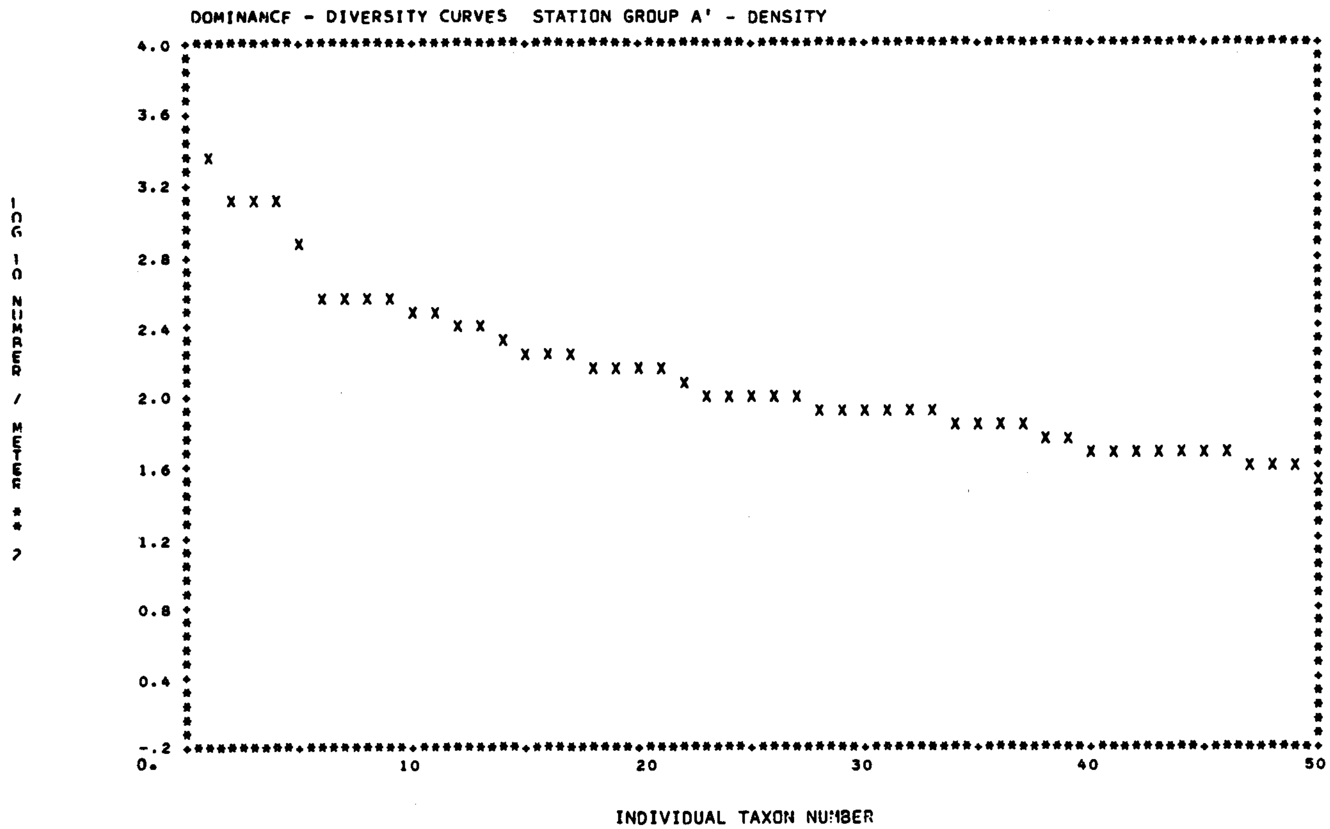
TAXON NAME	CRIT1	CRIT2	CRIT3	CRIT4	CRIT5	STA OCC
MONOCULODES SP. FRAG						2
MONOCULODES DIAMESUS						2
MONOCULOPSIS LONGICORNIS						1
MACHAIRONYX MUELLERI						8
DYOPEDUS SP.						2
PAROEDICEROS INTERMEDIUS						1
PAROEDICEROS LYNCEUS						3
WESTWOODILLA CAECULA						6
PARDALISCIDAE						4
NICIPPE TUMIDA						3
PHOXOCEPHALIDAE						5
PHOXOCEPALIDAE FRAG						4
HARPINIA SP.		X		X		22
HARPINIA EMERYI						1
HARPINIA KOBJAKOVAE						16
HARPINIA QURJANOVAE						13
HARPINIA SHURINI				X		1
PARAPHOXUS SP.						10
PARAPHOXUS ROBUSTUS						3
PARAPHOXUS SP.						5
PARAPHOXUS OCULATUS				X		22
PLEUSTIDAE FRAG						9
PLEUSTES SP.						1
PLEUSYMPTES SP.						1
PODOCERIDAE						6
DULICHIA SP.						2
STENOTHOIDAE						9
SYNOPIIDAE						1
TIRON BI OCULATA						3
PARATHEMISTO PACIFICA						1
CAPRELLIDAE						11
EUPHAUSIACEA						1
DECAPODA FRAGS.						2
PANDALUS SP.						1
EUALUS SP.						1
ARGIS SP.						2
ARGIS LAR			X		X	2
PAGURUS SP.						4
PAGURUS TRIGONOCHEIRUS						4
LABIDOCHIRUS SPLENDESCENS						1
CHIONOECETES OPILIO			X		X	6
SIPUNCULIDA				X		13
GOLFINGIA SP.			X		X	7
GOLFINGIA MARGARITACEA			X			20
PHASCOLION STROMBI						2
ECHIURUS SP.						1
ECHIURUS ECHIURUS ALASKANUS			X	X	X	1
PRIAPULIDA						1

TAXON NAME	CRIT1	CRIT2	CRIT3	CRIT4	CRIT5	STA OCC
PRIAPULUS CAUDATUS	X		X			31
PRIAPULUS SP.						0
ECTOPROCTA						12
ECTOPROCTA COLONIES			X		X	9
CHEILOSTOMATA						1
ALCYONIDIIDAE						1
ALCYONIDIUM SP.			X		X	1
ALCYONIDIUM DISCIFORME			X		X	3
ASTEROIDEA						7
ASTEROIDEA FRAGMENTS						1
CTENODISCUS CRISPATUS			X		X	14
ASTERIDAE						1
ECHINOIDEA			X		X	4
ECHINARACHNIUS PARMA		X	X		X	7
OPHIUROIDEA	X			X		26
OPHIURIDAE FRAGS.						5
DIAMPHIODIA CRATERODMETA	X	X		X		24
PANDELLIA CARCHARA						2
OPHIOPHOLIS ACULEATA						1
OPHIURIDAE						2
OPHIOPENIA SP.						1
OPHIURA SP.		X		X		5
OPHIURA SARSI	X	X	X	X	X	26
HOLOTHUROIDEA						3
CUCAMARIA SP.		X	X	X	X	2
SAGITTA ELEGANS						1
UROCHORDATA		X	X	X	X	9
MOLGULA GRIFFITHSII			X		X	1
ZOARCIDAE						1
AMMODYTES HEXAPTERUS			X			2
UNIDENTIFIED	X			X		29
UNIDENTIFIED ANI TISSUE FRAGS						1
UNIDENTIFIED FRAGS	X		X		X	27

TAXONS = 647

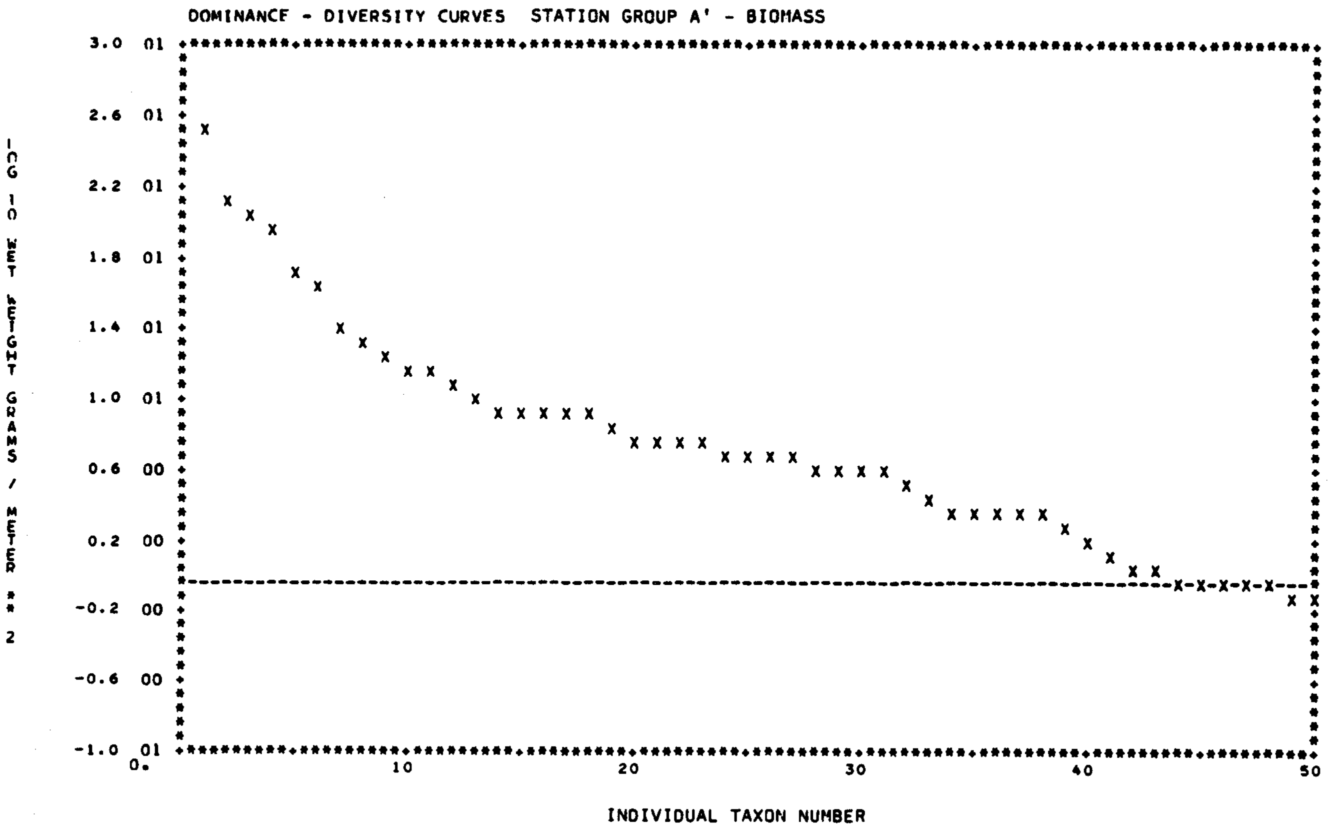
APPENDIX B

DOMINANCE-DIVERSITY CURVES OF DENSITY AND BIOMASS ESTIMATES FOR EACH STATION GROUP PRODUCED BY CLUSTER ANALYSIS OF *ln*-TRANSFORMED DENSITY DATA



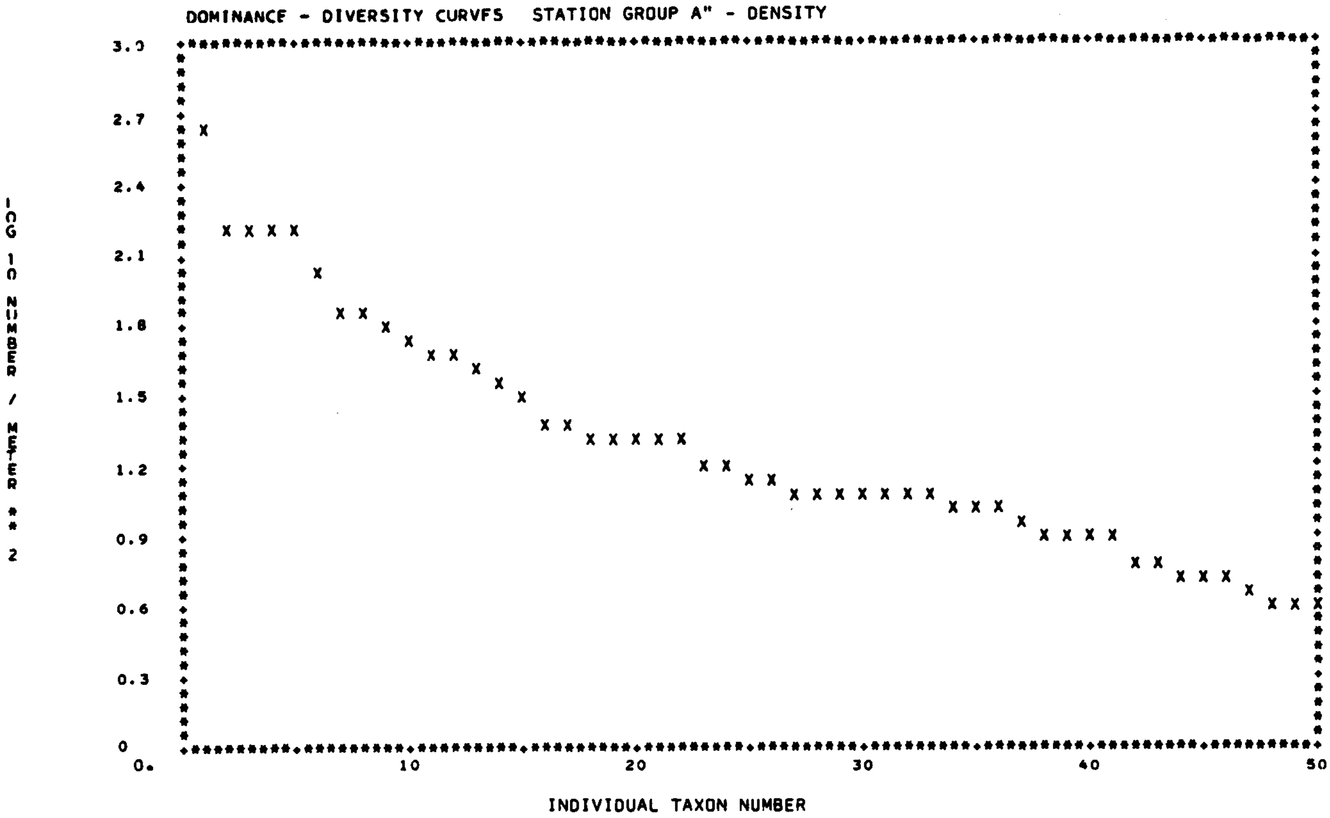
TAXON NO.	TAXON NAME	DATA VALUE	PLOT VALUE
1.	HETEROMASTUS FILIFORMIS	2278.000	3.358
2.	AXINOPSIDA SERRICATA	1376.000	3.139
3.	OWENIA FUSIFORMIS	1268.000	3.103
4.	OPHIURA SARSI	1210.000	3.083
5.	HAPLOSCOLOPLOS ELONGATUS	736.000	2.867
6.	RETUSA OBTUSA	394.000	2.595
7.	NEPHTYS PUNCTATA	386.000	2.587
8.	MALDANE GLEBIFEX	354.000	2.549
9.	CHAETODERMA ROBUSTA	342.000	2.534
10.	UROTHOE DENTICULATA	324.000	2.511
11.	MYRIOCHELE HEERI	290.000	2.462
12.	PRIAPULUS CAUDATUS	256.000	2.408
13.	MYRIOCHELE OCULATA	246.000	2.391
14.	ARICIDEA LOPEZI	196.000	2.292
15.	PARAPHOXUS OCULATUS	182.000	2.260
16.	CHONE CINCTA	176.000	2.246
17.	EUCHONE LONGIFISSURATA	164.000	2.215
18.	TRAVISIA FORBESII	154.000	2.188
19.	DIAMPHIODIA CRATERODMETA	150.000	2.176
20.	BARANTOLLA AMERICANA	138.000	2.140
21.	STERNASPIS SCUTATA	132.000	2.121
22.	CAPITELLA CAPITATA	126.000	2.100
23.	NUCULANA PERNULA	102.000	2.009
24.	ETEONE LONGA	100.000	2.000
25.	THYASIRA FLEXUOSA	100.000	2.000
26.	HARPINIA KOBJAKOVAE	100.000	2.000
27.	EUDORELLOPSIS USCHAKOVI	94.000	1.973
28.	BRADA VILLOSA	90.000	1.954
29.	CTENODISCUS CRISPATUS	86.000	1.934
30.	DRILONEREIS FALCATA MINOR	84.000	1.924
31.	LEUCON NASICA	82.000	1.914
32.	CHAETOZONE SETOSA	78.000	1.892
33.	ODONTOGENA BOREALIS	76.000	1.881
34.	APISTOBRANCHUS TULLBERGI	74.000	1.869
35.	AXINOPSIDA VIRIDIS	72.000	1.857
36.	NUCULA TENUIS	64.000	1.806
37.	GOLFINGIA MARGARITACEA	64.000	1.806
38.	LIOCYMA FLUCTUOSA	54.000	1.732
39.	CYLICHNA ALBA	54.000	1.732
40.	SCALIBREGMA INFLATUM	52.000	1.716
41.	EUDORELLA EMARGINATA	52.000	1.716
42.	ONUPHIS GEOPHILIFORMIS	50.000	1.699
43.	PISTA CRISTATA	50.000	1.699
44.	AMPELISCA MACROCEPHALA	50.000	1.699
45.	THARYX SECUNDUS	46.000	1.663
46.	YOLDIA THRACIAEFORMIS	46.000	1.663
47.	PRAXILLELLA GRACILIS	42.000	1.623
48.	YOLDIA AMYGDALEA	40.000	1.602
49.	EUCHONE ANALIS	38.000	1.580
50.	TAUBERIA GRACILIS	36.000	1.556

Figure 1. Dominance-diversity curve (density) calculated from Station Group A'.



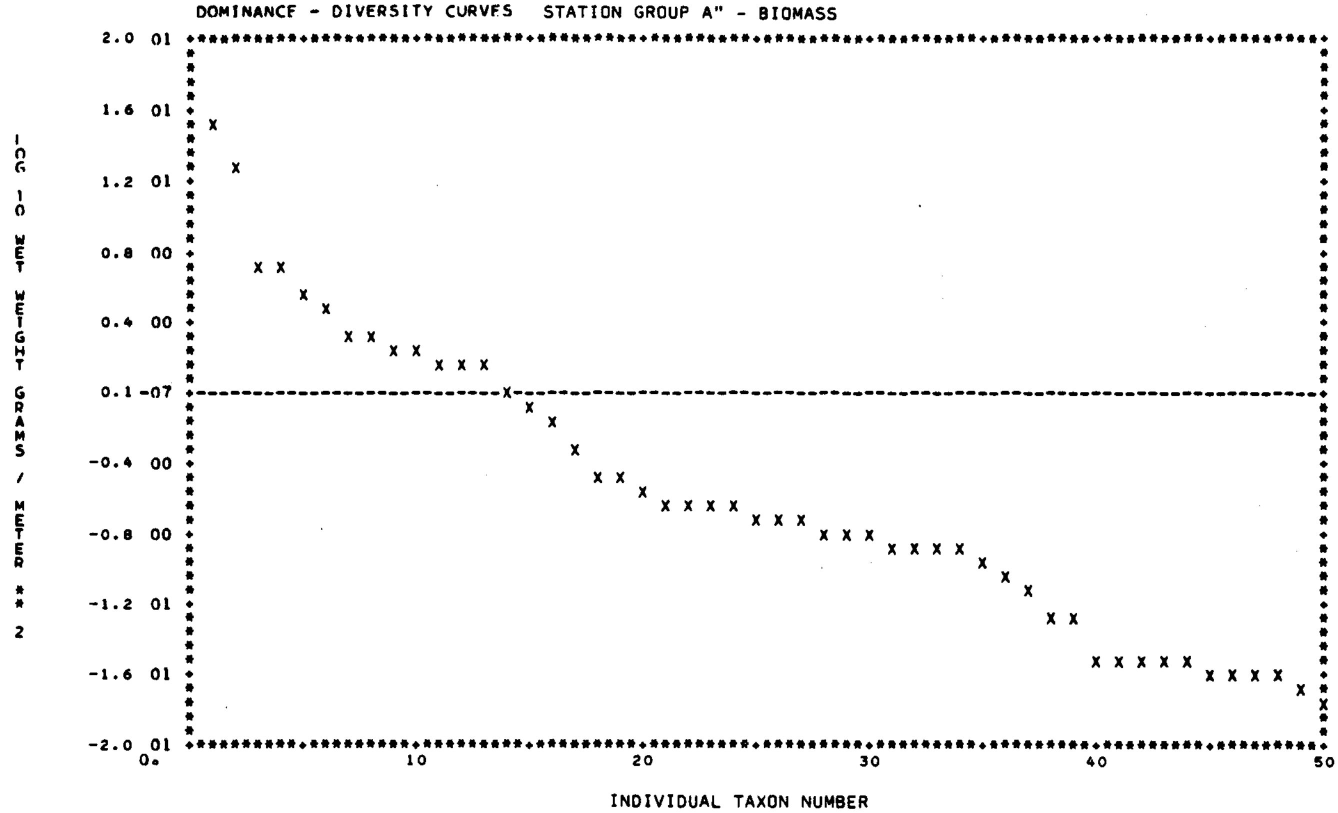
TAXON NO.	TAXON NAME	DATA VALUE	PLOT VALUE
1.	CTENODISCUS CRISPATUS	321.798	2.508
2.	OPHIURA SARSI	120.988	2.083
3.	NEPTUNEA LYRATA	112.980	2.053
4.	MALDANE GLEBIFEX	93.108	1.969
5.	YOLDIA THRACIAEFORMIS	50.020	1.699
6.	NEPHTYS PUNCTATA	40.300	1.605
7.	APHRODITA NEGLIGENS	25.116	1.400
8.	ARTACAMA CONIFERA	19.848	1.298
9.	AXIOTHELLA CANTENTA	16.902	1.228
10.	NEPHTYS CAECA	15.464	1.189
11.	PISTA BREVIBRANCHIATA	15.360	1.186
12.	OWENIA FUSIFORMIS	11.030	1.043
13.	EUCHONE LONGIFISSURATA	10.454	1.019
14.	CHONE CINCTA	8.832	0.946
15.	STERNASPIS SCUTATA	8.462	0.927
16.	PRAXILLELLA GRACILIS	8.318	0.920
17.	HAPLOSCOLOPLOS ELONGATUS	8.018	0.904
18.	CYCLOCARDIA CREBRICOSTATA	7.886	0.897
19.	DIAMPHIODIA CRATERODMETA	6.454	0.810
20.	CHAETODERMA ROBUSTA	6.088	0.784
21.	TRAVISIA FORBESII	5.774	0.761
22.	LAONICE CIRRATA	5.410	0.733
23.	FLABELLIGERA MASTIGOPHORA	5.310	0.725
24.	HETEROMASTUS FILIFORMIS	5.148	0.712
25.	PRIAPULUS CAUDATUS	5.138	0.711
26.	YOLDIA AMYGDALEA	4.450	0.648
27.	BRADA VILLOSA	4.370	0.640
28.	PISTA ELONGATA	4.110	0.614
29.	PISTA CRISTATA	3.974	0.599
30.	LIOCYMA FLUCTUOSA	3.920	0.593
31.	POLINICES PALLIDUS	3.700	0.568
32.	MACOMA CALCAREA	3.120	0.494
33.	LEPETA CAECA	2.574	0.411
34.	MYRIOCHELE HEERI	2.456	0.390
35.	TEREBELLIDES STROEMII	2.366	0.374
36.	SCALIBREGMA INFLATUM	2.290	0.360
37.	AXINOPSIDA SERRICATA	2.182	0.339
38.	NUCULANA PERNULA	2.090	0.320
39.	AMPHICTENE MOOREI	2.022	0.306
40.	MELINNA CRISTATA	1.452	0.162
41.	AMPHICTEIS GUNNERI	1.210	0.083
42.	SPIOCHAETOPTERUS COSTARUM	1.130	0.053
43.	SERRIPES GROENLANDICUS	1.114	0.047
44.	GOLFINGIA MARGARITACEA	0.964	-0.016
45.	APISTOBRANCHUS TULLBERGI	0.962	-0.017
46.	RETUSA OBTUSA	0.956	-0.020
47.	BARANTOLLA AMERICANA	0.934	-0.030
48.	YOLDIA HYPERBOREA	0.920	-0.036
49.	NEPHTYS CILIATA	0.812	-0.090
50.	NUCULA TENUIS	0.776	-0.110

Figure 2. Dominance-diversity curve (biomass) calculated from Station Group A'.



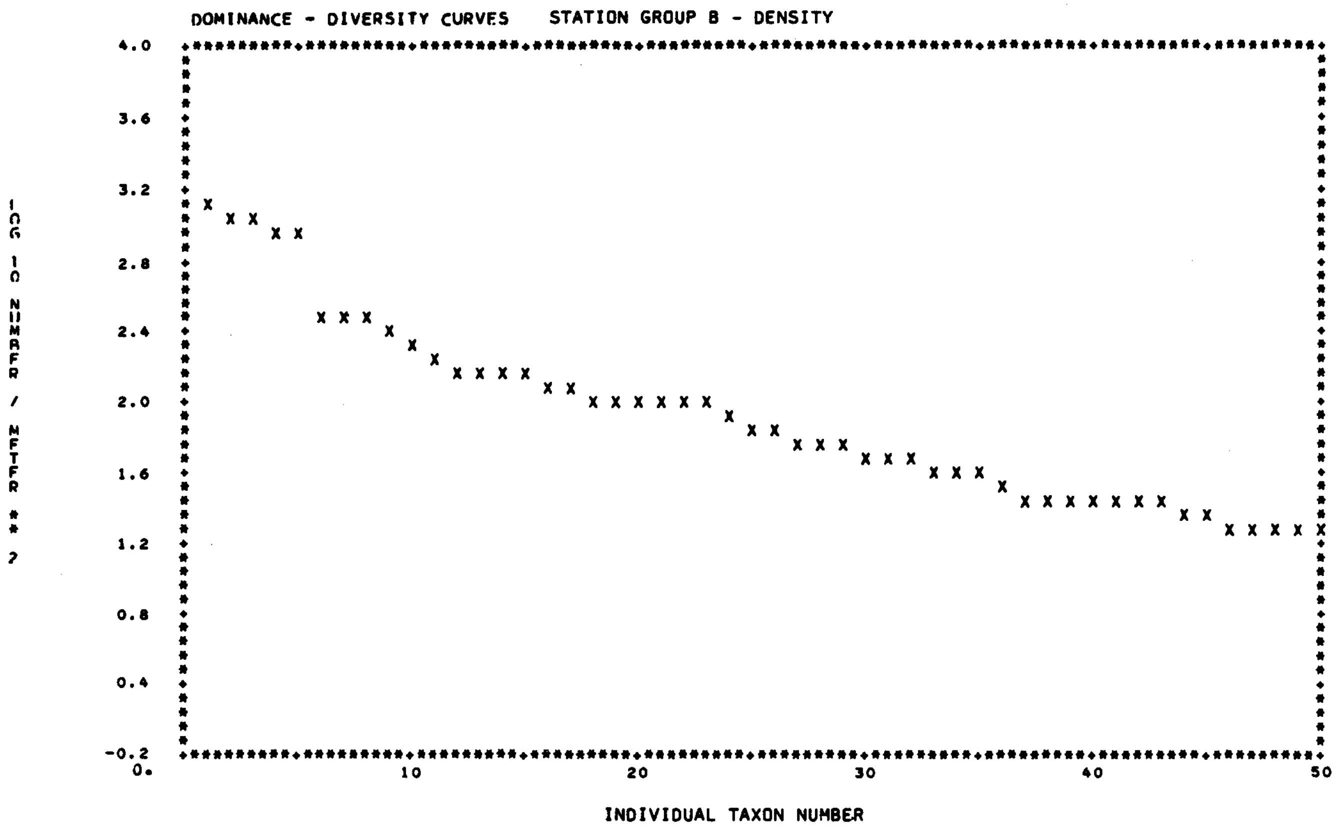
TAXON NO.	TAXON NAME	DATA VALUE	PLOT VALUE
1.	MYRIOCHELE OCULATA	426.500	2.630
2.	HAPLOSCOLOPLOS ELONGATUS	174.500	2.242
3.	ERICTHONIUS HUNTERI	169.500	2.229
4.	DIAMPHIODIA CRATERODMETA	167.000	2.223
5.	ECHIURUS ECHIURUS ALASKANUS	165.000	2.217
6.	THARYX SECUNDUS	102.500	2.011
7.	TEREBELLIDES STROEMII	71.500	1.854
8.	HARPINIA GURJANOVAE	70.000	1.845
9.	STERNASPIS SCUTATA	62.500	1.796
10.	GLYCINDE PICTA	51.500	1.712
11.	AMPHARETE FINMARCHICA	51.000	1.708
12.	HETEROMASTUS FILIFORMIS	45.000	1.653
13.	BYBLIS GAIMARDI	44.000	1.643
14.	SCALIBREGMA INFLATUM	35.500	1.550
15.	HETEROMASTUS GIGANTEUS	30.000	1.477
16.	PHOLOE MINUTA	25.000	1.398
17.	CISTENIDES GRANULATA	25.000	1.398
18.	HARMOTHOE IMBRICATA	22.000	1.342
19.	DIASTYLIS BIDENTATA	22.000	1.342
20.	GOLFINGIA MARGARITACEA	20.500	1.312
21.	BALANUS CRENATUS	20.000	1.301
22.	MELITA QUADRISPINOSA	20.000	1.301
23.	ETEONE LONGA	15.000	1.176
24.	PHOTIS SPASSKII	15.000	1.176
25.	ASABELLIDES SIBIRICA	14.000	1.146
26.	POTAMILLA NEGLECTA	14.000	1.146
27.	BRADA VILLOSA	12.500	1.097
28.	NUCULA TENUIS	12.500	1.097
29.	LEUCON NASICA	12.500	1.097
30.	PRIAPULUS CAUDATUS	12.500	1.097
31.	CHONE CINCTA	12.000	1.079
32.	AMPELISCA MACROCEPHALA	12.000	1.079
33.	BARANTOLLA AMERICANA	11.500	1.061
34.	PRAXILLELLA PRAETERMISSA	10.000	1.000
35.	RHODINE GRACILIOR	10.000	1.000
36.	LAONOME KROYERI	10.000	1.000
37.	YOLDIA MYALIS	9.500	0.978
38.	APISTOBRANCHUS TULLBERGI	8.000	0.903
39.	TAUBERIA GRACILIS	7.500	0.875
40.	EUDORELLA PACIFICA	7.500	0.875
41.	WESTWOODILLA CAECULA	7.500	0.875
42.	AMPHARETE ACUTIFRONS	6.000	0.778
43.	AMPELISCA ESCHRICHTI	6.000	0.778
44.	CYLICHNA ALBA	5.000	0.699
45.	ARGIS LAR	5.000	0.699
46.	CHIONOECETES OPILIO	5.000	0.699
47.	PAROEDICEROS LYNCEUS	4.500	0.653
48.	MAGELONA PACIFICA	4.000	0.602
49.	ANONYX LATICOXAE	4.000	0.602
50.	TIRON BIOCULATA	4.000	0.602

Figure 3. Dominance-diversity curve (density) calculated from Station Group A".



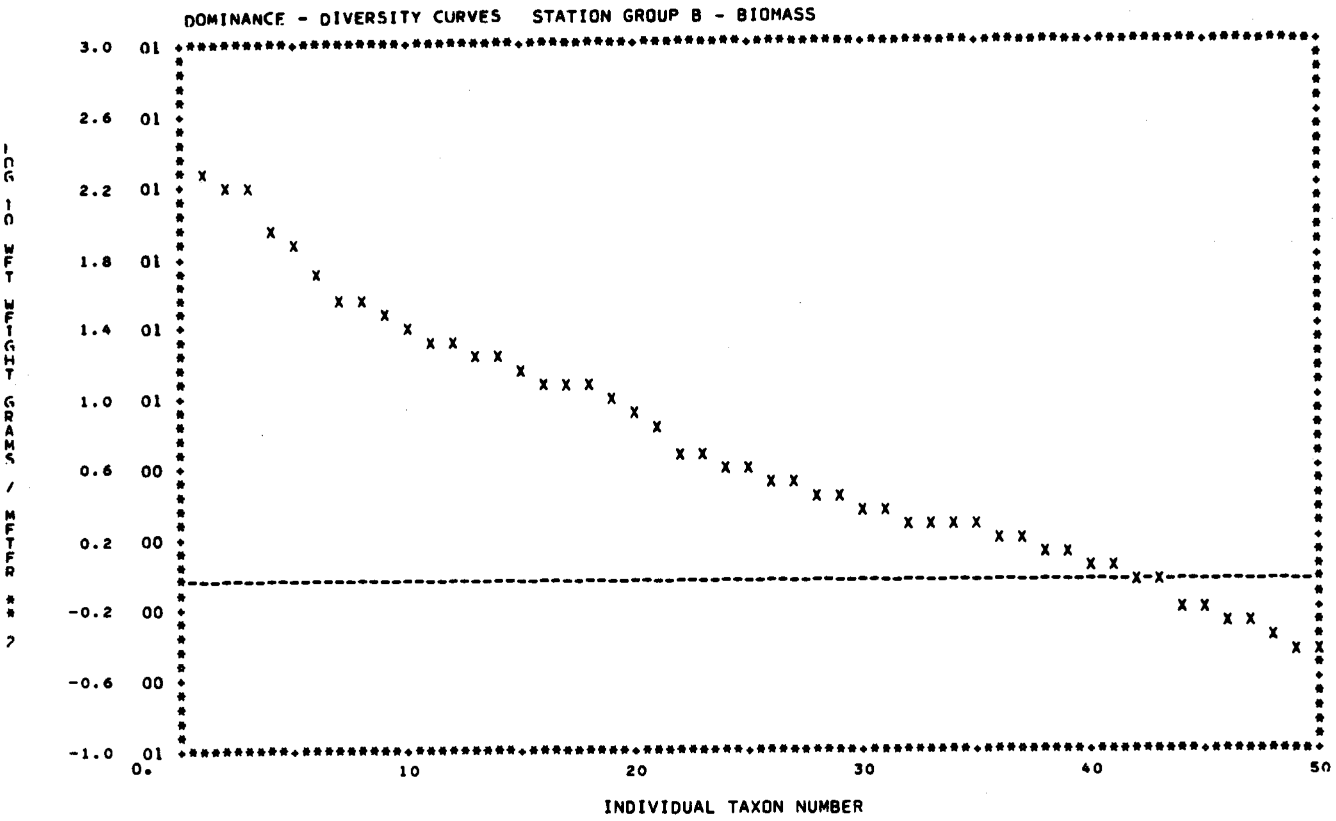
TAXON NO.	TAXON NAME	DATA VALUE	PLOT VALUE
1.	ARGIS LAR	35.265	1.547
2.	ECHIURUS ECHIURUS ALASKANUS	18.493	1.267
3.	STERNASPIS SCUTATA	5.658	0.753
4.	DIAMPHIODIA CRATERODMETA	5.099	0.707
5.	SERRIPES GROENLANDICUS	3.588	0.555
6.	TEREBELLIDES STROEMII	2.863	0.457
7.	SCALIBREGMA INFLATUM	2.179	0.338
8.	HAPLOSCOLOPLOS ELONGATUS	1.935	0.287
9.	CISTENIDES GRANULATA	1.862	0.270
10.	YOLDIA MYALIS	1.812	0.258
11.	MYRIOCHELE OCULATA	1.367	0.136
12.	AMPHARETE FINMARCHICA	1.356	0.132
13.	GOLFINGIA MARGARITACEA	1.330	0.124
14.	POTAMILLA NEGLECTA	1.048	0.020
15.	BALANUS CRENATUS	0.852	-0.070
16.	BYBLIS GAIMARDI	0.713	-0.147
17.	ERICTHONIUS HUNTERI	0.510	-0.292
18.	RHODINE GRACILIOR	0.356	-0.449
19.	NUCULA TENUIS	0.323	-0.491
20.	CHONE CINCTA	0.300	-0.523
21.	THARYX SECUNDUS	0.230	-0.638
22.	LAONOME KROYERI	0.230	-0.638
23.	LIOCYMA FLUCTUOSA	0.220	-0.658
24.	CHIONOECETES OPILIO	0.215	-0.668
25.	GLYCINDE PICTA	0.201	-0.697
26.	HARMOTHOE IMBRICATA	0.187	-0.728
27.	AMPELISCA ESCHRICHTI	0.180	-0.745
28.	DIASTYLIS BIDENTATA	0.162	-0.790
29.	MELITA QUADRISPINOSA	0.160	-0.796
30.	PRAXILLELLA PRAETERMISSA	0.158	-0.801
31.	PRIAPULUS CAUDATUS	0.132	-0.879
32.	AMPHARETE ACUTIFRONS	0.128	-0.893
33.	BRADA VILLOSA	0.126	-0.900
34.	ASABELLIDES SIBIRICA	0.122	-0.914
35.	PHOLOE MINUTA	0.113	-0.947
36.	AMPELISCA MACROCEPHALA	0.100	-1.000
37.	BARANTOLLA AMERICANA	0.078	-1.108
38.	ANONYX LATICOXAE	0.056	-1.252
39.	HETEROMASTUS GIGANTEUS	0.055	-1.260
40.	HETEROMASTUS FILIFORMIS	0.031	-1.509
41.	LEUCON NASICA	0.031	-1.509
42.	ANTINOELLA SARSI	0.030	-1.523
43.	EUCHONE ANALIS	0.030	-1.523
44.	MALDANE GLEBIFEX	0.028	-1.553
45.	HARPINIA GURJANOVAE	0.026	-1.585
46.	ETEONE LONGA	0.024	-1.620
47.	CYLICHNA ALBA	0.023	-1.638
48.	EUDORELLA PACIFICA	0.023	-1.638
49.	MAGELONA PACIFICA	0.022	-1.658
50.	WESTWOODILLA CAECULA	0.018	-1.745

Figure 4. Dominance diversity curve (biomass) calculated from Station Group A".



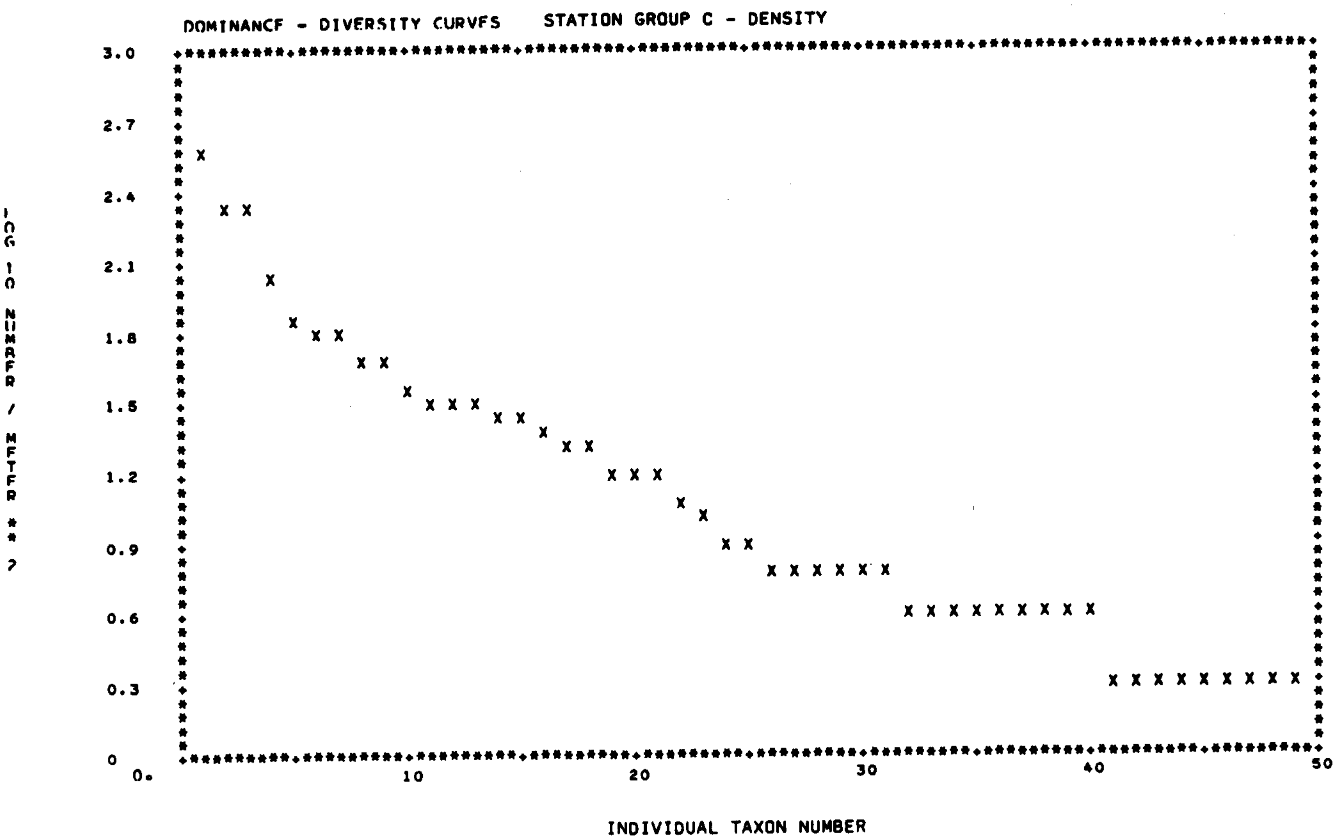
TAXON NO.	TAXON NAME	DATA VALUE	PLOT VALUE
1.	HETEROMASTUS FILIFORMIS	1284.000	3.109
2.	OPHIURA SARSI	1078.000	3.033
3.	MALDANE GLEBIFEX	1004.000	3.002
4.	AXINOPSIDA SERRICATA	966.000	2.985
5.	DIAMPHIODIA CRATERODMETA	926.000	2.967
6.	PRIAPULUS CAUDATUS	316.000	2.500
7.	RETUSA OBTUSA	292.000	2.465
8.	HAPLOSCOLOPLOS ELONGATUS	282.000	2.450
9.	PARAPHOXUS OCULATUS	244.000	2.387
10.	UROTHOE DENTICULATA	192.000	2.283
11.	CHAETODERMA ROBUSTA	178.000	2.250
12.	THYASIRA FLEXUOSA	152.000	2.182
13.	BARANTOLLA AMERICANA	148.000	2.170
14.	MELINNA CRISTATA	144.000	2.158
15.	MYRIOCHELE OCULATA	138.000	2.140
16.	PRAXILLELLA PRAETERMISSA	130.000	2.114
17.	NUCULA TENUIS	116.000	2.064
18.	LYSIPPE LABIATA	108.000	2.033
19.	APISTOBRANCHUS TULIBERGI	106.000	2.025
20.	LEUCON NASICA	106.000	2.025
21.	OWENIA FUSIFORMIS	104.000	2.017
22.	NEPHTYS PUNCTATA	98.000	1.991
23.	AXINOPSIDA VIRIDIS	92.000	1.964
24.	MYRIOCHELE HEERI	82.000	1.914
25.	TRAVISIA FORBESII	66.000	1.820
26.	CTENODISCUS CRISPATUS	64.000	1.806
27.	MYSELLA ALEUTICA	58.000	1.763
28.	BRADA VILLOSA	56.000	1.748
29.	EUCHONE LONGIFISSURATA	54.000	1.732
30.	ETEONE LONGA	50.000	1.699
31.	ARICIDEA LOPEZI	50.000	1.699
32.	NEOLEPREA SPIRALIS	50.000	1.699
33.	AXIOTHELLA CANTENTA	42.000	1.623
34.	PRAXILLELLA GRACILIS	42.000	1.623
35.	EUDORELLA EMARGINATA	42.000	1.623
36.	PHOLOE MINUTA	32.000	1.505
37.	STERNASPIS SCUTATA	30.000	1.477
38.	CYCLOCARDIA CREBRICOSTATA	30.000	1.477
39.	CYLICHNA ALBA	30.000	1.477
40.	HARPINIA KOBJAKOVAF	30.000	1.477
41.	TAUBERIA GRACILIS	28.000	1.447
42.	DRILONEREIS FALCATA MINOR	26.000	1.415
43.	GOLFINGIA MARGARITACEA	26.000	1.415
44.	NEPHTYS CAECA	24.000	1.380
45.	CHONE CINCTA	24.000	1.380
46.	MAGELONA PACIFICA	20.000	1.301
47.	THARYX SECUNDUS	20.000	1.301
48.	POTAMILLA NEGLECTA	20.000	1.301
49.	YOLDIA THRACIAEFORMIS	20.000	1.301
50.	AMPELISCA MACROCEPHALA	18.000	1.255

Figure 5. Dominance-diversity curve (density) calculated from Station Group B.



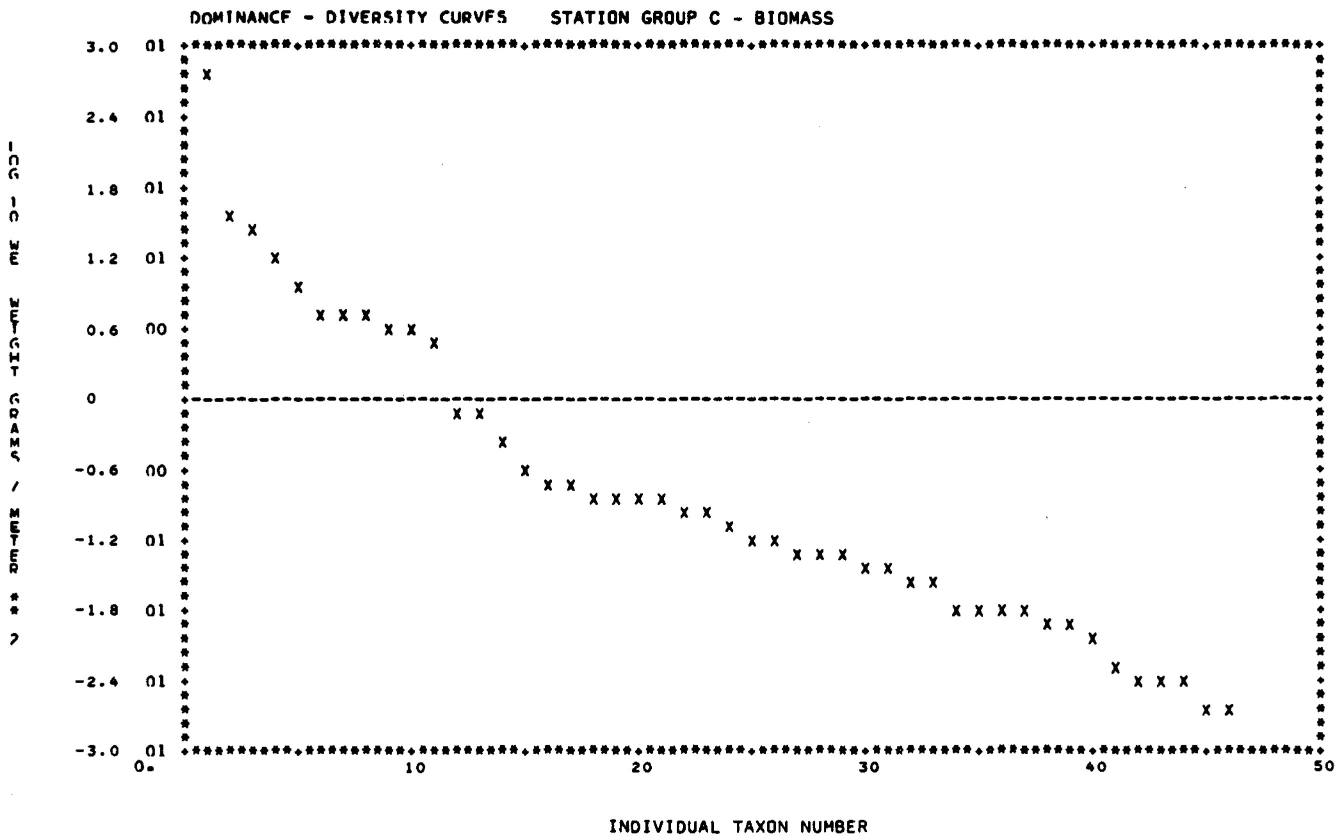
TAXON NO.	TAXON NAME	DATA VALUE	PLOT VALUE
1.	OPHIURA SARSI	174.928	2.243
2.	MALDANE GLEBIFEX	162.272	2.210
3.	CTENODISCUS CRISPATUS	161.760	2.209
4.	MACOMA BROTA	84.572	1.927
5.	NEPTUNEA LYRATA	75.826	1.880
6.	BUCCINUM SP.	48.724	1.688
7.	MACOMA CALCAREA	38.592	1.586
8.	DIAMPHIODIA CRATERODMETA	33.942	1.531
9.	NEPHTYS PUNCTATA	28.216	1.450
10.	NEOLEPREA SPIRALIS	23.088	1.363
11.	PRIAPULUS CAUDATUS	22.096	1.344
12.	GOLFINGIA MARGARITACEA	21.882	1.340
13.	YOLDIA THRACIAEFORMIS	17.656	1.247
14.	MELINNA CRISTATA	16.232	1.210
15.	PRAXILLELLA GRACILIS	14.092	1.149
16.	PISTA CRISTATA	12.526	1.098
17.	PAGURUS TRIGONOCHFIRUS	12.472	1.096
18.	YOLDIA AMYGDALEA	11.940	1.077
19.	AXIOTHELLA CANTENTA	10.220	1.009
20.	CYCLOCARDIA CREBRICOSTATA	8.050	0.906
21.	PRAXILLELLA PRAETERMISSA	7.082	0.850
22.	CHAETODERMA ROBUSTA	5.208	0.717
23.	YOLDIA HYPERBOREA	5.000	0.699
24.	HAPLOSCOLOPLOS FLONGATUS	3.990	0.601
25.	HETEROMASTUS FILIFORMIS	3.788	0.578
26.	MYRIOCHELE OCULATA	3.610	0.558
27.	CHONE CINCTA	3.452	0.538
28.	TRAVISIA FORBESII	2.868	0.458
29.	EUCHONE LONGIFISSURATA	2.700	0.431
30.	FLABELLIGERA MASTIGOPHORA	2.180	0.338
31.	NUCULA TENUIS	2.172	0.337
32.	AXINOPSIDA SERRICATA	1.902	0.279
33.	NEPHTYS CAECA	1.826	0.262
34.	THYASIRA FLEXUOSA	1.770	0.248
35.	PISTA ELONGATA	1.762	0.246
36.	LIOCYMA FLUCTUOSA	1.628	0.212
37.	BRADA VILLOSA	1.450	0.161
38.	STERNASPIS SCUTATA	1.380	0.140
39.	LYSIPPE LABIATA	1.352	0.131
40.	POLINICES PALLIDUS	1.186	0.074
41.	AMPHICTEIS GUNNERI	1.152	0.061
42.	POTAMILLA NEGLECTA	0.940	-0.027
43.	BARANTOLLA AMERICANA	0.938	-0.028
44.	NUCULANA FOSSA	0.682	-0.166
45.	TACHYRYNCHUS EROSUS	0.594	-0.226
46.	LEUCON NASICA	0.566	-0.247
47.	SPIOCHAETOPTERUS COSTARUM	0.500	-0.301
48.	RETUSA OBTUSA	0.446	-0.351
49.	LAONOME KROYERI	0.398	-0.400
50.	TEREBELLIDES STROEMII	0.392	-0.407

Figure 6. Dominance-diversity curve (biomass) calculated from Station Group B.



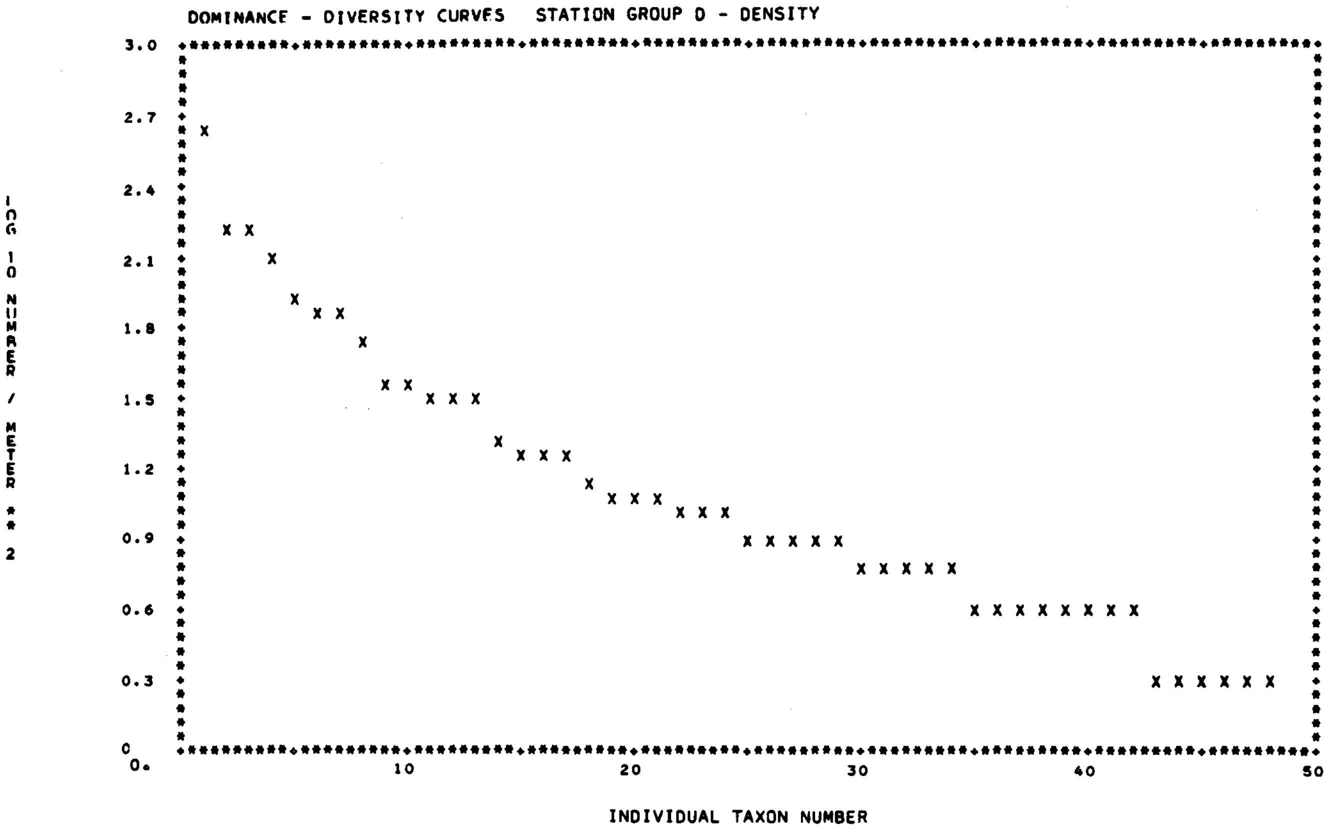
TAXON NO.	TAXON NAME	DATA VALUE	PLOT VALUE
1.	NUCULA TENUIS	366.000	2.563
2.	NUCULANA FOSSA	226.000	2.354
3.	CUCUMARIA SP.	214.000	2.330
4.	STERNASPIS SCUTATA	112.000	2.049
5.	SERRIPES GROENLANDICUS	68.000	1.833
6.	RETUSA OBTUSA	64.000	1.806
7.	MYRIOCHELE OCULATA	62.000	1.792
8.	BARANTOLLA AMERICANA	48.000	1.681
9.	MALDANE GLEBIFEX	48.000	1.681
10.	NEPHTYS CAECA	36.000	1.556
11.	SOLARIELLA VARICOSA	32.000	1.505
12.	HAPLOSCOLOPLOS ELONGATUS	30.000	1.477
13.	DIAMPHIODIA CRATERODMETA	30.000	1.477
14.	NEPHTYS PUNCTATA	28.000	1.447
15.	AXINOPSIDA SERRICATA	28.000	1.447
16.	HARPINIA KOBJAKOVAE	24.000	1.380
17.	LEUCON NASICA	22.000	1.342
18.	HARPINIA GURJANOVAE	20.000	1.301
19.	HETEROMASTUS FILIFORMIS	16.000	1.204
20.	LIOCYMA FLUCTUOSA	16.000	1.204
21.	BATHYMEDON NANSENI	16.000	1.204
22.	MACOMA CALCAREA	12.000	1.079
23.	OPHIURA SARSI	10.000	1.000
24.	THYASIRA FLEXUOSA	8.000	0.903
25.	CYLICHNA ALBA	8.000	0.903
26.	PHOLOE MINUTA	6.000	0.778
27.	GLYCINDE PICTA	6.000	0.778
28.	YOLDIA AMYGDALEA	6.000	0.778
29.	CLINOCARDIUM CILIATUM	6.000	0.778
30.	EUDORELLA PACIFICA	6.000	0.778
31.	EUDORELLOPSIS INTEGRA	6.000	0.778
32.	NEPHTYS CILIATA	4.000	0.602
33.	PRAXILLELLA PRAETERMISSA	4.000	0.602
34.	NEOLEPREA SPIRALIS	4.000	0.602
35.	LAONOME KROYERI	4.000	0.602
36.	CYCLOCARDIA CREBRICOSTATA	4.000	0.602
37.	ODONTOGENA BOREALIS	4.000	0.602
38.	PRIAPULUS CAUDATUS	4.000	0.602
39.	ECHINARACHNIUS PARMA	4.000	0.602
40.	DIAMPHODIA SP.	4.000	0.602
41.	ARCTEOBIA ANTICOSTIENSIS	2.000	0.301
42.	ETEONE LONGA	2.000	0.301
43.	CAPITELLA CAPITATA	2.000	0.301
44.	ASTARTE BOREALIS	2.000	0.301
45.	NATICA CLAUSA	2.000	0.301
46.	POLINICES PALLIDUS	2.000	0.301
47.	BYBLIS GAIMARDI	2.000	0.301
48.	MACHAIRONYX MUELLERI	2.000	0.301
49.	WESTWOODILLA CAECULA	2.000	0.301

Figure 7. Dominance-diversity curve (density) calculated from Station Group C.



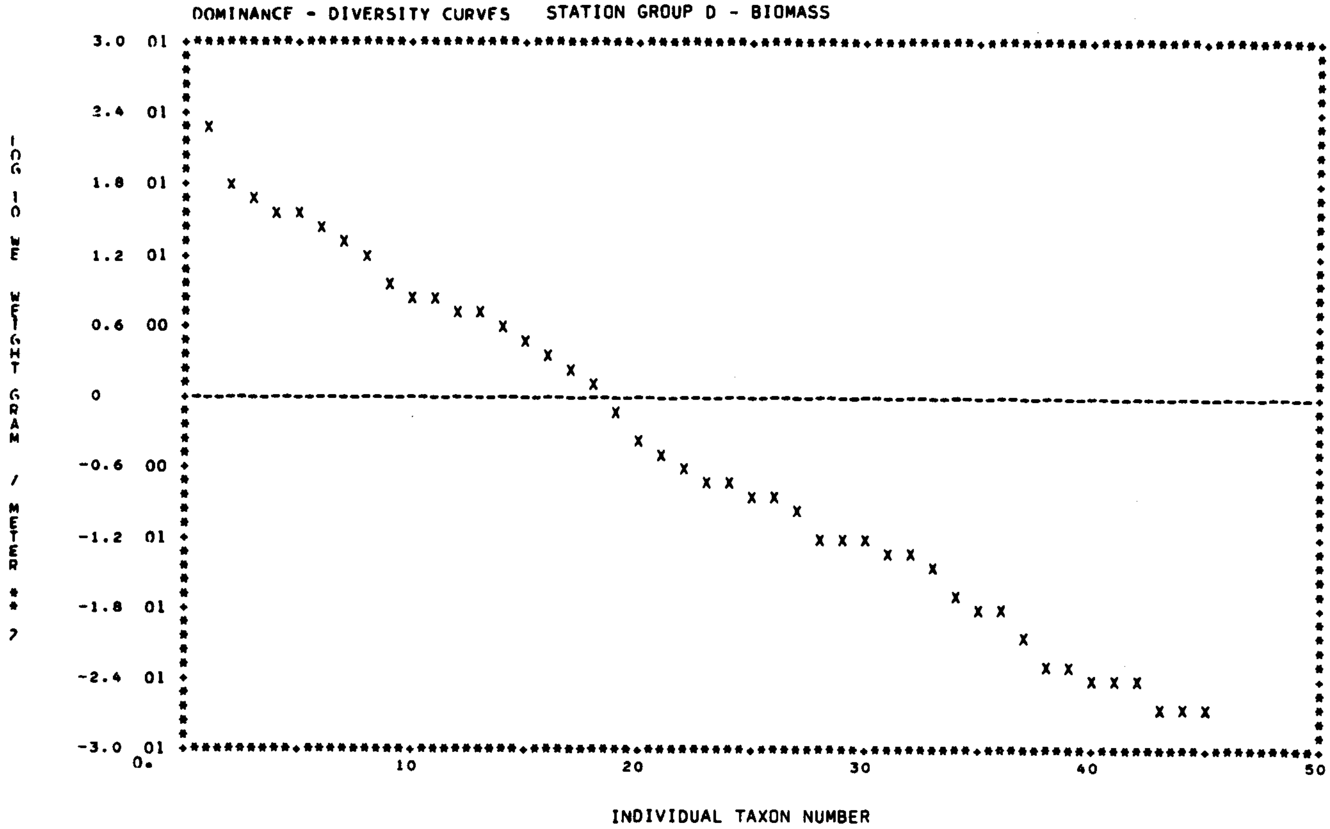
TAXON NO.	TAXON NAME	DATA VALUE	PLOT VALUE
1.	CUCUMARIA SP.	560.258	2.748
2.	NUCULANA FOSSA	34.898	1.543
3.	STFRNASPIS SCUTATA	26.056	1.416
4.	MACOMA CALCAREA	14.574	1.164
5.	NUCULA TENUIS	9.254	0.966
6.	CLINOCARDIUM CILIATUM	5.854	0.767
7.	NEPHTYS PUNCTATA	5.032	0.702
8.	YOLDIA AMYGDALEA	4.826	0.684
9.	MALDANE GLEBIFEX	4.476	0.651
10.	NEPHTYS CAECA	3.686	0.567
11.	NEOLEPREA SPIRALIS	3.248	0.512
12.	PRAXILLELLA PRAETERMISSA	0.720	-0.143
13.	POLINICES PALLIDUS	0.674	-0.171
14.	DIAMPHIODIA CRATERODMETA	0.456	-0.341
15.	SOLARIELLA VARICOSA	0.284	-0.547
16.	SERRIPES GROENLANDICUS	0.194	-0.712
17.	NEPHTYS CILIATA	0.172	-0.764
18.	LIOCYMA FLUCTUOSA	0.158	-0.801
19.	OPHIURA SARSI	0.150	-0.824
20.	LAONOME KROYERI	0.140	-0.854
21.	HAPLOSCOLOPLOS ELONGATUS	0.136	-0.866
22.	CYLICHNA ALBA	0.122	-0.914
23.	BARANTOLLA AMERICANA	0.102	-0.991
24.	LEUCON NASICA	0.078	-1.108
25.	AXINOPSIDA SERRICATA	0.062	-1.208
26.	PRIAPULUS CAUDATUS	0.060	-1.222
27.	MYRIOCHELE OCULATA	0.054	-1.268
28.	RETUSA OBTUSA	0.052	-1.284
29.	THYASIRA FLEXUOSA	0.050	-1.301
30.	HARPINIA GURJANOVAE	0.036	-1.444
31.	BATHYMEDON NANSENI	0.034	-1.469
32.	HETEROMASTUS FILIFORMIS	0.028	-1.553
33.	BYBLIS GAIMARDI	0.026	-1.585
34.	ECHINARACHNIUS PARMA	0.016	-1.796
35.	DIAMPHODIA SP.	0.016	-1.796
36.	EUDORELLA PACIFICA	0.014	-1.854
37.	ODONTOGENA BOREALIS	0.014	-1.854
38.	HARPINIA KOBJAKOVAE	0.012	-1.921
39.	NATICA CLAUSA	0.012	-1.921
40.	ETEONE LONGA	0.008	-2.097
41.	PHOLOE MINUTA	0.006	-2.222
42.	GLYCINDE PICTA	0.004	-2.398
43.	CYCLOCARDIA CREBRICOSTATA	0.004	-2.398
44.	EUDORELLOPSIS INTEGRA	0.004	-2.398
45.	ARCTEOBIA ANTICOSTIENSIS	0.002	-2.699
46.	MACHAIRONYX MUELLERI	0.002	-2.699

Figure 8. Dominance-diversity curve (biomass) calculated from Station Group C.



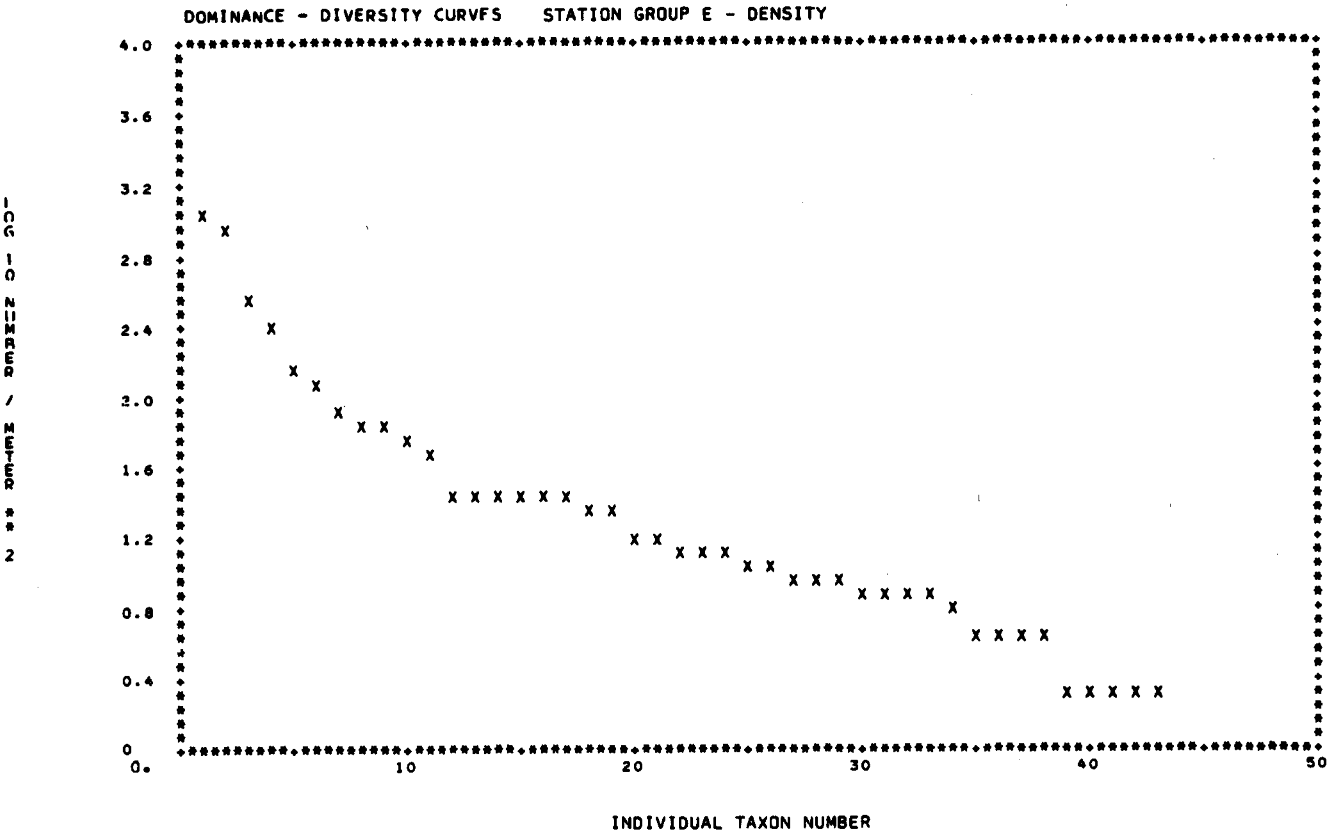
TAXON NO.	TAXON NAME	DATA VALUE	PLOT VALUE
1.	BARANTOLLA AMERICANA	464.000	2.667
2.	NUCULA TENUIS	172.000	2.236
3.	MALDANE GLEBIFEX	160.000	2.204
4.	MACOMA CALCAREA	130.000	2.114
5.	NEPHTYS PUNCTATA	80.000	1.903
6.	HETEROMASTUS FILIFORMIS	74.000	1.869
7.	PRIAPULUS CAUDATUS	68.000	1.833
8.	BRADA VILLOSA	58.000	1.763
9.	PRAXILLELLA PRAETERMISSA	36.000	1.556
10.	RETUSA OBTUSA	36.000	1.556
11.	CAPITELLA CAPITATA	32.000	1.505
12.	YOLDIA HYPERBOREA	32.000	1.505
13.	HAPLOSCOLOPLOS ELONGATUS	30.000	1.477
14.	ARICIDEA LOPEZI	22.000	1.342
15.	ETEONE LONGA	18.000	1.255
16.	NEPHTYS ASSIMILIS	18.000	1.255
17.	CYLICHNA ALBA	18.000	1.255
18.	EUDORELLOPSIS INTEGRA	14.000	1.146
19.	MELINNA CRISTATA	12.000	1.079
20.	AXINOPSIDA SERRICATA	12.000	1.079
21.	HARPINIA KOBJAKOVAF	12.000	1.079
22.	TEREBELLIDES STROEMII	10.000	1.000
23.	NUCULANA PERNULA	10.000	1.000
24.	EUDORELLA EMARGINATA	10.000	1.000
25.	NEMIDIA TAMARAE	8.000	0.903
26.	PRIONOSPIO STEENSTRUPI	8.000	0.903
27.	MALDANE SARSI	8.000	0.903
28.	ARTACAMA CONIFERA	8.000	0.903
29.	CLINOCARDIUM CILIATUM	8.000	0.903
30.	HESPERONE COMPLANATA	6.000	0.778
31.	TENONIA KISTAPENSIS	6.000	0.778
32.	AXINOPSIDA VIRIDIS	6.000	0.778
33.	ECHINARACHNIUS PARMA	6.000	0.778
34.	OPHIURA SARSI	6.000	0.778
35.	ANAITIDES GROENLANDICA	4.000	0.602
36.	SCALIBREGMA INFLATUM	4.000	0.602
37.	STERNASPIS SCUTATA	4.000	0.602
38.	CHAETODERMA ROBUSTA	4.000	0.602
39.	METRIDIA LUCENS	4.000	0.602
40.	LEUCON NASICA	4.000	0.602
41.	PONTOPOREIA FEMORATA	4.000	0.602
42.	DIAMPHIODIA CRATERODMETA	4.000	0.602
43.	ARCTEOBIA SPINELYTRIS	2.000	0.301
44.	PHOLOE MINUTA	2.000	0.301
45.	MYRIOCHELE OCULATA	2.000	0.301
46.	MACOMA BROTA	2.000	0.301
47.	EUDORELLOPSIS USCHAKOVI	2.000	0.301
48.	GOLFINGIA MARGARITACEA	2.000	0.301

Figure 9. Dominance-diversity curve (density) calculated from Station Group D.



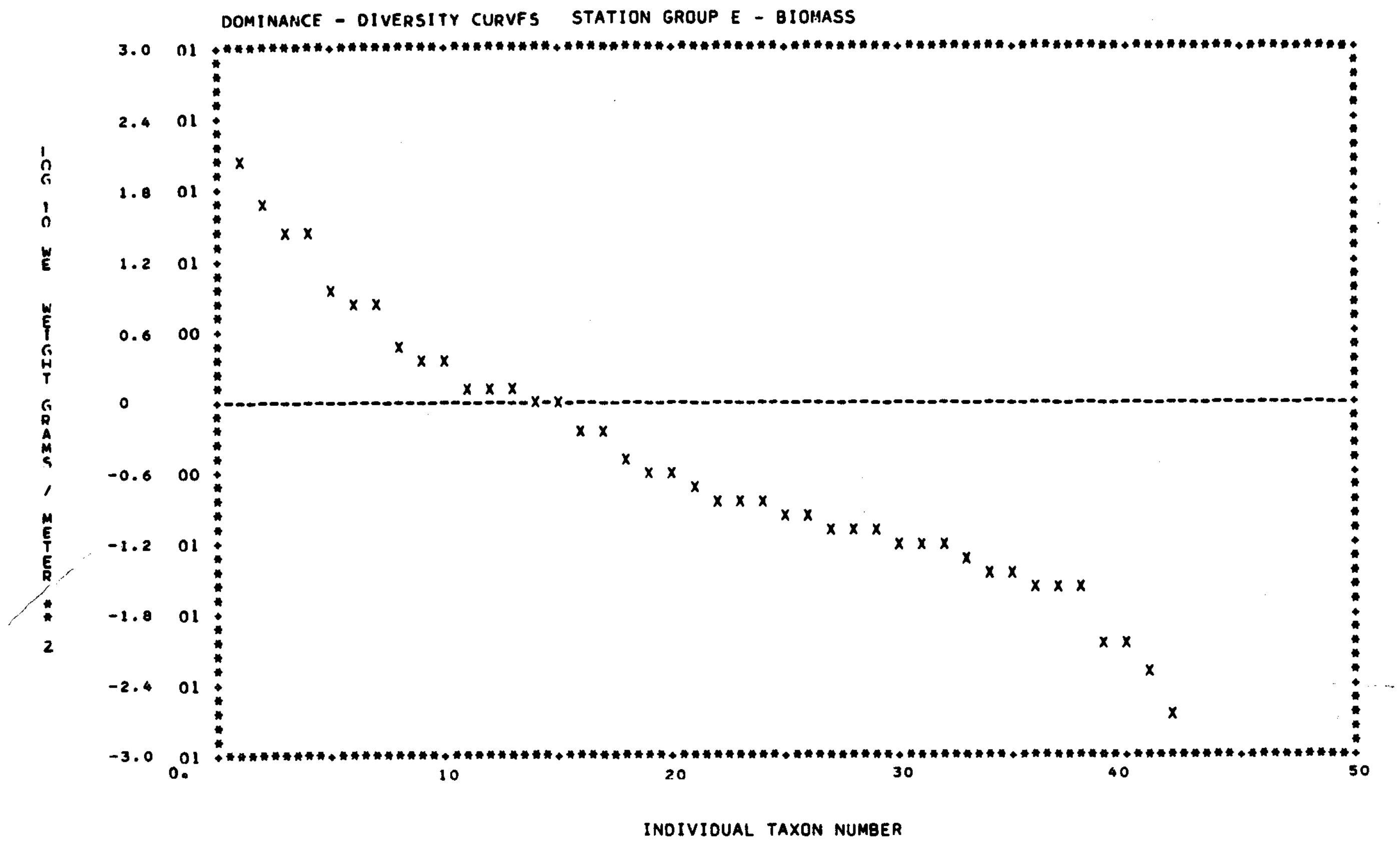
TAXON NO.	TAXON NAME	DATA VALUE	PLOT VALUE
1.	MACOMA CALCAREA	174.708	2.242
2.	NEPHTYS PUNCTATA	61.906	1.792
3.	ECHINARACHNIUS PARMA	52.046	1.716
4.	MALDANE GLEBIFEX	37.522	1.574
5.	YOLDIA HYPERBOREA	34.478	1.538
6.	ARTACAMA CONIFERA	27.376	1.437
7.	NUCULA TENUIS	18.956	1.278
8.	NEPHTYS ASSIMILIS	14.344	1.157
9.	PRAXILLELLA PRAETERMISSA	8.798	0.944
10.	OPHIURA SARSI	7.612	0.881
11.	NUCULANA PERNULA	6.174	0.791
12.	TEREBELLIDES STROEMII	5.906	0.771
13.	BARANTOLLA AMERICANA	5.556	0.745
14.	MELINNA CRISTATA	3.588	0.555
15.	PRIAPULUS CAUDATUS	3.016	0.479
16.	HAPLOSCOLOPLOS ELONGATUS	2.308	0.363
17.	MALDANE SARSI	1.862	0.270
18.	BRADA VILLOSA	1.200	0.079
19.	NEMIDIA TAMARAE	0.706	-0.151
20.	CAPITELLA CAPITATA	0.402	-0.396
21.	STERNASPIS SCUTATA	0.366	-0.437
22.	CHAETODERMA ROBUSTA	0.222	-0.654
23.	MACOMA BROTA	0.216	-0.666
24.	HETEROMASTUS FILIFORMIS	0.198	-0.703
25.	SCALIBREGMA INFLATUM	0.154	-0.812
26.	ETEONE LONGA	0.142	-0.848
27.	DIAMPHIODIA CRATERODMETA	0.096	-1.018
28.	CLINOCARDIUM CILIATUM	0.070	-1.155
29.	RETUSA OBTUSA	0.060	-1.222
30.	ANAITIDES GROENLANDICA	0.056	-1.252
31.	CYLICHNA ALBA	0.046	-1.337
32.	PONTOPOREIA FEMORATA	0.044	-1.357
33.	EUDORELLOPSIS INTEGRA	0.034	-1.469
34.	HESPERONE COMPLANATA	0.020	-1.699
35.	ARICIDEA LOPEZI	0.018	-1.745
36.	EUDORELLA EMARGINATA	0.018	-1.745
37.	AXINOPSIDA SERRICATA	0.010	-2.000
38.	AXINOPSIDA VIRIDIS	0.006	-2.222
39.	METRIDIA LUCENS	0.006	-2.222
40.	PRIONOSPIO STEENSTRUPI	0.004	-2.398
41.	HARPINIA KOBJAKOVAE	0.004	-2.398
42.	GOLFINGIA MARGARITACEA	0.004	-2.398
43.	TENONIA KISTAPENSIS	0.002	-2.699
44.	PHOLOE MINUTA	0.002	-2.699
45.	EUDORELLOPSIS USCHAKOVI	0.002	-2.699

Figure 10. Dominance-diversity curve (biomass) calculated from Station Group D.



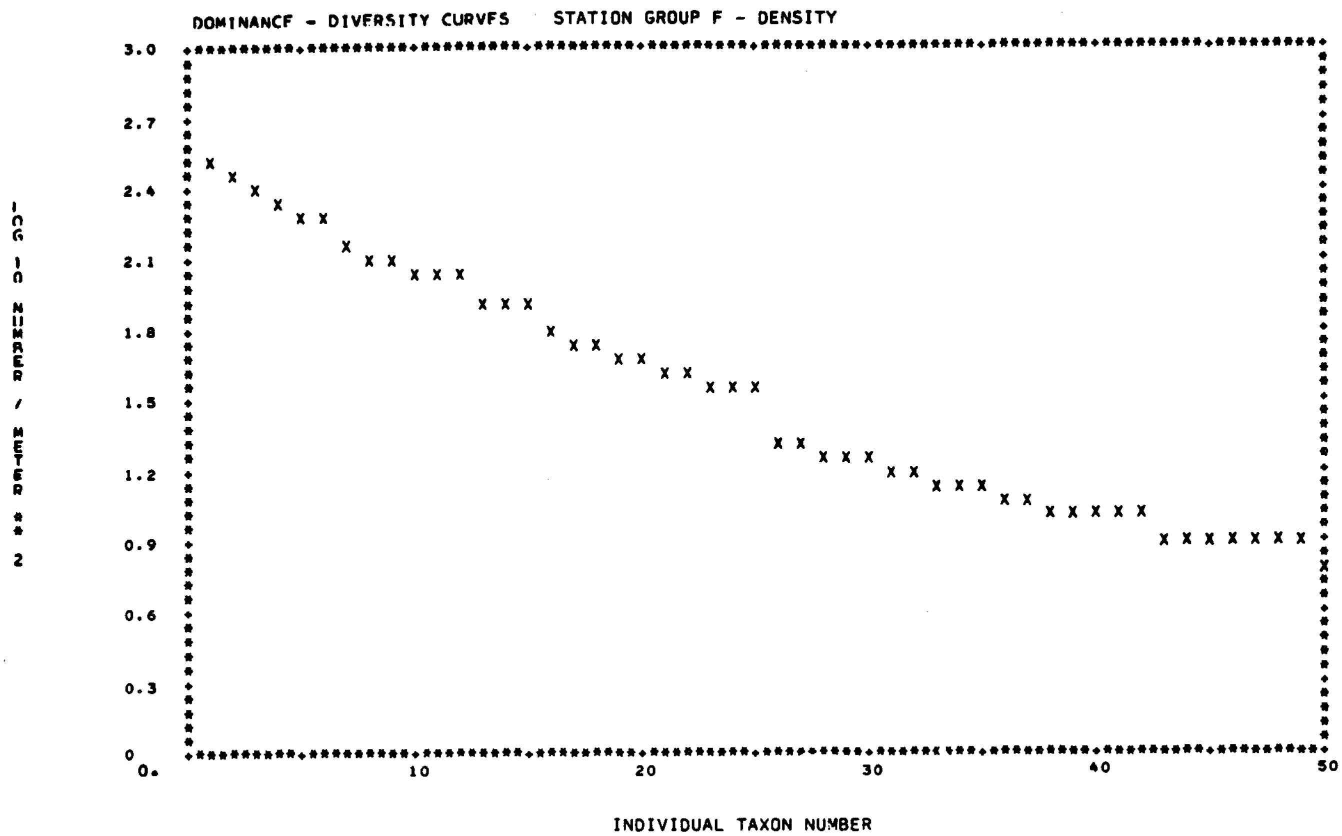
TAXON NO.	TAXON NAME	DATA VALUE	PLOT VALUE
1.	HAPLOSCOLOPLOS ELONGATUS	1030.000	3.013
2.	NUCULA TENUIS	998.000	2.999
3.	BARANTOLLA AMERICANA	380.000	2.580
4.	HARPINIA GURJANOVAE	230.000	2.362
5.	PROTOMEDEIRA CHELATA	134.000	2.127
6.	EUDORELLA PACIFICA	128.000	2.107
7.	BRADA VILLOSA	80.000	1.903
8.	GLYCINDE PICTA	70.000	1.845
9.	HETEROMASTUS FILIFORMIS	70.000	1.845
10.	MACOMA CALCAREA	54.000	1.732
11.	NUCULANA FOSSA	48.000	1.681
12.	CYLICHNA ALBA	30.000	1.477
13.	PROTOMEDIEIA FASCIATA	30.000	1.477
14.	ARICIDEA LOPEZI	28.000	1.447
15.	PRAXILLELLA PRAETERMISSA	26.000	1.415
16.	AXINOPSIDA SERRICATA	26.000	1.415
17.	THYASIRA FLEXUOSA	26.000	1.415
18.	CAPITELLA CAPITATA	24.000	1.380
19.	BYBLIS GAIMARDI	22.000	1.342
20.	NEPHTYS PUNCTATA	16.000	1.204
21.	TAUBERIA GRACILIS	16.000	1.204
22.	PHOLOE MINUTA	14.000	1.146
23.	ETEONE LONGA	14.000	1.146
24.	STERNASPIS SCUTATA	14.000	1.146
25.	NUCULANA PERNULA	12.000	1.079
26.	YOLDIA AMYGDALEA	12.000	1.079
27.	SCALIBREGMA INFLATUM	10.000	1.000
28.	AXINOPSIDA VIRIDIS	10.000	1.000
29.	RETUSA OBTUSA	10.000	1.000
30.	ANTINOELLA SARSI	8.000	0.903
31.	EUDORELLOPSIS DEFORMIS	8.000	0.903
32.	PRIAPULUS CAUDATUS	8.000	0.903
33.	DIAMPHIODIA CRATERODMETA	8.000	0.903
34.	TEREBELLIDES STROEMII	6.000	0.778
35.	NEPHTYS CAECA	4.000	0.602
36.	MALDANE GLEBIFEX	4.000	0.602
37.	PONTOPOREIA FEMORATA	4.000	0.602
38.	MACHAIRONYX MUELLERI	4.000	0.602
39.	NEMIDIA TAMARAE	2.000	0.301
40.	ANAITIDES GROENLANDICA	2.000	0.301
41.	AXIOTHELLA CANTENTA	2.000	0.301
42.	HARPINIA KOBJAKOVAF	2.000	0.301
43.	ARGIS LAR	2.000	0.301

Figure 11. Dominance-diversity curve (density) calculated from Station Group E.



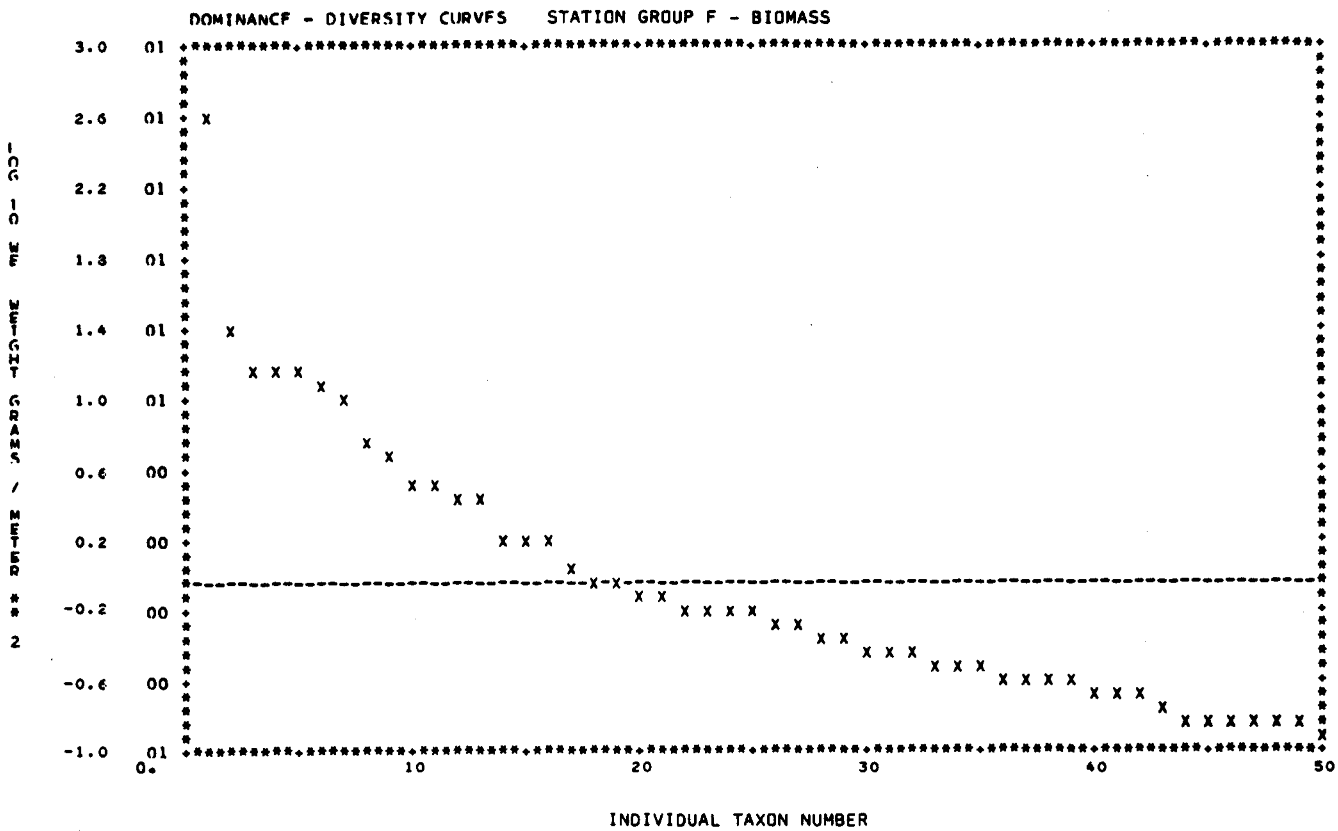
TAXON NO.	TAXON NAME	DATA VALUE	PLOT VALUE
1.	NUCULA TENUIS	106.102	2.026
2.	MACOMA CALCAREA	54.716	1.738
3.	NUCULANA FOSSA	27.424	1.438
4.	YOLDIA AMYGDALEA	26.242	1.419
5.	NUCULANA PERNULA	9.776	0.990
6.	HAPLOSCOLOPLOS ELONGATUS	7.584	0.880
7.	NEPHTYS PUNCTATA	7.462	0.873
8.	STERNASPIS SCUTATA	3.232	0.509
9.	PRAXILLELLA PRAETERMISSA	2.398	0.380
10.	TEREBELLIDES STROFMII	2.322	0.366
11.	NEPHTYS CAECA	1.482	0.171
12.	BRADA VILLOSA	1.348	0.130
13.	BARANTOLLA AMERICANA	1.248	0.096
14.	ARGIS LAR	1.126	0.052
15.	GLYCINDE PICTA	0.964	-0.016
16.	AXIOTHELLA CANTENTA	0.582	-0.235
17.	THYASIRA FLEXUOSA	0.568	-0.246
18.	CYLICHNA ALBA	0.336	-0.474
19.	MALDANE GLEBIFEX	0.274	-0.562
20.	BYBLIS GAIMARDI	0.252	-0.599
21.	HARPINIA GURJANOVAF	0.190	-0.721
22.	DIAMPHIODIA CRATERODMETA	0.154	-0.812
23.	EUDORELLA PACIFICA	0.128	-0.893
24.	PHOLOE MINUTA	0.126	-0.900
25.	HETEROMASTUS FILIFORMIS	0.100	-1.000
26.	PROTOMEDEIRA CHELATA	0.098	-1.009
27.	SCALIBREGMA INFLATUM	0.086	-1.066
28.	PRIAPULUS CAUDATUS	0.078	-1.108
29.	ARICIDEA LOPEZI	0.074	-1.131
30.	AXINOPSIDA SERRICATA	0.062	-1.208
31.	CAPITELLA CAPITATA	0.060	-1.222
32.	ANTINOELLA SARSI	0.056	-1.252
33.	PROTOMEDIEIA FASCIATA	0.054	-1.268
34.	TAUBERIA GRACILIS	0.034	-1.469
35.	AXINOPSIDA VIRIDIS	0.032	-1.495
36.	PONTOPOREIA FEMORATA	0.026	-1.585
37.	ETEONE LONGA	0.024	-1.620
38.	NEMIDIA TAMARAE	0.024	-1.620
39.	ANAITIDES GROENLANDICA	0.008	-2.097
40.	RETUSA OBTUSA	0.008	-2.097
41.	EUDORELLOPSIS DEFORMIS	0.006	-2.222
42.	HARPINIA KOBJAKOVAF	0.002	-2.699

Figure 12. Dominance-diversity curve (biomass) calculated from Station Group E.



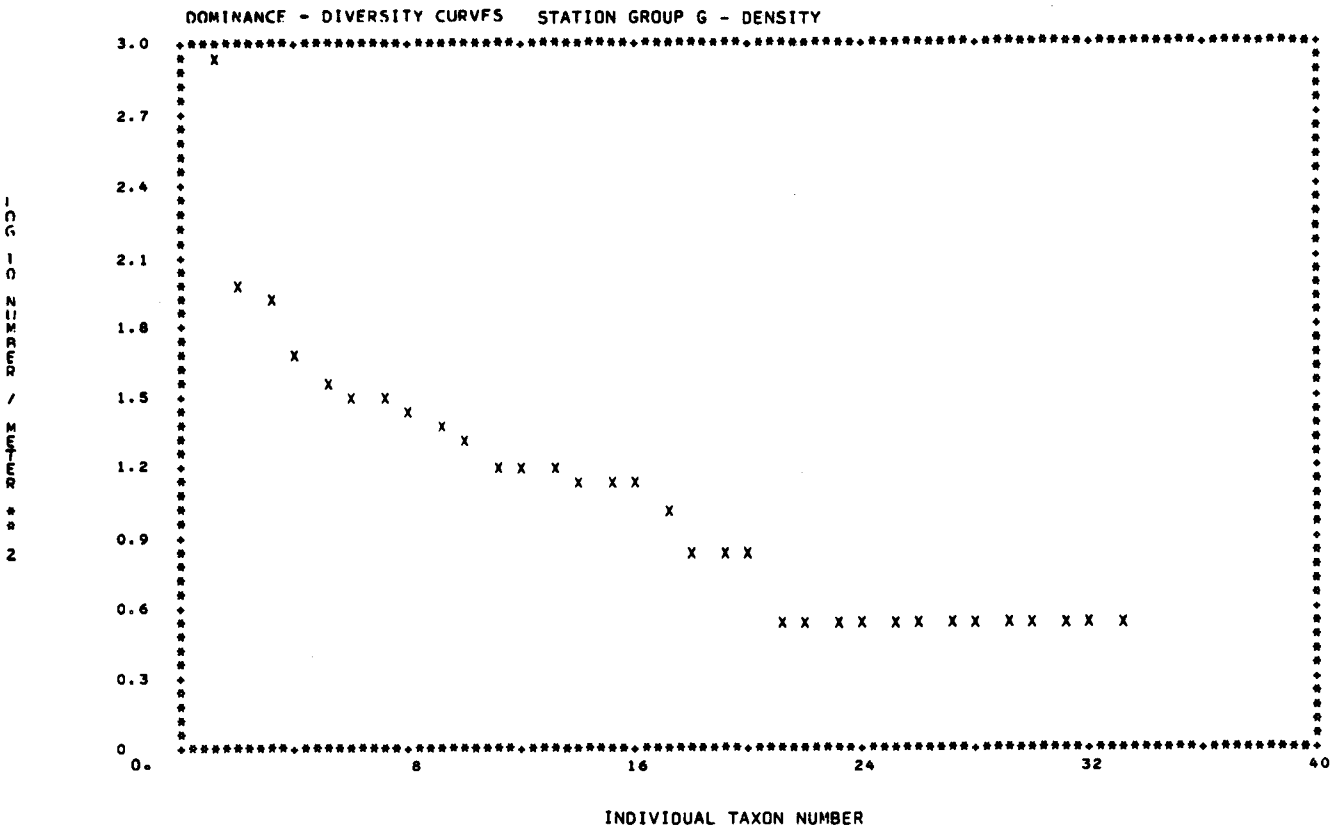
TAXON NO.	TAXON NAME	DATA VALUE	PLOT VALUE
1.	HARPINIA GURJANOVAE	316.000	2.500
2.	PRAXILLELLA PRAETERMISSA	284.000	2.453
3.	GLYCINDE PICTA	246.000	2.391
4.	HAPLOSCOLOPLOS ELONGATUS	214.000	2.330
5.	BARANTOLLA AMERICANA	180.000	2.255
6.	PARAPHOXUS OCULATUS	180.000	2.255
7.	AMPELISCA MACROCEPHALA	136.000	2.134
8.	ARCTEOBIA ANTICOSTIENSIS	128.000	2.107
9.	EUDORELLA PACIFICA	122.000	2.086
10.	PHOLOE MINUTA	116.000	2.064
11.	MYSELLA TUMIDA	108.000	2.033
12.	SPIOPHANES BOMBYX	106.000	2.025
13.	CYCLOCARDIA CREBRICOSTATA	86.000	1.934
14.	PHOTIS SPASSKII	80.000	1.903
15.	HETEROMASTUS FILIFORMIS	78.000	1.892
16.	ECHINARACHNIUS PARMA	62.000	1.792
17.	PONTOPOREIA FEMORATA	58.000	1.763
18.	TYPOSYLLIS ALTERNATA	56.000	1.748
19.	OPHELIA LIMACINA	50.000	1.699
20.	RHODINE GRACILIOR	46.000	1.663
21.	ETEONE LONGA	44.000	1.643
22.	GOLFINGIA MARGARITACEA	44.000	1.643
23.	SCOLOPLOS ARMIGER	36.000	1.556
24.	MALDANE GLEBIFEX	34.000	1.531
25.	EUDORELLOPSIS INTEGRA	34.000	1.531
26.	BRADA VILLOSA	20.000	1.301
27.	SERRIPES GROENLANDICUS	20.000	1.301
28.	ASTARTE BOREALIS	18.000	1.255
29.	BATHYMEDON NANSENI	18.000	1.255
30.	OPHIURA SARSI	18.000	1.255
31.	CISTENIDES GRANULATA	16.000	1.204
32.	SOLARIELLA VARICOSA	16.000	1.204
33.	NEPHTYS RICKETTSI	14.000	1.146
34.	SCALIBREGMA INFLATUM	14.000	1.146
35.	NATICA CLAUSA	14.000	1.146
36.	AMPHARETE ACUTIFRONS	12.000	1.079
37.	CHIONOECETES OPILIO	12.000	1.079
38.	NEPHTYS CAECA	10.000	1.000
39.	CAPITELLA CAPITATA	10.000	1.000
40.	TACHYRYNCHUS EROSUS	10.000	1.000
41.	CALANUS PLUMCHRUS	10.000	1.000
42.	WESTWOODILLA CAECULA	10.000	1.000
43.	ANTINOELLA SARSI	8.000	0.903
44.	MYRIOCHELE OCULATA	8.000	0.903
45.	ASABELLIDES SIBIRICA	8.000	0.903
46.	NUCULA TENUIS	8.000	0.903
47.	DIASTYLIS BIDENTATA	8.000	0.903
48.	MACHAIRONYX MUELLERI	8.000	0.903
49.	TIRON BIOCULATA	8.000	0.903
50.	GATTYANA TREADWELLI	6.000	0.778

Figure 13. Dominance-diversity curve (density) calculated from Station Group F.



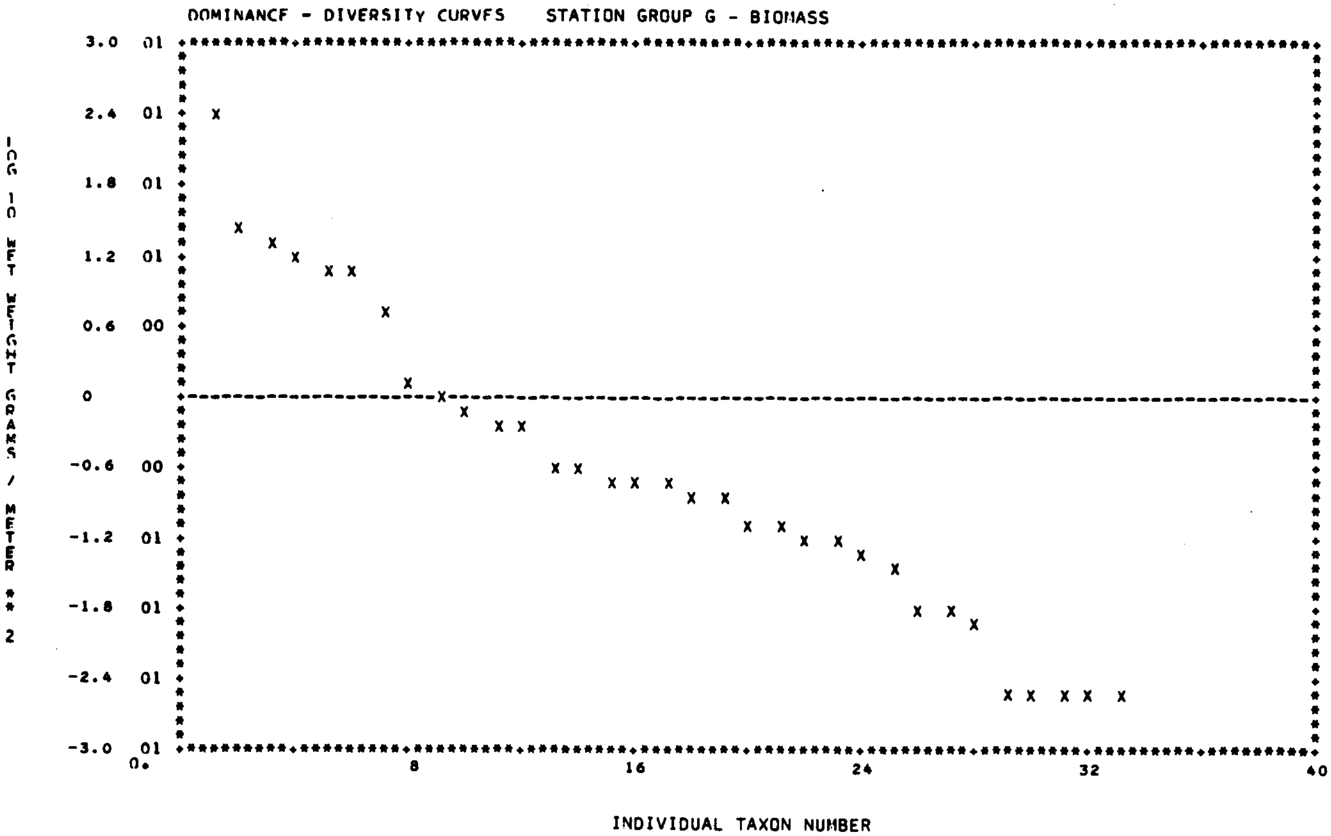
TAXON NO.	TAXON NAME	DATA VALUE	PLOT VALUE
1.	ECHINARACHNIUS PARMA	368.830	2.567
2.	NEPHTYS RICKETTSI	25.908	1.413
3.	SERRIPES GROENLANDICUS	15.730	1.197
4.	PRAXILLELLA PRAETERMISSA	15.728	1.197
5.	CYCLOCARDIA CREBRICOSTATA	13.616	1.134
6.	NEPHTYS CAECA	12.570	1.099
7.	CUCUMARIA SP.	10.268	1.011
8.	NATICA CLAUSA	5.494	0.740
9.	RHODINE GRACILIOR	4.798	0.681
10.	TACHYRYNCHUS EROSUS	3.560	0.551
11.	AMPHARETE ACUTIFRONS	3.450	0.538
12.	CISTENIDES GRANULATA	2.696	0.431
13.	LIOCYMA SP.	2.630	0.420
14.	SYNIDOTEA BICUSPIDA	1.720	0.236
15.	ARCTEOBIA ANTICOSTIENSIS	1.676	0.224
16.	SOLARIELLA VARICOSA	1.542	0.188
17.	HAPLOSCOLOPLOS ELONGATUS	1.048	0.020
18.	GLYCINDE PICTA	0.974	-0.011
19.	PONTOPOREIA FEMORATA	0.842	-0.075
20.	MYRIOCHELE OCULATA	0.808	-0.093
21.	AMPELISCA MACROCEPHALA	0.768	-0.115
22.	MELITA DENTATA	0.648	-0.188
23.	BARANTOLLA AMERICANA	0.622	-0.206
24.	MALDANE GLEBIFEX	0.596	-0.225
25.	ASABELLIDES SIBIRICA	0.584	-0.234
26.	MACOMA CALCAREA	0.540	-0.268
27.	ANTINOELLA SARSI	0.530	-0.276
28.	THYASIRA FLEXUOSA	0.442	-0.355
29.	CHIONOECETES OPILIO	0.440	-0.357
30.	ASTARTE BOREALIS	0.376	-0.425
31.	PHOLOE MINUTA	0.362	-0.441
32.	SCOLOPLOS ARMIGER	0.346	-0.461
33.	OPHELIA LIMACINA	0.310	-0.509
34.	BRADA VILLOSA	0.308	-0.511
35.	MYSELLA TUMIDA	0.294	-0.532
36.	AMPELISCA ESCHRICHTI	0.272	-0.565
37.	ETEONE LONGA	0.268	-0.572
38.	HARPINIA GURJANOVAE	0.262	-0.582
39.	TYPOSYLLIS ALTERNATA	0.252	-0.599
40.	PARAPHOXUS OCULATUS	0.224	-0.650
41.	GOLFINGIA MARGARITACEA	0.208	-0.682
42.	HARMOTHOE IMBRICATA	0.204	-0.690
43.	PHOTIS SPASSKII	0.182	-0.740
44.	SCALIBREGMA INFLATUM	0.154	-0.812
45.	ANONYX NUGAX	0.148	-0.830
46.	EUDORELLA PACIFICA	0.146	-0.836
47.	SPIOPHANES BOMBYX	0.142	-0.848
48.	HETEROMASTUS FILIFORMIS	0.136	-0.866
49.	ANAITIDES GROENLANDICA	0.132	-0.879
50.	TEREBELLIDES STROEMII	0.124	-0.907

Figure 14. Dominance-diversity curve (biomass) calculated from Station Group F.



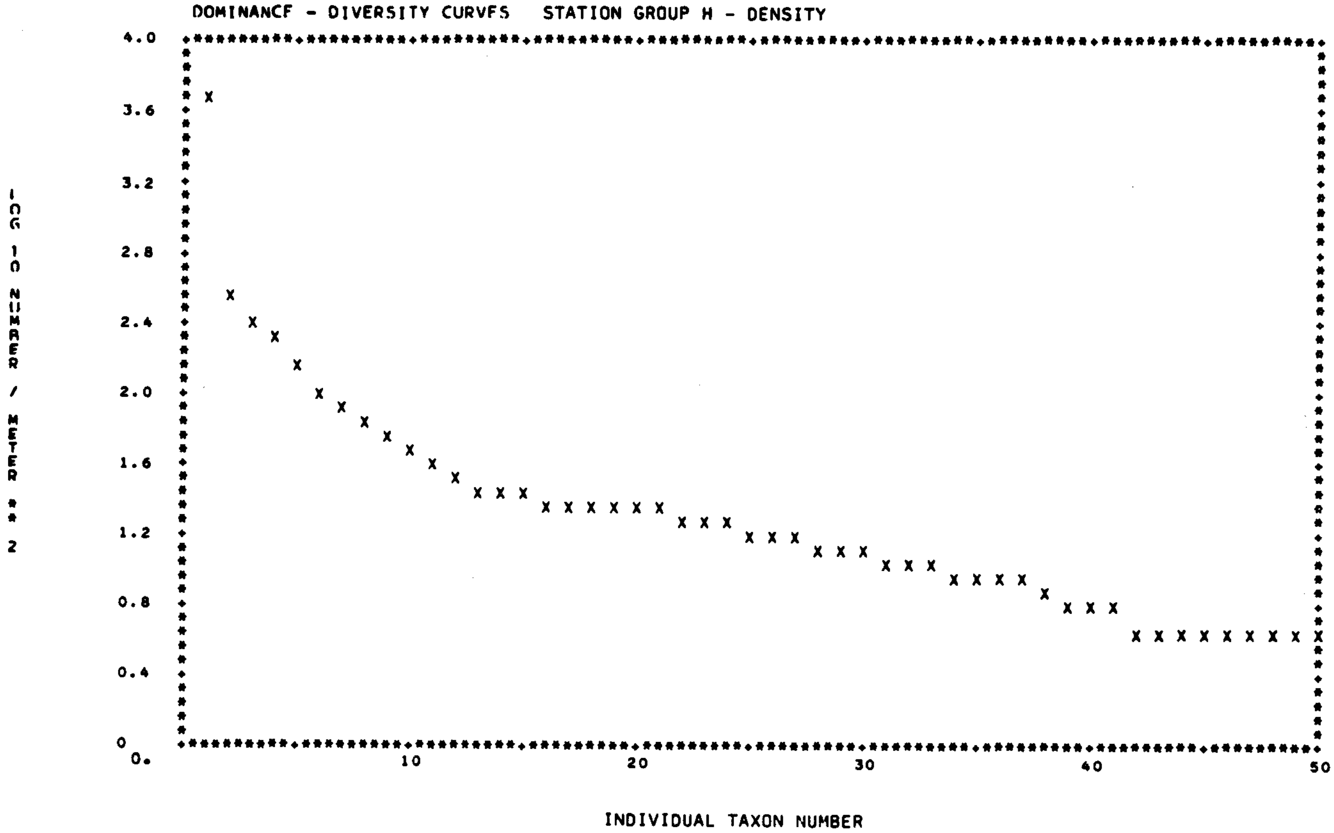
TAXON NO.	TAXON NAME	DATA VALUE	PLOT VALUE
1.	HIATELLA ARCTICA	819.999	2.914
2.	ASABELLIDES SIBIRICA	93.333	1.970
3.	BALANUS CRENATUS	83.333	1.921
4.	CISTENIDES GRANULATA	46.666	1.669
5.	OPHIURA SARSI	36.667	1.564
6.	NEPHTYS CILIATA	33.333	1.523
7.	GOLFINGIA MARGARITACEA	33.333	1.523
8.	DIASTYLIS BIDENTATA	26.667	1.426
9.	HARMOTHOE IMBRICATA	23.333	1.368
10.	OPHELIA LIMACINA	20.000	1.301
11.	TYPOSYLLIS ALTERNATA	16.667	1.222
12.	HAPLOSCOLOPLOS ELONGATUS	16.667	1.222
13.	MELITA DENTATA	16.666	1.222
14.	PHOLOE MINUTA	13.333	1.125
15.	GLYCINDE PICTA	13.333	1.125
16.	DIAMPHIODIA CRATERODMETA	13.333	1.125
17.	BARANTOLLA AMERICANA	10.000	1.000
18.	MACOMA CALCAREA	6.667	0.824
19.	PARAPHOXUS OCULATUS	6.667	0.824
20.	TIRON BIOCULATA	6.666	0.824
21.	ETEONE LONGA	3.333	0.523
22.	PRIONOSPIO CIRRIFERA	3.333	0.523
23.	SPIO FILICORNIS	3.333	0.523
24.	SCALIBREGMA INFLATUM	3.333	0.523
25.	MEDIOMASTUS CAPENSIS	3.333	0.523
26.	AMPHARETE ACUTIFRONS	3.333	0.523
27.	TEREBELLIDES STROEMII	3.333	0.523
28.	SERRIPES GROENLANDICUS	3.333	0.523
29.	LIOCYMA FLUCTUOSA	3.333	0.523
30.	NATICA CLAUSA	3.333	0.523
31.	EUDORELLA PACIFICA	3.333	0.523
32.	PLEUROGONIUM SPINOSSISMUM	3.333	0.523
33.	CHIONOECETES OPILIO	3.333	0.523

Figure 15. Dominance-diversity curve (density) calculated from Station Group G.



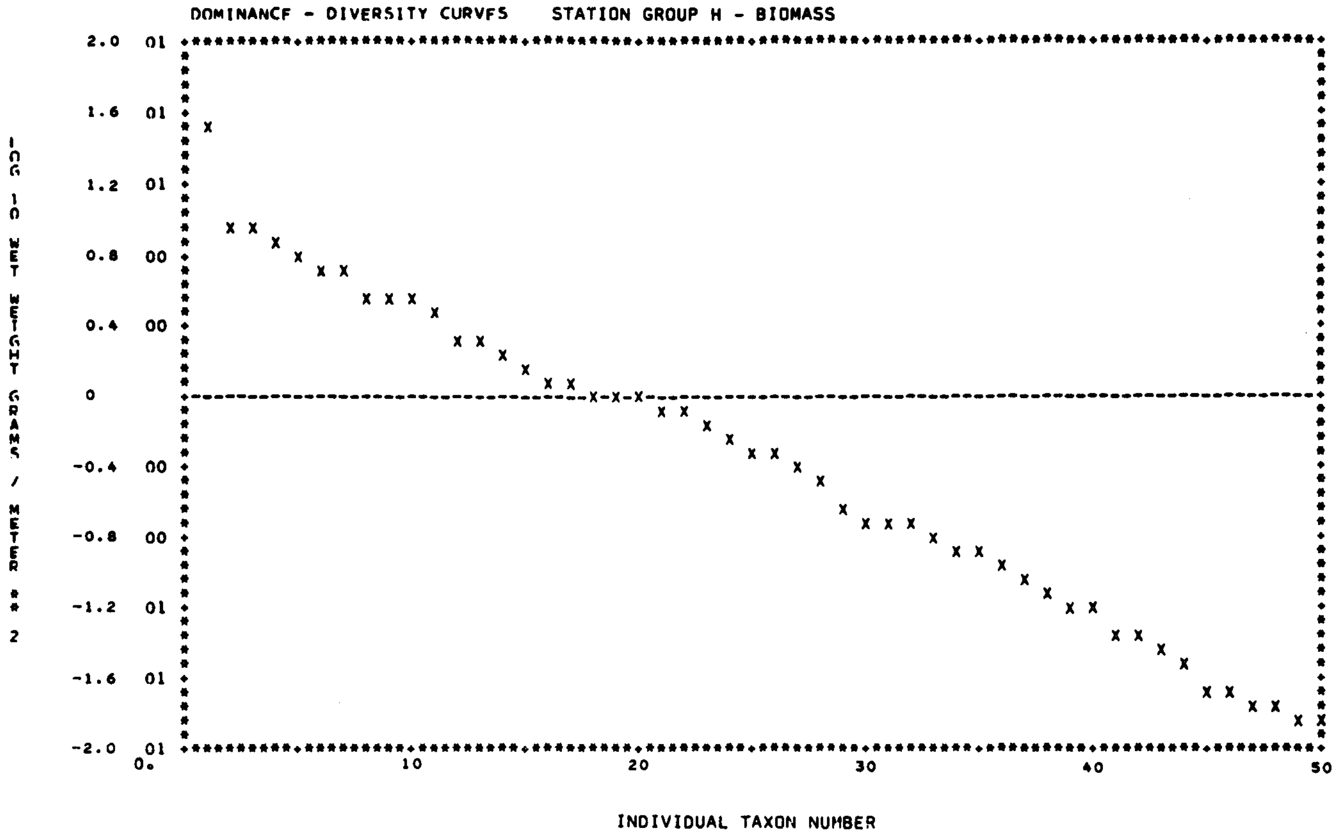
TAXON NO.	TAXON NAME	DATA VALUE	PLOT VALUE
1.	HIATELLA ARCTICA	265.853	2.425
2.	NATICA CLAUSA	31.013	1.492
3.	BALANUS CRENATUS	22.773	1.357
4.	NEPHTYS CILIATA	14.870	1.172
5.	CISTENIDES GRANULATA	12.810	1.108
6.	SERRIPES GROENLANDICUS	11.590	1.064
7.	ASABELLIDES SIBIRICA	4.930	0.693
8.	HARMOTHOE IMBRICATA	1.340	0.127
9.	MACOMA CALCAREA	1.053	0.022
10.	LIOCYMA FLUCTUOSA	0.763	-0.117
11.	OPHIURA SARSI	0.557	-0.254
12.	DIAMPHIODIA CRATERODMETA	0.527	-0.278
13.	GOLFINGIA MARGARITACEA	0.250	-0.602
14.	OPHELIA LIMACINA	0.233	-0.633
15.	SCALIBREGMA INFLATUM	0.217	-0.664
16.	MELITA DENTATA	0.216	-0.666
17.	DIASTYLIS BIDENTATA	0.203	-0.693
18.	CHIONOECETES OPILIO	0.150	-0.824
19.	TYPOSYLLIS ALTERNATA	0.147	-0.833
20.	HAPLOSCOLOPLOS ELONGATUS	0.080	-1.097
21.	BARANTOLLA AMERICANA	0.073	-1.137
22.	PHOLOE MINUTA	0.067	-1.174
23.	GLYCINDE PICTA	0.057	-1.244
24.	TEREBELLIDES STROEMII	0.050	-1.301
25.	SPIO FILICORNIS	0.040	-1.398
26.	AMPHARETE ACUTIFRONS	0.017	-1.770
27.	TIRON BIOCULATA	0.017	-1.770
28.	PARAPHOXUS OCULATUS	0.013	-1.886
29.	ETEONE LONGA	0.003	-2.523
30.	PRIONOSPIO CIRRIFERA	0.003	-2.523
31.	MEDIOMASTUS CAPENSIS	0.003	-2.523
32.	EUDORELLA PACIFICA	0.003	-2.523
33.	PLEUROGONIUM SPINOSSISMUM	0.003	-2.523

Figure 16. Dominance-diversity curve (biomass) calculated from Station Group G.



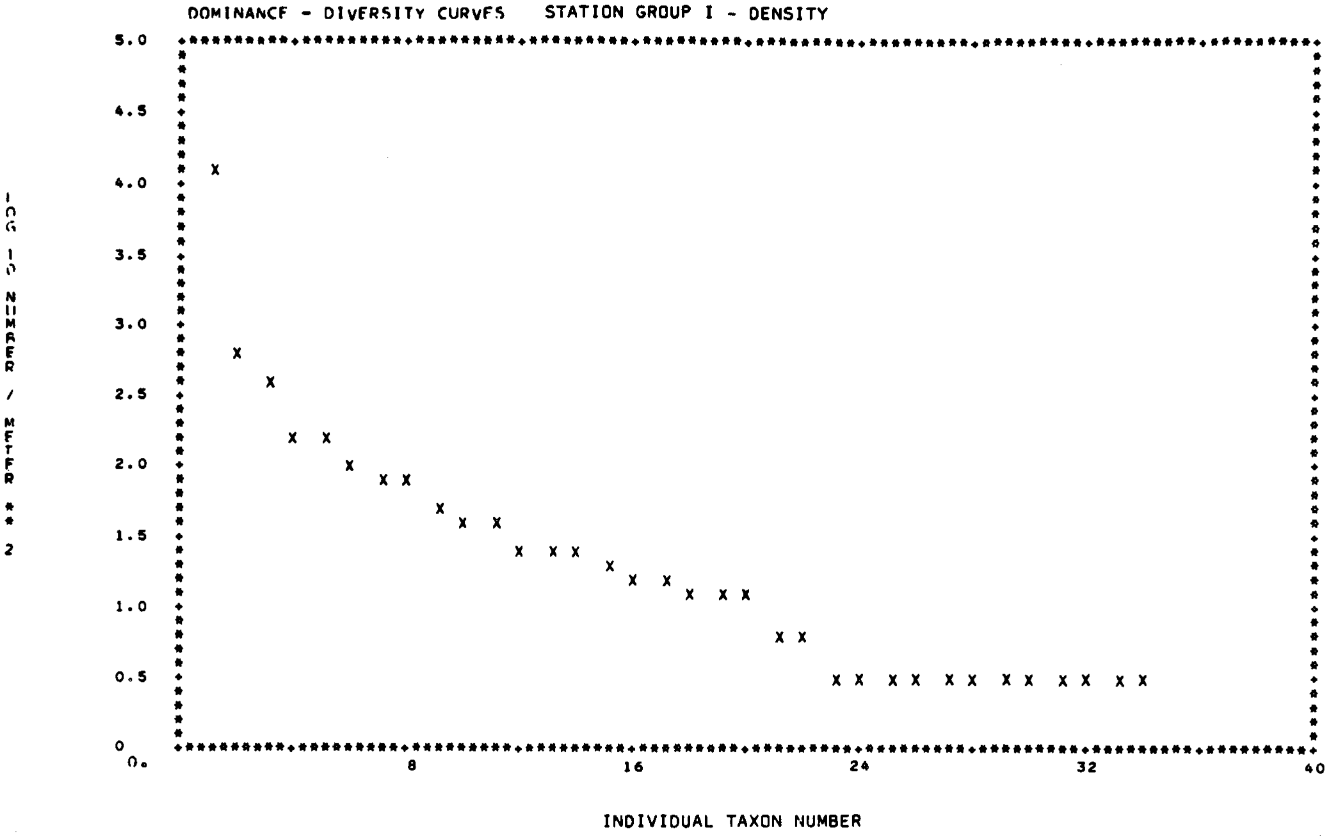
TAXON NO.	TAXON NAME	DATA VALUE	PLOT VALUE
1.	MYRIOCHELE OCULATA	4430.000	3.646
2.	ECHINARACHNIUS PARMA	388.000	2.589
3.	NUCULA TENUIS	244.000	2.387
4.	SPIOPHANES BOMBYX	206.000	2.314
5.	COROPHIUM CRASSICORNIS	150.000	2.176
6.	THYASIRA FLEXUOSA	94.000	1.973
7.	AMPELISCA MACROCEPHALA	82.000	1.914
8.	MACHAIRONYX MUELLERI	66.000	1.820
9.	GLYCINDE PICTA	60.000	1.778
10.	OPHIURA SARSI	48.000	1.681
11.	TACHYRYNCHUS EROSUS	42.000	1.623
12.	SERRIPES GROENLANDICUS	32.000	1.505
13.	PHOLOE MINUTA	28.000	1.447
14.	ALCYONIDIUM DISCIFORME	28.000	1.447
15.	CYLICHNA ALBA	26.000	1.415
16.	STERNASPIS SCUTATA	24.000	1.380
17.	CYCLOCARDIA CREBRICOSTATA	24.000	1.380
18.	NATICA CLAUSA	24.000	1.380
19.	HAPLOSCOLOPLOS ELONGATUS	22.000	1.342
20.	SCOLOPLOS ARMIGER	22.000	1.342
21.	CISTENIDES GRANULATA	22.000	1.342
22.	EUDORELLOPSIS INTEGRA	20.000	1.301
23.	NUCULANA PERNULA	18.000	1.255
24.	ASTARTE BOREALIS	18.000	1.255
25.	NUCULANA FOSSA	16.000	1.204
26.	SOLARIELLA VARICOSA	16.000	1.204
27.	BYBLIS GAIMARDI	16.000	1.204
28.	NEPHTYS LONGOSETOSA	14.000	1.146
29.	CHONE INFUNDIBULIFORMIS	14.000	1.146
30.	RETUSA OBTUSA	14.000	1.146
31.	MALDANE GLEBIFEX	12.000	1.079
32.	EUDORELLOPSIS DEFORMIS	12.000	1.079
33.	WESTWOODILLA CAECULA	12.000	1.079
34.	NEPHTYS PUNCTATA	10.000	1.000
35.	HETEROMASTUS FILIFORMIS	10.000	1.000
36.	ASABELLIDES SIBIRICA	10.000	1.000
37.	PHOTIS SPASSKII	10.000	1.000
38.	TRAVISIA PUPA	8.000	0.903
39.	ETEONE LONGA	6.000	0.778
40.	NEPHTYS CAECA	6.000	0.778
41.	CAMPYLASPIS UMBENSIS	6.000	0.778
42.	ARCTEOBIA ANTICOSTIENSIS	4.000	0.602
43.	HARMOTHOE IMBRICATA	4.000	0.602
44.	TAUBERIA GRACILIS	4.000	0.602
45.	CAPITELLA CAPITATA	4.000	0.602
46.	BARANTOLLA AMERICANA	4.000	0.602
47.	PRAXILLELLA PRAETERMISSA	4.000	0.602
48.	POTAMILLA NEGLECTA	4.000	0.602
49.	LAONOME KROYERI	4.000	0.602
50.	AXINOPSIDA SERRICATA	4.000	0.602

Figure 17. Dominance-diversity curve (density) calculated from Station Group H.



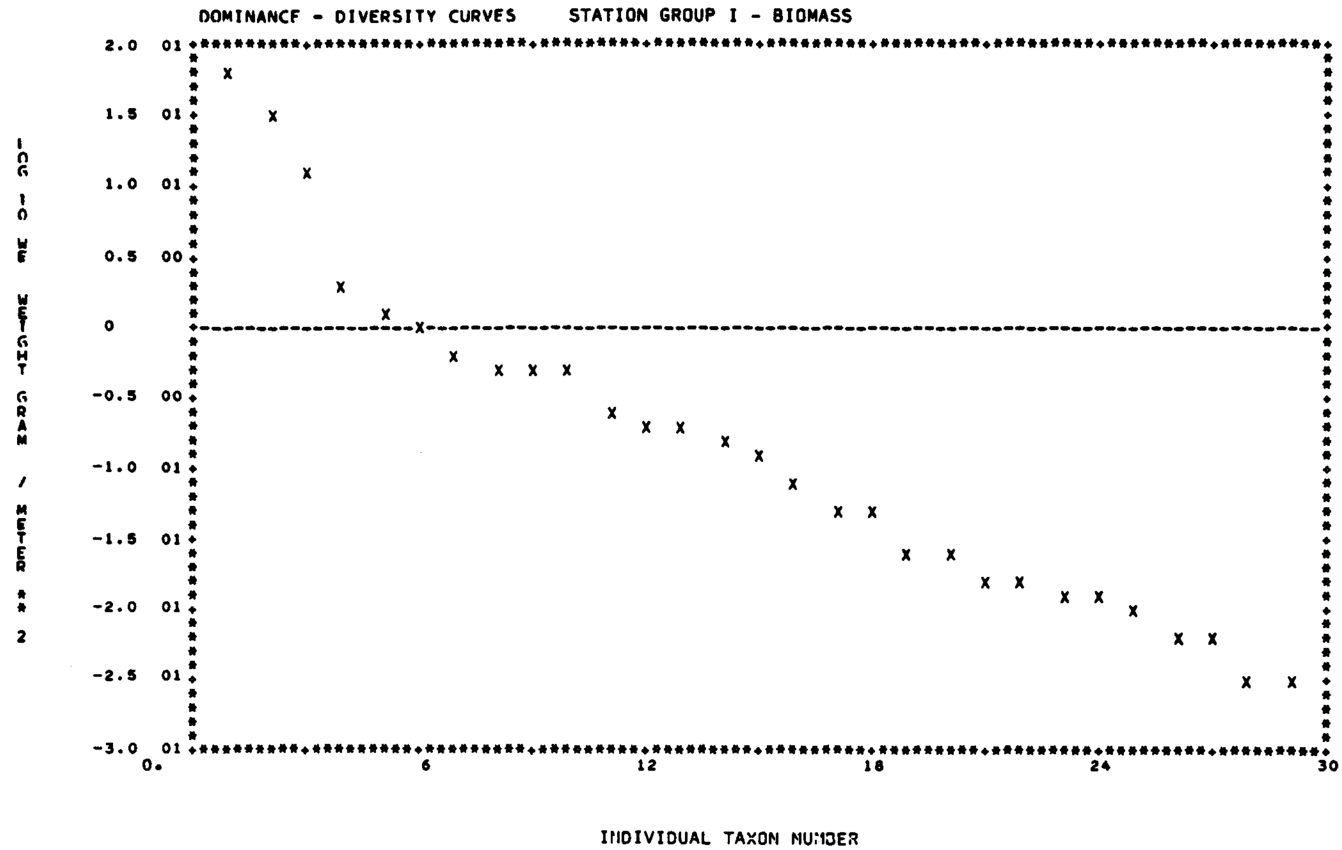
TAXON NO.	TAXON NAME	DATA VALUE	PLOT VALUE
1.	MACOMA CALCAREA	32.846	1.516
2.	TACHYRYNCHUS EROSUS	9.434	0.975
3.	MYRIOCHELE OCULATA	8.852	0.947
4.	CHONE INFUNDIBULIFORMIS	7.604	0.881
5.	CYCLOCARDIA CREBRICOSTATA	6.114	0.786
6.	AMPELISCA MACROCEPHALA	5.344	0.728
7.	AMMODYTES HEXAPTERUS	5.214	0.717
8.	ALCYONIDIUM DISCIFORME	3.624	0.559
9.	NUCULANA PERNULA	3.466	0.540
10.	ECHINARACHNIUS PARMA	3.458	0.539
11.	NUCULA TENUIS	2.776	0.443
12.	NEPHTYS CAECA	2.278	0.358
13.	MACOMA BROTA	2.070	0.316
14.	STERNASPIS SCUTATA	1.686	0.227
15.	BYBLIS GAIMARDI	1.390	0.143
16.	NEPHTYS PUNCTATA	1.200	0.079
17.	NEPHTYS LONGOSETOSA	1.156	0.063
18.	SPIOPHANES BOMBYX	1.054	0.023
19.	NUCULANA FOSSA	1.038	0.016
20.	LAONOME KROYERI	1.022	0.009
21.	ANAITIDES MUCOSA	0.898	-0.047
22.	THYASIRA FLEXUOSA	0.770	-0.114
23.	CISTENIDES GRANULATA	0.716	-0.145
24.	NATICA CLAUSA	0.554	-0.256
25.	DIAMPHIODIA CRATERODMETA	0.476	-0.322
26.	SERRIPES GROENLANDICUS	0.452	-0.345
27.	ASTARTE BOREALIS	0.430	-0.367
28.	SOLARIELLA OBSCURA	0.358	-0.446
29.	MALDANE GLEBIFEX	0.210	-0.678
30.	PRAXILLELLA PRAETERMISSA	0.190	-0.721
31.	SOLARIELLA VARICOSA	0.182	-0.740
32.	TRAVISIA PUPA	0.174	-0.759
33.	COROPHIUM CRASSICORNIS	0.154	-0.812
34.	CYLICHNA ALBA	0.142	-0.848
35.	GLYCINDE PICTA	0.132	-0.879
36.	HAPLOSCOLOPLOS ELONGATUS	0.118	-0.928
37.	AMPELISCA ESCHRICHTI	0.092	-1.036
38.	SCOLOPLOS ARMIGER	0.078	-1.108
39.	MACHAIRONYX MUELLERI	0.068	-1.167
40.	GOLFINGIA MARGARITACEA	0.062	-1.208
41.	PHOLOE MINUTA	0.040	-1.398
42.	HETEROMASTUS FILIFORMIS	0.040	-1.398
43.	OPHIURA SARSI	0.034	-1.469
44.	WESTWOODILLA CAECULA	0.032	-1.495
45.	RHODINE GRACILIOR	0.020	-1.699
46.	RETUSA OBTUSA	0.020	-1.699
47.	ARCTEOBIA ANTICOSTIENSIS	0.016	-1.796
48.	ETEONE LONGA	0.016	-1.796
49.	HARMOTHOE IMBRICATA	0.014	-1.854
50.	PHOTIS SPASSKII	0.014	-1.854

Figure 18. Dominance-diversity curve (biomass) calculated from Station Group H.



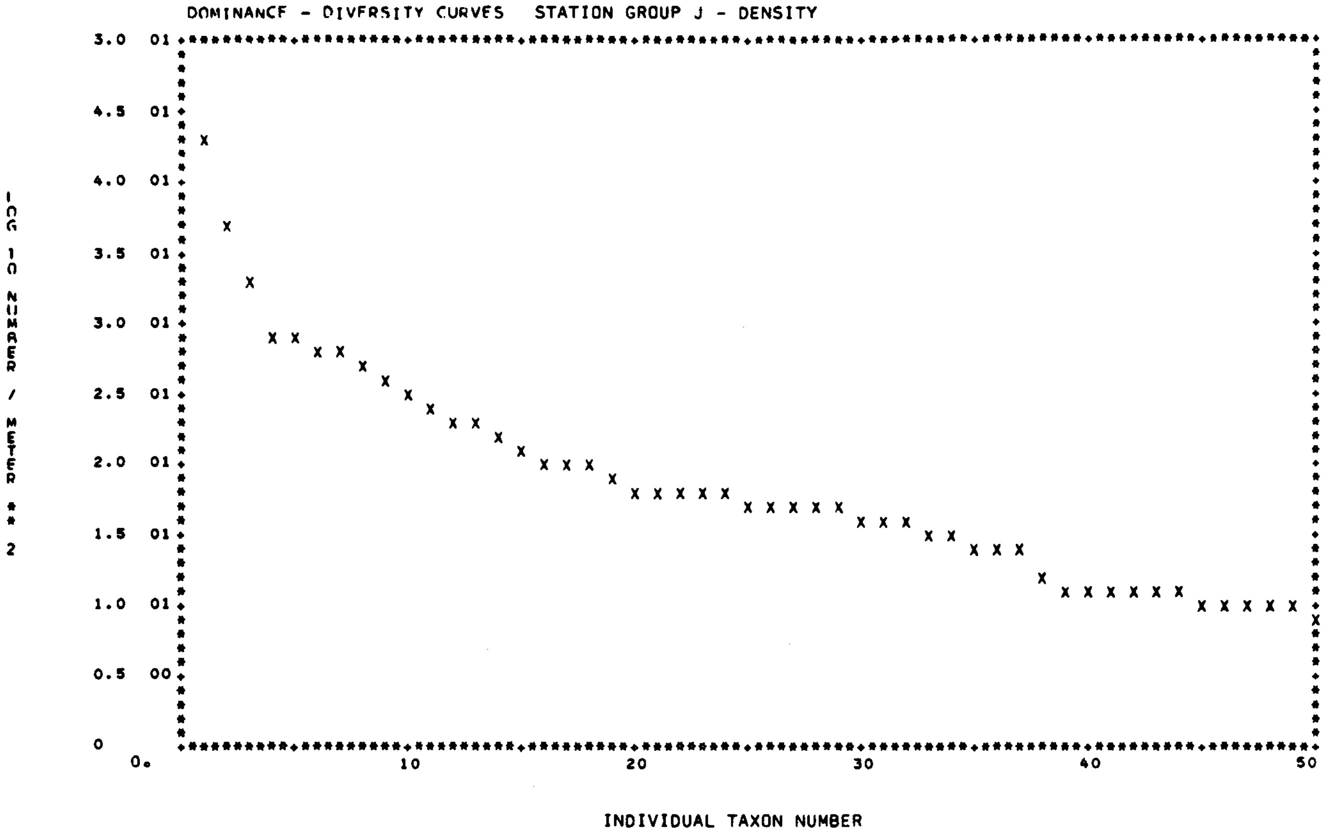
TAXON NO.	TAXON NAME	DATA VALUE	PLOT VALUE
1.	MYRIOCHELE OCULATA	********	4.055
2.	ASABELLIDES SIBIRICA	589.999	2.771
3.	ALCYONIDIUM DISCIFORME	376.666	2.576
4.	PHOLOE MINUTA	166.667	2.222
5.	OWENIA FUSIFORMIS	146.667	2.166
6.	SPIOPHANES BOMBYX	100.000	2.000
7.	NUCULA TENUIS	83.334	1.921
8.	GLYCINDE PICTA	83.333	1.921
9.	EUDORELLOPSIS DEFORMIS	53.334	1.727
10.	HAPLOSCOLOPLOS ELONGATUS	40.000	1.602
11.	SCOLOPLOS ARMIGER	40.000	1.602
12.	HETEROMASTUS FILIFORMIS	26.667	1.426
13.	CYLICHNA ALBA	23.333	1.368
14.	PROTOMEDIEIA FASCIATA	23.333	1.368
15.	PROTOMEDEIRA CHELATA	20.000	1.301
16.	ANAITIDES GROENLANDICA	16.667	1.222
17.	RETUSA OBTUSA	16.666	1.222
18.	CYCLOCARDIA CREBRICOSTATA	13.334	1.125
19.	DIASTYLIS ALASKENSIS	13.334	1.125
20.	MACHAIRONYX MUELLERI	13.334	1.125
21.	MYSELLA TUMIDA	6.667	0.824
22.	COROPHIUM CRASSICORNIS	6.667	0.824
23.	ANTINOELLA SARSI	3.333	0.523
24.	ETEONE LONGA	3.333	0.523
25.	NEPHTYS CAECA	3.333	0.523
26.	NEPHTYS PUNCTATA	3.333	0.523
27.	ARICIDEA MINUTA	3.333	0.523
28.	PRIONOSPIO STEENSTRUPI	3.333	0.523
29.	TEREBELLIDES STROEMII	3.333	0.523
30.	LAONOME KROYERI	3.333	0.523
31.	CYCLOCARDIA SP.	3.333	0.523
32.	PLEUROGONIUM RUBICUNDUM	3.333	0.523
33.	AMPELISCA MACROCEPHALA	3.333	0.523
34.	CHIONOECETES OPILIO	3.333	0.523

Figure 19. Dominance-diversity curve (density) calculated from Station Group I.



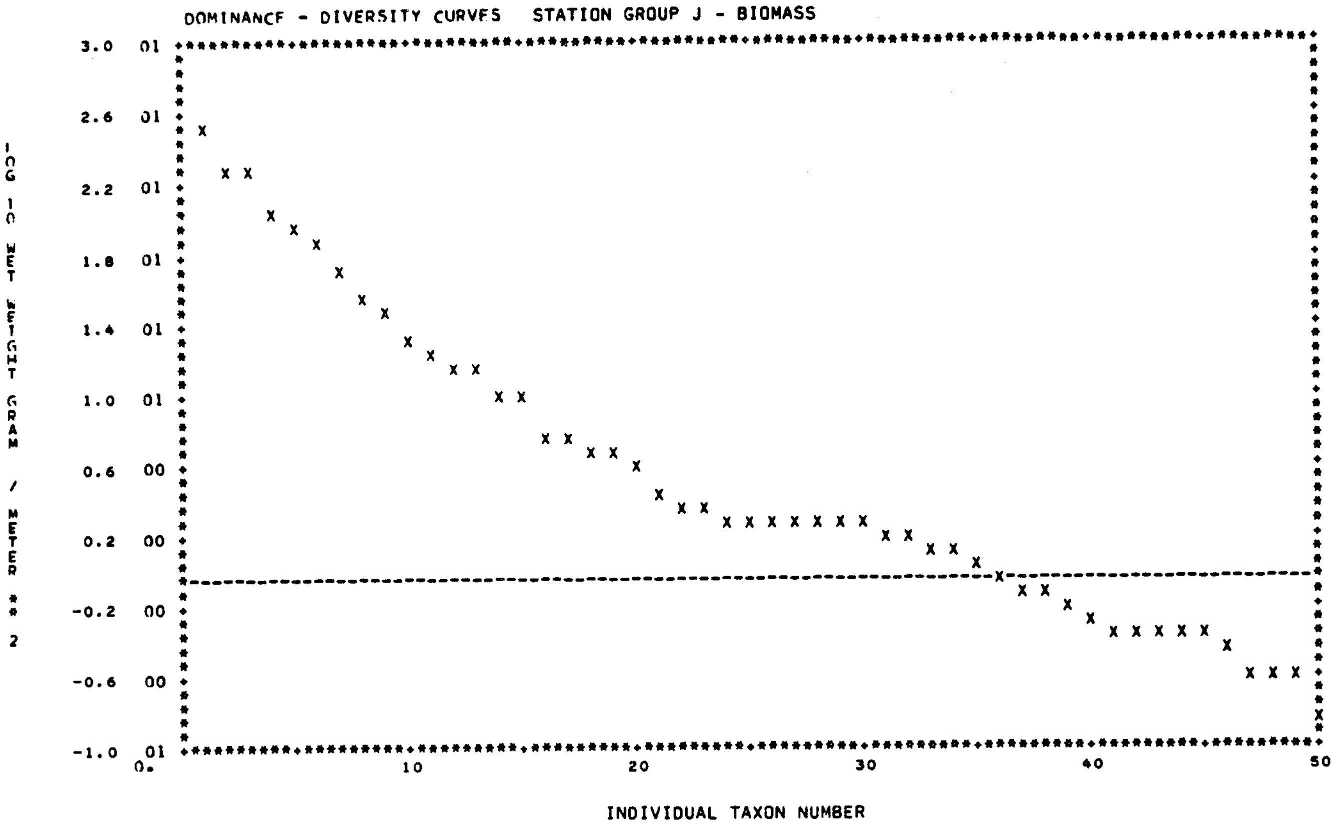
TAXON NO.	TAXON NAME	DATA VALUE	PLOT VALUE
1.	ALCYONIDIUM DISCIFORME	69.287	1.841
2.	MYRIOCHELE OCULATA	32.030	1.506
3.	ASABELLIDES SIBIRICA	13.400	1.127
4.	ANAITIDES GROENLANDICA	1.917	0.283
5.	HAPLOSCOLOPLOS ELONGATUS	1.253	0.098
6.	ANTINOELLA SARSI	0.900	-0.046
7.	SCOLOPLOS ARMIGER	0.627	-0.203
8.	GLYCINDE PICTA	0.510	-0.292
9.	TEREBELLIDES STROEMII	0.487	-0.312
10.	CYLICHNA ALBA	0.463	-0.334
11.	PHOLOE MINUTA	0.257	-0.590
12.	SPIOPHANES BOMBYX	0.217	-0.664
13.	NUCULA TENUIS	0.203	-0.693
14.	OWENIA FUSIFORMIS	0.153	-0.815
15.	DIASTYLIS ALASKENSIS	0.127	-0.896
16.	PROTOMEDIEIA FASCIATA	0.073	-1.137
17.	CHIONOECETES OPILIO	0.050	-1.301
18.	NEPHTYS CAECA	0.047	-1.328
19.	ETEONE LONGA	0.027	-1.569
20.	RETUSA OBTUSA	0.027	-1.569
21.	HETEROMASTUS FILIFORMIS	0.017	-1.770
22.	EUDORELLOPSIS DEFORMIS	0.017	-1.770
23.	CYCLOCARDIA SP.	0.013	-1.886
24.	MYSELLA TUMIDA	0.013	-1.886
25.	LAONOME KROYERI	0.010	-2.000
26.	AMPELISCA MACROCEPHALA	0.007	-2.155
27.	PROTOMEDEIRA CHELATA	0.007	-2.155
28.	NEPHTYS PUNCTATA	0.003	-2.523
29.	PRIONOSPIO STEENSTRUPI	0.003	-2.523

Figure 20. Dominance-diversity curve (biomass) calculated for Station Group I.



TAXON NO.	TAXON NAME	DATA VALUE	PLOT VALUE
1.	AMPELISCA MACROCEPHALA	********	4.307
2.	AMPELISCA BIRULAI	5572.000	3.746
3.	AMPELISCA ESCHRICHTI	2024.000	3.306
4.	MYSELLA TUMIDA	750.000	2.875
5.	PARAPHOXUS ROBUSTUS	742.000	2.870
6.	BYBLIS GAIMARDI	644.000	2.809
7.	HARPINIA GURJANOVAF	640.000	2.806
8.	BARANTOLLA AMERICANA	528.000	2.723
9.	EUDORELLOPSIS DEFFORMIS	416.000	2.619
10.	COROPHIUM CRASSICORNIS	298.000	2.474
11.	HAPLOSCOLOPLOS ELONGATUS	232.000	2.365
12.	ANONYX NUGAX	216.000	2.334
13.	EUDORELLA PACIFICA	186.000	2.270
14.	PRAXILLELLA PRAETERMISSA	150.000	2.176
15.	TRAVISIA PUPA	140.000	2.146
16.	HETEROMASTUS FILIFORMIS	108.000	2.033
17.	AMPHARETE FINMARCHICA	102.000	2.009
18.	AMPHARETE ACUTIFRONS	90.000	1.954
19.	ANONYX LATICOXAE	76.000	1.881
20.	SCOLOPLOS ARMIGER	68.000	1.833
21.	CYCLOCARDIA CREBRICOSTATA	64.000	1.806
22.	CHONE CINCTA	62.000	1.792
23.	ANONYX SARSI	62.000	1.792
24.	CAPITELLA CAPITATA	60.000	1.778
25.	NUCULA TENUIS	56.000	1.748
26.	PONTOPOREIA FEMORATA	52.000	1.716
27.	THYASIRA FLEXUOSA	50.000	1.699
28.	PHOTIS SPASSKII	50.000	1.699
29.	GLYCINDE PICTA	48.000	1.681
30.	PHOLOE MINUTA	42.000	1.623
31.	SPIO FILICORNIS	40.000	1.602
32.	DIPLODONTA ALEUTICA	36.000	1.556
33.	GOLFINGIA MARGARITACEA	34.000	1.531
34.	AXINOPSIDA VIRIDIS	30.000	1.477
35.	ONUPHIS IRIDESCENS	26.000	1.415
36.	ANAITIDES GROENLANDICA	24.000	1.380
37.	NATICA CLAUSA	24.000	1.380
38.	PARAPHOXUS OCULATUS	16.000	1.204
39.	ETEONE LONGA	14.000	1.146
40.	CISTENIDES GRANULATA	14.000	1.146
41.	ASTARTE BOREALIS	14.000	1.146
42.	MELITA QUADRISPINOSA	14.000	1.146
43.	TEREBELLIDES STROEMII	12.000	1.079
44.	CHIONOECETES OPILIO	12.000	1.079
45.	ANTINOELLA SARSI	10.000	1.000
46.	YOLDIA MYALIS	10.000	1.000
47.	CYCLOCARDIA SP.	10.000	1.000
48.	AXINOPSIDA SERRICATA	10.000	1.000
49.	ERICTHONIUS HUNTERI	10.000	1.000
50.	NEPHTYS PUNCTATA	8.000	0.903

Figure 21. Dominance-diversity curve (density) calculated for Station Group J.



TAXON NO.	TAXON NAME	DATA VALUE	PLOT VALUE
1.	AMPELISCA MACROCEPHALA	316.256	2.500
2.	ASTARTE BOREALIS	192.842	2.285
3.	SERRIPES GROENLANDICUS	176.764	2.247
4.	AMPELISCA BIRULAI	101.650	2.007
5.	CHIONOECETES OPILIO	92.256	1.965
6.	AMPELISCA ESCHRICHTI	74.682	1.873
7.	TRAVISIA PUPA	57.096	1.757
8.	CYCLOCARDIA CREBRICOSTATA	36.394	1.561
9.	BYBLIS GAIMARDI	29.354	1.468
10.	AMMODYTES HEXAPTERUS	22.340	1.349
11.	YOLDIA MYALIS	15.990	1.204
12.	ANONYX NUGAX	15.360	1.186
13.	PAGURUS TRIGONOCHEIRUS	13.226	1.121
14.	ANAITIDES GROENLANDICA	10.258	1.011
15.	NEPHTYS PUNCTATA	9.964	0.998
16.	CISTENIDES GRANULATA	5.598	0.748
17.	NATICA CLAUSA	5.278	0.722
18.	HAPLOSCOLOPLOS ELONGATUS	4.948	0.694
19.	PRAXILLELLA PRAETERMISSA	4.850	0.686
20.	ANONYX LATICOXAE	3.656	0.563
21.	ANONYX SARSI	2.928	0.467
22.	NEPHTYS RICKETTSI	2.402	0.381
23.	MYSELLA TUMIDA	2.126	0.328
24.	NUCULA TENUIS	1.984	0.298
25.	SCOLOPLOS ARMIGER	1.952	0.290
26.	ONUPHIS IRIDESCENS	1.916	0.282
27.	BARANTOLLA AMERICANA	1.806	0.257
28.	AMPHARETE FINMARCHICA	1.776	0.249
29.	PARAPHOXUS ROBUSTUS	1.766	0.247
30.	LIOCYMA FLUCTUOSA	1.742	0.241
31.	CHONE CINCTA	1.660	0.220
32.	GOLFINGIA MARGARITACEA	1.542	0.188
33.	TEREBELLIDES STROEMII	1.406	0.148
34.	PONTOPOREIA FEMORATA	1.256	0.099
35.	AMPHARETE ACUTIFRONS	1.082	0.034
36.	HETEROMASTUS FILIFORMIS	0.956	-0.020
37.	COROPHIUM CRASSICORNIS	0.798	-0.098
38.	THYASIRA FLEXUOSA	0.792	-0.101
39.	ANTINOELLA SARSI	0.650	-0.187
40.	HARPINIA GURJANOVAE	0.558	-0.253
41.	GLYCINDE PICTA	0.462	-0.335
42.	OPHELIA LIMACINA	0.440	-0.357
43.	PHOLOE MINUTA	0.422	-0.375
44.	CYLICHNA ALBA	0.402	-0.396
45.	EUDORELLOPSIS DEFORMIS	0.400	-0.398
46.	MACOMA CALCAREA	0.350	-0.456
47.	DIPLODONTA ALEUTICA	0.260	-0.585
48.	PROTOMEDEIA FASCIATA	0.246	-0.609
49.	EUDORELLA PACIFICA	0.238	-0.623
50.	SPIO FILICORNIS	0.140	-0.854

Figure 22. Dominance-diversity curve (biomass) calculated for Station Group J.

FISH DISTRIBUTION AND USE OF NEARSHORE WATERS IN THE NORTHEASTERN CHUKCHI SEA

by

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Final Report
Outer Continental Shelf Environmental Assessment Program
Research Unit 635

March 1984

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Additional thanks are extended to the people of the village of Point Lay whose help and hospitality were invaluable to the success of the summer program.

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1. INTRODUCTION

As part of the U.S. government's continuing desire to develop economically important natural energy reserves, the Department of the Interior recently authorized a lease sale which will permit industry to initiate petroleum exploration operations in the northeast Chukchi Sea. Scheduled to commence in February 1985, the "Barrow Arch No. 85" sale will open approximately 28 million acres of continental shelf to private development (Fig. 1-1). The proposed lease area is tentatively defined as north of 68.4°N latitude and south and west of a line that starts at a point where 71°N latitude intersects the coastline west of Barrow, then moves west to 162°W longitude, then north; the western boundary is at about 169°W longitude at the U.S.-U.S.S.R. 1867 Convention Line.

Offshore petroleum exploration and production operations pose a wide array of potential hazards to the well-being of the marine environment. The coastal waters of the Chukchi Sea are of particular environmental interest because they are an important part of the ecosystem supporting some of northern Alaska's fish, bird and marine mammal populations. Concern over maintaining the ecological integrity of the Chukchi system in the face of impending commercial operations prompted the National Oceanographic and Atmospheric Administration's Outer Continental Shelf Environmental Assessment Program (NOAA/OCSEAP) to initiate a detailed investigation of regional resources.

In the fall of 1982 LGL Ecological Research Associates, Inc. (LGL) was awarded a contract to conduct a single year study of the fishes of the northeast Chukchi Sea. LGL's investigation focused primarily on arctic fish usage of and ecological dependence on marine and estuarine environments. The study consisted of ship- and land-based synoptic fish surveys at a variety of locations along the NE Chukchi Sea coast from Peard Bay to Point Hope. Data were collected for the most part during the open-water, summer season and to a lesser extent in winter. Additional data regarding jig-fishing surveys near St. Lawrence Island and Kotzebue were also included.

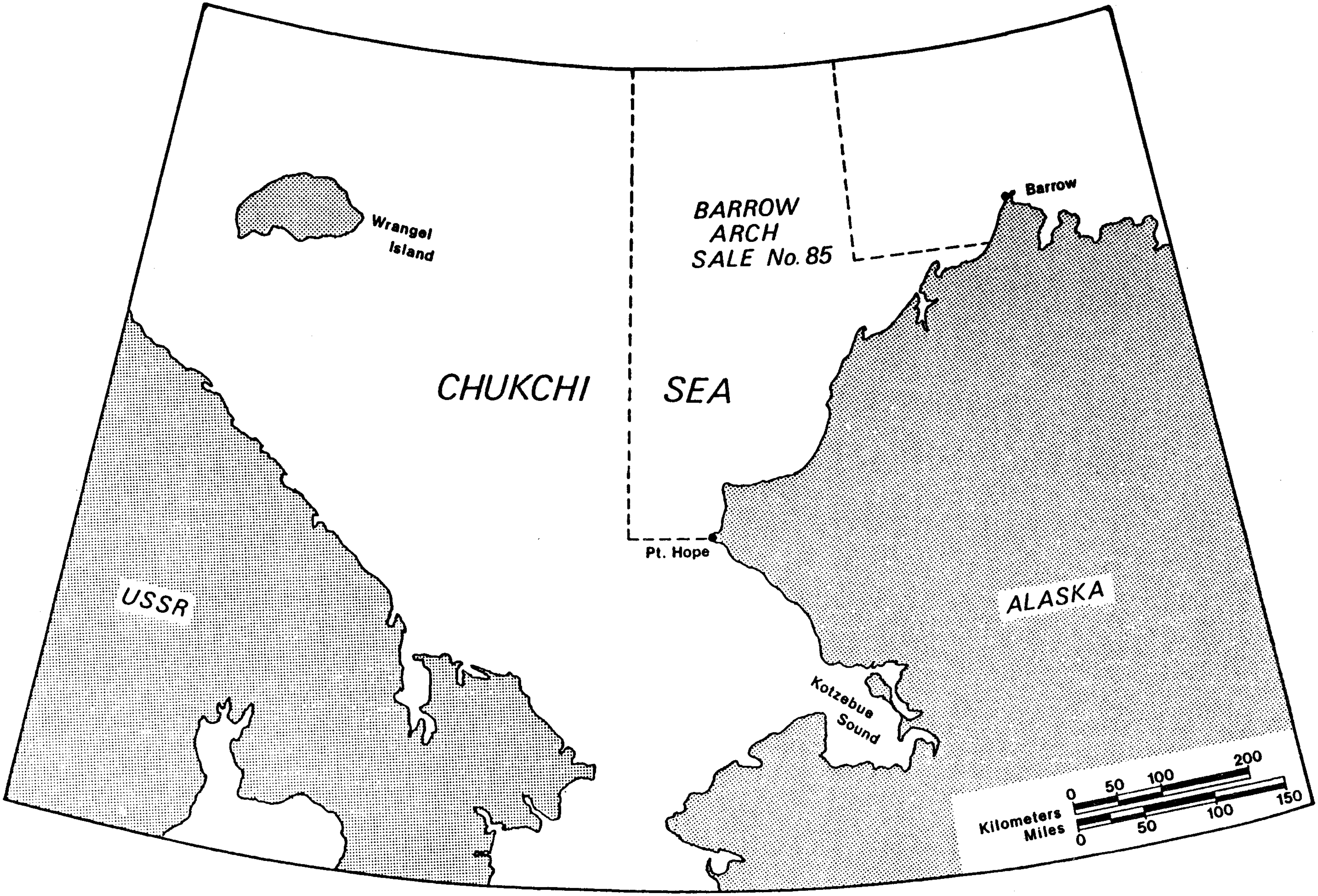


Figure 1-1. Lease area covered by "Barrow Arch Sale No. 85".

This report contains the results and interpretation of fish data gathered during the 1983 study. It provides an appraisal of fish community structure along the northeast Chukchi Sea coast and offers an initial assessment of fishery vulnerability to upcoming petroleum production operations.

1.1 Rationale and Scope

The 1983 study was designed to examine marine and anadromous fish usage of a variety of habitat types and geographic locations in the northeast Chukchi Sea and to incorporate these findings into a comprehensive profile of regional fishery processes. Results further served as an information base for assessing fish community vulnerability to the proposed Barrow Arch development.

While the overall study area encompassed both nearshore and offshore locations, a great deal of emphasis was placed on the survey of nearshore waters. This decision stemmed from numerous studies conducted in the Beaufort Sea as a result of that regions extensive oil and gas development. These investigations have demonstrated nearshore zones to be an important habitat supporting a number of arctic fish species (Bendock 1977, Craig and Griffiths 1981, Craig and Haldorson 1981, Furniss 1975, Griffiths and Gallaway 1982, Griffiths et al. 1983). Nearshore waters serve as principal migratory pathways for anadromous fish such as ciscoes, char, whitefish and salmon, and as summer feeding grounds for both anadromous and marine species. The nearshore emphasis was further supported by the fact that the petroleum industry will probably be technologically restricted to nearshore areas during the initial phase of exploration and development.

In view of the fact that the Chukchi coastline is long and has a variety of topological features, the study area was divided into four major habitat components--Peard Bay, Wainwright Inlet, Kasegaluk Lagoon and Ledyard Bay (Fig. 1-2). Each locale was presumably characterized by distinctive patterns of fish usage and provided some measure of geographic representation. Field investigations comprised three major sampling efforts. Under-ice fyke netting and gill netting surveys were conducted at each of the four locations during 15-28 March 1983. Kasegaluk Lagoon,

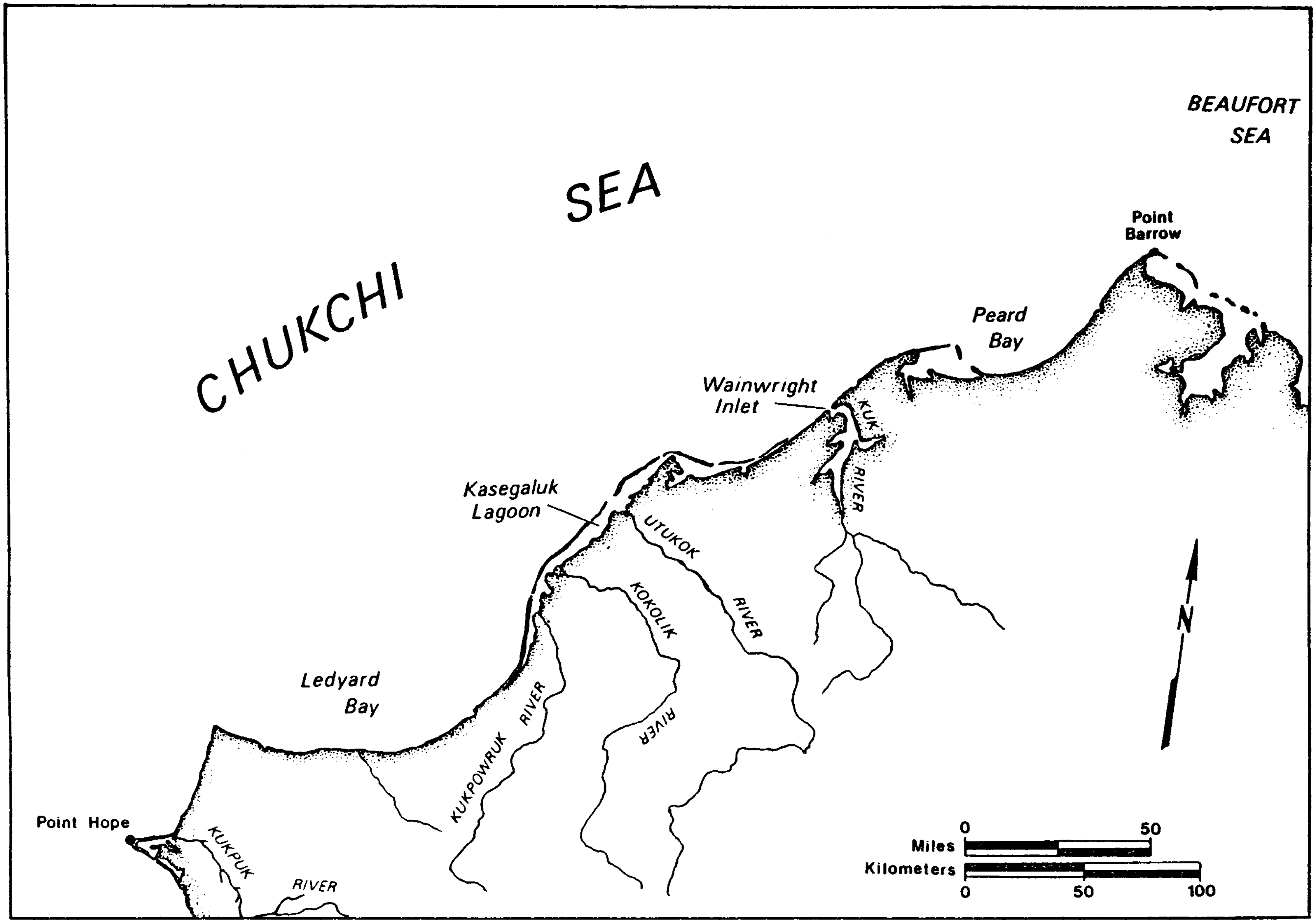


Figure 1-2. Northeast Chukchi Sea coastline.

the most prominent estuarine system on the Chukchi coast, was chosen as the site of more intensive summer study. Synoptic gill and fyke net surveys were conducted in the vicinity of the village of Point Lay primarily during two two-week periods--17 July-4 August and 15 August-1 September. Finally, operations based aboard the NOAA research vessel Discoverer employed gill nets and otter trawls to sample nearshore and offshore waters at Point Lay (Kasegaluk Lagoon), Wainwright Inlet and Ledyard Bay during the period 27 August to 12 September. Two additional otter trawl samples were taken off the west coast of the Lisburne peninsula.

1.2 Objectives

Specific objectives of this study were to:

1. Assess the distributions, habitat dependencies, trophic interactions and life histories of marine and anadromous fishes occupying the nearshore waters of the northeast Chukchi Sea during open-water and winter periods. Special emphasis should be placed on subsistence harvested and trophically important nearshore species.
2. Describe geographic areas or behavioral patterns which appear critical in the feeding, overwintering, spawning, rearing and subsistence use of nearshore fish species.
3. Compare patterns of nearshore habitat use by fish in the northeast Chukchi Sea with those occurring in nearshore regions of the Beaufort Sea, the southern Chukchi Sea and the northern Bering Sea.
4. Determine the vulnerabilities of nearshore fish in the northeastern Chukchi Sea to impacts from OCS oil and gas development.

2. CURRENT STATE OF KNOWLEDGE

The status of information regarding the fishes of the Chukchi Sea has recently been reviewed by Bowden and Moulton (1981), Morris (1981), Moulton and Bowden (1981), and Craig and Skvorc (1982). Unlike the Beaufort Sea, whose physical and biological processes have undergone intensive scrutiny because of petroleum exploration and development activities, the Chukchi Sea has received comparatively little attention. Most sampling efforts in this area have been directed toward the more southerly waters of Hope Basin ahnd Kotezbue Sound.

Fisheries data between Point Hope and Point Barrow are sparse and often of a secondary nature. The database for offshore waters is limited to trawl surveys in Ledyard Bay (Alverson and Wilmovsky 1966; Quast 1972, 1974) and near Barrow (Frost et al. 1978). Coastal information consists of species caught at Wainwright and Point Lay (Craig and Schmidt 1982) and in a kelp bed at Peard Bay (Mohr et al. 1957). Similarly, information on anadromous fishes in rivers flowing into the northern Chukchi Sea is limited to brief surveys (Hablett 1979, Bendock 1979, Bendock and Burr 1980). Incidental fisheries data are available for the Barrow region (Murdoch 1884, 1885; Cohen 1954; MacGinitie 1955; Wohlschlag 1956; McPhail 1966) and an under-ice location 400 km northwest of Barrow (Walters 1961). Additional information can be derived from papers describing subsistence fishing patterns at coastal villages (Wilmovsky 1956, Ivie and Schneider 1979, Schneider and Bennett 1979, Pedersen 1979, Pedersen et al. 1979) and the feeding habits of seabirds at Cape Lisburne (Schwartz 1966; Springer and Roseneau 1978, 1979).

Virtually all fisheries data available for the northeast Chukchi Sea have been gathered during the open-water season. The exceptions are winter data collected in 1959-1960 at a floating ice station located 400 km northwest of Barrow (Walters 1961) and an assortment of information about subsistence fishing, including some winter information (Murdoch 1884, 1885; Wilimovsky 1956; Ivie and Schneider 1979; Schneider and Bennett 1979; Craig and Schmidt 1982).

The above-mentioned research has, to date, identified 41 species of fish from the northeast Chukchi Sea (Morris 1981). The most abundant marine species are Arctic cod, starry flounder, Pacific halibut, saffron cod, Pacific herring, capelin and sculpin. Important anadromous species include pink and chum salmon, Arctic char, ciscoes, whitefish and smelt.

3. STUDY AREA

The northeast Chukchi Sea coastline extends for 550 km between Point Barrow and Point Hope (Fig. 1-2). Fronted in most places by bluffs and narrow gravel beaches, this area forms the leading edge of a shallow shelf basin that extends to the East Siberian Sea and down through the Bering Strait.

Nearshore waters of the Chukchi Sea are dominated by warm waters transported north from the Bering Sea which form the North Alaska Current. This current runs parallel to the coast in a northeasterly direction and its influence extends as far as Point Barrow. Under certain meteorological conditions, typically in fall and winter, mean northeast flow of the longshore current may exhibit large flow reversals. The following descriptions were provided by Hachmeister (ASI, pers. comm.) for the 1983 Chukchi Sea Synthesis Meeting.

> "Circulation in the inner shelf of the NE Chukchi, as in the Beaufort Sea, has been shown to be highly influenced by meteorological forcing. The Chukchi differs from the Beaufort, however, in that it exhibits a relatively high velocity (approximately 1.0-1.5 kt) nearshore current which in the summer derives its existence independently of the local wind field. Under certain meteorological conditions this current is observed to reverse from its mean northeasterly direction and flow to the southwest. In the summer of 1981 this current was found to reverse for periods of 5-7 days for 35-45 percent of the open water period (Wilson et al., 1981). In winter months, Coachman and Aagaard (1981) found these reversed flow conditions 20-40 percent of the time along the Cape Lisbourne inner shelf. The current, whether flowing northeast or southwest, typically follows the bathymetry at depths greater than 20 m and possesses a more wind-driven onshore-offshore component at depths less than 20 m."

This wind-driven component plays an important role in governing nearshore hydrographic conditions

"Measurements by Wiseman (1974, 1980) have shown that, when meteorological conditions confine the nearshore warm waters to the coast, temperatures may be as high as 13°C with salinities less than 29.0 o/oo in late July. However, as meteorological conditions periodically change and as surface waters are moved offshore. water in the nearshore region is replaced by deeper offshore water and exhibits both reduced temperatures (< 3°C) and increased salinities (> 31 o/oo). Hachmeister (1983) has measured nearshore (out to approximately 20 km) changes in temperature from 6 to 0°C and in salinity from 28 to more than 31 o/oo in less than two days in response to a shift from SW to NE winds."

Peard Bay is located in the northeast sector of the study area where the Chukchi Sea and Beaufort Sea water masses mix. This open embayment stretches from Point Barrow to Point Franklin and includes an exposed coastline as well as Peard Bay proper--a large body of water protected from direct ocean exposure by Point Franklin. The occurrence of a longshore. current-induced, anticyclonic gyre and a kelp community on a rocky substrate (Mohr et al. 1957) has caused speculation that Peard Bay may be the site of increased biological activity.

Wainwright Inlet is an inland body of brackish water lying at the mouth of the Kuk River drainage. It is a summer feeding area and migratory pathway for a variety of fish species and in winter it supports an important subsistence fishery for boreal smelt.

Kasegaluk Lagoon is a prominent coastal feature and is unparalleled in size by the smaller lagoons of the Beaufort Sea. It forms one of the largest estuarine habitats in Alaska's North Slope region. Protected by a continuous chain of offshore barrier islands that extend along 180 km of coastline, lagoon waters receive freshwater discharge from Kukpowpuk, Kokolik and Utukok rivers, as well as from tundra creeks and numerous smaller rivers. Kasegaluk Lagoon is a shallow water basin typically less than 1 m in depth, however, depths of 2-3 m do occur at the northeast end from Icy Cape to Pingovarak Pass. Seaward of the barrier islands ocean depths drop sharply to 2 m within 5-6 m from shore and to 8 m within 50 m from shore. Freshwater discharge, solar heating and the wind-driven intrusion of marine water through the dozen or so barrier island inlets govern lagoon hydrography.

Ledyard Bay represents the southern portion of the study area. With the exception of the Pitmegea River, the long, exposed coastline is devoid of major freshwater drainages. Because of the bay's proximity to the Bering Strait, local physical processes are strongly influenced by the warm waters of the North Alaska Current. The region's most prominent hydrographic feature is a persistent, clockwise gyre which presumably contributes to the productivity of the area.

3.1 Annual Cycle

Ice cover in the Chukchi Sea lasts for about seven to eight months each year. The formation of slush ice begins in September in lagoon and nearshore areas. Landfast ice begins forming in November and slowly builds seaward. By the end of winter ice cover may extend as far as the 20 m contour where it may reach a thickness of 2 m. Shallow nearshore areas and the entire Kasegaluk Lagoon system freeze to the bottom. Pack ice moves into the Chukchi in fall and may consist of multi-year ice fields up to 6 m in depth.

The shear zone between landfast and pack ice is dominated by the Chukchi polynya. This open water expanse persists throughout the winter and stretches from Point Barrow south to beyond Cape Lisburne. The polynya is wider to the southwest because of the warming influence of the Bering and SE Chukchi seas. It attains a width of about 1 km near Barrow by the end of winter.

Warmer temperatures and freshwater runoff in late spring-early summer initiate breakup. During June-July the northeasterly retreat of pack ice and the melting of fast ice widens the Chukchi polynya. Fragmented fast ice is driven offshore by S-SE winds but is occasionally driven back onto beaches when winds blow out of the north or west. A landfall of fragmented sea ice occurred at Point Lay on 21 July and remained for several days. Schmidt and Craig (in press) reported that Kasegaluk Lagoon was virtually ice-free from late June-late September.

3.2 Tides

As in most places along the arctic coast variations in sea level due to lunar tides are rather small, typically 10 cm or less. Storm surges, however, can cause considerable fluctuations in nearshore water levels. A positive storm surge of 40 cm was recorded by Hunkins (1964) and during the period 1962-1973. surge amplitudes have ranged from -1.10 to +1.89 m.

4. METHODOLOGY

4.1 Winter Program

Land based synoptic surveys were conducted during 15-28 March at Peard Bay, Peard Bay proper, Wainwright Inlet and Ledyard Bay (Fig. 4-1). Table 4-1 lists the geographic coordinates and sampling periods for each site. The single sampling day at Peard Bay proper reflects a variety of mechanical and logistical problems which hampered the start of the field program--this station was the first to be established. An attempt was made at establishing a sampling station in Kasegaluk Lagoon near Kukpowruk Pass, however, the effort proved unsuccessful because the entire water column was frozen. Hydrologic data were collected from a point just seaward of Kukpowruk Pass (Fig. 4-1). Each field site employed one fyke net and one gill net positioned within 100 m of each other. Hydrographic data were collected at each site.

4.1.1 Water Quality

Surface water temperature, surface salinity and surface turbidity were recorded with each daily check of the sampling sites. Temperature was measured in the field with in-glass mercury thermometers. Surface water samples were returned to base camp and analyzed with a YSI-33 Salinity/Conductivity meter (±0.9 ppt above 4.0°C, ±1 ppt below 4.0°C) and a Hach Model 2100 A Turbidimeter [measuring in nephelometric turbidity units (NTU's)]. In addition, vertical profiles of salinity and turbidity were measured once at each station. Water samples taken with a Van Dorn bottle were analyzed in the same method described above for surface samples.

4.1.2 Gill Nets

Monofilament gill nets used during the winter program were 45.7 m long by 1.8 m deep. Each net was vertically divided into three equally sized panels, with each panel being of a different mesh size (2.54, 3.81 and 5.08 cm stretched mesh). Gill net sets ranged from 20-26 h in duration and were positioned just beneath the prevailing ice layer to sample the upper 1.8 m of water column.

4.1.3 Fyke Nets

The under ice fyke net consisted of four wings, each 100 ft long by 1.8 m deep, eminating from a common 2 m x 2 m x 2 m centralized trap. The wings and trap were constructed of 1.27 cm mesh (stretched) knotless nylon netting. The common sides of any two adjacent wings converged into a 15 cm diameter circular throat which in turn emptied into the central trap. The entire device was suspended beneath the ice thus sampling the upper 1.8 m of the water column.

The fyke net was checked every 20-26 h. Because daily catches were low in number all specimens were retained for preservation in a 10% formalin solution. Identification, measurement and life history analyses were subsequently conducted at LGL's Bryan, Texas laboratory.

Table 4-1. Geographic coordinates and sampling periods for the four winter sites.

Location	Geographic Coordinates	Days Sampled
Peard Bay (proper)	70°51.3'N 158°49.2'W	1
Peard Bay	70°59.1'N 158°13.2'W	5
Wainwright	70°45.7'N 159°56.5'W	3
Ledyard Bay	69°16.1'N 163°34.2'W	4

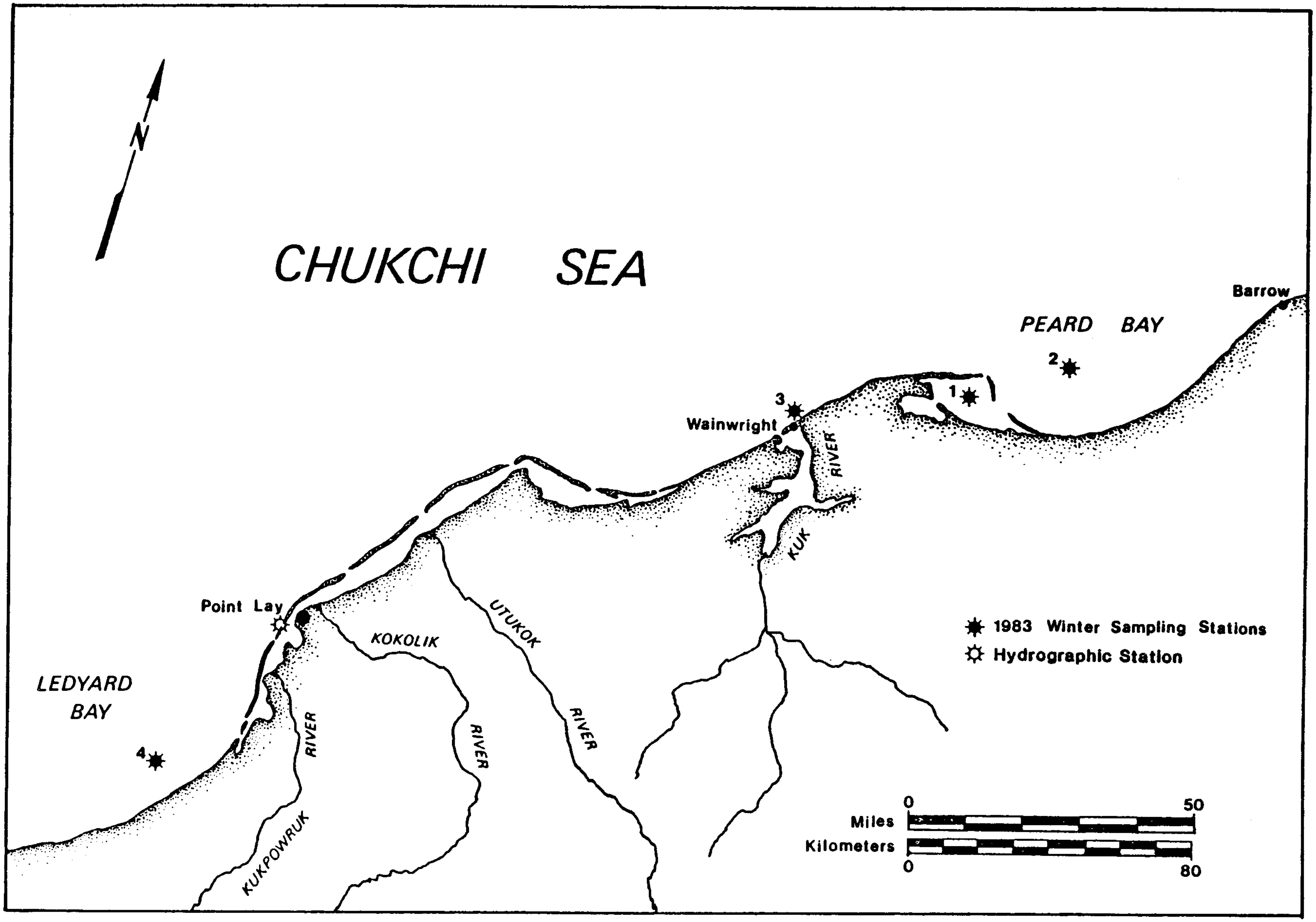


Figure 4-1. Sites sampled during 15-28 March 1983.

4.2 Kotzebue and St. Lawrence Island

Since winter data are difficult to obtain, some additional information is included in this report regarding winter jig-fishing catches in the vicinity of St. Lawrence Island during February 1983 and near Kotzbue in November 1978. Although collected outside the primary study area defined for the 1983 Chukchi investigation these data were available and serve to enhance our knowledge of Chukchi waters.

4.3 Summer Program (Land-based)

Intensive field surveys were conducted in the vicinity of Point Lay, Alaska, during summer. The sampling period was primarily divided into two increments, 17 July-4 August and 15 August-1 September. Survey efforts were most intensive during these periods, however, opportunistic samples were occasionally taken during the interim.

Figure 4-2 illustrates the sampling site locations. The programs original plan called for a fyke net to be in continuous operation at Station 1 and gill net samples to be taken at Stations 3, 4 and 5 on a rotating basis. This scheme worked well during the 15 July-4 August sampling period, however, inclement weather during the second sampling period forced us to place the fyke net on the lagoon side of the barrier island. Opportunistic gill net samples were taken at Stations 6, 7 and 8 at the discretion of the field chief.

Weather permitting, fyke and gill nets were checked daily. Fish were identified, enumerated and measured to the nearest 5 mm increment (maximum of 50 per species). Gill netted fish were retained for dietary and life history analyses. Selected species taken by fyke net were also preserved for later examination, however, stomach analyses of fyke netted fish was generally avoided since several species, most notably sculpin and cod, apparently feed on trapped fauna.

4.3.1 Water Quality

Surface water temperature, surface salinity and surface turbidity were measured in conjunction with daily fishing at each sampling station.

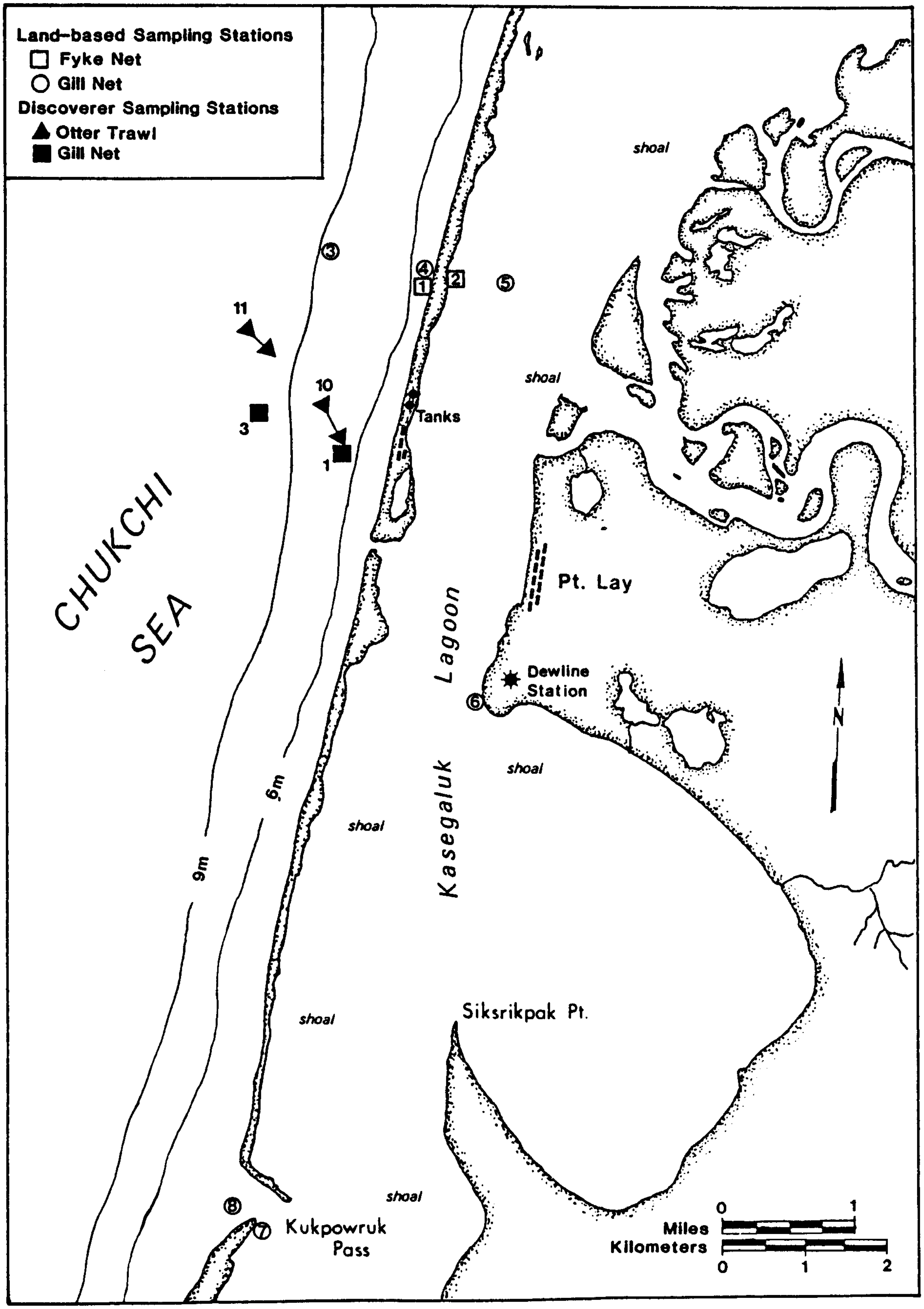


Figure 4-2. Sites sampled at Point Lay during July-August 1983. Also shown are nearshore Discoverer sampling stations.

In all cases, water temperature was measured with in-glass mercury thermometers (±0.5°C). Salinity and turbidity were measured from water samples collected at each station. Salinity was measured using a YSI-33 salinity/conductivity meter (±0.9 ppt above 4.0°C, ±1 ppt below 4.0°C). Turbidity was measured in nephelometric turbidity units (NTU) using a Hach Model 2100 A Turbidimeter.

4.3.2 Fyke Nets

The fyke net used at Station 1 during the 15 July-4 August sampling period actually consisted of two single trap models placed back to back (Fig. 4-3). Each single cod end trap consisted of a stainless steel frame mouth (1.2 x 1.2 m) attached to a knotless nylon net (3.7 x 0.9 x 0.9 m; 1.27 cm stretched mesh) containing two consecutive 15 x 25 cm throats. These traps were positioned on the seaward side of the barrier island at a depth of approximately 1 m. Two wings (25 cm stretched mesh) were connected to the frame--one ran diagonally to shore, the other ran diagonally seaward. Because the bottom dropped off rapidly the distal end of the seaward wing terminated at a point about 5 m offshore. This sharp drop off was the main reason for using this particular fyke net configuration.

The shallow waters of Kasegaluk Lagoon enabled us to use a conventional "T" configuration fyke net during the 17-31 August sampling at Station 2. A single 30 m lead was connected to the center of the main frame and two 10 m leads were attached to either side. The net was set perpendicular to shore so that the trap end was in about 1.0 m of water.

4.3.3 Gill Nets

Multipaneled monofilament gill nets were employed during the Point Lay study. Surface and Bottom nets were 30 m long by 1.8 m deep and divided vertically into four equally sized panels of 2.54, 5.08, 7.62 and 10.5 mm stretched mesh.

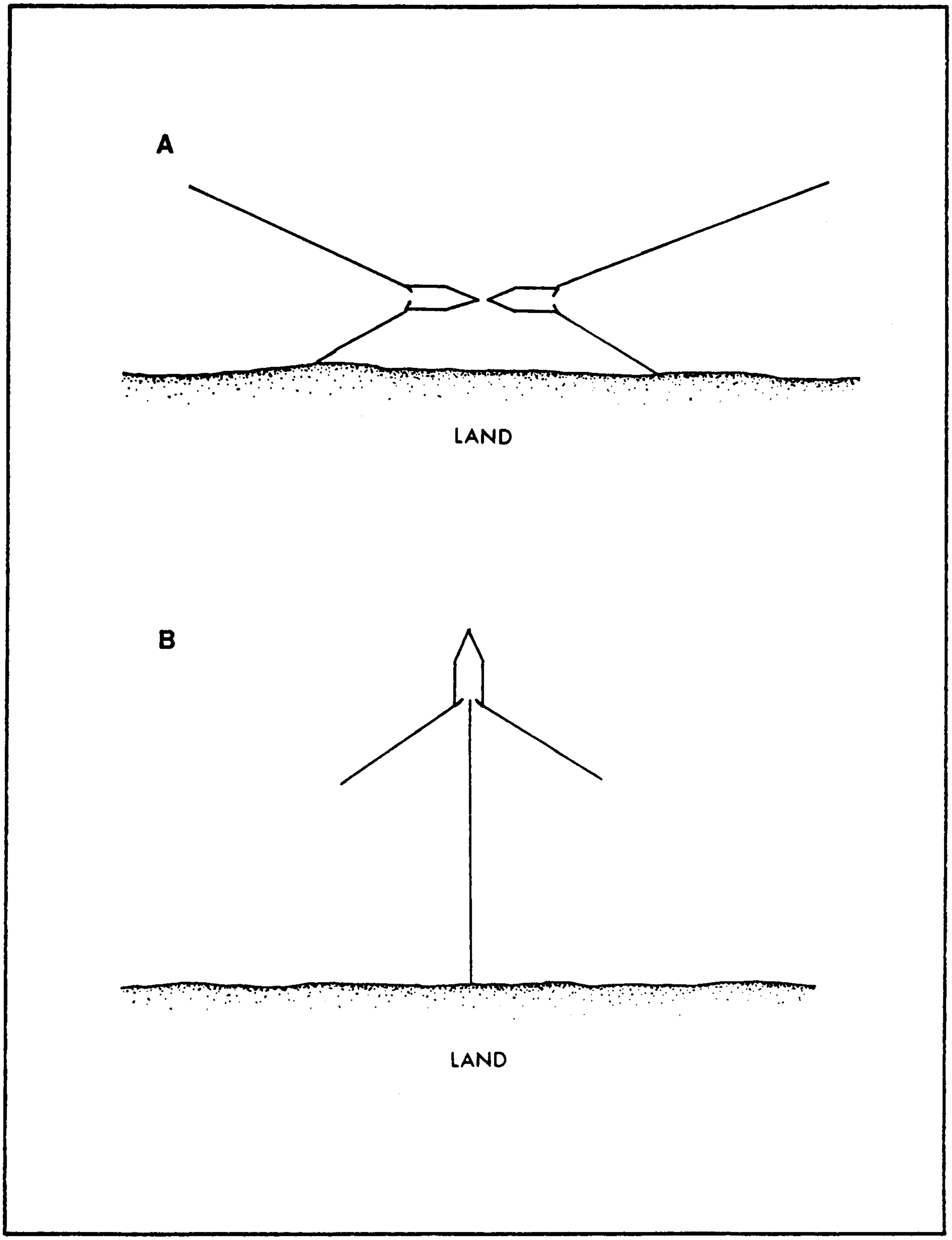


Figure 4-3. Fyke net configurations used during the 1983 Point Lay study; ocean side of barrier islands (A), lagoon side of barrier islands (B).

4.4 Summer Program (Ship-based)

LGL conducted nearshore and offshore fishing efforts as part of the 24 August-15 September cruise of the NOAA research vessel Discoverer. Gill net samples were taken at 13 locations, with surface and bottom nets being simultaneously deployed at each site. Twenty-six locations were sampled by otter trawl. General sampling locations are depicted in Figure 4-4 and the geographic coordinates of each sampling site are listed in Appendix 10-5.

The majority of tows employed a 7.6 m (25') gap, semi-balloon otter trawl operated directly from the Discoverer. At nearshore locations (Stations 9, 10, 11, 23, 25, 26) too shallow (<14 m)for the Discoverer, a smaller boat was used to tow a 3.7 m (12') gap trawl. Trawl samples were weighed and fish were separated from other components of the sample. Fish were weighed and all specimens were preserved in 10% formalin. In cases where trawl samples were extremely large (Stations 1, 3, 5, 8, 12, 13, 16, 18, 21, 29), subsamples were retained.

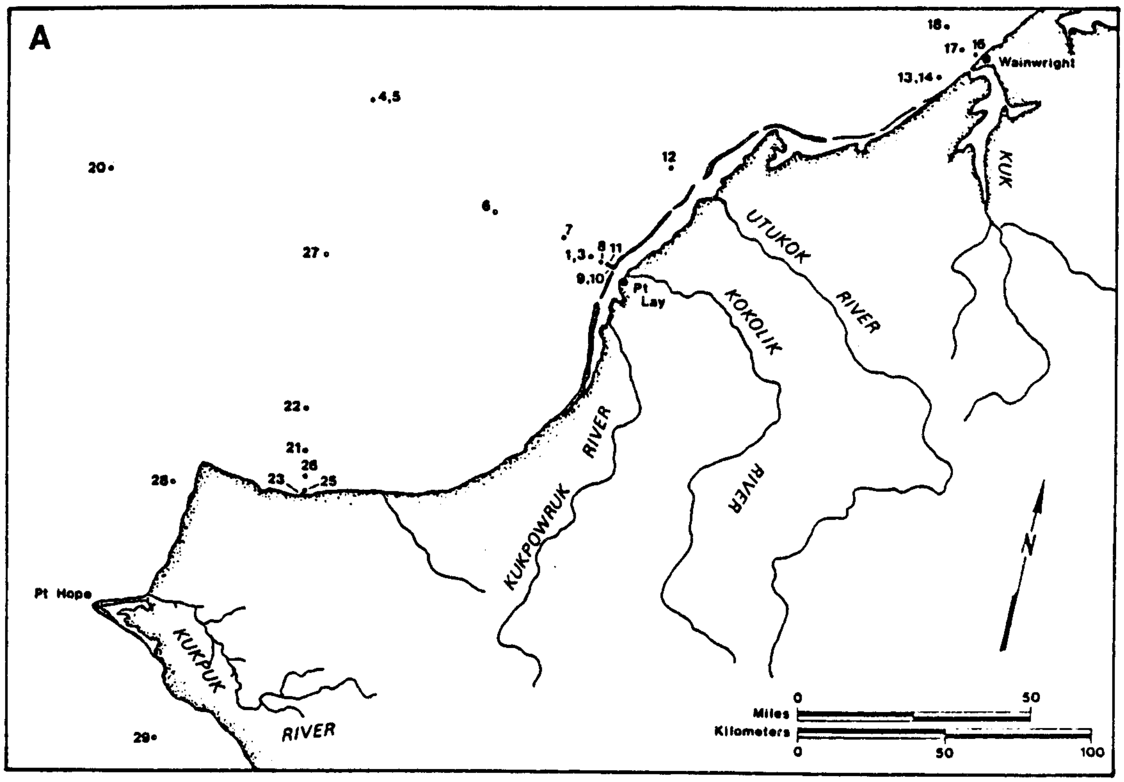
Samples were shipped to LGL's Bryan, Texas, office for analyses. Specimens were identified, enumerated and measured (to a maximum of 100 per species). Total weight for each species was recorded for each sampling effort. Stomach contents of Arctic cod, the most consistently abundant species taken by otter trawl, were analyzed.

4.4.1 Water Quality

The Discoverer's hydrographic data acquisition system recorded vertical profiles of temperature, salinity and conductivity (CTD) at 49 locations including all deep water sampling sites (Fig. 4-5).

4.4.2 Otter Trawls

Deep water tows employed a 7.6 m (25 ft) gap, semi-balloon otter trawl with a 3.8 m stretched mesh body and a 1.3 cm stretched mesh cod end liner. All trawls were 30 min in duration with the exception of trawls 28 and 29 (15 min). Several of the deep water trawls resulted in extremely large catches. In these instances, subsamples were retained for subsequent analyses.



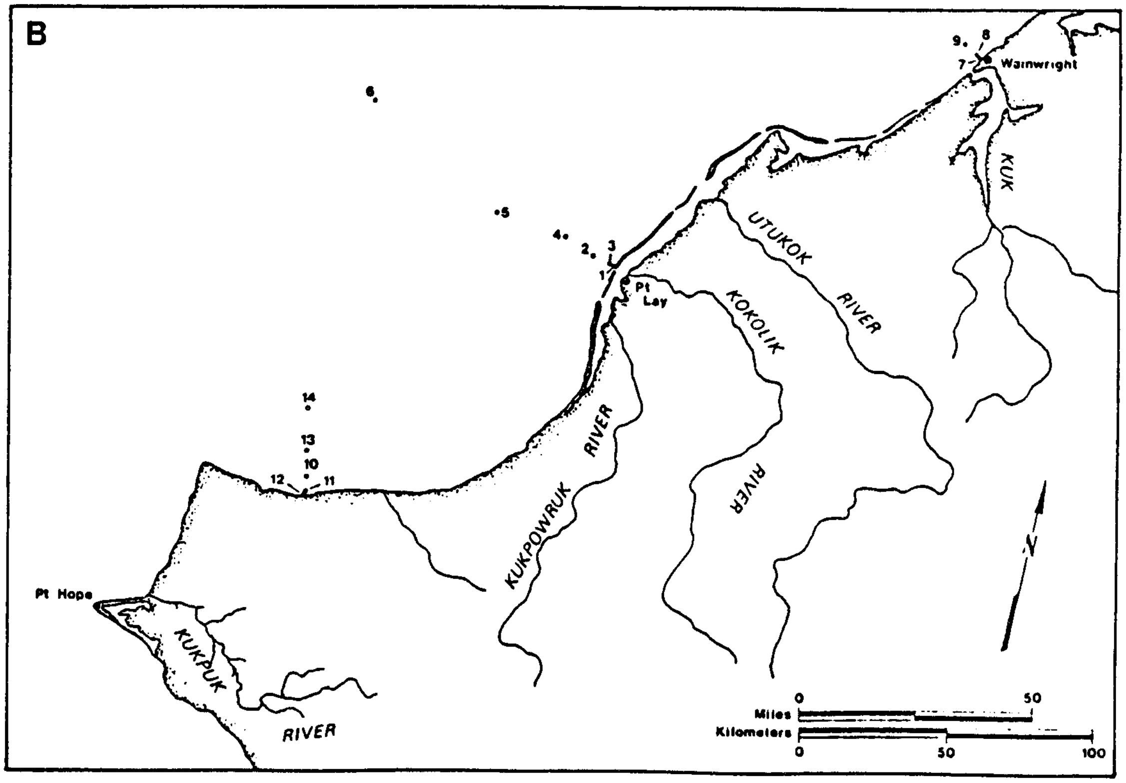


Figure 4-4. Otter trawl (A) and gill net (B) sites sampled during the 25 August-13 September 1983 Discoverer cruise.

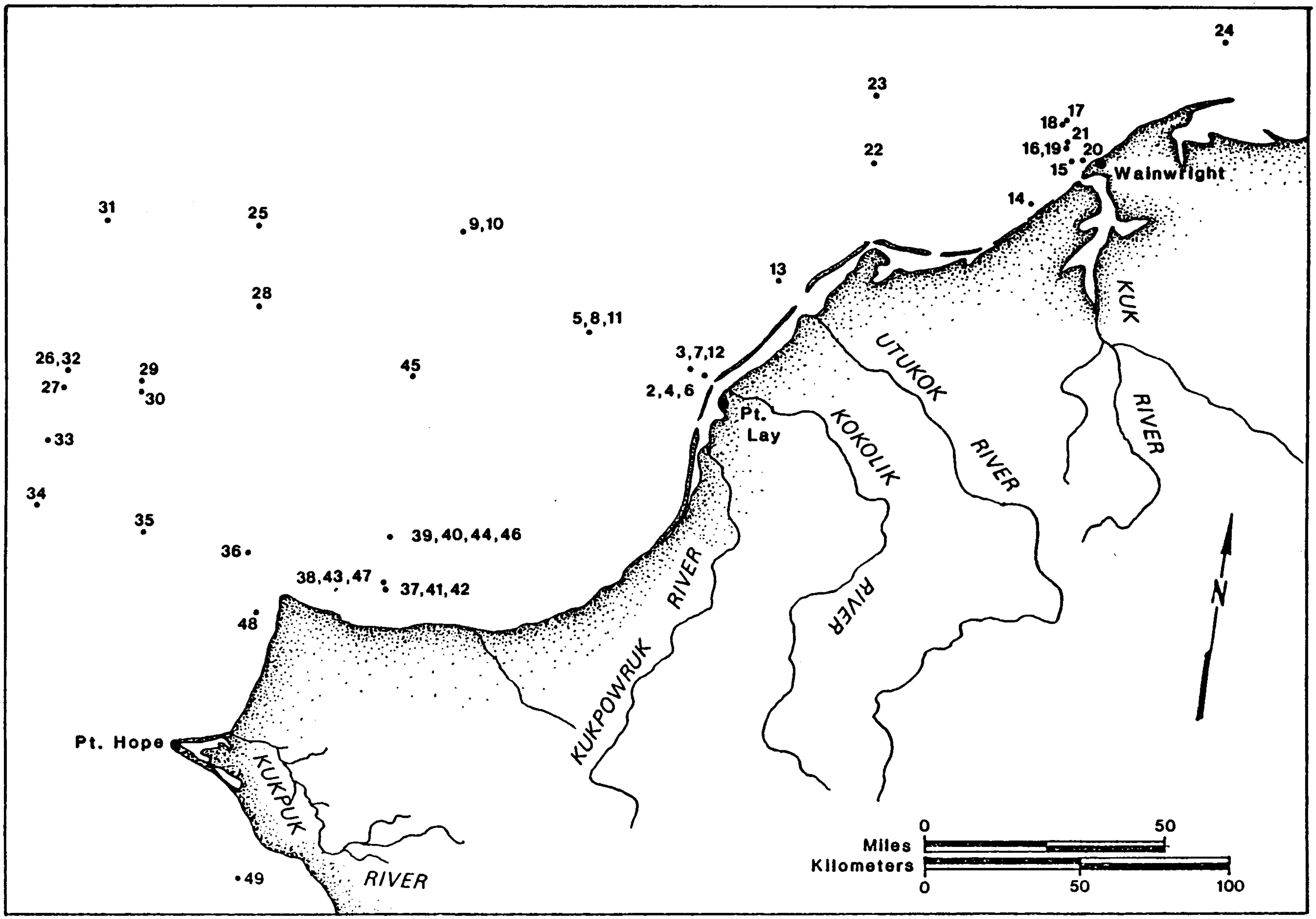


Figure 4-5. Location of CTD sampling sites during the 25 August-13 September 1983 Discoverer cruise.

Shallow water tows were made using a 3.7 m (12 ft) gap otter trawl with a 3.8 stretched mesh body and a 1.9 cm stretched mesh liner in the cod end. Nearshore trawls lasted for 9-10 min and the entire sample was preserved in each case.

4.4.3 Gill Nets

All gill nets were of monofilament construction measuring 61 m in length by 7.3 m in depth. They were vertically divided into four 15.25 m panels of 3.8, 6.4, 8.9 and 11.4 cm stretched mesh netting. All gill net efforts consisted of both surface and bottom nets. Soak time varied from 14-44 hours and all specimens were retained for preservation in 10% formalin solution.

4.5 Statistical and Analytical Procedures

4.5.1 Adjusted Catch

Otter trawl catches were adjusted to compensate for subsampling by dividing the catch (biomass) by the appropriate subsample fraction for each species at each station.

4.5.2 Catch Per Unit Effort Computations

Computation of CPUE for otter trawl samples assumes that the catch at each station is representative of abundance and diversity at that location. The computational formula for each species is given by

$$CPUE = \frac{1}{n} \sum_{i=1}^{n} N_i/A_i$$

where N_i is the number of fish caught at Station i and A_i the effort at Station i. Similarly, biomass per unit effort (BPUE) was calculated by

$$BPUE = \frac{1}{n} \sum_{i=1}^{n} B_i/A_i$$

where B_i is the biomass of fish caught at Station i.

4.5.3 Analysis of Variance and Covariance

In the analysis of the winter catch of Arctic cod it was noted that differences detected across stations in measures of food availability and feeding habits (e.g., body weight and stomach content weight) may be due to differences unrelated to feeding habits. For example, differences found in body weight between stations may be due to differences in length. Analysis of covariance is a set of techniques for the adjustment of main effects tests and multiple comparison procedures for the effect of observed concomitant variables.

The first step in the analysis of covariance is a simple analysis of variance. The model after possible transformation for linearity and normality is

$$Y_{ij} = \mu + \tau_j + \Sigma_{ij}$$

where Y_{ij} is the i^{th} replicate from the j^{th} station. At this juncture irrespective of proceding with the analysis of covariance multiple comparison procedures (Duncan, Scheffe's) may be used.

The model for analysis of covariance is given by

$$Y_{ij} = \mu + \tau_i + \beta\ (X_{ij}-\bar{X}) + \Sigma_{ij}$$

where Y_{ij} is as above and X_{ij} is the concomitant variable.

Before this model can be used for testing and estimation, several assumptions need to be verified. They are

1. The regression between the response variable Y and the concomitant variable X was necessary, i.e., the slopes of Y vs X within stations is significantly different from zero.
2. The relationship between Y and X is homogeneous between stations, that is the slopes of Y vs X are not significantly different across all stations.

The tests of these assumptions are given in Hicks (1973). It should be noted irrespective of whether these assumptions hold, the standard analysis of variance is still valid, though interpretation of observed differences may no longer eliminate the possible effect of the covariates.

The final step in the analysis of covariance is the main effects test and multiple comparisons procedure on the adjusted means. The means of the response variable Y adjusted for the covariate X are

$$\text{(adjusted) } \bar{Y}_{ij} = \bar{Y}_{ij} + \hat{\beta}\ (\bar{X}_{ij} - \bar{X}_{..}) \quad .$$

where Y_{ij} is the mean of the Y's for the j^{th} station, X_{ij} is the mean of the X's for the j^{th} station, $X_{..}$ the grand mean of the X's and the overall pooled slope of the regression of Y on X. Again, details of the main effects test and multiple comparisons procedures for the adjusted means are given in Hicks (1972).

4.5.4 Cluster Analysis

In order to compare and describe the relationships among stations or species with respect to the stomach contents of fish, cluster analyses were performed. This analysis was completed on two seperate data sets:

1. Arctic cod of similar length collected at 10 otter trawl stations, and
2. Selected species from gill net catches at Point Lay.

In both analyses the attribute (clustering variable) used was the percent of total stomach content biomass each observed content taxa constituted. In the first analysis classifications to be clustered were designated as stations. In the second, classifications were specified as fish species. Because of its demonstrated utility in ecology (Boesch 1977), a Bray-Curtis metric with complete linkage, clustering algorithm was used. The Bray-Curtis metric is a particular distance measure for determining the similarity of two classifications. The similarity, S_{jk} of classifications j and k is given by

$$S_{ij} = \frac{2\ \Sigma_{i=1}^{n} \text{Min}\ (X_{ij}\ ,\ X_{ik})}{\Sigma_{i=1}^{n}\ (X_{ij} + X_{ik})}$$

where X_{ij} is the value of the clustering variable for the i^{th} stomach content taxa and j^{th} classification. Dissimilarity D_{jk}, used in the dendrograms, is given by

$$D_{jk} = 1-S_{jk} \quad .$$

Complete linkage refers to the technique of determining the similarity of two classification clusters as a function of their least similar entities (Boesch 1977).

5. RESULTS AND DISCUSSION

This section provides a general summary of field and analytical results for the winter, Point Lay summer, and *Discoverer* cruise sampling efforts. In most cases results pertaining to specific species will be discussed in the Species Accounts section. Catch and hydrographic data are tabulated in the Appendices. Appendix 10.1 contains physical data (temperature, salinity and turbidity) for the winter and Point Lay summer studies; 10.2 provides length-weight measurements for cod taken in winter; 10.3 tabulates fish catch and effort data for the Point Lay summer study; 10.4 contains length-frequency data by gear type for dominant species taken during the Point Lay summer study; 10.5 shows fish catch and effort data for the *Discoverer* cruise; and 10.6 provides length-frequency data for the dominant species caught during the *Discoverer* cruise.

5.1 Winter Study

5.1.1 Water Quality Summary

Vertical profiles of salinity and turbidity are depicted in Figure 5-1 for Stations 1 (18 March), 2 (18 March), 3 (22 March) and 4 (29 March). Depth related changes in salinity were negligible at Stations 2 and 4, however, stratification at Station 2 may not have been detected since total depth in this area exceeded 20 m. Total depth at Stations 1, 3 and

4 were 6 m, 13 m and 11 m, respectively. Bottom salinity in Peard Bay proper (Station 1) was 3 ppt greater than at the surface. Salinity decreased linearly with depth at Station 3, falling from 25.1 ppt at the surface to 16.5 ppt at a depth of 10 m. This trend at Station 3 may reflect freshwater influence from the nearby Kuk River.

Daily surface salinities remained fairly constant within stations, ranging from 28.1-33.3 ppt at Station 2 (18-22 March), 25.1-28.0 at Station 3 (20-23 March), and 29.7-31.0 ppt at Station 4 (24-28 March).

Surface temperature remained between -0.5 and -1.0°C regardless of location or date. Turbidity values were low, ranging from 0.5-5.5 NTU (Fig. 5-1).

5.1.2 Catch Summary and Total Abundance

Winter fyke-netting resulted in the capture of 205 fish--204 Arctic cod (*Boregadus saida*) and 1 sculpin (Table 5-1). The lone sculpin was taken at Station 3 on 22 March.

Gill nets failed to capture any fish during the entire winter sampling period even though efforts encompassed over 270 total hours of soak time: five days at Station 2, three days at Station 3, and four days at Station 4. The disparity in Arctic cod catch between gill and fyke nets, given that both were set in close proximity to and at the same depth and time of each other, illustrates gear selectivity. Arctic cod taken by fyke net ranged from 44-99 mm FL and thus may have been too small for the 2.5, 3.8 and 5.1 cm gill net mesh sizes. Fyke net leads were not only constructed of smaller mesh net (1.3 cm) but also acted in a different capacity--directing fish movement as opposed to entangling fish. A similar occurrence of gear selectivity was reported by Griffiths et al. (1983). During periods in which their fyke nets were capturing thousands of Arctic cod, nearby gill nets took only a token number. Further, their tri-paneled gill nets (minimum mesh size = 1" stretched mesh) failed to capture cod less than 100 mm FL. Craig and Haldorson (1981) also reported that gill nets were inefficient in capturing small Arctic cod in Simpson Lagoon.

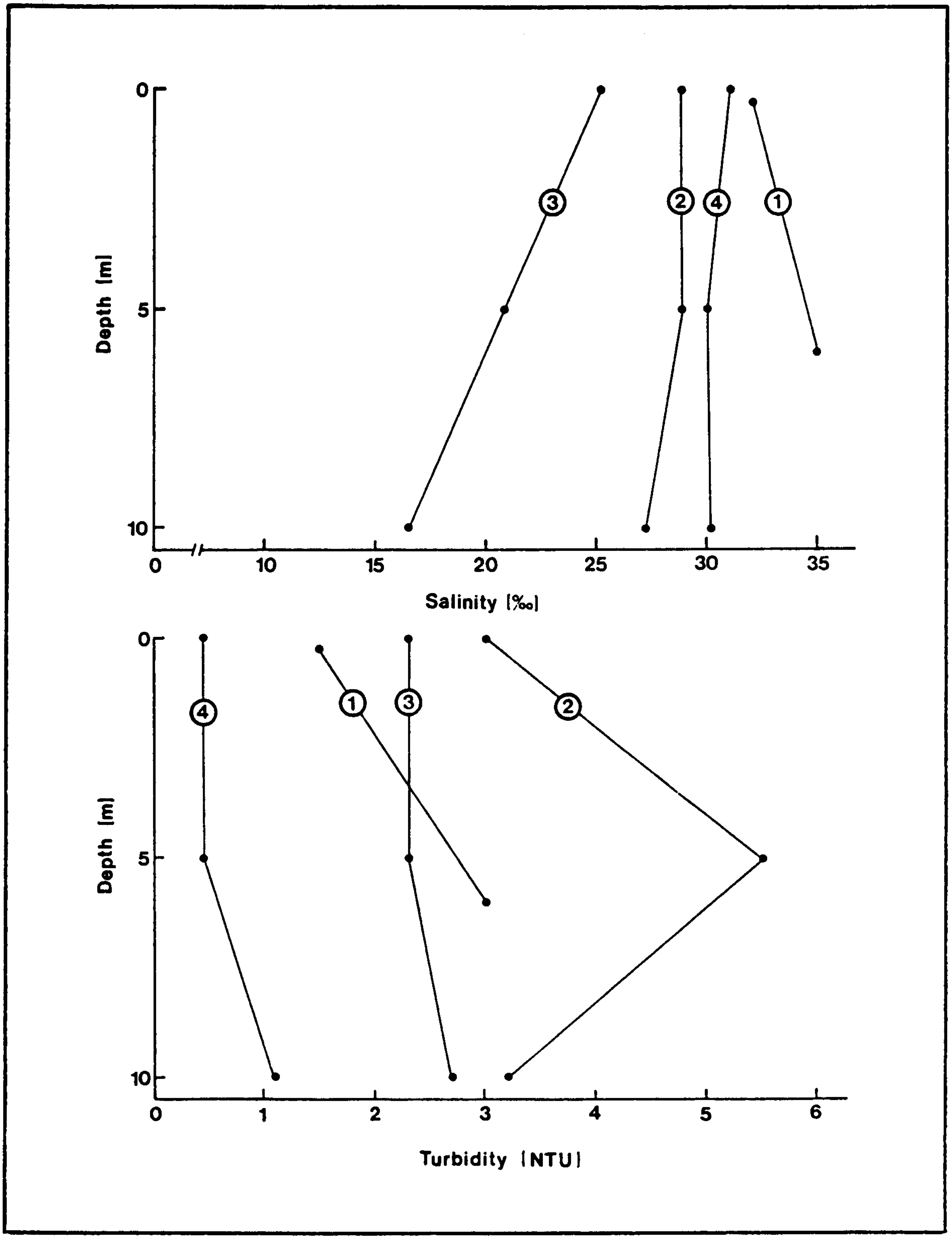


Figure 5-1. Vertical profiles of salinity and turbidity recorded at Stations 1 (Peard Bay proper), 2 (Peard Bay), 3 (Wainwright) and 4 (Ledyard Bay) during 15-28 March 1983.

5.1.3 Kotzebue and St. Lawrence Island

First reported by Craig and Haldorson (1981) the 33 saffron cod (*Eleginus gracilis*) collected were part of a subsistence catch of "tomcod" jigged through the ice just offshore from the village of Kotzebue, Southeast Chukchi Sea, on 15-30 November 1978.

During February 1983, saffron cod were jigged through the ice at a location about 1.5 km east of Savoonga, St. Lawrence Island. Arctic cod were jigged at the mouth of Fossil River, about 1.5 km southeast of Camp Iveetok.

All collected specimens were analyzed for length, weight, reproductive status, age and stomach content, and results are reported in the Species Account Section.

Table 5-1. Catch summary for Arctic cod taken by fyke net during 16-28 March, 1983.

	Station			
Date	1	2	3	4
3/16/83	2			
3/18/83		18		
3/19/83		40		
3/20/83		28		
3/21/83		58	20	
3/22/83		15	4	
3/23/83			3	
3/15/83				5
3/26/83				2
3/27/83				2
3/28/83				7

5.2 Point Lay Study

5.2.1 Water Quality Summary

Temperature, salinity and turbidity data are presented in Figure 5-2 for Stations 1 and 2. Data collected at these sites offer the best temporal profile of local hydrographic conditions because they were the stations most consistently monitored during the sampling period.

Two main warming trends in ocean water occurred during the first half of the sampling program--elevated temperatures were recorded from 20-23 July and from 1-6 August. A similar but reciprocal trend was noted in salinity. The 20-23 July period was characterized by mild SE winds and warm air temperatures. Warm freshwater discharge from the Kokolik and Kukpowruk rivers would account for observed temperature and salinity levels. River influence is evident in the generally lower salinity of lagoon water as compared with ocean water. Strong N-NW winds and heavy seas prevailed before and after the 20-23 July period. The resultant wind-driven influx of cold marine water served to lower the temperature and increase the salinity of coastal ocean water. Both lagoon and ocean water levels were higher at this time.

The lack of consistent hydrographic data for the ocean station during the second half of the summer sampling period makes comparative analysis difficult. Lagoon waters generally underwent a steady decrease in temperature during the last two weeks in August. This decline may be attributable, in part. to decreased river discharge and colder air temperatures. Sharp drops in lagoon salinity and spikes in turbidity around 12 and 29 August were accompanied by offshore and NE winds which tended to churn and lower the level of lagoon waters.

5.2.2 Catch Summary and Total Abundance

Fyke and gill netting efforts resulted in the capture of 17 fish species totaling 14,437 individuals--13,345 by fyke net and 1092 by gill net (Table 5-2). Marine species (10) accounted for nearly 99% of the total fyke net catch with the dominant species being Arctic cod (39%), capelin (25%), fourhorn sculpin (20%) and Arctic flounder (13%). The most abundant species taken by gill net were Pacific herring (48%), fourhorn sculpin (18%), boreal smelt (17%) and Arctic flounder (9%).

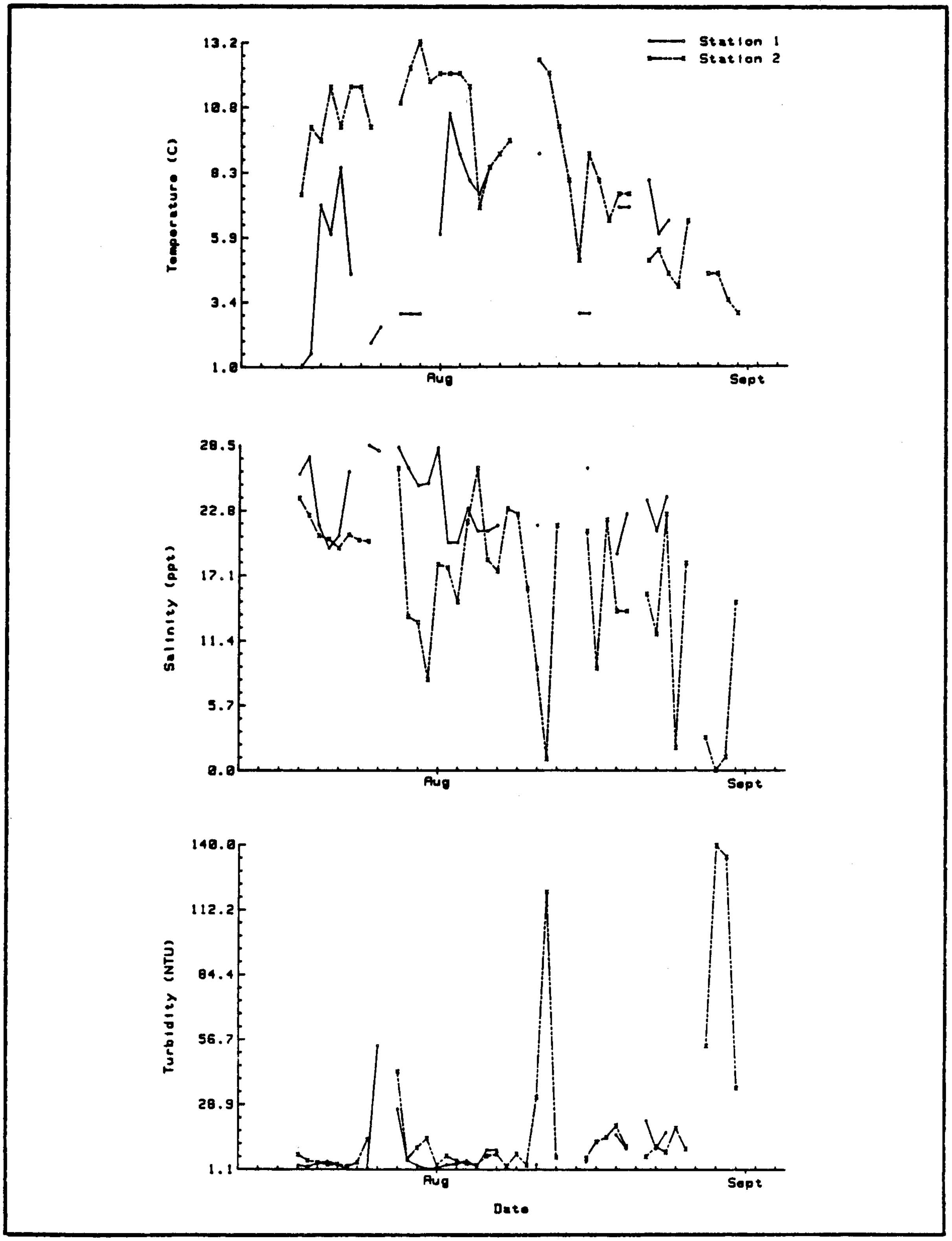


Figure 5-2. Temperature, salinity and turbidity recorded at Point Lay fyke net Stations 1 and 2 during July-August 1983.

These data illustrate the size/species selectivity of the different gear types. Nearly half of the 1092 gill-netted fish were Pacific herring, yet not a single herring was taken by either fyke net. Conversely, fyke nets captured 5205 Arctic cod while gill nets took only 12. Boreal smelt were taken by both gear types; however, while gill nets caught fish predominantly in the 200-260 mm length range, better than 60% of those caught by fyke net were less than 130 mm in length.

When compared with nearshore summer surveys conducted in the Beaufort Sea region, the most prominent feature of the 1983 Point Lay catch is the virtual absence of anadromous fish (Table 5-3). As in the present study, Beaufort Sea fyke net catches were generally dominated by Arctic cod and fourhorn sculpin. Excluding these two species, Arctic cisco, least cisco, Arctic char and broad whitefish accounted for ~73% of the remaining catch at Simpson Lagoon in 1978 and more than 90% of remaining catches at Simpson Lagoon (1977), Prudhoe Bay (1981) and the Sagavanirktok River delta (1982). During the latter three studies, Arctic cisco alone constituted 14.7, 15.0 and 29.1% of total fyke net catche, respectively. The 28 fyke net days at Point Lay resulted in the capture of three Arctic char and two least cisco. Not a single Arctic cisco or broad whitefish were taken, however, one Arctic cisco was caught at Point Lay during summer 1983 (Schmidt and Craig, in press). None of these species were taken by gill net and together the four species comprised 0.04% of the 1983 Point Lay catch.

5.2.3 Catch Rate

There is a noticeable similarity between hydrographic trends and overall fyke net catch (Fig. 5-3). Catch per unit effort (CPUE) for all fish increased during sharp transitions in temperature and salinity. This similarity may reflect the effect of sea conditions upon localized fish distribution. Northerly winds responsible for lower temperatures also created extremely rough seas and surf. The site of fyke net Station 1 in the barrier island surf zone would most likely be avoided by fish during harsh weather. Deeper, offshore waters, or Kasegaluk Lagoon, could serve as havens against these rough surface conditions. Conversely, repopulation of the surf corridor during calmer periods (elevated temperatures) could account for the observed increases in catch.

Table 5-2. Point Lay catch summary for July-August, 1983.

Species	Station: Ocean Fyke	Lagoon Fyke	Ocean Gill	Lagoon Gill	Total
Arctic cod (Boreogadus saida)	4014	1191	12	0	5217
Capelin (Mallotus villosus)	3343	1	16	0	3360
Fourhorn sculpin (Myoxocephalus quadricornis)	1491	1152	146	56	2845
Arctic flounder (Liopsetta glacialis)	1512	202	25	71	1810
Pacific herring (Clupea harengus pallasi)	-	-	457	70	527
Boreal smelt (Osmerus mordax)	1	133	144	42	320
Saffron cod (Eleginus gracilis)	110	155	3	1	269
Pink salmon (Oncorhynchus gorbuscha)	5	1	28	0	34
Great sculpin (Myoxocephalus polyacanthocephalus)	24	1	4	1	30
Longhead dab (Limanda proboscidea)	1	-	10	1	12
Arctic char (Salvelinus alpinus)	2	1	-	-	3
Sturgeon poacher (Agonus acipenserinus)	-	-	3	0	3
Least cisco (Coregonus sardinella)	2	-	-	-	2
Bering cisco (Coregonus laurettae)	-	1	1	-	2
Pacific sand lance (Ammodytes hexapterus)	-	1	-	-	1
Chum salmon (Oncorhynchus keta)	-	-	-	1	1
Threespine stickleback (Gasterosteas aculeatus)	-	1	-	-	1
	10,505	2840	659	433	14,437

Table 5-3. Fyke net catch summary for the six most abundant fish species caught during nearshore summer surveys in the Beaufort Sea. Values are percent of total catch followed parenthetically by catch per fyke net day.

	Beaufort Sea				Chukchi Sea
	Simpson Lagoon[1]		Prudhoe Bay[2]	Sagavanirktok Delta[3]	Point Lay
	1977	1978	1981	1982	1983
Arctic cod	7.6 (6.5)	77.9 (1607.1)	49.2 (179.8)	27.9 (147.7)	39.0 (183.1)
Fourhorn sculpin	69.6 (59.1)	17.9 (369.3)	23.7 (86.4)	27.7 (146.9)	19.8 (93.0)
Arctic cisco	14.7 (12.5)	0.8 (16.5)	15.0 (54.7)	29.1 (154.4)	0 (0)
Least cisco	2.3 (1.9)	1.2 (24.8)	6.6 (24.0)	2.3 (12.5)	<0.01 (0.07)
Arctic char	3.8 (3.2)	0.9 (18.6)	2.3 (8.5)	5.1 (27.8)	<0.01 (0.1)
Broad whitefish	0.1 (0.8)	0.2 (3.1)	0.9 (3.1)	5.6 (29.7)	0 (0)
Others	1.9	1.1	2.3	2.3	41.2

[1]Craig and Haldorson 1981.
[2]Griffiths and Gallaway 1982.
[3]Griffiths et al. 1983.

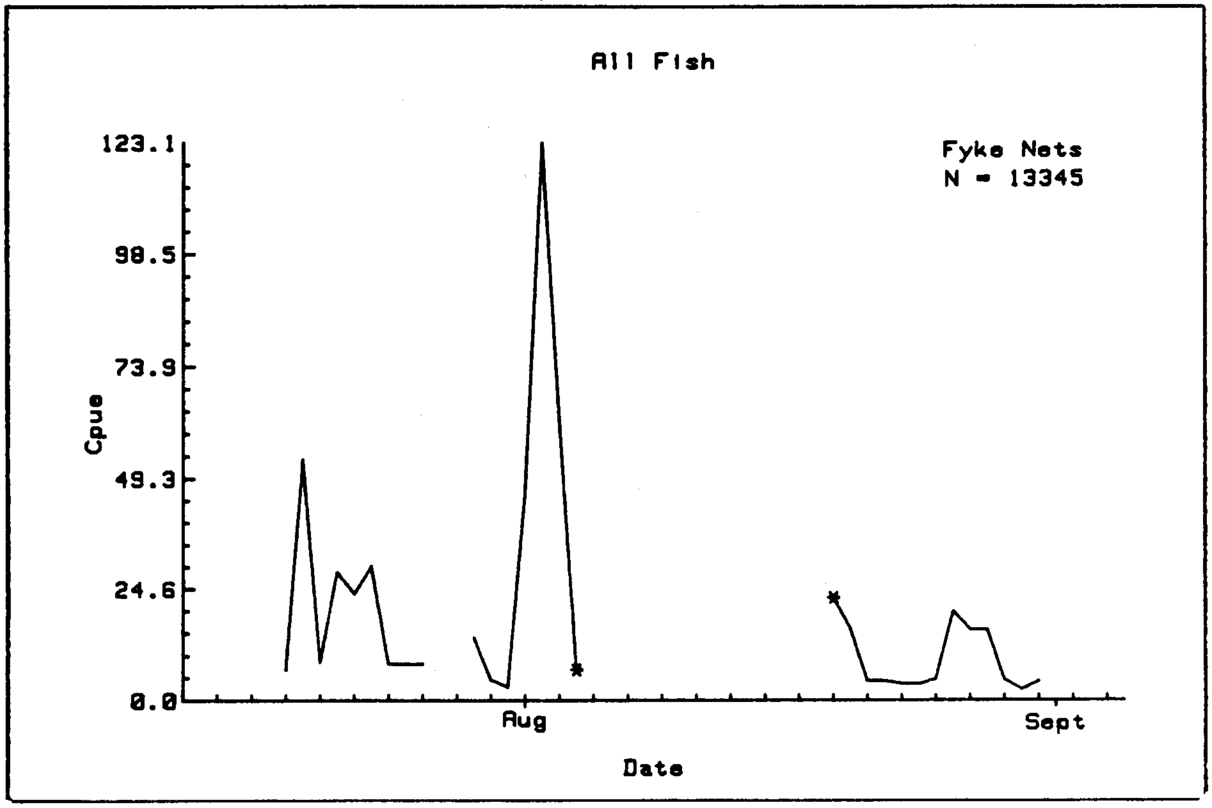


Figure 5-3. Daily catch rate (fish/h) of all fish taken by Point Lay fyke nets during July-August 1983.

5.2.4 Trophic Comparisons

The stomachs of 141 fish collected at Pt. Lay were examined for content. Five species were represented and with the exception of capelin, all specimens were taken by gill net. Detailed lists of stomach contents are provided in the Species Accounts Section.

Figure 5-4 denotes the presence of particular food items for each species. Cluster analysis revealed several similarities in feeding strategy among species (Fig. 5-5). Pink salmon and boreal smelt both tended to be piciverous, with fish accounting for 75 and 65% (of total wet weight content) of their diets, respectively (Tables 6-8 and 6-5). Fish and *Mysis littoralis* together comprised 80% (pink salmon) and 95% (boreal smelt).

The diets of capelin (95%) and Pacific herring (78%) were dominated by *Mysis littoralis* (Table 6-4). Fourhorn sculpin taken from both the ocean and lagoon sides of the barrier island fed predominantly on the

COINCIDENCE TABLE

STOMACH CONTENTS	Capelin	Pacific Herring	Pink Salmon	Boreal Smelt	Arctic Flounder	Fourhorn Sculpin Ocean	Fourhorn Sculpin Lagoon
Ephemoptera nymph							X
Calanoid	X	X		X	X		
Calanus glacialis		X					
Temora sp.							
Cyclopoid							
Harpacticoid	X	X					
Euphausiid	X		X				
Atylus carinatus			X				
Parathemisto abyssorum			X				
Amphipod	X	X	X	X	X	X	X
Onisimus littoralis		X	X	X		X	
Onisimus glacialis				X			X
Lysianassid	X			X	X	X	X
Gammarus setosus			X	X	X	X	X
Pontoporeia affinis		X		X	X		X
Oedicerotid	X	X	X	X	X		
Anonyx sp.			X				
Gammaracanthus			X				
Polychaete		X			X	X	
Unidentified worm					X		
Cirripede larvae							X
Bivalve							X
Saduria entomon		X		X	X	X	X
Mysid	X	X	X				
Mysid littoralis	X	X	X	X	X	X	X
Mysid relicta		X	X	X			X
Neomysis sp.	X	X	X	X			
Cumacea	X	X					
Fish egg			X				
Unidentified fish				X		X	X
Fish larvae	X	X	X	X			
Arctic cod		X	X	X		X	X
Fourhorn sculpin		X					X
Saffron cod						X	
Flatfish			X				
Ninespine stickleback							
Sand lance		X					
Decapod shrimp						X	
Juvenile decapod			X				

Figure 5-4. Food items consumed by fish taken at Point Lay during July-August 1983.

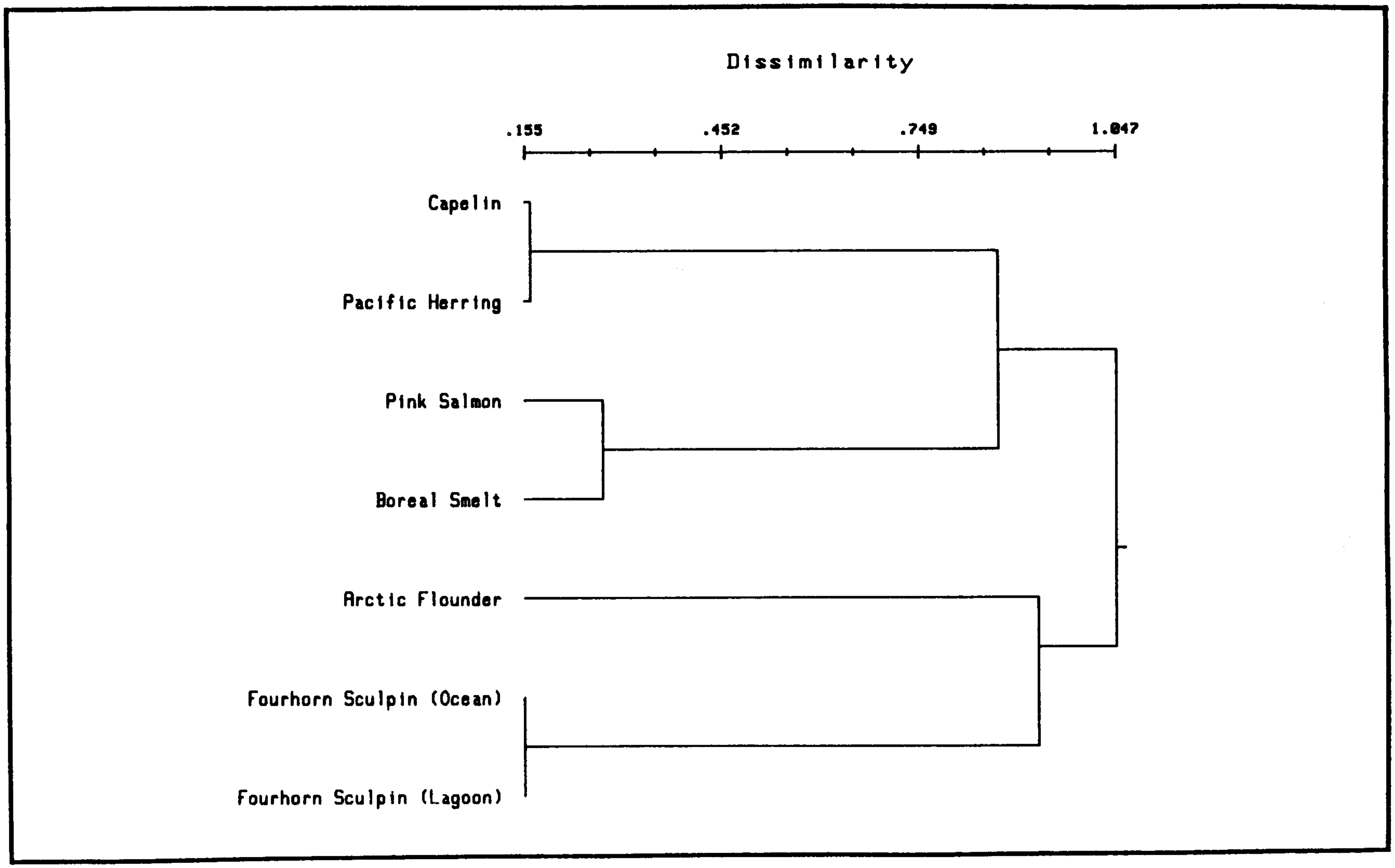


Figure 5-5. Cluster analysis dendrogram for six species of fish based on stomach content of specimens taken at Point Lay during July-August 1983.

isopod *Saduria entomen*: lagoon 65%, ocean 81% (Table 6-3). The benthic nature of Arctic flounder is reflected in the high incidence (48%) of tubular polychaetes (Table 6-7). A large remaining portion of their diet was unidentified worms (35%).

Because invertebrate sampling was not included in this study the ecological significance of these dietary dissimilarities/similarities in terms of competition is unclear. Even if these data were available, it is likely that different food preferences would be correlated with the functional design and feeding strategy of individual species. Any hypothesis regarding the trophic stability of the Kasegaluk Lagoon system would require a more detailed investigation of food availability and its relation to dietary overlap.

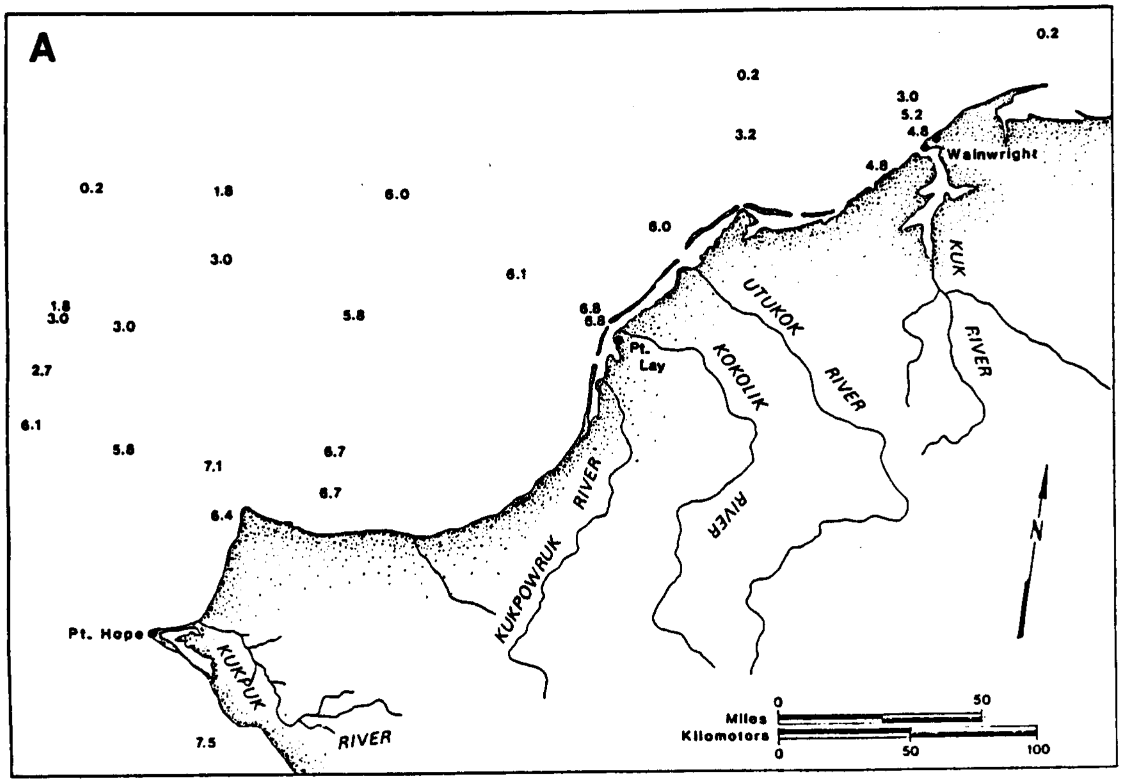
5.3 *Discoverer* Cruise

5.3.1 Water Quality Summary

Ocean temperatures ranged from -0.8 to 7.5°C (Fig. 5-6). Warmest waters (~≥6°C) occurred southeast of Icy Cape, extending from the coast to as far as 150 km offshore for surface water and 75 km offshore for bottom water. This thermal plume reflects the N-NE flow of warm water from the Bering Sea. Decreasing bottom temperatures coincided with increased distances from shore and greater depth. The interface between the Bering Sea plume and colder Arctic Ocean water was evident in a sharp decrease (~3°C) in sea surface temperature approximately 150 km offshore. Northeast of Icy Cape, where Chukchi and Beaufort Sea water masses mix, nearshore temperatures were somewhat cooler (~3-5°C).

Salinity was relatively constant throughout the study area, with surface and bottom conditions ranging from 28-32 ppt (Fig. 5-7). Lowest salinities were observed in nearshore areas near the mouths of major river drainages.

Vertical profiles of temperature and salinity were homogeneous at most of the nearshore stations (2, 4, 6, 12-16, 19-22, 36-47) where depths were less than 25 m. Deep water stations (>25 m) were characterized by distinct thermoclines and haloclines of varying duration and depth. Subsurface extensions of the warm Bering Sea plume into the colder Arctic Ocean water mass were observed at Stations 23, 25, 26, 28, 29 and 32 (Fig. 5-8).



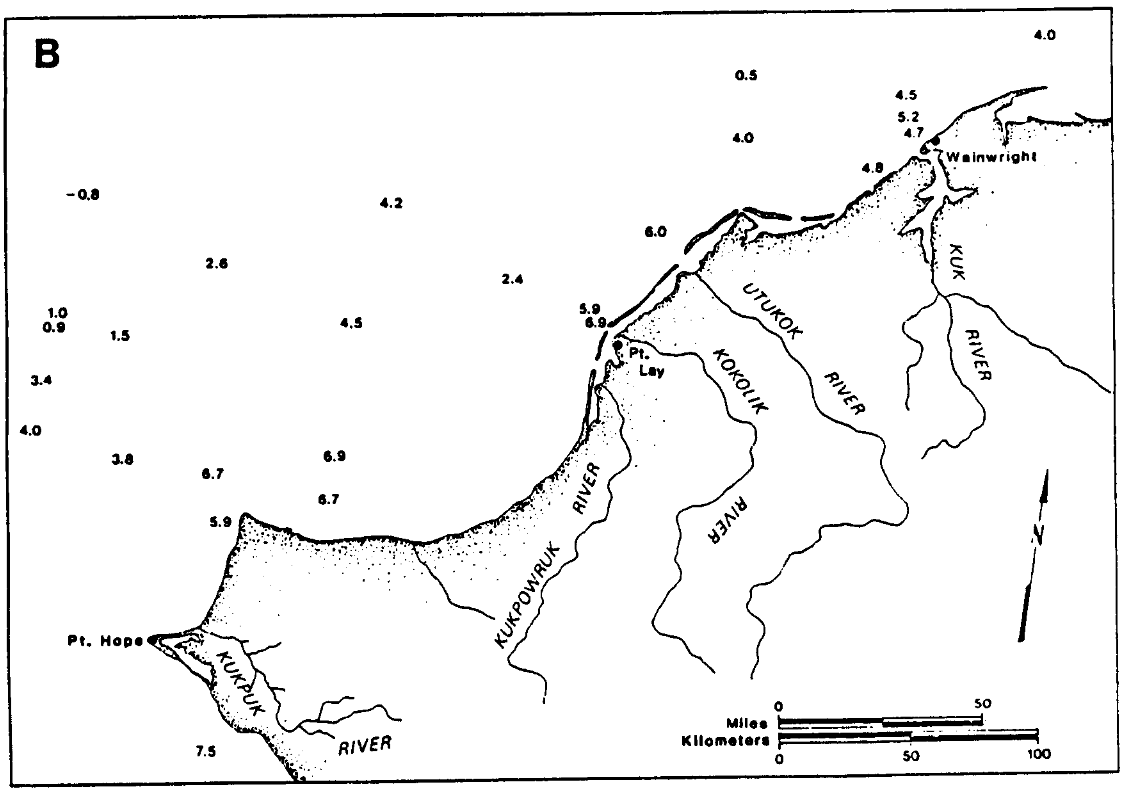


Figure 5-6. Surface (A) and bottom (B) temperatures recorded during the 25 August-13 September 1983 Discoverer cruise.

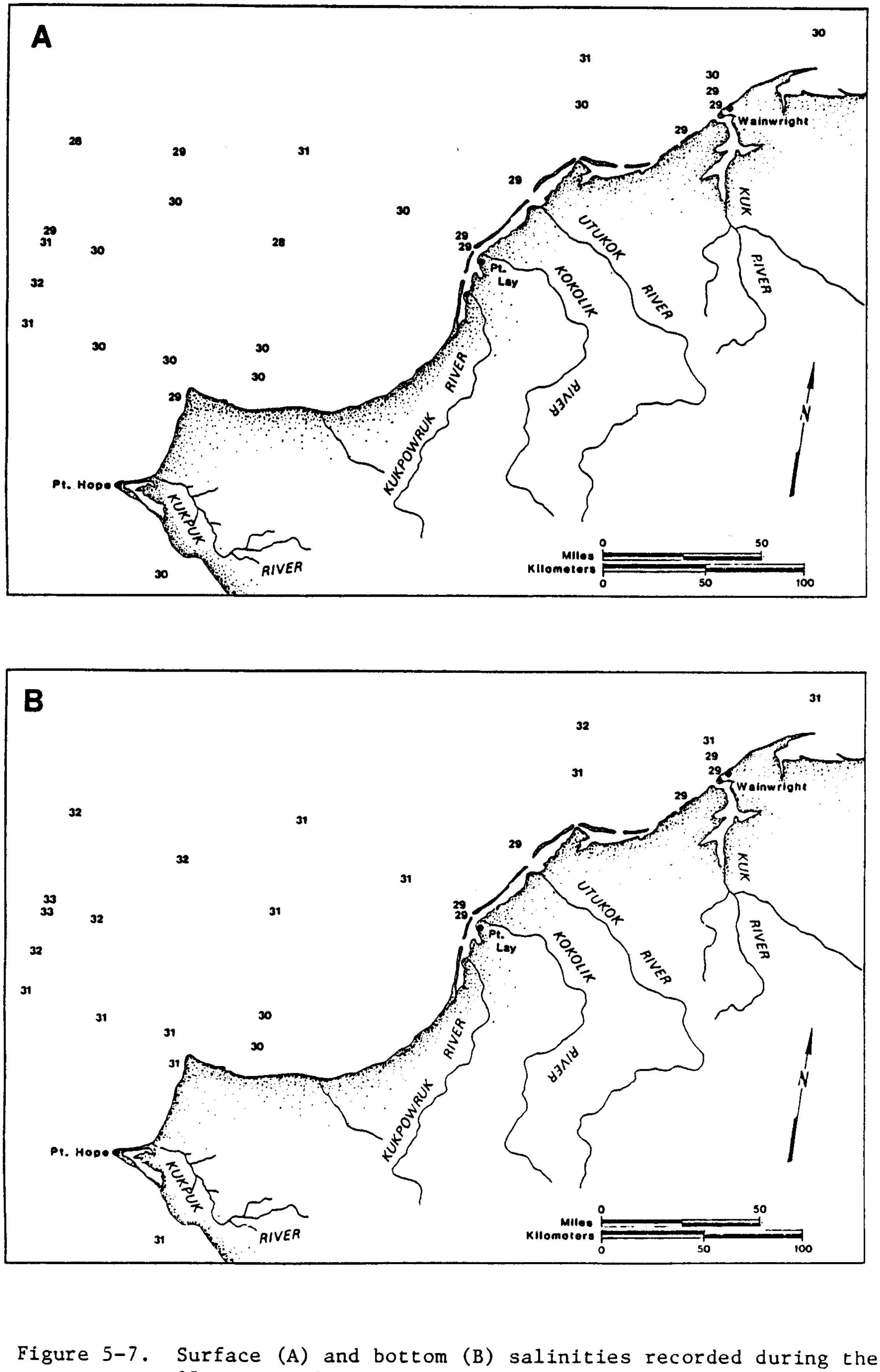


Figure 5-7. Surface (A) and bottom (B) salinities recorded during the 25 August-13 September 1983 *Discoverer* cruise.

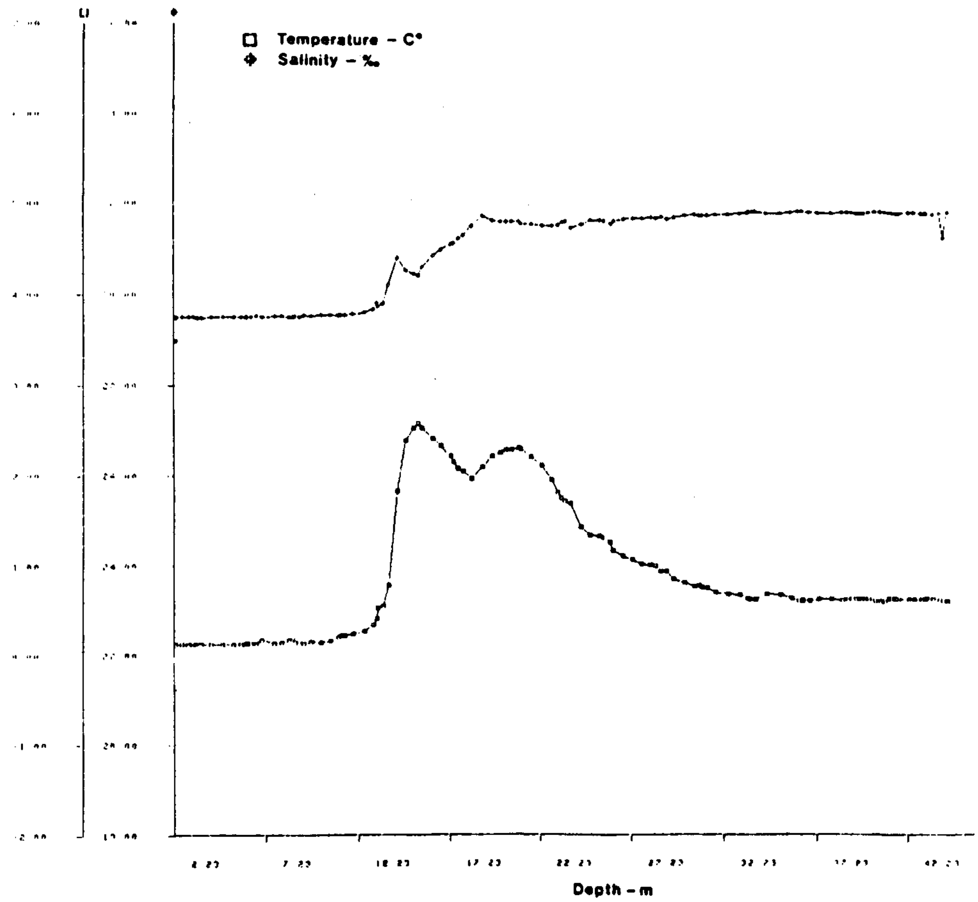


Figure 5-8. Vertical profile of temperature and salinity recorded at CTD Station 23. The subsurface band of warm water was indicative of Stations 23, 25, 26,]8, 29 and 32.

5.3.2 Catch Summary and Total Abundance

Otter trawl and gill-netting efforts caught a total of 7849 fish representing 5 orders, 12 families and 31 species (Table 5-4). Adjusted otter trawl catch at deep water stations (>14 m, 25 ft trawl) was dominated by Arctic staghorn sculpin (52%), Arctic cod (21%), shorthorn sculpin (8%), hamecon (7%) and saffron cod (5%) (Table 5-5). Together, these five species accounted for 93% of adjusted catch biomass: Arctic cod, 54%; Arctic staghorn sculpin, 24%; shorthorn sculpin, 7%; saffron cod, 6% and hamecon, 2%. In terms of percent average CPUE and percent average biomass per unit effort (BPUE) there is a change in the proportions of the two dominant species. Arctic staghorn sculpin increased from 52% to 55% of catch and from 24% to 29% of biomass while Arctic cod decreased from 21% to 17% of catch and 54% to 42% of biomass. This shift occurs because trawls focus was made in areas where Arctic cod were more abundant.

Comparisons of adjusted catch for nearshore stations (<14 m depth, 12 ft trawl) showed Arctic staghorn sculpin to be numerically dominant (51%) followed by shorthorn sculpin (19%), hamecon (14%), saffron cod (6%) and Arctic cod (3%) (Table 5-6). These five species comparised 96% of total biomass with 62% attributable to Arctic staghorn sculpin alone. Only a slight shift was noted in catch composition when viewed in terms of percent average CPUE and percent average BPUE.

Nine species totalling 102 fish were taken by gill nets of which Pacific herring and boreal smelt accounted for 46 and 33 specimens, respectively.

Table 5-4. Species caught during the 1983 *Discoverer* cruise.

CLUPEIFORMES

- Clupeidae
    - Pacific herring - *Clupea harangus pallasi*

SALMONIFORMES

- Salmonidae
    - Arctic char - *Salvelinus alpinus*
- Osmeridae
    - Boreal smelt - *Osmerus mordax*

GADIFORMES

- Gadidae
    - Arctic cod - *Boreogadus saida*
    - Saffron cod - *Eleginus gracilis*
    - Walleye pollock - *Theragra chalcogeamma*
- Zoarcidae
    - Fish doctor - *Gymnelis viridis*
    - - *Gymnelis hemifascratus*
    - Polar eelpout - *Lycodes polaris*
    - Arctic eelpout - *L. reticulatus*
    - Archer eelpout - *L. sagittarius*
    - Saddled eelpout - *L. muscosus*

PERCIFORMES

- Stichaeidae
    - Fourline snakeblenny - *Eumesogrammus praecisus*
    - Slender eelblenny - *Lumpenus fabricii*
    - Arctic shanny - *Stichaeus punctatus*
- Ammodytidae
    - Sandlance - *Ammodytes hexapterus*
- Hexogrammidae
    - Whitespotted greenling - *Hexogrammos stelleri*
- Cottidae
    - Hamecon - *Artediellus scaber*
    - Spatulate sculpin - *Icelus spatula*
    - Antlered sculpin - *Enophrys diceraus*
    - Arctic staghorn sculpin - *Gymnocanthus tricuspis*
    - Fourhorn sculpin - *Myoxocephalus quadricornis*
    - Shorthorn sculpin - *M. scorpius*
    - Eyeshade sculpin - *Nautichthys pribilovius*
    - Ribbed sculpin - *Triglops pingeli*
- Agonidae
    - Sturgeon seapoacher - *Agonus acipenserinus*
    - Arctic alligatorfish - *Asidophoroides olriki*
- Cyclopteridae
    - Snailfish - *Liparis* spp.

PLEURINECTIFORMES

- Pleuronectidae
    - Alaska plaice - *Pleuronectes quadrituberculatus*
    - Arctic flounder - *Licpsetta glacialis*
    - Yellowfin sole - *Limanda aspera*
    - Longhead dab - *Limanda proboscidea*

Table 5-5 Catch summary for deep water (>14m) stations sampled by 25' otter trawl during the 1983 Discoverer cruise.

Species	Adjusted Catch	Adjusted Biomass	Average CPUE	Average BPUE	Percent Average CPUE	Percent Average BPUE
Arctic staghorn sculpin	10699	186873	250.976	4447.25	55	29
Arctic cod	4339	424547	76.634	6421.20	17	42
Shorthorn sculpin	1608	51388	39.100	1386.28	9	9
Hamecon	1372	17698	33.169	470.64	7	3
Saffron cod	1054	50587	19.834	1375.90	4	9
Slender eelblenny	570	12353	8.724	193.78	2	1
Ribbed sculpin	366	6986	7.067	146.92	2	*
Sand lance	106	1584	2.253	35.46	*	*
Snailfish	101	1734	2.184	42.26	*	*
Sturgeon seapoacher	88	451	1.943	9.50	*	*
Antlered sculpin	80	11600	2.718	394.14	*	3
Walleye pollock	68	9349	2.194	308.16	*	2
Yellowfin sole	66	929	1.275	15.76	*	*
Arctic shanny	64	954	2.050	31.74	*	*
Fish doctor	37	298	.988	8.24	*	*
Saddled eelpout	33	1104	.762	30.74	*	*
Arctic alligatorfish	28	156	.747	4.86	*	*
Eyeshade sculpin	8	18	.140	.29	*	*
Arctic eelpout	8	546	.226	13.47	*	*
Whitespotted greenling	5	72	.152	2.38	*	*
Spatulate sculpin	4	4	.078	.08	*	*
Fourline snakeblenny	4	70	.140	2.45	*	*
Pacific herring	4	1410	.123	43.40	*	*
Gymnelis hemifasciatus	3	33	.041	.45	*	*
Polar eelpout	3	78	.024	.53	*	*
Archer eelpout	1	3	.008	.02	*	*
Arctic flounder	1	32	.008	.26	*	*
Boreal smelt	1	111	.016	1.80	*	*

* < 1%

Table 5-6. Catch summary for shallow water (<14m) stations sampled by 12' otter trawl during the 1983 Discoverer cruise.

Species	Adjusted Catch	Adjusted Biomass	Average CPUE	Average BPUE	Percent Average CPUE	Percent Average BPUE
Arctic staghorn sculpin	307	9647	98.151	4137.83	55	70
Shorthorn sculpin	115	2338	29.328	563.90	16	10
Hamecon	85	1512	17.554	258.43	10	4
Saffron cod	36	557	7.120	118.79	4	2
Arctic cod	19	734	9.667	319.35	5	5
Snailfish	15	573	9.442	412.81	5	7
Yellowfin sole	8	88	1.997	15.28	1	*
Fourhorn sculpin	4	42	3.333	35.00	2	*
Ribbed sculpin	4	42	.946	11.06	*	*
Slender eelblenny	3	47	.349	5.33	*	*
Sturgeon seapoacher	2	10	.548	2.74	*	*
Arctic alligatorfish	1	1	.123	.12	*	*

* < 1%

6. SPECIES ACCOUNTS

This section discusses the results for individual species. While emphasis is placed on the more abundant species taken during the 1983 Chukchi study, brief summaries of data collected for less abundant species are also provided.

6.1 Arctic Cod (*Boreogadus saida*)

The Arctic cod has a circumpolar distribution extending south to the northern Bering Sea (Pereyra et al. 1977, Lowry and Frost 1981). Arctic cod are reported to be one of the most common and abundant species in Arctic waters (Alverson and Wilimovsky 1966, Quast 1974, Lowry and Frost 1981) and are known to enter nearshore areas in the Beaufort Sea (Craig and Halderson 1981, Griffiths and Gallaway 1982, Griffiths et al. 1983).

Arctic cod was one of the most omnipresent and abundant species caught throughout the course of the 1983 Chukchi investigation. With the exception of a single cottid, they were the only species taken during the winter program, the most abundant species collected at Pt. Lay during summer, and the second most abundant species collected by otter trawling from the *Discoverer*. They constituted 36% of total catch at Point Lay and 21% of adjusted otter trawl catch (all stations combined).

Fyke net catch rate of Arctic cod was highly variable at Pt. Lay with spikes in CPUE coinciding with sharp changes in local hydrography: the 19 July surge preceded a 5.5°C rise in temperature and a 6 ppt decrease in salinity recorded on 20 July; a 4.5°C rise in temperature and a 8 ppt drop in salinity accompanied the 2 August pulse in CPUE and a 22 ppt decrease in salinity occurred simultaneously with the 25 August surge (Fig. 6-1). Griffiths et al. (1983) reported similar pulses of Arctic cod near the Sagavanirktok River delta, however, they were always associated with salinity increases. The nearshore abundance of Arctic cod is apparently linked with hydrographic characteristics and/or movements in water mass.

6.1.1 Size

Arctic cod taken during the winter survey ranged in size from 45-100 mm fork length (FL) with a cumulative length-frequency distribution

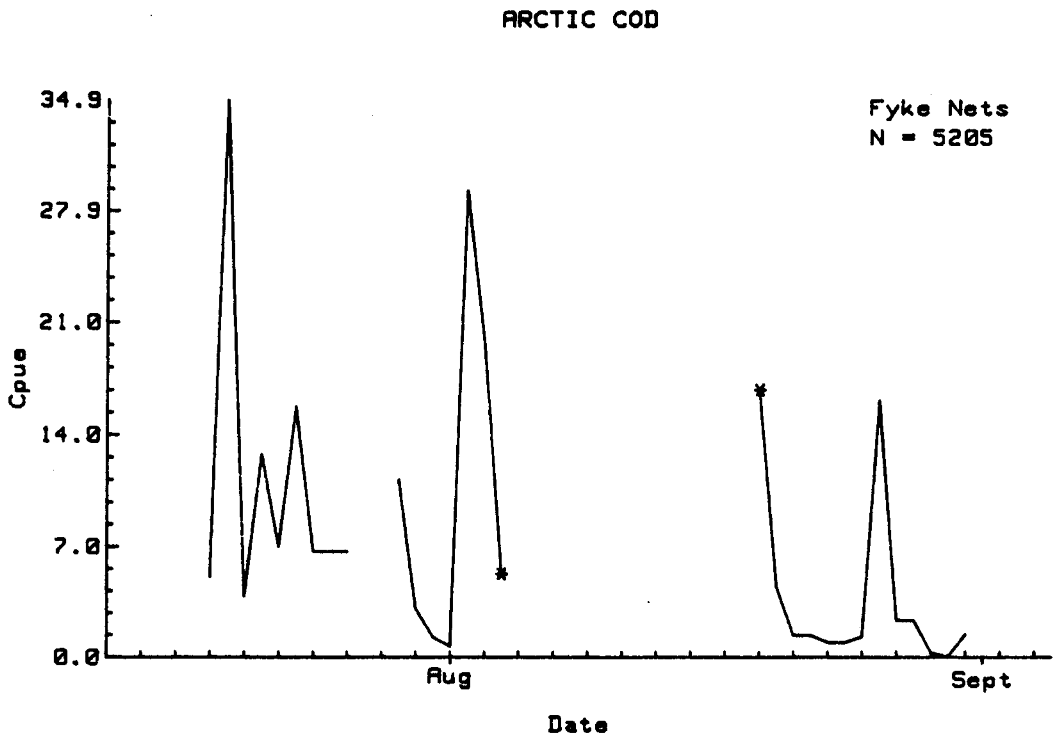


Figure 6-1. Daily catch rate (fish/h) of Arctic cod taken by Point Lay fyke nets during July-August 1983.

monomodal at 65-69 mm (Fig. 6-2). Length was not significantly ($P<0.05$) different among Stations 2, 3 and 4 (ANOVA). Results from Station 1 were not used in any analyses because of the small sample size (N=2).

Point Lay fyke nets took cod ranging from 40-265 mm FL (Fig. 6-3). The 18-27 July catch was dominated by small cod (~55-120 mm FL) whose length-frequency distribution had a modal peak at 75 mm. The presence of larger fish was more evident during the 28 July-4 August and 19-31 August periods, however, in both cases smaller individuals were still most abundant. The latter sampling period was marked by a distinctive mode at about 95-110 mm.

Otter-trawled cod ranged from 30-205 mm FL, however, the majority of fish were less than 120 mm (Fig. 6-4). Data from certain stations (3, 4, 5 and 6) suggested the presence of a smaller size cohort near 45 mm. Most large specimens were taken at depths greater than 40 m (Stations 4, 5, 20 and 27) and at Station 13 (20 m).

Lowry and Frost (1981) found length-frequency distributions for cod taken in the Beaufort and Chukchi seas during August-September similar to that for our otter-trawled fish. Their age analyses placed 1+ Arctic cod at 71 mm with a length-frequency mode at 70-85 mm. One year old cod from Simpson Lagoon averaged 84 mm (Craig and Haldorson 1981). If we assume our 85 mm cohort to be 1+ fish and further assume a preceding year growth increment of 34 mm (Lowry and Frost 1981) then the 45 mm cohort observed at Stations 3-6 may well contain young-of-the-year spawned in winter 1982-83. These fish may be expected to be in the vicinity of 65 mm (winter data) by March.

6.1.2 Dietary Analyses

6.1.2.1 <u>Winter Study</u>. A total of 73 Arctic cod stomachs were examined. A marked difference in stomach content weight (wet) was noted for fish taken at the three locations. Mean stomach content weight expressed as a percent of stomachless body weight increased as station locations moved southwest; 0.7% at Station 2, 2.2% at Station 3 and 5.0% at Station 4 (Table 6-1). Both ANOVA (subsequent to PROBIT transformation) and Scheffe's test analyses showed the difference to be significant ($P<0.05$) between stations. Regression of stomach content

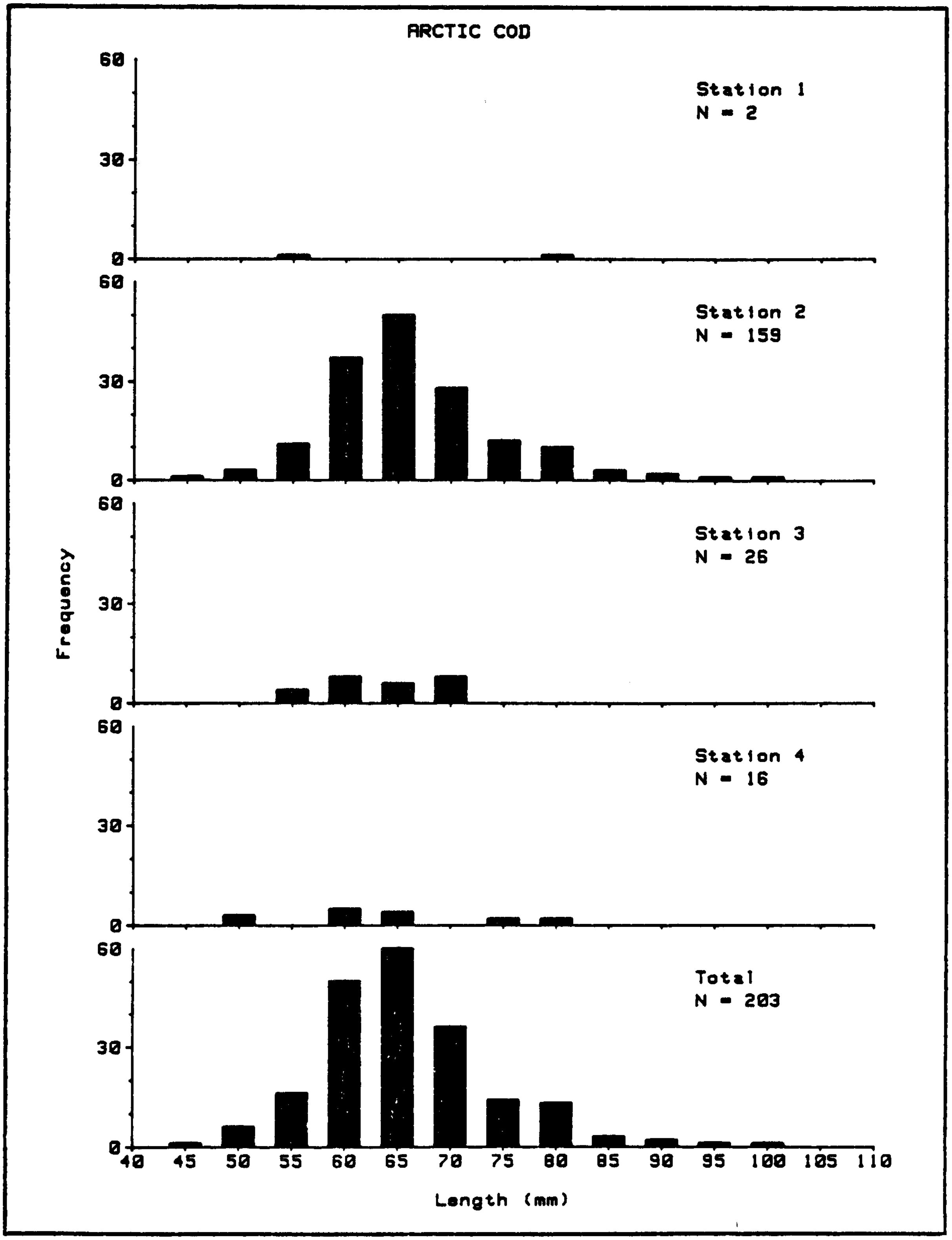


Figure 6-2. Length-frequency distributions for Arctic cod taken during 15-28 March 1983.

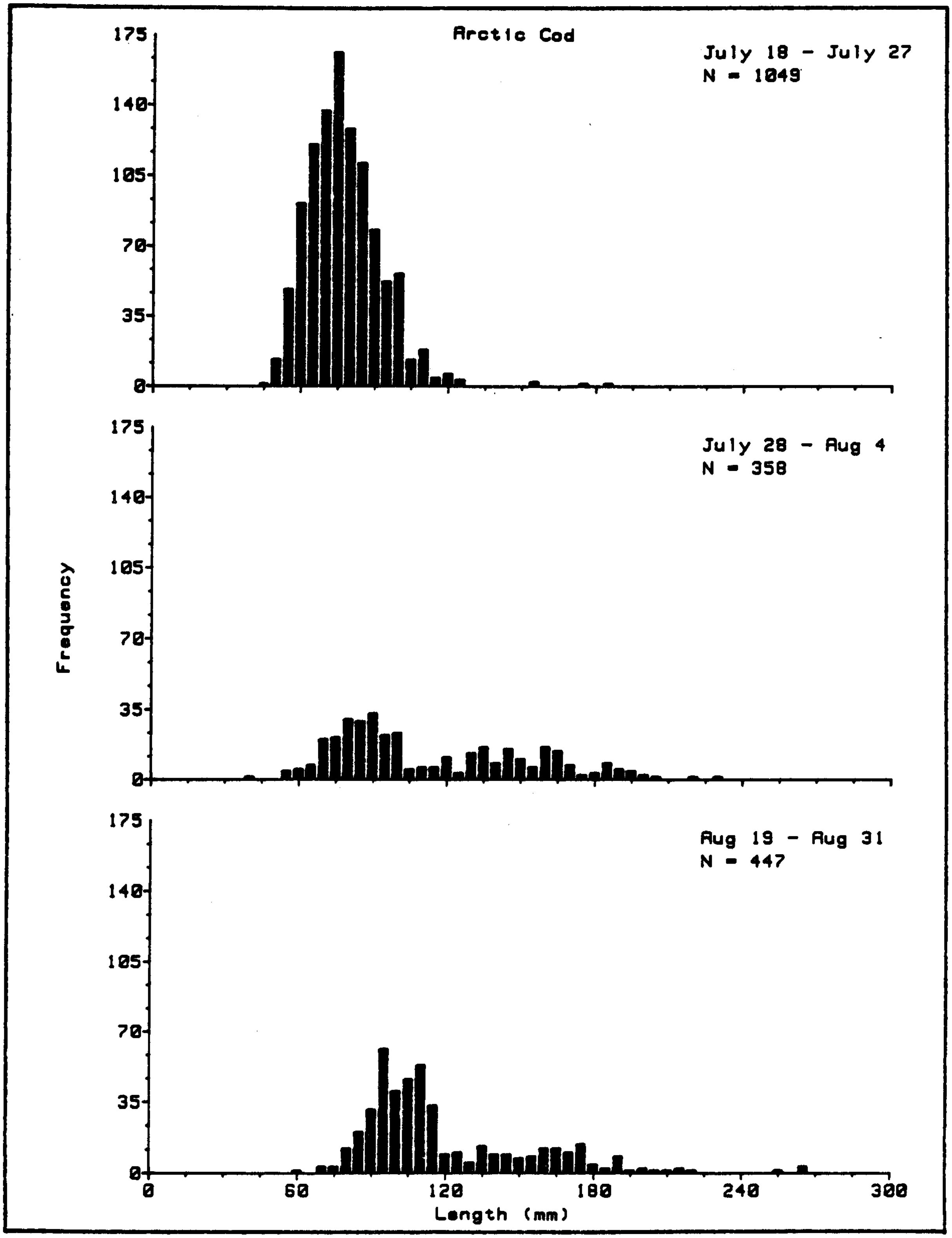


Figure 6-3. Length-frequency distributions of Arctic cod taken by Point Lay fyke nets during July-August 1983.

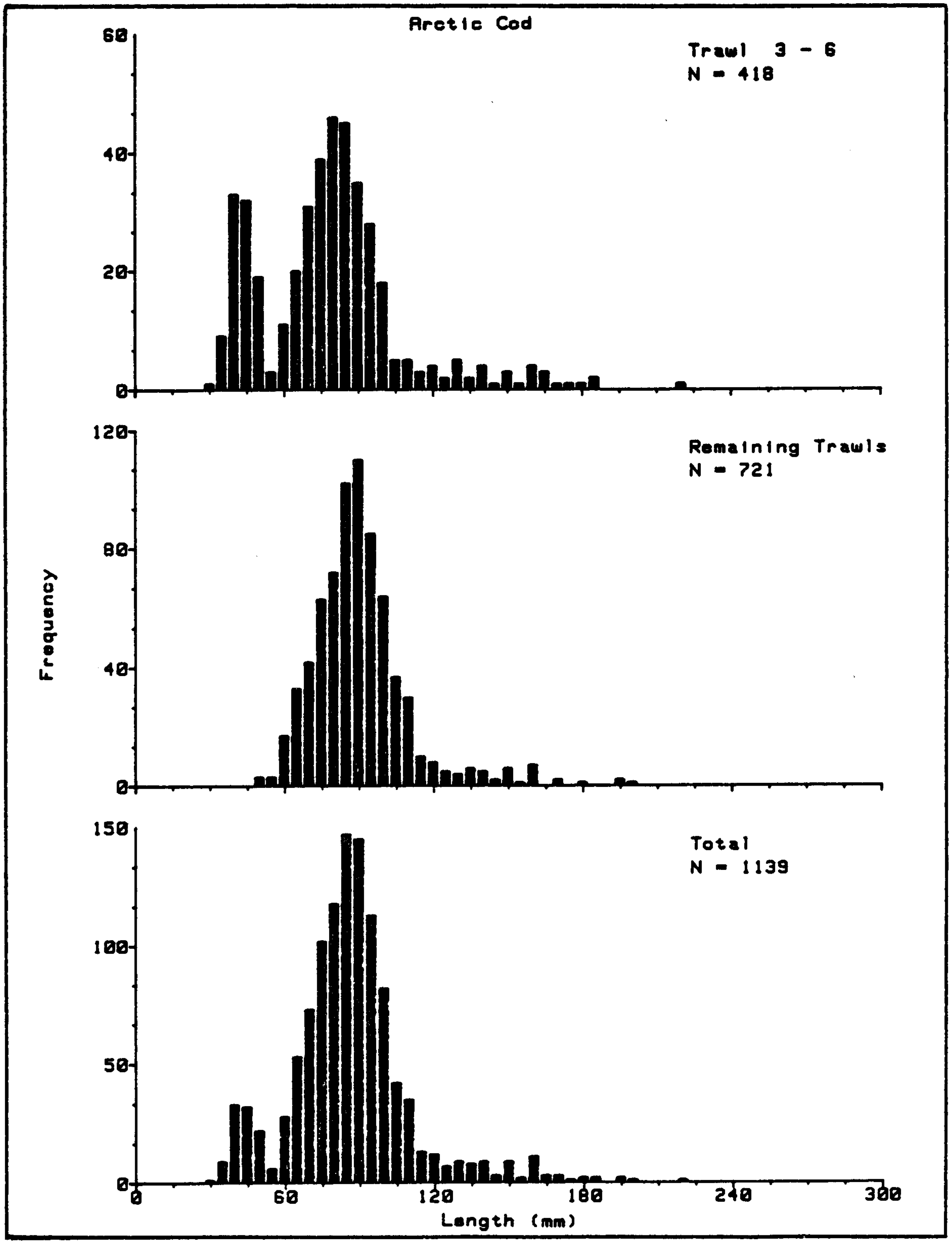


Figure 6-4. Length-frequency distributions of Arctic cod taken by otter trawl during the 25 August-13 September 1983 Discoverer cruise.

weight against stomachless body weight also revealed a significant ($P<0.01$) linear relationship within each station (Fig. 6-5). A test for homogeneity of slopes confirmed significant ($P<0.05$) differences in linear relationships between stations. Within the temporal limits of our sampling regime, Arctic cod taken at Ledyard Bay had consumed significantly more biomass per unit body weight than fish taken at Wainwright while cod from the Wainwright site had, in turn, consumed more biomass than Peard Bay fish.

Table 6-1. Wet weight of stomach contents expressed as a percent of stomachless body weight for Arctic cod taken at Peard Bay (Station 1), Wainwright (Station 2) and Ledyard Bay (Station 3).

Station	N	Mean	S.D.
1	33	0.67	0.72
2	26	2.22	1.65
3	16	4.96	2.35

To determine if the apparent difference in feeding intensity between locations was indicative of some longer term characteristic, length-weight relationships were analyzed for the three groups. Regressions of natural log (Ln) stomachless body weight versus Ln fork length showed significant ($P<0.01$) linear relationships within stations (Fig. 6-6). Analysis of covariance was performed on body weight using the covariate length, and the adjusted mean weight was found to be significantly ($P<0.05$) different between Stations 2 and 4 and between Stations 3 and 4. There was no significant ($P<0.05$) difference between Stations 2 and 3. Thus, fish in the northern part of the study area had achieved significantly less weight per unit length than fish of the same length from the southern part of the study area.

Identification of stomach contents for Arctic cod taken at Peard Bay was difficult due to the highly digested state of the relatively few organisms present. Of the 33 stomachs examined, 21% (7) were empty and 57% (19) had $\leq$0.01 g of wet weight content. Taxonomic identification was

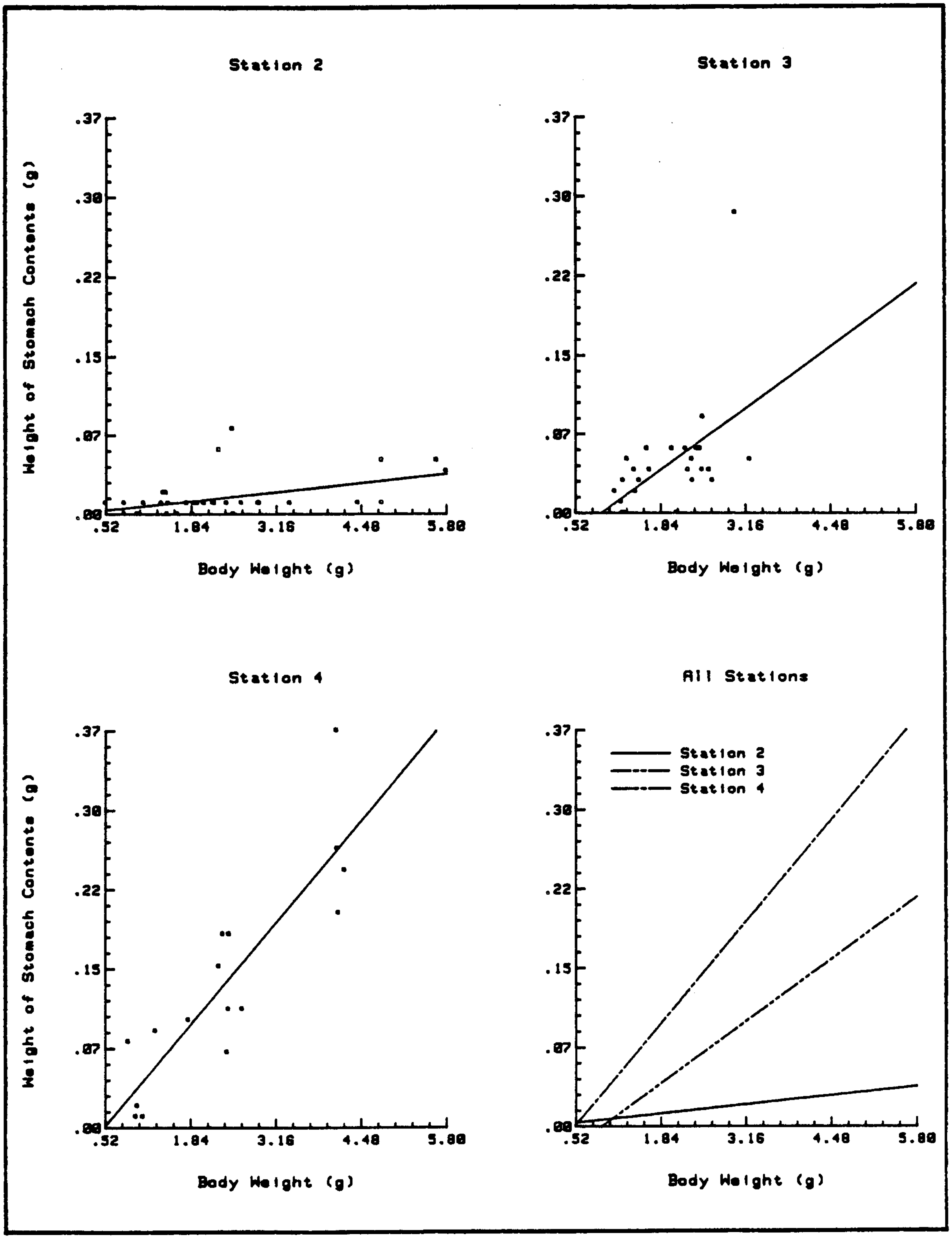


Figure 6-5. Regression plots of stomach content wet weight versus stomachless body weight for Arctic cod caught during the 15-28 March 1983 winter study.

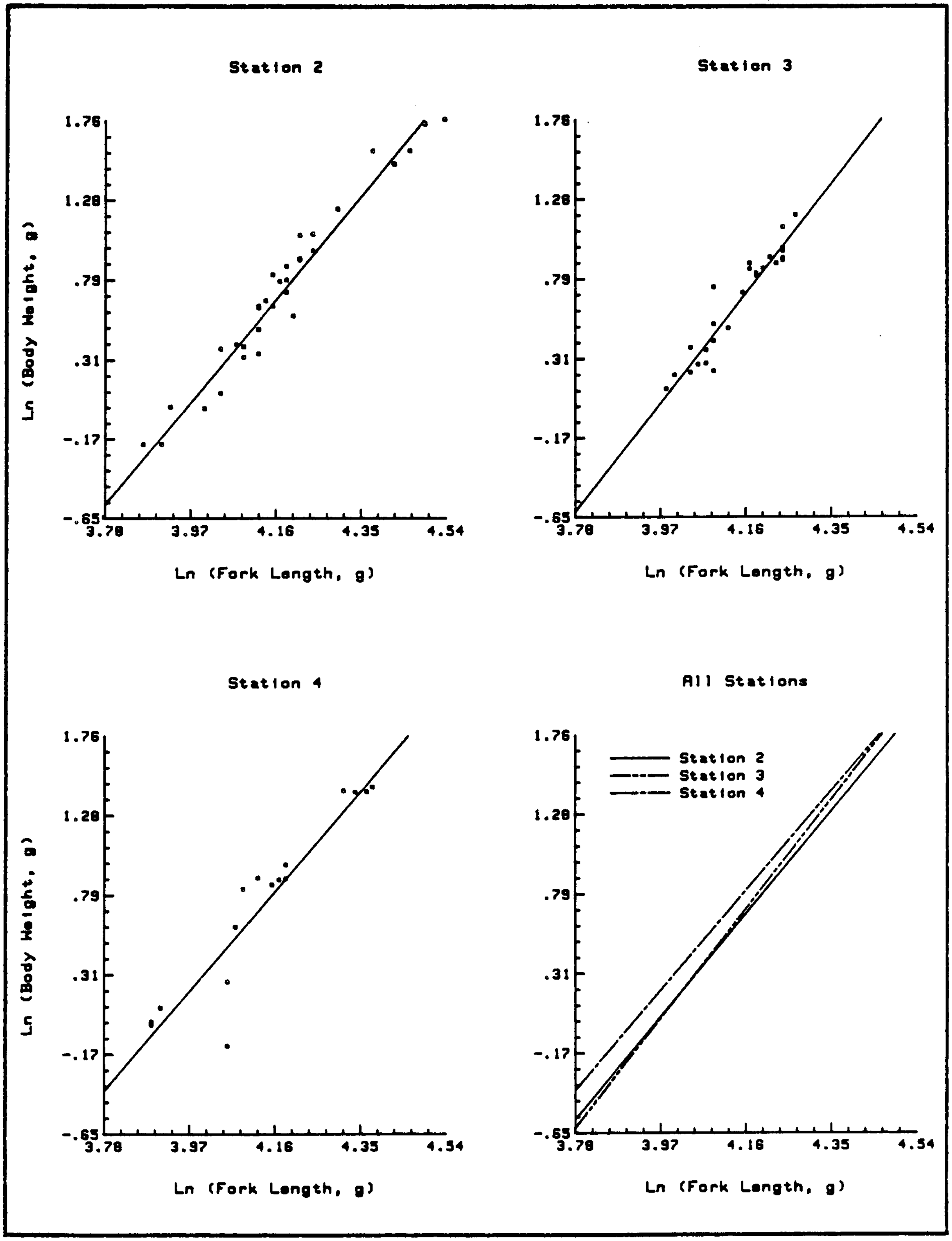


Figure 6-6. Regression plots of natural log (Ln) body weight versus Ln length for Arctic cod caught during 15-28 March 1983.

generally based on the presence of organism parts. This did enable a broad-based classification of major food groups in terms of occurrence, but did not permit a breakdown into biomass content.

In terms of percent occurrence, copepods were identified as the principle food item. They were present in 100% of the stomachs taken from Wainwright (N=24) and Ledyard Bay (N=16), but there was only a 57% (N=19) occurrence in Peard Bay fish. Mysids were present in 38, 25 and 18% of the fish from Peard Bay, Wainwright and Ledyard Bay, respectively. Amphipods occurred less than 10% of the time at Wainwright and Peard Bay, but did occur more frequently (38%) at Ledyard Bay.

Taxonomic classification of food items was more detailed for Arctic cod taken from Ledyard Bay. The planktonic/pelagic copepod, Calanus glacialis was by far the most prominent prey, constituting 85% of wet weight composition. The remaining biomass content was evenly divided between gammarid amphipods and mysids.

6.1.2.2 Discoverer Cruise. The stomachs of 141 Arctic cod taken at 10 different otter trawl stations were examined for content. In order to eliminate fish size as a dietary factor all analyzed specimens were 80-95 mm FL.

Food items varied considerably between stations (Table 6-2, Fig. 6-7). Benthic amphipods (Dyopedes sp., Ampelisca macrocephala) and cumacea (Diastylus rathkei) were dominant at Stations 3 (9+10) and 13 while pelagic/planktonic forms like decapod larvae, copepods (Calanus glacialis, Acartia longiremis) and the amphipod Apherusa glacialis were most prevalent at Stations 5, 20, 21 and 27. Both benthic and pelagic/planktonic fauna were observed at Stations 6, 7 and 18.

Arctic cod appear extremely adept at exploiting a variety of food sources and trophic niches. As pointed out by Lowry and Frost (1981), this trophic adaptatiliby may contribute to their overwhelming success in arctic marine waters.

6.1.3 St. Lawrence Island

Twenty Arctic cod taken off the mouth of the Fossil River ranged in size from 146-214 mm. All were males of uncertain reproductive status--at least several were considered to be immature fish based on a testes weight

Table 6-2. Stomach contents of Arctic cod (80-95 mm FL) taken by otter trawl during the 1983 *Discoverer* cruise. Values are percent total wet weight content followed parenthetically by the number of occurrences.

	Station									
Stomach Contents	3 (N=15)	5 (N=15)	6 (N=15)	7 (N=15)	9+10 (N=11)	13 (N=15)	18 (N=9)	20 (N=15)	21 (N=15)	27 (N=15)
Amphipod	-	-	-	6 (5)	-	-	1 (1)	* (1)	5 (3)	2 (1)
Dyopedes sp.	75 (15)	-	-	-	-	-	-	-	-	-
Protomedeia grandimana	* (1)	-	-	-	* (2)	* (1)	-	-	-	-
Acanthospephia incarinata	-	-	-	-	3 (2)	-	-	-	-	-
Pontogeneia rostrata	-	-	-	-	* (1)	-	-	-	-	-
Monoculodes zernovi	* (2)	-	1 (2)	-	5 (2)	-	-	-	-	2 (1)
Ampelisca macrocephala	3 (3)	-	-	-	* (1)	85 (15)	-	-	-	13 (1)
Byblis gaimardi	-	-	-	-	-	3 (5)	* (1)	-	-	-
Photes fischmannis	1 (3)	-	-	-	* (1)	-	-	-	-	-
Podoceropsis sp.	-	-	-	-	* (1)	-	-	-	-	2 (1)
Apherusa glacialis	-	11 (1)	28 (1)	-	-	-	-	-	-	-
Atylus sp.	-	-	-	-	-	-	-	* (1)	-	-
Anonyx nugax	-	-	-	-	-	-	-	-	1 (1)	-
Rhachotropis sp.	2 (1)	-	-	-	-	-	-	-	-	-
Copepod	-	-	-	2 (3)	-	-	-	-	-	35 (7)
Calanus glacialis	-	65 (15)	34 (10)	20 (5)	-	* (1)	-	97 (15)	2 (2)	-
Acartia longiremis	-	-	-	-	-	-	-	-	52 (14)	-
Pseudocalanus sp.	-	-	-	-	-	-	-	-	4 (3)	-
Cumacea	-	-	* (1)	4 (3)	-	-	2 (1)	-	18 (2)	-
Diastylus rathkei	1 (2)	-	5 (2)	5 (1)	72 (9)	* (1)	* (1)	-	12 (1)	2 (1)
Diastylus edwardi	13 (11)	-	-	-	7 (4)	* (1)	-	-	-	-
Eudorella sp.	-	-	* (1)	-	-	* (1)	* (1)	-	-	-
Diastylus sp.	-	-	-	33 (8)	-	-	-	-	-	-
Saggita elegans	-	* (2)	-	-	-	-	-	* (1)	1 (1)	-
Fish	-	12 (2)	3 (1)	-	-	7 (1)	47 (3)	-	-	-
Mysis	-	-	-	14 (3)	-	-	4 (1)	-	-	-
Mysis littoralis	1 (2)	1 (1)	24 (4)	13 (3)	6 (4)	-	43 (4)	-	2 (1)	-
Decapod larvae	-	7 (10)	* (1)	* (1)	-	* (1)	-	* (1)	-	40 (5)
Shrimp larvae	-	-	1 (1)	-	-	-	-	-	-	-

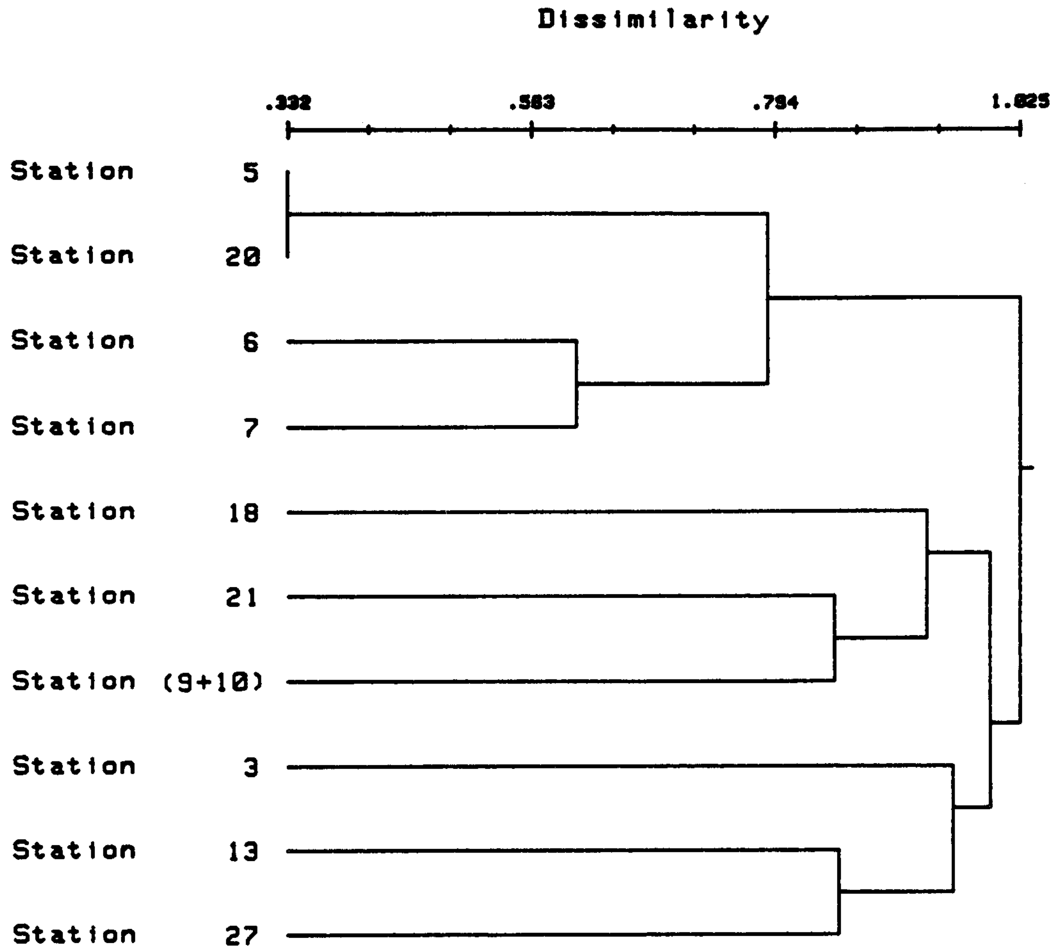


Figure 6-7. Cluster analysis dendrogram for 10 otter trawl stations based on stomach content of 80-95 mm FL Arctic cod.

of less than 0.1 g, while others appeared spawned out. The Arctic cod had little food (average 0.2 g) in their stomachs and of identifiable items, copepods (47%), decapods (45%) and amphipods (7%) were most prevalent.

6.2 Fourhorn Sculpin (*Myoxocephalus quadricornis*)

The fourhorn sculpin is a circumpolar marine spawner that is extremely tolerant of low salinities (Percy 1975. Kendall et al. 1975). They typically overwinter in deep, offshore waters and migrate into nearshore, brackish areas during summer to feed. Overwintering may also occur in the deltas of large river systems (Kogl and Schell 1974, Craig and Haldorson 1981).

In the nearshore waters of the Alaskan and Canadian Beaufort Sea, the fourhorn sculpin is one of the most abundant species (Griffiths et al. 1975. Kendall et al. 1975, Griffiths et al. 1977, Bendock 1979, Craig and Haldorson 1981, Griffiths and Gallaway 1982, Griffiths et al. 1983). This was also the case in lagoon and nearshore waters in the vicinity of Point Lay. This species ranked third in numerical dominance, being exceeded only by Arctic cod and capelin.

The average daily catch rates of fourhorn sculpin taken by fyke net are shown in Figure 6-8. Daily catch varied markedly throughout the season with sharp spikes in CPUE occurring on 19-23 July, 3 August, 20 August and 27-28 August. This trend again corresponds with the water quality differences described in the Catch Summary, Section 5.3.2. The tendency for fourhorn sculpin to prefer nearshore areas during summer is evidenced by comparing the Point Lay and *Discoverer* catch data. While nearly 20% (2845 fish) of the Point Lay catch consisted of fourhorn sculpin, this species accounted for only 4 of 7747 total fish taken by otter trawl in offshore waters. The four individuals were caught 1.6 km off Point Lay at Station 10. All 10 fourhorn sculpin caught by *Discoverer* gill nets came from Station 7 located 1.6 km off Wainwright.

6.2.1 Size

Sculpin taken at Point Lay ranged in total length from 35-275 mm. All of the 202 fish taken by gill net exceeded 80 mm in length (Fig. 6-9), while fyke nets took fish ranging in size from 35-265 mm (Fig. 6-10). The

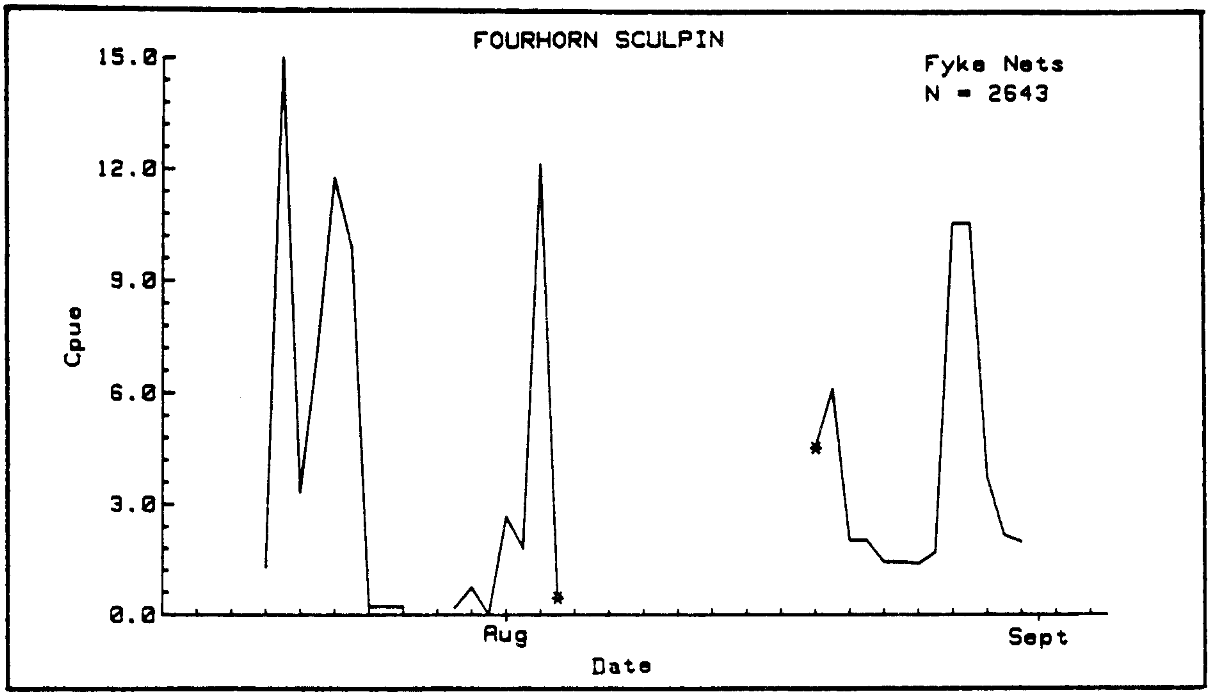


Figure 6-8. Daily catch rate (figh/h) of fourhorn sculpin taken by Point Lay fyke nets during July-August 1983.

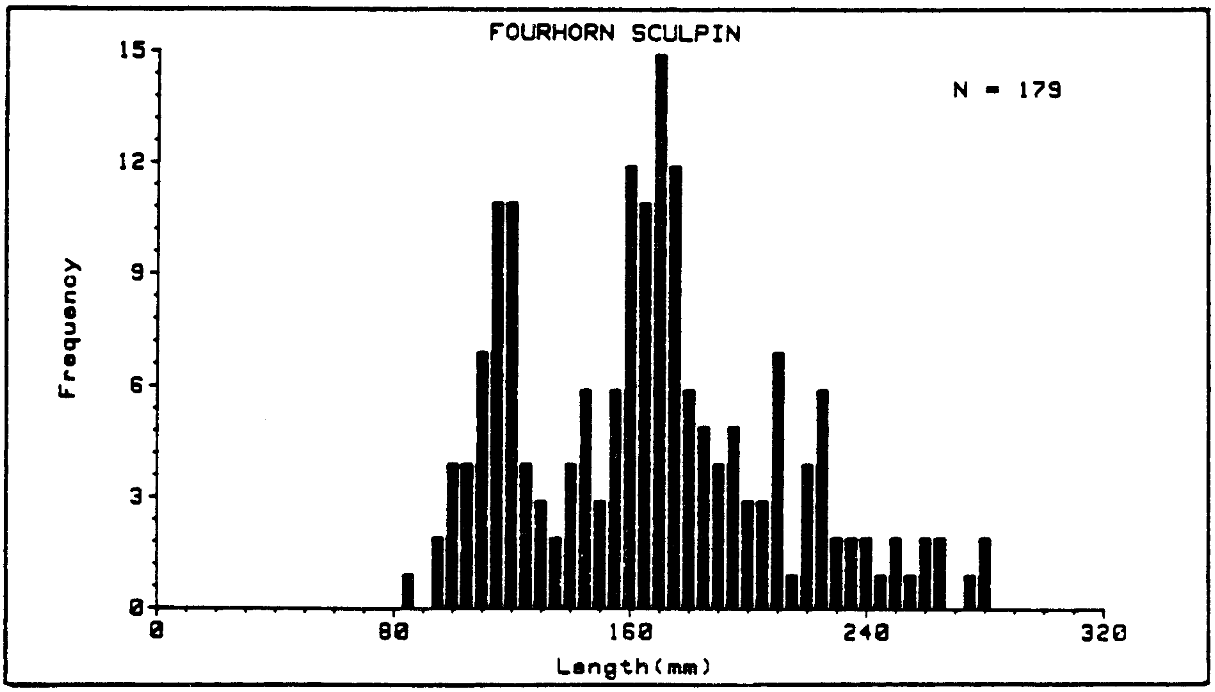


Figure 6-9. Length-frequency distribution of fourhorn sculpin taken by Point Lay gill nets during July-August 1983.

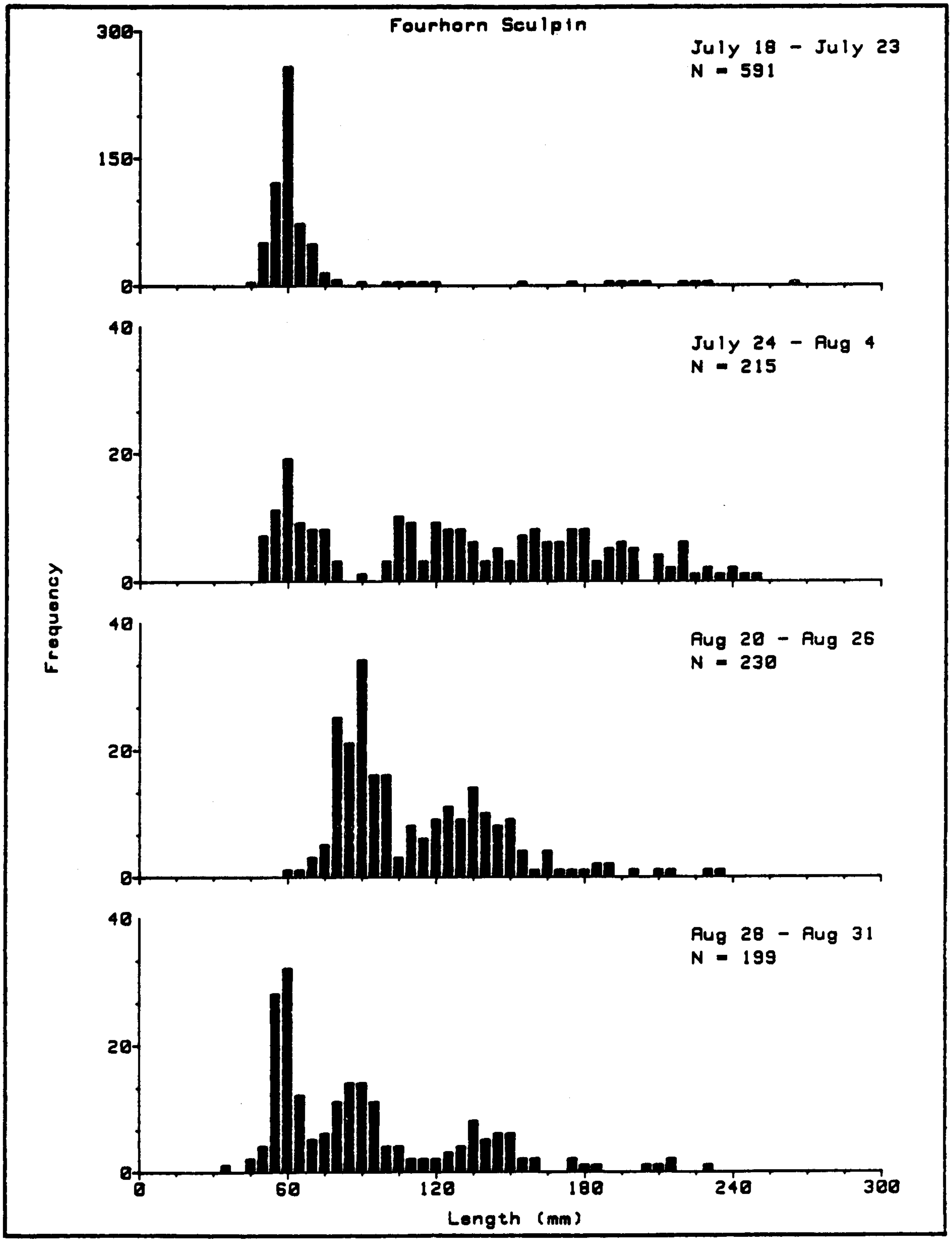


Figure 6-10. Length-frequency distributions of fourhorn sculpin taken by Point Lay fyke nets during July-August 1983.

most dramatic presence of a dominant size cohort is in the 18-23 July ocean fyke net data. Better than 78% of the 591 sculpin measured were 40-80 mm in total length with a distinct modal peak at 60 mm. This group probably represents a one-year-old age class (Craig and Haldorson 1981). From 24 July-4 August there was a more uniform representation of all sizes.

The length-frequency distribution of fourhorn sculpin taken by the lagoon fyke from 20-26 August was bimodal at 90 and 135 mm. Again, assuming similar age-length relationships described by Craig and Haldorson (1981) for Beaufort Sea sculpin, these two size cohorts should denote two and three year old fish. The one year old size class again dominates during the season's last four days (28-31 July). The reason for this smaller cohorts absence from 20-26 August is unclear.

The length-weight regression for fourhorn sculpin taken at Point Lay was:

$$\text{Log Weight (g)} = -6.4+3.6 \text{ Log Length (mm)}; \ r^2=0.99, \ N=17$$
$$\text{or} \quad \text{Ln Weight (g)} = 14.7+3.6 \text{ Ln Length (mm)}$$

This is similar to the relationship reported for fourhorn sculpin taken at Simpson Lagoon (Craig and Haldorson 1981).

6.2.2 Reproductive Status

Only 16 specimens were examined; 12 of which were females and 4 were males. Gonad weight as percent body weight averaged 5.1% (range: 3.8-10.0%, SD=2.2) for females and 7.1% (range: 4.1-9.0%, SD=2.8) for males.

6.2.3 Food Habits

In terms of percent total wet weight content, fourhorn sculpin (N=31, 115-275 mm TL) fed primarily on the isopod *Saduria entomon* (65-73%), fish (17-21%) and amphipods (2-4%) (Table 6-3). Empty stomachs occurred 21% of the time. Dietary preference was similar for fish taken on both the lagoon and ocean side of the barrier island. These three food groups were also found in sculpin taken from the Beaufort Sea (Percy 1975; Kendall et al. 1975; Griffiths et al. 1975, 1977; Craig and Haldorson 1981), however, isopods and amphipods were the two prevalent prey. The dominance

Table 6-3. Food items of fourhorn sculpin (115-275 mm TL) taken by gill net at Point Lay from 3-29 August, 1983. Values are percent wet weight composition followed parenthetically by number of occurrences.

Food Item	Lagoon N = 13		Ocean N = 17	
Plant	* (2)		-	
Pebble	1 (1)		* (3)	
Unidentified	* (1)		6 (7)	
Ephemoptera nymph	* (1)		-	
Cirripede larvae	* (1)		-	
Bivalve	* (1)		-	
Decapod shrimp	-		4 (4)	
Polychaete	-		* (3)	
Saduria entomon	81 (9)		65 (17)	
Unidentified amphipod	* (1)		* (2)	
Onisimus glacialis	* (1)		-	
Onisimus littoralis	-		2 (9)	
Lysianassid	* (1)		* (1)	
Gammarus setosus	* (3)		1 ( )	
Pontoporeia affinis	* (2)		-	
Total Amphipods		1 (5)		4 (14)
Mysis littoralis	* (5)		* (1)	
Mysis relicta	* (2)		-	
Total Mysids		* (6)		* (1)
Unidentified fish	6 (3)		8 (3)	
Fourhorn sculpin	* (2)		-	
Arctic cod	9 (3)		13 (6)	
Saffron cod	-		* (1)	
Total Fish		15 (7)		21 (10)

*<1%.

of *Saduria entomon* in summer is contrary to results reported by Craig and Haldorson (1981). Their study showed amphipods (49%) to be the dominant food item followed by isopods (6%), mysids (6%) and fish (3%). Interestingly, isopods became the major food source during winter (1977-1978:60%, 1978-1979:78%) at Simpson Lagoon.

6.3 Capelin (*Mallotus villosus*)

The capelin is a marine osmerid with a Pacific distribution throughout Alaska and arctic Alaska (Hart 1973). Spawning takes place in shallow, nearshore areas.

Although capelin was the second most abundant species collected during the Point Lay summer study, all but 2 of 3360 specimens were taken within a three-day period from 1-3 August (Fig. 6-11). No capelin were taken by otter trawl or gill net during the *Discoverer* cruise.

Capelin ranged in size from 110-155 mm FL with a single mode at 130 mm (Fig. 6-12). These fish were slightly larger than capelin caught in Simpson Lagoon in 1979 (Craig and Haldorson 1981).

6.3.1 Reproductive Status

The capelin taken during 1-3 August were apparently part of a spawning population. Egg sizes of ripe or nearly ripe females averaged 0.8 mm mm (range: 0.7-1 mm, N=29) and ovaries of non-spawned individuals averaged 19% (range: 10-25%, SD3.6, N=21) of total body weight. A number of spawned out individuals were also taken. Spawning may have been restricted to the seaward shoreline of the barrier island at Point Lay since no capelin were taken in the lagoon itself (Schmidt and Craig, in press). Paulke (1983) reported that this species spawns earlier (April to July) at various locations in the Bering Sea. In southern British Columbia, capelin spawn in late September or early October (Hart 1973)

6.3.2 Age and Maturity

Capelin mature at an earlier age than almost any other fish species in the Arctic. The spawning population at Point Lay consisted almost entirely (94%) of Age 2 fish (otolith based age), with the remaining 6% being Age 3. All but one male and one female were mature. Paulke (1983)

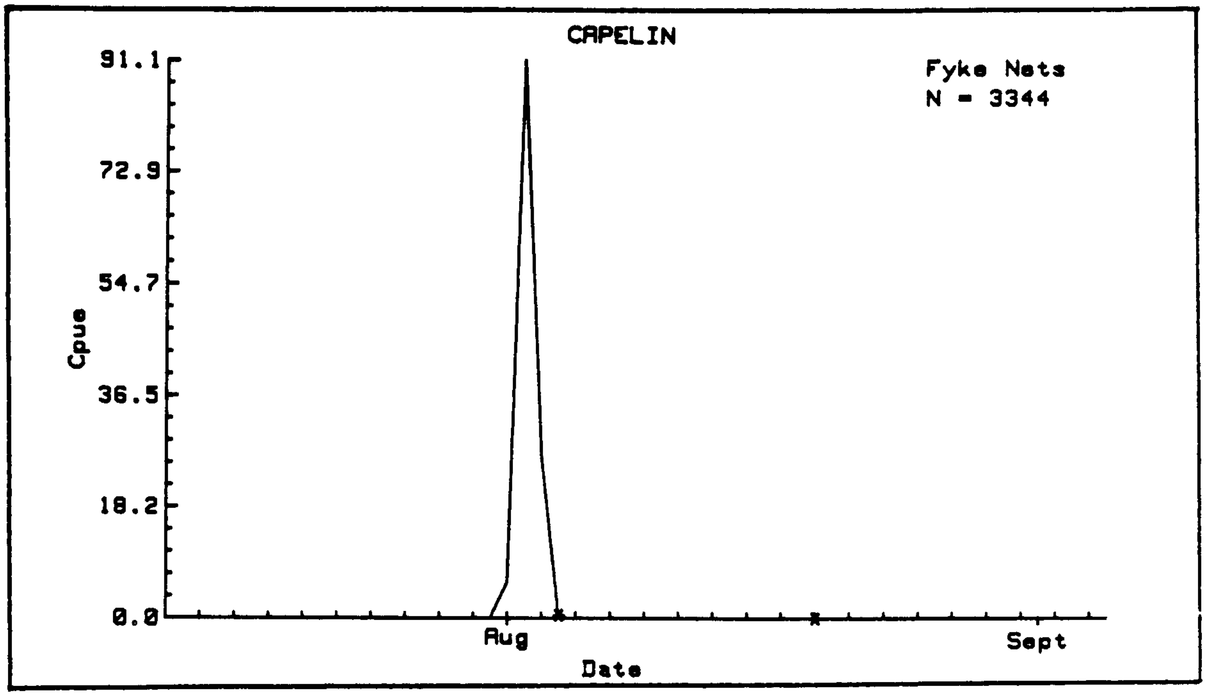


Figure 6-11. Daily catch rate (fish/h) of capelin taken by Point Lay fyke nets during July-August 1983.

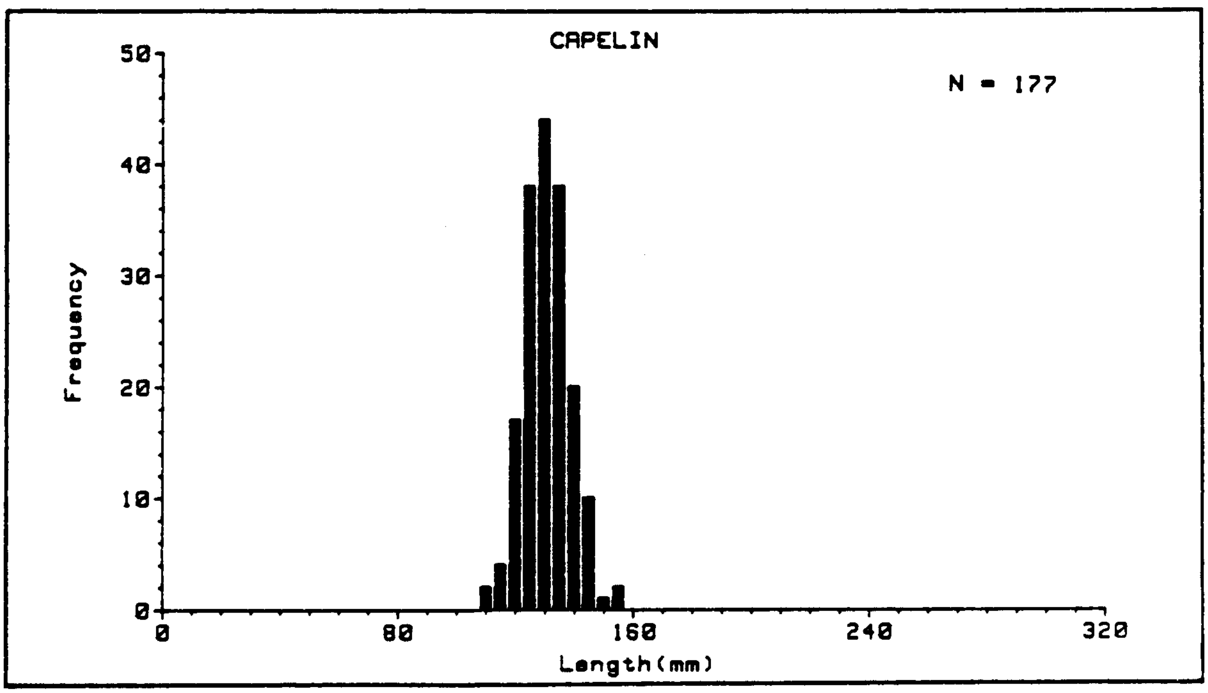


Figure 6-12. Length-frequency distribution of capelin taken by Point Lay fyke nets during July-August 1983.

found that although both age classes spawned in the Bering Sea, three-year-olds were most prevalent.

Males were generally about 10 mm longer than females, a fact also noted by Paulke (1983). At Age 2, females averaged 123.1 mm FL (range: 108-138 mm, SD=6.9, N=36) compared to 134.7 mm for males (range: 127-143 mm, SD=6.1, N=10). The only Age 3 fish in the collection were a 133 mm female and two males, 147 and 152 mm FL.

The length-weight regression for a sample of capelin from Point Lay was:

$$\text{Log Weight (g)} = -7.2+3.9 \text{ Log Length (mm)}; \; r^2=0.82, \; N=61$$
$$\text{or Ln Weight (g)} = -16.7+3.9 \text{ Ln Length (mm)}$$

6.3.3 Food Habits

Capelin were the most selective feeders of any of the fish examined. While 60% of the 52 stomachs checked were empty, the remaining 14 contained only one identifiable prey. Mysis littoralis occurred in all 14 stomachs and accounted for ~95% of total wet weight content. It should be noted that the capelin examined were taken from fyke net catches and data could reflect unnatural feeding circumstances. Fourhorn sculpin and Arctic cod, for example, feed on fauna which becomes trapped in fyke nets.

6.4 Saffron Cod (Eleginus navaga)

Saffron cod are marine fish which generally inhabit nearshore areas and often enter rivers (Morrow 1980). They spawn annually in nearshore waters during winter. While their distribution is generally limited to the northern Pacific Ocean, Bering and Chukchi seas, small numbers are present in the Canadian and Alaskan Beaufort Sea (Percy 1975, Kendall et al. 1975, Bendock 1977, Craig and Haldorson 1981, Griffiths and Gallaway 1982, Griffiths et al. 1983).

The 269 saffron cod taken at Point Lay constituted less than 2% of the total catch. Taken primarily (99%) by fyke net, the catch during the 18 July-4 August sampling period was essentially limited to 26 July, 1

August and 3 August (Fig. 6-13). A more consistent daily catch was noted during the latter half of August.

Length-frequency distributions differed between the two summer sampling periods at Point Lay (Fig. 6-14). From 18 July-4 August the distribution was monomodal at 90 mm with a size range of 80-125 mm FL. The distribution was bi-modal during 19-31 August with approximate modes at 70-75 mm and 120 mm. Fish from the smaller size cohort were taken primarily on 28 and 31 August.

Otolith aging was not performed on saffron cod caught during this study; however, determinations made by Craig and Haldorson (1981) for specimens taken in Simpson Lagoon indicated a length range of 79-192 mm for Age 1 fish and 145-242 mm for Age 2 fish. They concluded that the growth rate of these fish were generally similar to that reported for young saffron cod in Siberia (Andriyashev 1954). While growth rates for a particular species may be expected to vary with geographic location, it is likely that the 45-75 mm size cohort which appeared in Point Lay on 28 and 31 August represents young-of-the-year for this winter spawning species.

The length-weight regression for a sample of saffron cod taken from Point Lay was:

$$\text{Log Weight (g)} = -5.3+3.1 \text{ Log Length (mm)}; \; r^2=0.99, \; N=16$$

$$\text{or} \quad \text{Ln Weight (g)} = -12.1+3.1 \text{ Ln Length (mm)}$$

All of the saffron cod caught during the Discoverer cruise were taken by otter trawl. Fifth in numerical abundance, the 1090 specimens represented 5% of total catch. Most (83%) of these fish were taken at four locations--72 at Station 12 (Utokuk Pass), 106 at Station 21 (Ledyard Bay), 491 at Station 22 (Ledyard Bay) and 263 at Station 29 (50 km SE of Point Hope). Length-frequency distributions at the four sites were monomodal at about 60-65 mm FL (Fig. 6-15) which is similar to the smaller, and presumably young-of-the-year, cohort fyke-netted at Point Lay during the last few days of August.

Three sexually mature saffron cod were taken at trawl Station 29--two females (260, 280 mm) and one male (300 mm). No specimens were taken by Discoverer gill nets.

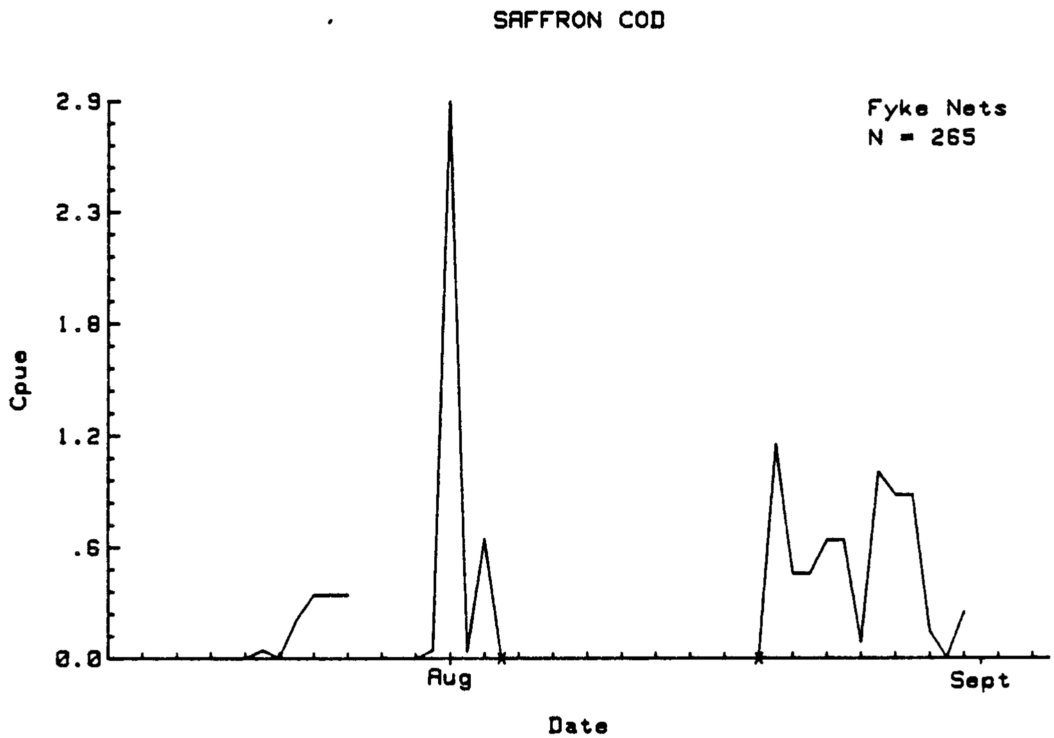


Figure 6-13. Daily catch rate (fish/h) of saffron cod taken by Point Lay fyke nets during July-August 1983.

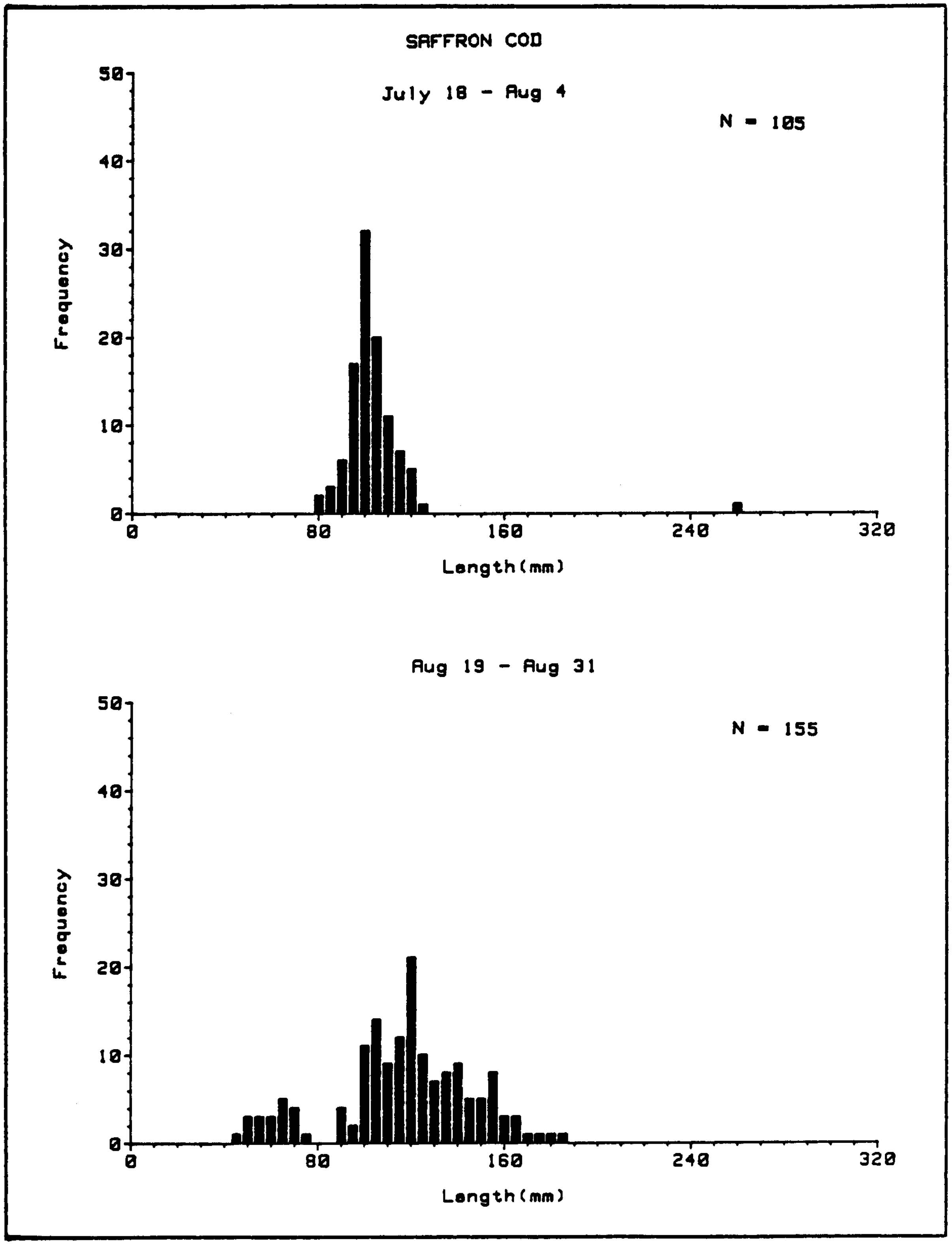


Figure 6-14. Length-frequency distributions of saffron cod taken by Point Lay fyke nets during July-August 1983.

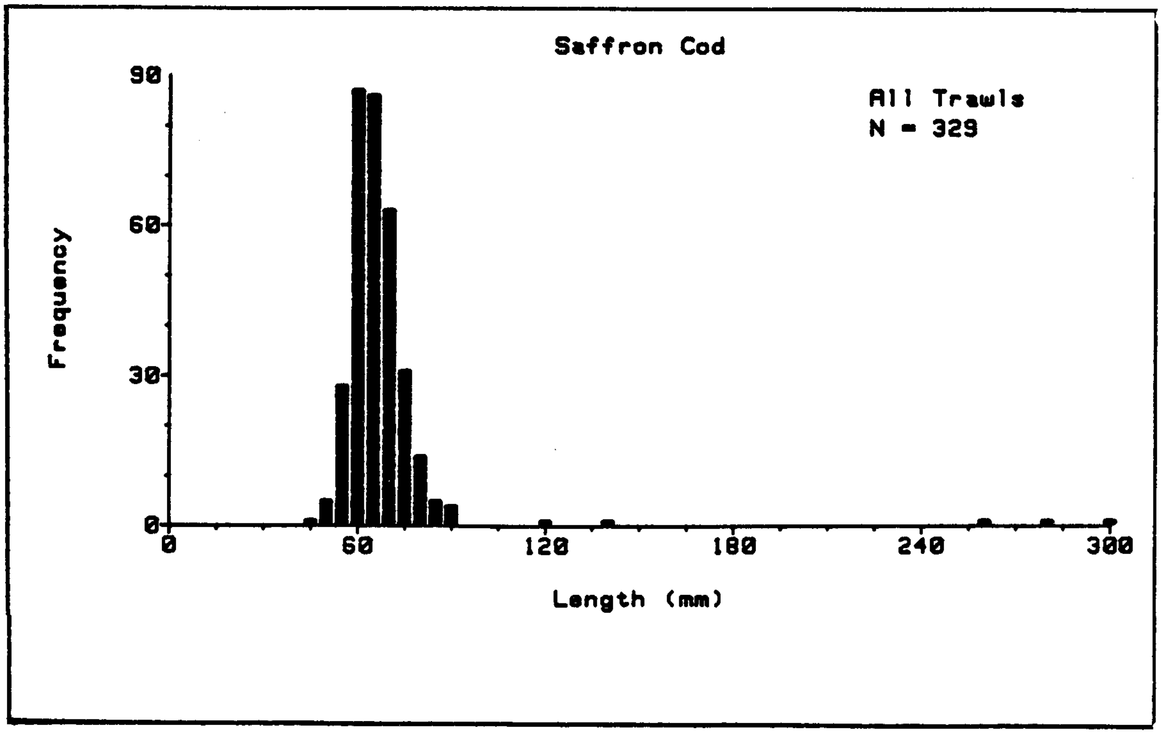


Figure 6-15. Length-frequency distributions of saffron cod taken by otter trawl during the 25 August-13 September 1983 Discoverer cruise.

6.4.1 Kotzebue

The sample consisted almost entirely of large, mature fish that were approaching a spawning condition. The average fork length was 238 mm (n=33, range=207-283 mm). Most were females (79) and all but one of each sex were mature. Egg diameters of females averaged 0.9 mm (n=11, SD=0.16, range=0.6-1.1 mm).

Only three fish (9%) in the Kotzebue sample had empty stomachs; the rest had eaten fish (68% total wet weight content), mysids (18%), mostly Neomysis rayii, and decapods (13%).

6.4.2 St. Lawrence Island

Twenty saffron cod were jigged through the ice near St. Lawrence Island in February 1983. They ranged in size from 231-345 mm FL (mean 290 mm, SD=31.5) and all were spawned out males. Most were 3-6 years of age, with two fish tentatively aged at 2 (otoliths were broken and burned to determine ages). These fish had eaten well as indicated by the amount of food in their stomachs (average 4.2 g of ingested food). Major food items were gammarid amphipods (58% of total wet weight content), fish (21%), mostly saffron cod and sculpins, and polychaetes (16%).

6.5 Pacific Herring (*Clupea harengus pallasi*)

The Pacific herring is a marine fish which is distributed along the North American coast from Cape Bathurst in the Canadian arctic to as far south as Baja, California (Hart 1983). The bulk of the population lies south of the Bering Straits and has been commercially exploited since the early 1900's. Population density in the Chukchi appears to be low and attempts to develop a herring fishery have been unsuccessful.

Spawning grounds are usually located in high energy, nearshore environments with spawn being deposited on vegetation or on bottom substrate which is free from silting (Haegele and Schweigert 1983). Pacific herring are spring spawners and spawning occurs earlier in the year for more southerly populations.

Except for four individuals taken by otter trawl, all of the herring caught at Point Lay and during the *Discoverer* cruise were taken by gill net. At Point Lay the 527 Pacific herring ranked fifth in abundance among all fish caught. Pacific herring were taken at 11 of 14 *Discoverer* gill-net stations with 14 of 46 total fish coming from Station 14 located 20 km off the Ledyard Bay coast.

6.5.1 Size.

With the exception of a single 120 mm individual, Pacific herring taken at Point Lay ranged in size from 205-295 mm FL (Fig. 6-16). Their length-frequency distribution was monomodal at 260 mm. Specimens taken by *Discoverer* gill nets ranged in size from 185-290 mm FL with 90% of the fish measuring $\leq$225 mm or $\geq$260 mm.

The length-weight regression for a sample of Pacific herring taken at Point Lay was:

$$\text{Log Weight (g)} = 4.0 + 2.6 \text{ Log Length (mm)}, \ r^2 = .45, \ N = 82$$

$$\text{Ln Weight (g)} = -9.2 + 2.6 \text{ Ln Length (mm)}$$

6.5.2 Reproductive Status

Both sexes were well represented in both the Point Lay (34 males, 48 females) and *Discoverer* (17 males, 18 females) samples.

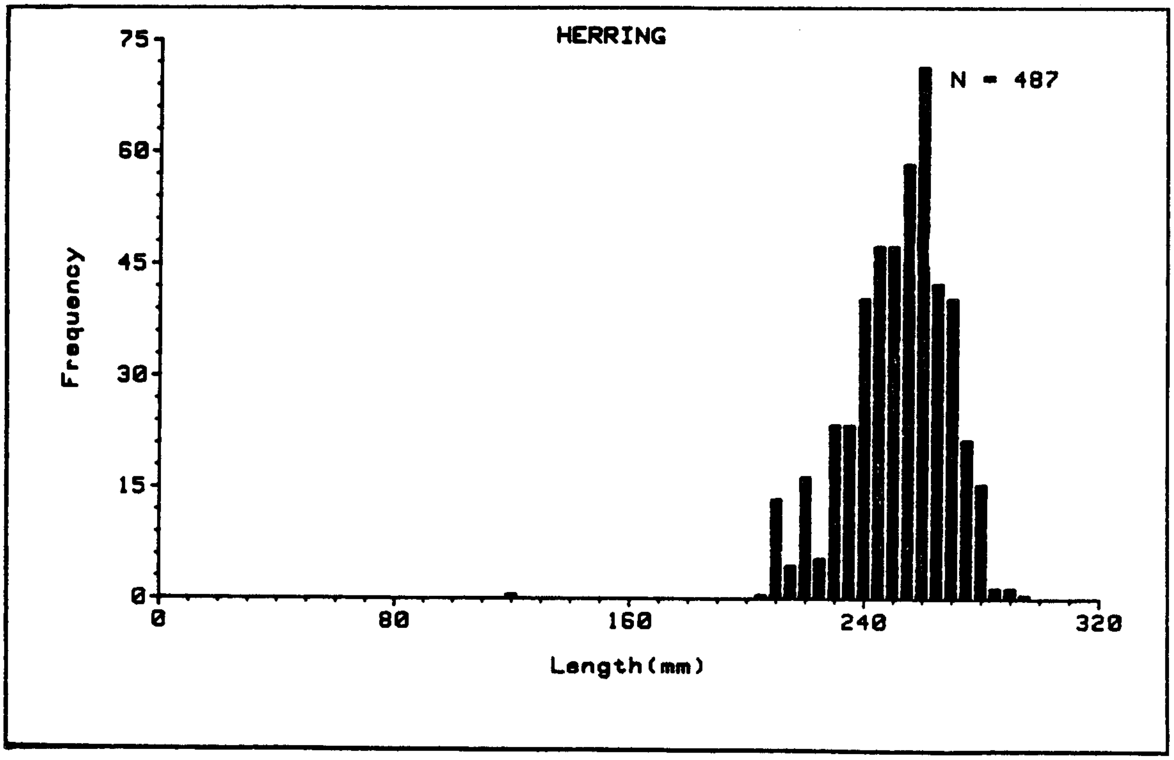


Figure 6-16. Length-frequency distribution of Pacific herring taken by Point Lay gill nets during July-August 1983.

There is evidence that herring may have spawned in the Kasegaluk Lagoon area during early summer. Gonad weight (as % body weight) for males (Fig. 6-17) and females (Fig. 6-18) increased from low levels during August (Fig. 6-17). Eggs were miniscule (~0.1-0.2 mm) at the beginning of the month but averaged 0.5 mm (range 0.2-1.0, SD=0.2, N=14) for females taken after 23 August. Hay (1983) reported that most British Columbia herring begin sexual maturation in late summer and become sexually mature in the subsequent spring.

There was no trace of young-of-the-year herring throughout the end of the summer at Point Lay. Morris (1980) states that young herring may attain sizes up to 100 mm during their first summer, however, this figure is probably associated with more southerly populations which spawn earlier and inhabit warmer waters. Young fish may have been too small for our fyke nets or may have moved offshore.

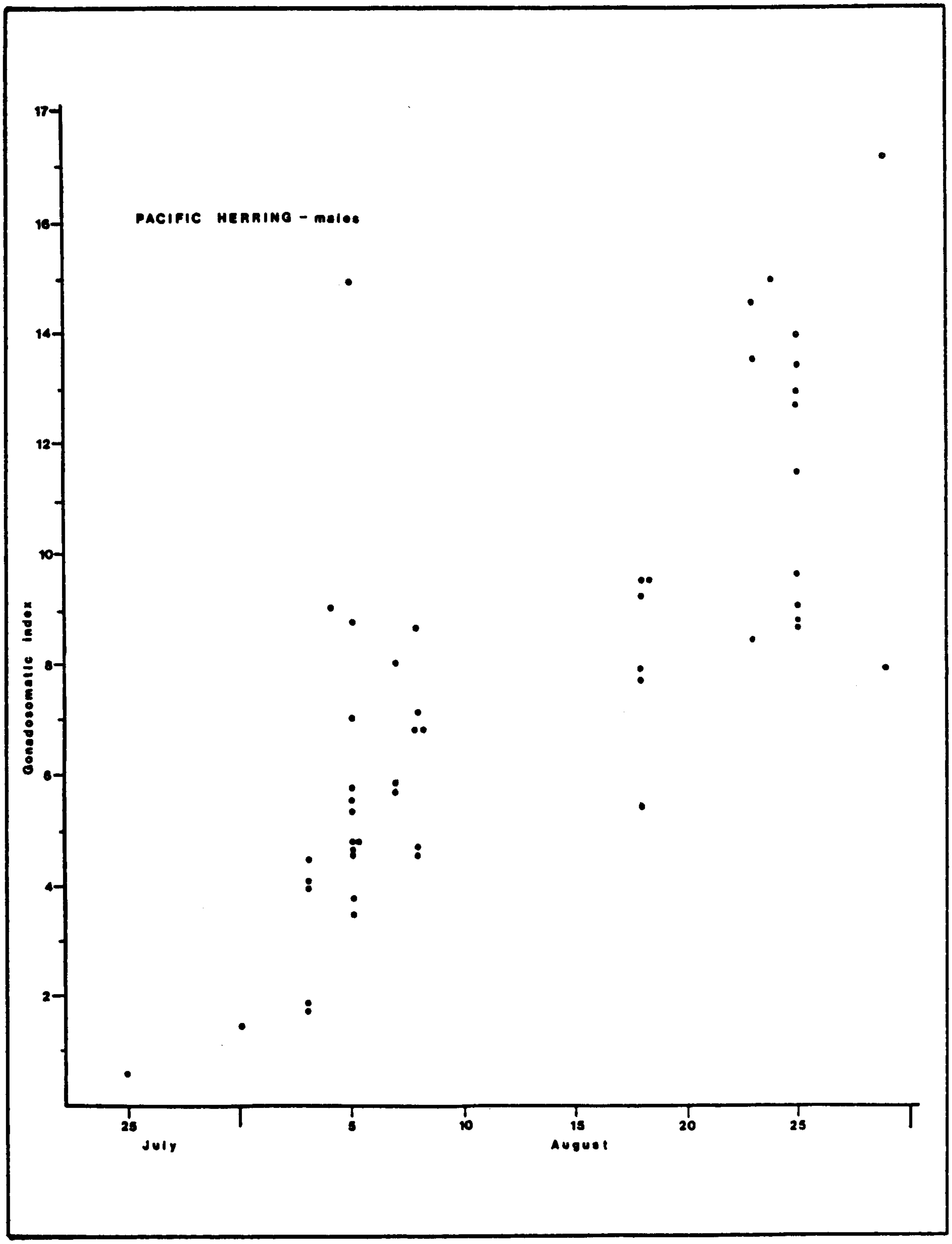


Figure 6-17. Gonadosomatic index (teste weight/body weight) for male Pacific herring taken at Point Lay in 1983. Included are specimens reported by Schmidt and Craig (in press).

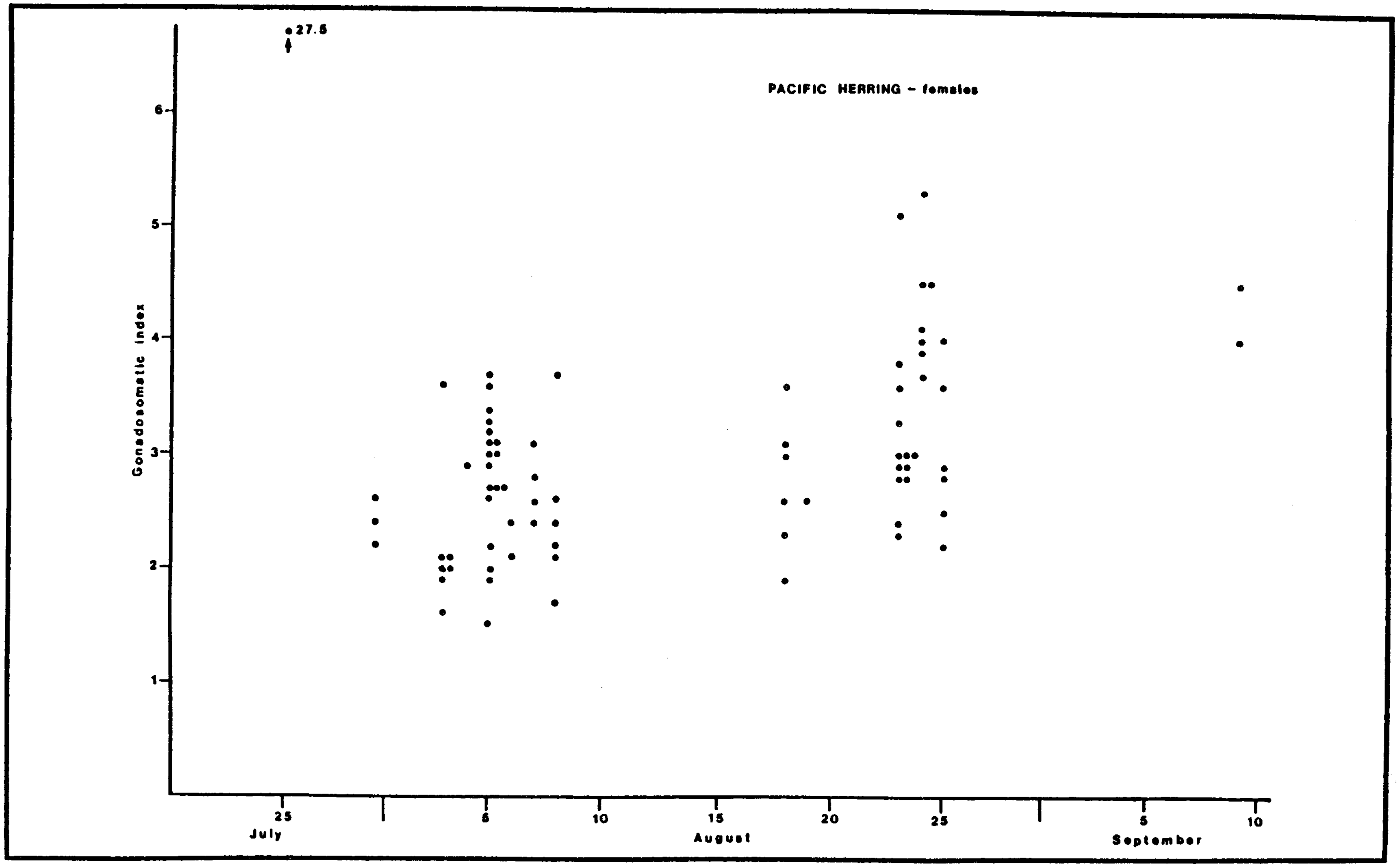


Figure 6-18. Gonadosomatic index (ovary weight/body weight) for female Pacific herring taken at Point Lay in 1983. Included are specimens reported by Schmidt and Craig (in press).

6.5.3 Feeding Habits

Pacific herring (210-285 mm FL) gill-netted during the Point Lay study fed primarily on *Mysis litoralis* and, to a lesser extent, fish (Table 6-4). Opportunistic feeding patterns are evident when the diets of fish caught on the seaward side of the barrier islands are compared with individuals gill-netted in the lower reaches of the Kokolik River (Schmidt and Craig, in press). The calanoid copepod *Temora* sp. accounted for 56% of stomach content in river-caught fish, with mysids and fish larvae constituting 17% each. *Temora* sp. were totally absent from in-ocean-caught herring and *Mysis litoralis* became the dominant mysid representative.

6.6 Boreal Smelt (*Osmerus mordax*)

The boreal smelt lives in marine and brackish water but returns to freshwater streams and lakes to spawn. Their arctic distribution extends from Vancouver Island around Alaska to Cape Bathurst in the Canadian arctic (Hart 1973).

A total of 304 boreal smelt were captured during the Point Lay study--134 by fyke net and 170 by gill net. Among all fish, they ranked seventh in abundance and made up 2.2% of the total catch. There was a marked absence of smelt in late July. All but one of the fyke-netted smelt were captured at Station 2 (lagoon) after 19 August (Fig. 6-19) and only six individuals were gill-netted prior to 3 August.

Smelt were not caught far offshore. Station 3, located 1.5 km offshore, caught only one individual during a total of 14.6 net-days (bottom and surface nets), however, they were taken by lagoon and nearshore ocean gill nets. Boreal smelt appear to prefer the bottom of the water column, at least when traveling seaward of the barrier islands. All but one of 77 fish taken at gill net Station 4 (depth 8 m) were caught in the bottom net.

Otter trawls accounted for only one boreal smelt, however, 33 individuals were taken by *Discoverer* gill nets. Of these, three were captured 1.5 km off Point Lay (Station 1) and the remainder within 1.5 km of Wainwright--28 at Station 7 (0.75 km) and two at Station 8 (1.5 km).

Bendock (1977) also reported a concentration of boreal smelt off the Kuk River near Wainwright.

6.6.1 Size and Age

Gill-netted fish taken at Point Lay ranged in size from 120-300 mm FL, however, a strong modal peak was apparent from 220-230 mm (Fig. 6-20). The length-frequency distribution of boreal smelt captured by fyke net showed a multimodal configuration containing distinct aggregations in the 50-70 mm and the 85-125 mm range (Fig. 6-21). A more even distribution was evident from 195-270 mm. The August catch showed size related variations in daily catch. Fish greater than 130 mm were taken from 19-26 August but were completely absent from 27 August onward. The smaller 50-70 mm size cohort showed up on 28 August until the 31 August conclusion of the sampling effort.

Table 6-4. Food items of Pacific herring (210-285 mm FL) taken by gill net at Point Lay during summer 1983. Values are percent wet weight composition followed parenthetically by number of occurrences.

Food Item	Ocean: 3-5 August N=11		River[1]: 5 August N=18		Ocean: 24-29 August N=25	
Plant	* (1)		* (11)		* (7)	
Pebble	-		* (2)		* (3)	
Unidentified	19 (11)		11 (11)		* (2)	
Errant polychaete	-		-		* (2)	
Cumaces	* (1)		-		6 (5)	
Saduria entomon	* (1)		-		-	
Calanoid	6 (1)		* (1)		-	
Calanus glacialis	* (1)		* (1)		-	
Temora sp.	-		56 (18)		-	
Cyclopoid	-		* (1)		* (1)	
Harpactecoid	-		* (9)		* (1)	
Total Copepods		6 (2)		57 (18)		-
Unidentified amphipod	* (2)		-		-	
Onisimus littoralis	-		-		* (3)	
Lysianassid	-		* (2)		-	
Oediceroid	-		-		* (2)	
Pontoporeia affinis	-		-		* (2)	
Total Amphipods		* (2)		* (2)		* (5)
Unidentified mysid	-		* (3)		* (1)	
Mysis littoralis	43 (10)		& (11)		81 (20)	
Mysis relicta	-		7 (4)		* (2)	
Neomysis sp.	-		2 (3)		2 (4)	
Total Mysids		43 (10)		17 (15)		84 (20)
Fish larvae	24 (2)		17 (6)		* (3)	
Arctic cod	-		-		* (1)	
Fourhorn sculpin	7 (1)		-		2 (1)	
Sand lance	-		-		5 (2)	
Total Fish		31 (3)		17 (6)		8 (7)

[1]Schmidt and Craig (in press).
*<1%.

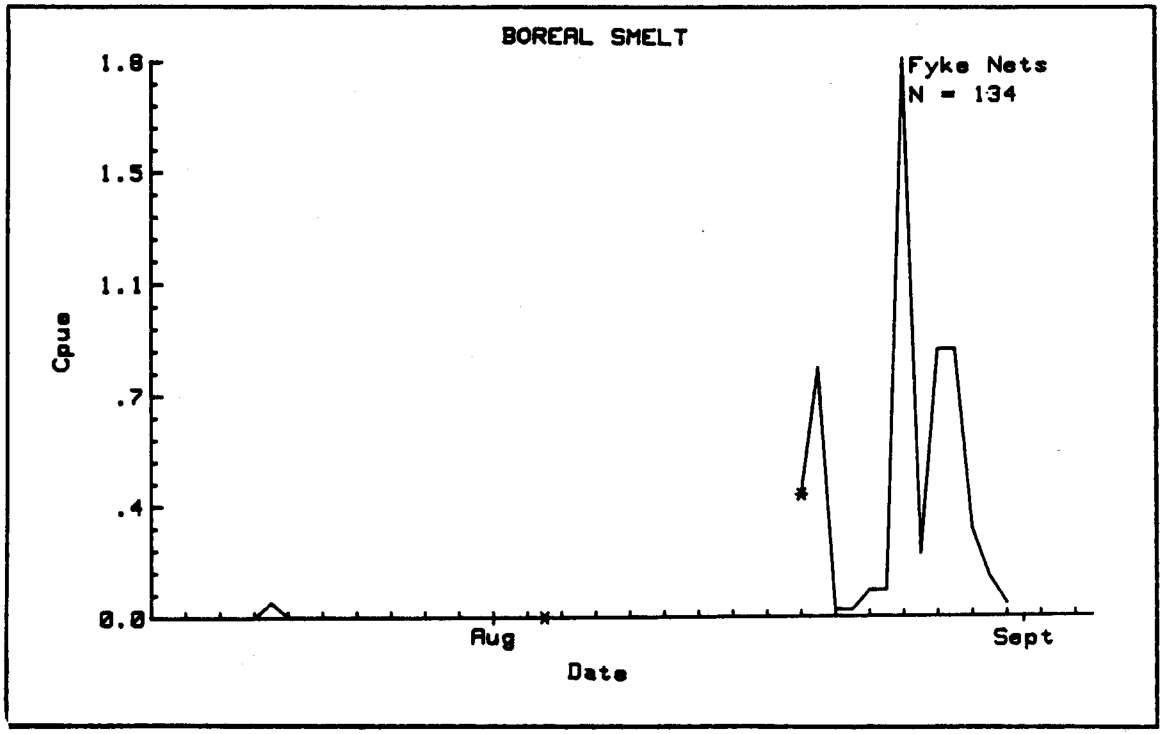


Figure 6-19. Daily catch rate (fish/h) of boreal smelt taken by Point Lay fyke nets during July-August 1983.

Age analyses were not performed on boreal smelt, however, otolith studies conducted by Craig and Haldorson (1981) indicated approximate length ranges for Beaufort Sea smelt of 56-89 mm and 90-142 mm for Age 0+ and 1+ fish, respectively. North Atlantic and Great Lake populations yield an approximate 1+ length of 111 mm (Morrow 1980). If these characteristics hold true for Chukchi smelt then the smallest size cohort observed in our fyke net data may represent young-of-the-year. The lack of young-of-the-year fish in fyke net catches prior to 28 August may reflect gear inadequacies (25 mm mesh leads) rather than the absence of young smelt in Kasegaluk Lagoon. Fry spawned at the beginning of the summer are 5-6 mm in length. The estuary system could, in fact, serve as first-year feeding and nursery grounds.

The length-weight regression for boreal smelt taken at Point Lay was:

$$\text{Log Weight (g)} = -5.9+3.3 \text{ Log Length (mm)};\ r^2=0.98,\ N=58$$
$$\text{or Ln Weight (g)} = -13.6+3.3 \text{ Ln Length (mm)}$$

which is nearly identical for the relationship determined for boreal smelt taken at Simpson Lagoon (Craig and Haldorson 1981).

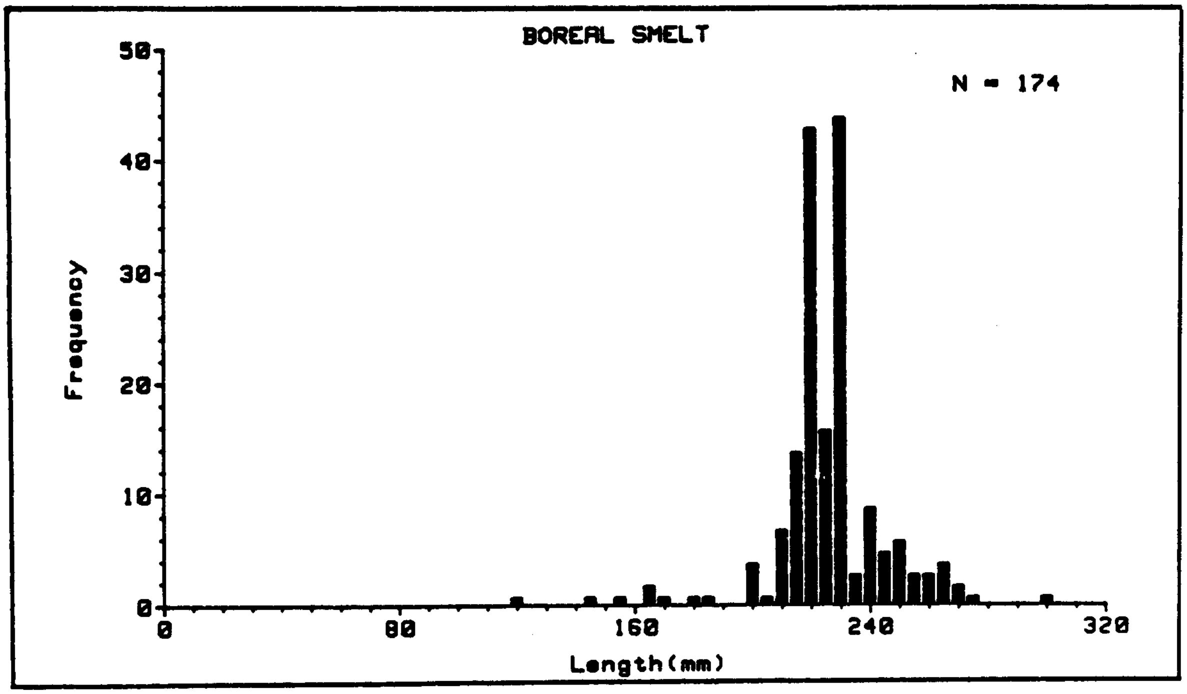


Figure 6-20. Length-frequency distribution of boreal smelt taken by Point Lay gill nets during July-August 1983.

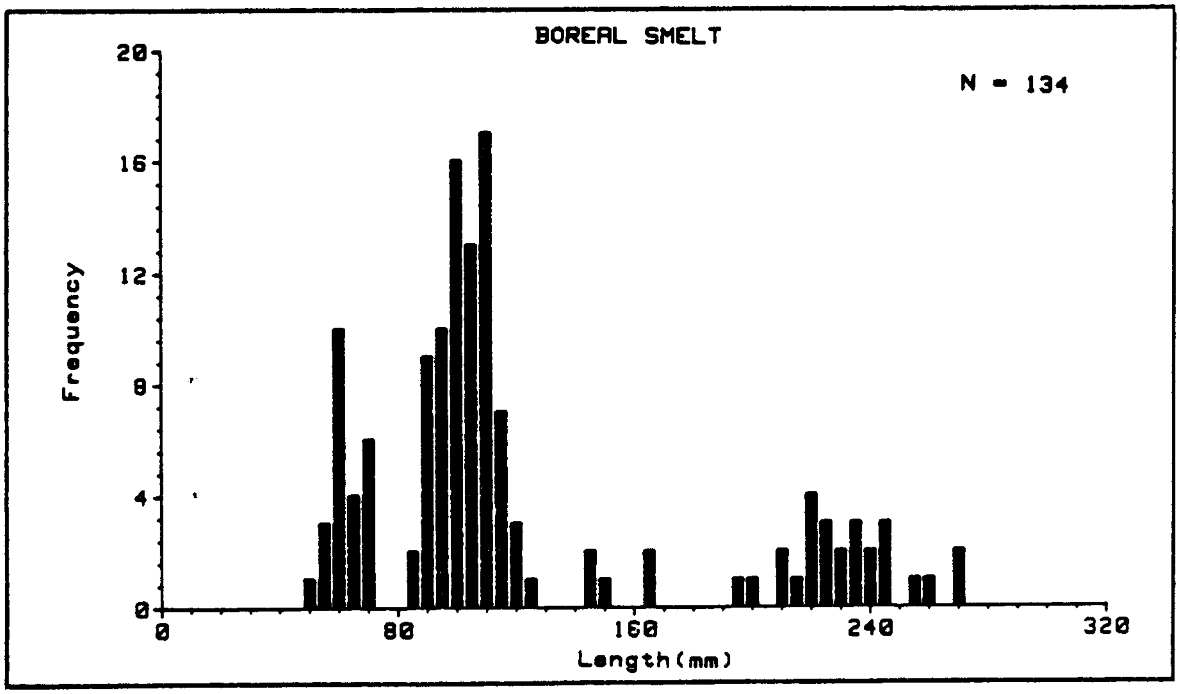


Figure 6-21. Length-frequency distribution of boreal smelt taken by Point Lay fyke nets during July-August 1983.

6.6.2 Reproductive Status

Analyses of reproductive status revealed the following breakdown: 21 sexually mature males (207-280 mm FL), 23 sexually mature females (200-262 mm FL), 9 immature males (104-182 mm FL) and 3 immature females (111-200 mm FL).

Average gonadal weight for mature males averaged 8.1% (range: 4.6-10.2%, SD=2.8, N=21) of body weight, but was only 1.2% (range: 0.7-1.8%, SD=0.6, N=3) in immature fish. These values are much higher than those reported for Beaufort Sea smelt where mature males averaged 3.4-4.9% gonadal weight year-round.

A consistent increase in ovary weight occurred during July and August (Fig. 6-22). This apparent post-spawning gonadal recovery along with the presence of apparent young-of-the-year fish in August, the report of a sexually ripe female near Point Lay in mid-June (Schmidt and Craig, in press) and the fact that boreal smelt do not to undergo extensive coastal migrations (Morrow 1980) make it very likely that the major rivers (Kokolik, Utukok, Kukpowruk) which feed Kasegaluk Lagoon are spawning sites for boreal smelt.

The 33 boreal smelt taken by _Discoverer_ gill nets near Wainwright ranged in size from 195-215 mm FL and all identifiable specimens appeared sexually mature (18 males, 6 females).

6.6.3 Feeding Habits

Stomach analyses of boreal smelt gill-netted from 19-22 August showed them to be strongly piscivorous (Table 6-5). Fish accounted for 65% of total wet weight content, with _Mysis littoralis_ (25%) being the only other prominent prey (Table 6-5). The dominance of Arctic cod in their diet reflects the high densities of this species in nearshore water. Schmidt and Craig (in press) likewise found fish (58%) and _Mysis littoralis_ to be primary food items during June to early August.

6.7 Arctic Flounder (_Liopsetta glacialis_)

The Arctic flounder is a shallow water flatfish not typically found far offshore. Its distribution is almost circumpolar and covers the Canadian and Alaskan Beaufort seas, through the Chukchi Sea, and down the

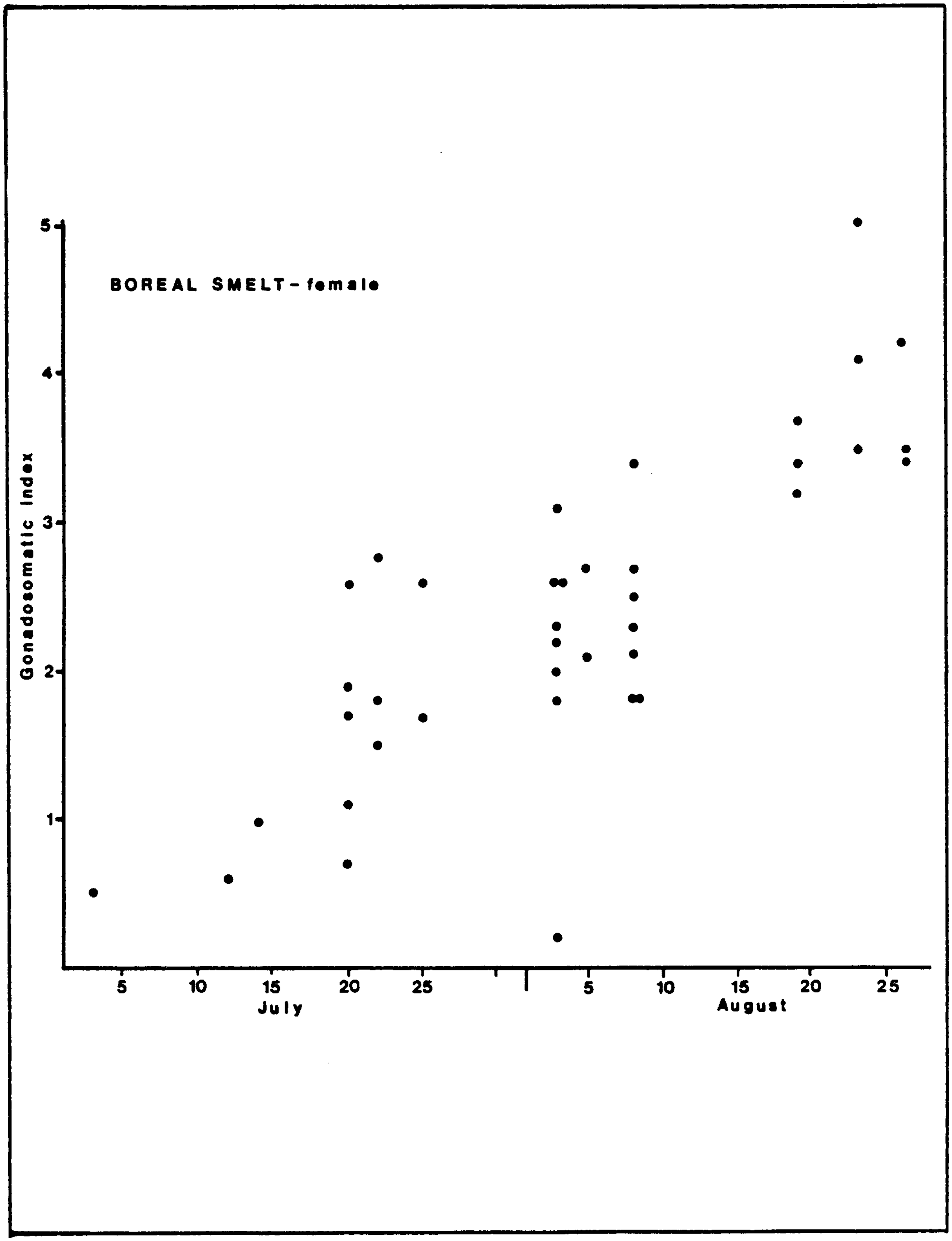


Figure 6-22. Gonadosomatic index (ovary weight/body weight) for female boreal smelt taken at Point Lay in 1983. Included are specimens reported by Schmidt and Craig (in press).

Table 6-5. Food items of boreal smelt (165-280 mm FL) taken by gill net at Point Lay from 22 July-26 August, 1983. Values are percent wet weight composition followed parenthetically by number of occurrences.

Food Item	Boreal Smelt N = 21	
Plant	* (5)	
Pebble	* (1)	
Unidentified	1 (3)	
Calanoid	* (1)	
Saduria entomon	* (1)	
Unidentified amphipod	* (1)	
Lysianassid	* (2)	
Onisimus glacialis	* (1)	
Onisimus littoralis	1 (3)	
Gammarus setosus	1 (6)	
Pontoporeia affinis	* (3)	
Oedicerotid	* (4)	
Total Amphipods		3 (11)
Mysis littoralis	30 (16)	
Mysis relicta	* (2)	
Neomysis sp.	* (1)	
Total Mydids		31 (16)
Unidentified fish	2 (2)	
Arctic cod	60 (6)	
Fish larvae	2 (2)	
Total Fish		65 (9)

*<1%.

Bering Strait to Bristol Bay. Spawning usually takes place in shallow coastal areas in late fall or winter (Morrow 1980).

During the 1983 Point Lay study, 1910 Arctic flounder were taken primarily by fyke net (94%). In terms of total catch they ranked fifth, accounting for 12% of all fish taken. Daily catch rates showed a trend similar to most other species with spikes occurring from 19-21 July and on 1 August during periods of sharp hydrographic transition (Fig. 6-23).

6.7.1 Size

Because of the tendency for Arctic flounder to congregate in shallow nearshore waters during summer, it was not surprising that only two individuals were caught as part of the Discoverer cruise. One 280 mm adult was taken by otter trawl at Station 27 (80 km off Ledyard Bay coast) and another 260 mm individual was taken at gill net Station 1 (0.8 km off Point Lay).

Arctic flounder taken by gill net ranged in size from 75-240 mm TL (Fig. 6-24). Length-frequency distributions of fyke-netted flounder taken at Point Lay revealed two primary size aggregates (Fig. 6-25). The smaller group ranged in size from 30-55 mm TL with a mode at about 45 mm. The remaining majority were part of an extremely broad based group covering the 85-240 mm size range. Length-frequency distributions for this larger group were monomodal at about 130-140 mm total length during the 18 July-4 August period (747 fish) but size distribution was rather flat for the 19-31 August period (189 fish). All Arctic flounder comprising the smaller cohort were taken prior to 27 July with the exception of three individuals caught on 28 August.

6.7.2 Age and Growth

Although this species has been collected in the USSR (Andriyashev 1954), the Beaufort Sea (Griffiths et al. 1975, Percy 1975, Jones and Den Beste 1978, Bond 1982. Griffiths 1983, Griffiths et al. 1983), the Bering Sea (Barton 1979), and various North American locations (Walters 1955), in most cases very few Arctic flounder have been examined in detail and so life history information for this species is fragmentary. Data analyses in the following discussions include specimens caught in this study as well as those collected by Schmidt and Craig (in press).

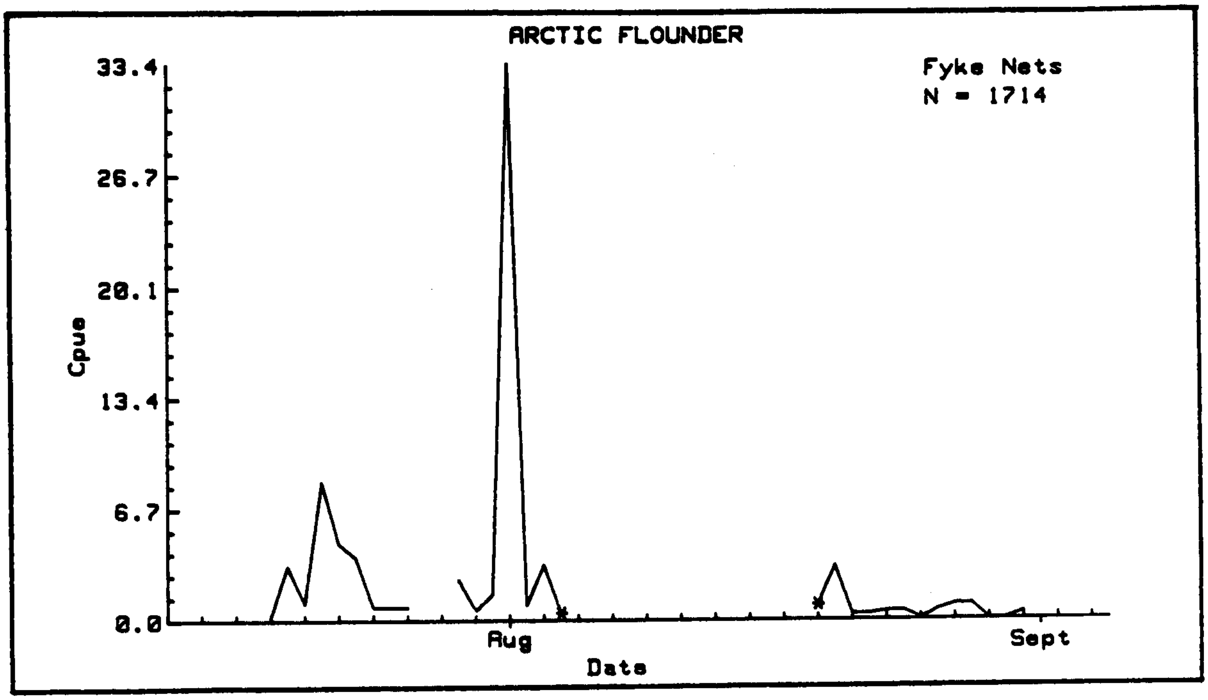


Figure 6-23. Daily catch rate (fish/h) of Arctic flounder taken by Point Lay fyke nets during July-August 1983.

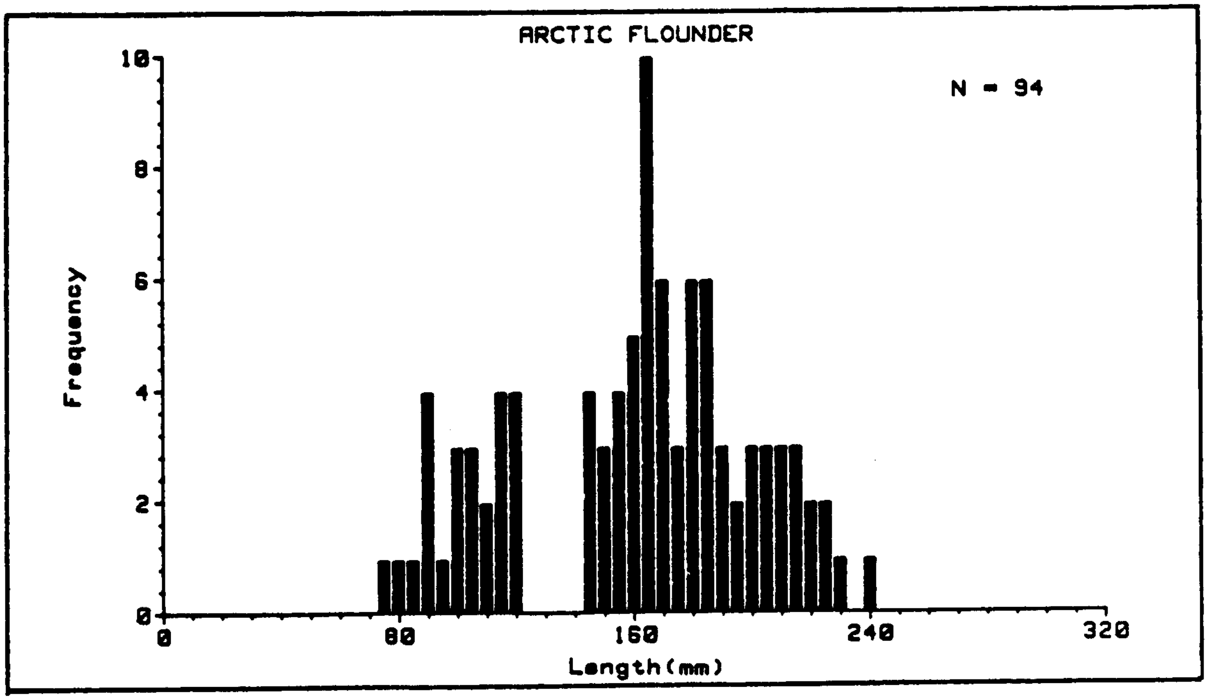


Figure 6-24. Length-frequency distribution of Arctic flounder taken by Point Lay gill nets during July-August 1983.

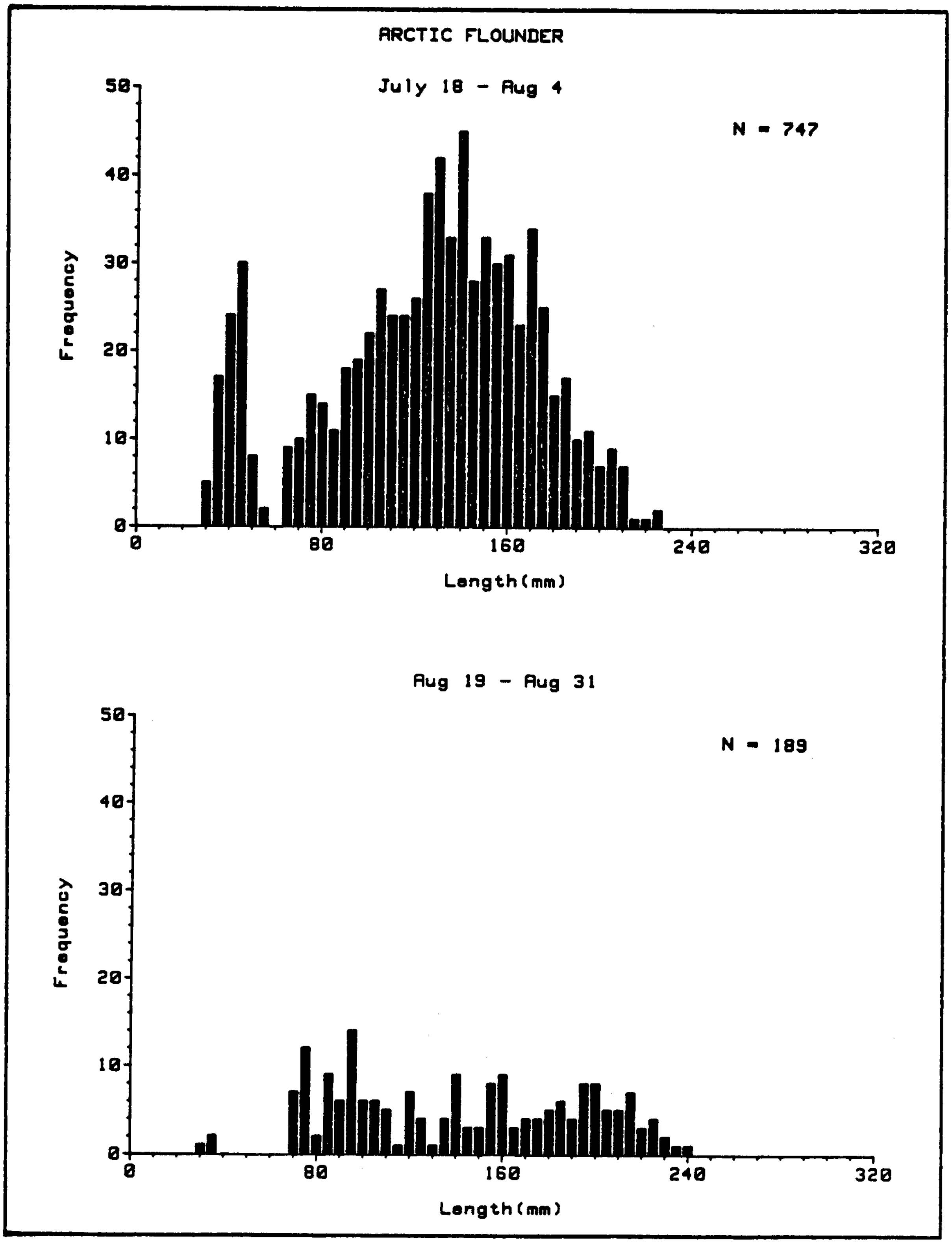


Figure 6-25. Length-frequency distributions of Arctic flounder taken by Point Lay fyke nets during July-August 1983.

The Point Lay sample ranged in age (otolith analysis) from young-of-the-year to Age 12 fish, but most Arctic flounders were 0-6 years old (Table 6-6). Males and females differed in longevity and growth rate; females lived longer and were generally 2 cm larger than same-age males (Table 6-6, Fig. 6-26). This sexual dimorphism has been noted by others (Andriyashev 1954, Walters 1955).

The Arctic flounder is a slow growing species and the population at Point Lay grows more slowly than populations in the Barents or Beaufort seas (Fig. 6-27). Reasons for this relatively slow growth are not known.

6.7.3 Reproductive Status

Arctic flounder at Point Lay reach sexual maturity at Ages 4-6 (Table 6-7) which is similar to that recorded for this species in the Barents Sea (Andriyashev 1954). Size at maturity was 130-159 mm for males and 150-189 mm for females (Fig. 6-28).

Arctic flounder spawn in mid-winter at which time egg sizes are 1.0-1.5 mm (Andriyashev 1954). Morrow (1980) notes that mature fish spawn only once every two years. At the onset of our study in late June, the ovaries of mature females contained eggs measuring 0.3-0.8 mm and a few retained eggs (2.0-2.0 mm) from a previous spawning. Gonadosomatic indices (percent ovary weight/body weight) for these known spawners was 1.6-6.5% during the period 25 June-4 July 1983 (Fig. 6-29). By late summer (24 August-1 September), egg sizes had increased slightly to 0.5-1.0 mm and gonadosomatic indices of mature and maturing females were 7.2-14.6% (Fig. 6-29). Nine mature or maturing males caught in mid-summer (3 August) had gonadosomatic indices of 2.7-6.7%.

6.7.4 Food Habits

Of the 71 Arctic flounder stomachs examined, over 78% were empty. Those which had eaten, consumed polychaete and unidentified worms, the isopod *Saduria entomon* and the amphipod *Onisimus littoralis*. An interesting change in diet was noted when stomach content for the Arctic flounder gill-netted from late July-August was compared with that recorded for Arctic flounder taken from 4-20 July (Schmidt and Craig, in press). Major prey items during the first period were *O. littoralis* (39%), *S. entomon* (28%) and polychaetes. After 22 July, polychaetes and other worms

Table 6-6. Age and length relationships of arctic flounder at Point Lay, 1983. Ages were determined by otolith (break and burn technique.

	Females*					Males					% in**
		Total Length (mm)			%		Total Length (mm)			%	Population
Age	n	Mean	Range	SD	Mature	n	Mean	Range	SD	Mature	(n=1321)
0	5	43	(34- 48)	5.7	0						12
1	9	70	(54- 87)	11.4	0						15
2	2	91	(90- 91)	0.7	0						6
3	4	125	(109-138)	9.5	0	1	136	-	-	0	21
4	6	161	(139-187)	18.2	33	1	143	-	-	0	7
5	19	171	(154-195)	12.9	63	4	146	(144-148)	1.7	75	17
6	17	181	(152-200)	14.8	76	3	168	(158-177)	9.5	100	8
7	10	201	(188-210)	8.2	100	4	175	(170-179)	3.8	100	5
8	12	207	(190-219)	9.1	100	3	181	(178-186)	4.4	100	4
9	10	210	(165-229)	19.4	100	1	185	-	-	100	3
10	6	214	(206-223)	6.3	100						2
11	5	231	(220-246)	9.9	100						1
12	2	241	(238-243)	3.5	100						0.3
Totals	107					17					101.3

*Includes unsexed fish Ages 0-2.
**Based on a length stratified subsample of fish ages applied to the total catch (Ricker 1975).

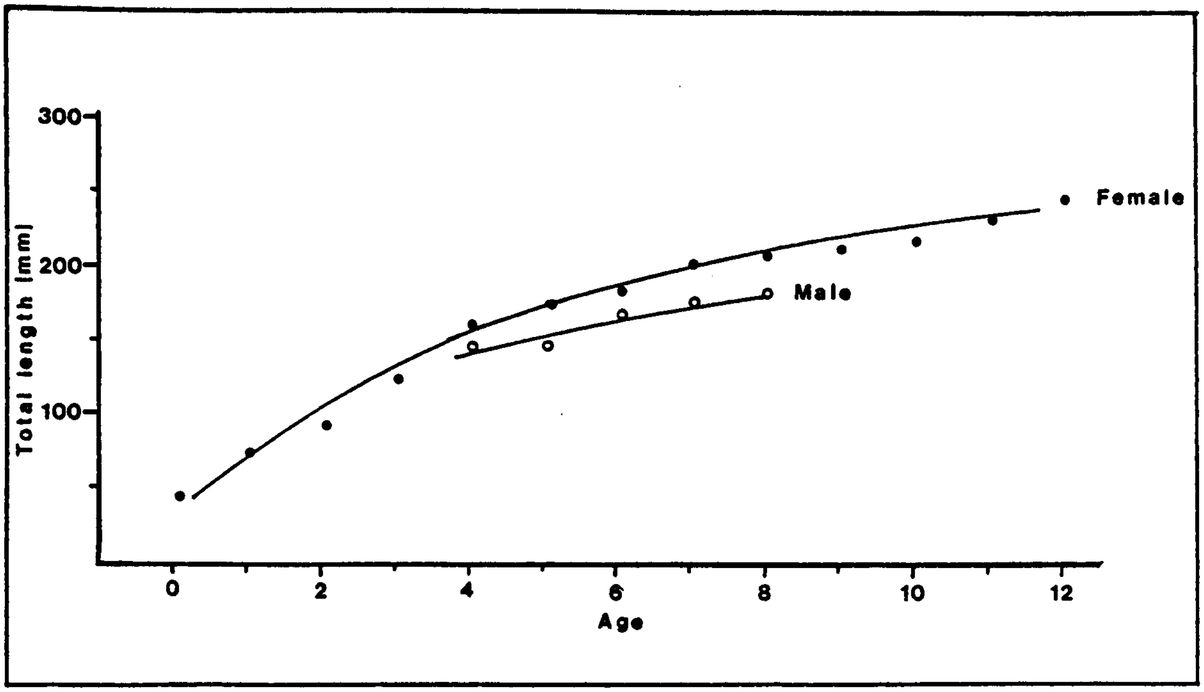


Figure 6-26. Growth of Arctic flounder taken at Point Lay during summer 1983.

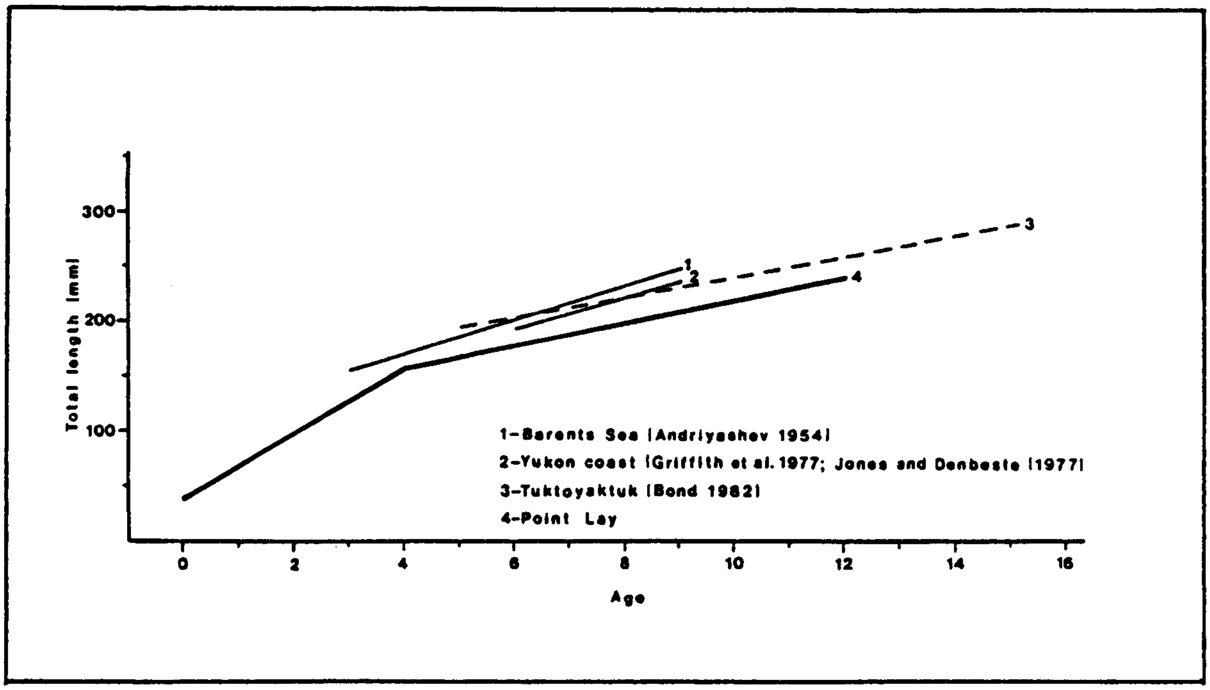


Figure 6-27. Growth patterns of Arctic flounder taken at Point Lay during summer 1983 and other areas.

constituted 83% of Arctic flounder diet. These infauna were found to be a prey source in Beaufort Sea studies but not to this extent (Bendock 1977, Craig and Haldorson 1981).

Admittedly, sample sizes are small, however, such changes could result from fluctuations in overall prey density, changes in predator/prey size relationships or spatial discontinuity in prey distribution. In any event, these data illustrate the trophic adaptability in Arctic flounder.

Table 6-7. Food items of Arctic flounder taken by lagoon gill nets at Point Lay during summer 1983. Values are percent wet weight composition followed parenthetically by number of occurrences.

Food Item	4-20 July N=9[1] (170-230 mm TL)		22 July-29 August N=9 (165-225 mm TL)	
Plant	* (2)		3 (3)	
Pebble	* (2)		* (1)	
Unidentified	4 (8)		-	
Chironomid larvae	* (4)		-	
Polychaete (tube)	17 (7)		48 (9)	
Unidentified worm	-		35 (4)	
Saduria entomon	28 (8)		4 (5)	
Calanoid	-		* (1)	
Unidentified amphipod	-		* (1)	
Onisimus glacialis	39 (9)		-	
Onisimus littoralis	1 (1)		-	
Lysianassid	4 (6)		4 (3)	
Gammarus setosus	2 (6)		4 (1)	
Pontoporeia affinis	4 (9)		1 (3)	
Oedicerotid	* (2)		* (1)	
Total Amphipod		50 (9)		10 (5)
Unidentified mysid	-		-	
Mysis littoralis	* (1)		* (1)	
Mysis relicta	* (1)		-	
Total Mysids		* (2)		* (1)

[1] Including six specimens reported by Schmidt and Craig (in press).

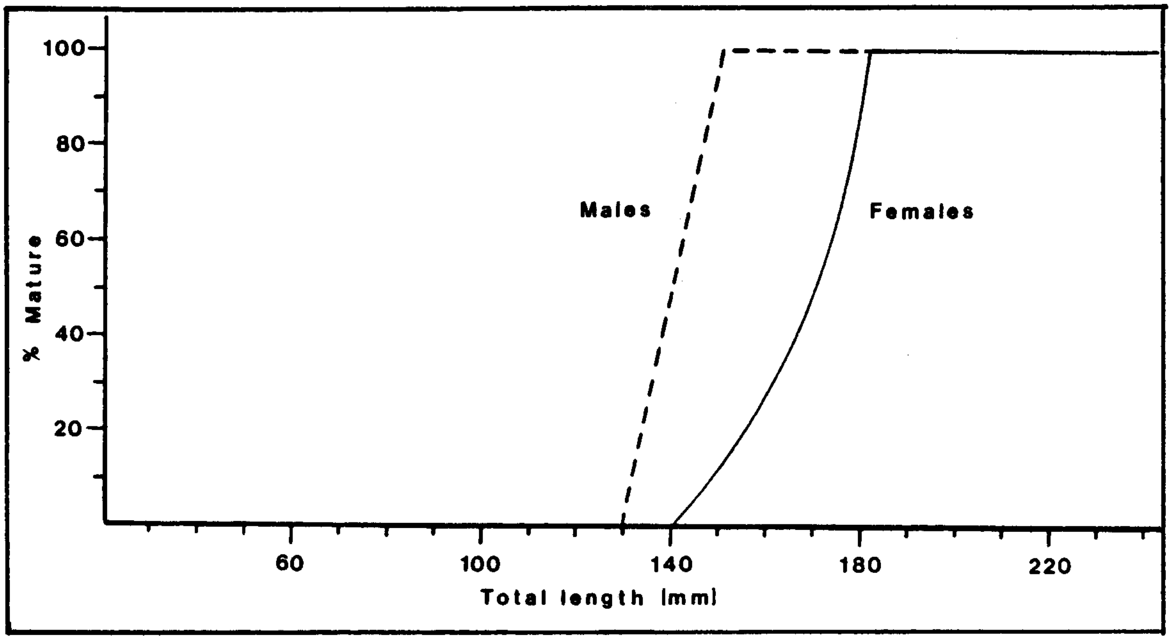


Figure 6-28. Size at maturity for Arctic Flounder taken at Point Lay during summer 1983.

6.8 Pink Salmon (Oncorhynchus gorbuscha)

Pink salmon are an anadromous species which spends its adult life at sea, then returns to natal streams to spawn. Their distribution covers coastal regions from southern California to the Canadian Beaufort Sea.

The 34 pink salmon caught during the Point Lay study were only a small portion (0.002%) of the total catch. No pink salmon were taken during the Discoverer cruise. Point Lay fish ranged in size from 385-505 mm FL. The length-weight regression was:

$$\text{Log Weight (g)} = -4.6 \text{ Log Length (mm)},\ r^2=0.80,\ N=25$$
$$\text{or Ln Weight (g)} = -9.8 \text{ Ln Length (mm)}$$

6.8.1 Reproductive Status

Out of a subsample of 27 salmon, females (21) far outnumbered males (6). All fish were sexually mature and apparently positioned for a late summer spawning run. The gonadosomatic index (ovary weight/body weight) for females averaged 14.4% (range: 10-1-18.8, SD=2.1, N=19) and egg diameters averaged 5.2 mm (range: 4.7-5.7 mm, SD=0.3, N=20).

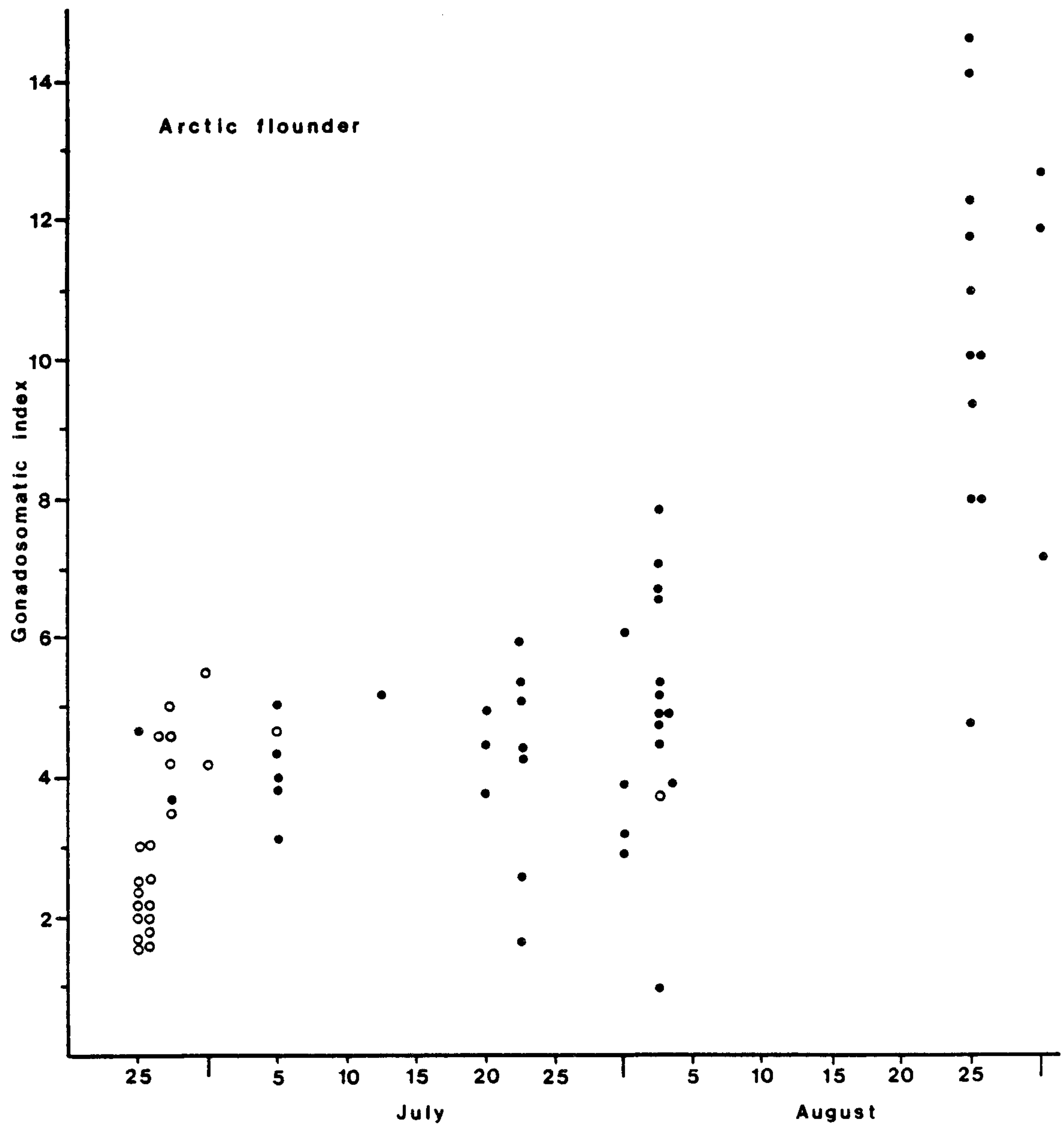


Figure 6-29. Gonadosomatic index (ovary weight/body weight) for female Arctic flounder judged to be mature (solid dots) and those with evidence of previous spawning (retained eggs) (open dots).

6.8.2 Feeding Habits

Half of the pink salmon examined had empty stomachs. The remaining 12 individuals had fed primarily on fish (74%), the amphipod Onisimus litoralis (12%), and Mysis litoralis (6%) (Table 6-8).

Table 6-8. Food items of pink salmon (422-505 mm FL) taken by gill net at Point Lay from 1-4 August, 1983. Values are percent wet weight composition followed parenthetically by number of occurrences.

Food Item	Pink Salmon N = 12	
Plant	* (4)	
Pebble	* (2)	
Unidentified	5 (10)	
Juvenile decapod	* (3)	
Euphausid	* (2)	
Unidentified amphipod	* (1)	
Onisimus littoralis	12 (6)	
Anonyx sp.	* (1)	
Gammarus setosus	1 (3)	
Gammaracanthus sp.	* (2)	
Atylus carinatus	* (2)	
Parathemisto abyssorum	* (1)	
Oedicerotid	* (1)	
Total Amphipods		13 (8)
Unidentified mysid	* (1)	
Mysis littoralis	6 (9)	
Mysis relicta	* (2)	
Neomysis sp.	* (1)	
Total Mysids		7 (10)
Fish larvae	16 (8)	
Fish egg	* (1)	
Arctic cod	58 (6)	
Unidentified flatfish	* (1)	
Total Fish		74 (10)

*<1%.

6.9 Arctic Staghorn Sculpin (*Gymnocanthus tricuspis*)

The Arctic staghorn sculpin is a demersal, marine fish with a circumpolar distribution. Tolerant of wide temperature and salinity fluctuations they are typically found in cold, marine waters at depths ranging from 0-240 mm (Andriyashev 1954).

This species numerically dominated otter trawl catches. Staghorns numbered 11,006 individuals and constituted 52% of all fish taken. They were present in 24 of 25 (7-48 m depths) trawls but none were caught by *Discoverer* gill nets. No staghorn sculpin were taken in Kasegaluk Lagoon or adjacent shallow waters.

Staghorns ranged in size from 25-135 mm TL. The length-frequency distribution showed a primary mode at about 40 mm and a secondary mode at 70 mm (Fig. 6-30). Tentative data reported by Andriyashev (1954) would age the 40 and 70 mm size cohorts as 1+ and 2+, respectively. Length-frequency distributions did vary among stations but no discernable geographic pattern was evident.

6.10 Shorthorn Sculpin (*Myoxocephalus scorpius*)

The shorthorn sculpin is widespread in arctic waters and is found as far south as the Bering Sea (Walters 1955). Taxonomically, this species is characterized by great variability in meristic and morphological features and is represented by several geographically distinct races.

Shorthorn sculpin were the third most abundant species taken by otter trawl. Present in 23 of 25 tow samples, the 1723 specimens comprised 8% of total catch. Fish ranged in total length from 30-215 mm. There was a notable absence of large fish (>65 mm) in all samples (Stations 1-18) collected northeast (inclusive) of the Point Lay transect--the distribution was monomodal at 40 mm and excluding one 115 mm specimen, ranged from 30-65 mm TL (Fig. 6-31). Cumulative length-frequencies for all samples taken southwest of the Point Lay transect (Stations 20-29) showed better representation of larger fish. The multimodel distribution contained distinct peaks at 40 and 70 mm. A 40 mm cohort would correspond with the 0+ age class in European representatives of this species (Bigelow and Schroeder 1953) and is probably the case with Chukchi specimens.

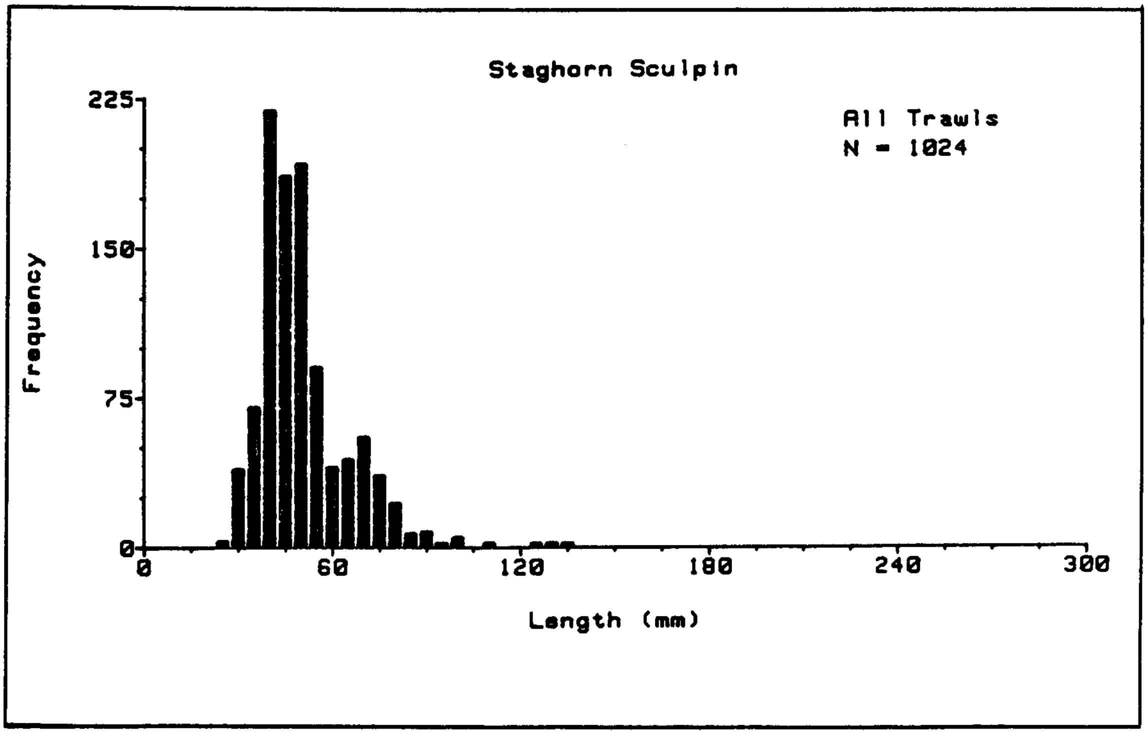


Figure 6-30. Length-frequency distribution of staghorn sculpin taken by otter trawl during the 25 August-13 September 1983 Discoverer cruise.

Four additional shorthorns were taken by gill net--two (185 and 315 mm) at Station 7 (0.8 km off Wainwright) and two (140 mm each) at Station 11 (1 km off the Ledyard Bay coast). No specimens were taken during the Point Lay study.

Assuming that otter trawls sampled representatively, reasons for the virtual lack of large shorthorns in the northeast half of the study area are unclear. If spawning took place along the entire Chukchi coast one would expect to find a significant trace of older fish. Older representatives would also be expected if the specimens taken at Stations 1-18 were a separate race. Even if spawning was localized around Cape Lisburne and the northeasterly group were the result of pelagic fry dispersed by the Alaskan current, larger members should show up provided the species can survive their first winter. One alternative is that the observed presence of shorthorn sculpin northeast of Ledyard Bay reflects an anomaly in the distribution of pelagic fry caused by 1983 patterns in coastal current.

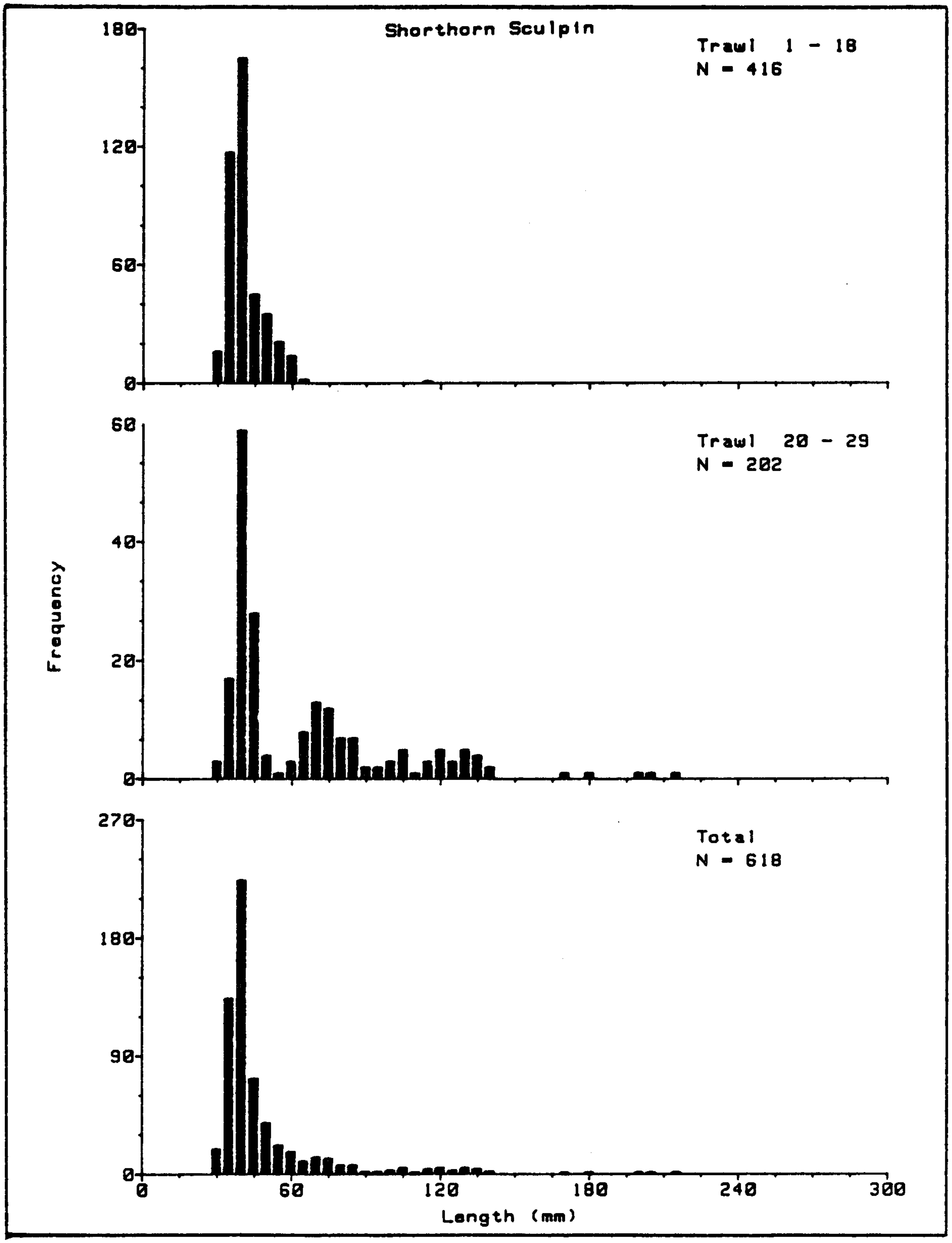


Figure 6-31. Length-frequency distributions of shorthorn sculpin taken by otter trawl during the 25 August-13 September 1983 Discoverer cruise.

6.11 Hamecon (*Artediellus scaber*)

The hamecon is a marine cottid belonging to a genus commonly referred to as hookear sculpins. Morphometrically and meristically similar to its Atlantic counterpart, the Arctic hookear sculpin (*A. uncinatus*), the hamecon is found in coastal waters from the Kara to the Chukchi Sea as far south as the northern Bering Sea (Walters 1955).

A total of 832 hamecon were taken by otter trawl which ranked it fourth in adjusted deep water (>14 m, 25 ft trawl) catches and third in adjusted shallow water (<14 m, 12 ft trawl) catches. Specimens were collected at all depths (7-48 m). The cumulative length-frequency distribution was monomodal at 30 mm, strongly skewed and ranged from 20-80 mm TL. Length distribution varied among stations without a distinctive pattern. The one exception was Station 20 located 150 km northeast of Cape Lisburne at which most of the larger specimens were taken (Fig. 6-32).

6.12 Other Sculpins

Five additional species of the family Cottidae were taken during the 1983 Chukchi study--four occurred solely in otter trawl samples (ribbed sculpin, *Triglops pingeli*; antlered sculpin, *Enophrys diceraus*; eyeshade sculpin, *Nautichthys pribilovius*; spatulate sculpin, *Icelus spatula*), and the fifth was taken only at Point Lay (great sculpin, *Myoxocephalus polyacanthocephalus*).

6.12.1 Ribbed Sculpin

The ribbed sculpin is circumpolar in distribution ranging south to the Bering Strait (Walters 1955). The 182 specimens taken by otter trawl ranged in size from 35-130 mm TL.

6.12.2 Great Sculpin

There is a possibility that this species may have been confused in the field with the morphometrically similar *M. jaok*. The Bering Sea is the northern limit for *M. polyacanthocephalus*, while *M. jaok* is found in arctic Alaska (Wilimovsky 1956). Thirty specimens (80-185 mm TL) were taken at Point Lay.

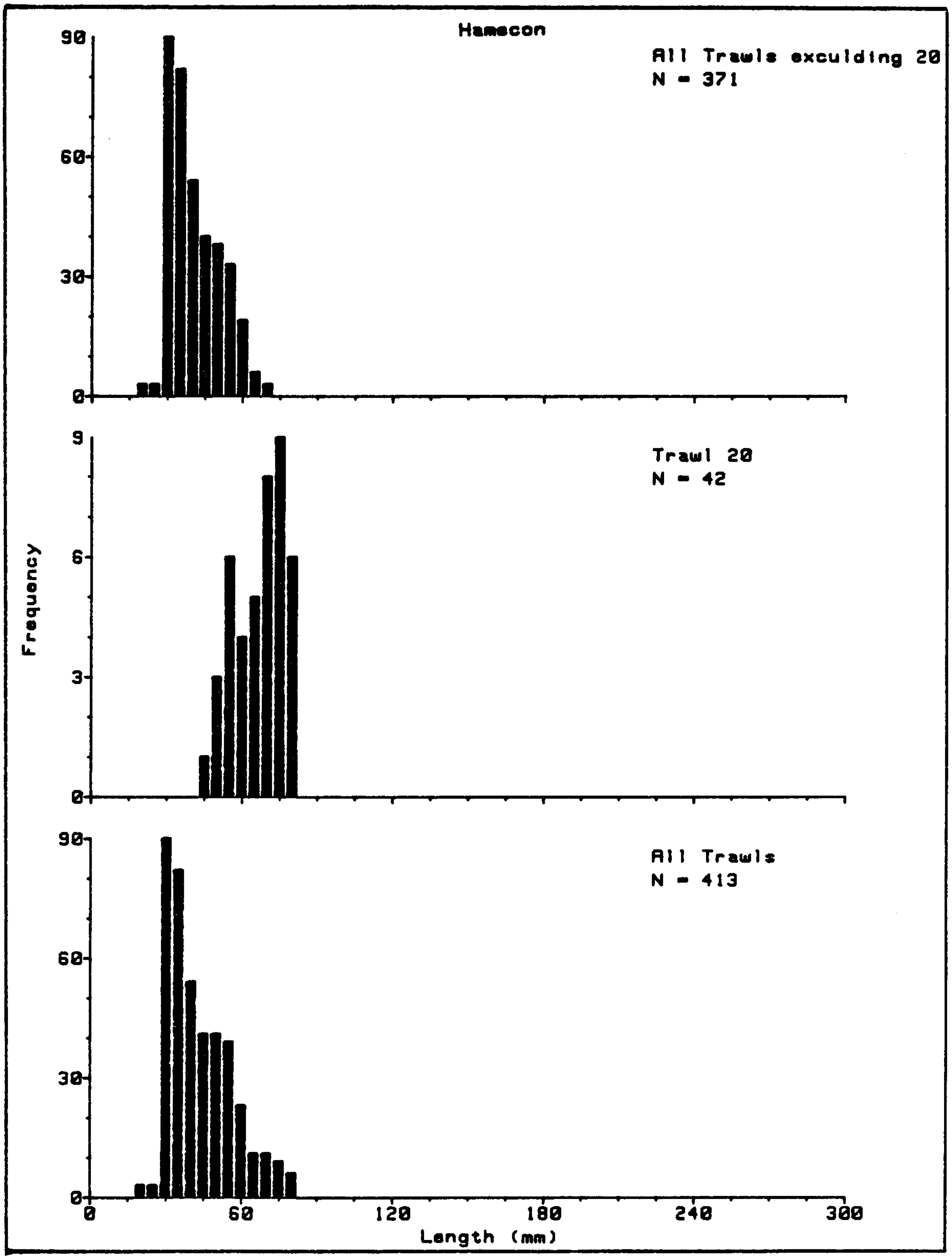


Figure 6-32. Length-frequency distributions of hamecon taken by otter trawl during the 25 August-13 September 1983 Discoverer cruise.

6.12.3 Antlered Sculpin

Typically found south of the Bering Straits this species is a coastal water inhabitant (Andriyashev 1954). All 20 specimens were taken at Station 29 located 50 km southeast of Point Hope. They ranged in size from 50-110 mm FL.

6.12.4 Eyeshade Sculpin

The eyeshade sculpin is also typically encountered south of the Bering Straits but has been reported for the Chukchi Sea (Quast and Hall 1972). Andriyashev (1954) reported that this species serves as an indicator of warm water in the northern Bering Sea. Five individuals (30-50 mm TL) were taken at trawl Stations 7, 17 and 18.

6.12.5 Spatulate Sculpin

Spatulate sculpin are distributed in coastal waters from the Kara Sea eastward to Greenland and south to the Bering Sea (Walter 1955). A single individual (35 mm TL) was caught at trawl Station 18 near Wainwright.

6.13 Other Flatfishes

Three additional species of flatfish were collected as part of the 1983 Chukchi study: yellowfin sole (Limanda aspera), longhead dab (Limanda proboscidea), and Alaska plaice (Pleuronectes quadrituberculatus).

6.13.1 Yellowfin Sole

The yellowfin sole was the numerically dominant flatfish taken by otter trawl. The 44 specimens ranged in size from 35-115 mm FL. Twenty-five individuals were taken at Station 21.

6.13.2 Longhead Dab

A total of 14 longhead dab were collected during the 1983 Chukchi study; 12 (80-155 mm TL) at Point Lay and 2 (140 and 150 mm TL) at Discoverer gill net Station 1 located 0.8 km off Point Lay.

6.13.3 Alaska Plaice

A single Alaska plaice (140 mm TL) was taken by Discoverer gill nets at Station 1.

6.14 Other Anadromous Fishes

Four additional anadromous species were collected at Point Lay: three Arctic char (*Salvelinus alpinus* - 180, 185 and 247 mm FL); two least cisco (*Coregonus laurettae* - 100 and 135 mm FL); two Bering cisco (*Coregonus sardinella* - 330 and 375 mm FL); and one chum salmon *Oncorhynchus keta* - 665 mm FL).

6.15 Sand Lance (*Ammodytes hexapterus*)

The sand lance is a marine fish which leads a varied life. They are found in nearshore or offshore waters, sometimes in large schools, and may bury themselves in either nearshore or offshore sandy substrates. They range from southern California through the Beaufort Sea (Walters 1955).

A total of 38 sandlance were taken by otter trawl at Stations 1, 3, 7, 8, 12, 21 and 28. They ranged in size from 85-160 mm FL. A single 95 mm individual was taken by fyke net at Point Lay. While this species ranked eighth in adjusted catch for deep water otter trawl stations, Quast (1972) found it to be one of the most abundant species during a 1970 sampling of the NE Chukchi Sea.

6.16 Walleye Pollock (*Theragra chalcogramma*)

The walleye pollock is a member of the cod family and generally ranges from the Bering Sea to central California (Hart 1973). The specimens taken by otter trawl during this study reflect the northern limits of this species range. Of the 28 individuals caught, 13 were taken at Station 29 (50 km SE of Point Hope), 10 at Station 28 (5 km off Cape Lisburne), 1 at Station 20 (100 km NW of Cape Lisburne) and 4 at Station 22 (20 km off the Ledyard Bay coast). Specimens ranged in size from 110-165 mm TL.

6.17 Snailfish (*Liparis* spp.)

Snailfish belong to a family (Cyclopteridae) of small northern fish, many of which have modified pelvic fins forming a ventral adhering disc presumably for attachment to rocks or other hard substrate. Their distribution is primarily neritic. Otter trawls collectd 50 individuals ranging from 50-90 mm TL.

6.18 Sturgeon Seapoacher (Agonus acipenserinus)

This bottom dwelling member of the family Agonidae is found in coastal waters from Oregon to Point Barrow (Walters 1955). Twenty-seven specimens were collected during the 1983 survey, three (45-65 mm TL) from Point Lay gill nets and 24 (35-90 mm TL) from otter trawl samples. All otter trawled specimens were collected in <22 m of water (Stations 1, 3, 8, 12, 21 and 26).

6.19 Arctic Alligatorfish (Aspidophoroides olriki)

A member of the poacher family, this demersal, marine species is found in arctic Alaskan waters as far south as the northern Bering Sea. All 15 specimens (45-70 mm TL) were taken by otter trawl at Stations 6, 7, 13, 20, 25 and 28.

6.20 Eelpouts

Six representatives of the demersal, marine family Zoarcidae were taken by otter trawl during the 1983 Chukchi cruise--the fish doctor (Gymnelis viridis), saddled eelpout (Lycodes mucosus), Arctic eelpout (Lycodes reticulatus), polar eelpout (Lycodes polaris), archer eelpout (Lycodes sagittarius) and Gymnelis hemifasciatus. Tentatively identified from McAllister et al. (1981), these species are pending taxonomic verification.

6.20.1 Fish Doctor

The fish doctor is a circumpolar, demersal species typically found in coastal waters less than 100 m in depth (Andriyashev 1954). The 37 specimens taken by otter trawl came from only five stations (6, 13, 18, 20 and 29) which covered depths of 20-47 m. Five individuals came from Station 29. Fish ranged in size from 55-120 mm TL.

6.20.2 *Gymnelis hemifasciatus*

Three specimens (80, 90 and 100 mm TL) of this rare species were caught at Station 6 located 32 km off Point Lay in 29 m of water.

6.20.3 Saddled Eelpout

This species is known from the Bering and Chukchi seas and has been reported to occur in the Beaufort Sea (Frost and Lowry 1983). A single specimen (50 mm TL) was taken at Station 16 near Wainwright.

6.20.4 Arctic Eelpout

Five specimens (115-250 mm TL) were collected, three at Station 20 and two at Station 27.

6.20.5 Polar Eelpout

Polar eelpout are distributed from the Kara Sea east to Greenland and as far south as the Bering Sea (Andriyashev 1954). All three specimens (85, 120 and 135 mm TL) were taken at Station 27 in Ledyard Bay.

6.20.6 Archer Eelpout

This species is considered to be a deep water inhabitant. The single 95 mm specimen was taken in 44 m of water at Station 27.

6.21 Pricklebacks

Otter trawls caught three species of the family Stichaeidae--fourline snakeblenny (*Eumesogrammus praecisus*), slender eelblenny (*Lumpenus fabricii*), and Arctic shanny (*Stichaeus punctatus*).

6.21.1 Fourline Snakeblenny

The species is rare to arctic Alaskan waters. Frost and Lowry (1981) collected two specimens off Wainwright. Two specimens measuring 85 and 95 mm TL were taken 100 km NE of Cape Lisburne (Station 20) in 47 m of water.

6.21.2 Slender Eelblenny

Often considered circumpolar in distribution, the slender eelblenny ranges from the Beaufort to Bering seas (Walters 1955). With 538 specimens taken, this species ranked sixth in total abundance. Lengths ranged from 50-185 total length.

6.21.3 Arctic Shanny

This coastal, marine species is found from the western Beaufort Sea to the Bering Sea (Walters 1955). Eighteen specimens were taken by otter trawl--1 (95 mm TL) at Station 13, 3 (90, 95 and 120 mm TL) at Station 28 and 14 (50-110 mm TL) at Station 29.

6.22 Whitespotted Greenling (*Hexagrammos stelleri*)

This species is known primarily from the North Pacific and Bering Sea. One specimen (70 mm TL) was collected at Station 21 and one (120 mm TL) at Station 29.

6.23 Threespine Stickleback (*Gasterosteus aculeatus*)

Pacific populations of threespine stickleback are typically found from Baja, California, to St. Lawrence Island (Morrow 1980); however, specimens have been reported from Simpson Lagoon (Craig and Haldorson 1981). A single 87 mm specimen was taken by Point Lay fyke net.

7. IMPACT VULNERABILITY AND GENERAL DISCUSSION

The main purpose of this study is to profile fishery processes in the NE Chukchi Sea and to determine their potential vulnerability to proposed oil and gas development associated with the "Barrow Arch Sale No. 85". Of particular interest are fish species which constitute important trophic links in the overall food web or are important to regional subsistence fisheries. Such impact appraisals are, to a certain degree, limited in scope because of the lack of scientific information previously accrued for the Chukchi area. Nevertheless, certain characteristics of this system appear unique, particularly when gauged against fishery dynamics of the adjacent Beaufort and Bering seas.

The following section addresses the vulnerability of NE Chukchi Sea fish species to potential OCS impacts. The species covered are reported to be important subsistence and/or forage fish: ciscoes, whitefish, Arctic char, chum salmon, pink salmon, Arctic cod, saffron cod, capelin, fourhorn sculpin, sandlance and Pacific herring.

7.1 Effects of Development

Industrial activities associated with oil and gas development may impact the environment in several ways. The presence of drilling and support facilities such as man-made islands and causeways physically remove part of the marine environment that would otherwise be used by local fauna. These facilities may also act in modifying physical characteristics of temperature, salinity, turbidity, current and noise, thereby altering (either positively or negatively) the ecological usefulness of local environs. Other impact sources include toxic additions such as discharges generated as natural by-products of drilling activity and oil spills.

The severity of any such industrial impact is related to the timing and location of the perturbation. Mild, and at times seemingly innocuous descriptions such as changes in local hydrography and low level drilling discharges, may adversely affect a population if they persist for long periods of time. Severe but spatially limited impacts may be biologically amplified if they occur at critical locations such as spawning grounds, feeding areas or across major migratory pathways. Further potential damage to the stability of the biological system need not be direct but may manifest itself as a disruption of the trophic chain.

7.2 Physical Environment

Temperature has repeatedly been demonstrated to be an important controlling factor in the biology of fishes. Nearly every facet of their physiological and biochemical character is thermally dependent. There are correlations between temperature and growth (Brett 1967, Brett et al. 1969, McCormick et al. 1972, Brett and Glass 1973, Shelbourne et al. 1973), the amount of food ingested (Kinne 1960, Brett and Higgs 1970), embryonic development and hatching success (Edsall 1970, Colby and Brooke 1973, Austin et al. 1975), resistance to infection (Amend 1970, Plumb 1973), and migratory behavior (McCleave 1978, Olla 1980). Further, laboratory studies have shown that fish will gravitate toward thermal levels which maximize physiological performance (Fry and Hart 1949, Fisher and Elson 1950. Brett 1971), scope for activity (Brett 1964, Beamish 1970) and growth potential (McCauley and Casselman 1980, Jobling 1981).

Although studied to a much lesser extent than temperature, salinity can affect a fishes metabolic rate, (Rao 1968, Hettler 1976), growth rate (Otwell and Merringer 1975. Hettler 1976) and hatching time (Kinne and Kinne 1962, Forrester and Alderdice 1966). Salinity can also modify thermal preferences (Kinne 1960, Garside et al. 1977, Fechhelm et al., in press).

From an ecological standpoint, OCS-induced alterations in temperature and salinity structure, as well as in other abiotic factors like turbidity and dissolved oxygen content, could jeopardize population success in a variety of ways. Potential damage would be greatest for species which depend upon the physical structure of a spatially limited environment (i.e., nearshore areas).

7.3 Anadromous Fish

7.3.1 Ciscoes, Whitefishes, Arctic Char, Chum Salmon

A notable finding of the 1983 investigation was the small number of anadromous fish taken in NE Chukchi waters. This contrasts sharply with Beaufort Sea studies in which Arctic cisco, Arctic char, least cisco, broad whitefish and humpback whitefish made up a conspicuous portion of survey catches (Craig and Haldorson 1981, Griffiths and Gallaway 1982, Griffiths et al. 1983). The presence of these species in the Beaufort Sea reflects that region's ability to successfully support anadromous fish stocks. Major freshwater drainages such as the Mackenzie, Colville, Sagavanirktok and other rivers act as spawning and overwintering grounds (Craig and McCart 1976). While specific patterns of river utilization and life history vary among species, arctic anadromous fish, in general, move into nearshore waters during the open-water season and disperse along the coastline to feed. River systems of the SE Chukchi Sea likewise supports major stocks of anadromous fish. Large populations of pink and chum salmon from the Noatak and Kivalina rivers (Geiger 1966, Smith et al. 1966), humpback whitefish (Alt 1978) and inconnu (Leibida 1970, Alt 1971) from the Kobuk River, and char from the Wulik and Kivalina rivers (Roguski and Winslow 1970, Alt 1978) enter coastal waters to feed and grow, and support extensive subsistence fisheries.

There are several reasons that could account for the low abundance of whitefish, cisco and char. First, rivers emptying into the NE Chukchi Sea may not be suitable for massive colonization. Second, coastal waters may not be productive enough to support large populations. Third, coastal waters may exhibit hydrological characteristics that impair their usefulness to anadromous species.

The effect of coastal hydrography has been an important issue in assessing fishery processes in the Beaufort Sea. Several studies have shown that the distribution of char, ciscoes and whitefishes is associated with a narrow band of relatively warm, brackish water which flows along the coast with prevailing currents (Craig and Haldorson 1981. Griffiths and Gallaway 1982, Griffiths et al. 1983). The width of this warm water band is usually 2-10 km depending upon coastal features such as barrier islands and freshwater plumes of large, North Slope rivers. Laboratory studies have shown that such hydrographic preference could be physiologically advantageous to the fish (Fry and Hart 1949; Brett 1964, 1971; Beamish 1970; Jobling 1981).

The situation in the Chukchi may differ considerably. Hachmeister (ASI, pers. comm.), conducting an OCSEAP-sponsored study of Chukchi Sea physical processes indicated that

> "...conditions for the nearshore regions from Point Lay to Key Cape and from Wainwright to Point Franklin will probably be to produce a more marine-like environment than those previously studied along the Beaufort Sea. In addition, the nearshore will also be subject to very large rapid changes in temperature and to some extent in salinity. This nearshore water will in turn be available for exchange with coastal lagoon systems in these areas which may also exhibit more marine-like physical properties."

The SE Chukchi Sea may also be hydrologically more amenable to supporting anadromous fish stocks. With its water mass being more directly influenced by relatively warm marine waters flowing northward from the Bering Sea and the presence of large rivers discharging freshwater into Hope Basin and Kotebue Sound, the SE Chukchi Sea is warmer and less saline than waters north of Point Hope.

7.3.1.1 Impact Vulnerability. All of the ciscoes, char and chum salmon taken during this study were adults (>5 years old). Schmidt and Craig (in press) also did not catch young individuals during their 1983 summer season at Point Lay. This, coupled with the absence of previously collected data indicating the presence of major spawning stocks in NE Chukchi Sea rivers, could mean that the few ciscoes, char and chum salmon which are present are incidental migrators from either Beaufort Sea or SE Chukchi Sea stocks. This being the case, the main migratory pathways accessing the coastal waters of the NE Chukchi Sea would be in the vicinity of the Barrow and Lisburne peninsulas. While the seaward extent of these migratory pathways is unknown, any environmental disruption, particularly major incidents like an oil spill, would increase the probability of reduced migration to NE Chukchi waters from adjacent regions.

7.3.1.2 Subsistence Implications. Despite the apparent low abundances, ciscoes, whitefish, char and chum salmon are caught in summer subsistence fisheries at the villages of Barrow, Wainwright, Point Lay and Point Hope (Ivie and Schneider 1979, Petersen et al. 1979, Schneider and Bennett 1979, Craig and Schmidt 1982, Skvorc 1982). If the few specimens caught during the 1983 Point Lay summer survey are indicative of low anadromous fish density in the NE Chukchi Sea, then natural or man-made perturbations to recruitment could affect subsistence harvests.

7.3.1.3 Trophic Implications. Because of their low abundance, ciscoes, whitefish, char and chum salmon are probably insignificant components of the NE Chukchi Sea trophic web.

7.3.2 Pink Salmon

The presence of pink salmon in the Point Lay area was not unexpected since the existence of small spawning stocks in the Utukok, Kokolik and Kukpowruk rivers has been previously documented (Bendock 1979). The 26 specimens examined during this study were sexually mature and apparently positioned for a spawning run in late summer. The same was true of the pink salmon caught as part of the North Slope Borough Survey (Schmidt and Craig, in press). It is likely that the Kuk River system also serves as a spawning site for pink salmon.

7.3.2.1 Impact Vulnerability. Pink salmon are an anadromous fish with a two-year life-cycle. Spawning adults probably move upstream in late summer just prior to freeze-up. As a rule they do not go far upstream, however, spawning in rivers of the NE Chukchi Sea is probably correlated with the presence of relatively deep water holes, the bottoms of which remain ice-free throughout the winter season. Young-of-the-year most likely move into coastal waters during the late spring thaw--June to early July. After spending about 21 months at sea, the adults return to spawn in their natal streams. Because of their life-cycle, runs of alternating years are genetically isolated. Each spawning river thus serves two distinct populations of salmon. Spawning migrations are generally dramatic since pink salmon tend to move into natal streams in distinct pulses. The ocean distribution of pink salmon in the NE Chukchi Sea is unknown. Both nearshore and offshore waters may serve as feeding grounds.

The life-cycle characteristics of pink salmon are important in assessing their vulnerability to developmental impacts. Pulses of out-migrating young-of-the-year in early summer and returning adults in late summer may be expected to be intense and short-lived. It is at these times that the estuary waters surrounding the mouths of the Utukok, Kokolik, Kuk, Kukpowruk and other smaller rivers are critical to the success of individual stocks. In addition, if Chukchi pink salmon behave in a fashion similar to that of more southerly populations (Thorsteinson 1962. McInerney 1964), young-of-the-year will spend part of their initial summer in and around estuarine waters.

Under a worst-case scenario, catastrophic oil spills could severely damage pink salmon populations if they impact at these critical times and locations. In some rivers (Utukok, Kokolik, and Kukpowruk), oil spill damage could be reduced by the presence of the Kasegaluk Lagoon barrier island chain. These barrier islands could offer partial protection from the intrusion of contaminated marine waters and enable fish to move along the coast in a lagoon corridor. Ocean access could be achieved by any of a dozen inlets along the 180 km long barrier island.

Because of the role that hydrographic factors play in reproduction, growth development and behavior, any plans for eventually constructing OCS support facilities in the Kasegaluk Lagoon/Point Lay vicinity should consider repercussions to local water quality.

7.3.2.2 Subsistence Implications. As was the case with ciscoes, whitefish and char, pink salmon are taken by coastal subsistence fisheries (Ivie and Schneider 1979, Petersen et al. 1979, Schneider and Bennett 1979, Craig and Schmidt 1982). A reduction in subsistence catch would be expected to vary in proportion to any impact to rivers supporting salmon populations.

7.3.2.3 Trophic Implications. Young fry probably serve as a food source for other fish during their initial summer, however, since local stocks are relatively small, this species is probably not a major link in the NE Chukchi Sea food web.

7.3.3 Boreal Smelt

Boreal smelt enter Chukchi River systems to spawn as soon as breakup permits. While upstream migrations of 100 km or more have been observed (Berg 1948), the run typically covers a short upstream distance. Spawning may even occur in brackish waters behind barrier beaches or in tidal zones (Bigelow and Schroeder 1963, McKenzie 1964). Hatching occurs in 10-29 days depending on temperature (Morrow 1980). Young fry are carried downstream to the estuary where they may spend their initial summer.

7.3.3.1 Impact Vulnerability. The vulnerability of Chukchi stocks of boreal smelt are essentially similar to that previously described for pink salmon, with estuaries being the critical location and the open water summer period being the critical time.

Modifications in the hydrographic characteristics of nearshore areas by OCS development could pose an additional hazard to boreal smelt, depending upon their reproductive strategy. Spawning in brackish areas would increase egg exposure to changes in temperature and salinity regimes caused by man-made structures. Temperature is an important determinant of hatching time and excessive salinity can kill eggs (Bigelow and Schroeder 1963). The presence of petroleum contaminants would further increase the probability of damage to the overall stock.

7.3.3.2 Subsistence Implications. Boreal smelt is an important subsistence fish, particularly at Wainwright during winter (Ivie and Schneider 1979, Schneider and Bennett 1979, Craig and Schmidt 1982). Since boreal smelt do not undergo extensive migrations (Morrow 1980), the Wainwright subsistence fishery and the Kuk River stock are closely tied entities. Damage to this population would most certainly be felt by the village of Wainwright.

7.3.3.3 Trophic Implications. While fry contribute to the trophic "soup" in estuaries during summer, this species by itself does not appear to constitute a major component in the Chukchi food chain.

7.4 Marine Fish

7.4.1 Capelin

The fact that capelin spawn in nearshore waters make this area critical to the population's success. Our data indicate that the seaward side of the barrier islands at Kasegaluk Lagoon serves as a spawning site; however, other portions of the Chukchi coastline may also be used for this purpose.

Physical requirements for spawning and hatching are unknown but seem to vary among geographic populations. In southern British Columbia, capelin spawn in 10-12°C waters. Spawning of the Atlantic population takes place at 2-3°C (Hart 1973). If spawning and early development in Chukchi populations are governed by strict temperature and salinity dependencies, then changes in hydrographic conditions created by the presence of nearshore OCS facilities (i.e., causeways) could affect the population. Oil spills which reach landfall would also have a detrimental affect on eggs and fry. Under worst-case scenarics, the net affect on the population would depend on the spatial limits of the impact and the range of coastline used for spawning.

7.4.1.1 Subsistence Implications. Capelin are not subsistence harvested along the NE Chukchi coast.

7.4.1.2 Trophic Implications. Young-of-the-year capelin are undoubtedly eaten by fish in nearshore areas during summer. Adults may be eaten by seals and birds and have been listed as an important item in the summer diet of belukha whales (Seaman and Burns 1980).

7;4.2 Arctic Cod

The Arctic cod is one of the most widely distributed and abundant of the marine fishes and measurable adverse impacts to Arctic cod are unlikely because (a) oil under ice has reduced dispersion and solubility and (b) the pelagic eggs would be widely dispersed. However, Arctic cod eggs are buoyant and thus susceptible to light density hydrocarbons in the event of a winter oilspill. Spawning may take place in nearshore areas during winter (Craig et al. 1982). Cod are often associated with the underside of sea ice and open ice fissures (Sekerak 1982), also consolidation areas for light density contaminants.

7.4.2.1 Subsistence Implications. Cod are taken incidentally but generally do not constitute a primary target species for subsistence fisheries.

7.4.2.2 Trophic Implications. The trophic importance of Arctic cod was summarized by Sekerak (1982):

> "(Arctic cod) are important because they figure prominently in the diet of many highly prized marine mammals and seabirds. Recent studies on the feeding ecology of vertebrates have confirmed that the Arctic cod is eaten by white whales, narwhals, ringed seals, bearded seals, harp seals, walruses (occasionally), thick-billed and common murres, black guillemots, black-legged kittiwakes, northern fulmars, Arctic terns, and glaucous, Sabine's, ivory and Ross' gulls (Quast 1974; Bradstreet, 1976, 1977, 1979, 1982; Divoky 1976, 1978; Lowry et al. 1978; Springer and Roseneau 1978; Davis et al. 1980; Bradstreet and Cross 1982). In many cases, the Arctic cod forms a significant fraction of the food consumed by the above marine mammals and seabirds. Arctic cod are also of indirect importance to polar bears and Arctic foxes, since their principal marine food, the ringed seal, also relies on Arctic cod as food. The importance of Arctic cod in arctic trophic relationships is underscored, since no alternate food source of equivalent value appears to exist."

7.4.3 Fourhorn Sculpin

Fourhorn sculpin are typically associated with nearshore waters throughout their life. Spawning takes place in winter when adhesive eggs are extruded onto the substrate. Hatching may take up to three months depending on temperature (Morrow 1980). Shortly after breakup both adults and fry move enmass into shallow coastal waters where they feed during summer (Andriyashev 1954, Westin 1970).

7.4.3.1 Impact Vulnerability. Nearshore areas are critical habitats for fourhorn sculpin. The presence of toxic contaminants during winter could increase egg mortality. Sculpin eggs are sensitive under normal circumstances and require parental care during incubation (Morrow 1980).

As with capelin, one advantage that fourhorn sculpin may hold over many of the anadromous species is a broad coastal distribution of critical habitat. Even though the nearshore habitat is important, large stretches of coastline between Point Hope and Point Barrow are probably used. This being the case, localized environmental descriptions would have a low probability of affecting the overall population.

7.4.3.2 Subsistence Implications. Fourhorn sculpin are not utilized in subsistence fisheries. Craig and Schmidt (1982) reported that sculpin gill netted by local villagers at Wainwright were discarded. They also found that some Point Lay fishermen prefer ocean fishing because of the lower occurrence of fourhorn sculpin than occurs in Kasegaluk Lagoon.

7.4.3.3 Trophic Implications. Sculpin serve as a food source for birds and marine mammals (Swartz 1966; Springer and Roseneau 1978, 1979; Lowry et al. 1979; Seaman and Burns 1980). From this standpoint localized disruptions in sculpin populations could deprive consumers of a forage species. This is particularly true of the large bird populations that inhabit the Cape Lisburne area.

7.4.4 Saffron Cod

The reproductive strategy of saffron cod is similar to that of fourhorn sculpin in that they spawn in nearshore areas during winter, presumably by extruding adhesive eggs onto the substrate (Morrow 1980), thus making eggs vulnerable to high density pollutant exposure; however, a broad coastal distribution could act as a buffer against localized impacts.

7.4.4.1 Subsistence Implications. Like Arctic cod, saffron cod are taken occasionally, often as part of winter "tomcod" taken by jig line.

7.4.4.2 Trophic Implications. Saffron cod serve as an important food item for marine mammals (Frost and Lowry 1981, Lowry et al. 1980, Seaman and Burns 1980).

7.4.5 Sand Lance

Sand lance spawn in shallow coastal areas but may otherwise inhabit either nearshore or offshore waters (Hart 1973). Data collected during the present study gave no indication of the time or location of spawning.

The sand lance is important to the Chukchi region because it is a principal food item of Cape Lisburne and Cape Thompson bird colonies (Springer and Roseneau 1978, 1979). Springer and Roseneau (1979) considered it to be a critical trophic component in the success of kittiwake populations:

> "One of the most critical elements of kittiwake biology in the region appears to be sandlance. In certain years the fish school in dense shoals in shallow, nearshore waters and are easy prey for most seabirds, especially kittiwakes which are restricted to feeding in waters less than about one meter in depth. Sandlance have been seen to fluctuate in their abundance and in the time when they arrive near the bird colonies, fluctuations which have coincided with major changes in kittiwake reproductive success."

Because of this predator/prey relationship, nearshore areas around the Lisbourne Peninsula should be considered a vulnerable area. Localized impacts to the sandlance population would, with time, be mitigated by recruitment and recolonization by more southerly stocks, however, bird populations could be severely affected during the interim.

7.4.6 Pacific Herring

Pacific herring are most vulnerable to OCS impacts during spawning periods. Adhesive demersal eggs located in shallow, nearshore areas would be exposed to high specific gravity contaminants. If Chukchi herring do spend their initial summer in nearshore habitats, modified hydrography caused by man-made structures could affect initial growth rates.

The most important subsistence use of herring occurs in the SE Chukchi Sea. Barton (1977) reported herring to be an important element at the village of Shishmaref but less vital to the subsistence of villages at Point Hope, Buchland and Deering. Herring are taken incidentally at Point Lay (Schmidt, LGL pers. comm.).

8. SUMMARY AND CONCLUSIONS

The most prominent species encountered during the 1983 Chukchi study were Arctic cod, Arctic staghorn sculpin, fourhorn sculpin, capelin, shorthorn sculpin, hamecon, Arctic flounder and saffron cod. Fourhorn sculpin and Arctic flounder are distributed nearshore (<1 km) while the remaining cottids were found exclusively in deeper, offshore (>1 km) waters. Arctic cod and saffron cod occupied both habitats.

Ciscoes, whitefish, Arctic char and chum salmon were much less abundant in the NE Chukchi Sea than in the adjacent Beaufort and SE Chukchi seas. The available evidence suggests that streams along the NE Chukchi coast support very small runs, if any, of these species. This being the case, then the few specimens which are present may be incidental migrants from Beaufort and SE Chukchi populations. Oil spill impacts to coastal regions around Barrow or the Lisburne peninsulas could impede migration/recruitment and in turn reduce subsistence catches.

Pink salmon and boreal smelt appear to be the two primary anadromous fishes of Chukchi Sea coastal waters. Large river systems like the Kokolik, Utukok, Kukpowruk and Kuk serve as spawning grounds for both species. The estuaries of these spawning rivers are important to reproduction and population success. Spawning runs of boreal smelt in spring and pink salmon in late summer could be impeded by the presence of petroleum contaminants. Estuaries are used by the fry of both species during their initial summer. Chemical contamination at this time could result in increased mortality of young-of-year. Alterations in the nearshore physical environment (i.e., temperature, salinity) caused by the presence of OCS support facilities could further affect early stages of growth and development. Any population damage would be felt in the subsistence fishing of either species. This is particularly true of the Kuk River smelt population which supports an important winter fishery at Wainwright.

Arctic cod are one of the most important forage fishes supporting marine mammals and bird populations. Because of its high abundance and wide distribution in arctic seas this species is, overall, best suited to withstand OCS impacts. From a more localized standpoint, however, Arctic cod are vulnerable to developmental-induced chemical contaminants. Low specific gravity pollutants could destroy buoyant eggs which are released in nearshore areas during winter spawning. The tendency for cod to congregate just beneath ice layers and around open water fissures during winter likewise renders them vulnerable to light density petroleum discharges.

Saffron cod, fourhorn sculpin, sandlance, Pacific herring and capelin all serve as food sources for higher vertebrate consumers. Saffron cod, and to a lesser extent Pacific herring, are also taken by susbistence fisheries.

One common thread of vulnerability shared by all of these species is their reproductive strategy. All spawn in shallow, coastal waters by extruding adhesive eggs on the substrate or local vegetation--saffron cod and fourhorn sculpin during winter and sandlance, capelin and herring in summer. Demersal eggs could be destroyed by the presence of high density petroleum contaminants. Further, the value of shallow, nearshore waters as feeding grounds and nursery areas could also be curtailed by contamination or through modifications in temperature and salinity regimes which might result from the construction of support facilities (i.e., causeways). Hydrographically-induced changes in early growth and development could, in the long run, adversely affect population strength.

One factor which could mitigate damage to NE Chukchi Sea populations centers on the spatial extent to which these species make use of coastal habitats. The greater the area of exploitable habitat the lower the probability that a spatially finite impact would severely affect the population. There is not enough information to determine the extent and hemogeneity of coastal distribution in the NE Chukchi Sea for these species.

Even though localized impacts may not result in long-term damage to the success of the general fish population, they could have more serious trophic repercussions to higher consumers. A prime example is the apparent trophic dependency that seabird colonies of Cape Lisburne have for sandlance and sculpin. Even a short-term reduction in the nearshore abundances of these fish could seriously affect these bird colonies, particularly during rearing of young.

As might be expected, the dominant marine and anadromous fish species of the Northeast Chukchi Sea are most vulnerable to OCS impacts which occur in shallow nearshore areas. This coastal edge is, to one degree or another, used for spawning, feeding and migration.

The environmental stability of this area should be considered if "Barrow Arch Sale No. 85" results in the discovery of commercially exploitable petroleum reserves.

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10. APPENDICES

10.1 Physical Data Listings

This section contains temperature, salinity and turbidity data measured during the 16-25 March winter study and the Point Lay summer study.

Physical Data: Winter study

DATE	STATION	DEPTH (m)	TEMPERATURE (°C)	SALINITY (‰)	TURBIDITY (NTU)
3/18	1	S	-0.5	32.0	1.5
		6	-	35.0	3.0
	2	S	-0.5	28.9	3.0
		5	-	28.9	5.5
		10	-	27.3	3.2
3/19	2	S	-0.5	28.2	5.0
3/20	2	S	-0.5	28.1	1.2
	3	S	-0.5	33.0	1.5
3/21	2	S	-0.5	28.2	2.6
	3	S	-0.5	29.0	2.3
3/22	2	S	-1.0	33.3	0.8
	3	S	-1.0	25.1	2.3
		5	-	20.9	2.3
		10	-	16.5	2.7
3/23	3	S	-1.0	28.0	1.3
3/24	4	S	-1.0	29.7	0.6
3/25	4	S	-1.0	30.0	0.5
3/26	4	S	-0.5	29.8	4.3
	H	S	-0.5	27.8	4.6
3/27	4	S	-1.0	31.0	0.4
		5	-	30.0	0.4
		10	-	30.1	1.1
3/28	4	S	-1.0	31.0	14.1

Temperature(°C): Pt. Lay summer study

	Fyke		Gill						Day
Station:	1	2	3	4*	5	6	7	8	Mean
Date									
7/18/83	1.0	7.5	-	-	-	-	-	-	4.3
7/19/83	1.5	10.0	-	-	-	-	-	-	5.8
7/20/83	7.1	9.5	-	-	-	-	-	-	8.3
7/21/83	6.0	11.5	-	-	10.0	-	-	-	9.2
7/22/83	8.5	10.0	-	-	10.8	-	-	-	9.8
7/23/83	4.5	11.5	-	-	9.5	-	-	-	8.5
7/24/83	-	11.5	-	-	11.5	-	-	-	11.5
7/25/83	1.9	10.0	-	-	11.0	-	-	-	7.6
7/26/83	2.5	-	-	-	-	-	-	-	2.5
7/27/83	-	-	-	-	-	-	-	-	-
7/28/83	3.0	10.9	-	-	-	-	-	-	7.0
7/29/83	3.0	12.2	-	-	-	-	-	-	7.6
7/30/83	3.0	13.2	4.4	-	-	-	-	-	6.9
7/31/83	-	11.7	-	-	-	-	-	-	11.7
8/1/83	6.0	12.0	-	-	-	-	-	-	9.0
8/2/83	10.5	12.0	-	-	12.0	-	-	-	11.5
8/3/83	9.0	12.0	-	-	-	11.0	-	-	10.7
8/4/83	8.0	11.5	-	-	-	-	-	-	9.8
8/5/83	7.5	7.0	-	-	-	-	-	-	7.3
8/6/83	8.5	8.5	-	-	-	-	-	-	8.5
8/7/83	-	9.0	-	-	9.0	-	-	-	9.0
8/8/83	-	9.5	-	-	-	10.5	-	-	10.0
8/9/83	-	-	-	-	-	-	8.0	-	8.0
8/10/83	-	-	-	-	-	-	-	-	-
8/11/83	9.0	12.5	10.0	-	-	-	-	-	10.5
8/12/83	-	12.0	-	-	-	-	-	-	12.0
8/13/83	-	10.0	-	-	-	-	-	-	10.0
8/14/83	-	8.0	-	-	-	-	-	-	8.0
8/15/83	3.0	5.0	-	-	-	-	-	-	4.0
8/16/83	3.0	9.0	-	-	-	-	-	-	6.0
8/17/83	-	8.0	3.0	-	-	-	-	-	5.5
8/18/83	-	6.5	-	-	-	-	-	-	6.5
8/19/83	7.0	7.5	6.0	-	7.5	-	-	-	7.0
8/20/83	7.0	7.5	-	-	-	-	-	-	7.3
8/21/83	-	-	-	-	-	-	-	-	-
8/22/83	8.0	5.0	-	-	-	-	-	-	6.5
8/23/83	6.0	5.4	-	-	-	-	-	6.5	6.0
8/24/83	6.5	4.5	-	-	.5	-	-	-	3.8
8/25/83	-	4.0	6.0	-	4.0	-	-	-	4.7
8/26/83	-	6.5	-	-	6.0	-	7.5	-	6.7
8/27/83	-	-	-	-	-	-	-	-	-
8/28/83	-	4.5	-	-	-	4.5	-	-	4.5
8/29/83	-	4.5	1.5	-	4.5	-	4.0	-	3.6
8/30/83	-	3.5	-	-	3.5	-	-	-	3.5
8/31/83	-	3.0	-	-	-	-	-	-	3.0
Mean	5.6	8.7	5.2	-	7.7	8.7	6.5	6.5	7.4
Std. Dev.	2.76	2.97	2.95	-	3.65	3.62	2.18	0.00	3.24
Std. Err.	.55	.48	1.20	-	1.01	2.09	1.26	0.00	.34
N	25	39	6	-	13	3	3	1	90

* Gill net station 4 = Fyke net station 1

Salinity (‰): Pt. Lay summer study

Station:	Fyke 1	Fyke 2	Gill 3	Gill 4*	Gill 5	Gill 6	Gill 7	Gill 8	Day Mean
Date									
7/18/83	26.0	23.9	-	-	-	-	-	-	25.0
7/19/83	27.5	22.4	-	-	-	-	-	-	25.0
7/20/83	21.5	20.6	-	-	-	-	-	-	21.1
7/21/83	19.5	20.3	-	-	15.5	-	-	-	18.4
7/22/83	20.6	19.5	-	-	13.1	-	-	-	17.7
7/23/83	26.2	20.7	-	-	20.5	-	-	-	22.5
7/24/83	-	20.2	-	-	22.7	-	-	-	21.5
7/25/83	28.5	20.1	-	-	19.0	-	-	-	22.5
7/26/83	28.0	-	-	-	-	-	-	-	28.0
7/27/83	-	-	-	-	-	-	-	-	-
7/28/83	28.3	26.5	-	-	-	-	-	-	27.4
7/29/83	26.5	13.5	-	-	-	-	-	-	20.0
7/30/83	25.0	13.0	24.0	-	-	-	-	-	20.7
7/31/83	25.2	8.0	24.0	-	-	-	-	-	19.1
8/1/83	28.3	18.1	-	-	-	-	-	-	23.2
8/2/83	20.0	17.8	-	-	16.3	-	-	-	18.0
8/3/83	20.0	14.8	-	-	-	22.0	-	-	18.9
8/4/83	23.0	21.8	-	-	-	-	-	-	22.4
8/5/83	21.0	26.5	-	-	-	-	-	-	23.8
8/6/83	21.0	18.5	-	-	-	-	-	-	19.8
8/7/83	21.5	17.5	-	-	16.0	-	-	-	18.3
8/8/83	-	23.0	-	-	-	20.0	-	-	21.5
8/9/83	-	22.5	-	-	-	-	22.3	-	22.4
8/10/83	-	16.0	-	-	-	-	-	-	16.0
8/11/83	21.5	9.0	20.0	-	-	-	-	-	16.8
8/12/83	-	1.0	-	-	-	-	-	-	1.0
8/13/83	-	21.5	-	-	-	-	-	-	21.5
8/14/83	-	-	-	-	-	-	-	-	-
8/15/83	-	-	-	-	-	-	-	-	-
8/16/83	26.5	21.0	-	-	-	-	-	-	23.8
8/17/83	-	9.0	25.0	-	-	-	-	-	17.0
8/18/83	-	22.0	-	-	22.0	-	-	-	22.0
8/19/83	19.0	14.0	26.0	-	13.0	-	-	-	18.0
8/20/83	22.5	14.0	-	-	-	-	-	-	18.3
8/21/83	-	-	-	-	-	-	-	-	-
8/22/83	23.7	15.5	-	-	-	-	-	-	19.6
8/23/83	21.0	12.0	-	-	-	-	-	15.8	16.3
8/24/83	24.0	22.5	-	-	6.8	-	-	-	17.8
8/25/83	-	2.0	23.4	-	.7	-	-	-	8.7
8/26/83	-	18.2	-	-	4.8	-	22.4	-	15.1
8/27/83	-	-	-	-	-	-	-	-	-
8/28/83	-	2.9	-	-	-	5.4	-	-	4.2
8/29/83	-	0.0	22.8	-	0.0	-	0.0	-	5.7
8/30/83	-	1.2	-	-	0.0	-	-	-	.6
8/31/83	-	14.8	-	-	-	-	-	-	14.8
Mean	23.7	16.0	23.6	-	12.2	15.8	14.9	15.8	18.1
Std. Dev.	3.13	7.23	1.90	-	8.22	9.06	12.90	0.00	7.63
Std. Err.	.61	1.16	.72	-	2.20	5.23	7.45	0.00	.79
N	26	39	7	-	14	3	3	1	93

* Gill net station 4 = Fyke net station 1

Turbidity (NTU): Pt. Lay summer study

	Fyke		Gill						Day
Station:	1	2	3	4*	5	6	7	8	Mean
Date									
7/18/83	2.9	7.5	-	-	-	-	-	-	5.2
7/19/83	2.3	4.9	-	-	-	-	-	-	3.6
7/20/83	3.8	4.1	-	-	-	-	-	-	4.0
7/21/83	4.6	3.1	-	-	8.2	-	-	-	5.3
7/22/83	3.2	3.4	-	-	5.3	-	-	-	4.0
7/23/83	1.1	2.5	-	-	2.3	-	-	-	2.0
7/24/83	-	4.3	-	-	3.4	-	-	-	3.9
7/25/83	1.5	14.0	-	-	16.0	-	-	-	10.5
7/26/83	54.0	-	-	-	-	-	-	-	54.0
7/27/83	-	-	-	-	-	-	-	-	-
7/28/83	27.0	43.0	-	-	-	-	-	-	35.0
7/29/83	5.0	5.6	-	-	-	-	-	-	5.3
7/30/83	2.9	10.5	2.3	-	-	-	-	-	5.2
7/31/83	1.4	14.5	1.3	-	-	-	-	-	5.7
8/1/83	1.8	3.0	-	-	-	-	-	-	2.4
8/2/83	3.2	7.0	-	-	15.0	-	-	-	8.4
8/3/83	3.5	4.8	-	-	-	3.1	-	-	3.8
8/4/83	5.0	3.6	-	-	-	-	-	-	4.3
8/5/83	2.2	3.1	-	-	-	-	-	-	2.7
8/6/83	9.5	7.0	-	-	-	-	-	-	8.3
8/7/83	9.6	7.8	-	-	8.5	-	-	-	8.6
8/8/83	-	2.5	-	-	-	5.8	-	-	4.2
8/9/83	-	7.8	-	-	-	-	24.0	-	15.9
8/10/83	-	3.0	-	-	-	-	-	-	3.0
8/11/83	3.2	32.0	5.6	-	-	-	-	-	13.6
8/12/83	-	120.0	-	-	-	-	-	-	120.0
8/13/83	-	6.4	-	-	-	-	-	-	6.4
8/14/83	-	-	-	-	-	-	-	-	-
8/15/83	-	-	-	-	-	-	-	-	-
8/16/83	4.5	6.0	-	-	-	-	-	-	5.3
8/17/83	-	13.0	1.8	-	-	-	-	-	7.4
8/18/83	-	15.0	-	-	1.5	-	-	-	8.3
8/19/83	16.0	20.0	5.0	-	5.0	-	-	-	11.5
8/20/83	10.0	11.0	-	-	-	-	-	-	10.5
8/21/83	-	-	-	-	-	-	-	-	-
8/22/83	22.0	6.7	-	-	-	-	-	-	14.4
8/23/83	10.0	11.0	-	-	-	-	-	18.0	13.0
8/24/83	17.0	8.5	-	-	20.0	-	-	-	15.2
8/25/83	-	19.0	3.9	-	22.0	-	-	-	15.0
8/26/83	-	10.0	-	-	25.0	-	19.5	-	18.2
8/27/83	-	-	-	-	-	-	-	-	-
8/28/83	-	54.0	-	-	-	38.0	-	-	46.0
8/29/83	-	140.0	6.9	-	135.0	-	14.9	-	74.2
8/30/83	-	135.0	-	-	94.0	-	-	-	114.5
8/31/83	-	36.0	-	-	-	-	-	-	36.0
Mean	8.7	20.8	3.8	-	25.8	15.6	19.5	18.0	16.7
Std. Dev.	11.41	34.46	2.11	-	39.17	19.42	4.55	0.00	28.32
Std. Err.	2.24	5.52	.80	-	10.47	11.21	2.63	0.00	2.94
N	26	39	7	-	14	3	3	1	93

* Gill net station 4 = Fyke net station 1

Physical Data: Discoverer Cruise

Station	Date	Latitude	Longitude	Depth (m)	Temperature (°C) Surface	Temperature (°C) Bottom	Salinity (ppt) Surface	Salinity (ppt) Bottom
1	8/26	69°51.2' N	166°51.5' W	43	8.9	5.8	30.2	31.0
2	8/27	69°46.6'	163°13.4'	17	6.8	6.8	28.6	28.6
3	8/27	69°49.4'	163°30.5'	24	7.0	4.5	28.7	30.0
4	8/27	69°48.3'	163°16.5'	17	7.0	7.0	28.7	28.7
5	8/28	69°53.5'	163°56.3'	27	6.6	2.4	29.9	30.6
6	8/28	69°47.2'	163°15.9'	16	6.7	-	28.7	-
7	8/29	69°49.2'	163°29.4'	23	6.8	6.8	28.6	28.6
8	8/29	69°52.2'	163°67.4'	27	6.4	2.3	29.8	30.6
9	8/30	70°06.8'	165°18.5'	40	6.3	4.3	30.7	31.0
10	8/30	70°06.4'	165°18.8'	41	5.7	4.0	30.8	31.0
11	8/30	69°52.9'	163°59.6'	31	5.8	2.4	29.9	30.8
12	8/31	69°48.5'	163°26.8'	24	6.4	6.5	28.7	29.3
13	9/1	70°07.6'	162°43.8'	15	6.0	6.0	28.9	29.8
14	9/1	70°30.7'	160°30.5'	17	4.8	4.8	29.3	29.3
15	9/1	70°38.1'	160°09.9'	18	4.8	5.0	29.3	29.5
16	9/2	70°37.8'	160°18.8'	22	5.3	5.3	27.0	27.0
17	9/2	70°43.4'	160°29.1'	43	2.9	4.6	29.5	30.9
18	9/2	70°42.8'	160°29.9'	42	3.1	4.5	30.0	30.6
19	9/2	70°39.3'	160°18.5'	23	5.2	5.2	30.0	30.0
20	9/2	70°39.2'	160°06.3'	19	4.8	4.7	29.3	29.3
21	9/3	70°40.8'	160°17.5'	25	5.2	-	30.1	-
22	9/4	70°40.8'	161°58.8'	41	3.3	4.0	30.7	31.3
23	9/4	70°54.8'	161°57.4'	45	0.2	0.5	29.6	31.7
24	9/5	71°03.8'	158°56.3'	55	0.2	4.0	29.6	30.8
25	9/6	70°18.0'	166°31.3'	46	1.8	-	28.9	-
26	9/7	69°46.6'	168°31.5'	52	1.6	-	28.8	32.5
27	9/7	69°36.3'	168°26.7'	51	3.0	0.9	30.8	32.6
28	9/8	69°59.1'	166°25.6'	46	3.0	2.6	30.2	31.8
29	9/8	69°45.1'	167°29.6'	48	2.2	1.3	29.3	32.1
30	9/8	69°38.6'	167°28.4'	48	3.8	1.6	30.2	32.0
31	9/8	70°23.3'	167°41.1'	50	0.2	-0.8	27.5	32.2
32	9/9	69°46.1'	168°30.6'	51	2.0	1.0	29.0	32.6
33	9/9	69°24.1'	168°29.1'	52	2.7	3.4	31.6	32.0
34	9/9	68°59.2'	168°25.6'	52	6.1	4.0	30.5	31.3
35	9/9	69°00.5'	167°30.2'	48	5.8	3.8	30.4	31.4
36	9/9	69°00.0'	166°33.5'	36	7.1	6.7	30.2	30.9
37	9/9	68°58.7'	165°32.5'	18	6.8	6.8	29.5	29.5
38	9/10	69°01.8'	165°40.0'	20	7.0	7.0	29.8	29.9
39	9/10	69°10.9'	165°35.2'	30	6.8	6.8	30.1	30.4
40	9/10	69°11.0'	165°35.6'	28	6.8	6.9	30.2	30.2
41	9/10	68°59.5'	165°32.7'	18	6.6	6.6	29.5	29.5
42	9/10	68°58.9'	165°32.1'	19	6.5	6.5	29.5	29.5
43	9/11	69°01.8'	165°32.3'	22	6.6	6.9	29.6	30.0
44	9/11	69°11.0'	165°34.0'	27	6.7	6.9	30.0	30.2
45	9/11	69°40.4'	165°27.6'	39	5.8	4.5	27.8	31.0
46	9/11	69°11.2'	165°33.9'	47	6.4	-	29.9	-
47	9/11	69°01.3'	165°33.7'	21	6.4	6.9	29.4	30.0
48	9/12	68°49.9'	166°23.3'	33	6.4	5.9	29.3	31.0
49	9/12	68°01.6'	166°07.7'	25	7.5	7.5	30.4	30.5

10.2 Winter Catch Data Listings

This section contains length, body weight, and stomach content wet weight data for the 204 Arctic cod taken during the 16-25 March sampling period. Stomach contents indicated as 0.01 g include all weights less than or equal to 0.01 g.

Winter Fyke Nets: ARCTIC COD

Station	Date	Weight(g)	Fork Length(mm)	Weight of Stomach Contents(g)
1	3/16/83	4.27	80	0.02
		1.32	55	0.01
2	3/18/83	3.97	80	-
		3.24	75	-
		4.17	80	-
		2.00	65	-
		2.56	70	-
		2.03	64	-
		1.72	65	-
		5.41	90	-
		1.96	64	-
		1.85	63	-
		2.16	67	-
		1.93	67	-
		2.93	75	-
		2.08	67	-
		2.30	67	-
		1.48	60	-
		1.68	61	-
		1.84	63	-
2	3/19/83	2.49	66	-
		2.48	67	-
		2.76	69	-
		1.44	58	-
		3.23	75	-
		2.91	70	-
		3.47	74	-
		2.45	65	-
		1.77	63	-
		2.74	66	-
		2.30	65	-
		1.54	62	-
		5.13	82	-
		2.27	67	-
		3.70	75	-
		1.87	60	-
		2.76	67	-
		2.31	60	-
		2.19	67	-
		2.35	68	-
		2.37	67	-
		2.03	65	-
		3.41	71	-
		-	-	-
		2.74	70	-
		1.92	65	-
		1.65	60	-
		1.96	64	-
		2.74	68	-
		2.42	67	-
		2.64	70	-
		3.06	72	-

Winter Fyke Nets: ARCTIC COD

Station	Date	Weight(g)	Fork Length(mm)	Weight of Stomach Contents(g)
2	3/19/83	1.47	58	-
		1.93	64	-
		2.05	64	-
		2.14	63	-
		1.10	53	-
		1.33	55	-
		1.03	53	-
		-	-	-
2	3/20/83	7.68	99	-
		3.57	75	-
		1.57	60	-
		2.43	69	-
		2.86	75	-
		2.07	67	-
		1.71	60	-
		4.25	79	-
		2.45	70	-
		2.43	67	-
		2.87	70	-
		2.59	58	-
		1.24	56	-
		1.50	60	-
		1.74	60	-
		3.97	78	-
		2.20	62	-
		1.96	61	-
		2.38	65	-
		3.26	75	-
		2.24	66	-
		2.22	62	-
		2.08	62	-
		2.24	68	-
		2.42	67	-
		2.44	70	-
		2.31	68	-
		1.13	55	-
2	3/21/83	3.38	74	0.01
		2.91	70	0.01
		2.40	66	0.01
		2.89	68	0.01
		2.21	66	0.01
		2.05	66	0.01
		2.56	68	0.08
		2.50	68	0.00
		2.33	64	0.06
		2.19	65	0.01
		1.95	63	0.01
		1.50	59	0.01
		1.95	64	-
		1.63	61	-
		1.62	61	-
		1.61	61	-
		0.97	54	-
		1.31	55	-
		1.55	58	-
		1.95	64	-

Winter Fyke Nets: ARCTIC COD

Station	Date	Weight(g)	Fork Length(mm)	Weight of Stomach Contents(g)
2	3/21/83	1.20	58	-
		1.93	60	-
		1.58	60	-
		4.85	80	0.05
		5.70	90	0.05
		1.43	62	0.02
		1.02	51	0.00
		4.44	84	0.01
		0.53	44	0.01
		4.00	78	-
		4.70	83	-
		3.05	74	-
		3.42	78	-
		2.52	69	-
		4.14	80	-
		-	-	-
		4.48	80	-
		2.75	68	-
		2.61	69	-
		2.97	73	-
		2.29	66	-
		1.94	63	-
		1.95	60	-
		2.52	68	-
		3.96	75	-
		2.22	65	-
		2.86	70	-
		3.06	70	-
		2.75	69	-
		1.62	62	-
		1.97	66	-
		1.82	63	-
		1.97	62	-
		1.61	62	-
		1.40	60	-
		1.72	60	-
		1.59	59	-
		1.62	57	-
2	3/22/83	5.84	94	0.04
		4.81	87	0.01
		1.89	64	0.01
		2.63	70	0.01
		1.86	62	0.00
		1.78	67	0.01
		1.47	60	0.00
		1.12	57	0.01
		1.89	62	0.01
		1.39	60	0.01
		1.47	57	0.02
		0.81	50	0.00
		1.63	62	0.00
		1.01	55	0.00
		0.82	48	0.01

Winter Fyke Nets: ARCTIC COD

Station	Date	Weight(g)	Fork Length(mm)	Weight of Stomach Contents(g)
3	3/21/83	3.28	70	0.28
		2.59	68	0.09
		2.47	65	0.06
		2.08	64	0.06
		1.47	57	0.02
		2.37	67	0.03
		1.71	60	0.04
		1.54	60	0.03
		1.15	54	0.02
		2.68	70	0.03
		1.29	60	0.03
		2.52	70	0.06
		-	-	-
		1.37	59	0.05
		2.47	69	0.06
		1.24	55	0.01
		1.25	57	0.00
		1.31	58	0.00
		2.09	60	0.00
		1.69	62	0.06
3	3/22/83	2.64	70	0.04
		3.28	72	0.05
		2.29	66	0.06
		1.47	59	0.04
3	3/23/83	2.38	65	0.05
		2.53	70	0.04
		2.31	66	0.04
4	3/25/83	4.47	80	0.24
		2.43	60	0.15
		1.04	49	0.02
		1.12	50	0.01
		1.01	49	0.01
4	3/26/83	2.62	62	0.18
		2.75	66	0.11
4	3/27/83	1.91	59	0.10
		1.96	58	0.08
4	3/28/83	4.47	77	0.37
		2.54	66	0.11
		2.48	65	0.07
		4.33	75	0.20
		2.52	64	0.18
		1.39	58	0.09
		4.37	79	0.26

10.3 Fish Catch and Effort Data Listings (Point Lay)

This section contains the fishing effort and catch by gear type for the 1983 Point Lay sampling period. The actual catch of the most abundant species taken at each station is given on a daily basis. Data is provided for the following species:

Fyke Nets	Gill Nets
Arctic cod	Pacific herring
Capelin	Boreal smelt
Fourhorn sculpin	Fourhorn sculpin
Arctic flounder	Arctic flounder
Boreal smelt	
Saffron cod	

EFFORT SUMMARY - FYKE NETS (Hours Fished)

Station:	1	2	
Date			
7/18/83	23.5		
7/19/83	20.3		
7/20/83	26.0		
7/21/83	22.5		
7/22/83	23.6		
7/23/83	24.5		
7/24/83	-		
7/25/83	-		
7/26/83	71.3		
7/27/83	-		
7/28/83	-		
7/29/83	26.5		
7/30/83	21.5		
7/31/83	22.5		
8/1/83	22.5		
8/2/83	29.6		
8/3/83	19.0		
8/4/83	24.5		
8/5/83			
8/6/83			
8/7/83			
8/8/83			
8/9/83			
8/10/83			
8/11/83			
8/12/83			
8/13/83			
8/14/83			
8/15/83			
8/16/83			
8/17/83			
8/18/83			
8/19/83		20.0	
8/20/83		19.5	
8/21/83		-	
8/22/83		47.0	
8/23/83		-	
8/24/83		46.5	
8/25/83		24.0	
8/26/83		29.5	
8/27/83		-	
8/28/83		50.0	
8/29/83		21.0	
8/30/83		23.0	
8/31/83		24.5	
Mean	27.0	30.5	
Std. Dev.	13.0	12.3	
Std. Err.	3.29	3.90	
N	14	10	
Total	377.8	305.0	682.8

EFFORT SUMMARY - GILL NETS (Hours Fished)

Station: Date	3S	3B	4S	4B	4XS	4XB	5	6	7	8	Total
7/18/83	-	-	30.0	30.0	-	-	-	-	-	-	60.0
7/19/83	23.0	23.0	-	-	-	-	-	-	-	-	46.0
7/20/83	-	-	-	23.2	-	-	-	-	-	-	23.2
7/21/83	-	-	-	-	-	-	19.8	-	-	-	19.8
7/22/83	-	-	-	-	-	-	21.3	-	-	-	21.3
7/23/83	-	-	-	-	-	-	24.5	-	-	-	24.5
7/24/83	-	-	-	-	-	-	25.0	-	-	-	25.0
7/25/83	-	-	-	-	-	-	22.8	-	-	-	22.8
7/26/83	-	-	24.0	-	-	-	-	-	-	-	24.0
7/27/83	-	-	-	-	-	-	-	-	-	-	0.0
7/28/83	-	-	50.0	50.5	-	-	-	-	-	-	100.5
7/29/83	-	-	25.3	25.5	-	-	-	-	-	-	50.8
7/30/83	24.3	24.3	-	-	-	-	-	-	-	-	48.6
7/31/83	18.5	18.5	-	-	-	-	-	-	-	-	37.0
7/1/83	-	-	-	23.0	-	25.0	-	-	-	-	48.0
8/2/83	-	-	-	-	-	-	21.3	-	-	-	21.3
8/3/83	-	-	-	-	-	23.5	-	23.0	-	-	46.5
8/4/83	-	-	-	-	24.0	-	-	-	-	-	24.0
8/5/83	-	-	-	-	-	-	-	-	-	-	0.0
8/6/83	-	-	-	-	-	-	-	-	-	-	0.0
8/7/83	-	-	-	-	-	-	-	-	-	-	0.0
8/8/83	-	-	-	-	-	-	-	-	20.0	-	20.0
8/9/83	-	-	-	-	-	-	-	-	-	24.0	24.0
8/10/83	-	-	-	-	-	-	-	-	-	-	0.0
8/11/83	24.0	-	-	24.0	-	-	-	-	-	-	48.0
8/12/83	-	-	-	-	-	-	-	-	-	-	0.0
8/13/83	-	-	-	-	-	-	-	-	-	-	0.0
8/14/83	-	-	-	-	-	-	-	-	-	-	0.0
8/15/83	-	-	-	-	-	20.5	-	-	-	-	20.5
8/16/83	-	-	-	-	-	-	28.0	-	-	-	28.0
8/17/83	19.3	19.3	-	-	-	-	-	-	-	-	38.6
8/18/83	-	-	-	-	-	-	24.0	-	-	-	24.0
8/19/83	53.0	53.0	-	-	-	-	24.0	-	-	-	130.0
8/20/83	-	-	21.0	21.0	-	-	20.0	-	-	-	62.0
8/21/83	-	-	-	-	-	-	-	-	-	-	0.0
8/22/83	-	-	47.0	47.0	-	-	20.0	-	-	-	114.0
8/23/83	-	-	24.5	24.0	-	-	-	-	-	24.5	73.0
8/24/83	-	-	29.0	29.0	-	-	-	-	-	-	58.0
8/25/83	20.0	20.5	-	-	-	-	21.5	-	-	-	62.0
8/26/83	-	-	-	-	-	-	22.5	-	22.5	-	45.0
8/27/83	-	-	-	-	-	-	-	-	-	-	0.0
8/28/83	-	-	-	-	-	-	-	21.0	-	-	21.0
8/29/83	72.0	72.0	-	-	-	-	72.0	-	72.0	-	288.0
8/30/83	-	-	-	-	-	-	24.0	-	-	-	24.0
8/31/83	-	-	-	-	-	-	-	-	-	-	0.0
9/1/83	-	-	-	72.0	-	-	-	-	-	-	72.0
Mean	31.8	32.9	31.4	33.6	24.0	23.0	26.0	22.0	38.2	24.3	
Std. Dev.	19.8	21.0	11.0	16.1	24.0	2.3	12.9	1.4	29.3	.4	
Std. Err.	7.0	7.9	3.9	4.9	24.0	1.3	3.3	1.0	16.9	.3	
N	8	7	8	11	1	3	15	2	3	2	
Total	254.1	230.6	250.8	369.2	24.0	69.0	390.7	44.0	114.5	48.5	1795.4

Catch Summary: Fyke Nets

Species	Station 1	Station 2	Total
Arctic cod	4014	1191	5205
Capelin	3343	1	3344
Fourhorn sculpin	1491	1152	2643
Arctic flounder	1512	202	1714
Saffron cod	110	155	265
Boreal smelt	1	79	134
Great sculpin	24	1	25
Pink salmon	5	1	6
Arctic char	2	1	3
Least cisco	2	-	2
Longhead dab	1	-	1
Bering cisco	-	1	1
Pacific sand lance	-	1	1
Threespine stickleback	-	1	1
	10,505	2840	13,345

Catch Summary: Gill Nets

Species	Station 3	4	4X	5	6	7	8	Total
Pacific herring	39	201	137	21	0	49	80	527
Fourhorn sculpin	0	58	59	21	19	16	29	202
Boreal smelt	1	77	0	7	20	15	66	186
Arctic flounder	0	11	13	18	50	3	1	96
Pink salmon	0	1	22	0	0	0	5	28
Capelin	0	6	9	0	0	0	1	16
Arctic cod	1	9	0	0	0	0	2	12
Longhead dab	0	4	5	0	0	1	1	11
Great sculpin	0	2	0	0	0	1	2	5
Saffron cod	0	1	0	1	0	0	2	4
Sturgeon poacher	0	2	0	0	0	0	1	3
Bering cisco	0	0	1	0	0	0	0	1
Chum salmon	0	0	0	0	0	1	0	1
	41	372	246	68	89	86	190	1092

FYKE NETS: Arctic Cod

Station: Date	1	2
7/18/83	119	-
7/19/83	709	-
7/20/83	99	-
7/21/83	287	-
7/22/83	164	-
7/23/83	385	-
7/24/83	-	-
7/25/83	-	-
7/26/83	476	-
7/27/83	-	-
7/28/83	-	-
7/29/83	296	-
7/30/83	66	-
7/31/83	28	-
8/1/83	15	-
8/2/83	866	-
8/3/83	375	-
8/4/83	129	-
8/5/83	-	-
8/6/83	-	-
8/7/83	-	-
8/8/83	-	-
8/9/83	-	-
8/10/83	-	-
8/11/83	-	-
8/12/83	-	-
8/13/83	-	-
8/14/83	-	-
8/15/83	-	-
8/16/83	-	-
8/17/83	-	-
8/18/83	-	-
8/19/83	-	335
8/20/83	-	86
8/21/83	-	-
8/22/83	-	64
8/23/83	-	-
8/24/83	-	43
8/25/83	-	31
8/26/83	-	475
8/27/83	-	-
8/28/83	-	115
8/29/83	-	6
8/30/83	-	1
8/31/83	-	35
Total	4014	1191
	5205	

FYKE NETS: Capelin

Station: Date	1	2
7/18/83	0	-
7/19/83	0	-
7/20/83	0	-
7/21/83	0	-
7/22/83	0	-
7/23/83	0	-
7/24/83	-	-
7/25/83	-	-
7/26/83	0	-
7/27/83	-	-
7/28/83	-	-
7/29/83	1	-
7/30/83	1	-
7/31/83	0	-
8/1/83	134	-
8/2/83	2698	-
8/3/83	498	-
8/4/83	11	-
8/5/83	-	-
8/6/83	-	-
8/7/83	-	-
8/8/83	-	-
8/9/83	-	-
8/10/83	-	-
8/11/83	-	-
8/12/83	-	-
8/13/83	-	-
8/14/83	-	-
8/15/83	-	-
8/16/83	-	-
8/17/83	-	-
8/18/83	-	-
8/19/83	-	0
8/20/83	-	0
8/21/83	-	-
8/22/83	-	0
8/23/83	-	-
8/24/83	-	0
8/25/83	-	0
8/26/83	-	0
8/27/83	-	-
8/28/83	-	0
8/29/83	-	0
8/30/83	-	0
8/31/83	-	1
Total	3343	1
	3344	

FYKE NETS: Fourhorn Sculpin

Station: Date	1	2
7/18/83	30	-
7/19/83	304	-
7/20/83	86	-
7/21/83	161	-
7/22/83	277	-
7/23/83	242	-
7/24/83	-	-
7/25/83	-	-
7/26/83	16	-
7/27/83	-	-
7/28/83	-	-
7/29/83	5	-
7/30/83	16	-
7/31/83	0	-
8/1/83	60	-
8/2/83	53	-
8/3/83	230	-
8/4/83	11	-
8/5/83	-	-
8/6/83	-	-
8/7/83	-	-
8/8/83	-	-
8/9/83	-	-
8/10/83	-	-
8/11/83	-	-
8/12/83	-	-
8/13/83	-	-
8/14/83	-	-
8/15/83	-	-
8/16/83	-	-
8/17/83	-	-
8/18/83	-	-
8/19/83	-	90
8/20/83	-	119
8/21/83	-	-
8/22/83	-	94
8/23/83	-	-
8/24/83	-	66
8/25/83	-	33
8/26/83	-	50
8/27/83	-	-
8/28/83	-	525
8/29/83	-	78
8/30/83	-	49
8/31/83	-	48
Total	1491	1152
	2643	

FYKE NETS: Arctic Flounder

Station: Date	1	2
7/18/83	5	-
7/19/83	67	-
7/20/83	27	-
7/21/83	188	-
7/22/83	109	-
7/23/83	92	-
7/24/83	-	-
7/25/83	-	-
7/26/83	57	-
7/27/83	-	-
7/28/83	-	-
7/29/83	65	-
7/30/83	13	-
7/31/83	36	-
8/1/83	752	-
8/2/83	27	-
8/3/83	63	-
8/4/83	11	-
8/5/83	-	-
8/6/83	-	-
8/7/83	-	-
8/8/83	-	-
8/9/83	-	-
8/10/83	-	-
8/11/83	-	-
8/12/83	-	-
8/13/83	-	-
8/14/83	-	-
8/15/83	-	-
8/16/83	-	-
8/17/83	-	-
8/18/83	-	-
8/19/83	-	18
8/20/83	-	63
8/21/83	-	-
8/22/83	-	17
8/23/83	-	-
8/24/83	-	25
8/25/83	-	2
8/26/83	-	18
8/27/83	-	-
8/28/83	-	46
8/29/83	-	0
8/30/83	-	2
8/31/83	-	11
Total	1512	202
	1714	

FYKE NETS: Saffron Cod

Station: Date	1	2
7/18/83	0	-
7/19/83	0	-
7/20/83	0	-
7/21/83	1	-
7/22/83	0	-
7/23/83	5	-
7/24/83	-	-
7/25/83	-	-
7/26/83	24	-
7/27/83	-	-
7/28/83	-	-
7/29/83	0	-
7/30/83	0	-
7/31/83	1	-
8/1/83	66	-
8/2/83	1	-
8/3/83	12	-
8/4/83	0	-
8/5/83	-	-
8/6/83	-	-
8/7/83	-	-
8/8/83	-	-
8/9/83	-	-
8/10/83	-	-
8/11/83	-	-
8/12/83	-	-
8/13/83	-	-
8/14/83	-	-
8/15/83	-	-
8/16/83	-	-
8/17/83	-	-
8/18/83	-	-
8/19/83	-	0
8/20/83	-	22
8/21/83	-	-
8/22/83	-	21
8/23/83	-	-
8/24/83	-	29
8/25/83	-	2
8/26/83	-	29
8/27/83	-	-
8/28/83	-	43
8/29/83	-	3
8/30/83	-	0
8/31/83	-	6
Total	110	155
	265	

FYKE NETS: Boreal Smelt

Station: Date	1	2
7/18/83	0	-
7/19/83	1	-
7/20/83	0	-
7/21/83	0	-
7/22/83	0	-
7/23/83	0	-
7/24/83	-	-
7/25/83	-	-
7/26/83	0	-
7/27/83	-	-
7/28/83	-	-
7/29/83	0	-
7/30/83	0	-
7/31/83	0	-
8/1/83	0	-
8/2/83	0	-
8/3/83	0	-
8/4/83	0	-
8/5/83	-	-
8/6/83	-	-
8/7/83	-	-
8/8/83	-	-
8/9/83	-	-
8/10/83	-	-
8/11/83	-	-
8/12/83	-	-
8/13/83	-	-
8/14/83	-	-
8/15/83	-	-
8/16/83	-	-
8/17/83	-	-
8/18/83	-	-
8/19/83	-	8
8/20/83	-	16
8/21/83	-	-
8/22/83	-	1
8/23/83	-	-
8/24/83	-	4
8/25/83	-	44
8/26/83	-	6
8/27/83	-	-
8/28/83	-	44
8/29/83	-	6
8/30/83	-	3
8/31/83	-	1
Total	1	133
	134	

GILL NETS: Fourhorn Sculpin

Station: Date	3	4	4X	5	6	7	8	Total
7/18/83	-	0	-	-	-	-	-	0
7/19/83	0	-	-	-	-	-	-	0
7/20/83	-	0	-	-	-	-	-	0
7/21/83	-	-	-	0	-	-	-	0
7/22/83	-	-	-	1	-	-	-	1
7/23/83	-	-	-	0	-	-	-	0
7/24/83	-	-	-	4	-	-	-	4
7/25/83	-	-	-	0	-	-	-	0
7/26/83	-	0	-	-	-	-	-	0
7/27/83	-	-	-	-	-	-	-	0
7/28/83	-	0	-	-	-	-	-	0
7/29/83	-	0	-	-	-	-	-	0
7/30/83	0	-	-	-	-	-	-	0
7/31/83	0	-	-	-	-	-	-	0
7/1/83	-	3	0	-	-	-	-	3
8/2/83	-	-	-	3	-	-	-	3
8/3/83	-	-	56	-	19	-	-	75
8/4/83	-	-	0	-	-	-	-	0
8/5/83	-	-	-	-	-	-	-	0
8/6/83	-	-	-	-	-	-	-	0
8/7/83	-	-	-	-	-	-	-	0
8/8/83	-	-	-	-	-	2	-	2
8/9/83	-	-	-	-	-	-	17	17
8/10/83	-	-	-	-	-	-	-	0
8/11/83	0	13	-	-	-	-	-	13
8/12/83	-	-	-	-	-	-	-	0
8/13/83	-	-	-	-	-	-	-	0
8/14/83	-	-	-	-	-	-	-	0
8/15/83	-	-	3	-	-	-	-	3
8/16/83	-	-	-	0	-	-	-	0
8/17/83	0	-	-	-	-	-	-	0
8/18/83	-	-	-	2	-	-	-	2
8/19/83	0	-	-	1	-	-	-	1
8/20/83	-	0	-	0	-	-	-	0
8/21/83	-	-	-	-	-	-	-	0
8/22/83	-	7	-	0	-	-	-	7
8/23/83	-	3	-	-	-	-	12	15
8/24/83	-	14	-	-	-	-	-	14
8/25/83	0	-	-	2	-	-	-	2
8/26/83	-	-	-	2	-	12	-	14
8/27/83	-	-	-	-	-	-	-	0
8/28/83	-	-	-	-	0	-	-	0
8/29/83	0	-	-	4	-	2	-	6
8/30/83	-	-	-	2	-	-	-	2
8/31/83	-	-	-	-	-	-	-	0
9/1/83	-	18	-	-	-	-	-	18
Total	0	58	59	21	19	16	29	202

GILL NETS: Arctic Flounder

Station: Date	3	4	4X	5	6	7	8	Total
7/18/83	-	0	-	-	-	-	-	0
7/19/83	0	-	-	-	-	-	-	0
7/20/83	-	0	-	-	-	-	-	0
7/21/83	-	-	-	0	-	-	-	0
7/22/83	-	-	-	9	-	-	-	9
7/23/83	-	-	-	0	-	-	-	0
7/24/83	-	-	-	1	-	-	-	1
7/25/83	-	-	-	0	-	-	-	0
7/26/83	-	0	-	-	-	-	-	0
7/27/83	-	-	-	-	-	-	-	0
7/28/83	-	0	-	-	-	-	-	0
7/29/83	-	0	-	-	-	-	-	0
7/30/83	0	-	-	-	-	-	-	0
7/31/83	0	-	-	-	-	-	-	0
7/1/83	-	0	0	-	-	-	-	0
8/2/83	-	-	-	1	-	-	-	1
8/3/83	-	-	13	-	50	-	-	63
8/4/83	-	-	0	-	-	-	-	0
8/5/83	-	-	-	-	-	-	-	0
8/6/83	-	-	-	-	-	-	-	0
8/7/83	-	-	-	-	-	-	-	0
8/8/83	-	-	-	-	-	0	-	0
8/9/83	-	-	-	-	-	-	1	1
8/10/83	-	-	-	-	-	-	-	0
8/11/83	0	7	-	-	-	-	-	7
8/12/83	-	-	-	-	-	-	-	0
8/13/83	-	-	-	-	-	-	-	0
8/14/83	-	-	-	-	-	-	-	0
8/15/83	-	-	0	-	-	-	-	0
8/16/83	-	-	-	0	-	-	-	0
8/17/83	0	-	-	-	-	-	-	0
8/18/83	-	-	-	1	-	-	-	1
8/19/83	0	-	-	0	-	-	-	0
8/20/83	-	1	-	0	-	-	-	1
8/21/83	-	-	-	-	-	-	-	0
8/22/83	-	0	-	0	-	-	-	0
8/23/83	-	0	-	-	-	-	0	0
8/24/83	-	1	-	-	-	-	-	1
8/25/83	0	-	-	4	-	-	-	4
8/26/83	-	-	-	0	-	2	-	2
8/27/83	-	-	-	-	-	-	-	0
8/28/83	-	-	-	-	0	-	-	0
8/29/83	0	-	-	2	-	1	-	3
8/30/83	-	-	-	0	-	-	-	0
8/31/83	-	-	-	-	-	-	-	0
9/1/83	-	2	-	-	-	-	-	2
Total	0	11	13	18	50	3	1	96

GILL NETS: Pacific Herring

Station: Date	3	4	4X	5	6	7	8	Total
7/18/83	-	0	-	-	-	-	-	0
7/19/83	0	-	-	-	-	-	-	0
7/20/83	-	0	-	-	-	-	-	0
7/21/83	-	-	-	0	-	-	-	0
7/22/83	-	-	-	0	-	-	-	0
7/23/83	-	-	-	0	-	-	-	0
7/24/83	-	-	-	0	-	-	-	0
7/25/83	-	-	-	0	-	-	-	0
7/26/83	-	0	-	-	-	-	-	0
7/27/83	-	-	-	-	-	-	-	0
7/28/83	-	0	-	-	-	-	-	0
7/29/83	-	0	-	-	-	-	-	0
7/30/83	0	-	-	-	-	-	-	0
7/31/83	0	-	-	-	-	-	-	0
7/1/83	-	1	0	-	-	-	-	1
8/2/83	-	-	-	0	-	-	-	0
8/3/83	-	-	13	-	0	-	-	13
8/4/83	-	-	2	-	-	-	-	2
8/5/83	-	-	-	-	-	-	-	0
8/6/83	-	-	-	-	-	-	-	0
8/7/83	-	-	-	-	-	-	-	0
8/8/83	-	-	-	-	-	5	-	5
8/9/83	-	-	-	-	-	-	58	58
8/10/83	-	-	-	-	-	-	-	0
8/11/83	24	28	-	-	-	-	-	52
8/12/83	-	-	-	-	-	-	-	0
8/13/83	-	-	-	-	-	-	-	0
8/14/83	-	-	-	-	-	-	-	0
8/15/83	-	-	122	-	-	-	-	122
8/16/83	-	-	-	1	-	-	-	1
8/17/83	0	-	-	-	-	-	-	0
8/18/83	-	-	-	18	-	-	-	18
8/19/83	1	-	-	0	-	-	-	1
8/20/83	-	39	-	0	-	-	-	39
8/21/83	-	-	-	-	-	-	-	0
8/22/83	-	29	-	1	-	-	-	30
8/23/83	-	64	-	-	-	-	22	86
8/24/83	-	32	-	-	-	-	-	32
8/25/83	13	-	-	0	-	-	-	13
8/26/83	-	-	-	1	-	39	-	40
8/27/83	-	-	-	-	-	-	-	0
8/28/83	-	-	-	-	0	-	-	0
8/29/83	1	-	-	0	-	5	-	6
8/30/83	-	-	-	0	-	-	-	0
8/31/83	-	-	-	-	-	-	-	0
9/1/83	-	8	-	-	-	-	-	8
Total	39	201	137	21	0	49	80	527

GILL NETS: Boreal Smelt

Station: Date	3	4	4X	5	6	7	8	Total
7/18/83	-	0	-	-	-	-	-	0
7/19/83	0	-	-	-	-	-	-	0
7/20/83	-	0	-	-	-	-	-	0
7/21/83	-	-	-	0	-	-	-	0
7/22/83	-	-	-	2	-	-	-	2
7/23/83	-	-	-	0	-	-	-	0
7/24/83	-	-	-	0	-	-	-	0
7/25/83	-	-	-	0	-	-	-	0
7/26/83	-	0	-	-	-	-	-	0
7/27/83	-	-	-	-	-	-	-	0
7/28/83	-	0	-	-	-	-	-	0
7/29/83	-	0	-	-	-	-	-	0
7/30/83	0	-	-	-	-	-	-	0
7/31/83	0	-	-	-	-	-	-	0
7/1/83	-	0	0	-	-	-	-	0
8/2/83	-	-	-	4	-	-	-	4
8/3/83	-	-	0	-	20	-	-	20
8/4/83	-	-	0	-	-	-	-	0
8/5/83	-	-	-	-	-	-	-	0
8/6/83	-	-	-	-	-	-	-	0
8/7/83	-	-	-	-	-	-	-	0
8/8/83	-	-	-	-	-	1	-	1
8/9/83	-	-	-	-	-	-	24	24
8/10/83	-	-	-	-	-	-	-	0
8/11/83	0	0	-	-	-	-	-	0
8/12/83	-	-	-	-	-	-	-	0
8/13/83	-	-	-	-	-	-	-	0
8/14/83	-	-	-	-	-	-	-	0
8/15/83	-	-	0	-	-	-	-	0
8/16/83	-	-	-	0	-	-	-	0
8/17/83	0	-	-	-	-	-	-	0
8/18/83	-	-	-	0	-	-	-	0
8/19/83	0	-	-	0	-	-	-	0
8/20/83	-	8	-	0	-	-	-	8
8/21/83	-	-	-	-	-	-	-	0
8/22/83	-	57	-	0	-	-	-	57
8/23/83	-	6	-	-	-	-	42	48
8/24/83	-	1	-	-	-	-	-	1
8/25/83	1	-	-	1	-	-	-	2
8/26/83	-	-	-	0	-	14	-	14
8/27/83	-	-	-	-	-	-	-	0
8/28/83	-	-	-	-	0	-	-	0
8/29/83	0	-	-	0	-	0	-	0
8/30/83	-	-	-	0	-	-	-	0
8/31/83	-	-	-	-	-	-	-	0
9/1/83	-	5	-	-	-	-	-	5
Total	1	77	0	7	20	15	66	186

10.4 Length-frequency Data Listings (Point Lay)

this section contains length-frequency data by gear type for fish that were measured during the Point Lay sampling effort. Data is provided for the following species:

Fyke Nets	Gill Nets
Arctic cod	Pacific herring
Fourhorn sculpin	Fourhorn sculpin
Arctic flounder	Boreal smelt
Saffron cod	Arctic flounder
Boreal smelt	
Capelin	

Gill Nets Species: Arctic Flounder

Date(M/D) Length(mm)	7/18	7/19	7/20	7/21	7/22	7/23	7/24	7/25	7/26	7/28	7/29	7/30	7/31	8/1	8/2	8/3	8/4	8/8	Total
75																			0
80																			0
85																			0
90																2			2
95																1			1
100																1			1
105																2			2
110																2			2
115																3			3
120																3			3
125																			0
130																			0
135																			0
140																			0
145																4			4
150																3			3
155					1											3			4
160							1									2			3
165					2											6			8
170					1											4			5
175					1											2			3
180					1											5			6
185																5			5
190																1			1
195																			0
200																3			3
205					1											2			3
210					1											2			3
215																3			3
220																2			2
225															1	1			2
230																1			1
235																			0
240					1														1
Total	0	0	0	0	9	0	1	0	0	0	0	0	0	0	1	63	0	0	74

Gill Nets Species: Arctic Flounder

Date(M/D) Length(mm)	8/9	8/11	8/15	8/16	8/17	8/18	8/19	8/20	8/22	8/23	8/24	8/25	8/26	8/28	8/29	8/30	9/1	Total	Grand Total
75															1			1	1
80													1					1	1
85													1					1	1
90								1							1			2	4
95																		0	1
100		1									1							2	3
105		1																1	3
110																		0	2
115		1																1	4
120		1																1	4
125																		0	0
130																		0	0
135																		0	0
140																		0	0
145																		0	4
150																		0	3
155																		0	4
160		2																2	5
165	1					1												2	10
170		1																1	6
175																		0	3
180																		0	6
185												1						1	6
190												1			1			2	3
195												2						2	2
200																		0	3
205																		0	3
210																		0	3
215																		0	3
220																		0	2
225																		0	2
230																		0	1
235																		0	0
240																		0	1
Total	1	7	0	0	0	1	0	1	0	0	1	4	2	0	3	0	0	20	94

Gill Nets Species: Fourhorn Sculpin

Date(M/D) Length(mm)	7/18	7/19	7/20	7/21	7/22	7/23	7/24	7/25	7/26	7/28	7/29	7/30	7/31	8/1	8/2	8/3	8/4	8/8	Total
85																			0
90																			0
95																1			1
100																		1	1
105																2			2
110																3			3
115														1		5			6
120																6			6
125																2			2
130																			0
135																			0
140																			0
145															1	3			4
150																2			2
155																2			2
160																4			4
165																4			4
170																7		1	8
175							1							1		4			6
180																1			1
185														1		1			2
190																2			2
195															1	2			3
200																3			3
205																3			3
210																3			3
215																1			1
220							1									2			3
225					1											2			3
230																			0
235																2			2
240							1												1
245																1			1
250							1								1				2
255																1			1
260																1			1
265																2			2
270																			0
275																1			1
280																2			2
Total	0	0	0	0	1	0	4	0	0	0	0	0	0	3	3	75	0	2	88

Gill Nets Species: Fourhorn Sculpin

Date(M/D) Length(mm)	8/9	8/11	8/15	8/16	8/17	8/18	8/19	8/20	8/22	8/23	8/24	8/25	8/26	8/28	8/29	8/30	9/1	Total	Grand Total
85												1						1	1
90																		0	0
95																1		1	2
100									1				2					3	4
105	1														1			2	4
110	1		1								1		1					4	7
115		1								1			3					5	11
120	3									1	1							5	11
125										1			1					2	4
130	1														2			3	3
135											1					1		2	2
140										2	2							4	4
145										1			1					2	6
150													1					1	3
155	1					1					1		1					4	6
160									5		2		1					8	12
165	1	2								2	2							7	11
170									1	2	1		2		1			7	15
175	3	3																6	12
180		2	1							2								5	6
185		2	1															3	5
190	1	1																2	4
195	1										1							2	5
200																		0	3
205																		0	3
210		2										1			1			4	7
215																		0	1
220										1								1	4
225	3																	3	6
230						1									1			2	2
235																		0	2
240	1																	1	2
245																		0	1
250																		0	2
255																		0	1
260													1					1	2
265																		0	2
270																		0	0
275																		0	1
280																		0	2
Total	17	13	3	0	0	2	0	0	7	13	12	2	14	0	6	2	0	91	179

Gill Nets Species: Pacific Herring

Date(M/D) Length(mm)	7/18	7/19	7/20	7/21	7/22	7/23	7/24	7/25	7/26	7/28	7/29	7/30	7/31	8/1	8/2	8/3	8/4	8/8	Total
120																			0
125																			0
130																			0
135																			0
140																			0
145																			0
150																			0
155																			0
160																			0
165																			0
170																			0
175																			0
180																			0
185																			0
190																			0
195																			0
200																			0
205																			0
210																			0
215																			0
220																			0
225																			0
230																			0
235																1		1	2
240																		1	1
245																4			4
250														1		2		1	4
255																1	1	1	3
260																1			1
265																4	1	1	6
270																			0
275																			0
280																			0
285																			0
290																			0
295																			0
Total	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	13	2	5	21

Gill Nets Species: Pacific Herring

Date(M/D) Length(mm)	8/9	8/11	8/15	8/16	8/17	8/18	8/19	8/20	8/22	8/23	8/24	8/25	8/26	8/28	8/29	8/30	9/1	Total	Grand Total
120									1									1	1
125																		0	0
130																		0	0
135																		0	0
140																		0	0
145																		0	0
150																		0	0
155																		0	0
160																		0	0
165																		0	0
170																		0	0
175																		0	0
180																		0	0
185																		0	0
190																		0	0
195																		0	0
200																		0	0
205															1			1	1
210			4					4	2	1			3					14	14
215						1		2		1			1					5	5
220	1	1						5	1	3		1	5					17	17
225		1				1		2		1			1					6	6
230		2	4			1		4	3	5	2		3					24	24
235	2	2	6			1			2	7	1		1					22	24
240	2		13			1		4	11	7	1		1					40	41
245	6	3	16			1			1	9	1	1	6					44	48
250	5	1	11			1		7	5	7		1	5		1			44	48
255	13	5	22			2		1		4	1	4	2		2			56	59
260	9	10	19	1		3		6	2	8	2	2	7		2			71	72
265	6	7	3			3	1			7	5	2	3					37	43
270	5	9	11			3		3	1	6	2		1					41	41
275	8	2	6							4	2							22	22
280		4	7						1	2		2						16	16
285										2								2	2
290	1	1																2	2
295								1										1	1
Total	58	48	122	1	0	18	1	39	30	74	17	13	39	0	6	0	0	466	487

Gill Nets Species: Boreal Smelt

Date(M/D) Length(mm)	7/18	7/19	7/20	7/21	7/22	7/23	7/24	7/25	7/26	7/28	7/29	7/30	7/31	8/1	8/2	8/3	8/4	8/8	Total
120																			0
125																			0
130																			0
135																			0
140																			0
145																			0
150																			0
155																1			1
160																			0
165																			0
170																1			1
175																			0
180																			0
185																1			1
190																			0
195																			0
200																			0
205																1			1
210																1			1
215															1				1
220															2	2			4
225																4			4
230					1											1		1	3
235																			0
240																			0
245																1			1
250																2			2
255															1	1			2
260																1			1
265																2			2
270																1			1
275					1														1
280																			0
285																			0
290																			0
295																			0
300																			0
Total	0	0	0	0	2	0	0	0	0	0	0	0	0	0	4	20	0	1	27

Gill Nets Species: Boreal Smelt

Date(M/D) Length(mm)	8/9	8/11	8/15	8/16	8/17	8/18	8/19	8/20	8/22	8/23	8/24	8/25	8/26	8/28	8/29	8/30	9/1	Total	Grand Total
120													1					1	1
125																		0	0
130																		0	0
135																		0	0
140																		0	0
145													1					1	1
150																		0	0
155																		0	1
160																		0	0
165													1					1	2
170												1						1	1
175																		0	0
180																		0	1
185													1					1	1
190																		0	0
195																		0	0
200								2		1								3	4
205																		0	1
210								1		3	1		1					6	7
215	1								3	5			1					10	14
220	3							1	28	5		1	1					39	43
225								1	1	7			4					13	16
230	9							1	24	7			3					44	44
235										3								3	3
240	3									5								8	9
245										3								3	5
250	3									1								4	6
255	1								1									2	3
260								1										1	3
265	3																	3	4
270										1								1	2
275										1								1	1
280																		0	0
285																		0	0
290																		0	0
295																		0	0
300	1																	1	1
Total	24	0	0	0	0	0	0	7	57	42	1	2	14	0	0	0	0	147	174

Fyke Net (Ocean)   Species: Arctic Cod

Date(M/D) Length(mm)	7/18	7/19	7/20	7/21	7/22	7/23	7/24	7/25	7/26	7/27	7/28	7/29	7/30	7/31	8/1	8/2	8/3	8/4	Total
40														1					1
45	1																		1
50	2	5	1	2	2				1										13
55	1	1	8	16	8	11			3				1	1	1		1		52
60	13	12	4	20	18	7			17				1				4		96
65	17	6	14	21	14	13			35				2		1		4		127
70	13	9	10	36	32	10			27			2	1	1	2		14		157
75	18	16	10	41	17	22			42			5			1	2	13		187
80	21	12	7	26	25	21			16			17	2	1			10		158
85	10	18	11	18	13	23			18			15	11				3		140
90	6	36	8	7	10	5			6			19	8				6		111
95	7	14	8	6	7	6			4			13	6	1			2		74
100	3	21	12	2	12	5			1			12	5	1	1		4		79
105	3	3	1		2	2			2			3	1				1		18
110	2	7	3		1	5						1	4	1					24
115		1	1	1					1				3	2			1		10
120		2	1	1	1				1			2	1	5		2	1		17
125		1		1					1					3					6
130												2	1	5	1	4			13
135												1	3	2	4	6			16
140												1	2	1	1	2	1		8
145													3	1	2	8	1		15
150												1	3	1		5			10
155	1								1			1				5			8
160															1	15			16
165												1	4			9			14
170													2			5			7
175	1															2			3
180																3			3
185									1			1	1			6			9
190												1	1	1		2			5
195												1				3			4
200																2			2
205																1			1
210																			0
215																			0
220												1							1
225																			0
230																1			1
235																			0
240																			0
245																			0
250																			0
255																			0
260																			0
265																			0
Total	119	164	99	198	162	130	0	0	177	0	0	100	66	28	15	83	66	0	1407

Fyke Net (Lagoon)   Species: Arctic Cod

Date(M/D) Length(mm)	8/19	8/20	8/21	8/22	8/23	8/24	8/25	8/26	8/27	8/28	8/29	8/30	8/31	Total	Grand Total
40														0	1
45														0	1
50														0	13
55														0	52
60	1													1	97
65														0	127
70	1												2	3	160
75	2												1	3	190
80	6							1		2			3	12	170
85	11			2						2			5	20	160
90	5	6		2		4	2	5		3	3		1	31	142
95	20	2		7		6	1	12		9			4	61	135
100	10	7		3		4	4	3		9				40	119
105	14	6		11			5	6					4	46	64
110	9	3		3		1	3	7		22	1		4	53	77
115	15	3		2		1	2	5			1	1	3	33	43
120				1		1	1	3			1		2	9	26
125	4	1				3							2	10	16
130	1	1				1	1	1						5	18
135	5	1		2		3	1						1	13	29
140	1	2		1			3			1			1	9	17
145	3			1		2	1	1		1				9	24
150	2	1		2			1	1						7	17
155		1		2		3		2						8	16
160	4	1		4		2				1				12	28
165	1	2		3		1	2	2					1	12	26
170	4	3		1		1				1				10	17
175		2		4		6	2							14	17
180	1	1					2							4	7
185								1					1	2	11
190	2	3		2		1								8	13
195										1				1	5
200						2								2	4
205				1										1	2
210		1												1	1
215		1		1										2	2
220						1								1	2
225														0	0
230														0	1
235														0	0
240														0	0
245														0	0
250														0	0
255		1												1	1
260														0	0
265		3												3	3
Total	122	52	0	55	0	43	31	50	0	52	6	1	35	447	1854

Fyke Net (Ocean)   Species: Fourhorn Sculpin

Date(M/D) Length(mm)	7/18	7/19	7/20	7/21	7/22	7/23	7/24	7/25	7/26	7/27	7/28	7/29	7/30	7/31	8/1	8/2	8/3	8/4	Total
35																			0
40																			0
45			2		1														3
50	2	1	25	10	11	1										5	2		57
55	10		26	20	27	37			2				5		1	2	1		131
60	10	107	16	46	45	33			2				2		10	1	4		276
65	2	5	7	17	20	21			2				1		5	1			81
70	1	3	5	14	18	7							1		4	2	1		56
75	3	1		4	3	3			1				1		1	1	4		22
80	1			1	1	3									2	1			9
85																			0
90			1	1												1			3
95																			0
100			1						1						1		1		4
105				1									1		3		6		11
110			1			1							1		2	2	4		11
115			1												2		1		4
120	1														3	1	5		10
125															2	3	3		8
130															1	2	5		8
135													1		1	1	3		6
140																2	1		3
145															2	1	2		5
150																	3		3
155		1				1							1		3	1	2		9
160															1	4	3		8
165																3	3		6
170									1						1	2	2		6
175						1									1	6	1		9
180													1			4	3		8
185															1		2		3
190				1					1						2	1	1		6
195			1												2		4		7
200		2		1								1			1	1	2		8
205				1															1
210									1			1				2			4
215																1	1		2
220					1				2			2				2			7
225		1											1						2
230				1					1						1				3
235															1				1
240									1			1							2
245									1										1
250																	1		1
255																			0
260																			0
265				1															1
Total	30	121	86	119	127	108	0	0	16	0	0	5	16	0	54	53	71	0	806

Fyke Net (Lagoon)   Species: Fourhorn Sculpin

Date(M/D) Length(mm)	8/19	8/20	8/21	8/22	8/23	8/24	8/25	8/26	8/27	8/28	8/29	8/30	8/31	Total	Grand Total
35												1		1	1
40														0	0
45												2		2	5
50										1	2	1		4	61
55										8	14	5	1	28	159
60						1				9	12	9	2	33	309
65						1				4	4		4	13	94
70				2		1				2	1	1	1	8	64
75		1		2		1	1			2	1	1	2	11	33
80		7		4		5	1	8		1	4	5	1	36	45
85		4		9		5	1	2		5	1	2	6	35	35
90		9		8		3	7	7		5	8		1	48	51
95		6		3		3	3	1		4	1	6		27	27
100		5		3		2	3	3		1	1		2	20	24
105						2		1			1	1	2	7	18
110		2		3		1	2					1	1	10	21
115		3					2	1				1	1	8	12
120		2		2		1	1	3		1	1			11	21
125		2		2		3	1	3				1	2	14	22
130		1		2		4	1	1		1	1	1	1	13	21
135				3		5	2	4				2	6	22	28
140		3		1		2	2	2		2		1	2	15	18
145		1						7		2		2	2	14	19
150		1		2		2	3	1		1	1	2	2	15	18
155						1		3				1	1	6	15
160		1										1	1	3	11
165		1		1		1	1							4	10
170						1								1	7
175							1						2	3	12
180				1								1		2	10
185		1		1									1	3	6
190							1	1						2	8
195														0	7
200		1												1	9
205													1	1	2
210						1							1	2	6
215				1								1	1	3	5
220														0	7
225														0	2
230								1					1	2	5
235								1						1	2
240														0	2
245														0	1
250														0	1
255														0	0
260														0	0
265														0	1
Total	0	51	0	50	0	46	33	50	0	49	53	49	48	429	1235

Fyke Net (Ocean)   Species: Arctic Flounder

Date(M/D) Length(mm)	7/18	7/19	7/20	7/21	7/22	7/23	7/24	7/25	7/26	7/27	7/28	7/29	7/30	7/31	8/1	8/2	8/3	8/4	Total
30		3				1			1										5
35		3	1	1	2	9			1										17
40	1	10	1	3	3	5			1										24
45		10	3	1	10	5			1										30
50		4			4														8
55		1		1															2
60																			0
65		2			2	4			1										9
70		1		2	2	4									1				10
75		3		4	2	2			2			1	1						15
80				3	5	1									4		1		14
85		1		2	3	1							1		3				11
90				6	2	3									3	2	2		18
95		2		1	2	4						1			4	1	4		19
100		2		6	4	2									6		2		22
105		1		6	4	4			2						2	3	5		27
110		1	1	4	7	2			1					1	3	2	2		24
115		1		5	2	5			1			1			5	2	2		24
120			1	6	3	3			1						5	3	4		26
125		1	1	7	4	3			1			2	2	1	7	2	7		38
130	1		1	8	9	4			1			2		3	5		8		42
135		1	1	6	2	4			2			1		5	5		6		33
140		4	3	5	8	4			1			9		3	5	1	2		45
145		3		5	7	3			1			3		2	1	1	2		28
150	1	2		6	5	1			2			7	1	3	2		3		33
155		2		4	2	2			6			4	1	3		2	4		30
160		1		6	3	4			5			4	1	1		3	3		31
165	1	1		6	1	1			2			3	2	3	1	1	1		23
170		2	4	4	3	3			2			11		3		2			34
175		1	2	4	3	2			6			3	2				2		25
180		1		3					2			2	1	5		1			15
185			1	2	1	4			6			2		1					17
190	1	2		2					3					1	1				10
195			2	3	1	1						2	1	1					11
200			2						2			2					1		7
205			2		2				1			1				1	2		9
210			1	1	1				1			3							7
215						1													1
220									1										1
225		1										1							2
230																			0
235																			0
240																			0
Total	5	67	27	123	109	92	0	0	57	0	0	65	13	36	63	27	63	0	747

Fyke Net (Lagoon)   Species: Arctic Flounder

Date(M/D) Length(mm)	8/19	8/20	8/21	8/22	8/23	8/24	8/25	8/26	8/27	8/28	8/29	8/30	8/31	Total	Grand Total
30										1				1	6
35										2				2	19
40														0	24
45														0	30
50														8	8
55														0	2
60														0	0
65														0	9
70	1									5		1		7	17
75	3	1						1		6			1	12	27
80										1			1	2	16
85	2	3		1									3	9	20
90	1	3								2				6	24
95	3	3		1				2		5				14	33
100	1	3		1						1				6	28
105		2								3		1		6	33
110		4		1										5	29
115		1												1	25
120	1	1				1		2		2				7	33
125		2								1			1	4	42
130						1								1	43
135						1		1		1			1	4	37
140	2	1				2		2		1			1	9	54
145						1		1		1				3	31
150		1				1		1						3	36
155		3				3		1		1				8	38
160	1	4				2		1		1				9	40
165		2								1				3	26
170		1				2				1				4	38
175		2								1			1	4	29
180		3				1				1				5	20
185	1	1		1		1	1			1				6	23
190	1			2						1				4	14
195		2		2		1		1		2				8	19
200		2		2		3		1						8	15
205		1				1	1	1					1	5	14
210		1				1		1		2				5	12
215	1			2		1				2			1	7	8
220		1						2						3	4
225		1		2		1								4	6
230		1		1										2	2
235				1										1	1
240						1								1	1
Total	18	50	0	17	0	25	2	18	0	46	0	2	11	189	936

Fyke Net (Ocean) Species: Saffron Cod

Date(M/D) Length(mm)	7/18	7/19	7/20	7/21	7/22	7/23	7/24	7/25	7/26	7/27	7/28	7/29	7/30	7/31	8/1	8/2	8/3	8/4	Total
45																			0
50																			0
55																			0
60																			0
65																			0
70																			0
75																			0
80															2				2
85									2						1				3
90									2						3		1		6
95									4						6		7		17
100									7						24		1		32
105				1		1			3						13		2		20
110						1			1					1	8				11
115						3			1						3				7
120									3						1		1		5
125									1										1
130																			0
135																			0
140																			0
145																			0
150																			0
155																			0
160																			0
165																			0
170																			0
175																			0
180																			0
185																			0
190																			0
195																			0
200																			0
205																			0
210																			0
215																			0
220																			0
225																			0
230																			0
235																			0
240																			0
245																			0
250																			0
255																			0
260																1			1
Total	0	0	0	1	0	5	0	0	24	0	0	0	0	1	61	1	12	0	105

Fyke Net (Lagoon)   Species: Saffron Cod

Date(M/D) Length(mm)	8/19	8/20	8/21	8/22	8/23	8/24	8/25	8/26	8/27	8/28	8/29	8/30	8/31	Total	Grand Total
45							1							1	1
50										3				3	3
55										2			1	3	3
60										2			1	3	3
65										2	2		1	5	5
70										3			1	4	4
75													1	1	1
80														0	2
85														0	3
90		1				2				1				4	10
95				1						1				2	19
100		1				1		3		5	1			11	43
105		1		1		1		3		8				14	34
110		1				1		1		6				9	20
115		1		1		3		5		1			1	12	19
120		4		2		1		7		7				21	26
125		1				3		5		1				10	11
130		2		2		2		1						7	7
135		2		3		2		1						8	8
140		2		1		2		3		1				9	9
145		2				2	1							5	5
150		1		2		2								5	5
155		1		3		4								8	8
160		1		1		1								3	3
165		1		2										3	3
170				1										1	1
175						1								1	1
180				1										1	1
185						1								1	1
190														0	0
195														0	0
200														0	0
205														0	0
210														0	0
215														0	0
220														0	0
225														0	0
230														0	0
235														0	0
240														0	0
245														0	0
250														0	0
255														0	0
260														0	1
Total	0	22	0	21	0	29	2	29	0	43	3	0	6	155	260

Fyke Net (Ocean)   Species: Boreal Smelt

Date(M/D) Length(mm)	7/18	7/19	7/20	7/21	7/22	7/23	7/24	7/25	7/26	7/27	7/28	7/29	7/30	7/31	8/1	8/2	8/3	8/4	Total
50																			0
55																			0
60																			0
65																			0
70																			0
75																			0
80																			0
85																			0
90																			0
95																			0
100		1																	1
105																			0
110																			0
115																			0
120																			0
125																			0
130																			0
135																			0
140																			0
145																			0
150																			0
155																			0
160																			0
165																			0
170																			0
175																			0
180																			0
185																			0
190																			0
195																			0
200																			0
205																			0
210																			0
215																			0
220																			0
225																			0
230																			0
235																			0
240																			0
245																			0
250																			0
255																			0
260																			0
265																			0
270																			0
Total	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1

Fyke Net (Lagoon)   Species: Boreal Smelt

Date(M/D) Length(mm)	8/19	8/20	8/21	8/22	8/23	8/24	8/25	8/26	8/27	8/28	8/29	8/30	8/31	Total	Grand Total
50										1				1	1
55										3				3	3
60										9	1			10	10
65										4				4	4
70										3	1	1	1	6	6
75														0	0
80														0	0
85							1			1				2	2
90							6			3				9	9
95							3			4	2	1		10	10
100	1						7			7		1		16	17
105		1					7			4	1			13	13
110		1					11			4	1			17	17
115		2					4			1				7	7
120							3							3	3
125							1							1	1
130														0	0
135														0	0
140														0	0
145							1	1						2	2
150								1						1	1
155														0	0
160														0	0
165		1						1						2	2
170														0	0
175														0	0
180														0	0
185														0	0
190														0	0
195		1												1	1
200								1						1	1
205														0	0
210	1	1												2	2
215				1										1	1
220	2	1						1						4	4
225	1	2												3	3
230		1				1								2	2
235	1	1				1								3	3
240		1						1						2	2
245		2				1								3	3
250														0	0
255		1												1	1
260	1													1	1
265														0	0
270	1					1								2	2
Total	8	16	0	1	0	4	44	6	0	44	6	3	1	133	134

Fyke Net (Ocean)   Species: Capelin

Date(M/D) Length(mm)	7/18	7/19	7/20	7/21	7/22	7/23	7/24	7/25	7/26	7/27	7/28	7/29	7/30	7/31	8/1	8/2	8/3	8/4	Total
110																2			2
115																3	1		4
120															6	5	6		17
125															10	17	11		38
130												1	1		18	12	12		44
135															16	9	13		38
140															4	6	10		20
145															2	2	6		10
150															1				1
155																1	1		2
Total	0	0	0	0	0	0	0	0	0	0	0	1	1	0	57	57	60	0	176

Fyke Net (Lagoon)   Species: Capelin

Date(M/D) Length(mm)	8/19	8/20	8/21	8/22	8/23	8/24	8/25	8/26	8/27	8/28	8/29	8/30	8/31	Total	Grand Total
110														0	2
115														0	4
120														0	17
125													1	1	39
130														0	44
135														0	38
140														0	20
145														0	10
150														0	1
155														0	2
Total	0	0	0	0	0	0	0	0	0	0	0	0	1	1	177

10.5 Fish Catch and Effort Listings (*Discoverer* Cruise)

This section contains fishing effort and catch data by gear type for the 1983 *Discoverer* cruise sampling effort. Actual catch by species is listed for each station.

Geographic Coordinates/Depth: Otter Trawls

Station	Date	Latitude	Longitude	Depth (m)
1	27/08/83	69° 47´N	163 16´N	17
3	28/08/83	69° 45´N	163 19´N	17
4	30/08/83	70° 7´N	165 24´N	42
5	30/08/83	70° 10´N	165 34´N	43
6	30/08/83	69° 52´N	164 4´N	29
7	31/08/83	69° 50´N	163 33´N	23
8	31/08/83	69° 47´N	163 15´N	15
9	31/08/83	69° 45´N	163 4´N	13
10	31/08/83	69° 46´N	163 4´N	13
11	31/08/83	69° 46´N	163 4´N	13
12	1/09/83	70° 9´N	162 45´N	18
13	1/09/83	70° 33´N	160 33´N	20
14	1/09/83	70° 31´N	160 34´N	17
16	2/09/83	70° 39´N	160 11´N	20
17	2/09/83	70° 40´N	160 17´N	24
18	2/09/83	70° 42´N	160 30´N	42
20	8/09/83	69° 45´N	167 29´N	48
21	10/09/83	69° 1´N	165 35´N	21
22	10/09/83	69° 11´N	165 40´N	30
23	10/09/83	68° 52´N	165 28´N	7
25	11/09/83	68° 52´N	165 27´N	7
26	11/09/83	68° 56´N	165 28´N	7
27	11/09/83	69° 40´N	165 33´N	44
28	12/09/83	68° 50´N	166 23´N	31
29	12/09/83	68° 1´N	166 1´N	26

Geographic Coordinates/Depth: Gill Nets

Station	Date	Latitude	Longitude	Depth (m)
1	29/08/83	69° 45´N	163° 4´W	9
2	28/08/83	69° 47´N	163° 16´W	18
3	28/08/83	69° 46´N	163° 6´W	13
4	31/08/83	69° 49´N	163° 29´W	23
5	30/08/83	69° 52´N	163° 57´W	27
6	30/08/83	70° 6´N	165° 20´W	41
7	3/09/83	70° 38´N	160° 5´W	15
8	2/09/83	70° 38´N	160° 5´W	15
9	3/09/83	70° 40´N	160° 17´W	22
10	10/09/83	68° 51´N	165° 29´W	16
11	10/09/83	68° 52´N	165° 33´W	10
12	10/09/83	68° 52´N	165° 28´W	10
13	11/09/83	69° 1´N	165° 33´W	22
14	11/09/83	69° 11´N	165° 34´W	27

Effort Summary: Otter Trawls

Station	Gear Type	Km Trawled
1	25′	1.792
3	25′	1.755
4	25′	5.803
5	25′	4.525
6	25′	3.843
7	25′	4.146
8	25′	3.932
9	12′	.730
10	12′	.200
11	12′	.294
12	25′	3.081
13	25′	4.815
14	25′	2.949
16	25′	3.067
17	25′	2.246
18	25′	2.692
20	25′	1.502
21	25′	3.248
22	25′	4.284
23	12′	1.479
25	12′	1.353
26	12′	.608
27	25′	6.499
28	25′	1.710
29	25′	1.549

Effort Summary: Gill Nets

Station	Hours Fished
1S	44
1B	44
2S	36
2B	36
3S	39
3B	39
4S	19
4B	19
5S	14
5B	14
6S	15
6B	15
7S	26
7B	26
8S	22
8B	22
9S	24
9B	24
10S	18
10B	18
11S	18
11B	18
12S	16
12B	16
13S	19
13B	19
14S	18
14B	18

Catch Summary: Otter trawl, Species by Station

Species	Station														
	1[1]	3[1]	4	5[2]	6	7	8[3]	9	10	11	12[4]	13[1]	14	16[4]	Total
Arctic staghorn sculpin (<u>Gymnocanthus tricuspis</u>)	566	665	28	11	63	22	73	16	31	10	366	14	4	3	1872
Arctic cod (<u>Boreogadus saida</u>)	100	106	247	96	136	171	121	9	9	0	6	78	4	6	1089
Hamecon (<u>Artediellus scaber</u>)	55	11	0	0	4	2	21	3	1	12	1	12	0	2	124
Shorthorn sculpin (<u>Myoxocephalus scorpius</u>)	105	65	1	2	10	64	22	0	0	1	26	7	4	1	308
Saffron cod (<u>Eleginus gracilis</u>)	2	2	0	0	1	0	0	1	0	0	8	1	1	0	16
Slender eelblenny (<u>Lumpenus fabricii</u>)	12	1	0	0	3	2	4	0	0	0	2	3	2	0	29
Ribbed sculpin (<u>Triglops pingeli</u>)	3	1	0	0	4	56	10	0	0	0	0	5	0	0	79
Snailfish (<u>Liparis spp.</u>)	1	6	0	0	10	15	3	3	9	2	1	0	0	0	50
Yellowfin sole (<u>Limanda aspera</u>)	2	1	1	0	0	1	0	0	1	0	2	0	0	0	8
Sand lance (<u>Ammodytes hexapterus</u>)	8	2	0	0	0	3	6	0	0	0	2	0	0	0	21
Walleye pollock (<u>Theragra chalcogramma</u>)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sturgeon seapoacher (<u>Agonus acipenserinus</u>)	4	6	0	0	0	0	6	0	0	0	2	0	0	0	18
Antlered sculpin (<u>Enophrys diceraus</u>)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Arctic shanny (<u>Stichaeus punctatus</u>)	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1
Arctic alligatorfish (<u>Asidophoroides olriki</u>)	0	0	0	0	2	3	0	0	0	0	0	1	0	0	6
Saddled eelpout (<u>Lycodes mucosus</u>)	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
Fish doctor (<u>Gymnelis viridis</u>)	0	0	0	0	2	0	0	0	0	0	0	1	0	0	3
Eyeshade sculpin (<u>Nautichthys pribilovius</u>)	0	0	0	0	0	3	0	0	0	0	0	0	0	0	3
Arctic eelpout (<u>Lycodes reticulatus</u>)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Fourhorn sculpin (<u>Myoxocephalus quadricornis</u>)	0	0	0	0	0	0	0	0	4	0	0	0	0	0	4
Pacific herring (<u>Clupea harengus pallasii</u>)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<u>Gymnelis hemifasciatus</u>	0	0	0	0	3	0	0	0	0	0	0	0	0	0	3
Polar eelpout (<u>Lycodes polaris</u>)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Fourline snakeblenny (<u>Eumesogrammus praeciscus</u>)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Whitespotted greenling (<u>Hexogrammos stelleri</u>)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Spatulate sculpin (<u>Icelus spatula</u>)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Archer eelpout (<u>Lycodes sagittarius</u>)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Arctic flounder (<u>Liopsetta glacialis</u>)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Boreal smelt (<u>Osmerus mordax</u>)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	858	866	277	109	238	342	266	32	55	25	416	123	15	13	3635

Catch Summary: Otter trawl, Species by Station

Species	Station												
	17	18[3]	20	21	22[1]	23	25	26	27	28	29[3]	Total	Grand Total
Arctic staghorn sculpin (*Gymnocanthus tricuspis*)	43	7	0	530	91	24	11	215	18	2	3	944	2816
Arctic cod (*Boreogadus saida*)	12	15	162	158	13	1	0	0	808	3	0	1172	2261
Hamecon (*Artediellus scaber*)	531	31	42	5	9	2	62	5	0	1	20	708	832
Shorthorn sculpin (*Myoxocephalus scorpius*)	156	6	8	41	12	7	9	98	1	5	21	364	672
Saffron cod (*Eleginus gracilis*)	0	0	0	216	98	13	4	18	0	15	59	423	439
Slender eelblenny (*Lumpenus fabricii*)	1	0	0	112	61	2	1	0	25	4	3	209	238
Ribbed sculpin (*Triglops pingeli*)	40	36	8	3	1	0	1	3	0	9	2	103	182
Snailfish (*Liparis spp.*)	7	0	3	0	1	0	1	0	1	0	1	14	64
Yellowfin sole (*Limanda aspera*)	1	0	1	25	1	0	5	2	0	1	0	36	44
Sand lance (*Ammodytes hexapterus*)	0	0	0	15	0	0	0	0	0	2	0	17	38
Walleye pollock (*Theragra chalcogramma*)	0	0	1	0	4	0	0	0	0	10	13	28	28
Sturgeon seapoacher (*Agonus acipenserinus*)	0	0	0	4	0	0	0	2	0	0	0	6	24
Antlered sculpin (*Enophrys diceraus*)	0	0	0	0	0	0	0	0	0	0	20	20	20
Arctic shanny (*Stichaeus punctatus*)	0	0	0	0	0	0	0	0	0	3	14	17	18
Arctic alligatorfish (*Asidophoroides olriki*)	0	0	7	0	0	0	1	0	0	1	0	9	15
Saddled eelpout (*Lycodes mucosus*)	5	1	5	0	1	0	0	0	0	0	0	12	13
Fish doctor (*Gymnelis viridis*)	0	2	1	0	0	0	0	0	0	0	5	8	11
Eyeshade sculpin (*Nautichthys pribilovius*)	1	1	0	0	0	0	0	0	0	0	0	2	5
Arctic eelpout (*Lycodes reticulatus*)	0	0	3	0	0	0	0	0	2	0	0	5	5
Fourhorn sculpin (*Myoxocephalus quadricornis*)	0	0	0	0	0	0	0	0	0	0	0	0	4
Pacific herring (*Clupea harengus pallasii*)	0	0	0	0	0	0	0	0	0	4	0	4	4
Gymnelis hemifasciatus	0	0	0	0	0	0	0	0	0	0	0	0	3
Polar eelpout (*Lycodes polaris*)	0	0	0	0	0	0	0	0	3	0	0	3	3
Fourline snakeblenny (*Eumesogrammus praecisus*)	0	0	2	0	0	0	0	0	0	0	0	2	2
Whitespotted greenling (*Hexogrammos stelleri*)	0	0	0	1	0	0	0	0	0	0	1	2	2
Spatulate sculpin (*Icelus spatula*)	0	1	0	0	0	0	0	0	0	0	0	1	1
Archer eelpout (*Lycodes sagittarius*)	0	0	0	0	0	0	0	0	1	0	0	1	1
Arctic flounder (*Liopsetta glacialis*)	0	0	0	0	0	0	0	0	1	0	0	1	1
Boreal smelt (*Osmerus mordax*)	0	0	0	1	0	0	0	0	0	0	0	1	1
	797	100	243	1111	292	49	95	343	860	60	162	4112	7747

[1] 20% subsample
[2] 30% subsample
[3] 25% subsample
[4] 10% subsample

Catch Summary: Gill nets, Species by Station

Species	Station 1S	1B	2S	2B	3S	3B	4S	4B	5S	5B	6S	6B	7S	7B	Total
Pacific herring (*Clupea harengus pallasii*)	2	4	0	0	1	1	0	1	0	0	1	0	1	1	12
Boreal smelt (*Osmerus mordax*)	2	1	0	0	0	0	0	0	0	0	0	0	7	21	31
Fourhorn sculpin (*Myoxocephalus quadricornis*)	0	0	0	0	0	0	0	0	0	0	0	0	1	9	10
Shorthorn sculpin (*Myoxocephalus scorpius*)	0	0	0	0	0	0	0	0	0	0	0	0	0	2	2
Arctic cod (*Boreogadus saida*)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Longhead dab (*Limanda proboscidea*)	0	2	0	0	0	0	0	0	0	0	0	0	0	0	2
Arctic char (*Salvelinus alpinus*)	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1
Arctic flounder (*Liopsetta glacialis*)	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1
Alaska plaice (*Pleuronectes quadrituberculatus*)	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1
	4	9	0	0	2	1	0	1	0	0	1	0	9	33	60

Catch Summary: Gill nets, Species by Station

Species	Station 8S	8B	9S	9B	10S	10B	11S	11B	12S	12B	13S	13B	14S	14B	Total	Grand Total
Pacific herring (*Clupea harengus pallasii*)	1	0	0	0	2	0	5	3	2	1	1	5	0	14	34	46
Boreal smelt (*Osmerus mordax*)	0	2	0	0	0	0	0	0	0	0	0	0	0	0	2	33
Fourhorn sculpin (*Myoxocephalus quadricornis*)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10
Shorthorn sculpin (*Myoxocephalus scorpius*)	0	0	0	0	0	0	0	2	1	1	0	0	0	0	4	6
Arctic cod (*Boreogadus saida*)	0	0	0	0	0	0	0	2	0	0	0	0	0	0	2	2
Longhead dab (*Limanda proboscidea*)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
Arctic char (*Salvelinus alpinus*)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Arctic flounder (*Liopsetta glacialis*)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Alaska plaice (*Pleuronectes quadrituberculatus*)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
	1	2	0	0	2	0	5	7	3	2	1	5	0	14	42	102

10.6 Length-frequency Data Listings (*Discoverer* Cruise)

This section shows length-frequency data for the most abundant species caught by otter trawl during the 1983 *Discoverer* cruise. Data is provided for the following species:

Otter Trawl
Arctic staghorn sculpin
Hamecon
Arctic cod
Shorthorn sculpin
Saffron cod
Ribbed sculpin
Slender eelblenny

Otter trawl :Arctic cod

Station

Length(mm)	1	3	4	5	6	7	8	9	10	11	12	13	14	16	17	18	20	21	22	23	25	26	27	28	29	Total
30	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
35	0	0	1	0	8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	9
40	0	1	2	5	25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	33
45	0	2	4	9	17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	32
50	0	2	1	9	7	0	0	0	0	0	2	0	0	0	1	0	0	0	0	0	0	0	0	0	0	22
55	1	0	0	0	3	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6
60	6	4	0	2	5	3	0	0	0	0	1	3	2	0	2	0	0	0	0	0	0	0	0	0	0	28
65	13	5	1	5	9	9	2	1	0	0	1	4	0	0	3	0	0	0	0	0	0	0	0	0	0	53
70	11	15	3	3	10	13	3	0	2	0	0	5	1	1	2	1	3	0	0	0	0	0	0	0	0	73
75	16	13	11	8	7	13	9	1	0	0	0	9	0	0	3	1	8	0	0	0	0	0	3	0	0	102
80	14	10	13	15	8	12	15	1	1	0	0	5	0	2	1	1	13	2	0	0	0	0	5	0	0	118
85	10	20	9	14	2	17	20	1	1	0	0	10	0	0	0	3	20	7	3	0	0	0	10	0	0	147
90	7	14	9	8	4	17	18	1	2	0	1	19	1	0	0	5	14	12	0	0	0	0	13	0	0	145
95	6	11	10	2	5	8	5	3	0	0	0	5	0	0	0	1	13	21	2	1	0	0	19	1	0	113
100	3	7	5	3	3	2	1	0	3	0	0	4	0	1	0	0	7	25	3	0	0	0	14	1	0	82
105	1	2	2	0	1	1	1	0	0	0	0	2	0	0	0	2	6	15	3	0	0	0	6	0	0	42
110	0	0	4	1	0	3	1	0	0	0	0	2	0	1	0	1	1	11	2	0	0	0	8	0	0	35
115	0	0	1	2	0	0	2	1	0	0	0	0	0	0	0	0	0	5	0	0	0	0	2	0	0	13
120	0	0	3	1	0	0	0	0	0	0	0	3	0	0	0	0	1	0	0	0	0	0	4	0	0	12
125	0	0	1	1	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	7
130	0	0	4	1	0	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	2	0	0	9
135	0	0	2	0	0	0	0	0	0	0	0	0	0	1	0	0	3	0	0	0	0	0	1	1	0	8
140	0	0	3	1	0	0	0	0	0	0	0	2	0	0	0	0	1	1	0	0	0	0	1	0	0	9
145	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1	0	0	3
150	0	0	3	0	0	0	0	0	0	0	0	1	0	0	0	0	3	0	0	0	0	0	2	0	0	9
155	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	2
160	1	0	2	0	2	1	0	0	0	0	0	2	0	0	0	0	0	1	0	0	0	0	2	0	0	11
165	0	0	1	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3
170	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	3
175	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
180	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	2
185	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
190	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
195	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	2
200	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1
205	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
210	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
215	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
220	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
	89	106	100	96	116	102	78	9	9	0	6	78	4	6	12	15	95	100	13	1	0	0	101	3	0	1139

Otter trawl :Arctic staghorn sculpin

Station

Length(mm)	1	3	4	5	6	7	8	9	10	11	12	13	14	16	17	18	20	21	22	23	25	26	27	28	29	Total
25	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	3
30	0	1	9	8	4	0	3	0	0	0	2	0	1	1	2	0	0	3	3	0	0	1	0	0	1	39
35	5	1	2	3	12	2	2	0	0	0	17	1	0	0	3	0	0	12	0	0	0	2	8	0	0	70
40	43	19	5	0	14	9	8	0	0	0	57	4	1	2	21	3	0	2	24	0	0	6	1	0	0	219
45	32	44	9	0	3	7	17	1	0	0	21	4	2	0	16	2	0	24	0	0	0	4	0	0	0	186
50	13	25	1	0	6	3	21	1	2	0	9	3	0	0	1	0	0	38	33	1	0	31	4	0	0	192
55	6	4	0	0	15	1	3	1	3	0	0	1	0	0	0	0	0	7	3	9	0	33	4	0	0	90
60	3	0	1	0	3	0	1	0	1	1	4	0	0	0	0	0	0	3	1	7	3	12	0	0	0	40
65	5	3	0	0	2	0	5	4	3	2	0	0	0	0	0	0	0	7	4	6	3	0	0	0	0	44
70	7	6	0	0	2	0	7	2	11	0	0	0	0	0	0	0	0	6	8	0	1	3	0	1	1	55
75	2	0	0	0	0	0	3	3	5	3	1	1	0	0	0	0	0	5	7	0	0	5	1	0	0	36
80	0	1	1	0	0	0	1	4	4	2	0	0	0	0	0	0	0	4	1	0	1	3	0	0	0	22
85	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	2	2	0	1	0	0	0	0	7
90	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	1	2	1	2	0	0	0	0	8
95	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	2
100	1	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	5
105	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
110	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0	0	0	0	0	0	2
115	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
120	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
125	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1
130	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1	2
135	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
	118	105	28	11	63	22	73	16	31	10	111	14	4	3	43	7	0	116	91	24	11	100	18	2	3	1024

Otter trawl :Hamecon

Station

Length(mm)	1	3	4	5	6	7	8	9	10	11	12	13	14	16	17	18	20	21	22	23	25	26	27	28	29	Total
20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	1	0	0	0	0	3
25	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	3
30	29	5	0	0	0	0	1	0	0	0	1	4	0	1	46	3	0	0	0	0	0	0	0	0	0	90
35	18	5	0	0	1	0	7	0	0	0	0	0	0	0	40	0	0	2	3	0	1	0	0	0	5	82
40	4	1	0	0	3	0	3	0	1	1	0	0	0	0	11	10	0	1	1	0	16	2	0	0	0	54
45	2	0	0	0	0	1	3	1	0	1	0	2	0	0	7	9	1	0	1	0	10	1	0	1	1	41
50	1	0	0	0	0	1	5	0	0	5	0	1	0	1	1	3	3	0	2	0	16	0	0	0	2	41
55	0	0	0	0	0	0	1	2	0	2	0	3	0	0	1	3	6	0	2	1	11	1	0	0	6	39
60	0	0	0	0	0	0	0	0	0	3	0	0	0	0	3	1	4	0	0	1	7	1	0	0	3	23
65	0	0	0	0	0	0	1	0	0	0	0	1	0	0	2	0	5	0	0	0	0	0	0	0	2	11
70	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	8	0	0	0	0	0	0	0	1	11
75	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	9	0	0	0	0	0	0	0	0	9
80	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6	0	0	0	0	0	0	0	0	6
	55	11	0	0	4	2	21	3	1	12	1	12	0	2	112	31	42	5	9	2	62	5	0	1	20	413

Otter trawl :Shorthorn sculpin

Station

Length(mm)	1	3	4	5	6	7	8	9	10	11	12	13	14	16	17	18	20	21	22	23	25	26	27	28	29	Total
30	5	2	0	1	0	0	3	0	0	0	0	0	1	0	4	0	0	0	0	0	0	3	0	0	0	19
35	38	25	0	0	2	4	3	0	0	0	15	2	2	0	25	1	1	2	1	0	1	10	0	0	2	134
40	45	27	0	1	6	33	9	0	0	0	9	1	0	0	33	1	1	7	1	1	2	45	0	0	2	224
45	16	6	1	0	1	10	1	0	0	0	0	0	0	0	9	1	0	0	1	0	1	25	1	0	0	73
50	0	2	0	0	1	6	3	0	0	0	0	4	1	1	16	1	0	0	0	0	0	4	0	0	0	39
55	1	1	0	0	0	6	1	0	0	0	0	0	0	0	11	1	0	0	0	0	0	1	0	0	0	22
60	0	1	0	0	0	5	1	0	0	1	1	0	0	0	4	1	0	0	0	0	0	2	0	0	1	17
65	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	2	0	0	0	0	1	0	0	5	10
70	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	1	2	1	0	2	2	13
75	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	3	3	2	0	0	1	12
80	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	0	0	0	1	0	0	1	7
85	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	2	1	0	2	0	1	0	7
90	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	2
95	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	2
100	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	1	0	3
105	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	1	2	5
110	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1
115	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	1	4
120	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	1	0	0	0	0	0	0	5
125	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	3
130	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	3	0	0	0	0	0	0	1	5
135	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	1	0	0	0	0	0	4
140	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	2
145	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
150	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
155	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
160	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
165	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
170	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1
175	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
180	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1
185	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
190	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
195	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
200	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
205	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
210	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
215	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
	105	65	1	2	10	64	22	0	0	1	26	7	4	1	102	6	8	41	12	7	9	98	1	5	21	618

Otter trawl :Saffron cod

	Station																								
Length(mm)	1	3	4	5	6	7	8	9	10	11	12	13	14	16	17	18	20	21	22	23	25	26	27	28	29	Total
45	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1
50	0	2	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	1	0	0	0	0	0	0	0	5
55	1	0	0	0	0	0	0	0	0	0	3	0	1	0	0	0	0	12	0	0	0	1	0	3	7	28
60	1	0	0	0	1	0	0	0	0	0	3	0	0	0	0	0	0	40	11	0	1	2	0	4	24	87
65	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	24	40	2	1	5	0	2	11	86
70	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	18	26	4	1	7	0	0	7	63
75	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	7	11	5	1	1	0	4	2	31
80	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	4	2	0	1	0	2	2	14
85	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	1	0	0	2	5
90	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	1	4
95	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
100	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
105	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
110	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
115	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
120	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1
125	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
130	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
135	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
140	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1
145	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
150	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
155	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
160	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
165	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
170	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
175	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
180	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
185	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
190	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
195	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
200	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
205	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
210	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
215	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
220	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
225	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
230	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
235	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
240	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
245	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
250	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
255	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
260	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
265	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
270	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
275	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
280	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
285	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
290	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
295	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
300	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
	2	2	0	0	1	0	0	1	0	0	8	1	1	0	0	0	0	106	98	13	4	18	0	15	59	329

Otter trawl :Slender eelblenny

Length(mm)	Station 1	3	4	5	6	7	8	9	10	11	12	13	14	16	17	18	20	21	22	23	25	26	27	28	29	Total
50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	7	2	0	0	0	0	0	0	9
55	0	0	0	0	2	0	0	0	0	0	0	0	0	0	1	0	0	6	1	0	0	0	1	0	0	11
60	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	2
65	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	3	0	0	4
70	0	0	0	0	1	1	0	0	0	0	0	0	2	0	0	0	0	11	4	0	0	0	2	0	0	21
75	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	20	11	0	0	0	1	0	0	33
80	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	26	19	0	0	0	1	0	0	47
85	0	0	0	0	0	0	1	0	0	0	2	0	0	0	0	0	0	20	10	0	0	0	0	0	0	33
90	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	8	5	0	1	0	0	0	1	17
95	3	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	8	4	0	0	0	0	0	1	17
100	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	2	3	0	0	0	2	0	1	9
105	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	3
110	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0	1	2	0	6
115	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	3
120	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	0	0	5
125	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	2
130	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	3
135	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	2
140	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
145	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	3	0	0	4
150	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	2
155	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1
160	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	2
165	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
170	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1
175	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
180	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
185	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1
	12	1	0	0	3	2	4	0	0	0	2	3	2	0	1	0	0	112	61	2	1	0	25	4	3	238

Otter trawl :Ribbed sculpin

Length(mm)	Station 1	3	4	5	6	7	8	9	10	11	12	13	14	16	17	18	20	21	22	23	25	26	27	28	29	Total
35	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	0	0	0	0	0	0	0	0	0	0	5
40	0	0	0	0	0	0	0	0	0	0	0	0	0	0	7	0	0	0	0	0	0	0	0	0	0	7
45	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	2	0	0	0	0	0	1	0	0	0	4
50	1	0	0	0	3	0	0	0	0	0	0	0	0	0	5	4	0	0	0	0	0	1	0	0	0	14
55	1	0	0	0	1	5	0	0	0	0	0	0	0	0	9	9	0	0	0	0	0	0	0	0	0	25
60	0	0	0	0	0	10	0	0	0	0	0	1	0	0	11	11	0	0	0	0	0	0	0	0	0	33
65	1	1	0	0	0	22	1	0	0	0	0	2	0	0	2	2	0	0	0	0	0	0	0	3	0	34
70	0	0	0	0	0	15	4	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	3	0	24
75	0	0	0	0	0	2	5	0	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0	2	0	11
80	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0	2
85	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	2	0	0	0	0	0	0	0	0	5
90	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	1	0	4
95	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	3	0	0	0	0	0	0	0	0	4
100	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	2
105	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
110	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1
115	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1
120	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0	0	0	2
125	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
130	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	2
	3	1	0	0	4	56	10	0	0	0	0	5	0	0	40	36	8	3	1	0	1	3	0	9	2	182

ECOLOGICAL CHARACTERIZATION OF THE YUKON RIVER DELTA

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SUMMARY

The purpose of this report is to characterize the biological and physical components and processes in the Yukon River delta and vicinity with a view to evaluating the vulnerabilities of the important biota and their habitats to OCS oil and gas activities in Norton Sound. That purpose is addressed by reviewing available information and presenting in sequence the following:

(1) Characterizations of important Yukon Delta faunal species.

(2) Discussions of physical processes and components directly important to those species or influencing the vulnerability of those species to oil spills.

(3) Delineation of the Yukon Delta area into spatial ecological zones separated on the basis of distributional patterns of faunal use and physical factors regulating that use.

(4) Evaluation of the relative vulnerabilities of these ecological zones to impact by oil that might be spilled in Norton Sound.

(5) Presentations of additional research needs perceived to be high priority for helping to predict the effects of OCS development activities.

Faunal species populations in the Yukon Delta region judged to be of major interest to people and to be significantly influenced by Yukon Delta and its processes and components included (1) marine mammals (gray whale, belukha, ringed seal, spotted seal, and bearded seal), (2) water-associated birds (swan, brant, several species of geese and ducks, sandhill crane, and a number of shorebird species), (3) fishes (salmon and a number of other anadromous species; herring and several other marine species), and (4) one invertebrate, the red king crab. Lower trophic levels of major importance to these species are invertebrates (primarily in estuarine and marine environments), primary production (phytoplankton in the sea and multicelled plants on land), and detritus.

Some of the delta's vertebrate populations are major portions of regional or world populations of species or subspecies. This is particularly true for birds; the delta is a unique and important bird habitat not duplicated elsewhere. Some Yukon River salmon populations are large proportions of

total Bering Sea numbers; non-salmonid fish are very important in regional subsistence economies. Most mammals, except perhaps belukha, find equivalent or better habitats elsewhere.

It appears that biota in the marine and estuarine environments is supported primarily by a detritus-driven food web and secondarily by plankton consumed in the water-column. Several questions remain about these aquatic food webs:

(1) What proportion of the nutrients that fuel these marine and estuarine food webs is derived from Yukon discharge and what proportion comes from shelf zones farther south and west?

(2) What proportion of the detritus consumed by benthic fauna is marine-derived (e.g. phytoplankton that has settled) and what proportion is derived from Yukon (and other river) discharge?

(3) What are the primary lower trophic links in the estuarine food web of fishes and birds?

In the terrestrial environment, emergent and submerged plants, and the invertebrates that feed on detrital remnants of these plants, are the major food web base. Fewer unknowns exist about trophic dependencies here.

Physical processes particularly important in the delta area are (1) storm surge frequency and magnitude, (2) dynamics and magnitude of salt wedge intrusions into delta distributary channels, and (3) three-dimensional circulation and transport patterns on the very shallow delta platform. Storm surge magnitudes (particularly with respect to distance inland that the delta is inundated by water), and predicted return frequencies for different magnitudes, must be known to predict impacts on waterfowl habitat. Salt wedge intrusion in terms of distance of intrusion upstream and seasonal and weather-caused changes in distance intruded is probably critical to the vulnerability of delta fishes to oil spills in the area. Three dimensional circulation on the delta platform is probably important for (1) annually transporting invertebrate prey to the shallows where birds and anadromous fish congregate to feed, and (2) maintaining biologically important clear-water zones near the coast between distributaries.

The zones most vulnerable to adverse effects of oil in the delta are those nearest the coastline. Zones far seaward and far landward of the coast either are relatively safe from oil contact, cleanse themselves rapidly, or contain animal populations that are relatively resistant to oil damage and/or that are not as important as populations in zones nearer the coast.

Vulnerabilities of zones nearest the coast are high but may vary depending on factors that have yet to be quantified precisely. For example, frequency and magnitude of delta inundation by storm surge, distribution of salmon juveniles in summer, and mechanisms that maintain/replenish invertebrate populations in nearshore shallows are known hardly at all, but strongly influence vulnerabilities of zones near the coast.

Further information is needed most desperately in the estuarine environment (including the nearshore delta platform and the delta distributaries influenced by marine water). Needs are greatest in the areas of physical process: frequency and magnitude of storm surge, three-dimensional circulation and transport, etc. Biological study needs in this environment include distributional and use patterns of non-salmonid anadromous fishes; distribution, use patterns, and residence times of juvenile salmon; and distributions in summer of molting and feeding waterfowl on the delta platform.

The second priority for research is in terrestrial environments. Basic surveys to determine seasonal distribution of bird use is critical to predicting impacts, and is yet to be done. A basic issue--responses of nesting and feeding goose and duck populations to oil in their habitats--is yet to be adequately addressed.

No high-priority research needs that are not currently being addressed are recommended for the marine environment beyond the delta front. An important issue not yet resolved is the nutrient and carbon contribution of Yukon River discharge to marine food webs, but a research program to address this is currently commencing, directed from the University of Alaska.

INTRODUCTION

The Yukon River delta (defined herein to mean the prograding portion of the Yukon Delta north of Cape Romanzof) and its immediate vicinity at the southwestern limit of Norton Sound, Alaska, is thought to be extremely sensitive to oil- and gas-related activities that might occur in Norton Sound (Zimmerman 1982). In anticipation of exploration for petroleum in Federal lease sale areas in Norton Sound, the Outer Continental Shelf Environmental Assessment Program (OCSEAP) of the National Oceanic and Atmospheric Administration (NOAA) in early 1983 developed a research Task Statement and issued a solicitation for proposals for a qualified organization to develop an Ecological Characterization of the Yukon River delta. OCSEAP subsequently awarded a contract to conduct this work to LGL Ecological Research Associates, Inc. (LGL). This report is LGL's response to the work.

Research Objectives

The stated general objectives of the work to be conducted were three as follows:

(1) To assemble and evaluate existing information that would clarify the phenomena that make the Yukon Delta so biologically productive,

(2) To define the habitat zones of the biota and their relative vulnerabilities to proposed oil and gas development activities, and

(3) To identify further information needed to adequately define the distributional (zonation) characteristics and the vulnerabilities of the biota.

To meet these objectives, four major tasks were required to be addressed as follows:

(1) <u>Preparation of Annotated Bibliography</u> - A bibliography that analyzes and describes the present status of knowledge about the coastal edge of the Yukon River delta is required. Because the primary interest is in selected groups of biota (particularly birds), the emphasis should be on literature about the Yukon Delta biota, the physical components and processes that influence the biota, and

the vulnerabilities of the biota and the physical phenomena to impact from OCS activities.

(2) Characterization of Ecologically Important Phenomena - The oceanographic, climatological and ecological phenomena that lead to the formation of biotic zones within and along the coastal edge delta must be described and evaluated. Information must be applied to developing this characterization.

(3) Summarization of Vulnerabilities - The relative vulnerability of each biotic zone in the Yukon River delta area to the effects of proposed OCS oil and gas activities must be described. Because major OSC-related activities will probably not occur in the delta region itself (Zimmerman 1982), the major threat is probably oil spilled offshore of the delta. Thus, data about oil behavior in arctic and subarctic seas, effects of wind on oil in water, effects of oil on biota, and rates of degradation of oil must be evaluated to respond to this requirement.

(4) Identification of Further Information Needs - The last requirement is to identify significant data and information needed to adequately define biotic zonation in the coastal edge of the Yukon River delta and the vulnerabilities of the biotic zones to OCS-related actions. Implicit in this objective is that the importance of each zone to the well-being of selected species populations must be clear, so that the influence of oil (or other OCS-related perturbation) in the zone can be translated into population-level effects.

Study Area

In relation to the proposed OCS development in Norton Sound, Zimmerman (1982) defines the coastal limits of the Yukon Delta as Stebbins-Stuart Island to the northeast and Cape Romanzof to the southwest. Because saline water from Norton Sound is known to sometimes intrude as far as 160 km up the Yukon River, and storm surges inundate delta lowlands as far as 40 km inland (Zimmerman 1982), it appears that the study area should include these zones of influence. Waterbirds that use the delta forage as much as 50 km offshore from the delta edge (Zimmerman 1982). The influence of Yukon River water extends much beyond even the limits of Norton Sound; the outer limits of the sources of sea water that intrudes into the delta are not known.

Given these various distances from the delta front of different zones of influence, selection of boundaries for the study area of emphasis must be arbitrary. Figure 1 depicts how we limit the boundaries, given the zones of influence discussed above. Note that the Kuskokwim River delta and that relatively inactive portion of the Yukon River delta south of Cape Romanzof are not included in the main study area.

Methods

Methods were in three categories--(1) the collection of information, (2) the preparation of the annotated bibliography, and (3) the analysis and synthesis of information.

The primary sources of information collected were three: published literature, unpublished reports and documents, and verbal communication with scientists who had worked in the region. Major sources of published literature were (1) OCSEAP-funded research, (2) published reports of recent synthesis meetings and interdisciplinary research efforts, and (3) research published in technical journals. Major sources of unpublished reports were collected from the U.S. Fish and Wildlife Service, U.S. Minerals Management Service, the Alaska Department of Fish and Game, the University of Alaska (theses, dissertations), and environmental consulting organizations. Interviews with scientists provided verbal information as yet unreported, plus important leads to other relevant literature.

The preparation of the Annotated Bibliography required first determining which of the documents collected contained important information from within the study area. (Much of the information collected was from near, but not in, the area designated for study.) Then a short summary of each document was prepared, to include how the reported data were collected, what the report authors found, and the importance of the document in developing a characterization of the Yukon River delta. The annotated bibliography is included as a separate report.

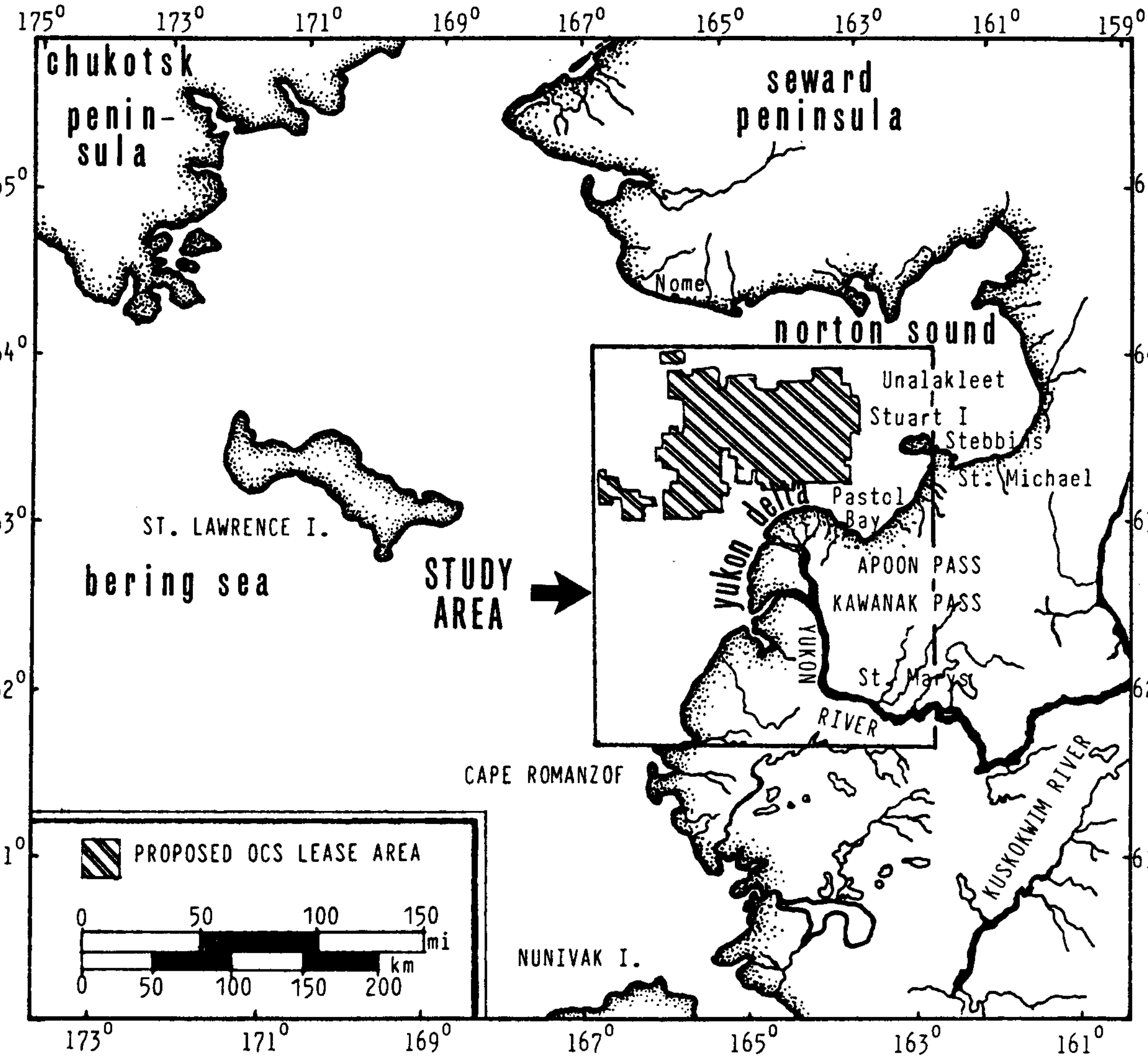

Fig. 1. Location of the area of emphasis for the study "Ecological Characterization of the Yukon River Delta."

The analysis and synthesis of information for developing the characterization and description of vulnerabilities proceeded in the following sequence:

(1) The major species and groups of interest were identified. The Annotated Bibliography provided information on the status of vertebrate populations in the Yukon Delta area. If the delta had large proportions of the Bering Sea or world populations of animal species of high public interest, these species were considered to be important for purposes of this study. Species important in commercial or subsistence harvests, animals commonly using the area and classed as rare and endangered, and species identified by scientists and regulatory authorities to be of particular concern for other reasons were included.

(2) Information that helped define the physical and biological phenomena likely to be important to populations of these species in the delta region were assembled. This included relevant information from the study area and from elsewhere. Phenomena known or suspected to affect population natality or mortality rates were emphasized in the search.

(3) Geographic zones of use within the delta were described according to how vertebrates distribute themselves. Phenomena responsible for this zonation of use were described and the timing and nature of the use described.

(4) Information that helped clarify how the species of interest, and the physical and biological phenomena important to them, were likely to be affected by the introduction of oil or by other OCS-related perturbations was synthesized. In particular, the vulnerabilities of the vertebrates to OCS-related activities were described on the basis of how vulnerable each zone is to pollution by oil and what the expected effects of oil pollution would be on the vertebrates that use that zone.

YUKON DELTA BIOTA: SPECIES CHARACTERIZATIONS

Based on information reviewed, we developed a list of species or groups that commonly use the study area and that are generally conceded to be of interest to people (Table 1). Included are species of commercial, recreational, aesthetic and subsistence value. All of these except one (red king crab) are vertebrates.

In the discussions that follow, we characterize species populations important in the Yukon Delta study area in terms of their abundance, distribution, principal trophic relationships, and habitat factors important to them. Where possible, factors that regulate their populations or productivity in the delta area are identified.

Marine Mammals

Marine mammals species sufficiently common in the study area to be included here are gray whale, belukha, and ringed, spotted and bearded seals. Occurrences of other species are irregular and sporadic.

Gray Whale

The gray whale is the only endangered vertebrate species to occur more or less regularly in the study area, and the only cetacean other than the belukha commonly found there (Zimmerman 1982; Nelson 1980). Known to be common in the Norton Basin area from May to November (Zimmerman 1982; Cowles 1981; Nelson 1980), it undoubtedly occurs during this time in the deeper waters of the study area north and northwest of the Yukon Delta. Those that occur in the study area are part of the East Pacific stock of gray whales (Cowles 1981); this population winters near the coast of Baja California and summers in the Bering, Chukchi and western Beaufort Seas. The major gray whale summering area is to the west and northwest of the study area in the Norton and Chirikof basins (Cowles 1981).

It is not known how many gray whales use western Norton Sound in the area of study. They are seen there commonly during summer (Nelson 1980), but they are more abundant to the north and west. They presumably use the

Table 1. Species of commercial, recreational, aesthetic, or subsistence value that commonly use the Yukon Delta study area.

Common Name	Scientific Name	Type of Use	Season of Use
Gray Whale	*Eschrichtius robustus*	Feeding	June-Sept.
Belukha	*Delphinapterus leucas*	Feeding,calving	Apr.-Oct.
Ringed Seal	*Phoca hispida*	Pupping,feeding	Nov.-June
Spotted Seal	*Phoca vitulina*	Feeding,hauling	May-Dec.
Bearded Seal	*Erignathus barbatus*	Feeding	Nov.-Dec.
Whistling Swan	*Cygnus columbianus*	Nesting	May-Sept.
Black Brant	*Branta bernicula nigricans*	Nesting	May-Sept.
Emperor Goose	*Anser canagicus*	Nesting	May-Sept.
Lesser Snow Goose	A.c. *caerulescens*	Staging	Aug.-Sept.
White-fronted Goose	*Anser albifrons*	Nesting	May-Aug.
Cackling Canada Goose	*Branta canadensis minima*	Nesting	May-Sept.
Taverner's Canada Goose	B. c. *taverni*	Nesting	May-Sept.
Pintail	*Anas acuta*	Nesting,molting	May-Sept.
Steller's Eider	*Polysticta stelleri*	Molting (?)	July-Aug.
Spectacled Eider	*Somateria fischeri*	Nesting	May-Sept.
King Eider	S. *spectabilis*	Molting(?)	July-Aug.
Common Eider	S. *mollissima*	Nesting	May-Sept
Black Scoter	*Melanitta nigra*	Nesting,molting	May-Sept.
Surf Scoter	M. *perspicillata*	Molting	July-Aug.
Bar-tailed Godwit	*Limosa lapponica*	Nesting,staging	May-Sept.
Black Turnstone	*Arenaria melanocephala*	Nesting,staging	May-Sept.
Western Sandpiper	*Calidris nuri*	Nesting	May-Sept.
Rock Sandpiper	C. *ptilocnemis*	Nesting,staging	Apr.-Sept.
Dunlin	C. *alpina*	Staging	May-Oct
Bristle-thighed Curlew	*Numenius tahitieinsis*	Staging	July-Aug
Other Shorebirds		Staging	

(continued)

(Table 1, continued)

Common Name	Scientific Name	Type of Use	Season of Use
Sandhill Crane	*Grus canadensis*	Nesting	May-Sept.
Chum Salmon	*Oncorhynchus keta*	Adult migration, juvenile feeding	Summer
King Salmon	*O. tshawytscha*	"	"
Coho Salmon	*O. kisutch*	"	"
Pink Salmon	*O. gorbuscha*	"	"
Sockeye Salmon	*O. nerka*	"	"
Arctic Char	*Salvelinus alpinus*	Resident	Year-round(?)
Sheefish	*Stenodus leucichthys*	"	"
Broad Whitefish	*Coregonus nasus*	"	"
Humpback Whitefish	*C. pidschian*	"	"
Least Cisco	*C. sardinella*	"	"
Bering Cisco	*C. laurettae*	"	"
Blackfish	*Dallia pectoralis*	"	"
Burbot	*Lota lota*	"	"
Pike	*Esox lucius*	"	"
Arctic Lamprey	*Lampetra japonica*	"	"
Pacific Herring	*Clupea pallasi*	Resident (marine)	Year-round
Saffron Cod	*Eleginus gracilis*	"	"
Arctic Cod	*Boreogadus saida*	"	"
Starry Flounder	*Pleuronectes stellatus*	"	"
Capelin	*Mallotus villosus*	"	"
Pacific Sandlance	*Ammodytes hexapterus*	"	"
Slimy Sculpin	*Cottus cognatus*	"	"
Yellowfin Sole	*Limanda aspera*	"	"
Alaska Plaice	*Pleuronectes quadrituberculatus*	"	"
Rainbow Smelt	*Osmerus mordax*	Migration upriver, marine resident	Fall upstream migration
Pollock	*Theragra chalcogramma*	Resident(marine)	Year-round
Red King Crab	*Paralithodes platypus*	"	"

study area mainly for feeding (see Cowles 1981; Zimmerman 1982). It does not appear that they use the shallow waters near the delta front to any extent; they are seen mostly in deeper waters in the middle and northern parts of western Norton Sound.

Gray whales in summer feed mainly on benthic amphipods (Frost and Lowry 1981). Additionally they eat small amounts of polychaetes, small bivalves, gastropods, ascidians, priapulids, isopods, mysids and herring. They feed by scooping prey from the sea floor (L.Martin, LGL Ecological Research Associates, pers. comm.). Most of their feeding appears to take place in summer (Frost and Lowry 1981), and their summer distribution appears to coincide with regions of high densities of the benthic amphipods on which they feed (Cowles 1981).

Within their summer feeding grounds, little is known of habitat preferences of gray whales. They feed largely in waters less than 50-60 m deep (Frost and Lowry 1981). They presumably select substrates where benthic amphipods are common. Based on the limited data available, it appears that the study area itself is of minor importance to gray whales. Why they prefer other areas is not known, but is perhaps related to greater food abundance elsewhere.

Factors that regulate gray whale populations are speculative. The world population (restricted to the Pacific) is now estimated to be 15,000 to 17,000 (Cowles 1981). During the late 1800's and early 1900's, their populations were severely reduced by commercial whaling, but they are now probably as abundant as they were in pre-whaling years (Frost and Lowry 1981; Cowles 1981). Little human-caused mortality currently exists (Nelson 1980). Food in their summer range is undoubtedly very important to them, for they appear to feed little in other parts of their range. Whether their populations are approaching the limits that their food supply can maintain is not known, but one may speculate that summer food may be the ultimate limiting factor. As discussed above, the Yukon Delta study area probably contributes an insignificant proportion of food to the total whale population.

Belukha

Belukhas are circumpolar in distribution, with a world population of about 100,000 (Fay 1978). They are the most abundant cetaceans utilizing the Yukon Delta area. The shallow delta waters provide summer habitat for a proportion of the Bering Sea population. Of the 12-16,000 individuals in this population, about 3,000 spend the summer in coastal regions of the Bering Sea (Frost et al. 1982). The others migrate north through the Bering Strait. Belukhas concentrate in three main areas along the Bering Sea coast: inner Bristol Bay, off the mouths of the Yukon River, and in northeastern Norton Sound (Frost et al. 1982).

Belukhas winter in the open ice front zones of the Bering Sea (Seaman and Burns 1981). They move northward in the spring, following the retreating ice. They are first seen off the mouths of the Yukon River in May and June, and remain until late September or October (Harrison and Hall 1978; Frost et al. 1982). It is not known what proportion of the 3,000 belukhas which remain south of the Bering Strait utilize the study area. The largest single sighting reported for the area was of 100 animals feeding off the river mouth in July 1981 (Frost et al. 1982).

During the summer, belukhas feed and presumably calve in the Yukon Delta region, and up the Yukon River. They have been reported as far as 100 km upriver (Klinkhart 1966). Although there are no specific reports of belukhas calving in the study area, it is known that they use warm estuarine areas as calving grounds (Sergeant and Brodie 1975; Gurevich 1980), and they are found in the study area during the summer calving season (mid-May through early September) (Seaman and Burns 1981; Frost et al. 1982).

Belukha diets in Norton Sound include a variety of seasonally abundant fish: salmon, saffron cod, herring, sculpin, smelt, capelin, and other species (Nelson 1980, Seaman and Burns 1981). Belukhas arrive in the study area in time for the first salmon runs. When the salmon migrations diminish in the fall, they feed on the plentiful saffron cod (Frost et al. 1982). Belukhas eat both juvenile and mature salmon, and were once thought to be in competition with commercial and subsistence harvests. More recent studies have shown that their level of consumption is not significant (Brooks 1979).

Belukhas have two natural predators--killer whales and man. Estimates of losses to killer whale predation are not available. Subsistence hunters along the Alaskan coast kill a total of approximately 300 belukhas annually (Seaman and Burns 1981). Although Norton Sound is an important area for belukha whaling (up to one quarter of the annual harvest), no kills were reported from the Yukon Delta villages (Seaman and Burns 1981).

It appears that two major characteristics of the study area make it an important summer area for Bering Sea belukha. The first is an abundant supply of prey fish, and the second is the warm water necessary for calving. Seaman and Burns (1981) found that belukha movement and aggregation patterns in the Norton Basin were related mainly to prey availability. Belukhas in eastern Canada were found to abandon areas when the flow of relatively warm river water was diminished by hydroelectric development (Sergeant and Brodie 1975). These two characteristics are found elsewhere along the Bering coast, and account for the concentrations of belukhas in inner Bristol Bay and Norton Bay (Frost et al. 1982). The study area thus does not provide a unique environment for belukha, but may be one of the few good quality summering grounds for that portion of the population that remains south of the Bering Strait.

Factors that regulate belukha numbers are not well known. A few populations in eastern Canada have been affected by overhunting or environmental changes (Sergeant and Brodie 1975); however, there is not commercial harvest of Alaskan belukha. Subsistence harvest levels are well below sustainable yields as estimated by Sergeant and Brodie (1975), and are less than half of harvest levels earlier in the century (Seaman and Burns 1981). Whether populations are limited by suitable calving areas, predation, or food supply is not known.

Ringed Seal

Ringed seals are the most abundant seals in the arctic. Their distribution is circumpolar and is generally associated with sea ice. The study area is used as an early spring breeding ground by a portion of the population that winters south of the Bering Strait (Nelson 1980). The area is also used by ringed seals as they migrate northward in late May and June and south in late November and December following the edge of the ice pack (Cowles 1981). In addition, the area may be utilized by a few juveniles who sometimes spend the entire summer in the ice-free Bering Sea (Brooks 1979).

The worldwide population of ringed seals is estimated at 7 to 8.5 million, with about 1 to 1.5 million in the Bering and Chukchi Seas (Burns 1978).

Censuses have been difficult to conduct, because ringed seals are mostly solitary animals, and spend a great deal of time in the water or in sub-nivean lairs, and thus are not often visible from the air (Burns 1978).

During late winter and early spring, ringed seals are found in areas of shore-fast ice, 5-40 km offshore, for breeding purposes (Braham et al. 1977). Females give birth during March and April in sub-nivean lairs, where the pups remain for about two months before being weaned (Burns and Eley 1977). The number of ringed seals that utilize the shore-fast ice in the study area is not known, but may be low because of the shallowness of the water off the delta. Ringed seal densities vary greatly depending on local ice conditions (Burns 1978).

The diet of ringed seals includes a wide variety of invertebrates and fish captured near the bottom, within the water column, or under ice. Seals caught in the Nome area were found to be eating only a few species of fish: saffron cod and arctic cod were their main prey (Lowry et al. 1980). Young seals (less than 5 years old) were found to eat fewer cod and more crustaceans than did older seals (Lowry et al. 1980).

Probable predators of ringed seals include polar bears, arctic foxes, red foxes, and wolves (Burns 1978). Hunters in the Norton Sound area harvest between 1000 and 1500 ringed seals annually (Nelson 1980). There is no commercial harvest of ringed seals because ships cannot operate in their icy habitat. Worldwide harvest levels are thought to be well below what the population can sustain (Brooks 1979; Burns 1972).

The critical factor defining optimum ringed seal breeding habitat is ice stability. For the first two months of its life, the ringed seal pup does not leave the birthing lair (Burns 1970). Stable ice ensures that the pup will not get wet before acquiring its adult fur, and that the snow roof will remain in place, protecting it from predators. The shore-fast ice along the Yukon Delta provides such a habitat. However, it is near the southern limit of ringed seal breeding distribution, and hosts only a fraction of the Bering/Chukchi population (Nelson 1980).

Ringed seal populations may be limited by food availability. Lowry et al. (1980) found that spatial and temporal differences in seal abundance could be related to food sources. Smith and Hammill (1981) found the limited availability of suitable ice-fast habitat seemed to affect ringed seal numbers in eastern Canada. Recently declining pregnancy rates may indicate that ringed seal populations are nearing their carrying capacity (Burns and Eley 1977).

Spotted Seal

Spotted seals are found only in the North Pacific. They winter at the southern edge of the sea ice pack, and spend the summer along the coasts of the Bering and Chukchi Seas. Their population is estimated at 200,000 to 300,000 (Burns 1978, Lowry and Frost 1981).

Spotted seals pass through the study area in November to January as the ice pack extends southward, and again in April to June as it retreats (Cowles 1981). In addition, spotted seals summer along the coast of the Bering Sea. Subadults leave the ice pack during May and June, and adults and pups follow (Lowry and Frost 1981). Spotted seals have been reported utilizing the Yukon Delta and St.Michael Island as haulout areas between May and October (Frost et al. 1982).

Spotted seals eat mainly fish. Their summer diet in the eastern Bering Sea includes arctic and saffron cod, capelin, pollock, herring, sand lance, sculpin, and shrimp (Lowry et al. 1979; Lowry and Frost 1981). Spotted seals often concentrate near large rivers such as the Yukon, in search of returning anadromous fish (Burns 1978).

Spotted seals have no major predators besides man. Gulls, killer whales, and Greenland sharks are thought to occasionally kill adults or their young (Burns 1978). Commercial harvests have decreased to approximately 3000 per year (Burns 1978). Subsistence hunters harvest about 800 to 1000 spotted seals annually, mostly from villages around Norton Sound (Nelson 1980). Annual harvests are thought to be far below the maximum sustainable yield (Burns 1972). The study area does not provide unique habitat for the spotted seal, which is widely distributed along the western Alaska coast during the summer months. However, the area does provide food sources and haulout areas which a portion of the Bering Sea population utilizes.

Factors which regulate spotted seal populations are not known. Natural predation levels are low, and suitable habitat is not limited. Spotted seal prey species are intensively harvested by commercial fishermen, but food has not been identified as a limiting factor (Burns 1978).

Bearded Seal

Bearded seals are the largest seals found in the study area. They are circumpolar in distribution, with an estimated population of 300,000 in the Bering and Chukchi Seas (Burns 1978). They are mainly solitary, and live in areas of drifting sea ice. Most of the Bering/Chukchi population winters between the southern edge of the ice pack; Norton Sound provides some winter habitat. Bearded seals cannot utilize shore-fast ice areas as ringed seals do because they do not maintain breathing holes, but rather haulout near cracks and leads in the ice (Lowry et al. 1979). In the spring, bearded seals migrate northward through the Bering Strait, preceding the disintegration of the ice pack. They return south in November and December (Cowles 1981). Some juveniles remain in the Bering Sea all summer (Burns 1978).

Bearded seals may thus be found wintering in the study area from November through June, or migrating through in May or November. During this time, the seals are largely aquatic, using the ice for occasional haulouts. They give birth to their pups on the ice in late April, and also use the ice for basking and molting in spring (Burns 1964). Bearded seal pups can swim soon after birth and have a short nursing period (12-28 days), and thus are not dependent upon stable shore-fast ice conditions (Burns 1978).

Bearded seals are bottom feeders, eating mostly benthic invertebrates and a few fish. Major prey species in the Norton Sound area include clams, shrimps, and brachyuran crabs. Younger seals were found to eat more shrimp and fewer clams than did older seals (Lowry et al. 1979, 1980).

Bearded seals have two major predators, polar bears and man (Burns 1978). Total annual harvests by man are between two and four thousand animals per year, mostly taken by subsistence hunters.

In summary, the study area does provide habitat for bearded seals, but it is not unique. The species is widely scattered over a large area. Some juveniles may frequent the study area during the summer, and some adults winter there (Cowles 1981). Bearded seal densities in any given winter would depend on ice conditions, as they require faulted or broken ice (Burns 1972).

The bearded seal population in the Bering and Chukchi Seas is thought to be close to its pre-exploitation levels (Burns 1972; Brooks 1979). Factors limiting its population are not known, but there are indications that the growing number of walruses in the Bering and Chukchi Seas may be competing with bearded seals for food (Lowry et al. 1980).

Waterfowl and Cranes

The entire Yukon-Kuskokwim Delta complex provides one of the largest continuous regions of productive breeding habitat for waterfowl and cranes in North America (Bellrose 1976). It is particularly valuable as habitat for nesting geese of several species (King and Dau 1981). Ducks, swans, and sandhill cranes also use the area in large numbers as resting and molting habitat (King and Dau 1981; Boise 1977). The intertidal areas of the Yukon Delta are used as feeding habitat for almost all waterfowl and crane species present there, although to varying degrees by species. The following accounts include those forms whose overall populations are large on the study area, or those with a significant proportion of their regional or worldwide populations occurring in the Yukon Delta area.

In addition to those species mentioned for which individual accounts have been prepared, several other species of ducks nest commonly on the Yukon-Kuskokwim Delta and would be expected to occur on the Yukon Delta study area. Among the most abundant of these are the oldsquaw, greater scaup, canvasback, mallard, American widgeon, northern shoveler, green-winged teal, and red-breasted merganser. These species nest near tundra ponds and lakes throughout the region and may feed in intertidal mudflat or nearshore water habitats of the Yukon Delta in considerable numbers.

Survey data for all waterfowl on the Yukon Delta study area is notably lacking. Annual aerial survey transects flown by U.S. Fish and Wildlife Service personnel over most of Alaska's important waterfowl breeding areas do not include segments covering the study area, but do cover a major portion of the Yukon-Kuskokwim wetland complex (King and Conant 1983).

All of the waterfowl species discussed below generally prefer the coastal fringe of the Yukon Delta for breeding, molting, and staging purposes. The juxtaposition of extensive shallow nearshore waters and intertidal areas with expansive wet and moist tundra habitats makes this region particularly attractive to large numbers of waterfowl and cranes.

Tundra Swan

The tundra swan (formerly whistling swan) is normally the only species of swan found in the Yukon Delta study area, and occurs there during the summer breeding season from May through September. It is one of the most widely distributed of the waterfowl nesting on the Yukon-Kuskokwim Delta, which harbors a summer population of approximately 40,000 birds (Bellrose 1976). Swans are most common on coastal tundra from Cape Romanzof south to Nelson Island, where nesting densities average 0.4 nests/km^2 in the vegetated intertidal zone (King and Dau 1981). Densities on the Yukon Delta study area are probably below this level, but Jones and Kirchhoff (1978) still considered them to be fairly common breeders on their study site.

Tundra swans arrive on the Yukon Delta from late April to early May, depending on the progress of the spring thaw (Lensink 1973). Nest initiation occurs almost immediately, with most nests placed on slightly raised tundra hummocks which become snow-free earlier and are less subject to spring flooding than surrounding wet tundra (King and Dau 1981). Both adults of a breeding pair remain on lakes and ponds near the nest site for the majority of the summer, while non-breeding birds gather into flocks of from a few birds up to 1000 or more individuals. These flocks of non-breeders often use the vegetated intertidal zone of the Yukon-Kuskokwim wetland complex for feeding and molting (King and Dau 1981).

Juvenile swans require approximately 85 days in which to fledge in the Yukon Delta area (Bellrose 1976). Both non-breeders and family groups begin to assemble into large flocks along the coast and near inland lakes during September, and most swans have departed the area by late September or early October (King and Dau 1981).

Tundra swans breeding on the Yukon Delta form a portion of the western population of this species, migrating to wintering areas in several western states (Sladen 1973). Migration routes vary between a strictly Pacific coastal route or one through interior Alaska, Yukon Territory and southward through Rocky Mountain provinces and states.

Food requirements of breeding or summering swans are poorly known; however, at all other times of the year, emergent and submerged portions of waterplants form the bulk of their diet (Palmer 1976). Several species of pondweed (Potamogeton sp.) commonly grow in still or slow-moving fresh and brackish waters on the Yukon Delta and are undoubtedly utilized by tundra swans.

Probably the major environmental factor regulating productivity of tundra swans and, perhaps ultimately, swan populations, concerns climatic conditions on the breeding grounds. Lensink (1973) has convincingly demonstrated a link between spring temperatures on Yukon-Kuskokwim breeding grounds and both numbers of swans nesting and numbers of chicks raised to fledging. If nesting is delayed by a late breakup of ice on rivers and lakes, breeding adults are forced to expend more of their reserves toward body maintenance, resulting in lowered clutch sizes or even failure to nest. Hunting may also have some controlling influence on swan numbers, as an estimated 2,614 swans and 326 swan eggs are taken by subsistence hunters on the entire Yukon-Kuskokwim Delta (Copp and Smith 1981).

Brant

Probably the most marine of the geese, the brant spends the majority of its lifetime on or near saltwater habitats. From 30 to 50 percent of the world population of black brant (the Pacific subspecies of brant) nests on the Yukon-Kuskokwim Delta, primarily along a narrow band of sedge and grass habitats extending only a few kilometers inland from the Delta coast (King and Dau 1981).

An estimated 75,000 brant nest on the Yukon-Kuskokwim Delta, frequently in loose, scattered colonies very near the coast (Bellrose 1976). Populations on the Yukon Delta study area are probably lower than on areas farther south in the Yukon-Kuskokwim Delta. Jones and Kirchhoff (1978) observed several flocks but only one brood on their study site, while nest densities near Hooper Bay south of Cape Romanzof may exceed 1500 nests/km^2 over much of the coast (King and Dau 1981). Brant arrive on the Yukon Delta in mid-May, following a generally gradual migration along the Pacific coast of North America. Preferred habitats during the nesting season are of two types: meadows dominated by sedge and grass with numerous small, shallow ponds; and elevated intertidal mudflats with scattered pads of sedges (King and Dau 1981). Habitat use during the brood-rearing season is very similar, with most family groups and flocks of non-breeders associated with intertidal meadows on the Yukon Delta study site of Jones and Kirchhoff (1978). Foods on the breeding grounds consist of sedges and grasses (mainly *Carex subspathacea*, *C. ramenskii*, and *Puccinellia phryganodes*) grazed on brackish meadows (Palmer 1976). Fall departure from the delta occurs in late August, when large flocks of brant gather on bays and lagoons south of the Yukon-Kuskokwim Delta to feed on eelgrass (*Zostera marina*) (Hansen and Nelson 1957). Virtually the entire population of black brant stage at Izembek Lagoon on the Alaska Peninsula, before departing en masse on a trans-oceanic flight across the Gulf of Alaska.

Habitat factors of importance to brant on the Yukon Delta appear to be the availability of suitable intertidal meadows with luxuriant growths of sedges and grasses and the presence of numerous ponds and sloughs in which to escape from predators during the molting/brood-rearing period in late July and August. More than any other waterfowl in the area, brant are highly susceptible to the effects of storm tides on nests and eggs. They generally nest closer to the coast than other geese and have, in the past, incurred heavy losses of nests and eggs to floods (King 1963); however, flood losses appear to be relatively infrequent and are usually local in nature.

In the 1960's black brant populations underwent a steady decline, probably related to hunting pressure in California, as wintering populations there were reduced to very low levels on traditionally-used bays and lagoons. Protection from overharvest and movement of brant to undisturbed sites on the Baja California coast has increased survival rates (Kramer et al. 1979). Productivity of brant may be affected by several factors, including cold spring or summer weather, tidal flooding of nests, or predation of nests. Of the four goose species studied by Mickelson (1975) on the Yukon-Kuskokwim Delta, brant suffered the highest egg mortality from predation (55.4% of nests destroyed), principally from avian sources such as jaegers and glaucous gulls. Arctic foxes may also prey on brant nests, although most colonies are located on islands in lakes and ponds, along the coast, or on patches of tundra separated from the mainland by extensive mudflats or large sloughs, thereby inhibiting access by foxes (C. J. Lensink, unpubl. data; in Bellrose 1976). Subsistence harvests of adults and gathering of eggs may lead to significant decreases in some nesting colonies on the Yukon-Kuskokwim Delta (Byrd 1981). Recent estimates of subsistence harvests place the annual kill of adult brant at about 3555 birds in this area (Copp and Smith 1981).

Other Geese

The other nesting goose species (aside from brant) on the Yukon Delta include cackling and Taverner's Canada goose, white-fronted goose, and emperor goose. The snow goose rarely, if ever, nests on the Yukon-Kuskokwim Delta, but may be common in spring and fall in transit to Siberian nesting grounds. In general, the Yukon Delta study area probably supports lower densities of nesting geese than the coastal regions from Cape Romanzof south to Nelson Island (Spencer et al. 1951; Figure 2). The most common nesting geese on the study area were Taverner's Canada geese and emperor geese, followed by much lower numbers of white-fronted geese and cackling Canada geese (Jones and Kirchhoff 1978).

The importance of the entire Yukon-Kuskokwim Delta as rearing habitat for geese cannot be understated. Nearly 100% of the world's population of cackling Canada geese nest on the coastal portions of the delta (Mickelson 1975). Of the other species, 95% of Pacific Flyway white-fronted geese nest here, and probably almost all of the some 28,000 to 88,000 snow geese nesting on Wrangel Island, Siberia, stop on the delta during spring and/or fall migration. In addition, a large percentage of the world's population of emperor geese (80-90%) and Taverner's Canada geese (over 50,000 birds) nest on the delta.

Arrival of geese usually takes place during the first two weeks of May, and nesting is initiated as soon as suitable nest sites are free of ice, snow, and meltwater. On the Yukon Delta, emperor geese nest close to the coast, while Canada and white-fronted geese usually nest well within the shrub zone (i.e., outside of tidal influence).

All geese commonly use the productive intertidal meadows along the coast of the Yukon Delta for feeding during the summer molting/brood-rearing period (Jones and Kirchhoff 1978). The presence of tidal sloughs, ponds, and tidal flooding in this area provides for a relatively predator-free environment for young geese. Important foods here include the sedges *Carex ramenskii* and *C. subspathacea*, *Triglochin palustris*, and the seeds and

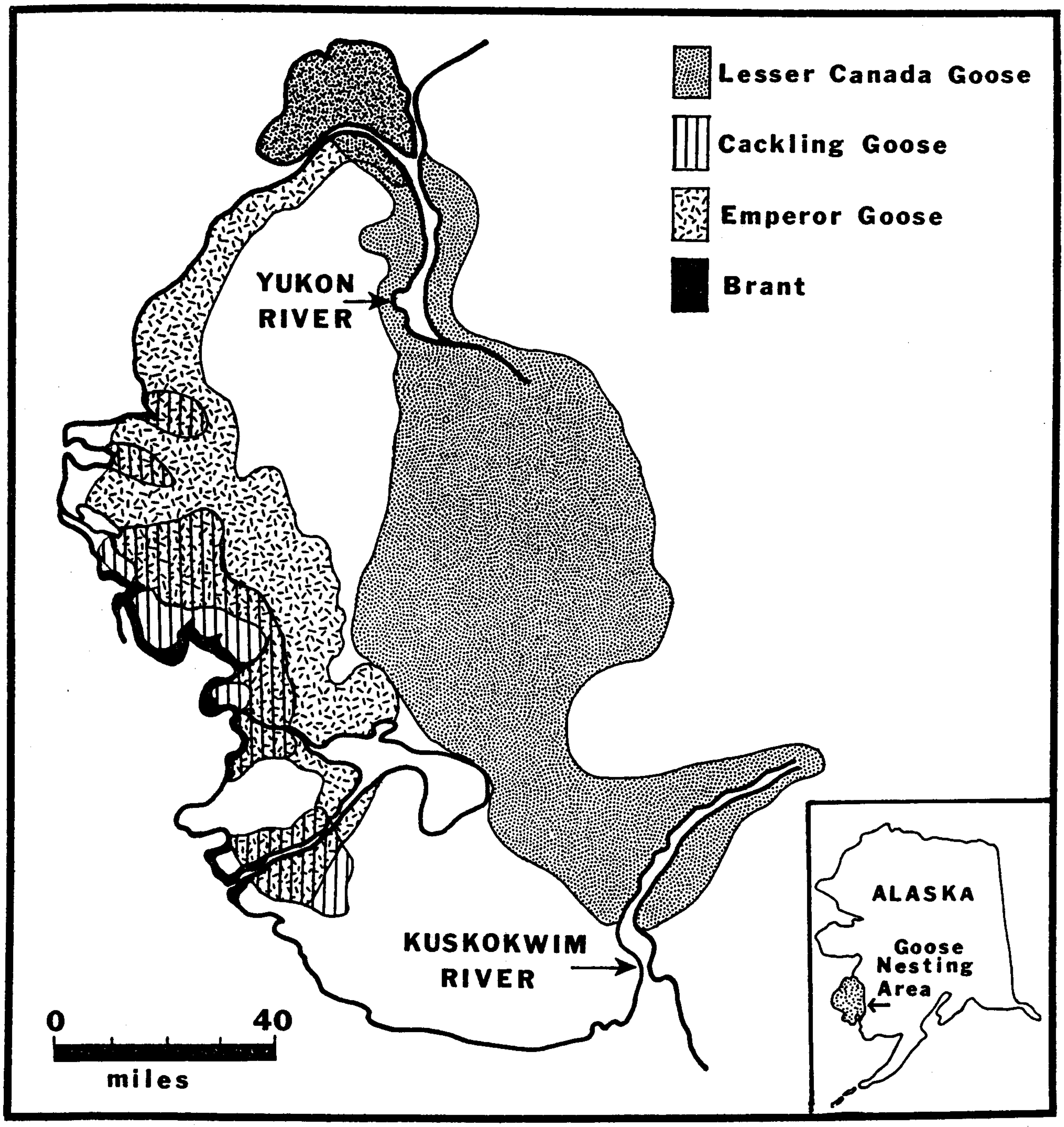

Fig. 2. Known nesting concentrations of brant, and cackling and lesser Canada and emperor geese nesting in the Yukon-Kuskokwim Delta region, 1950 (from Spencer et al. 1951).

leaves of various grasses. Immediately following fledging and molt, most geese move inland in mid-August to feed on ripening berries, particularly crowberries (Empetrum nigrum) (Palmer 1976).

Fall departure of geese from the Yukon Delta occurs from late August through September; snow geese arrive in September and October, and utilize both inland and coastal meadows for feeding (King and Dau 1981). White-fronted, Canada, and snow geese depart the delta for wintering areas primarily in California and other western states; emperor geese move south and west, to wintering sites in the Aleutian Islands (Bellrose 1976).

While all geese nesting on the Yukon Delta are vulnerable to some amount of flooding, only those species nesting commonly along the outer coastline (principally brant, but also cackling geese and emperor geese) may incur reduced productivity due to flooding of nests by tidal surges. An important habitat feature for most species appears to be the presence of suitable brood-rearing habitat, which normally consists of brackish meadows near the coast or along inland tidal sloughs on the Yukon Delta (Mickelson 1975). This habitat not only provides an abundance of food for broods and molting birds, but also provides flightless birds escape cover (open-water sloughs and lakes) from foxes and other mammalian predators.

In recent years, populations of many goose species breeding on the Yukon-Kuskokwim Delta have been decreasing. While the ultimate cause for the decrease is unknown, investigations are under way to determine the role of spring and summer subsistence harvests of geese and their eggs by Eskimos in regulating goose populations. Total spring harvest estimates for geese on the entire Yukon-Kuskokwim Delta include 6050 cackling Canadas, 7305 Taverner's Canadas, 5876 whitefronts, 8316 emperors, and 629 snow geese. In addition, an estimated 15,241 goose eggs are also taken (Copp and Smith 1981). Other recent estimates of subsistence harvests extrapolated from Klein's (1966) study placed harvest levels at between 22,500 and 35,600 Canadas and whitefronts alone (Timm and Dau 1979). Harvests of geese in other portions of the Flyway, spring weather conditions on the Yukon-Kuskokwim Delta, and other environmental factors could also be contributing to declining goose populations (Mickelson 1975; Eisenhauer and Kirkpatrick 1977; Ely 1980).

Northern Pintail

The northern pintail is one of the most abundant nesting ducks on the study area, and the most abundant staging species there (Jones and Kirchhoff 1978). Approximately 10 percent of North American populations and one-quarter of Alaskan populations of this duck normally occupy the Yukon-Kuskokwim Delta in summer; total numbers may approach 1,000,000 or more (King and Dau 1981). Periodic severe droughts in prairie nesting areas farther south cause many pintails to forego nesting and move northward, to augment summer pintail populations in the Yukon Delta and elsewhere (Derksen and Eldridge 1980). Pintails utilize both coastal and inland tundra for nesting, and gather in large flocks during portions of the summer to feed on intertidal mudflat and meadow habitats.

Pintails normally arrive on the Yukon Delta in early May and initiate nesting soon thereafter, depending on the progress of the spring thaw. While waiting for nesting areas to become ice-free, large flocks of pintails aggregate on tidal meadows and mudflats within the Yukon Delta study area (Kirchhoff 1978). Attractiveness of intertidal areas in this region results from the low salinity and relatively high clarity of tidal waters over portions of the coast that provide for extensive beds of the pondweed *Potamogeton filiformis* to form on mudflats and tide pools (Fig. 3). Associated with these pondweed beds are high densities of brackish-water invertebrates, particularly the isopod *Saduria entomon*, the mysid *Neomysis intermedia*, and amphipods and polychaetes (Kirchhoff 1978). Immediately inland from the mudflats but still under the influence of higher high tides are lush meadows of sedges (*Carex* spp.) and various grasses bisected by tidal sloughs. These areas also provide valuable feeding habitat for pintails as well as geese (Kirchhoff 1978).

The number of pintails using intertidal habitats on the Yukon Delta study area varies through the summer. Use is high in May and early June as break-up progresses. Numbers of pintails were highest on the intertidal meadow during the first weeks of this period, then use of mudflats increased as offshore ice melted and this habitat became available to birds (Kirchhoff 1978). Pintail use decreases dramatically in late June and July, when nesting and molting occurs on inland tundra and large sloughs, respectively, By early August, pintails return to the intertidal zone in numbers. Aerial

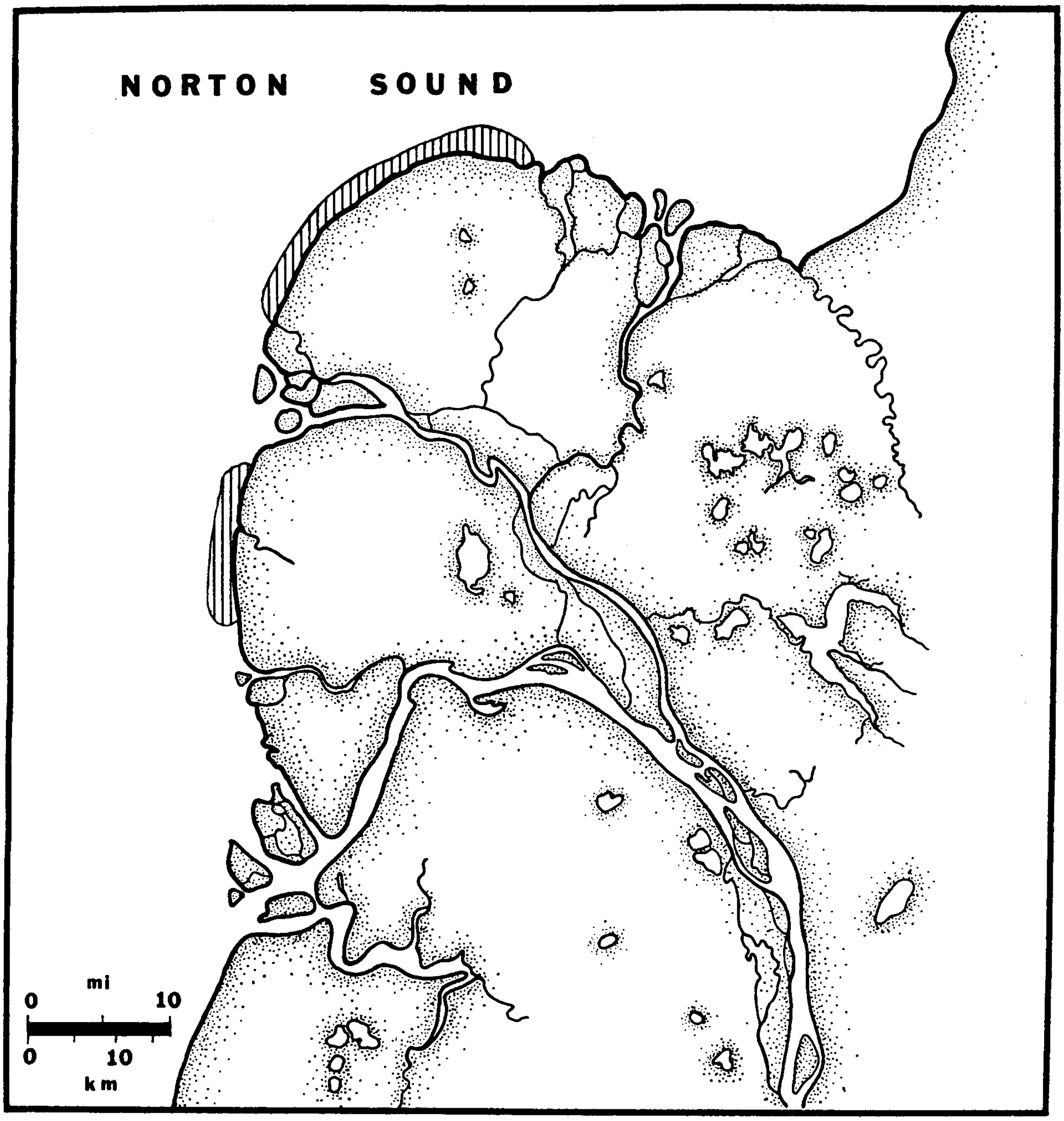

Fig. 3. Areas of relatively high water clarity in summer (vertical lines) immediately off the Yukon Delta coast (from Kirchhoff 1978).

survey and ground transect estimates place the number of pintails using the northern half of the study area alone at 40,000 to 50,000 birds (Jones and Kirchhoff 1978). Fall migration from the study area is initiated in late August and continues into September (Kirchhoff 1978).

The unique environmental conditions present on the Yukon Delta study area, particularly the extensive intertidal zone and freshwater intrusion into surrounding Norton Sound waters, provides extensive feeding habitat for pintails in summer. While foraging within intertidal habitats on the Yukon Delta, pintails consumed mainly mysids and isopods, along with some seeds of Carex and Potamogeton. Seeds and vegetable matter were more prevalent in pintail stomachs in spring, but invertebrates assumed a major role later in the summer (Kirchhoff 1978).

Sport harvest levels for pintails have been high in recent years throughout much of their range due to generally stable or increasing populations of this duck. Pintails were the most prevalent duck species harvested by Eskimo subsistence hunters during a recent survey on the Yukon-Kuskokwim Delta (Copp and Smith 1981); estimated take was 6102 pintails, compared to a total of 18,913 ducks taken overall. Population regulating factors are unknown, but are certainly influenced by weather conditions on the breeding grounds and sport and subsistence harvest levels.

Eiders

All four species of eider occur on the Yukon-Kuskokwim Delta or are present in its nearshore waters (King and Dau 1981). The common eider nests strictly on coastal island and delta shores and would be expected to occur only at the coastal fringe of the Yukon Delta at any time of year, but this species was not observed by Jones and Kirchhoff (1978) at their study site. The king eider occurs in the study area as a migrant and winter visitant during open water periods; occasionally, molting subadults occur in summer in nearshore waters. Very large numbers (100,000's to possibly over 1,000,000) occur in open leads during spring migration when they form a major proportion of the subsistence harvest by Eskimos (Copp and Smith 1981). The common nesting eider on the Yukon Delta study area is the spectacled eider, which was reported as a successful nester by Jones and Kirchhoff (1978) along ponds and sloughs in their study area. Like the king eider, the Steller's eider nests in the more northerly tundra areas of Alaska and eastern Siberia, and occurs on the Yukon Delta only as a very rare breeder and an uncommon migrant (King and Dau 1981).

As sea ice begins to break up in late April and May, large flocks of eiders of several species (common, king, and some Steller's) follow the opening lead systems near shore on their way to northern Alaskan and Siberian breeding grounds. Frequent stops may be made en route due to unfavorable winds or cold temperatures, and any of these species could be present in open water offshore of the Yukon Delta in spring (King and Dau 1981).

The nesting eider species, common and spectacled, choose very different habitats in which to nest. Common eiders prefer coastal spits and barrier islands where they are safer from mammalian nest predators, but they also occasionally nest on mainland shores, often near driftwood logs or other cover (Schamel 1974; Mickelson 1975). Once the eggs hatch, young common eiders are led immediately to Bering Sea nearshore waters and lagoons, where the broods are raised (King and Dau 1981).

Spectacled eiders arrive from the northwest on the Yukon-Kuskokwim Delta, flying directly from northern Bering Sea wintering grounds (Dau and Kitschinski 1977). Nest sites on islands, peninsulas, or shores of ponds are preferred in wet coastal tundra areas that are occasionally subject to tidal flooding during storm surges (Mickelson 1975). Young spectacled eiders are raised on tundra ponds and sloughs and move to the sea at fledging (Dau 1974).

Molting of subadult, non-breeding, and male eiders takes place at sea from July through August. The entire coastline of the Yukon-Kuskokwim Delta may provide suitable molting habitat for all species of eiders although no important concentration areas near the Yukon Delta are known (King and Dau 1981). Fall migration is much more dispersed and gradual than spring migration, with locally nesting birds and those from farther north moving to nearshore feeding areas scattered throughout the Bering Sea.

While on marine waters, eiders feed predominantly on benthic and epibenthic invertebrate prey, including bivalves and crustaceans (Palmer 1976). The larger eiders (common and king) feed primarily on mollusks, mainly clams and mussels, while the smaller eiders (Steller's and possibly spectacled) feed on amphipods, other crustaceans, and bivales (Petersen 1980). Dau (1974) found foods of breeding spectacled eiders and their young on tundra ponds to consist of Tipulid and Trichopteran larvae, pelycopod molluscs, and some vegetable matter.

Eiders are amona the most marine of waterfowl. They are found in freshwater only during the breeding season, and common eiders even then rarely leave salt water. Eiders dive for their food and are thus restricted to shallow areas of the Bering Sea,generally along coastlines. Water clarity and bottom substrates may affect their feeding in areas such as the mouth of the Yukon River; the constant sediment outfalls here may smother potential benthic prey and the turbidity may hinder feeding efficiency.

It is difficult to identify population regulating mechanisms for such little known birds as the eiders. Over 5000 eiders are estimated to be harvested annually by Eskimos on the Yukon-Kuskokwim Delta (Copp and Smith 1981), but it is generally believed that spring subsistence harvests by natives has little impact on eider populations (Klein 1966). Most of those harvested are king and common eiders, both of which have continental populations of over 1 or 2 million each. They are subject to almost no sport harvest throughout their range.

Scoters

Although all three species of scoter are found within the study area, only the black scoter would be expected to nest there. Along with the black scoter, large numbers of white-winged and surf scoters (tens of thousands) conduct a molt migration to the nearshore waters of the Yukon-Kuskokwim Delta in summer (C. P. Dau, unpubl. data). Aerial survey flights by Dau have only recently documented this newly discovered molting concentration.

Scoters are large, primarily marine ducks nesting commonly over much of Alaska. White-winged and surf scoters nest near interior Alaska lakes and ponds, while black scoters nest on coastal tundra in western Alaska and on ponds in the Alaska Range (Gabrielson and Lincoln 1959). Nesting of scoters occurs later in the season than for other ducks, with nest initiation taking place from early June to early July. The eggs often do not hatch until early August, particularly for black scoters (Dick and Dick 1971; Bellrose 1976). In July, while nesting and brood-rearing is occurring, adult male scoters along with subadult and non-breeding scoters migrate to nearshore molting sites along the coasts of Alaska.

Much of the Alaskan coastline harbors molting scoters in summer. Heavy concentrations were noted recently in the shallow nearshore waters off the Yukon-Kuskokwim Delta from the Cape Newenham area to Pastol Bay, including waters of the Yukon Delta study area (C. P. Dau, unpubl. data). Due to the recent nature of these findings, food habits of these molting birds is unknown. Scoters feed primarily on bivalve molluscs (clams, mussels) and other benthic marine invertebrates in other portions of their range, and likely do so on the Yukon Delta (Palmer 1976).

Surf scoters are present on the molting grounds from mid-July to mid-August, when black scoters become much more common; these remain through mid-September (C. P. Dau, unpubl. data). White-winged scoters are found in consistently low numbers throughout the molting period. Observations of migrating scoters in July at Cape Pierce (Dick and Dick 1971; D. R. Herter unpubl. data) indicate that birds from breeding areas outside the Yukon-Kuskokwim Delta are moving to this molting area as well.

Factors that regulate scoter populations are unknown. Likely influences include various breeding ground conditions or winter food availability. Sport harvests of scoters are very low and represent only a small percentage of total continental populations, which are in hundreds of thousands for each species (King and Dau 1981). Subsistence harvests are likewise fairly low on the Yukon-Kuskokwim Delta (Copp and Smith 1981), although these ducks are preferred species of Indian hunters in Interior Alaska regions, where harvest estimates are lacking.

Sandhill Crane

Of the almost 200,000 lesser sandhill cranes migrating to Alaska, possibly half nest on the Yukon-Kuskokwim Delta, where nest densities may be 1.5 birds/km^2 on the productive, outer coastal segment of the delta (Boise 1977).

Unlike most waterfowl, cranes appear to be fairly evenly distributed along all coastal portions of the delta, with numbers diminishing only well inland (several kilometers) from the coast. Sandhill cranes were considered common and nested successfully on Jones' and Kirchhoff's (1978) study site, where they were most commonly observed in wet coastal tundra and the intertidal sedge meadows.

Sandhill cranes arrive on the Yukon Delta in the first week or two of May, from wintering grounds in Texas, New Mexico, and Mexico (Lewis et al. 1977). As with waterfowl, nests are most often placed on raised ground that becomes free of snow, ice, and meltwater earlier in the spring (Boise 1977). Observations by Jones and Kirchhoff (1978) suggest that coastal nesting cranes may feed in intertidal sedge meadows; here probable food sources are the abundant gastropod Lymnea and various plants. Chicks are fledged and fall departure has begun by late August or early September (Kessel 1979). During most of the summer, wandering flocks of subadults and/or failed breeders are common on the delta, and often forage in intertidal meadows (Boise 1977).

Food requirements of sandhill cranes on Alaskan breeding grounds have not been well documented; however, animal foods seem to be important, especially to growing chicks. Adult cranes collected by Boise (1977) contained tundra voles, snails, and small fish; snails and insects such as craneflies and midges are probably important foods for chicks. Particularly later in the summer, cranes feed on berries of ericaceous plants and the bulbs of arrowgrass (Triglochin palustris) (C. M. Boise, pers. comm. 1981).

Sandhill cranes are typically found in open, wet areas with low-growing vegetation; their omnivorous food habits allow them to adapt to many different ecological regions. Factors of importance to cranes on the Yukon Delta appear to be the presence of wet sedge tundra and an abundance of invertebrate and vertebrate foods early in the summer, and vegetable foods in late summer.

Sandhill cranes never occur in great nesting densities and are likely limited by food supplies on the breeding grounds, or by food availability in winter. Cranes are harvested by both sport hunters and subsistence hunters. Recent surveys on the Yukon-Kuskokwim Delta estimated 1477 cranes and 643 crane eggs were taken in one year by Eskimos there. Despite these harvest levels, lesser sandhill crane populations have been increasing in recent years (Lewis et al. 1977) and continue to increase (U.S.F.W.S. 1982).

Shorebirds

The intertidal zone of the eastern Bering Sea coast is used extensively by breeding and migrating shorebirds. The Yukon-Kuskokwim Delta in particular is used by more species, in greater numbers, and in higher densities than any other littoral area in the region (Gill and Handel 1981). The study area, as part of the Yukon-Kuskokwim Delta, is used by many of these shorebirds. However, no specific shorebird surveys have been carried out in the study area, so there are no estimates available of local shorebird populations. Similarly, other biological data on these birds, such as food sources, migration timing, and habitat must be extrapolated from studies done in other areas. Much of this work is from the southern section of the Yukon-Kuskokwim Delta, in the Hooper Bay region. Some work was done in the study area by Jones and Kirchhoff (1978) on waterfowl. Their report provides an annotated species list, which included some information on shorebirds.

All of the shorebirds discussed below depend on the extensive intertidal zones within the study area for a major portion of their late summer food supply. The proximity of these rich feeding grounds to extensive, productive nesting areas is what makes the study area valuable habitat (Gill and Handel 1981). As mentioned above, the relative importance of this area to other areas of the Yukon-Kuskokwim Delta has not been determined, though the delta as a whole is known to be the most important area for shorebirds on the eastern Bering Sea coast (Gill and Handel 1981).

Bar-tailed Godwit

Found throughout the palearctic, the bar-tailed godwit is restricted to western Alaska in North America where it is frequently the most abundant large shorebird (Gill and Handel 1981). It is a common nesting species on the Yukon Kuskokwim Delta and northward to the Sagavanirktok River area on the Beaufort Sea coast (Gabrielson and Lincoln 1959; Hanson and Eberhardt 1979). Several tens of thousands of bar-tailed godwits use the littoral areas of the Yukon-Kuskokwim Delta during the summer (Gill and Handel 1981). They were regularly seen in the study area by Jones and Kirchhoff (1978).

Bar-tailed godwits first arrive on the study area in mid- to late May (Gill and Handel 1981). They migrate directly from their southwest Pacific wintering grounds to the mouth of the Yukon River, where some feed initially in the ice-free littoral areas (Gill and Handel 1981). These birds soon join the rest of the population on their inland breeding grounds (Gill and Handel 1981). Bar-tailed godwits nest inland from the coast in the willow zone and commonly feed in the upper intertidal zone (Holmes and Black 1973; Jones and Kirchhoff 1978).

Bar-tailed godwits move to coastal mudflats to feed in June, with adults generally preceding juveniles (Gill and Handel 1981). The birds leave the area in early September, flying to staging areas on the Alaskan Peninsula and then to southern Pacific wintering grounds.

Bar-tailed godwits feed on mudflats and sandbars, probing for marine worms, crustaceans, and molluscs (Terres 1980). Their diet in the study area is not known, but sampling of the intertidal mudflats revealed a community of invertebrates including mysids, isopods, amphipods, and polychaetes (Jones and Kirchhoff 1978). Dipteran larvae are thought to be the staple of many shorebirds' diets during the nesting period (Gill and Handel 1981); these were found in high densities in tidal mud near Hooper Bay, south of the study area (Holmes and Black 1973).

Factors limiting bar-tailed godwit populations are not known, though Gill and Handel (1981) stated that "food is probably the single most important factor regulating population numbers, timing of breeding, and habitat use" of arctic nesting shorebirds. The same conclusion was also reached by Holmes (1970) about dunlins.

Black Turnstone

Most of the world's population of black turnstones nests on the coastal tundra of the eastern Bering Sea coast, from the Alaska Peninsula to Cape Prince of Wales, but primarily on the Yukon-Kuskokwim Delta (Gabrielson and Lincoln 1959; Gill et al. 1981). Several thousand black turnstones use the littoral areas of the Yukon-Kuskokwim Delta in the summer (Gill and Handel 1981), and numerous individuals were observed on the Yukon Delta study site by Jones and Kirchhoff (1978).

Black turnstones arrive in the study area during May, and move directly to their breeding sites (Gill and Handel 1981). They nest in coastal wet meadows and salt grass meadows, in areas that are occasionally flooded by storm tides (Holmes and Black 1973; Gill and Handel 1981). Holmes and Black (1973) found that nests were usually close to mud-bordered ponds, where the birds would feed. During early to mid-June, the young hatch, and the adults start moving away from nest sites to feed in the intertidal zone (Gill and Handel 1981). Adult black turnstones leave the study area in early July, with the young following in late August and September (Gill and Handel 1981). They winter along the Pacific coast, from southern Alaska to Mexico (Terres 1980).

Black turnstones eat barnacles, slugs, small molluscs, crustaceans, small marine animals, and occasionally berries (Terres 1980). As with bar-tailed godwits, their diet in the study area is largely unkonwn. Most likely they eat dipteran larvae while nesting (Gill and Handel 1981), and dipteran larvae, mysids, isopods or amphipods while feeding on the intertidal mudflats (Holmes and Black 1973; Jones and Kirchhoff 1978).

Bristle-thighed Curlew

The bristle-thighed curlew is a rare bird that nests only in western Alaska (Terres 1980). Its actual breeding grounds are still largely unknown. Only two nests have been located, both in the Nulato Hills near Mountain Village (Allen and Kyllingstad 1949), although other nests are suspected on the Seward Peninsula uplands (B. Kessel pers. comm., 1982). Total population estimates of bristle-thighed curlews have not been attempted, but they are not known to be common anywhere.

Bristle-thighed curlews fly directly from their wintering grounds on central Pacific islands to their breeding grounds. Small flocks gather on wet meadows and dwarf shrub tundra of the Yukon-Kuskokwim Delta in July to fatten on berries before the fall migration (Gill and Handel 1981). Scattered flocks of usually fewer than 20 birds may occasionally use littoral areas of the delta. The species has generally left the delta region by late August (Gill and Handel 1981).

Bristle-thighed curlews eat berries and probably insects, molluscs and crustaceans (Terres 1980). They also eat the eggs of other birds, particularly terns, on their wintering grounds (Terres 1980).

So little is known of the biology of this bird that it is hard to estimate the importance of the Yukon-Kuskokwim Delta as a staging area, although relatively large numbers have been seen there in summer (Boise pers. comm., 1981), and it is certainly important habitat for the species. Jones and Kirchhoff (1978) did not report seeing any bristle-thighed curlews on their study site, although these birds probably occur on the Yukon Delta study area during the migration or summer staging periods.

Dunlin

The dunlin is the most abundant shorebird using Bering Sea intertidal habitats (Gill and Handel 1981). They are common nesting birds from the Alaska Peninsula northward along the coast. Several hundreds of thousands of these birds feed in summer and fall along the Yukon-Kuskokwim Delta (Gill and Handel 1981). They were one of the most common shorebirds seen on the Yukon Delta study area by Jones and Kirchhoff (1978).

Dunlins arrive on the Yukon-Kuskokwim Delta area between 10 and 20 May (Holmes 1970). They usually move directly to their breeding grounds, on wet tundra above the zone of normal tidal influence (Jones and Kirchhoff 1978). During years of late snow-melt, dunlins feed on ice-free intertidal areas before moving to their nesting grounds (Gill and Handel 1981). Dunlin nesting territories are evenly dispersed, with a density in the Hooper Bay area south of Cape Romanzof of about 13 pairs per 10 ha (Holmes 1970). After the young have fledged, the adult birds return to the littoral areas. They feed in the intertidal zone while the adults molt, and juveniles complete feather growth. Dunlins are the last shorebirds to leave the delta area in fall, flying to their U.S. and Mexican coastal wintering grounds in early October (Gill and Handel 1981).

The diet of breeding dunlins in the Kolomak River area near Hooper Bay was extensively studied by Holmes (1970). By far the most important prey items were chironomid and dipteran larvae. Adult dipteran insects and trichopteran larvae were occasionally eaten. Dunlin diets at Barrow were similar, though different species of dipteran larvae were present there (Holmes 1970). After returning to the coast, dunlins were found to add polychaetes, small molluscs, isopods, and other small marine invertebrates to their diet (Holmes 1970).

In a detailed study of dunlin density, territoriality and food supply, Holmes (1970) concluded that dunlins have evolved a territorial system which limits ther population to a level matching the available food supply. Dunlins nesting at Barrow, where food is less plentiful, had much larger territory sizes than those nesting in the Kilomak River area (Holmes 1970).

Western Sandpiper

The western sandpiper is very abundant throughout western Alaska, its only known nesting area. Its main nesting area is the Yukon-Kuskokwim Delta, where densities may reach 50-75 pairs per 10 ha (Holmes 1970). Several hundreds of thousands also feed there during the summer (Gill and Handel 1981).

Western sandpipers arrive in mid-May, similarly to dunlins. They nest on dry heath tundra, on hummocks and ridges (Holmes and Black 1973). Their nest sites are clustered on drier ground, with most feeding taking place in surrounding marshy areas (Holmes 1970). Western sandpipers begin to move to the coast in mid-July to feed in intertidal areas. The adults leave the Yukon-Kuskokwim Delta in late July, with the young following in September (Gill and Handel 1981).

Western sandpipers hatch in mid-June at the same time as the first major emergence of adult insects (Holmes 1972). The young birds feed on adult dipterans and coleopterans, gradually switching to a diet of dipteran larvae (Holmes 1972). While on intertidal mudflats, they probe into the shallow surface zone, taking many invertebrate prey species, particularly small bivalve molluscs (Senner 1977).

Food supplies seem to be the major factor limiting western sandpiper populations. Limited food supplies determine their breeding and migration schedules (Holmes 1972). Food abundance and availability on the wintering grounds, however, may be of more consequence to this species than food on the expansive breeding grounds.

Rock Sandpiper

The rock sandpiper is a bird of the North Pacific and even in winter only rarely ranges as far south as the northern California coast (Terres 1980). Several tens of thousands are found during summer and early fall on the intertidal areas of the Yukon-Kuskokwim Delta (Gill and Handel 1981). Although they were not mentioned by Jones and Kirchhoff (1978) on their Yukon Delta study site, they likely occur there.

Rock sandpipers are among the earliest of shorebirds to arrive on the Yukon-Kuskokwim Delta. They congregate in the ice-free intertidal areas during the last half of April, and continue to use these areas into June (Gill and Handel 1981). They nest on moist tundra close to the coast and return to the tidal flats in July (Gill and Handel 1981). The birds use roosting sites in the cut banks adjacent to the intertidal zone. Their numbers build until early September, with some birds remaining until late October (Gill and Handel 1981).

Rock sandpipers typically eat crustaceans, small molluscs, insects, worms, some algae, seeds, and berries (Terres 1980), but their diet in the study area has not been documented.

Other Shorebirds

Juveniles of two other shorebird species, the pectoral sandpiper and the sharp-tailed sandpiper use the Yukon-Kuskokwim Delta as a staging area from late August to early October (Gill and Handel 1981). Generally, the sharp-tailed sandpipers feed on the intertidal mudflats, while the pectoral sandpipers feed in the less frequently flooded, vegetated intertidal zone (Gill and Handel 1981). Jones and Kirchhoff (1978) observed these species in the study area in August, but did not distinguish between them.

The semipalmated sandpiper was listed by Jones and Kirchhoff (1978) as an abundant breeder on the coastal tundra of their Yukon Delta study site. Semipalmated sandpipers are uncommon on other portions of the Yukon-Kuskokwim Delta (Gill and Handel 1981) but wherever they occur they prefer nest sites in habitats occasionally inundated by extreme high tides. Identifications of semipalmated and western sandpipers were confused early in the field season by Jones and Kirchhoff (1978), but their observations of semipalmated sandpiper nest densities and habitat preferences coincide well with those of Shields and Peyton (1979) on the Akulik-Inglutalik River Delta in eastern Norton Bay. The Yukon Delta study area probably represents the southern extreme of commonly used semipalmated sandpiper nesting habitat.

Fishes

The Norton Basin region, into which the Yukon River flows, contains about 87 fish species; it represents a transition region between arctic and subarctic fish communities. Three distinct groups of fish occur in this region (Wolotira 1980):

1. coldwater fishes indigenous to arctic marine waters (e.g. arctic cod, arctic flounder),
2. subarctic boreal fishes whose distribution is centered south of the study area in the Bering Sea or Pacific Ocean (e.g. salmon, cod, yellowfin sole, starry flounder, Pacific herring), and
3. northern anadromous/estuarine fishes (e.g. arctic char, white-fishes, smelts).

As reviewed by Wolotira (1980) and Burns et al. (1982), demersal and pelagic fish resources in the Norton Sound region are substantially less abundant than in more southerly Alaskan Shelf regions (Fig. 4). Low sea water temperatures are believed to be the cause of the apparent paucity of commercial fish stocks in Norton Sound (Burns et al. 1982).

Species characterizations for the major species or groups of fish are presented in the following sections. Data pertaining to the Yukon Delta, although limited, are emphasized; information obtained from other areas is drawn upon where general principles probably apply to the study area as well.

Salmon

All five species of Pacific salmon (chinook, chum, coho, pink and sockeye) occur in Norton Sound. The Yukon River is the major producer of salmon in this region and it supports large runs of chum, chinook and coho with smaller numbers of pinks and sockeye. In recent years, combined commercial and subsistence harvests of salmon have averaged about 300,000 fish in the Norton Basin region (ADF&G 1979b) and 1,547,000 in the Yukon River (Geiger et al. 1982). Although the magnitude of salmon resources in the study area is small in comparison to other Alaskan regions, Burns et al. (1982) emphasize that the importance of this resource to the local economy is substantial:

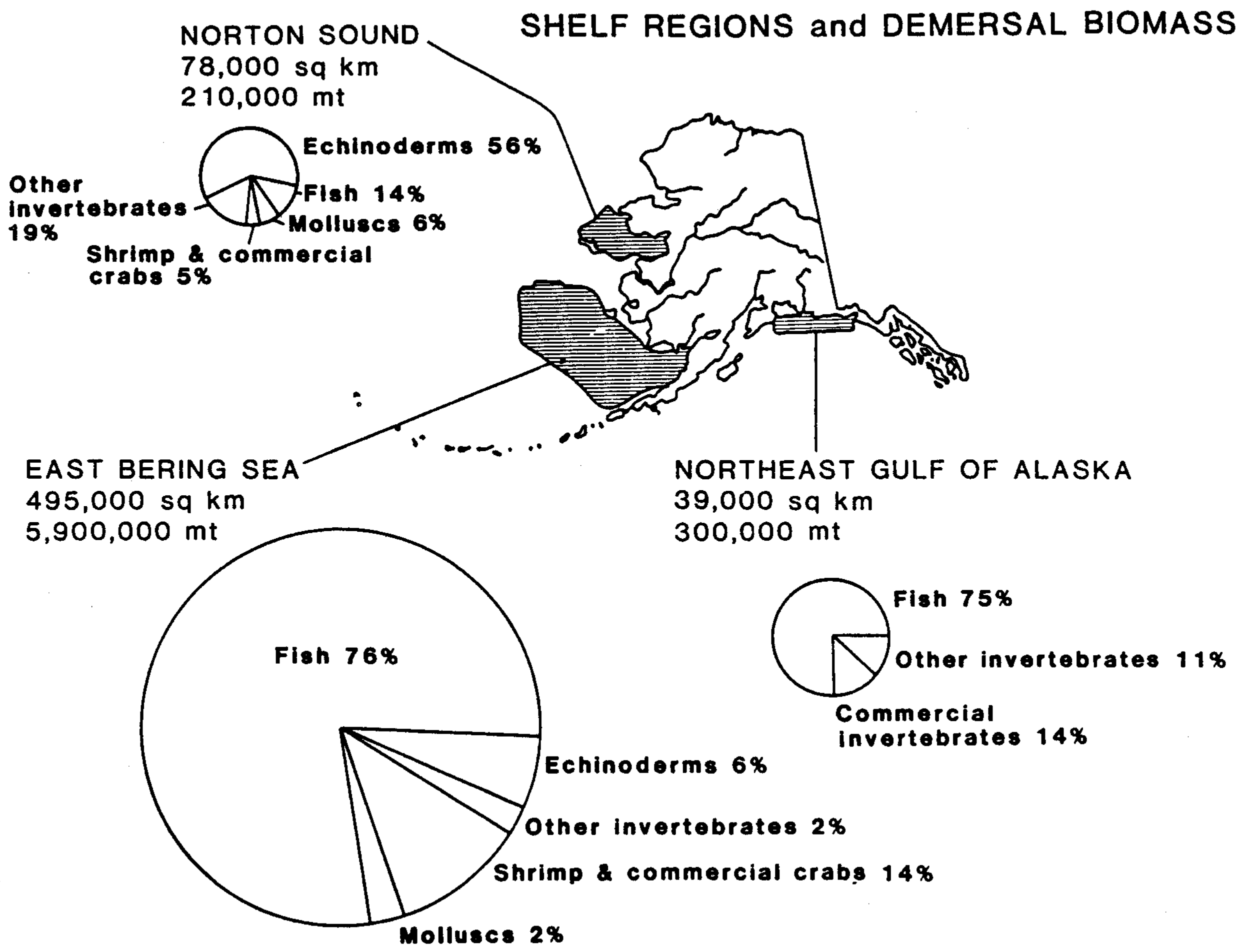

Fig. 4. A comparison of demersal fishery resources for regions of the Alaska Continental Shelf (Wolotira et al. 1977; Kaimmer et al. 1976; Ronholt et al. 1978). Figure provided by R. Wolotira in Burns et al. (1982).

> "A greater proportion of the salmon harvest in this region is used for subsistence than in most other areas of coastal Alaska. In recent years (1967-1976) an average of more than 15% of salmon harvested in Norton Basin were used for subsistence. This proportion is more than double that for the Bristol Bay region. The only region with a higher subsistence use proportion is the Yukon-Kuskokwim area where 18-20% of annual harvests are used for this purpose."

Information about salmon use of the Yukon Delta is very limited except for seasonal harvests of adults taken in fisheries. However, some general estimates of habitat use can be made based on studies conducted in the Bering Sea (Straty 1981) and regions farther south.

The five salmon species have basically similar life cycles in that they migrate as young fish to the sea and, upon maturity, return to their natal river to spawn and then die. The duration of freshwater residency by juvenile salmon varies according to the species from a few days to two years. Thereafter the fish migrate downstream and dwell in estuaries and other nearshore habitats for up to two months. Although there is little direct evidence that estuaries are essential for salmon feeding and growth, it has long been recognized that estuarine habitats play an important role in salmon biology. For example, Reimers (1981, cited in Smith 1972) described five life history types among chinook juveniles in an Oregon river, and he concluded that 90% of the total adult return was derived from a single type which lived several months in the estuary before moving to the open sea. Many other studies have also demonstrated that estuarine habitats provide rich feeding grounds for juvenile salmon (e.g. Naiman and Siebert 1979; Healey 1979).

Young salmon derive a second major benefit from estuarine habitats--the fish are provided with a gradual transition from fresh to salt water (Gilhousen 1962; Smith 1972). This change requires a physiological adjustment for juvenile salmon, and estuary waters provide an environment in which these fish can adapt to new salinity regimes. Natural mortalities of juvenile salmon may be high at this time. Juvenile pink salmon in British Columbia experienced a much greater mortality during this initial (40 days) residence in coastal marine waters than during their remaining period of life (410 days) (Parker 1965).

The seaward migration of juvenile salmon into coastal waters begins in spring and may extend over a considerable period during early summer. The timing of smolt migrations is species and stock specific and variable according to annual differences in environmental conditions such as the timing of spring breakup. In Bristol Bay, it generally appears that juvenile chinook salmon are the earliest to enter the bay in mid- to late May, and sockeye, chum, pink, and coho salmon, in that order, enter from late May to late July (Straty 1981). In Norton Sound (primarily Golovnin Bay), juvenile chum and pink salmon migrate into coastal waters at the onset of ice breakup (9 June 1977) and remain until about the second week of July (Barton 1979). After that time they may move offshore (Barton 1979; Merritt and Raymond 1983) although Straty (1981) felt that juveniles of the small size reported by Barton would likely remain in nearshore waters for a longer period but may have been missed by the sampling gear used.

During their nearshore residence, juvenile salmon feed primarily on plankton and fish. Major food items of pink and chum fry are copepods and small tunicates; coho juveniles are piscivorous, with herring larvae and sand lance being important prey; sockeye and chinook juveniles eat copepods, tunicates, other invertebrates, and fish (Manser 1969; Naiman and Siebert 1979; Healey 1979; and others). Neimark et al. (1979) note that chum juveniles in Norton Sound eat insects and fish. The abundance, distribution and types of zooplankton available in coastal waters greatly influence the distribution, growth and survival of juvenile salmon (Straty and Jaenicke 1980). Diets of large salmon in offshore waters consist of euphausiids, amphipods, copepods, decapod larvae, pteropods, squid and fish (Hart 1973).

Pink salmon reach maturity in two years, the other species in 3-6 years. The timing of their return migrations to natal rivers in the Norton Sound region differs among the species (Table 2). Details about their return runs into the Yukon River are summarized by Regnart and Geiger (1982).

Table 2. General periods when adult salmon are present in bays and estuaries in the Norton Sound region (ADF&G 1976, cited in Barton 1979).

SALMON	Adult Salmon Present in Bays and Estuaries
Chinook	15 June to 1-15 July
Chum	20-25 June to 20-25 July
Pink	25 June - 1 July to 15-20 July
Coho	1-20 August
Sockeye	25 June - 25 July

Chinook Salmon. Annual harvests of chinooks in the Yukon River average (1973-1982) 114,000 fish in the commercial fishery and 30,000 fish in the subsistence fishery (Geiger et al. 1982). The total number of chinooks and other salmon that enter the river is not well known. Based on tag recovery studies, ADF&G estimates that annual runs of chinooks during 1966-1970 were 161,000-600,000 fish. Over 100 spawning grounds have been located for chinooks in the vast drainage area (330,000 sq, mi.) of the Yukon River.

The majority of chinooks enter the river after ice breakup during June and early July. Based on limited observations, there is some evidence that the run of upstream stocks is earlier than that of stocks which spawn lower in the drainage.

Chum Salmon. Summer and fall chum salmon represent two major stocks in the Yukon River. Characteristics of the summer chums are: (1) earlier run timing (early June to mid-July in the lower river), (2) rapid maturation in fresh water, (3) smaller body size (6-8 lbs.), (4) greater population size, and (5) nearly all spawning takes place in the lower 500 mi of the drainage. Characteristics of fall chum include: (1) later run timing (mid-July to early September in the lower river), (2) larger size (7-9 lbs) and robust body shape and bright silvery appearance in the lower river, (3) smaller population size, and (4) spawning occurs in the upper portions of the drainage.

Recent annual harvests of summer and fall chum are 929,000 and 328,000 fish, respectively, in the commercial fishery and 206,000 and 153,000 fish, respectively, in the subsistence fishery. Estimates of annual harvests and escapements in recent years yield minimum population estimates of 1.2-5.6 million summer chum and 0.3-0.9 million fall chum.

Barton (1979) reports that in 1977 peak abundance of chum smolts moving downstream occurred 8-25 June (at least during the time of observation, 6 June-6 July) at a location 101 km upstream from Flat Island.

Pink, Coho, Sockeye Salmon. Relatively few coho are harvested in the Yukon River--the recent average is 23,000 fish in the commercial fishery. A few pink and sockeye salmon are taken incidently in fisheries for other species.

Other Anadromous, Brackish and Freshwater Species

Very little is known about anadromous brackish and freshwater species in the lower Yukon Delta, although a general description of their contribution to subsistence fisheries is available. Whitefishes, sheefish and ciscoes are important in subsistence fisheries throughout the drainage. Approximately 72,000 whitefish and 11,500 sheefish were taken incidental to salmon fishing in 1982 (Geiger et al. 1982); total yearly harvest information is not available. Subsistence fishermen operate gill nets and other gear largely in the main rivers and, to a lesser extent, in coastal marine waters; traps and fish weirs are used in fall and winter to capture whitefish, blackfish and burbot; sheefish, pike, arctic char and "tomcod" (saffron cod) are jigged through the ice in winter; and, dip nets are used in late May to early June to take smelt in the delta area and in late October to early November to take lamprey in the main Yukon River downstream from Grayling (Geiger et al. 1982).

Barton (1977) collected a variety of anadromous, brackish and freshwater fishes in the lower Yukon Delta (Kwikluak Pass) between Flat Island and Emmonak (Table 3). Three species (Bering cisco, humpback whitefish and sheefish) accounted for 70% of the catch and they were widely distributed in the coastal region examined (Barton 1979). Additional anadromous species which are commonly present in Norton Sound include least cisco, broad whitefish, arctic char and boreal smelt (Table 3).

Fish use of the extensive network of channels, lakes, ponds and bays in the Yukon Delta is not known but it is probable that the area is (1) an important migratory pathway for anadromous species on their way to or from coastal waters, (2) an overwintering site, (3) a spawning site for a few species, and (4) a major nursery and feeding area for juvenile and adult fish of many species. Regarding the first point, there is probably a very complex array of upstream and downstream movements of various life history stages (young-of-year, juveniles, spawners, mature non-spawners) of fishes migrating into or through the delta. Some species may use the deeper waters of the delta for overwintering, or its waterways for spawning (e.g. northern pike, ninespine sticklebacks), but most fish use of the estuary is presumably for feeding during the open-water season. Estuaries are, in general, prime feeding areas for fishes, and an estuarine residence is often an essential phase during the juvenile stages of the life-cycle of many species. Trophic relationships between fishes and their prey in the Yukon Delta are not known, but diets of common nearshore fishes from Norton Sound indicate that mysids (Neomysis spp.) are a major food item, followed in importance by unidentified eggs and copepods (Acartis clausi, Eurytemora spp.) (Figure 5).

Table 3. Relative abundance of common fishes caught in the Yukon River delta between Flat Island and Emmonak, 9 June - 5 August 1976 (Barton 1977), and percent occurrence at various sampling stations in Norton Sound (Barton 1979).

Species	Composition (%) Yukon Delta (s & g)**	Composition (%) Norton Sound offshore (g)	Occurrence (%) Norton Sound (nearshore) (s)	Occurrence (%) Norton Sound (nearshore) (g)
Bering cisco	39	1	42	20
Humpback whitefish	21		16	11
Sheefish	10			
Chum salmon	8	1		
Longnose sucker	7			
Least cisco	4		23	21
Northern pike	3			
Starry flounder	2	2	41	25
Pink salmon	2	*		
Burbot	2			
Broad whitefish	1		15	5
Arctic char	*	3	9	14
Boreal smelt	*		44	13
Ninespine stickleback	*		26	
Coho salmon	*	1		
Chinook salmon	*			
Saffron cod			42	31
Pacific herring		91		21
Pond smelt			24	4
Sand lance			24	
Arctic flounder			23	9
Poachers			23	2
Sculpins		*	20	7
Pink salmon (juveniles)			16	
Chum salmon (juveniles)			15	
Pricklebacks				2
Threespine stickleback			1	
Greenlings				8
Yellowfin sole				4
Round whitefish				1
Total catch	884	345		
Number of stations			69	66

* < 0.5%

** s(seine), g(gill net)

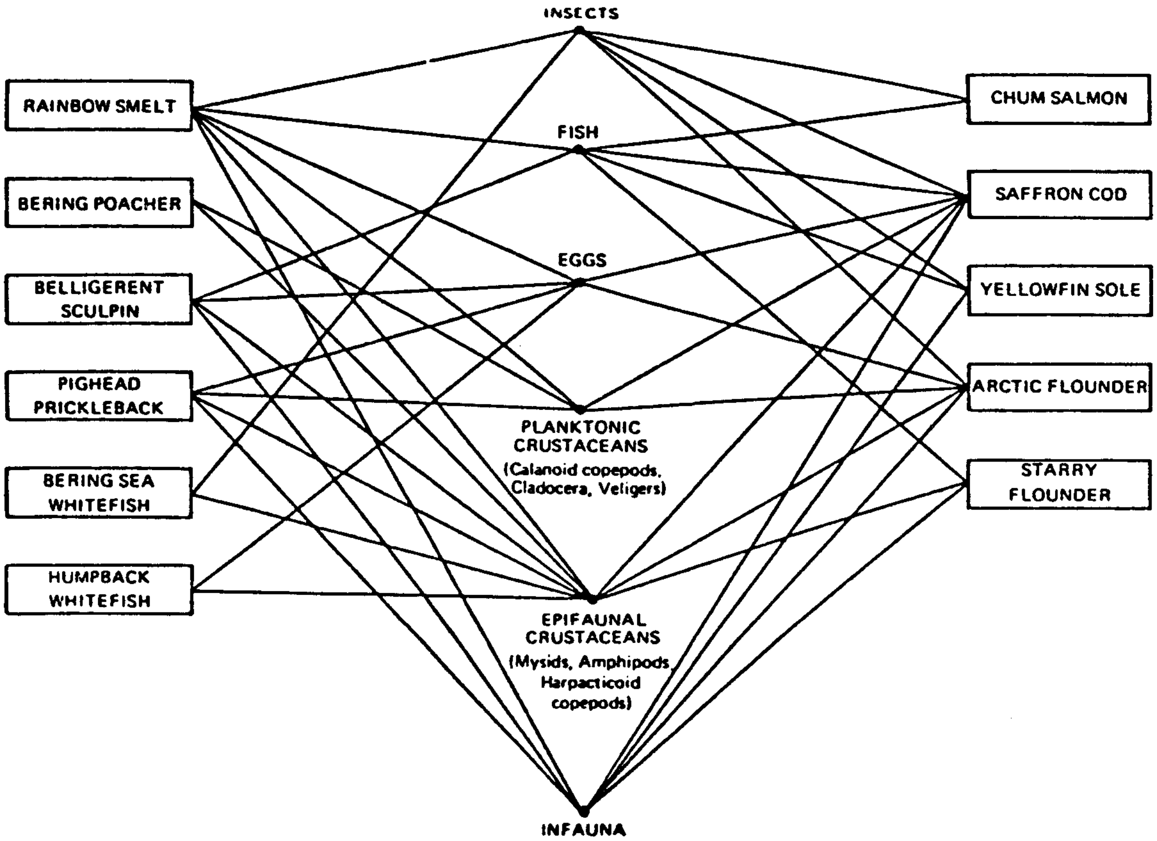

Fig. 5 Prey dependencies for eleven fishes sampled (near shore) in eastern Norton Sound, Alaska (from Neimark et al. 1979).

Many of the fish species (except salmon) inhabiting the lower Yukon River also occur in another large, northern system, the Mackenzie River in the Beaufort Sea. Some findings of fish studies in the Mackenzie Delta probably apply to the Yukon Delta as well and demonstrate some of the complexities of fish use of arctic delta habitats (from Percy 1975):

(1) The outer Mackenzie Delta provides essential habitat for the maintenance of the freshwater, coastal marine and anadromous fish resources in much of the southern Beaufort Sea area. The inshore zone is an important nursery, feeding and overwintering site for both nearshore and offshore species. It is especially important to those anadromous species which form the basis of the domestic and commercial fishery in the delta (broad whitefish, arctic char, arctic cisco, sheefish);

(2) Standing stocks of fish are greatest nearshore since anadromous species tend to remain in shallow coastal waters during summer months rather than move offshore;

(3) Delta channels serve as important migration corridors for anadromous fishes, but fish use of delta channels may differ. Some species tend to migrate through certain channels rather than through the entire delta (also see deGraff and Machniak 1977);

(4) Juveniles of many species, as well as mature fish which spawn in alternate years, reside and feed in delta habitats. Food habit studies suggest that most fish are opportunistic feeders; that is, they eat a variety of foods and will consume whatever is most abundant;

(5) Large turbid lakes in the delta contain substantial fish populations (broad and humpback whitefish, sheefish, least cisco, pike) in summer. Clear lakes are used primarily by lake trout and least cisco;

(6) Delta lakes and channels are used extensively for overwintering by a variety of species. Some anadromous fish may also overwinter in nearshore areas beyond the delta because freshwater discharge from the river continues to influence outer areas even in winter.

Herring

Pacific herring is the most important marine pelagic species in Norton Basin (Burns et al. 1982). It plays an important role in the marine food-web and it is harvested in both commercial and subsistence fisheries. Major population centers for herring are to the south of Norton Sound. Three principal overwintering grounds have been identified in the Bering Sea: northwest of the Pribilof Islands, in the Gulf of Olyutorski and near Cape Navarin (Barton and Wespestad 1980). The relationship of Norton Sound herring and herring to the south is unclear. Some Norton Sound herring may mix with the Pribilof and Navarin stocks and others may remain year-round in Norton Sound (Barton and Wespestad 1980).

Commercial harvests of herring in Norton Sound have occurred since the early 1900's. Annual harvests have been highly variable (from almost nil to over 2000 mt), depending on fish abundance and the availability of markets (Wolotira 1980). The subsistence fishery nearest the Yukon Delta is located at Cape Romanzof (village of Scammon Bay) where 3.52 mt were harvested in 1982. Since 1980 a commercial herring fishery has also operated at Cape Romanzof; its 1982 harvest was 596 mt (Geiger et al. 1982).

The life cycle of herring follows a cyclical pattern of spring spawning in shallow coastal waters, larval and juvenile rearing in shoreline environments, followed by a migration to deeper offshore waters for feeding and maturation. The time when herring spawn in Norton Sound is greatly influenced by climatological conditions, particularly the extent of the Bering Sea ice pack (Barton 1979). In general most spawning occurs immediately after ice breakup in mid-May and continues through June. Barton (1979) notes that these fish remain in nearshore waters both before and after spawning throughout the early spring and summer months. In fall, herring are widely distributed throughout coastal and offshore waters of Norton Sound (Barton 1979, Wolotira et al. 1977).

Although spawning concentrations of herring are greater south of the Yukon River, spawning also occurs at various locations in Norton Sound (Fig. 6). Spawning generally occurs in intertidal or shallow subtidal waters on kelp (*Fucus* sp.) in areas of exposed rocky headlands. Barton (1979) noticed a distinct change in spawning habitats in northern Norton Sound and Kotzebue Sound where the fish spawned on eelgrass (*Zostera* sp.) in shallow bays, inlets or lagoons. The duration of spawning may range from a few days to several weeks.

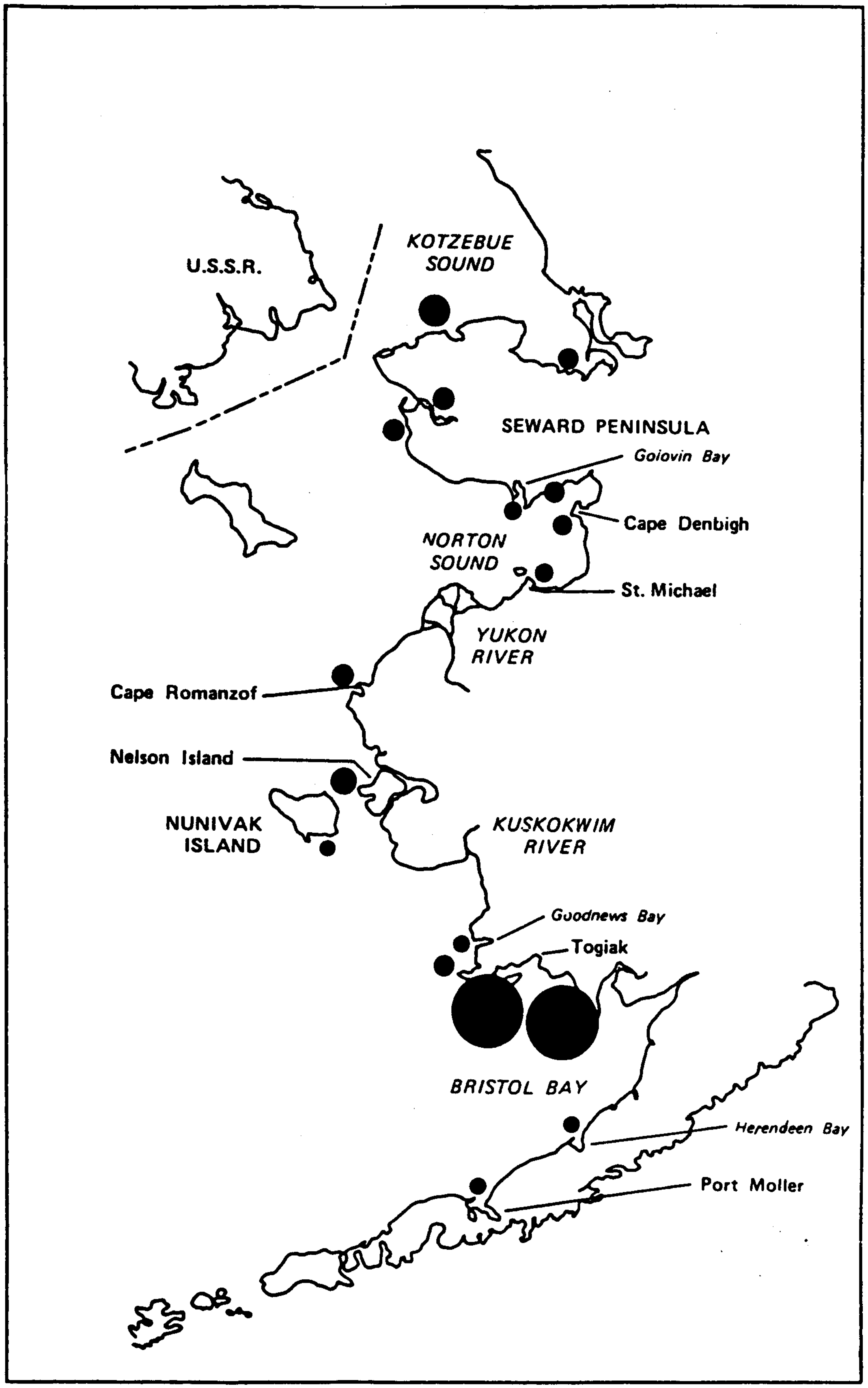

Fig. 6. Distribution of herring biomass in coastal spawning areas (from Barton 1979).

Eggs take 10-21 days to hatch depending on water temperature (Reid 1972). Reid further notes that natural mortality of herring eggs may be very high (50-99%), and mortality of larval herring immediately after hatching may exceed 99%. Studies in British Columbia found that major causes of mortality were wave action, egg exposure to air, and bird predation (Taylor 1964). Barton and Steinhoff (1980) made similar observations of egg mortality in the Yukon-Kuskokwim Delta region. After hatching, tremendous numbers of herring larvae and post larvae may populate coastal surface waters during summer months.

Herring are an important link in the marine foodweb. Barton (1979) found that herring in the Yukon-Kuskokwim Delta area fed mostly upon copepods and barnacle larvae, while herring in Norton Sound ate a variety of invertebrates (Table 4). Hart (1973) summarizes herring trophic relationships as follows. Early herring larval stages feed on invertebrate eggs, copepods and diatoms, and in turn are prey for fish, ctenophores, jellyfish and chaetognaths. Juvenile herring initially consume ostracods, copepods, diatoms and fish larvae; larger juveniles consume mostly planktonic crustaceans such as copepods, amphipods, cladocerans, decapods, barnacle larvae and euphasiids. Adults perfer larger crustaceans and small fishes. The herring adult is in turn eaten by a variety of fish, seabirds, and marine mammals. It has been estimated that 95% of total herring mortality is by predation (Laevastu and Favorite 1978) which might account for wide fluctuations in herring abundance despite seemingly small changes in fishing pressure or environmental factors (Wespestad and Barton 1979).

Table 4. Food items eaten by herring (Barton 1979).

	Yukon-Kuskokwim Delta area		Norton Sound area	
Food Item	Occurrence %	Composition* %	Occurrence %	Composition* %
Mysidacea	25	10	8	2
Copepoda	75	30	67	15
Cladocera			83	19
Cirripedia	50	20	50	11
Cumacea			33	8
Decapoda			25	6
Mollusca			17	4
Annelida			17	4
Platyhelminth	25	10	8	17
Misc. unident.		30		15

* visual estimate

Other Marine Species

The importance of the Yukon Delta environment for marine species is not known. Although marine fishes were virtually absent in Barton's (1979) sampling efforts between Flat Island and Emmonak (Table 3), it is likely that the river's detritus and nutrient input and variety of deltaic habitats contribute to the overall productivity of the region and thus affect the marine fish community. The presence of some marine fishes directly within the delta presumably occurs whenever marine waters intrude into the delta because of tidal changes, meteorological events, or reduced river discharge. Marine and fresh waters may mix resulting in brackish waters or the marine water may extend far into the delta as a subsurface layer of water. In the Mackenzie River delta, Percy (1975) observed that seasonal fluctuations in river discharge affected the distribution and abundance of the fish fauna: marine species normally present beyond the outer delta moved nearer shore with the encroachment of brackish water in fall.

The demersal marine fish resource of Norton Basin is dominated by cods and flatfishes (Table 5) which comprise over 75% of the demersal fish biomass estimated present (Wolotira et al. 1977). Saffron cod and starry flounder are the predominant demersal forms. Saffron cod is by far the most abundant, accounting for nearly one-half the total demersal fish biomass.

Table 5. Estimated biomass and populations of the seven most abundant demersal fish species in Norton Basin (after Wolotira el al. 1977).

Species	Biomass Estimate mt	Population Estimate thousands of fishes
Saffron Cod	16,844 (48)[1/]	763,038
Starry Flounder	4,033 (12)	5,744
Shorthorn Sculpin	3,929 (11)	15,948
Alaska Plaice	1,058 (3)	10,921
Yellowfin Sole	1,235 (4)	30,723
Arctic Cod	660 (2)	38,978
Pollock	87 (-)	5,503

1/ Number in parentheses indicates proportion of total demersal fish biomass.

Saffron cod are found throughout the Norton Basin region during ice-free months. Wolotira et al. (1977) and Barton (1979) found it to be one of the most widely distributed and frequently encountered fish species in nearshore areas during coastal surveys in 1976 and 1977. Highest abundances were found in the Pt. Clarence-Grantly Harbor area and in Golovnin Bay. Offshore concentrations have been located in western Norton Sound out to about the 25 m isobath. The winter distribution of saffron cod in the region is not known, though it appears to be a major food item in the diets of marine mammals occurring near shore-fast ice. Additionally, it is caught by coastal inhabitants through nearshore ice throughout the winter months (Wolotira 1980). Spawning of saffron cod in Norton Sound occurs from late fall to early winter. Larvae have been found in surface waters of Norton Sound in early summer (Barton 1979). This species feeds upon crustaceans (shrimps, amphipods and mysids), polychaete worms, and other fish (Morrow 1980).

The starry flounder is the most abundant flatfish in the Norton Sound region (Wolotira 1980). It comprised about 10% of the total demersal fish biomass estimated for this region in 1976 (Wolotira et al. 1977). Starry flounders occur primarily in shallow water areas, at least during ice-free months (Wolotira 1980). It was found inshore wherever coastal sampling was performed during 1976-1977 and in greatest amounts in Golovnin Bay (see Barton 1979). Offshore concentrations appear to center in the outer portion of Norton Sound. Very few starry flounder have been found in inner Norton Sound. The winter distribution of starry flounders in Norton Basin is not known (Wolotira 1980). Spawning has not been documented for Norton Basin, but in the Gulf of Anadyr in the western Bering Sea, spawning apparently occurs mostly in June (Pertseva-Ostroumova 1960). Principal foods of starry flounders in Norton Sound appear to be clams; echinoderms and sand dollars are also eaten (Feder and Jewett 1981).

Other relatively abundant demersal fish species in the region are short-horn sculpin, yellowfin sole, Alaska plaice, pollock and Arctic cod (Wolotira 1981). Little feeding information on the sculpins is available from the Bering Sea (Feder and Jewett 1981), but based on their known foods elsewhere they probably feed primarily on benthic invertebrates and fish. Existing data suggest that yellowfin sole may feed mainly on mysids and euphausiids in Norton Sound (see Feder and Jewett 1981); plaice on bivalve mollusks, amphipods and polychaetes (Feder and Jewett 1981); pollock on euphausiids, copepods, hyperiid amphipods, and fish (Smith 1981); and arctic cod on copepods and crustaceans (mysids, amphipods) (Feder and Jewett 1981).

Other relatively important pelagic species include Pacific sand lance (which at times is demersal in habit), rainbow (toothed) smelt, and capelin. These are important as forage fish for marine birds, some mammals, and other fish.

Sand lance occurs in a variety of habitats--offshore and nearshore, demersal and mid-water--and is sometimes thought of as a demersal species (Wolotira 1980). It periodically is abundant in nearshore waters of Norton Sound. Sand lance was the most abundant fish captured during nearshore studies in 1977; they were especially abundant in Golovnin Bay and widely distributed in the Port Clarence and Grantly Harbor areas (Wolotira 1980; Barton 1979). Drury et al. (1981) found sand lance to be a major food of kittiwakes and puffins in northern Norton Sound. The reproductive cycle of sand lance in northern waters is not known, but larvae have been encountered in surface waters at several offshore locations in Norton Sound in early summer. Sand lance larvae feed on phytoplankton; adults consume crustaceans, barnacle larvae, copepods and chaetognaths.

Similarly to sand lance, little is known about rainbow smelt and capelin in Norton Sound. Rainbow smelt are anadromous, assembling in shallow water and then migrating upstream in fall. Surveys during summer have found smelt in most of Norton Sound (Wolotira et al. 1977); nearshore surveys have encountered smelt at nearly every location sampled (Barton 1979). Young rainbow smelt feed on mysids and amphipods; older fish are largely piscivorous, consuming cod and other small fish (Macy et al. 1978). Capelin is a marine smelt that spawns in spring in intertidal sandy regions in the southeastern Bering Sea. L. Barton (pers. comm.) observed capelin to be an abundant spawner in the vicinity of Nome and eastward along sand and gravel beaches to Cape Nome. It feeds on fish and small crustaceans including copepods, euphausiids, amphipods, and decapod larvae (Macy et al. 1978).

Lower Trophic Levels

Lower trophic levels are important for several reasons. A few species in the invertebrate community (e.g. king crabs) are harvested for food. Most of the vertebrates valued by humans are dependent on some invertebrates for food. At a lower level, carbon and nutrients are the base of the vertebrate food web , and perturbations at these levels may be felt at the higher levels that are of more direct concern to people.

Invertebrates Used by Humans

The red king crab (Paralithodes camtschatica) is the only invertebrate species significantly utilized by people in Norton Sound. It is probably the extreme northernmost red king crab population that will sustain a commercial fishery (Powell et al. 1983). A total of 3,781 mt of male red king crabs was harvested commercially from Norton Sound during the period 1977-1982. The largest known annual subsistence harvest is 22.7 mt.

The red king crab's major center of abundance and harvest is in the southeastern Bering Sea, in Bristol Bay and immediately north of the Alaska Peninsula (Feder and Jewett 1981). The population in Norton Sound is relatively small and is centered in the northwestern part of the sound south and east of Sledge Island (Wolotira et al. 1977; Powell et al. 1983).

The distribution of red king crabs generally approximates an area deeper than about 15 m that extends in an east-west direction in northern Norton Sound. There appears to be a seaward (southwesterly) migration of at least adult males in early summer and a return northeastward migration during fall (Powell et al. 1983).

Major foods for adult red king crabs include bivalve molluscs, polychaetes, echinoderms, and crustaceans (Feder and Jewett 1978a, 1981). Post-larval crabs also eat benthic foods--diatoms, copepods, ostracods, and other small organisms that have presumably settled from the water column, plus other detrital materials.

The relatively small size of adult king crabs in Norton Sound and the proximity of Norton Sound to the northern distributional limits of this species has suggested to some that low water temperatures there may be an important physical constraint to crab populations (see Feder and Jewett 1981; Powell et al. 1983). Additionally it appears that water depth is an important consideration; crabs in Norton Sound are found in the relatively deep waters. Water temperature and depth constraints, possible competition for food by the abundant sea stars, and commercial and subsistence harvest (Powell et al. 1983) may all have effects in regulating the distribution and population levels of red king crabs in Norton Sound.

Invertebrate Communities

For convenience in discussion, we will classify invertebrate communities in the Yukon Delta region as terrestrial/freshwater; estuarine, and marine. Terrestrial/freshwater communities are defined as those that occur in terrestrial environments and in ponds, lakes and streams not normally influenced by intrusions of marine water. Estuarine communities we define to occur in waters of the delta region that are measurably brackish at times when the biota under discussion use them; they would thus extend several tens of kilometers upstream of and to sea from the delta coast. Marine communities are those that have developed under an essentially marine hydrographic regime, though brackish water may occasionally impinge upon them.

Terrestrial/freshwater forms are mostly insects, their macrobenthic larval forms, and crustaceans. Estuarine communities are relatively rich in euryhaline, mobile zooplankton and epibenthos and are probably poor in infauna. Benthic forms dominate the biomass of marine areas.

Little work has been done on terrestrial and freshwater invertebrates in the Yukon Delta region. The most numerous and ubiquitous terrestrial invertebrates are dipterans, mostly mosquitoes (Jones and Kirchhoff 1978). Dipteran larvae (especially chironomids) are the most numerous benthic invertebrates in Alaskan tundra ponds and streams near Pt. Thompson (Chukchi Sea) and ponds near Barrow (Watson et al. 1966; Butler et al. 1980), and presumably are abundant in Yukon Delta aquatic habitats as well. Based on findings in Cape Thompson ponds, we may assume that benthic forms in the Yukon Delta might also include Trichoptera larvae, Plecoptera larvae, Ostracoda, Isopoda, Amphipoda, Conchostraca, Oligochaeta, and Nematoda in ponds; and Ephemeroptera larvae, Plecoptera larvae, turbellarians and relatively low numbers of crustaceans in streams (see Watson et al. 1966). Zooplankters in ponds are probably dominated by crustaceans and include calanoid and cyclopoid copepods, rotifers and cladocerans (see Watson et al. 1966; Butler et al. 1980).

No intensive studies of the estuarine invertebrate community in the vicinity of the Yukon River delta have been made. Almost nothing is known of the invertebrates that occur in the delta distributary channels and the adjacent, submerged delta front. One might suspect that they would be typically euryhaline and perhaps the same species that occur in other coastal, brackish waters of Norton Sound. Neimark et al. (1979) found the coastal waters in extreme eastern Norton Sound (which he believed were freshened appreciably by Yukon River water) to contain zooplankton species adapted to widely-ranging temperatures and salinities. The major groups he found there were cladocerans and copepods (particularly calanoid copepods). His sampling techniques were unsuitable for capturing epibenthic or benthic species, but he found fish in these coastal waters to feed heavily on epibenthic Neomysis (N. rayii, N. czerniawskii, N. mirabilis) and to some extent on benthic oligochaetes, polychaetes, bivalves, and insect larvae (Neimark et al. 1979), suggesting these invertebrates to be common estuarine inhabitants. Virtually no epifaunal or infaunal sampling has been done in the estuarine environments of the delta region or in shallow coastal waters anywhere in Norton Sound. It may be assumed that, in waters less than a few meters deep, infaunal populations are sparse because of ice action on the substrate, and, in fact, Nelson et al. (1981) found bioturbation of the substrate to occur at very low intensities on the Yukon Delta platform. However, observations of scoter concentrations in shallow waters off the delta (C. P. Dau, unpubl. data) suggest that infauna, on which scoters commonly feed, may be more abundant than presumed.

Kirchhoff (1978) is one of the few investigators who has sampled invertebrates in the Yukon Delta estuary. He found the very shallow mudflat areas (<1 m deep) just off the delta coast to contain many individuals of the mysid Neomysis intermedia and the isopod Saduria entomon shortly after the disappearance of shorefast ice in early June. Neomysis was especially abundant later in the summer.

The invertebrates of the Norton Sound marine waters that are influenced by the Yukon River discharge have been more thoroughly investigated. The most data are available for epifauna; less information is available for zooplankton and infauna.

Feder and Jewett (1978a, b) found that echinoderms, principally sea stars, dominated the epifaunal invertebrate biomass (80% of total) of Norton Sound. These authors attributed the absence of large biomasses of arthropods (crustacea) such as are found in the southeastern Bering Sea to temperature barriers (i.e. bottom waters of Norton Sound remain considerably colder in summer than do those farther south in the Bering Sea). Other relatively important epibenthic organisms these authors found were snow crabs, king crabs, and crangonid shrimps.

No extensive surveys of infauna have been made in Norton Sound (Feder and Jewett 1981). But based on the known food habits of benthic predators (see stars, crabs, flounders) in Norton Sound, Feder and Jewett (1981) assume that bivalve molluscs, particularly clams, form a large portion of the infaunal biomass. Moreover, benthic grab samples taken by Feder and Mueller (1974) just south of Nome in Norton Sound show relatively high biomass levels of clams in comparison to other infaunal groups.

The zooplankton of Norton Sound, and indeed of the entire Bering Sea, is dominated in terms of biomass and productivity by copepods (Cooney 1981; Neimark et al.1979). Norton Sound, and other inner shelf domains of the Bering Sea, appear to have mostly relatively small herbivorous and omnivorous copepods (Cooney 1981). Most are thought to be inefficient grazers of the phytoplankton community. Outer shelf regions, are reported to have larger copepods that consume larger proportions of the annual primary production.

Carbon and Nutrient Sources

Carbon sources in freshwater and terrestrial ecosystems are primarily terrestrial and emergent grasses, sedges, and shrubs. Secondarily, algal production in ponds contributes to the total primary production (see Hobbie 1980). Nutrient sources are frequently from local substrates but many of the ponds and other low-lying wetlands are occasionally inundated by river floodwater and/or tidal storm-surge flooding from the sea. The relative importance of nutrients introduced by flooding has not been evaluated, but is presumably high in many cases.

In estuarine and marine habitats, the carbon sources (via primary production) and nutrient supplies to lower trophic levels are strongly influenced by two phenomena--the domination of Norton Sound by Alaska coastal water (to be discussed later) and the discharge of the Yukon River. Each water mass brings to the region major supplies of nutrients and fixed carbon.

The major nutrient supply to the outer and middle shelf ecosystems of the Bering Sea appears to be injected annually by the intrusion of near-bottom North Pacific water along the continental shelf slope (Coachman and Walsh 1981; Coachman and Takenouti 1975). The onshore flux of these nutrients to the inner shelf region (including the Yukon Delta region) appears to be slow; the slope nutrients do not appear to penetrate rapidly past the tidal mixing front (McRoy et al. 1983). But the actual extent to which nutrients and carbon from the North Pacific waters reach the Yukon Delta region is not known.

An obvious source of nutrients and carbon to the Yukon Delta region is from river discharge. The largest proportion of this supply presumably comes from the Yukon River itself, but a lesser amount undoubtedly is carried into the region by the Alaska coastal current that moves northward along the east coast of the Bering Sea.

McRoy et al. (1983) present a hypothetical picture of nutrient and carbon supply to the western Norton Sound region and beyond to the northwest. In winter (January to April) diffusive resupply of nutrients beneath the ice from middle and outer shelf regions, coupled with lack of phytoplankton uptake, leads to increasing nitrate concentrations in extreme western Norton Sound. The spring plankton bloom quickly depletes this supply. Then, during summer and fall, southerly winds lead to a downwelling near shore that curtails inputs of nutrients from the shelf-break.

At the same time that shelf-break nutrients are depleted (early summer), the Yukon River sends its major annual pulse of nitrates into western Norton Sound. By July, this riverine nutrient supply apparently diminishes, and *in situ* regeneration of nutrients dominates therafter until fall.

McRoy et al. (1983) postulate that, since organic carbon is co-transported with fine-grain sediments, carbon fixation by phytoplankton production entrained within the Alaskan coastal jet may not significantly enter demersal environments south of Bering Strait. But they show that carbon levels appear to be enhanced in benthic environments immediately to the north, east, and west of the Yukon Delta. Presumably this is caused by deposition of terrigenous carbon from Yukon discharge. A quantitative appraisal of nutrient and carbon sources and fates in the Yukon Delta region remains to be made.

Important Food Webs

Food webs that support important vertebrates and invertebrates in the Yukon Delta region are separated for discussion into terrestrial/freshwater, estuarine, and marine components. Similarly to discussions under the previous section "Lower Trophic Levels," these are defined as follows:

Terrestrial/Freshwater - Food webs typical of terrestrial environments (including plants in intertidal zones) and aquatic environments not normally influenced by marine water.

Estuarine - Feeding interactions in waters measurably brackish when the biota under discussion use them. These waters extend as far as several tens of kilometers offshore and upstream from the delta coast, and include fauna in unvegetated intertidal zones.

Marine - Trophic linkages in areas typically dominated by marine waters.

Terrestrial/Freshwater Food Web

Important vertebrate constituents of terrestrial and freshwater systems on the Yukon Delta are primarily birds. There are freshwater fishes (pike, burbot, grayling, etc.) in the area of study, but they appear to be of minor importance compared to the birds and to those fishes we have called "estuarine", which includes fish in all the Yukon Delta distributaries (see definition above and the following section on the "Estuarine Food Webs").

Abundant birds use the area almost exclusively from May through September. A generalized food web of important birds is shown in Figure 7. Food webs of birds that feed in Yukon Delta terrestrial or freshwater habitats are short and simple. Most consume vegetation--aquatic, emergent and terrestrial plants--directly without intermediate faunal links.

Pintails (and additional dabbling ducks not shown such as mallard, widgeon and green-winged teal) may feed in the edges of the estuarine habitat in the mud-flat and clear-water fringes of the coast on *Potamogeton*. In addition some feed farther inland in the vegetated intertidal zones and in the shallows of ponds and lakes. Sedge and grass seeds are important in these vegetated intertidal areas (Kirchhoff 1978). Pintails also feed on epibenthic invertebrates in the intertidal zone and farther seaward (see "Estuarine Food Webs" below).

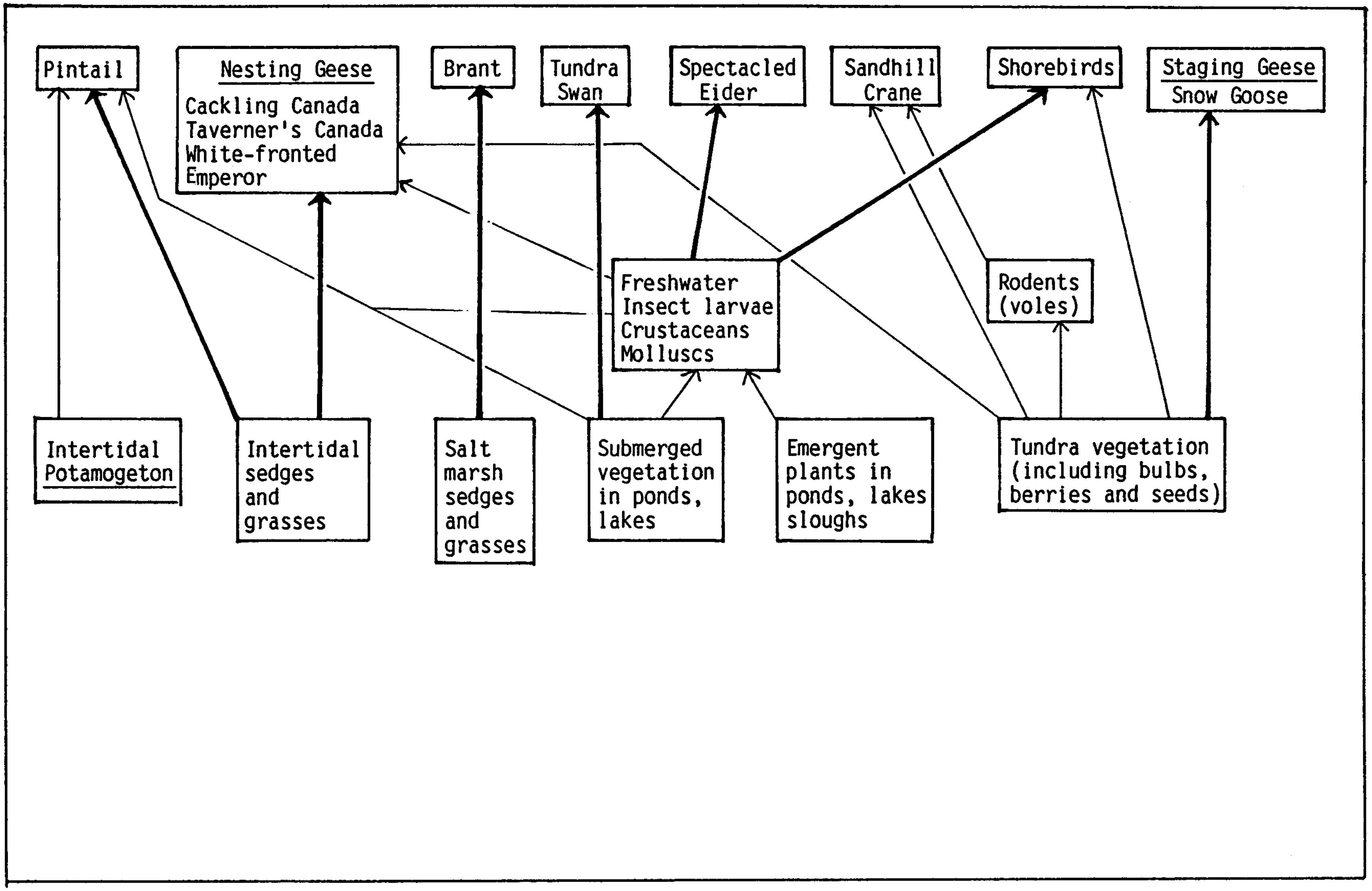

Fig. 7. Generalized terrestrial/freshwater food web of important species on the Yukon Delta, Alaska. Arbitrarily included is multicellular vegetation in intertidal zones and tidal flats. Fauna in areas influenced by salt water is not included.

Nesting geese (cackling and Taverner's Canada geese, white-fronted goose, emperor goose) feed primarily on sedges and grasses in vegetated intertidal areas (including stream and slough margins subject to tidal inundation). They also feed to some extent on tundra vegetation outside the intertidal zone, but the intertidal vegetation appears to be most important.

Brant feed almost exclusively on sedges and grasses in terrestrial sites commonly inundated by brackish water (salt marsh habitats of the vegetated intertidal zone).

Tundra swans, spectacled eiders, some nesting shorebirds, and sandhill cranes (to some extent) base their food chains on submerged and emergent vegetation in freshwater ponds, lakes and sloughs. Swans consume vegetation directly; eiders, cranes, and shorebirds eat invertebrates that consume plant detritus.

Tundra vegetation, frequently as berries, tubers, or seeds, provides important forage for staging snow geese, nesting geese of several species, some nesting and staging shorebirds (e.g. bristle-thighed curlew, rock sandpipers), and sandhill cranes. This vegetation provides the greatest use in late summer and early fall when geese, cranes and some shorebirds feed on berries.

Sandhill cranes are probably the most omnivorous in their diets of any of the abundant bird species. Foods commonly range from sedge tubers to berries to invertebrates to small rodents.

Estuarine Food Web

The estuarine food web, which we have defined as aquatic environments seaward to the limit of major influence of Yukon River water and inland to the extent of salt-water influence, is much more complex than terrestrial food webs. Many vertebrates, including mammals, birds and fishes, find important feeding habitat there. The prey base is varied, and the carbon sources are unclear (Fig. 8).

Most vertebrates--marine mammals, birds, salmon, marine fishes--use the area primarily or exclusively during the open-water period, May to November. A few--mainly some of the non-salmonid anadromous fishes--may in addition to feeding in the estuary in summer, overwinter there (and presumably feed there in winter). It is unclear whether the main prey base

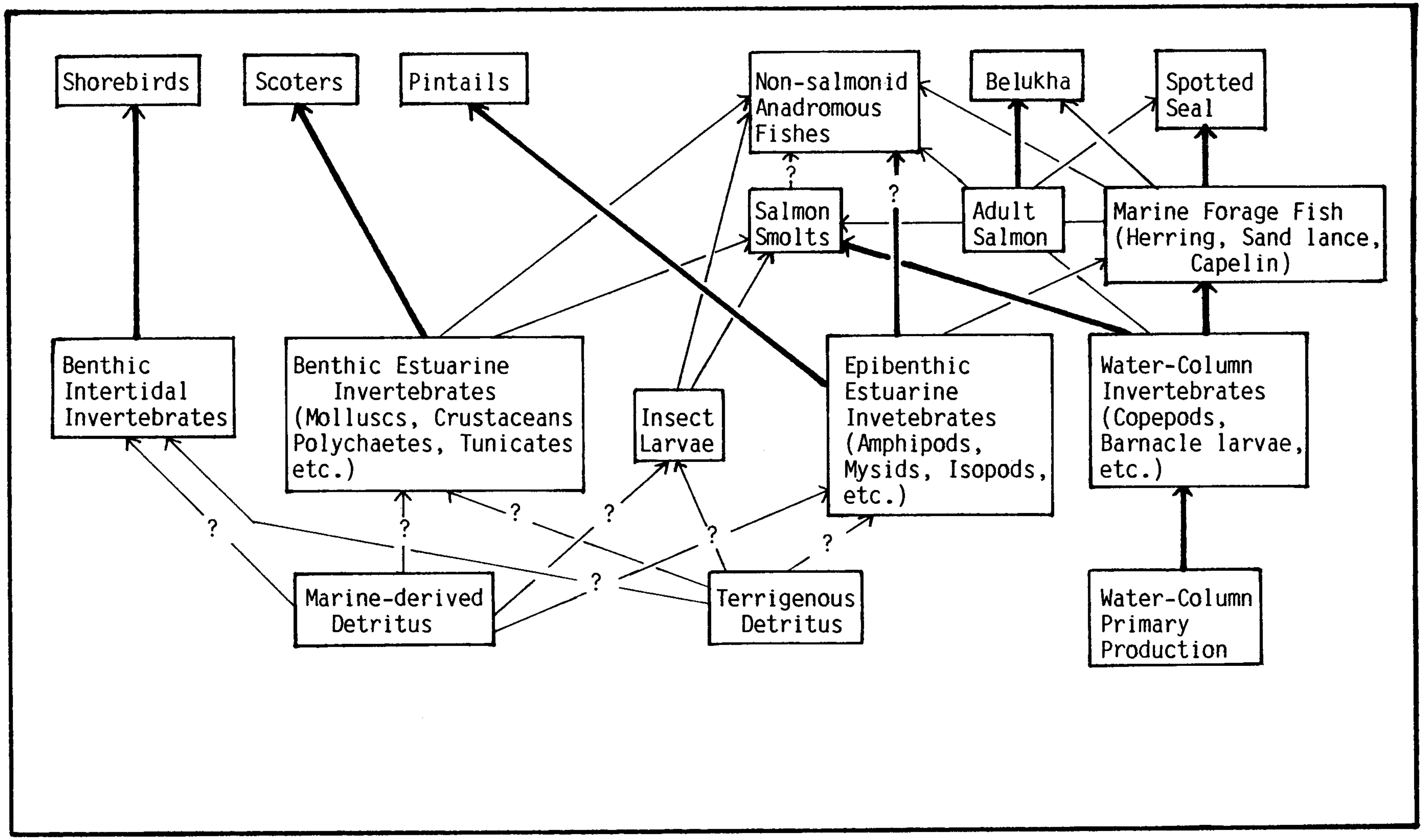

Fig. 8. Generalized estuarine food web of important species in the vicinity of the Yukon Delta, Alaska. Note that "estuarine" habitat extends several tens of kilometers seaward of the delta coast and inland up river distributaries. (Arrow widths represent relative importance of food sources to consumers; (?) represents major uncertainties.

is there year round or only seasonally, but in some cases (e.g. when prey is epibenthic and water-column invertebrates) it seems that seasonal invasion by the prey of parts of the estuary that are ice-bound in winter may be required.

The estuarine food web seems to have two major bases--primary production in the water column and benthic detritus. Further, benthic detritus may be derived either from land and introduced by river flow (terrigenous) or come from marine production as settling plankton, or (more likely) both. A discussion of the potential sources of carbon (and nutrients) appears in the preceding section "Lower Trophic Levels." There is almost no information available to indicate which source of detritus is most important.

The birds that feed in estuarine habitats appear to depend on a detritus-driven food chain. Shorebirds feed mainly on benthic (primarily intertidal) invertebrates. Diving ducks (primarily scoters but also oldsquaws, scaup, and others) likewise depend on benthic (perhaps epibenthic in some cases) invertebrates as food, but the large numbers of pintails that use the zone immediately seaward of the delta coast use primarily epibenthos. In all cases the food base for these invertebrates is presumably detrital.

Non-salmonid anadromous fishes (ciscoes, whitefishes, sheefish, etc.) probably feed largely on epibenthic crustaceans and benthic invertebrates, if we may rely on data from other areas. Thus we would expect their food-chains to be mainly detritus-based. But almost no data exist on their food habits in the delta estuary, so this conclusion is highly speculative.

Salmon probably do not feed extensively in the estuary as adults, but probably spend a few weeks to months there as actively-feeding juveniles after they come down the Yukon River from spawning sites upstream. Data from elsewhere suggest that these juveniles probably feed primarily on water-column invertebrates (copepods, barnacle larvae) and secondarily on detrital-feeding benthos while they are in the estuarine habitat. But again, no data are available from local studies and our conclusions must be tentative.

Marine mammals that feed in the estuarine habitat (mainly belukhas and spotted seals) eat adult salmon, non-salmonid anadromous fishes, and marine forage fish (herring, sand lance, capelin). The primary food base for the other anadromous fishes is probably mainly benthic and epibenthic, as we have seen. The main food base for the marine fish is probably pelagic.

Marine Food Web

The marine food web that has potential to be significantly affected by Yukon River discharge has marine mammals and marine fishes as its major top consumers (Fig. 9). Some top consumers--starry flounder, saffron cod, red king crab--and most of the invertebrate prey species are present in abundance year-round. Most vertebrate consumers--gray whale; belukha; bearded, ringed and spotted seal; many of the fishes--are only seasonally abundant. More on-site data on food chains are available from the marine system than from either the estuarine or terrestrial systems discussed above.

Similarly to the estuarine food web, there appear to be two major carbon sources--pelagic from marine primary production and benthic from a combination of marine and terrigenous detritus. Also similarly to the estuarine system the relative abundance of detritus that is available to the food chain from each source (terrigenous, marine) is not known.

Two marine mammals--gray whale and bearded seal--are obviously linked directly to the benthic detrital system by their benthic prey. They feed in the deeper marine waters in western Norton Sound; much greater populations of both species, and presumably better food supplies, exist beyond the study area to the north and west.

The one invertebrate of extensive commercial and subsistence use--the red king crab--is likewise a benthos feeder. Like gray whales and bearded seals, it has larger populations elsewhere--in the southeastern Bering Sea.

The third group of benthos-dependent consumers is the demersal, benthic-feeding fish populations (starry flounder, Alaska plaice, saffron and arctic cod, shorthorn sculpin, yellowfin sole) and the marine mammals (belukha, ringed seal) that consume benthic-feeding fishes. Flounder and plaice share bivalves and other sedentary benthos with the king crabs and the bearded seals. But it appears that cod, sculpin and sole, on which belukha and ringed seal feed, are more dependent on relatively mobile, epibenthic invertebrates (mysids, amphipods, shrimps, etc.).

From available data it seems that the marine "forage fish" species-herring, sand lance, capelin, smelt and pollock--feed mainly on water-column zooplankton (copepods, mysids, amphipods, barnacle larvae, etc.) and fish. Thus they are dependent primarily on a marine primary production carbon base, which in turn is fueled by nutrients from probably two main sources--

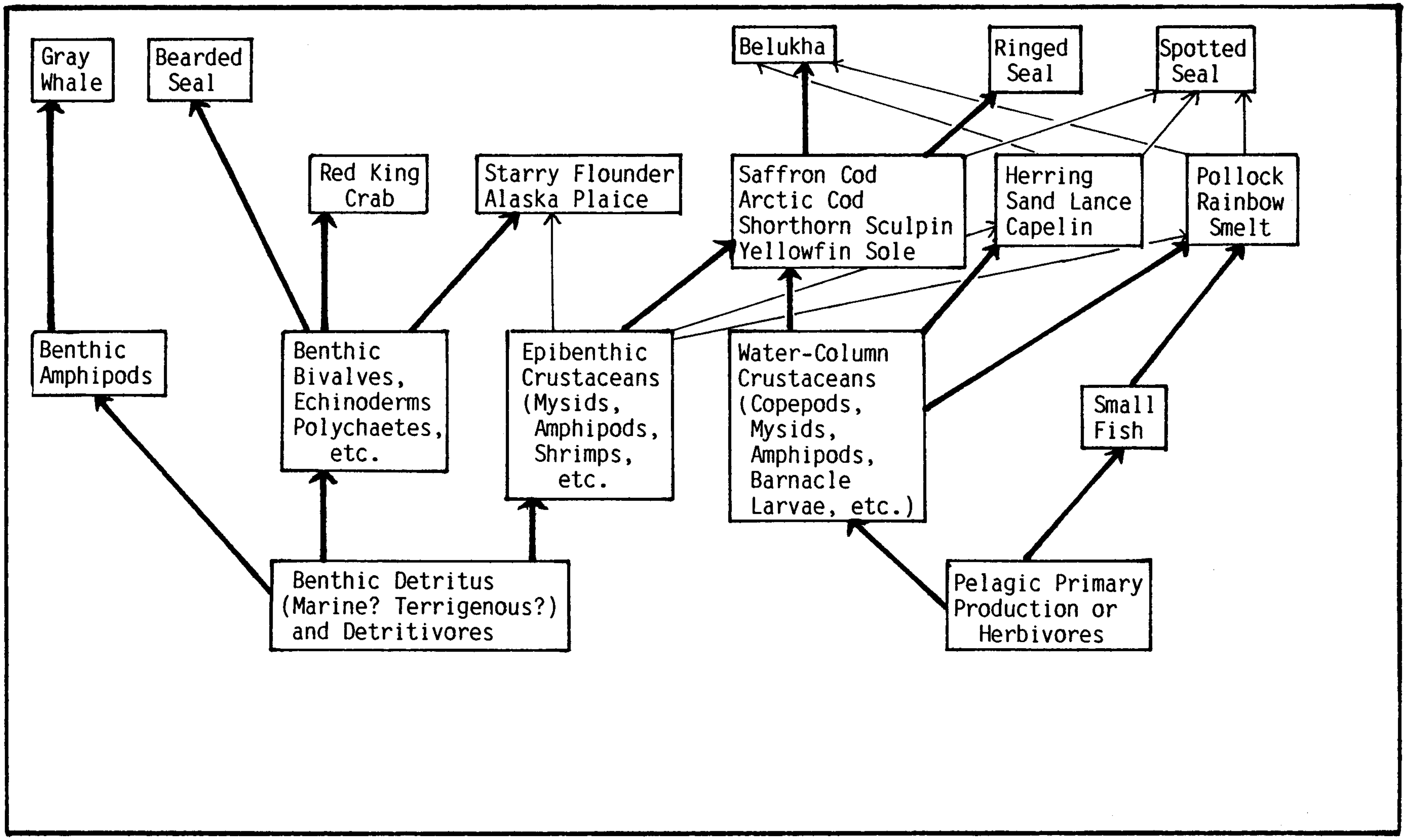

Fig. 9. Generalized marine food-web of important species in Norton Sound, Alaska, whose food chains are judged to be potentially affected by Yukon River discharge. Many important consumers in Norton Sound (e.g., cliff-nesting seabirds) are not included because we judge that Yukon River discharge is relatively unimportant to them. (Arrow widths represent relative importance of food sources to consumers.)

the outer continental shelf and the Yukon River. Belukha and spotted seal apparently depend to some extent on these forage fish and thus on this pelagic food web.

Summary

In summary, the terrestrial/freshwater food web is short and is fueled directly from terrigenous sources, but both estuarine and marine food webs have two separate sources of nutrients and carbon. These sources are the Yukon River (which discharges nutrients and detrital carbon into the estuarine and marine environments) and the marine nutrients (which are advected into the region from the southern Bering Sea and farther south) and carbon (fixed by *in situ* primary production).

In both estuarine and marine environments, benthic detritus supports a great diversity and biomass of invertebrates and vertebrates of interest to man. Whether the major source of this detritus is terrigenous or pelagic cannot be determined from existing data. Likewise, neither is it evident whether the pelagic primary production from which much of the marine detritus is obviously derived is driven by nutrients from land (Yukon discharge) or from sea (outer shelf nutrients).

In the estuarine environment, and especially in the marine system, pelagic primary production also supports a large and diverse food web. But the standing stock biomass thereby produced is probably smaller per unit area than the biomass produced from detritus. It seems probable that, in comparison to the detrital food web, a smaller proportion of the pelagic food web depends on Yukon River discharge (via river introduction of nutrients). But no data exist to support any of these conjectures.

PHYSICAL PROCESSES AND COMPONENTS

This section describes the geology, ice, hydrography, transport (of sediment and oil) and environmental hazards in the study area. Emphasis is on those processes and components that influence the biota discussed in the preceding sections, that would influence biota in the event of an oil spill, or that would cause spills.

Geology

The emergent portion of the Yukon Delta is a depositional plain that has built rapidly seaward into Norton Sound since the sea level reached its present stand about 5,000 to 6,000 year ago (Nelson and Creagor 1977). It is bordered to the landward by higher-elevation non-deltaic sediments and to the seaward by a rapidly prograding delta front (Dupre 1980). It extends beyond the delta coast as a shallow sea platform (Fig. 10). The topography and bathymetry in the vicinity of the delta and the substrate characteristics in depositional environments reflect the dynamic nature of the geologic processes occurring in the area.

Topography and Bathymetry. The emergent portion of the Yukon River delta is a gently sloping plain with active and abandoned distributary channels and channel bars, natural levees, interdistributary marshes, and lakes (Dupre 1980). The increase in elevation as one moves inland from the coast is on the order of .2 m/km for 50 to 80 km inland (slope of about 1:5000) (Fig. 11). The delta is fan-shaped; the highest ground is more or less centrally located with a radial slope toward the coast (Jones and Kirchhoff 1977).

Seaward of the emergent edge of the delta, slightly less gentle slopes (1:1000 or less) persist, such that water (or ice in winter) is typically shallow (up to 3 m) as far out as 30 km (Dupre 1980) (Fig. 10). Beyond this gently sloping sub-ice platform is the delta front (Dupre 1980), which is steeper (slopes typically greater than 1:5000); water depths along the

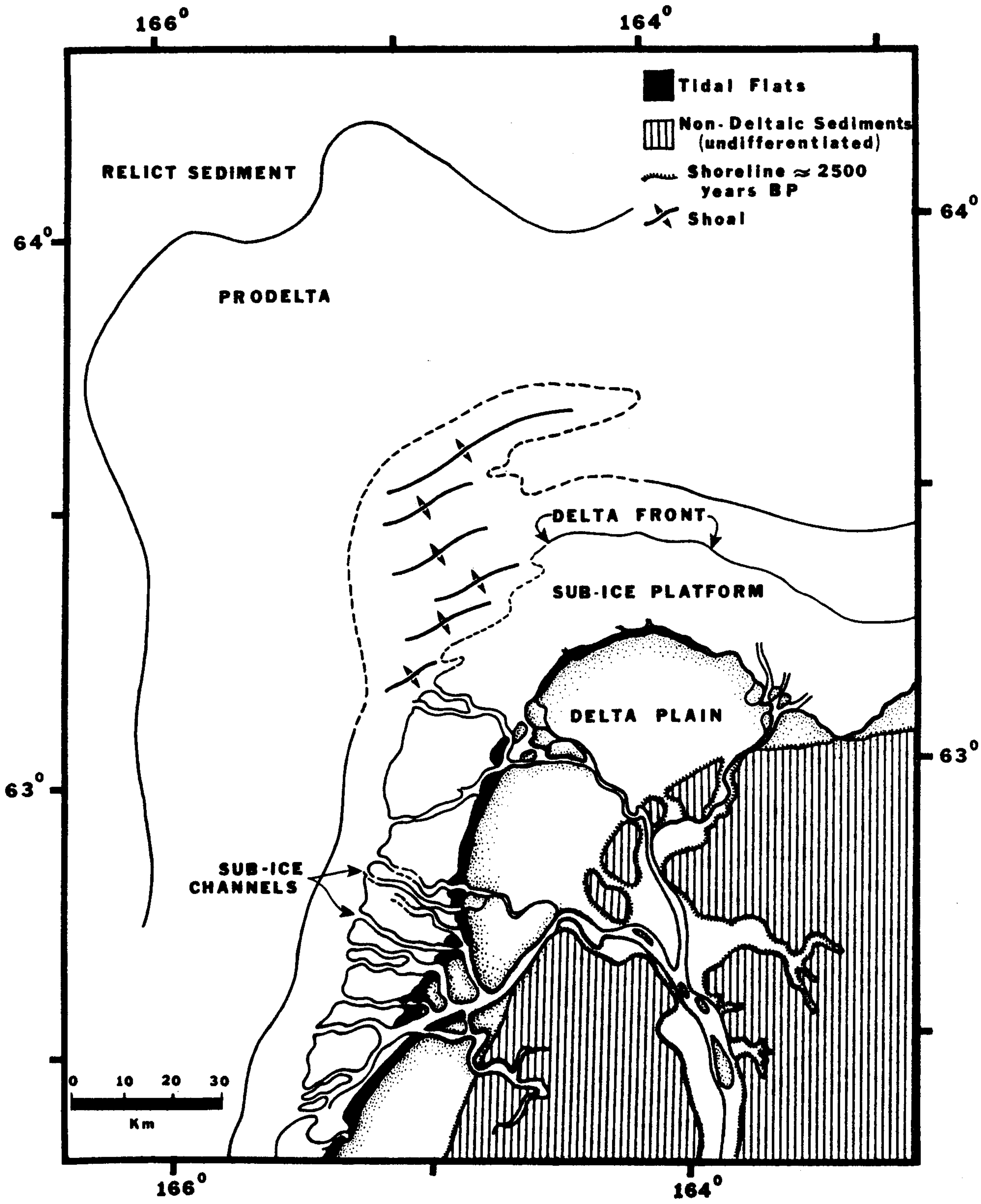

Fig. 10. Emergent and submerged geological features of the Yukon River Delta, Alaska (from Dupré 1980).

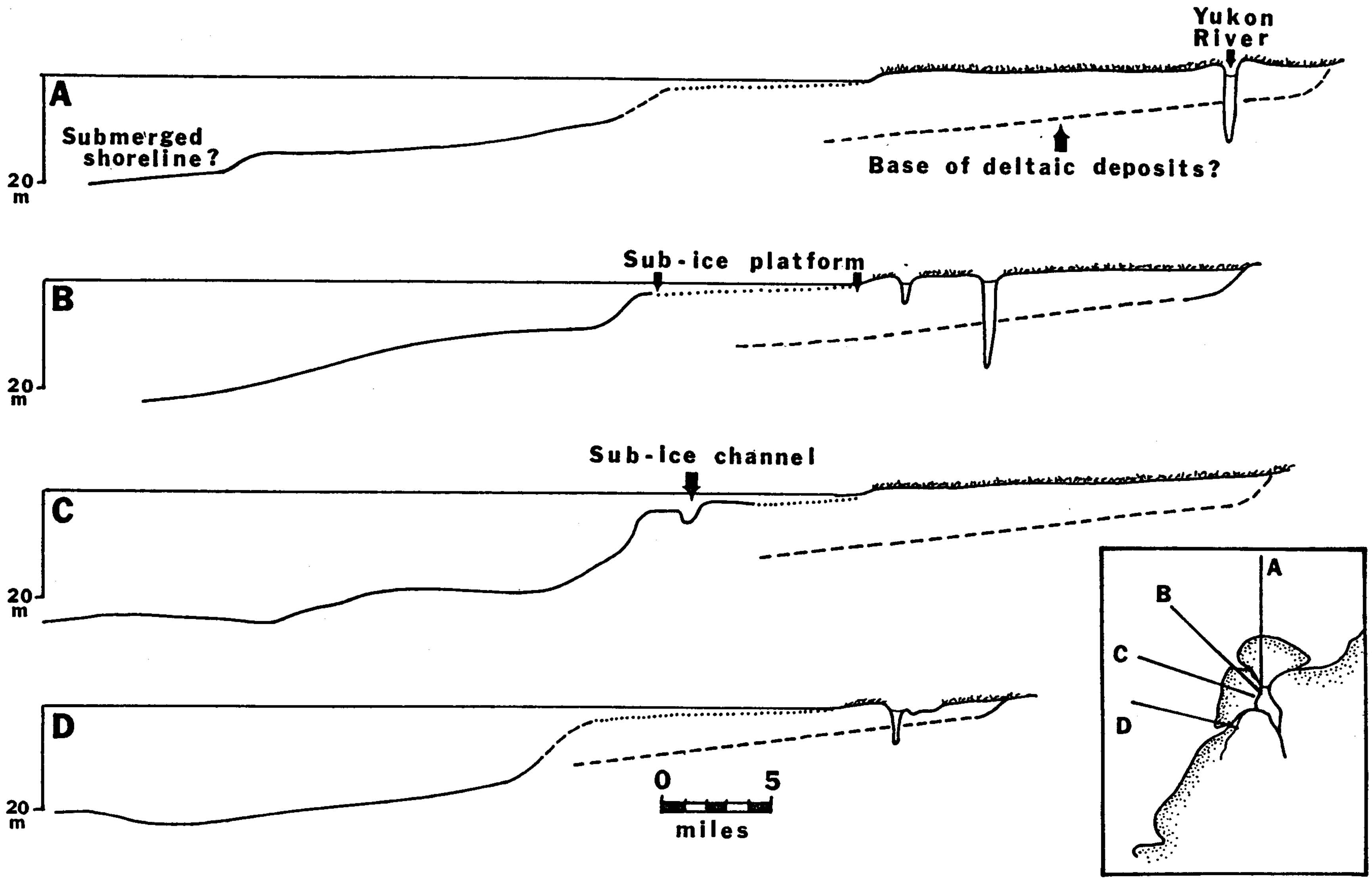

Fig. 11. Selected profiles through the Yukon Delta (from C & GS Chart 9370, after Dupré 1980).

delta front increase from about 3 to 14 m. Beyond the delta front is the prodelta, which has more gentle slopes than the front (typically 1:2000); the prodelta extends up to 100 km offshore, to the distal edge of the deltaic sediments (Dupré 1980).

Both the emergent and submerged (delta platform) portions of the delta contain major distributary channels that carry Yukon River discharge. These are readily visible on land. Each major pass (Kwikluak, Kawanak, Apoon, etc.) tends to subdivide into two or more channels as it nears the coast. Not so obviously, these channels continue as offshore subsea extensions (Fig. 10). The subaqueous channels are typically .5 to 1 km wide, 5-15 m deep, and extend up to 20 km beyond the shoreline (Dupré 1980).

Substrate Characteristics. Substrates on both the emergent and submerged portions of the delta are depositional, less than about 2500 years old (Dupré 1980). Permafrost appears to be present though discontinuous and relatively thin (2-3 m) in many areas of the delta region except perhaps along large streams and rapidly prograding coastlines (Dupre 1978). Permafrost is almost certainly non-existent, or thin and discontinuous, in subsea delta sediments (Dupré 1980). Pingos occur occasionally in the delta plain (Burns 1964).

The emergent portion of the delta contains assortments of sands, silts and clays in substrates. River channel and bar deposits are typically well-sorted sand and silty sand. Upwards and laterally from stream courses, organic matter and smaller particle sizes of sediments predominate. Poorly sorted silt, mud, and organic detritus are common on natural levees, meander swales, and other between-distributary environments.

At the margin of the emergent delta, tidal flats typically extend 100 to 1000 m offshore. The substrates of the flats range from poorly sorted sandy silts in low-energy environments (e.g. on the northern side of the delta) to moderately- and poorly-sorted silty sand in areas of higher wave energy (such as on the western side of the delta). The tidal flat deposits are generally finer, contain larger amounts of organic detritus, and are subject to more extensive bioturbation in their top few centimeters than are environments farther seaward (Dupré and Thompson 1979).

Seaward of the tidal flats, the subaqueous delta platform sediments appear to be characterized by an offshore increase in the percent of sand, unlike the nearshore sediments of most deltas (Dupré and Thompson 1979). This increase may be caused by the relatively high wave energy to which deeper portions of the platform are exposed. (The shallowness of nearshore areas diminishes wave energies.) Beyond the delta platform, the relatively steeply sloping delta front appears to contain higher amounts of silt, as does the prodelta beyond that. Clays are relatively uncommon in all subaqueous portions of the delta, in part because of their relative scarcity in Yukon River discharge and in part because of their bypassing the region to be deposited north of the Bering Straits in the Chukchi Sea (Nelson and Creager 1977; Dupré 1978).

Dynamic Processes. In general the modern Yukon River delta is a rapidly building system. It is a relatively young geologic feature, having formed since approximately 2500 years ago, when the river course shifted to where it presently enters Norton Sound (Dupré and Thompson 1979). It is a product of deposition of sediment from the Yukon River.

The emergent delta plain contains distributaries radiating fan-like from the farthest inland points on the delta. The distributaries frequently shift their courses because ice jams channel waters and refocus flow somewhat differently during each spring flood. Active channels may be closed off and abandoned channels reopened by this flooding (Dupré and Thompson 1979).

The delta plain is fringed by rapidly prograding tidal flats and distributary mouth bars (Dupré and Thompson 1979). Rates of shoreline progradation may locally be up to 50 m/yr (Dupré 1980). The platform seaward of the coast is also building from deposition, as is the delta front beyond the platform. The progradation and deposition at the delta front may be caused by both river discharge and storm-induced reworking of sediments (Dupré 1980).

Storm surge and ice annually rework the subsea and shoreline portions of the delta. Locally the shoreline is eroded, although the delta is generally a prograding one. Jones and Kirchhoff (1977) noted that extreme eastern portions of the delta coast were erosional, and that more westerly portions were depositional. Dupré (1980) also noted that western parts of the delta appeared to be prograding rapidly.

Ice Regimes

Ice is a dominant force in the physical environment of the Yukon Delta region. The ice-dominated regimen begins with ice formation in October and lasts to spring breakup in May. Freezeup begins as temperatures drop in early fall and ice starts to accumulate around the delta. In winter, strong northerly winds cause ice to converge along the northern delta front; ice ridging and associated gouging of the bottom result. In May, warming temperatures melt ice from river channels, and winds shift to predominantly southerly. Offshore winds and river overflow caused by melting ice and snow trigger ice breakup; ice is then quickly carried away from the delta front. The following details of the ice regime are from Dupré (1980).

Freezeup. Ice typically begins to form along the shore in late October, as coastal temperatures drop below 0° C. Bottomfast ice soon forms on intertidal mudflats and subaqueous levees; smaller sub-ice channels begin to be covered by floating shorefast ice. Larger sub-ice channels, which are extensions of the main distributaries, continue to maintain a channelized flow of fresh water, and are the last of the nearshore areas to be covered with ice.

Shorefast ice expands farther offshore in November until it reaches its maximum width of 15 to 60 km; its outer limits approximate the outer boundary of the shallow sub-ice delta platform (see Fig. 10). Most of the shorefast ice is floating, and is separated from the bottomfast ice near shore by active tidal cracks along approximately the 1 m isobath. The inner zone of bottomfast ice is often covered with aufeis formed by over-ice flow of water forced upward through tidal cracks by tides, storms, or both.

Winter. The winter period begins about early December. At this time there is a relatively stable band of shorefast ice fringed to the seaward by the stamukhi, or shear, zone. Beyond the shear zone, in which ridged and deformed ice predominate, there is seasonal pack ice. Because wind is predominantly from the north during winter, the pack ice in Norton Sound is forced southward against the shorefast ice surrounding the delta, creating intense bottom-gouging in the shear zone. Figure 12 illustrates winter ice conditions in the delta region.

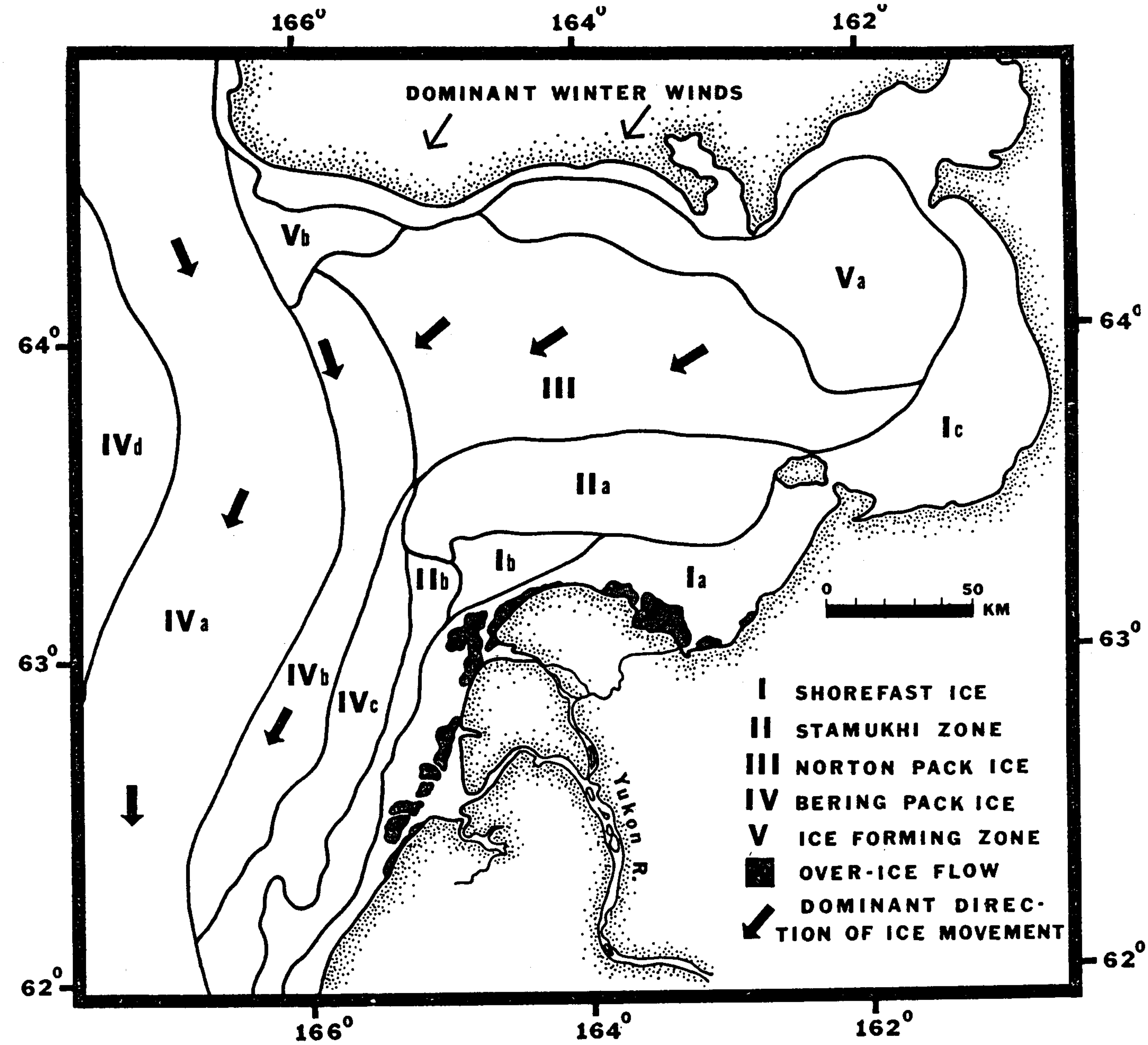

Fig. 12. Generalized depiction of late winter ice conditions in the Yukon Delta region (from Dupré 1980).

Breakup. Spring breakup in the delta region typically beings in early May. It is marked by a tremendous increase in sediment and water discharge from the Yukon River that results in ice jams, extensive inland flooding and river bank erosion.

As river discharge begins to increase, floating fast ice begins to lift, both in the river and along the coast. The bottomfast ice begins to be flooded by over-ice flow. Some sediment is carried onto the sea ice, bypassing much of the inner sub-ice delta platform. Much of the water and sediment is carried by the sub-ice channels that cross the sub-ice platform, to be deposited along these channels and in the delta front or prodelta seaward of the platform. The floating ice over the channels soon breaks up and is removed to sea.

During breakup it is common for southerly winds to predominate and assist in moving ice away from shore. Large pieces of floating shorefast ice break off and move offshore. Grounded ice may remain temporarily in some shallow areas to the northwest of the delta. By June the shorefast ice is usually gone. At this time the distributary channels are introducing an apron of sediment underwater over much of the delta platform and prodelta regions.

Hydrology

Hydrographic processes associated with the Yukon River discharge, and oceanographic processes in adjacent marine waters, have very important implications for biota of the region. Water regimes in the area strongly influence the distribution and abundance of mammals, birds, fishes and major food web components.

River Discharge. The Yukon is one of the major rivers of North America and is 24th among world rivers in mean discharge (Lerman 1981). It drains 45 pecent of the total land area draining into the Bering Sea. It has a pronounced seasonal pattern of runoff (Fig. 13). On average it decreases from 2×10^3 m^3/sec in November to 1×10^3 m^3/sec in April; thereafter it increases rapidly to a peak of 13.5×10^3 m^3/sec in Juneand then steadily decreases again to November levels (Ingraham 1981).

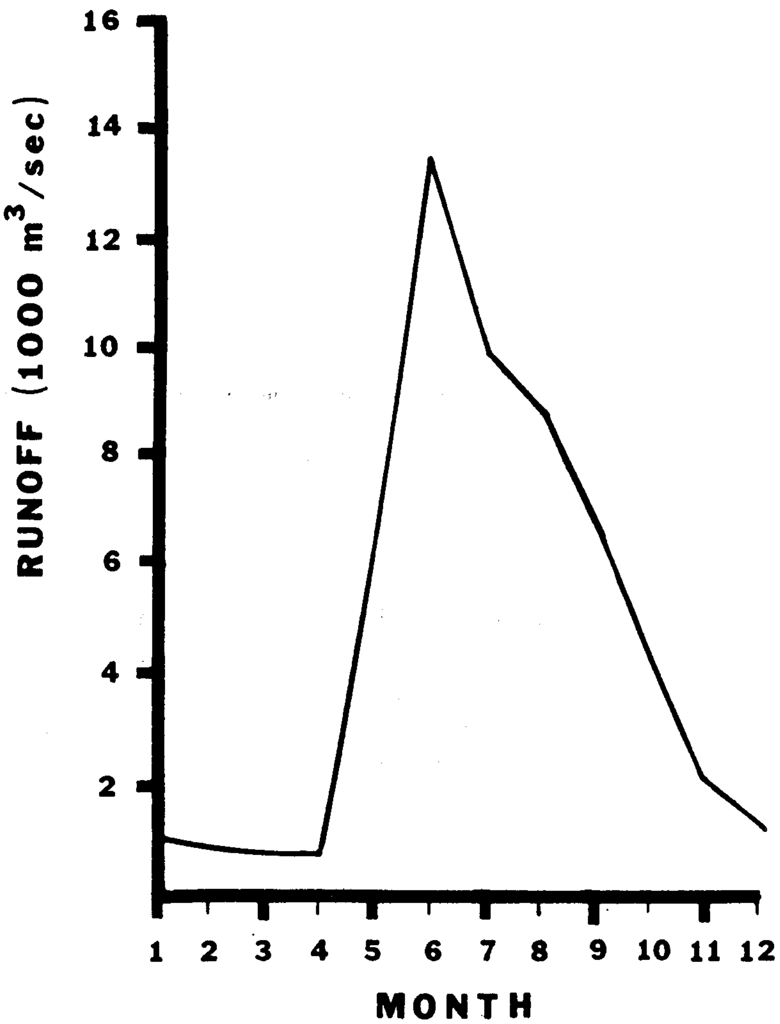

Fig. 13. Yukon River runoff by month at Ruby. Long-term (1957-1978) mean (from Ingraham 1981).

One of the most striking features of Yukon River water is its large sediment load. Its suspended sediment load of 88 x 10^6 metric tons per year ranks it 18th among rivers of the world; this load is exceeded in eastern Pacific rivers only by the Colorado. It has been estimated that the Yukon supplies 90% of the riverborne sediment entering the Bering Sea (McManus et al. 1974).

The nutrient (nitrogen) content of Yukon River water is low compared to many major rivers of the world (McRoy et al. 1983). Little is known of the input of terrigenous carbon. Circumstantial evidence suggests, however that the nutrients and carbon from Yukon discharge may have a major influence on continental shelf food webs downstream of the Yukon Delta (see McRoy et al. 1983; Venkatesan et al. 1981).

Nearshore Fate of Discharge. Above we noted the extreme seasonality of Yukon river discharge. This results in late May and early June flooding of major portions of the delta, and in late winter in relatively low flows restricted to under-ice channels. Estuarine-type water quality (warm, brackish) and exchange patterns would be expected to prevail in Norton Sound in and near the delta, particularly in summer when discharge rates are still relatively high and ice is absent. This has generally been found to be true.

Because the shallow water off the coast of the delta prevents easy vessel access, few measures of water quality have been made nearshore. Jones and Kirchhoff (1977) report that local residents find fresh water several miles seaward of the delta. The sediment-laden river plume, visible on Landsat imagery, suggests that fresh water is found at the surface up to several tens of km seaward of the coast.

Measurements made in deeper parts of Norton Sound suggest that the influence of the Yukon River discharge in summer is present, at least at the surface, for long distances to the northwest, to Bering Strait and beyond. Additionally, part of the outflow is diverted into eastern Norton Sound to freshen surface waters there (Sharma et al. 1974; Muench et al. 1981).

Drake et al. (1980) suggest that flow very near the coast may at times be southward, especially along the west shore of the delta. Their conclusion is based on examination of turbidity plumes in Landsat images and NOAA satelite photography and has not been substantiated by current-meter data, because no such data exist.

Estuarine Mixing Processes. The extent to which the typically estuarine phenomenon of salt wedge instrusion occurs, and its dynamics related to the different types of river distributaries, have not been investigated to any extent. Brackish water has been reported to sometimes occur up to 160 km inland (Zimmerman 1982). Some speculate that during peak flows saline water may not intrude into the distributaries at all (R. Gibbs, University of Delaware, College of Marine Studies, pers. comm.). Matthews (1973) documented the occurrence of a classic salt wedge extending in late summer up the Acharon Channel/Kwikluak Pass distributary, but did not attempt to estimate the distance of salt wedge intrusion. He did note that periodic storms temporarily disrupted the salt wedge layering near the coast in late summer.

The Yukon river discharges 1,000,000 f^3s^{-1} of fresh water during its peak flow in late spring through 12 active delta distributaries (Dupre 1978) and a number of sloughs (Fig. 14). The sloughs between the north fork (Apoon) (A) and the middle fork (Kawanak) (C) are shown in Landsat photography to be disconnected from main distributaries by late July. The mouths of distributaries and sloughs (during peak flow periods especially) behave as estuaries since sea water at the mouths is measurably diluted by fresh water derived from land drainage (Jones and Kirchhoff 1978).

Excluding the ice-dominated season, the mouths of main distributaries are river-controlled estuaries by late May of each year with circulation and stratification patterns primarily determined by the rate at which river water is being added at their heads. Seasonal variations in response to their runoff cycles can be observed, and from early August to early November these main distributary estuaries are controlled by a combination of storm tides, astronomical tides and river runoff. Slough mouths, however, undergo a transition from river control in May to tide control in late summer. Evidence for these transitions (Jones and Kirchhoff 1978) are the relatively clear waters off the sloughs in August (Fig. 15) indicating little upstream input of sediment-laden freshwater and lack of connection to the major distributaries. Opaque sediment-laden water was seen off Apoon (A), Kawanak (C) and Kwikluak (B) mouths (Fig. 14) which are the end points of the major distributaries.

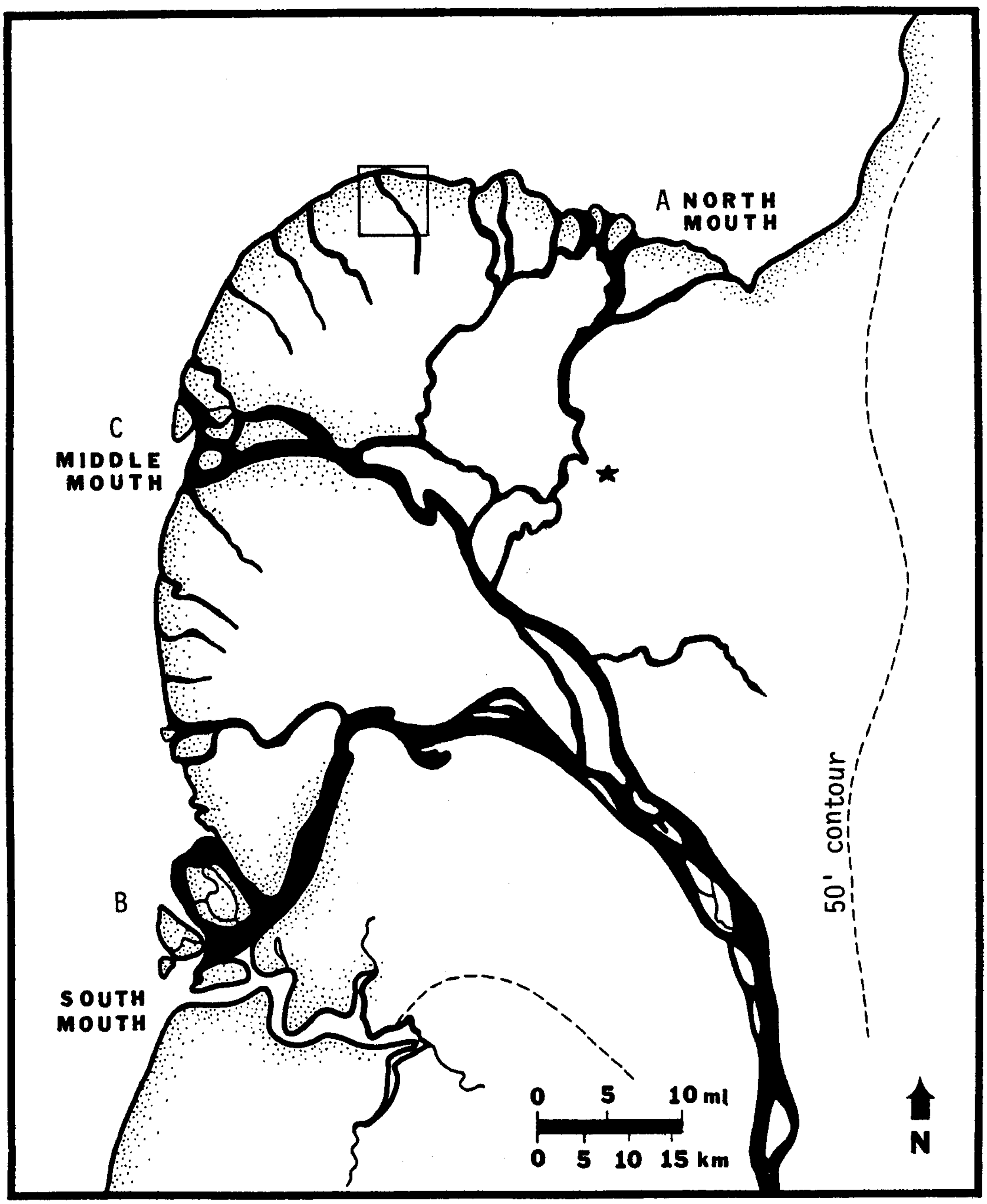

Fig. 14. Yukon River distributaries and sloughs with approximate 50' elevation contour.

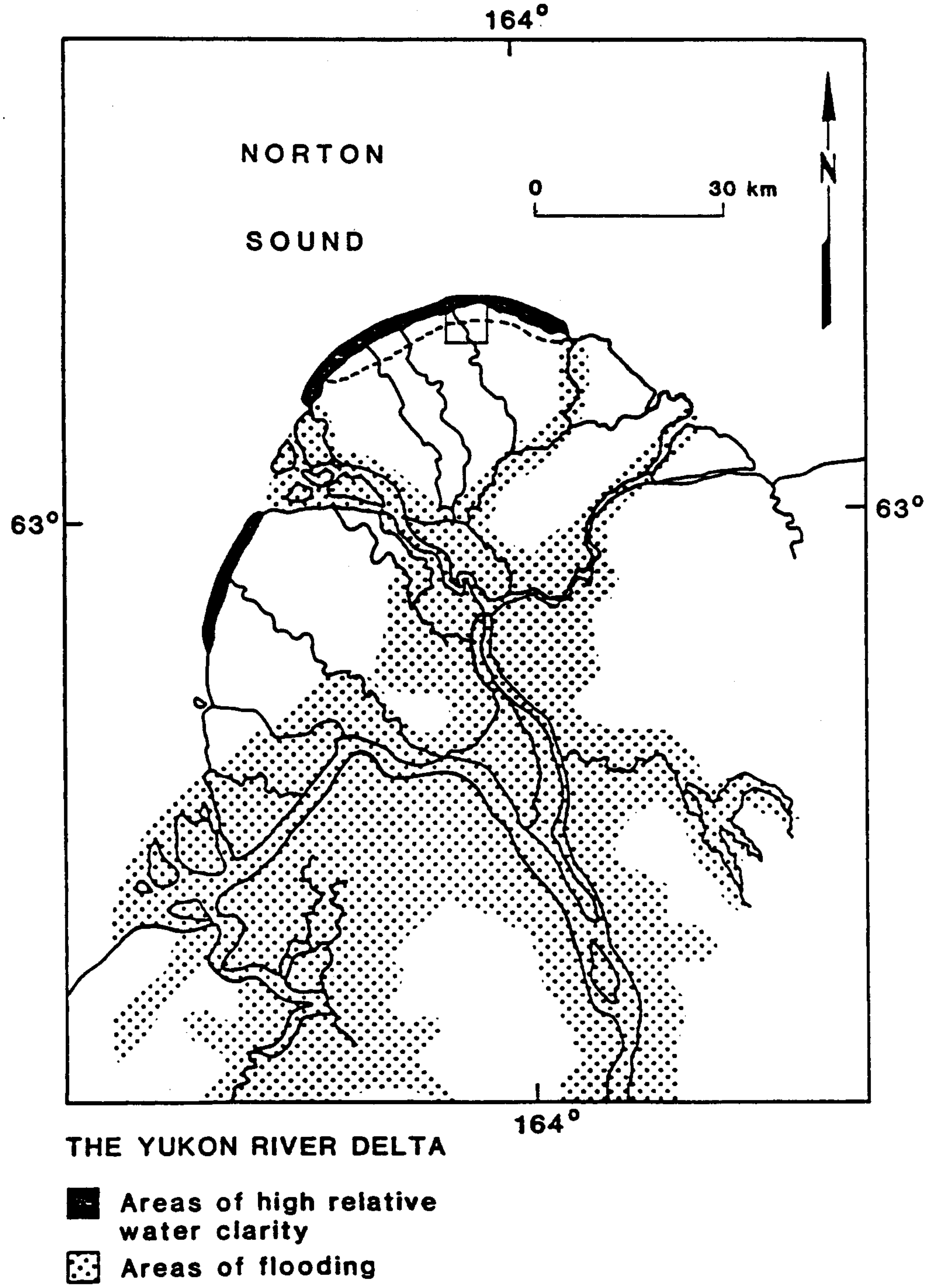

Fig. 15. The Yukon Delta region showing interdistributary clear waters and the extent of spring riverflooding (Jones and Kirchhoff, 1978).

(1) Sloughs - Using limited data from Jones and Kirchhoff (1978) we have made an attempt to predict the upstream extent of oceanic salt intrusions in sloughs. The mouth of Uwik Slough (enclosed in rectangle, top of Fig. 14) had a salinity of 4 ppt; at 12 km inland, it showed "barely a trace" of salt at high tide. Its depth ranged from 3 m at the mouth to .38 m at its head (more than 24 km inland). The tidal range is $\sim$ 1 m and of the mixed (mainly diurnal) type (NOS chart 16240, Rev. May 1982, and Defant 1960). Silvester (1974) has devised a mathematical technique to estimate tidally driven salt intrusion distances upstream as follows (see Fig. 16):

$$D = \text{Eddy Diffusion Coefficient} = \left(\frac{Vr}{2}x'\right)/\ln\frac{\bar{s}}{S_o} \qquad (1)$$

where Vr = mean river velocity

S_o = salinity of source (coastal water)

$\bar{s}$ = salinity at river mouth during low water slack

x' = distance offshore of source salinity at low tide (its most seaward position)

$$x' = \frac{T\sqrt{gd}}{2\pi}\left[1 - \cos(2\pi t/T)\right] \qquad (2)$$

where T = period of tide $\sim$(86,400 s for diurnal)

g = acceleration of gravity = 9.8 ms^{-2}

t = time of tidal cycle in seconds

d = depth of river or slough

$L_{\ell ws}$ = length of intrusion of water with salinity (3)

s' at low water slack tide (ℓws)

$$L_{\ell ws} = x'\left(K\sqrt{D/V_r x'} - 1\right)$$

note: $K = 3 @ \frac{s'}{S_o} = .01$ (1% of source)

At high water slack tide (hws) the bulk of water of given salt concentration is forced upstream (L_{hws}) by the amount of tidal excursion (H). According to Ippen (1966):

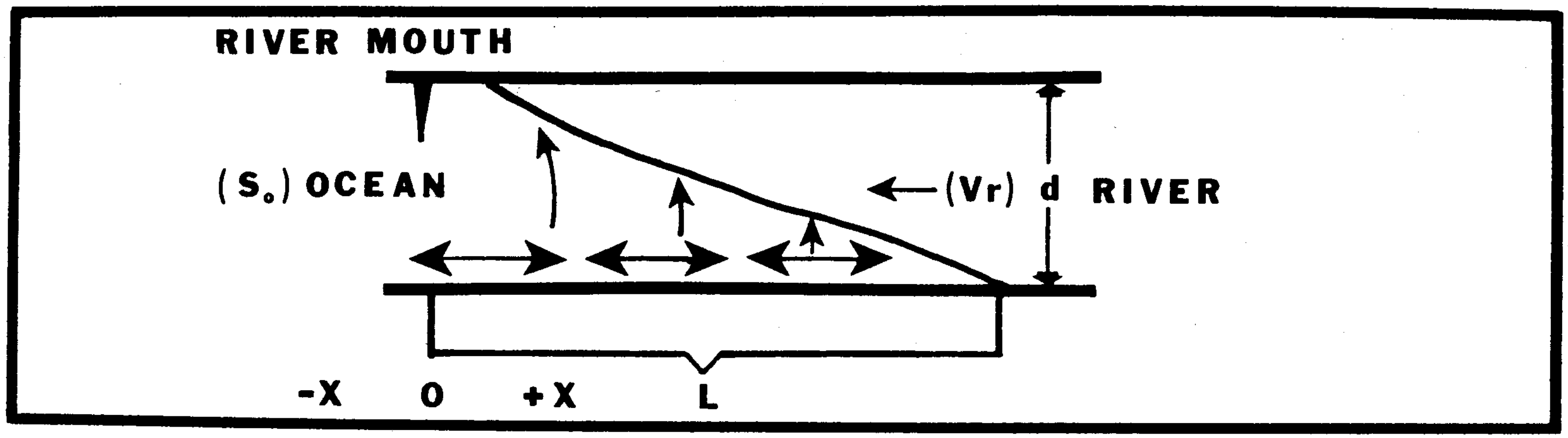

Fig. 16. Sketch of interaction of ocean waters and river waters at an estuary mouth under tidally induced mixing. V_r = river current, S_o = salinity at high water slack at mouth of estuary.

$$L_{hws} - L_{\ell ws} = \left(\frac{T\sqrt{dg}}{2\pi} - L_{\ell ws}\right) (1 - \exp[-H/d]) \qquad (4)$$

Note: This equation does not include frictional effects and assumes $H/d < 1$.

Since Vr has not been measured, we make assumptions that the slough is connected to the distributaries in August to arrive at an upper bound value. The Yukon River flow in August is $\sim$ 400,000 f^3s^{-1} (Carlson 1977). Dividing this flow rate by 2 allows for shunting (electrical analog) water to the south mouth and the middle and north mouths combined (Fig. 14). Dividing the resultant half flow rate by 3 allows for shunting water to the three main distributaries between the north and middle mouths. If the four sloughs to the northwest of the Okshokwewhik distributary are connected to it and it branches off to feed five minor distributaries to the northeast (Fig. 14) we must divide its flow rate by (4 x 2)8. This gives an approximate river flow rate to Uwik Slough (rectangle, Fig. 14) of 8333 f^3s^{-1} or 236.1 m^3s^{-1}.

An idealized rectangular river of 250 m x 3 m cross section (N.O.S. Chart 16240; Jones and Kirchhoff 1978) would have a river current (Vr) of $\sim .3\ ms^{-1}$ $\left(\frac{236.1}{250x3}\right)$. If we assume that the salinity of 4 ppt is reduced to 2 ppt during low water slack at the Uwik Slough mouth and it goes back up to 4 ppt one hour later, equation (2) can be written:

$$x' = \frac{86400\ \sqrt{9.8 \times 3}}{2\pi} \quad (1-\cos[360 \times \frac{1}{24}])$$

$x' = 2.535 \times 10^3$ m seaward of the mouth.

From equation (1):

$$D = \frac{-.3}{2}\ (2535/\ell n(.5)$$

where Vr = -.3 (due to negative direction, Fig. 16)

$$D = 548.6\ m^2s^{-1}$$

Inserting these results into (3) and solving for the distance where the salinity is .01 s_o:

$$L_{\ell ws} = 2535\ (3\sqrt{548.6/.3(2535)} - 1\ )$$

$= 3.924 \times 10^3$ m at low water slack (minimum distance upstream)

Using equation (4):

$$L_{hws} - L_{\ell ws} = (74560 - 3924)\ [1 - \exp\ (-\frac{1}{3})\ ]$$

$$= 20.023 \times 10^3 \text{ m}$$

or $L_{hws} = 23.947 \times 10^3$ m inshore from the mouth for a salinity of $\frac{1}{100} \times s_o$ or .04 ppt.

Since a salinity of .04 ppt can be considered "barely a trace" (Jones and Kirchhoff 1978) and the calculated 24 km distance inshore doesn't include frictional effects and actual depth changes, it is apparent that Silvester's techniques (above) can be used for modeling salinity intrusion distances in sloughs.

(2) Major Distributaries - The first major distributary, Okwega Pass (clockwise from A, Fig. 14) has its bottom depths recorded (N.O.S. chart 16240, Rev. May 1982) and averages at least 6 m depth from its mouth to Hamilton (★ on Fig. 14). At Hamilton, a distance of ~50 km upstream, saline water has been found underlying the surface freshwater (Zimmerman 1982). As in part (1) above, the August total Yukon flow rate of $400{,}000 f^3 s^{-1}$ is divided in two at the first major bifurcation. The three major shunts divide it by three. Finally the Apoon mouth distributary and the Okwega Pass distributary act to divide the flow by at least two. Therefore 400,000/12 yields a flow rate of 33,333 $f^3 s^{-1}$ at the mouth of Okwega Pass. An idealized rectangular river of 1.5×10^3 m x 6 m (N.O.S. chart 16240) cross section results in an estimated river current (Vr) of $[945/(1.5 \times 10^3 \times 6)]$ .1 ms^{-1}. If we again assume that a recorded salinity of 4 ppt is reduced to 2 ppt during low water slack at the river mouth, and it takes three hours to get back to 4 ppt after a low water slack (more than three times the volume in part [1]), equation (2) can be used as:

$$x' = \frac{86400\sqrt{9.8 \times 6}}{2\pi}\ (1 - \cos\ [360 \times \frac{3}{24}\ ])$$

$x' - 30.883 \times 10^3$ m seaward of the mouth.

From equation (1) [Vr expressed as a (-) velocity, Fig. 16]:

$$D = \frac{(-.1)}{2}\ (30883)/\ln .5 = 2227.7 \text{ m}^2\text{s}^{-1}$$

Inserting these results into (3) and solving for the distance where the salinity is .01 s_o:

$$L_{\ell ws} = 30883\ (3\sqrt{2227.7/.1(30883)} - 1)$$
$$= 47.805 \times 10^3 \text{ m at low water slack.}$$

Using equation (4):

$$L_{hws} - L_{\ell ws} = (105444 - 47805.2)\ (1 - \exp[-\frac{1}{6}])$$
$$= 8.849 \times 10^3 \text{ m}$$

or $L_{hws} = 56.653 \times 10^3$ m inshore from the mouth $(\frac{1}{100} \times s_o) = .04$ ppt.

It must be noted that any initial salinity s_o can be used. Again, these simple approximations effectively model the length of salinity intrusion upstream and in this case the results are quite close to observations.

Norton Sound Circulation. Norton Sound is a relatively shallow embayment extending north and east from the Yukon River delta. Depths vary from less than 10 m in the southern portion to more than 30 m in an east-west trough in the northern part just south of Nome (Muench et al. 1981) (Fig. 17). Circulation and water mass characteristics in the Norton Sound area strongly affect the fate and biological effects of Yukon River discharge.

In summer, the western part of Norton Sound (west of Stuart Island, see Fig. 17) is dominated by a northward moving water mass called Alaskan Coastal Water (Coachman et al. 1975). This water mass typically moves northward along the coast of the eastern Bering Sea; it is somewhat lower in salinity than water farther from shore because river discharge freshens it as it moves along the coast. In western Norton Sound, it takes on a cyclonic pattern, swinging eastward past the Yukon Delta, northward about the center of the sound, and westward along the northern shore. Most of the Yukon River discharge is entrained in this water mass, contributing significantly to its makeup. The Alaskan Coastal Water moves out of Norton Sound, through Bering Strait, and follows the Chukchi Sea coast until past Barrow (Drake et al. 1980; Coachman et al. 1975; Muench et al. 1981; Schumacher et al. 1978). (There is a persisting flow northward through Bering Strait both summer and winter, though periodic short-term reversals in direction occur [Muench et al. 1978]).

Waters in the eastern part of Norton Sound (east of Stuart Island) in summer are isolated to a great extent from those in the western half (Muench et al. 1981; Schumacher et al. 1978). In principle this means

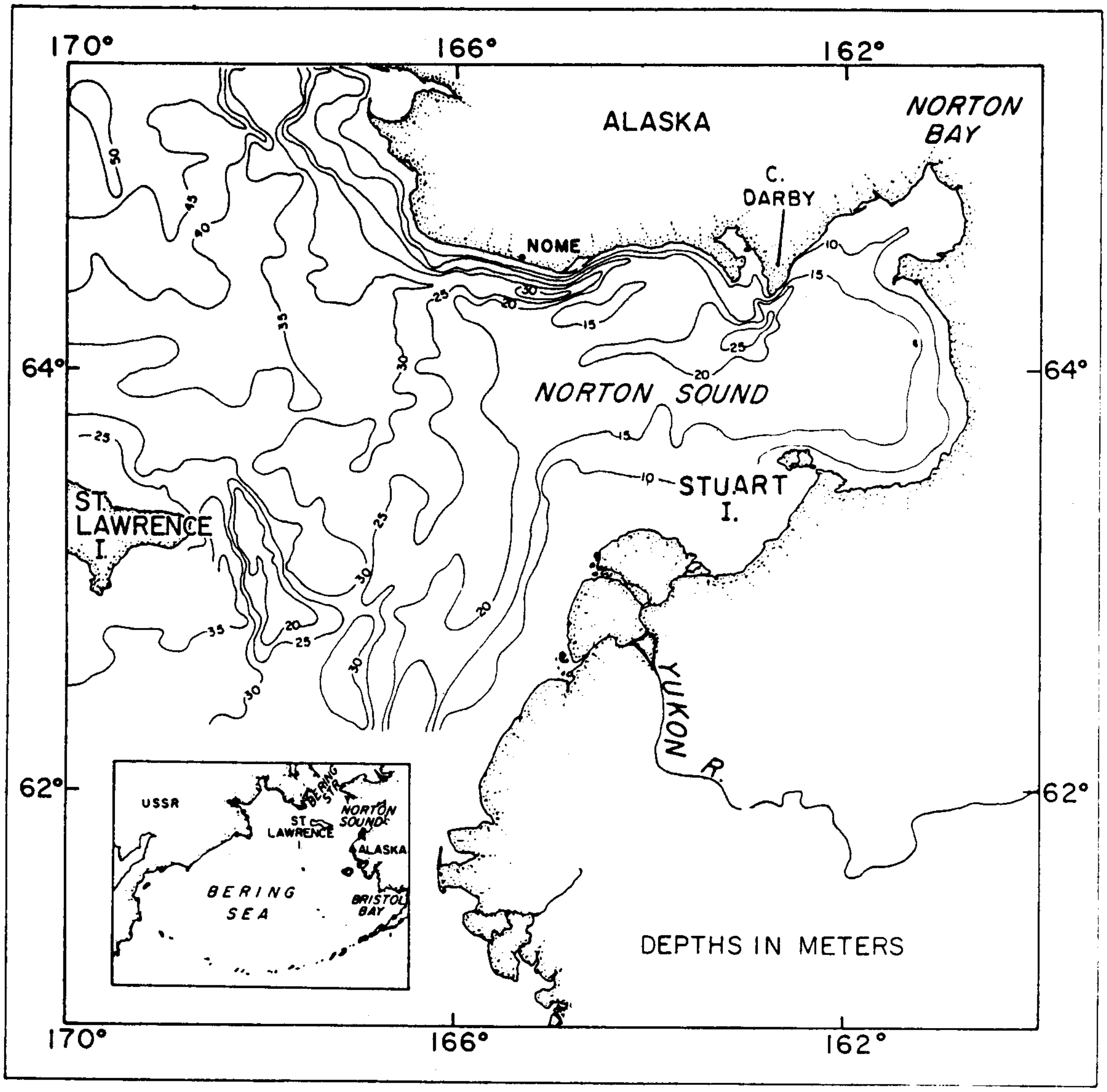

Fig. 17. Bathymetry of the Norton Sound region (from Muench et al. 1981).

that Yukon River water, discharged into western Norton Sound, has little influence in eastern Norton Sound (Schumacher et al. 1978). But it has been suggested that in fact a small proportion of Yukon River water is diverted into eastern Norton Sound (Drake et al. 1980; Schumacher et al. 1978; Sharma et al. 1974; Burbank 1979).

Water column stability appears to be greater in summer in eastern Norton Sound than in the western part. In the east, a strong pycnocline decouples upper- and lower-layer circulation, and bottom waters generally remain much colder (2-3 C°) than surface waters (up to 16° C) throughout summer (Muench et al. 1981). The upper layer has a mean weak cyclonic flow; the lower layer exhibits little mean flow. In the west, greater water column mixing (no decoupling) and smaller differences in surface and bottom temperatures appear to prevail. As seen above, cyclonic and generally northward-flowing currents prevail.

Current speeds in western Norton Sound are greater than in the east, primarily because of the influence of the rapidly-moving Alaskan Coastal Water through the western sound. Mean surface current speeds of 12-18 cm/sec at stations in western Norton Sound in late summer 1978 indicate the rapid exchange of western sound waters (Muench et al. 1981).

In winter, circulation patterns appear to be generally the same as in summer. Water mass movement past the Yukon Delta and through western Norton Sound remains generally northward (Salo et al. 1983). Presumably winter currents in the eastern sound remain slower than in the west. Conversely to summer, however, the water column is everywhere nearly homogeneous vertically. Lowered river inputs of fresh water and exclusion of salts from water freezing at the surface destroy the pycnocline that maintains the two-layered system in the eastern sound in summer (Drake et al. 1979).

Thus in both summer and winter, the major portion of Yukon River discharge moves through western Norton Sound and continues northward through Bering Strait into the Chukchi Sea. This has important implications for transport and fate of Yukon sediments, as we shall see later.

Transport

Transport processes associated with river discharge and estuarine and marine circulation are exceedingly important from a biological standpoint.

Transport and deposition of sediments affect substrate quality and thereby the biota living on or in the substrate. Organic detritus carried in the water influences fertility and productivity of detrital sinks. Zooplankton, epibenthic invertebrates, and larval fish frequently depend on transport to accomplish important migrations or local movements.

River Discharge. The Yukon River is a regionally important source of sediments, biological detritus and organisms. Annually it dumps 88 x 10^6 metric tons of sediment into the Bering Sea (McManus et al. 1974). A large but unquantified amount of organic detritus from terrestrial environments accompanies this sediment as it flows into the sea (McRoy et al. 1983). Millions of larval salmon from upstream spawning areas are likewise discharged into the ocean (Regnart and Geiger 1982).

As noted earlier, the Yukon supplies about 90 percent of the annual riverborne sediment entering the Bering Sea (McManus et al. 1974). More than 95 percent of its sediment load is delivered during the ice-free months of late May through October (Drake et al. 1980). Samples taken from the Yukon in summer show suspended sediments to be about 10% clay, 60-70% silt, and 20-30% very fine sand. Presumably higher percentages of fines (clay, fine silt) would occur in winter when flow rates are reduced.

Amounts of organic detritus discharged by the Yukon River were not estimated in the literature we reviewed. Undoubtedly the annual discharge of detritus, particularly in early summer, is quite large, but it remains to be measured.

Salmon (five species) spawn in the Yukon River and its tributaries; millions of salmon smolts are discharged annually into the Bering Sea from the Yukon (see Regnart and Geiger 1982). In terms of immediate value to humans, these smolts are probably the most important suspended component that the Yukon carries to the sea. Juveniles of other species (e.g. rainbow smelt) also are transported from upstream spawning sites to the sea.

Estuarine Transport. The transport pathways and fates of suspended sediments and organic materials once they are discharged from the Yukon distributaries are relatively complex, frequently different among types of suspended materials, and sometimes unknown. In addition to transported materials supplied by the river, marine-derived organisms may be strongly affected by transport in the vicinity of the delta.

The majority of inorganic sediments appears to have two different transport pathways and depots, depending on grain size. Sand and coarse silt particles are deposited along subsea channels in the delta platform, on the platform itself, on the prodelta, and across the mouth of Norton Sound north and northwest of points of discharge (Drake et al. 1980). This depositional pattern reflects the flow pathways of the majority of Yukon water.

Fines (clay, fine silt) are seldom deposited in the high-energy environment that fronts the delta platform on the west and north, but appear to have three general fates. First, much of this material appears to be transported by the rapidly moving Alaska Coastal jet to settle out in less high-energy environments in the Chukchi Sea beyond Bering Strait (Drake et al. 1979; McManus et al. 1974, 1977; Nelson and Creagor 1977). Second, another portion reaches the relatively quiet waters of eastern Norton Sound, there to settle out (Cacchione and Drake 1979a). Third, another fraction moves southward along the shore from the delta to settle in lagoons and bays between the delta and Cape Romanzof (Dupre 1978; Drake et al. 1980). The northward delivery of materials toward the Chukchi appears more or less constant; delivery eastward into Norton Sound and southward toward Cape Romanzof appears to be intermittent. Fig. 18 illustrates the tendency for transport sediment from Yukon discharge to be generally northwestward toward Bering Strait. Fig. 19 shows an instance when sediment-laden waters appear to have been held in the delta nearshore zone on north and west sides and transported southward from the mouth of the southernmost major distributory (Acharon Channel).

The transport pathways and depositional fates of organic detritus discharged from the Yukon have not been studied. If we assume, as have others (Bordovskiiy 1965; Froelich et al. 1971), that organic matter tends to behave similarly to inorganic fines in suspension and to be co-deposited with them, organic detritus from Yukon discharge would settle mostly in the Chukchi Sea, in eastern Norton Sound, and in lagoons and bays south of the delta. Little would accumulate in western Norton Sound or in any environments between the Yukon Delta and the Chukchi Sea. Indeed, McRoy et al. (1983) show that organic carbon levels in surface sediments are high (> 1.0% dry weight) in nearshore areas immediately south of and in front of the Yukon

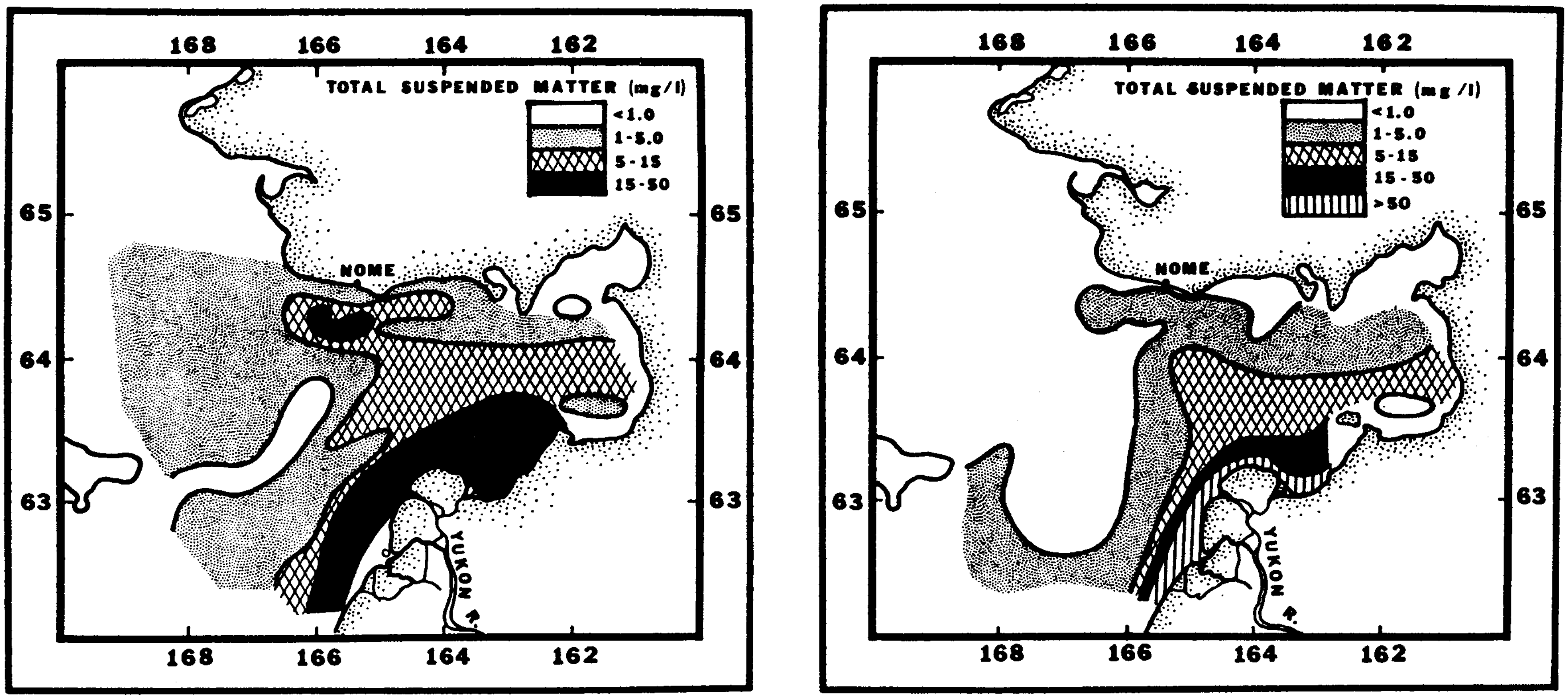

Fig. 18. Distribution of total suspended matter 5 m above the bottom (left) and at the surface (right) in Norton Sound, 7-18 July 1979 (from Feely et al. 1981).

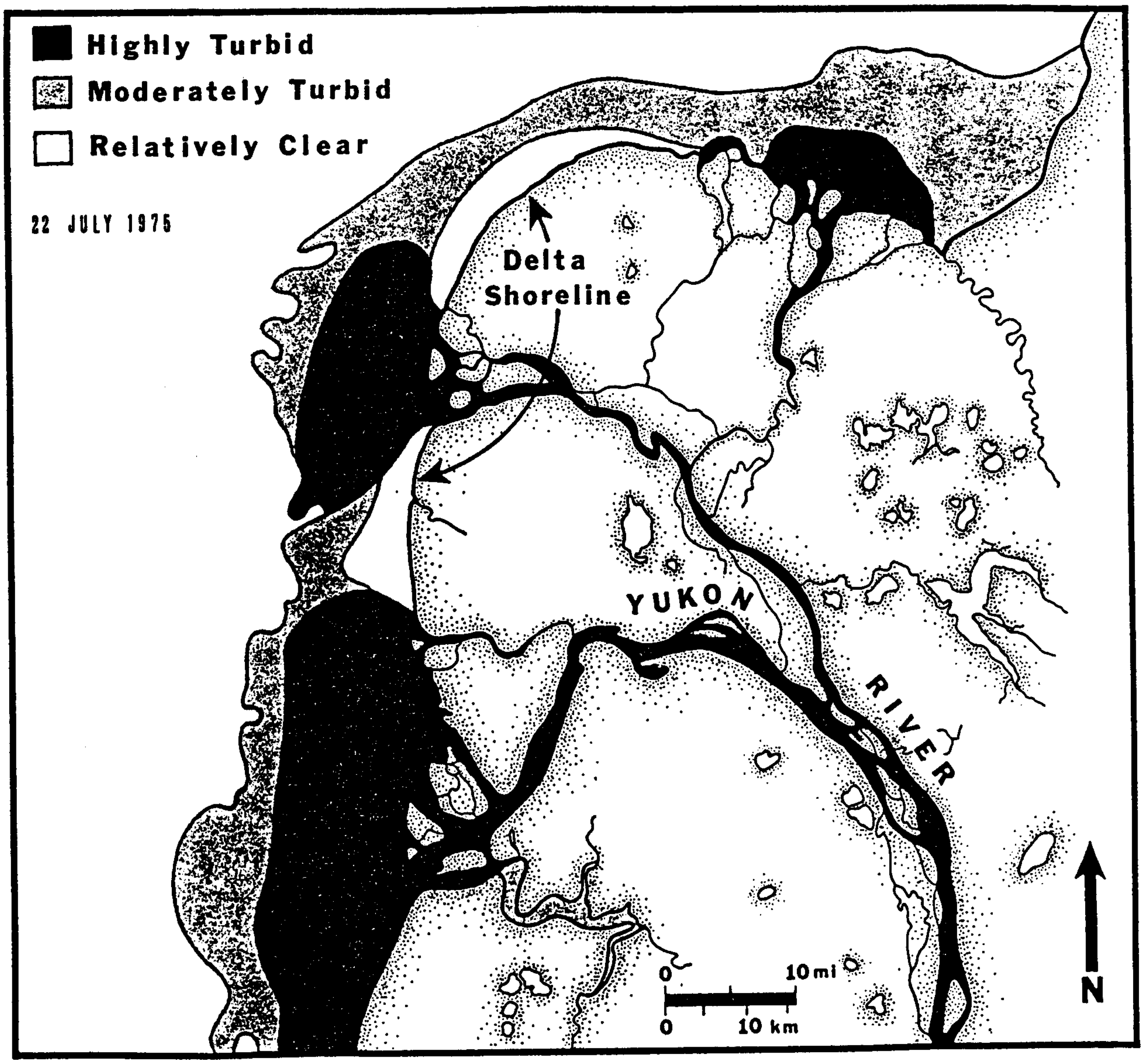

Fig. 19. Map based on ERTS imagery of 22 July 1975 showing distribution of turbid waters in and near the Yukon River delta, Alaska.

Delta and in southern and eastern Norton Sound, and beyond Bering Strait in the Chukchi Sea, but low ($<$ 1.0% dry weight) in areas in between. Whether depositional patterns of Yukon-derived detritus cause this observed pattern in sediments is not known, but may be considered likely in view of the presumably large proportion of northern Bering Sea detritus contributed by Yukon discharge.

What happens to juvenile salmon, smelt, and other fish in the few months after they reach Norton Sound waters is virtually unknown. They need not follow current patterns once they reach the sea, for they are independently mobile to some extent. Some probably reside in coastal areas for a few weeks to months before moving to distant marine habitats where they eventually mature (see Hartt and Dell undated). Further discussion of this issue appears in "Yukon Delta Biota: Species Characterizations" in this volume.

In addition to transporting river-derived materials, estuarine and marine waters in the delta region are responsible for transport of marine-derived organic material and organisms (phytoplankton, invertebrates). Very little is known about transport patterns of these, but a few items deserve mention. Epibenthic and zooplanktonic organisms appear important to feeding birds (especially pintails) and fish (e.g., whitefish, ciscoes) that use the delta channels and nearshore shallows in summer (Kirchhoff 1978; Neimark et al. 1979). Because much of the nearshore region in which these invertebrates appear to occur in summer are frozen to the bottom in winter, there must be rapid repopulation of the shallows in summer. Being poor swimmers, some of the invertebrates may take advantage of currents to transport themselves landward, as has been found to occur in Beaufort Sea shallows (see Griffiths and Dillinger 1981). The mechanisms by which this transport may take place have not been studied here, but the salt wedge intrusion at the bottom seems a reasonable transport pathway.

Environmental Hazards and Pollutant Transport

Physical processes in the Yukon Delta region strongly influence the chances that pollutants (oil) will be spilled in the Norton Sound environment and, as well, will control the fate of oil should it be spilled. Winds, storms, waves and currents determine the trajectories and fates of spilled oil during the open-water season, and to some extent determine the likelihood that oil will be spilled. Ice characteristics and dynamics in winter influence the likelihood of oil spills and determine its movement and fate in the delta region.

Effects of Storms, Waves and Currents

Though storms may hit the delta in any season, there is a storm-dominated season existing from August to November. During this time the frequent high-speed southwesterly winds with longer fetch distances result in high wave energy, particularly on the western side of the delta. In addition, due to wave refraction, wave energy is concentrated by headlands such as a delta formation (Bascom 1964). This combination of high wave energy from the sea and rapidly decreasing sediment discharge in late summer from the Yukon River cause significant coastal erosion (Dupre and Thompson 1979).

Though long time-series of surface wind data have not been collected in the Yukon Delta area, Kozo (in prep.) has shown that wind data from Alaskan surface wind stations (Fig. 20) separated by distances less than 200 km have cross correlation values of .75 at 0 lag time. This means that data from both Unalakleet (~170 km from the Yukon Delta) and Cape Romanzof (~125 km from the delta) can be extrapolated to the delta. Both these areas have orographic wind channeling in the winter months under stable atmospheric conditions so they may not have similar conditions as the Yukon Delta at this time, But in the summer months, when atmospheric stability approaches neutral and synoptic wind conditions promote southwesterly flow, they definitely represent Yukon Delta wind conditions.

A closer examination of the synoptic and mesoscale meteorology shows that the average large scale wind vector switches from the northeast in winter to the southwest for the open water periods of July and August (Brower et al. 1977). Since the ocean surface current flow also has the same general direction (Fig. 21), we may draw two conclusions. The first is that surface contaminants southwest of the Yukon Delta may be pushed by the wind and currents toward the delta shore. At the same time, surface contaminants in the Lease Sale 57 area (see Fig. 1) will be pushed away from the Yukon Delta, most likely reaching the coast to the east of Nome (Samuels

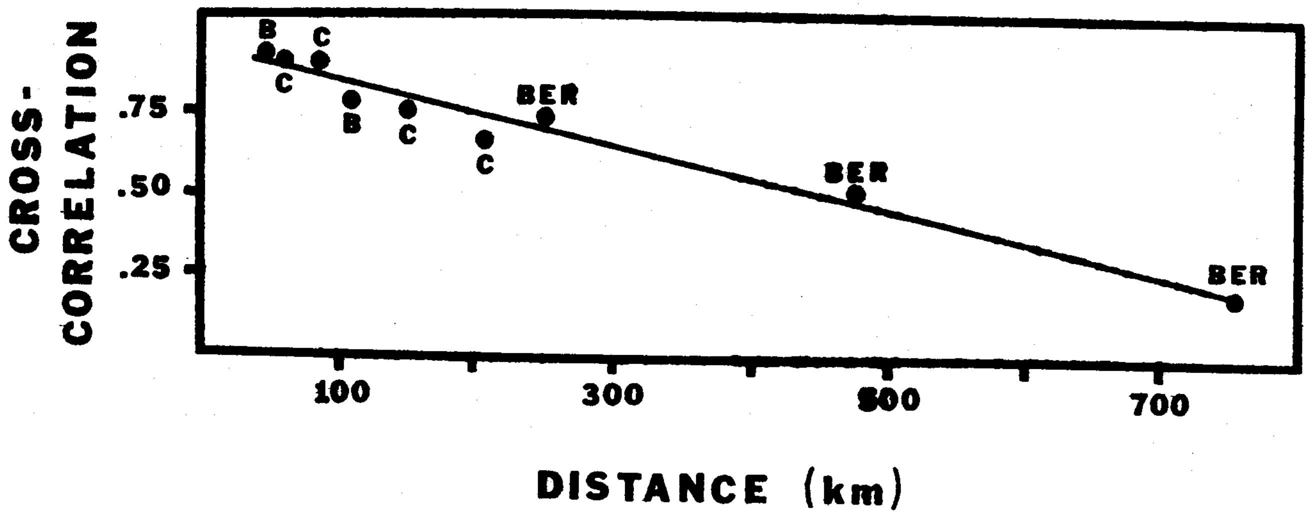

Fig. 20. Cross correlation values for land surface wind stations versus distance (km) of separation. B = Beaufort coast, C = Chukchi coast, BER = islands in Bering Sea.

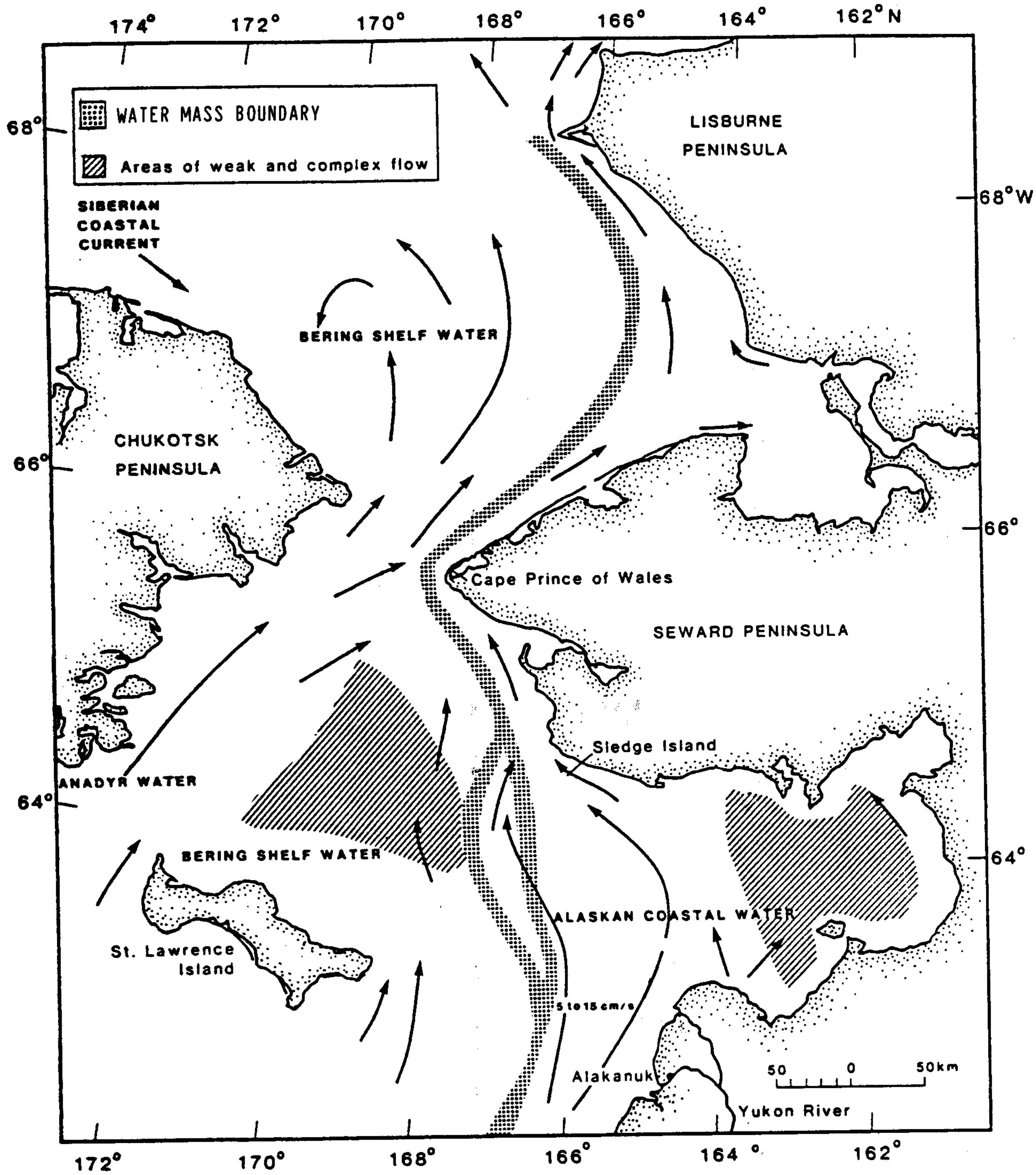

Fig. 21. Movement of water masses in the Bering Strait Region (Drury et al. 1981).

and Lanfear 1981) or moving to the northwest out of Norton Sound under winds and prevailing currents combined. The second conclusion is that the average summer wind field should promote a down-welling and shoreward transport of outer shelf water with concomitant increase in the water level at the coast. This increased water level allows waves, which are focused by the delta, to push contaminants further inshore.

Summer mesoscale winds, in particular sea breezes, can dominate the local meteorology 25% of the time and can reach speeds up to 15 ms^{-1} (Zimmerman 1982). These winds promote a shoreward transport of surface contaminants in a 20 km zone seaward of the coast (Kozo 1982). The convex curvature of the Yukon Delta (opposite to that of a bay) helps promote focusing of thermally-driven wind systems (as well as ocean waves, see above) so that they tend to blow perpendicular to coastlines (McPherson 1970).

Storm Surges. Rises in water level due to strong winds (setup) are of major concern. Abnormal setup in nearshore regions will not only flood low-lying terrain, but will provide a base on which high waves can attack the upper part of a beach and penetrate farther inland (U.S. Army Shore Protection Manual 1977). Accretion and erosion of beach materials, cutting of new inlets through barrier beaches and shoaling of channels can occur.

The Bering Sea has an average of 3.5 cyclonic events per year in the 15-20 ms^{-1} range (David Liu, Rand Corporation, pers. comm.). Given the average wind direction and the probable nature of oceanic Yukon Delta geomorphology, the delta has a high vulnerability to storm surge events.

Fig. 22 shows the coastline of Alaska divided into 25 coastal sectors (Wise et al. 1981). Sector 10 has limited data to create surge height-frequency interval curves. The results of Fig. 20, however, show that the interval curve (Fig. 23) for sector 10 (Fig. 22) can be applied since wind frequencies are proportional to storm surge heights. It should also be noted that the large percent of atypical easterly orographic winds at Unalakleet in winter months are not included in Fig. 23 since only winds from the southwest to northwest quadrant are used to construct the curve (favorable fetch directions, Wise et al. 1981).

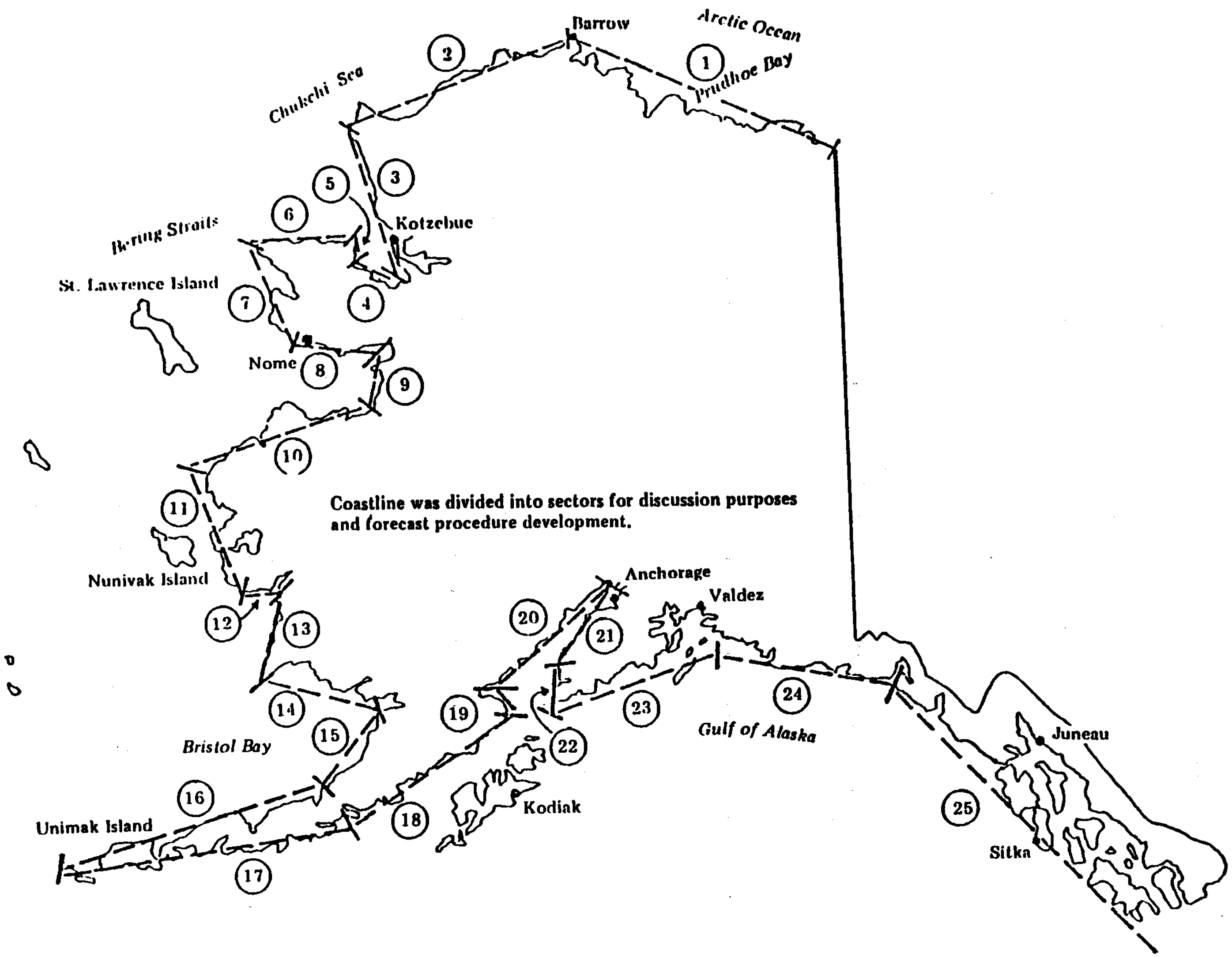

Fig. 22. Coastal sectors (from Wise et al. 1981).

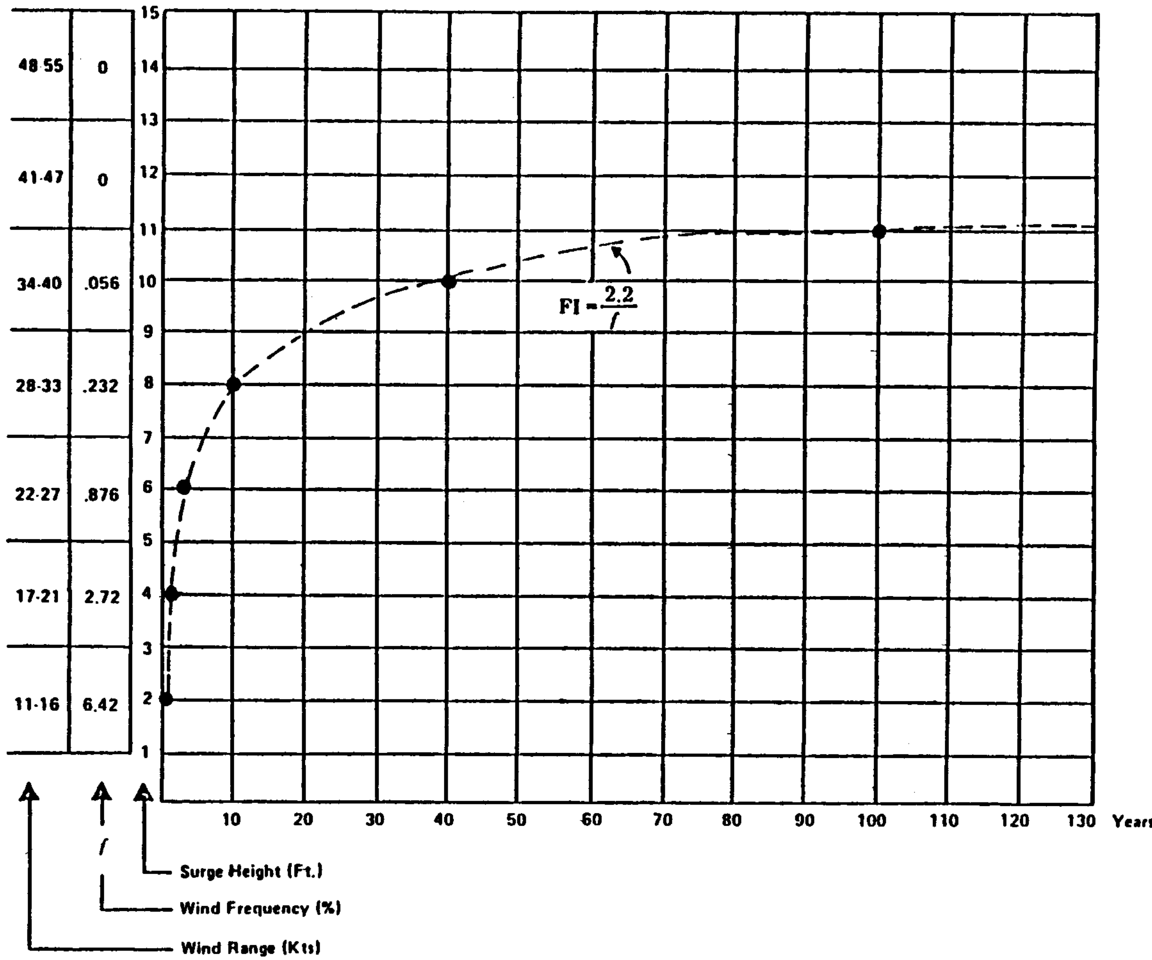

Fig. 23. Surge height-frequency interval curve, Sector 9. Graph is derived from surge data and Unalakleet southwest to northwest wind directions and related wind range frequencies. Constant in FI formula is derived from assumption of one 11-foot surge every 100 years (from Wise et al. 1981).

The proportionality equation is (Wise et al. 1981):

$$FI = \frac{K}{f},$$

where FI ≡ frequency interval,

f ≡ wind frequencies for a given wind speed class and set of directions,

K ≡ constant of proportionality for a given area such as sector q.

A typical storm surge forecast for August can be made using data from storm case histories (Wise et al. 1981) and duration tables (Brower et al. 1977). Assume a cyclonic gale force wind of 35 knots (17.5 ms^{-1}) from the southwest. The preliminary surge height from Fig. 23 is 9 ft (20 year return period). Duration tables (Brower et al. 1977) show that at least 5% of the August wind events greater than 20 knots last 12 hours. The preliminary surge height must be reduced by 10% to 8.1 ft for a 12 hour duration (see Appendix A, part II C). Typical low pressure centers are 970 mb from storm case histories. Appendix A, part II E, states that the surge height should be raised 1 ft for every 30 mb increment below 1004 mb. Therefore the surge height must be raised 1.1 to 9.2'. It will be assumed that the astronomical tide is coincident with the surge so no further corrections are made. This sea level rise (2.8 m) is consistent with actual reports inthe area (Zimmerman 1982).

Waves. The above wind speeds and direction, with unlimited fetch for the above duration produce significant wave heights (deep water) of 24 ft (Pierson et al. 1971) as seen on co-cumulative spectra charts for wind speeds as a function of duration. This wave height in shallow water for a 10 sec period converts to a wave of 9 m (Table C1, U.S. Army Shore Protection Manual Vol. III 1977). The surge height indicated in the previous section, coupled to the shallow water significant wave height, totals 39.2 ft or 11.9 m, and shows that 40 km inland penetration in the delta (Zimmerman 1982) is very possible, since the 50' contour is ~100 km inland.

Effects of Ice

The sea and river ice-dominated season in the Yukon Delta extends from mid-November to mid-May. It is the longest season, but it is the season when movement of pollutants is most restricted. Positively bouyant oil spills occurring under an ice canopy require current speeds in excess of 20 cm/s^{-1} to move against the opposing friction of the ice skeletal layer. In a week's time, oil can become incorporated into the ice skeletal layer through the winter freezing process. Norton Sound is well within the 75% probability of sea ice cover from December 1 until May 15 (Figs. 24 and 25) and is considered to be an ice factory supplying up to ten times its area of ice to the Bering Sea (Thomas and Pritchard 1981). As ice leaves the sound, it moves either north following the generally northward moving currents or south under the influence of northerly winds. These periods of southward movement could become relevant to Yukon Delta operations.

Though sea ice in Norton Sound is mainly first year (less than 1 m thick), large ice rubble-field features have been seen indicating total ridge thicknesses of 24 m caused by ice pile-up (Thomas and Pritchard 1981). The largest concentration of these piles are in shoal areas (delta front) off the Yukon Delta. Periodic strong winds can move these rubble piles seaward and they can represent extreme ice hazards to transiting ice breakers which ordinarily cannot crash through ice greater than 4 m thick. Also, if they impinge on drilling structures, the structure will be destroyed. Another source of ice thicker than 1 m is arctic pack ice (2 to 3 m thick) moving through the Bering Straits from the Chukchi Sea after "breakout" periods caused by northerly winds and/or current reversals.

There is a major zone west of the Yukon Delta in water depths of 3 to 14 m (delta front) characterized by periods of ice deformation and accretion during westerly winds and offshore movement of ice and large polynya development during easterly winds (Dupré 1980). This area is significant because it is offshore of the south and middle Yukon Delta mouths which have sub-ice channels connected to the polynya area. These channels are considered active during the ice season from recent observations (Dupré 1980) of suspended sediments.

Sub-ice Channels. The sub-ice channels are extensions of the major distributary channels (Dupre 1980) and are most common on the western margin of the Delta. The channel geometry is 1.5 x 10^3 m wide by ~10 m deep and they can extend up to 20 km beyond the shoreline. The flow rate for the Yukon in mid-winter is approximately 40,000 f^3s^{-1} or 10% of the August rate (Carlson 1977).

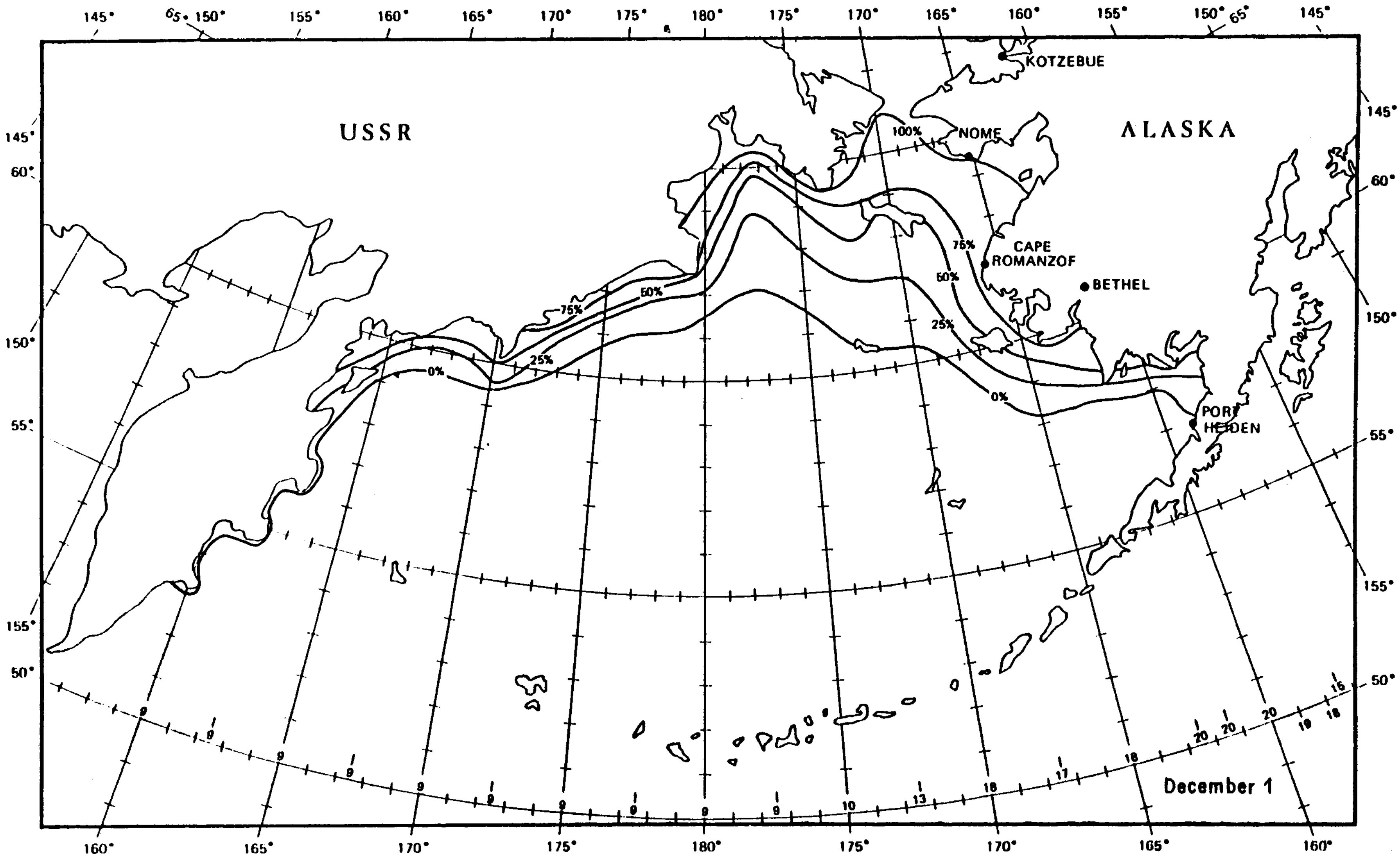

Fig. 24. Empirical probabilities of the ice limit for December 1 (from Webster 1981).

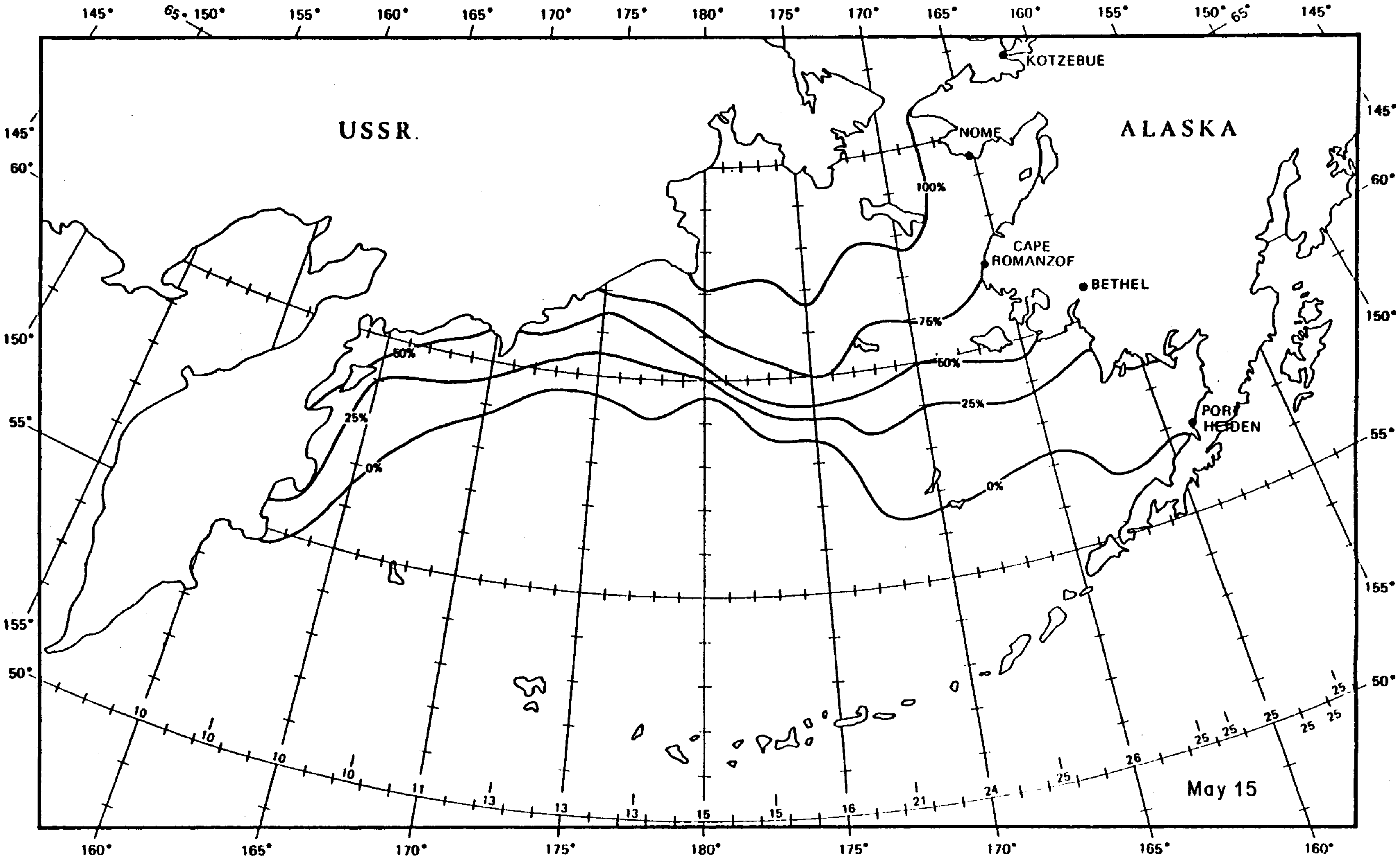

Fig. 25. Empirical probabilities of the ice limit for May 15 (from Webster 1981).

The method of dividing the flow rate by the number of distributaries used earlier gives a hypothetical distributary current of .02 ms^{-1} (2 cms^{-1}) moving at depth below the river ice and running into a sub-ice channel. The tidal current can now be estimated in a subsurface channel under a 1 m tidal excursion. Though the under-ice channel to the sea is topped by a sea ice lid, a tidal excursion of 1 m can produce a pressure difference which will force sea water and sediment into the channel and shoreward. The situation is approximated as a classical Poiseuille flow in a pipe driven by a pressure differential. The equation (6) (Lamb 1945) is:

$$u = \frac{\Delta p}{4 \rho D \ell}(a^2 - r^2) \qquad (6)$$

where $\Delta p \equiv$ the pressure differential caused by the tidal excursion (H),

$\Delta p = \rho g H$, ρ = density of sea water,

$D \equiv$ turbulent diffusion coefficient,

$\ell \equiv$ length of the channel (sub-ice) (taken here as $\sim$10 km from N.O.S. chart 16240),

$a \equiv$ radius of an equivalent pipe that approximates the channel (since $[1.5 \times 10^3 \text{ m} \times 10 \text{ m}] = 1.5 \times 10^4$ m, letting $\pi a^2 = 1.5 \times 10^4$ m, gives a = 69 m for an equivalent pipe radius,

$r \equiv$ radial length from the center of the pipe (r = 0) to the side (r = 9),

$g \equiv$ acceleration of gravity

$u \equiv$ velocity in the channel.

Using the above information and substituting into (6) we have:

$$u = \frac{9.8 \times 1 \times [69]^2}{4 \times D \times 10^4} \quad \text{(at r = 0, center of channel).}$$

D is calculated from the method used in equations (1) and (2) (see "Estuarine Mixing Processes"), and the .02 ms^{-1} river current estimated above. The time for the salinity offshore at the ice-channel mouth to reach the salinity at high water slack was chosen a $\sim$½ hour (less than at any other season due to limited volume output). This gives a diffusion coefficient (D) equal to 16.8 m^2s^{-1}, which can be used above to give u = .07 ms^{-1} within the sub-ice channels. This value, which depends on D, is very speculative. Though not moving oil under an ice canopy (less than 20 cms^{-1}), it could move water soluble fractions and some sediment types (muds and fine sands). The motion would be shoreward at high tides and offshore at low tides.

Breakup and Freezeup. The breakup period which terminates the ice dominated season signals the commencement of the period when ice floes are mobile and subject to both winds and currents. Ice in the shorefast zone ablates and can also begin moving. River flooding causes freshwater to overflow the shorefast ice areas. A concomitant change in albedo causes increased radiational ablation which, together with the mechanical ablation, speeds the nearshore ice destruction. River sediment can deposit on the ice itself and float beyond the inner shelf.

The freezeup period is also dynamic since late fall storms may fracture new thin ice and move it out of the area, leading to new manufacture of ice with later small scale winds blowing off shore due to land breeze effects. Thermohaline circulation will be at its peak nearshore, leading to small scale circulation cells perpendicular to the shelf. The flow will be offshore at depth and onshore under the ice (Kozo 1983). These density driven flows will be augmented in subice channels which have greater bottom slopes. They will occur only in channels that do not carry significant amounts of river discharge.

ZONATION OF BIOLOGICAL USE

In this section we present and discuss a somewhat arbitrary classification of Yukon Delta habitats into ecological zones. This classification has two purposes that are related. First, (in this section) it will show how animals distribute their use of the region. Second, (in the following section on Vulnerabilities) the zones will be compared according to their vulnerability to oil pollution from OCS activities.

We define an ecological zone as an area which has physical qualities and patterns of animal use that are somewhat similar throughout the area but perceptibly different from those of adjacent areas. Our attempt at zonation is thus an effort to put lines on a Yukon Delta map where habitat characteristics and animal use patterns change more or less abruptly.

One factor above all others influences ecological zonation, and coincidentally, (as we will discuss later) vulnerabilities of the zones to oil pollution. That factor is distance above or below mean sea level (elevation, bathymetry). This factor controls zonation through the medium of water. Thus each distinct zone is primarily a function of its position above or below sea level and of the coincident water regime. Additionally, elevation in respect to mean river level effects zonation (again through the medium of water).

Zonation is more apparent and more readily mapped above sea level than below it, because very few measurements that clarify animal use or distribution patterns have been made below the sea surface. But we will discuss zonation below sea level as well, based on (1) data that describe different physical regimes (water depth, ice action, water quality, etc.) offshore, and (2) known or suspected responses of animals to these different regimes. Our confidence in the accuracy of descriptions of zones beyond the coast will be appreciably less than that for zones above sea level.

The zones we will describe are as follows, beginning with those at highest elevations and proceeding more or less downward to those at greatest depths below the surface (see Fig. 26):

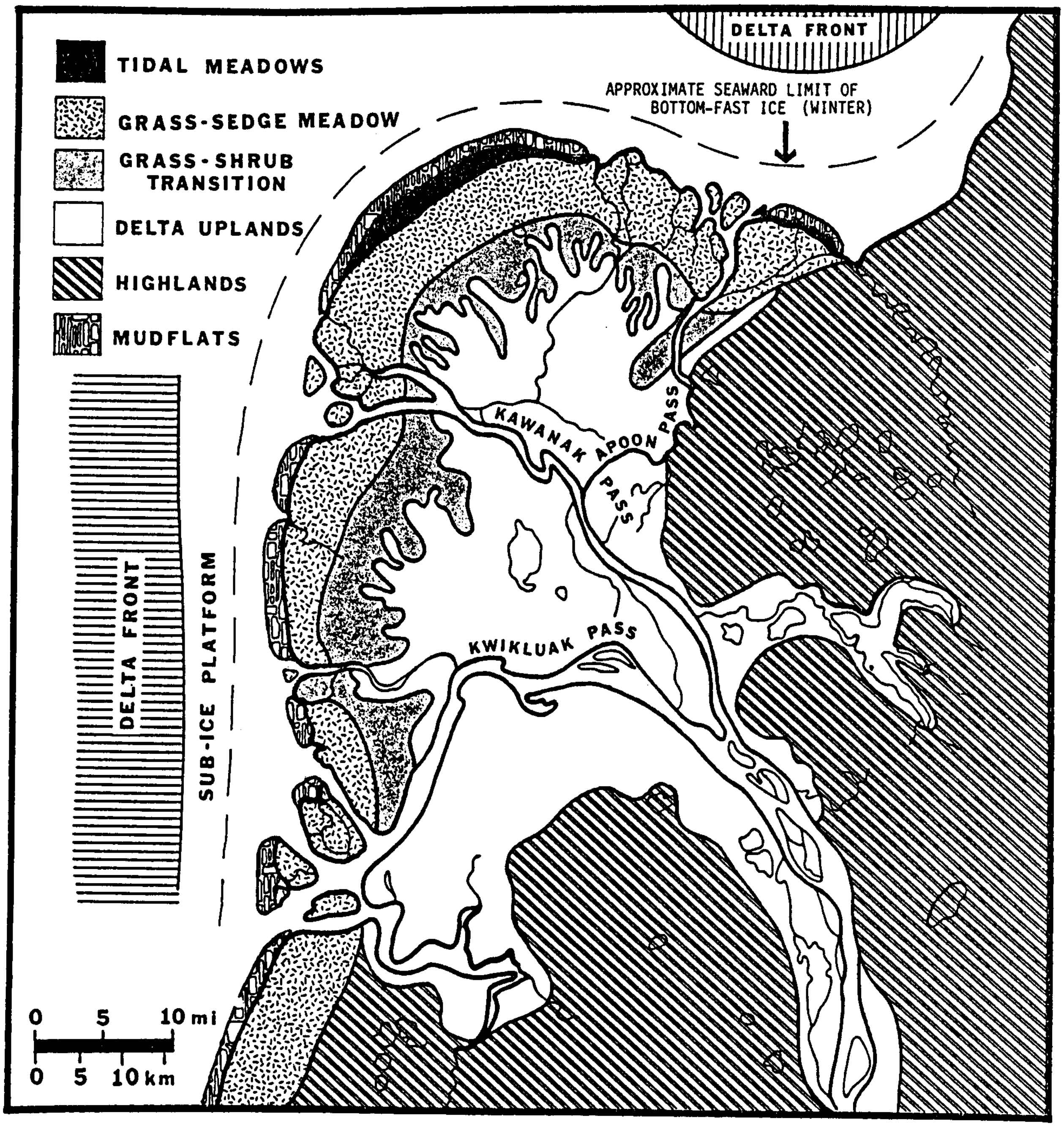

Fig. 26. Ecological zones in the Yukon River Delta area, Alaska. Delineations based on interpretations of ERTS imagery and information from R. Jones (pers. comm.), C. Dau (pers. comm.), Kirchhoff (1978), Jones and Kirchhoff (1978), Dupré (1980), Holmes and Black (1973), and Byrd (1981). This map has not been ground-truthed.

(1) Highlands - Inland areas not currently influenced by deltaic processes (river flooding, storm surge override, etc.)

(2) Delta Uplands - In general the highest delta environments above sea level. Largely subject to flooding during peak spring river overflows, but seldom subject to storm surge inundation; contain greater abundances of large shrubs and trees (willow, alder) than lower delta habitats.

(3) Grass/Shrub Transition - Coastward of and generally slightly lower and wetter than delta uplands, with fewer and smaller shrubs and more grass/sedge vegetation.

(4) Grass/Sedge Meadow - Somewhat lower than Grass/Shrub Transition; dominated by wetland grasses and sedges; does not flood during normal high tides but subject to inundation from moderate storm surge.

(5) Tidal Meadow - Below the Grass-Sedge Meadow, this zone is dominated by the sedge *Carex ramenskii* in nearly pure stands. Frequently flooded by normal high tides.

(6) Coastal Mudflats - Extending from the normally emergent coastal edge to as far as 1 to 1.5 km offshore, these mudflats have large portions that are frequently exposed at low tide, but that are under water at other times. A broad, gentle rise parallels the coast at the outer edge of this zone, impounding a shallow basin of relatively clear water (5-12 cm deep) at low tide that in summer supports an abundant growth of the pondweed (*Potamogeton filiformis.*

(7) Minor Distributary Channels and Sloughs - The delta has many small distributaries and sloughs, many of which are flushed by overflow water at the peak of spring flooding. After peak floods subside, most are not fed by Yukon water but open only to the sea or to other sloughs.

(8) Major Distributary Channels - These channels include the major distributaries (Kwikluak, Kawanak, and Apoon passes) that are up to 10 m or more deep and .5 to 3 km wide. They flow essentially year-round; they continue seaward as subsea (summer) or sub-ice (winter) channels beyond the delta coast.

(9) Delta Platform - The delta platform zone extends from the outer edge of the Coastal Mudflats to the Delta Front. Its bottom slopes very gradually, such that its outermost edges, which may be 20-30 km seaward of the coast, may be only 3 m deep. This outer edge approximates the outer limit of shore-fast ice in winter. This winter ice ($\sim$1 m thick at maximum) is bottomfast for a considerable distance offshore.

(10) Delta Front - Beginning at the outer margin of the delta platform, the bottom in this region slopes more steeply, increasing in depth from about 3 to about 14 m in about 5 km horizontal distance.

(11) Marine Environment - We class all areas beyond the Delta Front as the marine environment. In fact, based on existing data, we cannot distinguish between the Delta Front and the environments beyond in terms of use patterns of animals, though differences probably exist.

Highlands

These non-deltaic areas are relatively unimportant for purposes of this study. First, they are relatively invulnerable to oil hazard. Perhaps more important, they do not provide unique habitat for large numbers of animals; i.e. extensive amounts of similar habitat that supports similar populations exist elsewhere in the region. These highland areas are nesting places for some shorebird species and waterfowl species that have dispersed nesting habits and do not require extensive wetlands as nesting habitat (e.g. white-fronted goose, green-winged teal, pintails, greater scaup, etc.) (Holmes and Black 1973). Among the shorebirds, American golden plovers, western sandpipers, and northern phalaropes would be expected to nest commonly there.

Delta Uplands

Much of the delta uplands flood annually from river overflow (Jones and Kirchhoff 1978), thus precluding extensive use by ground-nesting species that initiate nesting before spring breakup. These early-nesting species include pintails and lesser and cackling Canada geese among others; these two species represent the largest nesting waterfowl populations on the Delta (Jones and Kirchhoff 1978). Existing data (Jones and Kirchhoff 1978) suggest that geese, green-winged teal, and pintails nest in this zone on elevated, wooded levees of distributaries and where drift logs and stumps provide elevated islands of habitat beyond the normal reach of flood waters. One of the more conspicuous uses of this zone that is low or absent in other zones is by passerine birds such as yellow warblers, common redpolls, and sparrows that nest in willows and alders along stream channels (Jones and Kirchhoff 1978).

Grass/Shrub Transition

The major species that nest in the Delta Uplands (above) extend their nesting into this zone to some extent. Passerine birds nest in willow/alder areas along watercourses. Canada geese (two subspecies--lesser Canada goose is more common in the delta than is cackling Canada goose), white-fronted goose, pintails, and green-winged teal are particularly abundant nesters in the raised willow habitat (and to some extent in other elevated habitats) in this zone (Jones and Kirchhoff 1978). Other birds that these authors found to commonly breed in the willow habitats of this and the delta uplands include common snipe, bar-tailed godwit, mew gull, and arctic tern.

Grass/Sedge Meadow

The grass-sedge meadow, not flooded by normal tides but commonly flooded by storm surge, hosts large numbers of both nesting and feeding birds. Birds that prefer this zone for nesting include black brant, emperor goose, spectacled eider, sandhill crane, and dunlin (Jones and Kirchhoff 1978). (Byrd [1981] describes this habitat to be also preferred by cackling Canada geese and white-fronted geese on the Yukon-Kuskokwim Delta south of Cape Romanzof, but Jones and Kirchhoff imply that these two species prefer the willow zone farther inland on the Yukon Delta.)

Feeding aggregations of birds (other than nesting inidividuals) are few and short-term in this zone. Kirchhoff (1978) observed feeding pintails to be abundant on ponds and temporary wetlands in this type in early June, but not thereafter. Jones and Kirchoff (1978) found some post-nesting cackling and lesser Canada geese to feed here temporarily in late June and early July on their way to the Tidal Meadow habitat nearer the coast.

Tidal Meadow

Very few birds nest in this zone, presumably because it is very frequently flooded by normal high tide, but it is a favored feeding zone for many, especially waterfowl. Feeding pintails are extremely abundant here in early June and in August (Kirchhoff 1978). Post-nesting broods of cackling and lesser Canada geese, white-fronted geese, and emperor geese congregate here to feed beginning in late June. Sandhill cranes appear to prefer to feed here in early June. Bar-tailed godwits, Hudsonian godwits, and whimbrels also congregate to feed there in early summer (Jones and Kirchhoff 1978).

Coastal Mudflats

As the Tidal Meadow habitat is the favored feeding area for geese, so are the mudflats favored by shorebirds, pintails, and other dabbling ducks. Pintails, the most abundant waterfowl on the Yukon Delta, apparently occur in their largest concentrations in the coastal mudflats. Here they feed on invertebrates in the clear-water zones between major river distributaries in late June and late July-early August (Jones and Kirchhoff 1978; Kirchhoff 1978). These authors saw American widgeons and shovelers feed on the mudflats with pintails, but in much smaller numbers.

Shorebirds in particular feed in the Coastal Mudflat habitat, normally after nesting farther inland. Jones and Kirchhoff (1978) observed dunlins, long-billed dowitchers, semi-palmated sandpipers, and Hudsonian godwits feeding in abundance on the Yukon Delta mudflats from early July until late summer. Gill and Handel (1981) reported in addition that bar-tailed godwits, whimbrels, black turnstones, northern and red phalaropes, short-billed dowitchers, sanderlings and western, least, sharp-tailed and rock sandpipers used the mudflat zone in the region. (Their observations included those birds using the Kuskokwim Delta as well.) Numbers of shorebirds using the Yukon Delta mudflats may be in the millions annually (see Gill and Handel 1981).

Minor Distributary Channels and Sloughs

Many small sloughs and interdistributary channels open to the sea in the Yukon Delta and thus are tidally influenced; these are very important to feeding and molting birds in mid to late summer and probably to anadromous fishes. Kirchhoff (1978) reported pintails to molt in large numbers in these sloughs in late July. Cackling and lesser Canada geese, and perhaps white-fronts and emperor geese as well, move to these sloughs to molt in midsummer. Black brant broods also use the sloughs after leaving the nest sites, and some of the shorebirds feed in the exposed mudflats at slough margins.

R. Jones (pers. comm.) reports some of the anadromous fishes (white-fish, cisco, sheefish?) to be abundant in these sloughs in summer. It seems doubtful that salmon would use them to any extent. The fish species and levels of use occurring in these sloughs have not been well-documented, though it appears likely, based on evidence from elsewhere (see "Fishes" section, this volume), that this habitat might be very important as a feeding habitat for adult fish and as a nursery/feeding area for juveniles of several species.

Major Distributary Channels

The main distributary channels in the Yukon Delta are of great importance to salmon and other anadromous fishes. Adult salmon are required to migrate up these channels to spawning areas, and salmon smolts must move down them to the sea, though it is doubtful that either adults or juveniles feed in the river channels to any extent. Many non-salmonid fishes, especially Bering cisco, humpback whitefish and sheefish, use these channels for migrating between feeding and spawning habitats, and perhaps for feeding and overwintering. The number of adult salmon that use these channels is reasonably well known; very little is known of their use by other species.

In addition to fish use, belukha are frequently observed in these channels in summer and have been reported far upstream. Presumably their main use of them is for feeding on fish. Very little is known about how many belukha use the channels or how this use varies from year to year.

Delta Platform

Extremely little is known of ecological use of this zone, primarily because almost no biological work has been done there. Belukhas are occasionally observed there in summer. Ringed seals presumably occupy the fast ice that covers this zone in winter, but because of the shallow depths in most places seals may be less abundant here than in other fast-ice areas of Norton Sound.

Large concentrations of molting scoters (mainly surf scoters and black scoters) have recently been observed using this zone from mid-July to mid-September (C.P. Dau, unpubl. data; Jones and Kirchhoff 1978). These birds presumably feed during molt, probably on benthic invertebrates based on what is known about their general feeding habits. Lesser numbers of molting eiders have also been observed to use this zone.

Undoubtedly both marine and anadromous fishes use these waters, but nothing is known of their patterns of use. This region is crossed by subsea channels of the major delta distributaries, which fish migrating upstream and downstream presumably follow. Salmon smolts reach this zone at the termination of their downstream migration; it is possible that they linger here for weeks or months in summer to feed and acclimate to salt water. The region could be an important summer foraging/rearing area for non-salmonid anadromous species as well, and marine forage fish might feed there in summer. In the absence of data speculation must prevail.

Epibenthic invertebrates presumably invade this area in summer from deeper waters offshore, for after ice-out they quickly become abundant in mudflats that were frozen to the bottom in winter (Jones and Kirchhoff 1978; Kirchhoff 1978). Mysids, isopods, amphipods, and others are sought here as food by pintails (Kirchhoff 1978) and probably by other birds and by fish (see Neimark et al. 1979). How these invertebrates traverse the inner delta platform is not known.

Delta Front and Marine Environment

Insufficient sampling has been done to determine whether these environments differ from one another in their ecological use. From several studies we have a general description of ecological use of shallow waters of western

Norton Sound, and in the absence of data we will assume this use applies to both these environments.

These environments are primarily seasonal feeding areas for gray whales, bearded seals, and ringed seals, though each of these species finds better habitats farther offshore. Few marine birds use Norton Sound in the vicinity of the Yukon River delta front. Pelagic fishes (herring, capelin, pollock etc.) are common in the area; they are usually more abundant in summer than in winter. Starry flounders and saffron cod are the most common benthic fishes.

The invertebrate community is primarily benthic and secondarily pelagic. Echinoderms and bivalves are a large proportion of the benthic biomass; copepods generally dominate water-column invertebrate communities. Red king crabs become abundant in deeper parts of Norton Sound far offshore of the delta.

Discussion

We have delineated ten ecological zones in the Yukon Delta region. Differences in ecological use among zones are dictated primarily by the elevational/bathymetric position of each zone and the associated water regime. The zones that are highest in elevation (non-deltaic Highlands, Delta Uplands) and those at greatest depths (Delta Front, Marine Environment) are least important in terms of supporting unique populations not widely distributed elsewhere. As one nears the delta coast in aquatic or terrestrial environments, the importance of zones in supporting large and unique animal populations increases.

Of these important zones that are just above and just below mean sea level, the least information is available about those below sea level. The absence of data from these estuarine environments (including delta distributaries and sloughs) is striking. From what is known about both the low-lying terrestrial and the shallow estuarine environments, they serve mainly as feeding, growing and (in the case of some birds) molting habitat. Generally, breeding takes place farther inland (or farther to sea for some fishes). Exceptions include black brant and emperor geese, which nest quite near the coast.

Why these areas very near the coast are preferred habitat for many of the birds is reasonably clear. There is relative freedom from terrestrial predators such as foxes, and there is an abundant food supply in the form of luxuriant vegetation and readily accessible invertebrates.

Whether the nearshore estuarine areas are preferred habitat for salmon smolts and young and adults of whitefishes, ciscoes, and other anadromous species is not known, though data from elsewhere suggest that it probably is. Relatively warm, brackish water and abundant invertebrate food sources may enhance the attractiveness of the nearshore shallows for these fishes.

Most evidence suggests that the nearshore shallows in summer support large populations of epibenthic and benthic invertebrates that serve as food for birds and fish. Logic suggests that this environment would be largely depleted of invertebrates in winter, because of stresses associated with ice and perhaps high salinities. Whether it is in fact depleted of these invertebrates is unknown; if it is, the mechanism by which invertebrates repopulate the area each summer is obviously an important one, but likewise unknown.

In summary, it is clear that the ecological zones nearest the coastline are the most important areas for biota. In these environments, important information gaps related to ecological zonation and the processes responsible for such zonation exist in the aquatic environment.

VULNERABILITIES OF ZONES AND THEIR BIOTA

In this section we discuss the vulnerabilities of the ecological zones and the species that use them to contamination by oil from offshore development. We define vulnerability to mean the likelihood that quantities of oil that may be biologically harmful will reach zones, remain there for extended periods, or harm animals that use zones. We see the vulnerability of an ecological zone to have three components:

(1) the likelihood that oil will reach the zone;

(2) the expected duration of oil that has reached a zone;

(3) the expected level of harmful impact on animals that use an oiled zone.

Because none of these components of vulnerability has a generally accepted scale of measure, we use an index of vulnerability (scale of 1 to 5) in each case. What the index means in each case is described in the appropriate section below.

Will Oil Reach the Zone?

We use an arbitrary scale of 1 to 5 to designate the susceptibility of an ecological zone to being oiled should large quantities of oil reach the Yukon Delta area. It is beyond the scope of this report to address endless scenarios of when, where, and under what weather conditions oil might be spilled, and its trajectory and fate under various conditions. Thus we will not discuss the likelihood that oil will be spilled in large quantities and move onto the delta. (Presumably the likelihood of this occurring is quite small.) To develop a rating system with a somewhat quantitative basis, we will assume that large amounts of oil do move onto the delta and that they persist in the water column and in the surface for a period of about a week. Given these artibrary assumptions, the vulnerability index by which we rate ecological zones is as follows.

Rating	Likelihood of Oil Reaching Zone
1	Oil will not reach zone under any conditions.
2	Chances < 1 in 100 that oil will reach zone.
3	Chances between 1 in 10 and 1 in 100 that oil will reach zone.
4	Chances somewhere between certainty and 1 in 10 that oil will reach zone.
5	Certain that oil will reach zone.

Below is a listing of the ecological zones (see Fig. 26) and our estimate of the relative vulnerability of each. Rationale for these judgements about vulnerability follow.

Ecological Zone	Oil Contact Vulnerability
Highlands	1
Delta Uplands	2
Grass/Shrub Transition	2
Grass/Sedge Meadow	4
Tidal Meadow	4
Coastal Mudflats	4
Minor Distributaries	4
Major Distributaries	4
Delta Platform	5
Delta Front	5
Marine Environment	5

From the above list we see that the Highlands zone is absolutely invulnerable to contamination. Because of the elevation of this zone, it cannot be reached by oil from the marine environment.

Delta Uplands and Grass/Shrub Transition are very seldom flooded by marine waters (see discussion in "Hazards and Pollutant Transport" section and Fig. 23). Our estimates are that major portions of each might be flooded on the order of once per 5 to 10 years or less. Given the assumption of a one-week duration of oil in the delta marine environment, and random chance about which week in the year this would occur, chances are perhaps one in 250 to one in 500 or less that this zone would be oiled. Because the spill would have to coincide with a storm surge sufficient to reach this zone, chances are drastically lower that the zone would be oiled from what they would be should oil be in marine environments year-round. (Assuming a much longer period of residence of oil in the delta marine environment would drastically increase the chances of oil reaching these environments.)

Grass/Sedge Meadows, flooded much more frequently by storm surge than are the farther inland Delta Uplands and Grass/Shrub Transition zone, should perhaps be 4. Several storms a year probably flood this zone, almost all occurring between 1 August and 30 November (see discussion in "Hazards and Pollutant Transport" section of this volume.) Should we assume this area to be flooded weekly during this four-month period, but not flooded at other times of the year, then chances are one in three (four months in twelve) that oil persisting one week in coastal waters would reach this zone. (Reducing the assumed frequency of flooding would quickly give this zone a lower vulnerability rating. We do not have sufficient information to determine if this zone is indeed flooded as frequently as once per week.)

Tidal Meadows, Coastal Mudflats, Minor Distributaries and Major Distributaries are all assigned a vulnerability rating of 4 (chances greater than 1 in 10, but not certain) that oil in the marine environment would reach them. For four to five months a year (July through November), marine water spreads over large portions of these areas at least once weekly, and sometimes daily. High tides flood Tidal Meadows and Coastal Mudflats; marine waters reach deep into the delta distributaries as salt wedges. During some periods, however, these environments would probably not be reached. For several months in winter, Tidal Meadows and Coastal Mudflats are separated from marine waters by ice barriers. During peaks of river runoff, salt wedges might not penetrate appreciably into the delta, and marine waters and any entrained oil would be kept out of these zones.

Marine and adjacent estuarine environments (Marine Environment, Delta Front, and Delta Platform) all receive ratings of 5, i.e., certain to be oiled. By assumption, we have provided for waters in these environments to contain oil for one week's duration; none are entirely or primarily ice at any time of year.

In summary, note again that the assumptions and the scale of ratings used in this section to determine relative vulnerabilities of zones to being oiled are somewhat arbitrary. The above discussions make it clear, however, that the vulnerability of a zone to being oiled is highly dependent on a few factors. The first, naturally, is what the chances are that oil will be spilled and transported into the delta region (not discussed here). Beyond this, the important factors are (1) duration of oil in the coastal aquatic environment, and (2) frequency with which storm surge covers the various zones. Relatively slight differences in each of these could cause drastic differences in the vulnerabilities of especially the terrestrial zones to being oiled. It is clear that, because of the frequency of tide and storm-caused flooding, zones at the coastal edge are much more susceptible to oil impacts than are those slightly farther inland.

How Long Will Oil Persist?

In this section we are concerned with persistence of oil in zones once it has reached them. Our primary concern is with substrates (e.g. benthic environments, terrestrial soils and vegetation), because the residence of harmful quantities of oil in water is short and relatively easily to predict. Similar to the previous section, we use a rating system of 1 to 5, indicating shortest oil residence time to longest. The rating system and expected persistance of oil in each zone are based primarily on work by Gundlach et al. (1981). Work of these authors is primarily in shoreline and wetland environments; we estimate persistence in deep benthic environments by estimating the wave energies to which each is exposed.

Our rating system is as follows:

Rating	Persistence of Oil in Zone
1	A few days to a few weeks.
2	A few weeks to a few months.
3	A few months to a year.
4	One to several years.
5	Several years or more.

A listing of the ecological zones (see Fig. 26) and our estimate of the relative vulnerability of each in terms of oil persistence follows:

Ecological Zone	Oil Persistence Vulnerability
Highlands	Not susceptible to oiling
Delta Uplands	3
Grass/Shrub Transition	5
Grass/Sedge Meadows	4
Tidal Meadows	4
Coastal Mudflats	4
Minor Distributaries	4
Major Distributaries	3
Delta Platform	4
Delta Front	3
Marine Environment	3

From this rating chart, we see that the Highlands is not susceptible to oiling (because it is above flooding zones), and that all other zones are probably moderately to highly vulnerable in terms of oil persistence.

We rate Delta Uplands, Major Distributaries, Delta Front and Marine Environments as moderately vulnerable zones in which oil is likely to persist from a few months to a year. All of these zones are subject to seasonal, but not continuous, high-energy events, which have been found to be important in removing oil (Gundlach et al. 1981). Spring river flooding covers much or most of the Delta Uplands; we presume that oil deposited there during the past year would be largely removed by this flooding. Likewise, channels (and presumably bottoms) of major distributaries are extensively reworked annually by spring flooding. Existing data (Drake et al. 1979, 1980) suggest Norton Sound benthic environments near the Yukon Delta front to be high-energy environments because of periodic strong bottom currents that resuspend sediments; we assume such events would also resuspend and remove oil on the substrates.

We judge that oil introduced into Grass/Sedge Meadows, Tidal Meadows, Coastal Mudflats, Minor Distributaries, and Delta Platform environments may persist for one to several years (also see Gundlach et al. 1981) (vulnerability rating of 4). All are relatively quiet environments, though periodic moderate-energy events affect each. Grass/Sedge Meadows and Tidal Meadows are vegetated, and thus, though periodically inundated by high tide and storm surges, would not cleanse readily (see Gundlach et al. 1981). Large portions of these zones are not flooded annually by river overflow (see Figs. 15 and 26, this volume). Minor Distributaries, Coastal Mudflats, and to some extent, the Delta Platform zone are relatively low-energy environments where fine and organic suspended materials "settle out." They are scoured to some extent by spring river overflow (Minor Distributaries) and wave action (Coastal Mudflats, Delta Platform), but spilled oil in these fine-particled substrates would have a tendency to bind with sediment and possibly become incorporated in substrate interstitial water (Gundlach et al. 1981), thus persisting for up to several years.

Rather arbitrarily, we rate the Grass/Shrub Transition zone as 5 (oil likely to persist for several years or more). The rationale is that neither moderate- nor high-energy "cleansing" events appear to be frequent here.

The data available suggest that much of this zone may not be flooded annually by river overflow. (Note that these data are few and our interpretation of them may be misleading.) Storm surge inundations are relatively infrequent, and most likely to be low-energy events this far from the coast.

In summary, all zones that are susceptible to oiling are moderately to highly vulnerable on our scale in terms of persistence times. (This is relative to all environments rated by Gundlach et al. [1981] in the northeastern Bering Sea.) The least vulnerable are those subject to frequent high-energy events (storm-generated wave action, river scour) that would tend to clean substrates. The most vulnerable are those where high-energy events are absent or infrequent, and that have substrates (vegetation, fine-grained sediments) that tend to hold oil on the surface or within substrate pore spaces.

Will the Oil Harm the Biota?

The third type of vulnerability we consider is the response of important species of biota to having their habitats oiled. Important species are here defined to be those treated in the "Species Characterizations" section of this report (Table 1), and the Yukon Delta populations of which are recognized as important for sport , subsistence, or commercial harvest, or as aesthetically valuable populations. Similarly to treatment of the other two classes of vulnerability, we use a scale of 1 to 5 to rather arbitrarily determine whether each zone's biota is vulnerable to having its habitat oiled. A description our our scale of vulnerability follows.

Rating	Vulnerability of Biota to Oil
1	No significant adverse effects to important species populations or their food chains are anticipated.
2	Small proportions of food supplies for important populations could be lost for one to several years.
3	Small proportions of important delta species populations could suffer direct increased mortality and/or decreased recruitment for one to several years; or important populations could lose large proportions of their delta food supply for one to several years.
4	Large proportions of important species populations that use the delta could suffer direct increased mortality and/or decreased recruitment for one year.
5	Large proportions of important species populations that use the delta could suffer direct increased mortality and/or decreased recruitment for several years.

Our estimates of the relative vulnerabilities of each zone in terms of the biota that uses it are as follows:

Ecological Zone	Biological Use Vulnerability
Highlands	Not susceptible to oiling
Delta Uplands	3
Grass/Shrub Transition	5
Grass/Shrub Meadows	5
Tidal Meadows	5
Coastal Mudflats	5
Minor Distributaries	5
Major Distributaries	3
Delta Platform	4
Delta Front	2
Marine Environments	2

With the exception of the Highlands zone, which is not susceptible to oiling, all zones appear vulnerable to some level of adverse effect. The deep-water zones are less vulnerable than shallow-water or terrestrial areas.

Five zones--Grass/Shrub Transition, Grass/Sedge Meadows, Tidal Meadows, Coastal Mudflats, and Minor Distributaries--are rated most highly vulnerable. Large amounts of oil spilled could cause, in each of these zones, increased mortalities and/or decreased recruitments for up to several years of large proportions of important delta waterfowl, and perhaps shorebird, populations. Oil in Grass/Shrub Transition, Grass/Sedge Meadows, Tidal Meadows, and Minor Distributary zones could cause direct mortality, decreased hatching success of eggs, and decreased survival of young (see reviews in LGL Alaska Research Associates 1982; Bourne 1968; Holmes and Cronshaw 1977) in the large proportions of delta populations that annually use these habitats. Oil on Coastal Mudflats could cause mortality/morbidity in the large pintail populations that feed there and perhaps could have similar adverse effects on several shorebird species populations that feed there.

In the Delta Platform zone (rating of 4) populations of salmon juveniles and molting seaducks are of greatest concern. Oil in this region could conceivably cause large mortalities among one or more salmon species at the stage of their lives when they are most sensitive to oil and least able to avoid it (see review by Rice et al 1983). Oil would almost certainly adversely affect the scoter and eider populations that molt there in summer. Neither oil nor its immediate effects would likely persist more than one year in toxic quantities in the water column or on the water surface in this environment.

Two zones--Delta Uplands and Major Distributaries--are rated 3, that is, small proportions of important populations could directly be affected. Included would be the effects of oil introduced by salt wedge intrusion on salmon juveniles or perhaps on overwintering anadromous species in Major Distributaries. Most adult fish using the main channels would presumably avoid harmful concentrations of oil (see review by LGL Alaska Research Associates 1982) though it could delay or alter their normal migrational patterns, and thus might affect population recruitment (Starr et al. 1981). On the Delta Uplands, the absence of nesting or other uses by large proportions of delta populations preclude a greater vulnerability rating, though the small numbers of geese and ducks that nest there could probably be adversely affected for up to several or more years.

In the Delta Front and Marine Environments, we cannot conceive of more than small proportions of populations being affected. This zone is quite extensive, oil is unlikely to affect large portions of the zone, and most vertebrates that use the zone (fishes, marine mammals) are capable of avoiding oil in water or in benthic environments.

Summary and Discussion

Table 6 summarizes vulnerability ratings by ecological zone as discussed in this section. Recall that a rating of 1 indicates lowest vulnerability, 5 indicates highest vulnerability. Attempting to combine these ratings into one rating per zone is inappropriate. By so doing, we would lose sight of why given ratings were assigned, and thereby be less able to define strategies for environmental protection.

Table 6. Vulnerability ratings of ecological zones in the Yukon River delta, Alaska, in terms of three classes of vulnerability (1 = lowest vulnerability, 5 = highest) (see Fig. 26 for depiction of zones).

Ecological Zone	Type of Vulnerability		
	Oil Contact	Oil Persistence	Biological Use
Highlands	1	-	-
Delta Uplands	2	3	3
Grass/Shrub Transition	2	5	5
Grass/Sedge Meadows	4	4	5
Tidal Meadows	4	4	5
Coastal Mudflats	4	4	5

(continued)

Table 6. (continued)

	Type of Vulnerability		
Ecological Zone	Oil Contact	Oil Persistence	Biological Use
Minor Distributaries	4	4	5
Major Distributaries	4	3	3
Delta Platform	5	4	4
Delta Front	5	3	2
Marine Environment	5	3	2

From this table we see that oil contact is judged most likely to occur in the marine and coastal aquatic environments and least likely to reach the highest terrestrial environments. We also see that oil is likely to persist longer and to cause biological problems of greatest concern in environments at the coast and inland as far as the Delta Uplands.

Given that the zones at and just above sea level are highly vulnerable in terms of oil persistence and biological use, then their vulnerability to oil contact becomes of large concern. We have seen that relatively small increases in sea level and wave height can cause water (and oil carried by water) to move far inland. We have also noted that the vulnerabilities of these lower terrestrial zones are highly responsive to two factors--the frequency of storms that would inundate areas increasingly farther inland and the duration of large amounts of oil in waters off the delta. Neither of these factors is readily predictable given existing information.

The "Environmental Hazards and Pollutant Transport" section in this volume analyzes existing data to give a general prediction of the extent of delta inundation under extreme storm events. But this section does not and cannot, at the current level of knowledge, give expected frequencies of inundation of various zones.

FURTHER INFORMATION NEEDS

The Yukon Delta presents somewhat of a paradox in terms of the importance of its resources and the level of scientific endeavor that has been focused there. The abundance of fishes of commercial and subsistence use, and waterfowl of international significance, is tremendous. Large proportions of regional or world populations of several species of birds and fishes use the area. The influence of river discharge on productivity of the northern Bering Sea and the Chukchi Sea is unclear but probably great. Yet scientific research conducted in the area has been sporadic, and frequently focused on a few specific issues, such as salmon harvest.

Thus in identifying critical research needs one must be selective, for there are many research gaps. To be selective, we will focus on those data gaps where answers appear imperative before the extent of impact of oil spills on important delta biota can be reasonably assessed. Thus the relative importance of a population (judged by whether it is unique, large, harvested for human use, or otherwise high profile) is one factor by which we judge need; the other factor is the extent to which the new information would enhance the capabilities to predict impact.

In order of priority, the areas needing study are (1) estuarine environments, (2) terrestrial environments, and (3) marine environments. Studies needed are as follows.

Estuarine Environment

Physical processes in this environment are probably more in need of study than are biological problems. The greatest need is probably to refine estimates of frequency and seasonal timing of storm surges in terms of extent of delta inundation. The rationale is obvious: important populations of birds nest and feed in zones subject to frequent inundation. Only vague estimates of the chances of spilled oil reaching these various zones are available.

Second, the distribution, feeding dependencies, and residence times of juvenile salmon in the Yukon Delta estuarine region are almost entirely unknown. Existing data suggest they might spend considerable time in the estuary in the open water season, at a time when they are highly sensitive to oil pollution, feeding and acclimating to salt water. If so, the Yukon salmon fishery might be extremely sensitive to the effects of oil in estuarine environments at this time.

Third, the population levels, seasonal distributions, and feeding dependencies of non-salmonid anadromous fishes in the delta channels and on the delta platform are mostly unknown. A basic survey effort is needed in this area before the sensitivities of these populations to oil spills or other development-related actions can be evaluated.

The fourth greatest research need in this environment is to characterize the extent, flow characteristics, and seasonality of salt wedge intrusions into the delta channels. This phenomenon would be an important oil transport mechanism, may be important to annual shoreward replenishment of epibenthic food supplies to estuarine fishes and birds, and is probably important to anadromous fish that overwinter in the delta.

A fifth need in the estuarine environment is to investigate the circulation and transport patterns responsible for (1) maintaining the clear water and resultant plant production in the interdistributary zones near the shore in which waterfowl feed, and (2) maintaining or annually replenishing the invertebrate populations in these zones, in mudflats, and in tidal sloughs on which shorebirds, waterfowl, and probably estuarine fishes, feed. Determining the vulnerability of this important portion of the estuarine food web to oil pollution depends on answers to these questions.

Finally, aerial surveys need to be conducted in the delta platform area in mainly July and August to determine the distribution and abundance of molting/feeding scoters, eiders, and other waterfowl that occur beyond the coastal mudflats. These birds would be highly susceptible to spilled oil.

Terrestrial Environment

The primary research need in the terrestrial environment is to conduct intensive basic surveys between early May and October to determine the distribution, abundance and use patterns of the entire delta (including mudflat areas) by waterfowl,and, secondarily, by shorebirds. These need to be conducted for more than one year to help evaluate the annual variability in bird abundance and distribution. By coupling these data with more precise information on frequency, seasonal occurrence, and delta inundation potential of storm surges, hazards of oil spills to terrestrial birds can be better predicted. Note that extensive surveys of this nature have been conducted, particularly on waterfowl, in areas south of Cape Romanzof in the Yukon-Kuskokwim Delta area, but very few such surveys have been carried out on the Yukon Delta in our study area.

A second need is to evaluate the response of geese (brant, emperor geese, delta Canada geese subspecies, and white-fronted geese) and perhaps feeding pintails, to oil in their nesting and feeding habitats. This would require an experimental oil spill, so perhaps would be impractical. (Some information could be reasonably extrapolated from existing literature.) Such things as whether geese avoid oil on land, whether oiled nesting habitat invariably means oiled eggs with reduced hatching success, whether oiled vegetation is ingested and what the consequences are, etc. would be candidate hypotheses for such a study. Until some evaluation of their responses to oiled habitats is available, the effects of oil on waterfowl in these very important terrestrial environments will remain speculative.

Marine Environment

We see no high-priority needs at this time for research in the marine environment off the Yukon Delta. First, a moderate amount of survey work on fishes, epibenthic invertebrates, and marine mammals has been recently carried out in western Norton Sound. (Equivalent levels of survey have not been conducted in estuarine and terrestrial environments.) Some of the data from those studies were taken in our study area; other data may reasonably be applied to marine environments in the study area. Second, almost invariably, populations of important species that use the marine environments of the study area find more favorable environments elsewhere in the Bering/Chukchi region; the study area is not a "special" environment for them.

One area of marine research that does appear important and has not been addressed in depth is the nutrient and carbon contribution of Yukon River discharge to marine food webs. Fortunately a large-scale, interdisciplinary study has already been launched, and thus we do not recommend work in this area. Thus study is called Inner Shelf Transfer and Recycling (ISHTAR); its Principal Investigator is Dr. C. P. McRoy of the University of Alaska (see McRoy et al. 1983).

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APPENDIX. FORECAST PROCEDURES (Wise et al. 1981).

I. Definitions

A. SURGE - the height of the ocean's surface above forecast (tidal) levels.

B. FAVORABLE RELATIVE FETCH WIND DIRECTION - Assume the coastal configuration to be straight line segments as shown on Figure 20 When facing seaward the *relative* wind direction is measured *clockwise* from the coast. Thus the coast to the left is 0°; seaward +090°; to the right 180°. If to the left and offshore, it has negative values. Favorable relative wind directions are:

Sector	Favorable Direction
1	-020 to 090
2	-020 to 090
3	080 to 140
4	010 to 050
5	-050 to -010
6	040 to 090
7	020 to 090
8	120 to 190
9	030 to 100
10	-020 to 080
11	-020 to 120
12	050 to 150
13	-020 to 090
14	070 to 120
15	010 to 090
16	-020 to 090

In an idealized model the most favorable directions are from -020 to 090 but topography working in conjunction with gravity acting on anomalous sea surface slopes creates surges (generally of lesser magnitude) in areas wherein the wind is not blowing from an idealized "favorable" direction. The favorable directions *shown above* are those relative directions where the wind creates an anomalous sea height somewhere nearby that, in turn, affects the sector of interest.

C. FETCH - An area in which wind direction and speed are reasonably constant and do not vary past the following limits:

1) The wind direction or orientation of the isobars does not change direction at a rate greater than 15° per 180 nmi and the total changes does not exceed 30°.

2) The wind speed does not vary more than 20 percent from the average wind speed in the area of the direction fetch being considered. Example: average wind is 40; acceptable range is 32 to 48.

D. FETCH DURATION - the number of hours a coastal area is subjected to fetch winds.

E. LOWEST PRESSURE - The lowest pressure coincident with fetch induced surge.

F. SEA ICE COVERAGE (minimum expected during storm) - Percent of sea ice coverage in tenths.

G. SEA ICE CHARACTER - Primary concern is thinness and weakness. Thin or unconsolidated ice can be destroyed by storm action.

H. BOUNDARY LAYER STABILITY - The difference between the sea and air temperatures. The boundary layer temperature difference should be used when estimating the fetch wind speed. The following guidelines are suggested:

Correction to Geostrophic Wind for the
Sea-Air Temperature Difference

$T_s - T_a$	Percent of geostrophic winds used
0 or negative	60
0 to 10	65
10 to 20	75
20 or above	90

II. Procedure

A. Determine

1) Fetch wind (speed, and direction). Consider boundary layer conditions. If direction is favorable continue with determination of:
   a) fetch duration
   b) ice cover
   c) lowest pressure
   d) tidal variation if over 1 foot

B. Preliminary Surge Height - Using wind speed, read correlated surge height from appropriate coordinate labels (see Fig. 21, this volume).

C. Duration Adjusted Surge Height - If fetch duration is less than:

1) 3 hours reduce surge by 60 percent
2) 6 hours reduce surge by 40 percent
3) 9 hours reduce surge by 20 percent
4) 12 hours reduce surge by 10 percent
5) 12+ hours no reduction

D. Ice Cover Adjusted Surge Height - If ice cover is less than:

1) 1.5 tenths no reduction
2) 3.0 tenths reduce surge by 20 percent (cumulative to above)
3) 5.0 tenths reduce surge by 50 percent (cumulative)
4) 10.0 tenths reduce surge by 75 percent (cumulative)
5) Surges to 3 feet with 10 tenths ice cover have been reported with ice to 3 feet thick between October and January. Also, consider sea ice character. Thin ice, weak, ice, or unconsolidated ice can be effectively destroyed during storm conditions—particularly in the northern Bering Sea, with subsequent surges to 9 feet.

E. Pressure Adjusted Surge Height - Raise the surge height one foot for every 30 mb pressure increment below 1004 mb.

F. Tidal Adjusted Surge Height - Check tide tables or other sources. If peak of surge is reasonably coincident with normal high water, make no correction. If surge misses normal high water, subtract as appropriate from surge height.

ECOLOGICAL CHARACTERIZATION OF THE YUKON RIVER DELTA

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Final Report
Outer Continental Shelf Environmental Assessment Program
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INTRODUCTION

This annotated bibliography is submitted to accompany the report Ecological Characterization of the Yukon River Delta submitted by LGL Ecological Research Associates (LGL) to the Outer Continental Shelf Environmental Assessment Program (OCSEAP) of the National Oceanic and Atmospheric Administration (NOAA). The purpose of the bibliography is to reference and briefly describe published and unpublished research that has been conducted wholly or partly in the study area designated for the Yukon Delta characterization study (Fig. 1).

Included in this bibliography are studies of biota, investigations of the physical and chemical components and processes that influence the biota, and research that analyzes the vulnerabilities of the biota and their habitats to impact from oil and gas development in Norton Sound. Some disciplines have been investigated to a limited extent in the area of study, but to a much greater extent in peripheral areas (e.g. birds in the Yukon-Kuskokwim delta areas south of the study area.) Reports of investigations that took place outside the study area are not included in this bibliography except when they occurred very near the study area and their results have obvious and strong implications for characterizing the study area. Research seeming to have no relevance to biota, its habitat, or its vulnerability to OCS development is not included.

This Bibliography has two parts, (1) Literature (published and unpublished) and (2) Interviews. The Literature section describes the printed material reviewed; the Interviews section summarizes the important information obtained via interviews with scientists. Within each section, listings are alphabetical by authors' or interviewed persons' last names.

To assist users in finding printed information by subject, an index is provided following the Literature section.

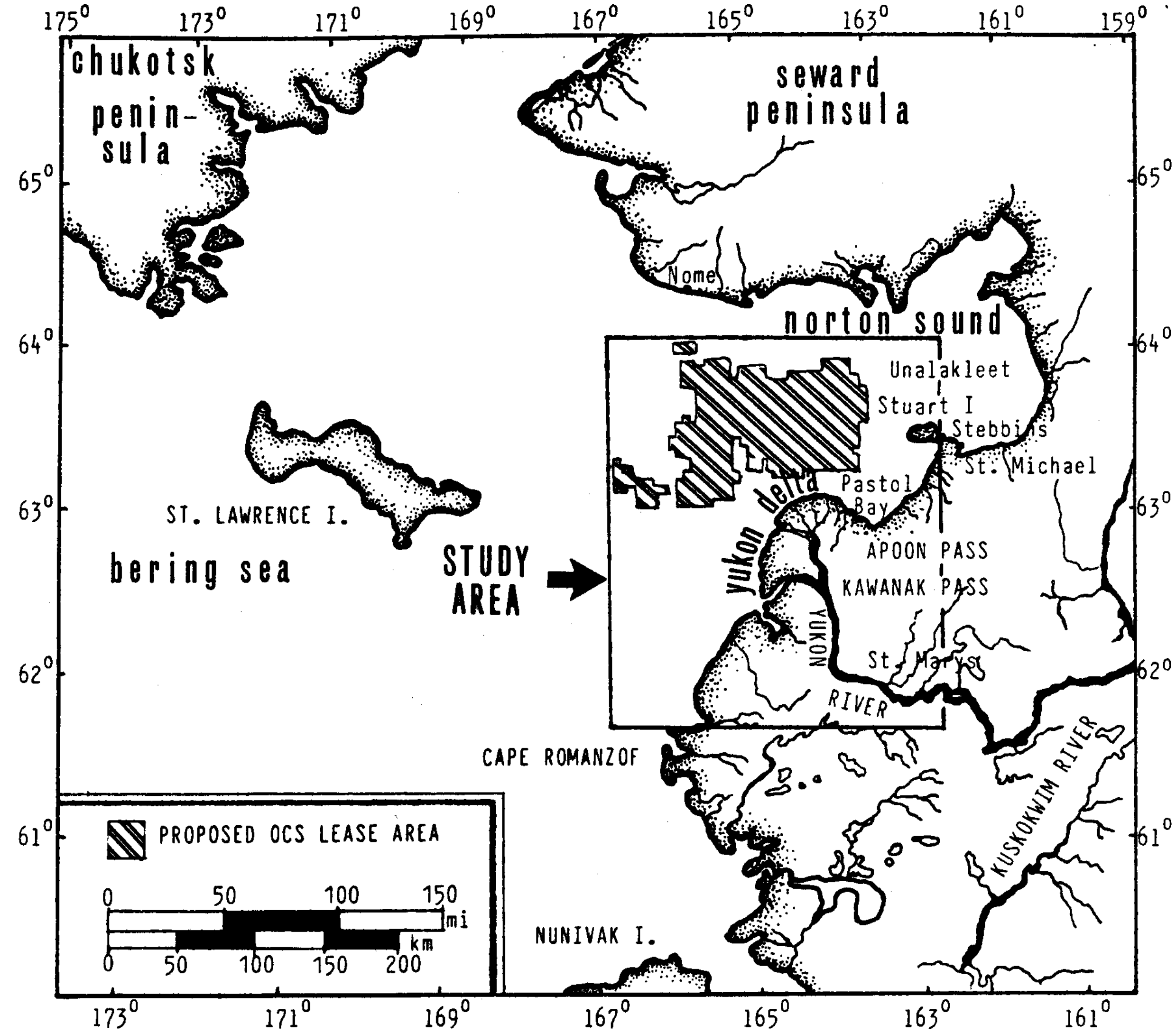

Fig. 1. Location of the area of emphasis for the study "Ecological Characterization of the Yukon River Delta."

PART 1. LITERATURE

1. ADF&G (Alaska Department of Fish and Game). 1981. Recommendations for minimizing the impacts of hydrocarbon development on the fish, wildlife and aquatic plan resources of the northern Bering Sea and Norton Sound. Maps. Prepared by ADF&G Habitat Division.

This map packet contains 17 maps (scale = 1:500,000) of the Norton Sound area including St. Lawrence Island. Depicted on these maps are (1) physical environmental phenomena (ice conditions, wind and circulation patterns, sediment transport directions, substrate and shoreline characteristics), (2) distributions of biological use (benthic invertebrates, marine and anadromous fishes, waterfowl and shorebirds, marine mammals), (3) subsistence use areas, and (4) sensitivities of areas to various potential aspects of hydrocarbon development in coastal waters of Norton Sound. These maps were developed to accompany Starr et al. (1981) (this bibliography). They provide a good regional overview of biological use, critical habitats,and threats to habitats, but the scale is too large to provide much detail about the Yukon delta.

2. ADF&G. 1981. File data - gill net (variable mesh) catches in the Yukon delta. Commercial Fish Division, St. Marys, AK.

In addition to their annual test fishing program for salmon in the Yukon delta, ADF&G used variable mesh gill nets to collect additional fish species at a site near the juncture of Middle Mouth (Kawanak Pass) and North Mouth (Apoon Pass). Fish caught during the summer of 1982 were pink salmon, whitefish (broad, humpback and round), sheefish, least cisco, pike and lamprey. A summary of these data will be represented in the 1982-83 salmon test fishing report for the lower Yukon River (J. Brady, ADF&G, pers. comm.). In terms of the present project, this information is one of the few available data sources describing the occurrence of fishes (other than adult salmon) in the Yukon delta.

3. Ahlnas, Kristina. 1981. Surface temperature enhanced NOAA-satellite infrared imagery for the Bering, Chukchi and Beaufort seas and the Gulf of Alaska. Univ. Alaska Inst. Mar. Sci. Rep. IMS R80-2.

This report gives a brief history of the NOAA-VHRR (very high resolution radiometer) satellite surveillance project in Alaska. An introductory explanation of the theory behind satellite imagery enhancement is given, and all archived enhanced negatives are listed by date, temperature range, and geographic location. Examples of satellite image of various parts of Alaska are shown. This report had little use in the Yukon delta characterization,but the satellite imagery described has great potential for helping to characterize physical oceanic processes in the delta region.

4. Alaska Governor's Agency Advisory Committee on Leasing. 1982. A draft social, economic and environmental analysis of the proposed Norton Basin Oil and Gas Lease Sale 38. Distributed by Alaska Department of Natural Resources, Juneau. 163 p. + Appendices.

This report is a draft environmental statement prepared in anticipation of the State of Alaska Lease Sale 38. This lease sale was to have included tracts in State of Alaska waters (within three miles of shore) in eastern and southwestern Norton Sound. Nearly the entire periphery of the modern Yukon delta was to have been included. A large amount of this report is on discussions of social, economic, subsistence, water quality, and risk analyses. However, useful background discussions of marine, estuarine and terrestrial biota are compressed into about ten pages. Because this report focuses to a great extent on the Yukon delta study area, it is a quite useful overview of biota for purposes of our study. Useful maps of resources and resource use accompany the report.

5. Alexander, V., and T. Chapman. 1981. The role of epontic algal communities in Bering Sea ice. Pages 773-780. In: D. W. Hood and J. A. Calder (eds.) The eastern Bering Sea Shelf: Oceanography and resources. Vol. 2. NOAA/OMPA, BLM. Juneau, AK.

This report summarizes and discusses what is known about ice algae production in the Bering Sea; discussions are based largely on work conducted in western Norton Sound and vicinity by the authors in April 1977. Ice algae appeared to be of temporal importance in the annual primary productivity cycle, but its production represented a small proportion of the total. The primary significance of this production probably lies in providing organic material in spring prior to water-colum production. The report appears to be relatively unimportant to the Yukon delta characterization study.

6. Allen, A. A. and H. Kyllingstad. 1949. The eggs and young of the bristle-thighed curlew. Auk 66:343-350.

During an expedition to the Mountain Village area in June 1948, the first two nests of the bristle-thighed curlew ever reported were discovered. The eggs and young are described in this paper. This paper was not useful for our study,though the location was in the Yukon delta study area. It was simply a narrative account of the curlew eggs and young.

7. Alt, K. T. 1979. Contributions to the life history of the humpback whitefish in Alaska. Trans. Am. Fish. Soc. 108:156-160.

Humpback whitefish were collected throughout Alaska using gill nets. Gill raker counts varied, but with no clear pattern that would justify defining more than one species. The most common age class sampled was VII, with fish maturing between V and VII, and some living to XIV. Annual migration patterns and spawning habits are described. Although some fish were collected from the Yukon River (Marshall), regional humpback whitefish habits are not described separately. This report was of minimal use in the Yukon delta studies.

8. Bakkala, R. G. 1970. Synopsis of biological data on the chum salmon, Oncorhynchus keta (Walbaum) 1972. F.A.O. Species Synopsis No. 41. U.S. Fish Wildl. Circular 315. 89 p.

This report is a comprehensive review of the scientific literature in English on chum salmon. Information presented includes nomenclature, taxonomy, morphology, distribution, ecology and life history, population dynamics,fishing, and protection and management. The report contains numerous data, including data on Yukon River salmon, as the available literature is quite extensive. The report was useful to a limited extent in providing sources for additional work on salmon in the Yukon River area.

9. Barton, H. 1979. Finfish resources survey in Norton Sound and Kotzebue Sound. Pages 75-313. In: Envir. Assess. Alaskan Cont. Shelf, Final Rep. Prin. Invest. Vol. 4. NOAA/OCSEAP, BLM. Boulder, CO.

The data for this report were obtained by aerial surveys, catch sampling, and questioning local residents about subsistence use. The data are presented in tables and figures in an appendix. The discussion in the text is organized by species. Herring, salmon, sand-lance and cod were among the most important species and preliminary reports of this study can be found in earlier OCSEAP annual reports of the same research unit as follows:

(1) Barton, L. H. Annu. Rep. Prin. Invest., Vol. 7. 1977.

10. Barton, L., & V. Wespestad. 1980. Distribution, biology and stock assessment of western Alaska's herring stocks. Pages 27-53. In: Proc. Alaska herring symposium. Alaska Sea Grant Rep. 80-4.

This paper reviews Pacific herring stocks in western Alaska, primarily the Bering Sea. The relationship between the Norton Sound stock and other major stocks in the Bering Sea is unclear. It is possible that a portion of the Norton Sound stock remains in Norton Sound all year rather than migrating to known offshore wintering grounds. The general biology and seasonal distribution of Bering Sea herring are discussed. This report provides a useful overview of a species which is most susceptible to perturbation during spawning, incubation and rearing stages, all of which occur in shallow shoreline environments which might be contaminated by an oil spill; however, herring spawning in the immediate vicinity of the Yukon delta is not known (but presumably negligible due to unsuitable spawning substrates).

11. Bartonek,J. C., and S. G. Sealy. 1979. Distribution and status of marine birds breeding along the coasts of the Chukchi and Bering seas. Pages 21-31. In: J. C. Bartonek and D. N. Nettleship (eds.) Conservation of marine birds of northern North America. USDI Fish Wildl. Ser., Wildl. Res. Rep. 11.

This paper reviews the available literature on breeding marine birds along the Chukchi and Bering sea coasts of Alaska. It points out the extensive amount of work on this topic in the Yukon-Kuskokwim delta, almost all of which has been done south of Cape Romanzof, in the vicinity of Hooper and Hazen bays. The authors note, however, that the avifauna of the aggrading portion of the Yukon delta (in our study area) have not been accorded similar attention. The paper has limited value to the Yukon delta study except to point out the general lack of data from mainland sites there.

12. Baxter, R. 1978. Yukon-Kuskokwim Delta whitefish studies. Alaska Fish Trails and Game Trails 11(4):18- 9.

This paper, based on Alaska Department of Fish and Game research, presents a brief description of whitefish occurrence and biology on the Yukon-Kuskokwim delta. Whitefish spend the summer in tundra waters feeding. During fall they move upstream to spawning and wintering grounds. They return downstream in the spring, arriving at summer feeding grounds after breakup. This provided useful background for our Yukon delta study.

13. Brady, J. 1983. Lower Yukon River salmon test and commercial fisheries, 1981. Alaska Dept. Fish and Game, Tech. Rep. 89. Juneau, AK. 91 p.

This report presents the 1981 data for adult salmon caught at two locations in the Yukon delta: Big Eddy near Emmonak and Middle Mouth near the divergence of the middle mouth (Kawanak Pass) and the north mouth (Apoon Pass). Target species were chinook, chum and coho salmon which were caught by gill net from 28 May to 30 August 1981. Timing of salmon runs into the Yukon River were monitored; mid-point dates of runs were: chinook (15 June), summer chum (22 June-1 July), fall chum (2 August), and coho (17 August). Appendix tables of this report list other fishes caught in the test fishery: pink and sockeye salmon, arctic char, sheefish, whitefish, burbot and pike. In terms of the present project, this report provides information about migration timing of important salmon species, but because of the sampling gear used (large mesh gill nets), catches of smaller fish species may not be representative of their abundances.

14. Braham, H. W., J. J. Burns, G. A. Fedoseev, and B. D. Krogman. 1983. Habitat partitioning by ice-associated pinnipeds: Distribution and density of seals and walruses in the Bering Sea, April 1976. Unpublished report. 37 p. plus figures.

This report analyzes the results of aerial surveys conducted over the Bering Sea pack ice in April 1976. Results showed that walruses and ringed, ribbon, spotted, and bearded seals partitioned the habitat by distributing themselves differently according to north-south and east-west gradients. Surveys flown included the Norton Sound area. This is a very useful paper; it helps explain the seasonal patterns of seal and walrus distribution in the Yukon delta study area and vicinity.

15. Braham, H. W., C. H. Fiscus and D. J. Rugh. 1977. Marine mammals of the Bering and southern Chukchi Seas. Pages 1-99. In: Assess. Alaskan Cont. Shelf, Annu. Rep. Princ. Invest. Vol I, Receptors-Mammals. NOAA/OCSEAP, BLM. Boulder, CO.

This report is based on two years of field work and information from the literature. The patterns of spatial and temporal distribution of marine mammal species are presented, to the extent known. Sightings are discussed, and data gaps delineated. In general, information on pinnipeds was more complete than for cetaceans, and information on fall distribution in the northern Bering-Chukchi Seas was more complete than information on spring distribution. Relatively few survey transects were located in Norton Sound and the Yukon delta study area relative to the intensity of survey to the west and south. Other OCSEAP reports of this and a related research effort (RU 069) include:

(1) Braham, H. W., and B. D. Krogman. Annu. Rep. Prin. Invest. Vol. 1. 1977.

(2) Braham, H. W., and B. D. Krogman. Annu. Rep. Prin. Invest. Vol. 1, 1978.

(3) Fiscus, C. H., and H. W. Braham. Annu. Rep. Prin. Invest. Vol. 1, 1976.

16. Brooks, J. W. 1979. Status of marine mammal stocks in Alaska. Pages 59-69. In: Proc. 29th Alaska Sci. Conf., Fairbanks.

This report summarizes available information on the distribution and abundance of whales, porpoises, seals, walrus, sea otter, and polar bear in Alaskan waters. Little information relevant to the Yukon delta study is presented, though the author mentions belukhas in Norton Sound and the Yukon delta estuary. This is a relatively unimportant paper in terms of utility to the Yukon delta study; other more recent and complete data are available.

17. Brower, W. A., H. W. Searby, and J. L. Wise. 1977. Climatic atlas of the outer continental shelf waters and coastal regions of Alaska, Bering Sea. Vol. 2. NOAA/OCSEAP, BLM. Boulder, CO.

This atlas describes climatology and provides data summaries of surface marine and atmospheric parameters for the outer continental shelf waters and coastal regions of the Bering Sea, including the Yukon delta study area. Its object is to serve as an environmental guide in assessing potential impact of oil and gas exploration and development. The outcome of OCSEAP Research Unit 347, it is preceded by preliminary OCSEAP reports such as:

(1) Wise, J. L., and W. A. Brower. Annu. Rep. Prin. Invest., Vol. 15, 1977.

18. Burbank, D. C. 1979. Drift bottle trajectories and circulation in the NE Bering Sea and SE Chukchi Sea. Alaska Dept. Fish and Game, Marine/Coastal Habitat Manage. 16 p. plus appendices.

A surface drift bottle study was conducted during the summer of 1979. These data, in addition to circulation data from the literature, were used to map the surface circulation patterns of Norton Sound and areas of the Bering and Chukchi Seas. Currents were found to be northward along the Yukon-Kuskokwim delta and through the Bering Strait. Surface currents followed the coastline northeast and eastward into Norton Sound, resulting in more inflow than had been previously believed. This is a very useful study; it is one of the few circulation studies that has addressed currents very near the shore over the Yukon delta platform.

19. Burns, J. J. 1962 - 1972. Marine mammal investigation. Work plan segment reports. Fed. Aid in Wildl. Rest. Alaska Dept. Fish and Game.

<u>1963 W-6-R-4, p. 12-16.</u> The number of hair seals (including bearded, ringed, ribbon and spotted seals) harvested in western Alaska during 1963 was estimated at 16,500-18,000. The author described the bounty program ($3 per seal) and concluded that it was unnecessary, given the high economic value of seal skins.

1964 W-6-R-5,6, p. 22-45. This report is a description of the biology of bearded seals, based on observations and specimens collected from 1962 through 1964. Most of the data presented are morphological data such as weight and length of foetuses, pups and adults. Distribution, harvest, and future needs are also discussed.

1965 W-6-R-6, W-14-R-1, p. 40-47. The number of hair seals (including bearded, ringed, ribbon and spotted seals) harvested in western Alaska in 1965 was estimated at a minimum of 21,015. Progress on the study of the biology of these species is reported.

1966 W-12-R-1,2, p. 28-44. This report contains a description of marine mammal pupping, much of which was later published in the Journal of Mammology (Burns 1970). It also contains a resume of the findings of studies on bearded seals, reported previously (see 1964 report). The 1966 hair seal harvest (including bearded, ringed, ribbon and spotted seals) for western Alaska was estimated at 15,000 animals.

1967 W-14-R-2,3, p. 1-7. The number of hair seals (including bearded, ringed, ribbon and spotted seals) harvested in western Alaska during 1967 was estimated at 13,000. The magnitude of Soviet seal hunting is also discussed, and estimated at twice the Alaskan harvest.

1968 W-14-R-3, W-17-1, p. 1-25. This report contains a description of the biology of ribbon seals based on collections and observations during 1967 in western Alaskan waters. The distribution, growth and reproduction of ribbon seals are discussed. The 1968 hair seal harvest (including bearded, ringed, ribbon and spotted seals) for western Alaska was estimated at 10,000-11,000 animals.

1972 W-17-3,4,5, p. 1-29. This report contains a description of research undertaken on the life history of spotted seals. Research included tagging and recovery to verify seal movements, with most data from the southern Bering Sea. Species status reports are presented on spotted, ribbon, bearded and ringed seals. These status reports include distribution and migration, abundance and trends, general biology, pathology, ecological problems, allocation problems, regulation, and current research and funding. The 1971 hair seal harvest (including bearded, ringed, ribbon and spotted seals) for western Alaska was estimated at 17,500 animals. The 1972 harvest was estimated at 13,500 seals.

Note: These reports do not deal with Norton Sound specifically, though data from villages around Norton Sound are included in the harvest totals.

20. Burns, J. J. 1970. Remarks on the distribution and natural history of pagophilic pinnipeds in the Bering and Chukchi Seas. J. of Mammology 51(3):445-454.

This paper is based on Alaska Dept. of Fish and Game investigations from 1962 to 1970. Five species are discussed: ringed seal, bearded seal, spotted seal, ribbon seal and walrus. A brief species description is followed by a discussion of the spatial and temporal distribution of the mammals. The author concluded that breeding adults separated, and could be found in different habitats during spring: spotted seals and ribbon occupied the southern edge of the ice, ringed seals used land-fast ice, and bearded seals were found in pack ice. By extrapolation, and according to a figure in this paper, ringed seals and bearded seals would be expected to use the Norton Sound area for pupping and breeding. The paper concludes with a discussion of the possible ecological reasons for this distribution, and its implications for hunting success. It is a good general reference for seal habitat use in Norton Sound and vicinity.

21. Burns, J. J., and T. J. Eley. 1978. The natural history and ecology of the bearded seal (*Erignathus barbatus*) and the ringed seal (*Phoca hispida*). Pages 99-162. *In*: Envir. Asess. Alaskan Cont. Shelf, Annu. Rep. Prin. Invest. Vol. 1. NOAA/OCSEAPP, BLM. Boulder, CO.

The authors summarized available literature and collected additional data on several aspects of the ecology of ringed and bearded seals--reproduction, distribution, abundance, habitats, food habits, and subsistence use. The region of study included the Bering, Chukchi, and Beaufort seas. Included in the study, but not an area of particular focus, was Norton Sound. The greatest value of this work is the probability that much of the data on habitat and food preferences can be extended to the Yukon delta study area; most of the data were taken elsewhere. Additional useful reports of this OCSEAP research project (RU 230) include:

(1) Burns and Eley. Annu. Rep. Prin. Invest. Vol. 1, 1976.

(2) Burns and Eley. Annu. Rep. Prin. Invest. Vol. 1, 1977.

22. Burns, J. J., L. H. Shapiro and F. H. Fay. 1981a. The relationship of marine mammal distributions, densities and activities to sea ice conditions. Envir. Assess. Alaskan Cont. Shelf, Final Rep. Prin. Invest. 11:489-670.

Distributions of marine mammals, determined by aerial and ship-board surveys from 1958 to 1979 were correlated with aerial photography and satellite imagery to determine causative relationships. A detailed description of pack, fast, fringe and front-zone ice is followed by a discussion of the distribution of marine mammals and their utilization of various ice habitats. Few of the data contributing to these analyses were from the Yukon delta study area, but much of the results is applicable to the area. Preliminary reports of this research can be found in earlier OCSEAP annual reports of Research Unit 248, including:

(1) Burns, J. J., L. H. Shapiro, and F. H. Fay. Annu. Rep. Prin. Invest. Vol. 1, 1977.

23. Burns, J. J., L. H. Shapiro, and F. H. Fay. 1981b. Ice as marine mammal habitat in the Bering Sea. Pages 781-797. In: D. W. Hood and J.A. Calder (eds.) The eastern Bering Sea shelf: Oceanography and resources. Vol. 2. NOAA/OMPA, BLM. Juneau, AK.

In this paper the function of ice as habitat for several species of marine mammals--seals, walrus, bowhead and belukha whales, polar bears--is discussed. Focus is not specifically in Norton Sound or the Yukon Delta study area, though notes on mammals and their response to ice in Norton Sound occur in several places. The main value of the paper is that it describes in a generic sense how mammals use ice-infested habitats; thus it becomes clear that ice is a major factor regulating mammal use of the Yukon delta region.

24. Burrell, D. 1978. Natural distribution and environmental background of trace heavy metals in Alaskan shelf and estuarine areas. BLM/NOAA, OCSEAP, Annu. Rep. 8:199-493.

This report is one of a series describing baseline levels and toxicities of heavy metal ions and sediment sizes in several marine regions of Alaska; sediment sizes and concentrations of heavy metals in sediment and water samples from Norton Sound are presented. In general, surficial sediments are coarser and heavy metal concentrations are lower than occur in the Gulf of Alaska. Also, all heavy metal concentrations from Alaskan marine samples were as low or lower than those recorded for similar unpolluted ocean environments in more temperate regions. These data provide baseline conditions prior to industrial development of the region.

25. Burrell, D. C., K. Tommos, A. S. Naidu, and C. M. Hoski. 1981. Some geochemical characteristics of Bering Sea sediments. Pages 305-319. In: D. W. Hood and J. A. Calder (eds.) The eastern Bering Sea shelf: Oceanography and resources. Vol. 1. NOAA/OMPA, BLM. Juneau, AK.

Based on analysis of samples taken on OCSEAP-sponsored cruises, biogeochemical data are presented for surficial Bering Sea sediments. Most analyses are for samples from the southeastern Bering Sea and Norton Sound. Sand-sized sediment predominated, gravel occurred locally nearshore, and mud was a minor component in all areas except near the Yukon River discharge. Heavy metal contents, and relationships between sediment substrate and benthos, were discussed for the southeastern Bering Sea but not for Norton Sound. This is a moderately important paper in that it compares substrates influenced by Yukon River discharge with those elsewhere in the Bering Sea.

26. Cacchione, D. A., and D. E. Drake. 1978. Sediment transport in Norton Sound--Northern Bering Sea, Alaska. Pages 308-451. In: Envir. Assess. Alaskan Cont. Shelf, Annu. Rep. Prin. Invest. Vol. 12. NOAA/OCSEAP, BLM. Boulder, CO.

In this study, hydrographic, geological and geophysical data were collected from shipboard in summer and additional winter data were collected from beneath the ice with helicopter support. Data collections were focused particularly in the areas off the Yukon River delta. Several findings were important to this study: (1) Transport of sediment from Yukon River discharge was generally northwest across the mouth of Norton

Sound (2) The eastern Norton Sound has weak or intermittent currents; sediments there are characteristic of those in low-energy environments (3) Storms play a major role in resuspension and transport of sediments northwest and west of the Yukon delta (4) Suspended sediment transport is active beneath the winter ice cover. Additional reports of this OCSEAP-funded research (RU 430) can be found in:

(1) Cacchione, D. A., and D. E. Drake. Annu. Rep. Prin. Invest. Vol. 18, 1977.

27. Cacchione, D. A. and D. E. Drake. 1979. Sediment transport in Norton Sound, Alaska. U.S. Geol. Survey, Open File Rep. 79-1555. 88 p.

Data for this report were obtained from sampling cruises in 1976 and 1977, winter sampling in 1976, and underwater sampling with the GEOPROBE system (a multi-instrumented bottom tripod). The authors recognized two different sedimentation regimes: quiescent and storm. Although occurring less than 10% of the time, the storm regime probably accounted for over 50% of sediment transport. Tidal currents were thought to be important agents of winter and non-storm sediment transport. Preliminary data and analyses for these studies can be found in earlier OCSEAP annual reports (see Cacchione and Drake 1978, this volume). These studies support findings of several others that sediment settling into western Norton Sound, probably derived largely from the Yukon River, may be largely ephemeral in that environment. The Chukchi Sea appears to be a more stable repository for these sediments.

28. Cline, J. D. and M. L. Holmes. 1977. Submarine seepage of natural gas in Norton Sound, Alaska. Science 198:1149-1153.

Analysis of samples of seawater from Norton Sound by helium extraction and gas chromatography revealed unusual concentrations of natural gas. The area of submarine seepage was located 40 kilometers south of Nome. The authors discuss these data with relation to geologic characteristics of the area, reaching the conclusion that the gases are of thermogenic rather than recent biogenic origin. This information has little relevance to the Yukon delta characterization study. Other related reports of this same OCSEAPP-funded research include:

(1) Cline, J. D. Envir. Assess. Alaskan Cont. Shelf, Quart. Rep. Prin. Invest. Vol. 3, Oct- Dec. 1976.

(2) Cline, J. D., and M. L. Holmes. Envir. Assess. Alaskan Cont. Shelf, Annu. Rep. Prin. Invest. Vol. 13, 1977.

(3) Cline, J. D., and M. L. Holmes. 1978. Anomalous gaseous hydrocarbons in Norton Sound: Biogenic or thermogenic. In: Proc. offshore Tech. Conf. OTC #3052.

29. Clukey, E., D. A. Cacchione and C. H. Nelson. 1980. Liquefaction potential of the Yukon prodelta, Bering Sea. Proc. 12th Ann. Offshore Tech. Conf.:315-325.

Data for this report were obtained from research cruises in 1976 and 1977, and from sampling using the GEOPROBE system (a multi-instrumented bottom tripod). According to engineering equations, a storm with 6 m wave height would theoretically liquify sediments to 3.5 m depth in one hour, though consolidation of sediments would reduce this potential. The authors conclude that the sandy silt of the Yukon delta may be susceptible to liquefaction during storms, possibly intensifying erosion and resuspension of sediments. The main value of this report is its description of potential geologic hazards to petroleum exploration and development in the Yukon delta area. Secondarily it shows that shallow bottoms in the area are unstable and thus perhaps poor habitat for certain benthic communities.

30. Coachman, L. K., K. Aagaard, and R. B. Tripp. 1975. Bering Strait: The regional physical oceanography. Univ. Washington Press, Seattle 172 p.

This book summarizes and discusses what is known about the physical oceanography of the Bering Strait region. Much of the field data were collected by the authors. The authors discuss the discrete water masses in Bering Strait,the patterns of current velocity and direction, and the effects of northward flow on the Chukchi Sea. They address numerical aspects of flow dynamics. This book is useful for giving a general picture of water mass identity, movement, and fate in the Yukon delta/ Norton Sound area and northward.

31. Coachman, L. K., R. L. Charnell, J. D. Schumacher, K. Aagaard, and R. D. Muench. 1977. Norton Sound/Chukchi Sea Oceanographic processes. In: Envir. Assess. Alaskan Cont. Shelf, Annu. Rep. Prin. Invest. Vol. 15. NOAA/OCSEAP, BLM. Boulder, CO.

This is the first annual report of a series on this subject under OCSEAP sponsorship. For a listing of additional reports and an overview of research conducted, see Muench et al. (1979) and Schumacher et al. (1978) (this volume).

32. Cooney, R. T. 1977. Zooplankton and micronekton studies in the Bering-Chukchi/Beaufort Seas. Pages 275-363. In: Envir. Assess. Alaskan Cont. Shelf, Annu. Rep. Prin. Invest. Vol. 10. NOAA/OCSEAP, BLM. Boulder, CO.

The primary study area for this OCSEAP-sponsored research was the southeastern Bering Sea. However, some sampling was done between the Yukon River and Point Hope in the Chukchi Sea during the summer of 1976, and results are presented in this report. The author concluded that a sparse plankton community existed during winter under the ice. As the ice melted, an oceanic assemblage moved northwards. A coastal community was also found, with high standing stocks of two cladocerans and a neritic copepod, together with numerous meroplanktonic species. This study had some value in relation to the Yukon delta characterization study in that few other zooplankton studies have been conducted in the northeastern Bering Sea. But generally most of the sampling done was outside our area of interest.

33. Copp, J. and M. F. Smith. 1981. A preliminary analysis of the spring take of migratory waterfowl by Yupik eskimos on the Yukon-Kuskokwim Delta, Alaska. U.S. Fish Wildl. Serv. Unpubl. Rep., Yukon Delta Nat. Wildl. Refuge. Bethel, Alaska. 53 p.

Data on bird and egg take by Yupik eskimos were collected during the summers of 1980 and 1981. The villages surveyed included two on the northern Yukon River delta--Kotlik and Mountain Village. The population characteristics of these villages, the hunters, and hunting results are presented in tabular format and discussed in the text. No conclusions were drawn as to population trends of bird species, but the authors did compare their findings with those of D. R. Klein (1966) (this volume). This is one of the few papers on waterfowl in which data from our Yukon delta study area are included, thus it is a relatively useful reference.

34. Cowles, C. J. 1981. Marine mammals, endangered species, and rare plants potentially affected by proposed federal lease sales in the northern Bering Sea and Norton Sound vicinity. Technical Paper No. 5. BLM, Alaska OCS Office. 19 p.

This report contains a summary of the biology of each potentially affected species. Marine mammals discussed include: spotted seal, ringed seal, bearded seal, ribbon seal, walrus, polar bear, beluga whale, minke whale, and killer whale. Endangered species discussed include bowhead whale, gray whale, humpback whale, fin whale, sei whale and peregrine falcon. Other endangered species and rare plants that have been known to occur in the area are mentioned. This provides one of the best summaries available of the use of habitats in the Yukon delta study area by marine mammals.

35. Cowles, C. J.,D. J. Hansen, and J. D. Hubbard. 1981. Types of potential effects of offshore oil and gas development on marine mammals and endangered species of the northern Bering, Chukchi and Beaufort seas. USDI Bureau of Land Management, Alaska Outer Continental Shelf Office. Tech. Paper #9. 23 p.

This paper summarizes information on types of potential effects on marine mammals, endangered species and rare plants that may be associated with oil and gas lease sales in the northern Bering Sea and arctic regions. It constitutes a new and experimental type of Environmental Impact Statement. It is not site-specific in the sense that data on effects come from many locations. In reference to Norton Sound and the Yukon delta study area, however, the presence of species of animals and the kinds of situations that exist to make them vulnerable to development actions are addressed. This is a useful paper in prediction of impacts in the study area.

36. Crawford, D. (no date). Lower Yukon River sheefish study. Unpub. rep. by Alaska Dep. Fish and Game. Anchorage, AK. 54 p.

This report describes the subsistence fishery for sheefish in the lower Yukon River, including catches at several sites in the Yukon delta (Kotlik, New Hamilton, Emmonak, Alakanut, Sheldons Point). Data were collected by interview and subsistence catch calendars during early and late winter, 1977-1978. Catches indicate species presence in winter (sheefish, whitefish, burbot, pike, lamprey, blackfish, grayling and

smelt), and timing of peak catch periods reflect periods of under-ice movements. In terms of the present project, this report was useful because winter data are extremely limited for the study area.

37. Dau, C. P., and S. A. Kistchinski. 1977. Seasonal movements and distribution of the spectacled eider. Wildfowl 28:65-75.

The authors review available information, much of which was collected by them, on movements and distribution of the spectacled eider in Alaska and Siberia. Observations show that nesting patterns are similar on their Alaskan and Siberian nesting grounds. Seasonal movements to and from nesting grounds are poorly known. Most of the Alaskan work contributing to this paper was done outside the Yukon delta of our study, largely on nesting grounds near Hooper Bay in the Yukon-Kuskokwim delta, where nesting densities in Alaska are greatest. The paper provides useful information on nesting and migration behavior but no useful site-specific information from within the Yukon delta study area.

38. Dau, C. P. and P. G. Michelson. 1979. Relation of weather to spring migration and nesting of cackling geese on the Yukon-Kuskokwim delta, Alaska. Pages 94-104. In: R. L. Jarvis and J. C. Bartonek (eds.) Management and biology of Pacific Flyway geese. O.S.U. Book Stores,Inc. Corvallis, OR.

The authors observed the spring migration and nesting of cackling geese from 1969 through 1978, near Hooper Bay. They found that photoperiod and weather determined the arrival time of spring migrants. Nesting depended on local snowmelt and the availabiligy of nesting sites. Delayed nesting resulted in smaller clutch sizes.

39. Drake, D. E., D. A. Cacchione, R. D. Muench and C. H. Nelson. 1980. Sediment transport in Norton Sound, Alaska. Mar. Geol. 36:97-126.

This paper reports on the results of 80 days of data from the GEOPROBES system (a multi-instrumented bottom tripod), as measured in the north-flowing current across the outer part of Norton Sound. Sediment transport during fair weather was found to be dominated by tidal currents. The level of sediment transport during stormy weather was found to be at least four times as high as during fair weather. This is an important paper supporting the findings of several others about the transport and fate of sediments discharged into Norton Sound by the Yukon river. Findings of this same study may also be found in Cacchione and Drake (1978, 1979) (this volume).

40. Drake, D. E., C. E. Totman and P. L. Wiberg. 1979. Sediment transport during the winter on the Yukon prodelta, Norton Sound, Alaska. J. Sed. Petrol. 49(4):1171-1180.

Measurements of sediment load were taken in Norton Sound during the summer of 1976 and 1977, and during the winter of 1977-78. Despite a reduction in runoff and sea momentum in winter, sediment loads and transport were found to be similar to those of summer. The authors concluded that tidal currents were responsible, re-working sediments deposited by the river during the summer. This is an important study relating to physical processes on the submerged portion of the Yukon delta.

41. Drury, W. H., J.O. Biderman, J. B. French, Jr., and S. Hinckley. 1978. Ecological studies in the northern Bering Sea: Birds of coastal habitats on the south shore of Seward Peninsula, Alaska. In: Envir. Assess. Alaskan Cont. Shelf, Annu. Rep. Prin. Invest. Vol. II, Receptors-Birds. NOAA/OCSEAP, BLM. Boulder, CO.

Field studies were conducted in northern Norton Sound to identify those aspects of wildfowl biology that deserved careful attention in order to avoid adverse impacts of hydrocarbon development on the birds. The research concentrated mainly on seabirds--black-legged kittiwakes, common murres, pelagic cormorants, glaucous gulls and others--that nested on cliffs. The use of Norton Sound waters by these birds was found to be strongly limited by distance from cliffs that birds would travel to forage. Most of the Yukon delta study area was beyond the normal foraging range of birds at Norton Sound cliff-nesting sites, thus this study had little direct importance to characterizing the Yukon delta area. But because of the insight the study offered to mechanisms regulating bird distribution and abundance in the region, it had considerable indirect importance. Other useful reports of this OCSEAP-funded study (RU 237) include:

(1) Drury, W. H. Annu. Rep. Prin. Invest. Vol. 2, 1976.

(2) Drury, W. H., and B. B. Steele. Annu. Rep. Prin. Invest. Vol. III, 1977.

42. Dupré, W. R. 1980. Yukon delta coastal processes study. Final report. In: Envir. Assess. Alaska Cont. Shelf, Ann. Rep. Prin. Invest. NOAA/OCSEAP, BLM. Boulder, CO.

This report describes results of extensive field investigations in the Yukon River delta area to characterize the depositional environment and associated geologic processes. Conclusions are very important to the Yukon delta characterization: (1) The depositional environments of the Yukon delta differ from most large river deltas in having a broad, shallow sub-ice platform and associated channels that are extensions of river distributaries; (2) The shallowness of Norton Sound and the marked seasonality of marine and fluvial processes cause a complex pattern of sediment resuspension and reworking; (3) The predicted paths and fates of transported sediment and pollutants are more complex than might be expected in deeper, more temperate delta estuaries. Previous reports of this OCSEAP research project (RU 208) tend to deal to a greater extent with the Yukon-Kuskokwim delta region to the south; they include:

(1) Dupré, W. R. Annu. Rep. Prin. Invest. Vol. 10, 1979.
(2) Dupré, W. R. Annu. Rep. Prin. Invest. Vol. 11, 1978.
(3) Dupré, W. R. Annu. Rep. Prin. Invest. Vol. 14, 1977.

43. Dupré, W. R. and R. Thompson. 1979. The Yukon delta: A model for deltaic sedimentation in an ice-dominated environment. Proc. 11th Ann. Offshore Tech. Conf.:657-664.

Field mapping of the Yukon delta from 1975-1978 resulted in identification of three types of sedimentation: ice-dominated, river-dominated, and storm-dominated. Ice-dominated sedimentation created a sub-ice platform, a feature not found in other deltas studied. The authors describe this platform, and suggest that it may be characteristic of deposition in an ice-dominated environment. This is one of the more important research papers in existence related to physical processes in the Yukon River delta.

44. Eisenhauer, D. I. and C. M. Kirkpatrick. 1977. Ecology of the emperor goose in Alaska. Wildl. Monogr. 57:1-62

Emperor geese were intensively studied from 1971 through 1973 on the southern side of Kokechik Bay. The authors also made some winter observations along the Alaskan Peninsula and at Adak Island. Published and unpublished reports pertaining to emperor geese were reviewed. This paper presents a comprehensive description of the distribution, feeding habits and life cycle of the emperor goose.

45. Ellanna, L. J. 1980. Bering-Norton petroleum development scenarios, socio-cultural systems analysis. Vols. I and II. Tech. Rep. No. 54. For Bureau of Land Management, Alaska OCS office.

These volumes deal with baseline social and economic conditions (Vol. 1) and the social and economic consequences of various scenarios of oil finds in Norton Sound (Vol. II). They focus little on ecosystem components or effects on these components, so were not as useful as most studies centered in Norton Sound.

46. Ellson, J. G., D. E. Powell and H. H. Hildebrand. 1950. Exploratory fishing expedition to the northern Bering Sea in June and July, 1949. USDI Fish and Wildl. Serv., Fishery Leaflet 369. 56 p.

This report contains a summary of previous investigations and knowledge of the Bering Sea, and a description of the results of 51 otter trawl days made in the northeastern Bering Sea and Norton Sound in June and July 1949. Bottom temperatures were recorded and their variation correlated with fish species occurrence. Flatfish, shrimp, tanner crabs and capelin were the most common species found in Norton Sound. The information presented here is useful but in general has been superseded by more recent and more extensive research efforts in Norton Sound.

47. Fathauer, T. F. 1975. The great Bering Sea storms of 9-12 November, 1974. Weatherwise Mag., Amer. Meteor. Soc. 28:76-83.

This paper describes the unusual phenomenon of two successive storms that caused flooding along much of the coast of western Alaska. Both storms approached Norton Sound from the southwest, driving water into the Sound and raising water levels 12.5 feet in Nome. Maps of successive air pressure patterns are presented. This is an important paper that describes the kinds of storms in the Yukon delta study area that would be particularly damaging to delta ecosystems should they coincide with large oil spills in selected locations.

48. Favorite, F., and T. Laevastu. 1981. Finfish and the environment. Pages 597-610. In: D. W. Hood and J. A. Calder (eds.) The eastern Bering Sea shelf: Oceanography and resources. Vol. 1. NOAA/OMPA, BLM. Juneau, AK.

These authors summarize existing knowledge of the biological and physical features of the eastern Bering Sea shelf ecosystem that are important to fishes. They provide a monthly chronology of mean environmental conditions and discuss distributions and spawning areas of major commercial fishes of the eastern Bering Sea. Norton Sound and the Yukon delta study area are occasionally referred to, but most discussions center on more southerly portions of the Bering Sea. The main value of the paper in reference to the Yukon delta study is that it discusses the processes and conditions (of temperatures, water depths) that cause the Norton Sound area to be less productive of fish than areas farther south.

49. Fay, F. H., R. A. Dieterich, L. M. Shutts, and N. K. Murray. 1979. Morbidity and mortality of marine mammals. Pages 1-34. In: Envir. Assess. Alaskan Cont. Shelf, Annu. Rep. Prin. Invest. Vol. I, Receptors--Mammals. NOAA/OCSEAP, BLM. Boulder, CO.

Authors located primarily by aerial survey, beached carcasses of marine mammals in the Beaufort, Norton, St. George, Bristol Bay, Kodiak, Cook Inlet and northeastern Gulf of Alaska OCS lease areas. Via necropsy, they determed causes of mortality. They found pathological conditions to be more common in pinnipeds from the Bering Sea than in those from elsewhere. They found that the rate of occurrence of gray whale carcasses has increased dramatically in the present decade. Few data are from the Yukon delta study area. Additional useful reports on this same NOAA/OCSEAP research project (RU 194) can be found as follows:

(1) Fay, F. H. Annu, Rep. Prin. Invest. Vol. 1, 1977.

(2) Fay, F. H. Annu. Rep. Prin. Invest. Vol. 1, 1978.

50. Feder, H. M., and S. C. Jewett. 1978. Survey of the epifaunal invertebrates of Norton Sound, southeastern Chukchi Sea, and Kotzebue Sound. Institute of Marine Science Tech. Rep. R78-1, Univ. Alaska, Fairbanks. 124 p.

Trawling operations carried out during the fall of 1976 yielded the data for this report. Echinoderms, primarily sea stars, comprised over 80% of the invertebrate biomass in Norton Sound. The biology as well as the distribution of invertebrates are discussed. This report is one of the few studies of benthic invertebrates in marine waters of the Yukon delta study area and was thus quite important for our Yukon delta study. This paper is similar to a report of the same study published under the auspices of OCSEAP (RU 502), who funded the study (see Feder and Jewett, 1978 OCSEAP Annual Report, below). Principal OCSEAP reports of this research are:

(1) Feder, H. M. Annu. Rep. Prin. Invest. Vol. 10, 1977.

(2) Feder, H. M., and S. C. Jewett. Annu. Rep. Prin. Invest. Vol. 1, 1978.

51. Feely, R. A., G. J. Massoth, and A. J. Paulson. 1981. The distribution and elemental composition of suspended particulate matter in Norton Sound and the northeastern Bering Sea shelf: Implications for Mn and Zn recycling in coastal waters. Pages 321-337. In: D. W. Hood and J. A. Calder (eds.) The eastern Bering Sea shelf: Oceanography and resources. Vol. 1. NOAA/OMPA, BLM. Juneau, AK.

The distribution and elemental composition of suspended particulate matter in Norton Sound and the northeastern Bering Sea shelf were studied by analyzing water samples taken in July 1979. Results showed that the bulk of suspended material in Norton Sound consisted of (1) sedimentary material discharged from the Yukon River and (2) resuspended bottom sediments. Carbon and nitrogen in samples were primarily from terrestrial organic material in estuarine samples and marine organic material in offshore samples. Enrichment of Mn and Zn in offshore samples was attributed to Mn recycling in the sediments and the resulting Mn oxyhydroxides scavenging Zn. This paper provides some of the best available data for helping determine the importance of Yukon River discharge to Bering Sea biota.

52. Fiscus, C. H., and H. W. Braham. 1976. Resource assessment: Abundance and seasonal distribution of bowhead and belukha whales--Bering Sea. Pages 141-158. In: Envir. Assess. Alaskan Cont. Shelf, Annu. Rep. Prin. Invest. Vol. 1. NOAA/OCSEAP, BLM. Boulder, CO.

One of the first annual reports by the National Marine Fisheries Service to OCSEAP of an ongoing study of the distribution and abundance of marine mammals (see also Braham et al. 1977, this volume), this report is brief and relatively uninformative relative to whales in the

Yukon delta study area. Additional OCSEAP-sponsored research relative to this effort include:

(1) Braham, H. W., C. H. Fiscus, and D. J. Rugh. Annu. Rep. Prin, Invest. Vol. 1, 1977.

(2) Braham, H. W., and B. D. Krogman. Annu. Reps. Prin. Invest. Vol. 1, 1977 and 1978.

53. Frost, K. J., L. F. Lowry, and J. J. Burns. 1982. Distribution of marine mammals in the coastal zone of the Bering Sea during summer and autumn. Envir. Assess. Alaskan Cont. Shelf, Fin. Rep. Prin. Invest. NOAA/OCSEAP, MMS. (In press).

The purpose of this study was to compile all available sightings of marine mammals in the coastal zone of the eastern Bering Sea during summer and autumn and to evaluate the importance of coastal areas to the various species. Specific attention was focused on identifying terrestrial hauling areas used by pinnipeds; and bays, lagoons and estuaries used by cetaceans. The Yukon delta study area was identified as particularly important to belukhas. Other mammals that occurred in the deeper waters of Norton Sound in the study area were bearded and ringed seals and gray whales. Spotted seals hauled out in nearby coastal areas. This report was very useful in the context of the Yukon delta characterization study.

54. Gaudet, D. M., and G. Schaefer. 1982. Migrations of salmon in Norton Sound, Alaska, determined by tagging in 1978-1979. Alaska Dept. Fish and Game, Info. Leaflet No. 198. Juneau, Alaska. 43 p.

Tagging and recovery data were used to delineate salmon migration patterns in Norton Sound. The authors' conclusion was that salmon caught in Norton Sound were generally not bound for other regions, but were headed to spawn in nearby rivers. A main migration route was hypothesized, in the middle of Norton Sound. The data presented were important in helping to characterize use of the study area by adult salmon.

55. Geiger, M. F., F. M. Anderson, and J. Brady. 1982. Annual management report, 1982, Yukon area. Alaska Dept. Fish and Game, Div. Comm. Fish., Anchorage, AK. 148 p.

This report contains the majority of current and historical information about the management of commercial and subsistence fisheries in the north Yukon delta area. Data from many specific research projects are included; this report supersedes information found in previous management reports. Emphasis is on the commercial salmon fishery catch trends and stock status. Subsistence utilization and non-salmonid fishes are treated less exhaustively. This report was extremely useful in the Yukon delta characterization study.

56. Geiger, M., F. Andersen, and J. Brady. 1983. Yukon area commercial and subsistence salmon fisheries, 1983 management plan. Alaska Dept. Fish and Game, Div. Com. Fish., Arctic-Yukon-Kuskokwim Region, Anchorage, AK. 15 p.

This report describes ADF&G's management plans for the 1983 commercial and subsistence harvest in the lower Yukon River. The current status of Yukon salmon species is briefly described. Annual commercial catches in recent years (1978-82) have averaged almost 1.5 million salmon: chinook (133,000), summer chum (942,000), fall chum (323,000), coho (23,000). In terms of the present project, this report provides general background statistics about salmon runs in the Yukon River.

57. Gilbert, C. H. 1922. The salmon of the Yukon River. U.S. Bur. Fish. Bull. 38:317-332.

The data for this paper were gathered during the summer of 1920, at the mouth of the Kwiguk Channel on the South Mouth of the Yukon River. Two salmon species, king and chum salmon, are described in detail, with data on their life history and on the composition of the Yukon River runs. Sockeye, coho, and humpback salmon are discussed briefly. The data presented are important, but generally have been superseded by more recent data of similar kinds.

58. Gill, R. E., and C. M. Handel. 1981. Shorebirds of the eastern Bering Sea. Pages 719-738. In: D. W. Hood and J. A. Calder (eds.) The eastern Bering Sea shelf: Oceanography and resources. Vol. 2. NOAA/OMPA,BLM. Juneau, AK.

This paper provides an overview of shorebird resources of the eastern Bering Sea, based largely on work conducted since 1975. Shorebird relationships to littoral and supralittoral habitats of the area are discussed. The authors note the extreme importance of the Yukon-Kuskokwim delta region to shorebirds, particularly in late summer. The report is very important in that it emphasizes the Yukon-Kuskokwim delta region in many discussions; however, it is notable that very few data are available from the modern (north) Yukon delta emphasized in our study.

59. Grauvogel, C. 1973. Seal survey-inventory progress report - 1973. Game Management Units 17-26, coastal waters. Alaska Dept. Fish and Game, unpub. rep. 7 p.

This report presents seal harvest data from 1962-1972 from villages in western Alaska. A method for determining total seal harvests through sample villages is presented. Much of these data are from J. J. Burns' Annual Marine Mammal Reports, and includes eight villages on the Norton Sound coast.

60. Gundlach, E. R., J. L. Sadd, G. I. Scott, and L. C. Thebeau. 1981. Oil spill sensitivity of coastal environments and wildlife, Norton Sound and the Pribilof Islands, Alaska. In Envir. Assess. Alaskan Cont. Shelf, Final Rep. Prin. Invest. NOAA/OMPA, MMS. Juneau, AK. (In press).

Based on aerial and ground surveys of shorelines, these authors prepared environmental sensitivity maps of coastal Norton Sound and the Pribilof Islands, evaluating the sensitivity of coastal regions to oil spill. In the Yukon delta study area, almost all shorelines received high sensitivity ratings. Most shorelines bordering the Yukon delta proper were very sensitive (rating of 10 on a scale of 1 to 10). This is an important paper related to the Yukon delta characterization study; it shows the great sensitivity of coastal environments to spilled oil.

61. Gurevich, V. S. 1980. Worldwide distribution and migration patterns of the white whale (beluga), Delphinapterus leucas. Rep. Int. Whal. Comm. 30:465-480.

This paper includes a section on the general biology of the beluga, followed by a description of its distribution in various geographic regions. It is based on an extensive literature review, which incorporates Russian literature on the subject. The distribution of white whales in Alaskan waters is discussed, though data are scarce and conclusions sketchy. A map portrays Norton Sound as summer range, and the Yukon delta and lower Yukon River as part of the winter range. This is one of several papers that generally describes belugas as using Norton Sound and Yukon delta waters.

62. Gusey, W. F. 1979. The fish and wildlife resources of the Norton Sound region. Envi. Affairs, Shell Oil Co. Houston, Texas.

This book is a comprehensive catalogue of the fish and wildlife species found in Norton Sound. Birds are described by geographic region, and there are brief descriptions of mammals by species. The wildlife refuges of the area, and threatened or endangered species are described. A chapter on the fisheries and fish resources of the region completes the book. The data for this book are derived from scientific literature and personal communication with scientists doing research in the Norton Sound area. This book was moderately useful as background for the Yukon delta characterization study, but was too general for most purposes.

63. Hanley, P. T., W. W. Wade, G. S. Harrison and D. F. Jones. 1980. Alaska OCS socio-economic studies program, Norton Basin. OCS Lease Sale No. 57, petroleum development scenarios. Tech. Rep. No. 49. Prepared for Bureau of Land Mangement, Alaska OCS office, by Dames and Moore. 199 p. plus appendices.

This report includes reviews and analyses of (1) the petroleum technology that may be required to develop Norton Sound oil and gas reserves,(2) the petroleum geology of Norton Basin, (3) economic and manpower aspects of Norton Basin petroleum resource development and (4) facilities siting potentials in the area. Though it addresses the Yukon delta study area, we did not find it very useful in the context of objectives of the Yukon delta characterization study.

64. Hansen, D. J. 1981. The relative sensitivity of seabird populations in Alaska to oil pollution. USDI Bureau of Land Manage., Alaska Outer Continental Shelf office, Tech. Pap. No. 3. Anchorage, AK.

This paper represents a consolidation of information on potential effects of oil pollution on marine and coastal birds in Alaska. It is a partial substitute for a traditional type of Environmental Impact Assessment on the subject of effects on birds of OCS leasing in Alaska. General sensitivities of birds to oil are briefly discussed and a listing of Alaskan birds with high oil vulnerability indices is given. The Yukon and Kuskokwim river deltas are noted as perhaps the most critical bird nesting regions of Alaska in terms of potential damage to birds by oil pollution. This short report is a useful summary of hazards to birds of OCS development.

65. Hansen, H. A. 1961. Loss of waterfowl production to tide floods. J. Wildl. Manage. 25(3):242-248.

This paper is based on field work carried out by S. T. Olson on the Yukon-Kuskokwim delta in 1951, and C. Trainer and P. Sheperd on the Copper River delta in 1959. Density and distribution of waterfowl on the Yukon-Kiskokwim delta is described with regard to storm tide levels. Tenacity of nesting waterfowl on the Copper River delta during storm surges resulted in an 83 percent hatching success, despite innundation of nests.

66. Harrison, C. S., and J. D. Hall. 1978. Alaskan distribution of the beluga whale, Delphinapterus leucas. Canadian Field Nat. 92(3): 235-241.

These authors summarize results of observations of beluga whales in Alaska. On this basis they describe important locations of populations to be in the Gulf of Alaska, Cook Inlet, Northern Bristol Bay, and Norton Sound. They note several sightings in Norton Sound near the Yukon River mouth in summer, but have no data for this area in winter. This paper is moderately important; several other papers likewise report beluga whales near the Yukon delta in summer.

67. Hood, D. W., and J. A. Calder (eds.). 1981. The eastern Bering Sea shelf: Oceanography and resources. Vols. 1 and 2. NOAA/OMPA. Distributed by Univ. Washington Press, Seattle.

These volumes are a compilation of seventy papers dealing variously with physical and chemical oceanography, ice, geology, microbiology, plankton, benthic fauna, fisheries, birds and mammals of the eastern Bering Sea. A number of these papers discuss data collected in the Yukon delta project study area. As a unit these volumes are probably the best current source of information relevant to this study.

68. Hood, D. W., V. Fisher, D. Nebert, H. M. Feder, G. J. Mueller, D. Burrell, D. Boisseau, J. J. Goering, G. D. Sharma, D. T. Kresge, and S. R. Fison. 1974. Environmental study of the marine environment near Nome, Alaska. Univ. Alaska Inst. Mar. Sci. Rep. 74-3. 142 p. plus appendices.

The purpose of this study was to collect baseline data to define the sedimentary, biological, physical-chemical, and socioeconomic environments in the vicinity of Nome, Alaska. The biological and physical stations occupied were in Norton Sound just south of Nome. They barely impinged upon the northern limits of the Yukon delta study area as we have defined it, and thus are of questionable use in this bibliography. The data are useful, however, for generally characterizing the northern Norton Sound environment.

69. Hood, D. W., and E. J. Kelley (eds.). 1974. Oceanography of the Bering Sea, with emphasis on renewable resources. Proceedings of the International Symposium. Univ. Alaska Inst. Mar. Sci. Publ. No. 2. 623 p.

This book is a series of papers on physical, chemical and biological aspects of the Bering Sea. Emphasis is on southern parts of the Bering. Most papers have little or no direct utility for the Yukon delta characterization study. Papers that address portions of the Yukon delta study area include:

(1) Fay, F. H. The role of ice in the ecology of marine mammals of the Bering Sea. Pages 383-399.

(2) Konishi, R., and M. Saito. The relationship between ice and weather conditions in the eastern Bering Sea. Pages 425-450.

(3) Nelson, C. H., D. M. Hopkins, and D. W. Scholl. Cenozoic sedimentary and tectonic history of the Bering Sea. Pages 485-516.

70. Hoskin, C. M. 1978. Benthos-sedimentary substrate interactions. Pages 1-43. In: Envir. Assess. Alaska Cont. Shelf, Annu. Rep. Prin. Invest. Vol. 12, Hazards. NOAA/OCSEAP, BLM. Boulder, CO.

This author analyzed bottom sediment samples from Kotzebue Sound, Norton Sound and the southeastern Bering Sea. Most of the analytical effort focused on the southeastern Bering Sea, where the author attempted to determine the relationship between the grain size mode of bottom sediment, and distribution and abundance of macrobenthos. Some samples from Norton Sound were apparently from deeper waters of the Yukon delta study area; Norton Sound samples contained an average of 47 percent mud. Little useful information is presented in this report. This project is OCSEAP-funded research (RU 290); other project reports include:

(1) Hoskin, C. M. Annu. Rep. Prin. Invest. Vol. 13, 1976.

(2) Hoskin, C. M. Annu. Rep. Prin. Invest. Vol. 17, 1977.

71. Hunt, G. L., P. J. Gould, D. J. Forsell, and H. Peterson. 1981. Pelagic distribution of marine birds in the eastern Bering Sea. Pages 687-718. In: D. W. Hood and J. A. Calder (eds.) The eastern Bering Sea shelf: Oceanography and resources. Vol. 2. NOAA/OMPA, BLM. Juneau, AK.

These authors analyze existing data, including much collected by themselves,on the distribution and abundance of seabirds in the eastern Bering Sea. Most of the surveys and most of the birds were concentrated in the southeastern Bering Sea. Levels of surveys in the Norton Sound and in the Yukon delta study area were low; abundance of birds in the Yukon delta area was particularly low. The prime value of this paper is to show that seabird use of the Yukon delta study area is very low in comparison to seabird use of other parts of the Bering Sea.

72. Ingraham, W. J.,Jr. 1981a. Temperature and salinity observations at surface and near bottom over the eastern Bering Sea shelf, averaged by 1° x ½° squares. NOAA/NMFS, Northwest and Alaska Fisheries Center, Seattle, WA. 52 p.

This report summarizes available observations of temperature and salinity from the eastern Bering Sea on a monthly time and 1° x ½° space scale. Winter data are very limited. Summer data from Norton Sound and the Yukon delta study area show these areas to be generally colder (especially at bottom) and fresher than most other Bering Sea shelf areas. This is a useful summary of data, supporting what a number of other authors have said about waters of the Norton Sound area.

73. Ingraham, W. J., Jr. 1981b. Shelf environment. Pages 455-469. In: D. W. Hood and J. A. Calder (eds.) The eastern Bering Sea shelf: Oceanography and resources. Vol. 1. NOAA/OMPA, BLM. Juneau, AK.

This report presents monthly mean environmental conditions of ice, temperature, runoff and salinity for January-March, May and September for the eastern Bering Sea shelf area, including Norton Sound. Details on Yukon River runoff and apparent effects of this runoff on Norton Sound waters are presented. The author concludes that environmental conditions over the shelf are highly variable from year to year and that these variations presumably affect the distribution and productivity of fish and other biota. The main value of this paper is that it points out the great effect that physical environmental variables are likely to have on biota in the northern Bering Sea.

74. Jewett, S. C., and H. M. Feder. 1980. Autumn food of adult starry flounders, Platichthys stellatus, from the northeastern Bering Sea and the southeastern Chukchi Sea. J. Cons. Int. Explor. Mer, 39(1):7-14.

The stomach contents of 307 starry flounders collected during 1976 were analyzed and the results presented in this paper. Brittle stars and protobranch clams were the most common food sources. Many of the sample points were within Norton Sound, and data are presented separately for that area. Sand dollars were an important food source for starry flounders in the Norton Sound area, but not elsewhere. This report was useful in constructing food webs for the Yukon Delta study area.

75. Jewett, S. D., and H. M. Feder. 1981. Epifaunal invertebrates of the continental shelf of the eastern Bering and Chukchi seas. Pages 1131-1155. In: D. W. Hood and J. A. Calder (eds.) The eastern Bering Sea shelf: Oceanography and resources. Vol. 2. NOAA/OMPA, BLM. Juneau, AK.

Existing information on the distribution, abundance, and biomass of dominant epifaunal species, largely from the authors' own work, is reviewed. Species accounts are given. Though much of the discussions center on the commercially important species of the southeastern Bering Sea, the epifauna of Norton Sound is discussed at length. The biomass dominance of the Norton Sound epifaunal community by echinoderms (mostly sea stars) is quantified. This paper, one of the few that treats benthic marine fauna in the Yukon Delta study area, is an important one in characterizing that element of the study area fauna.

76. Jones, R. D., Jr., and M. Kirchoff. 1977. Waterfowl habitat on the Yukon Delta. Pages 419-446. In: Envir. Assess. Alaskan Cont. Shelf, Annu. Rep. Prin. Invest. Vol. 5. NOAA/OCSEAP, BLM. Boulder, CO.

The authors spent the summer of 1976 on the north delta of the Yukon River. Their report contains descriptions of the vegetation of the delta, as well as other physical characteristics such as air temperature, precipitation, and tidal variation. Bird species occurrence is described. Bird food sources, from rodents to isopods and other invertebrates, are also discussed. This and related reports of this OCSEAP-sponsored research on the outer fringes of the Yukon delta are unique and important efforts to document avian biota and its habitat use in this region. Related reports include Jones and Kirchhoff (1978) (this volume) and the following brief report:

(1) Jones, D. R. 1977. A winter habitat survey of the Yukon delta. Pages 447-451. In: Envir. Assess. Alaskan Cont. Shelf, Annu. Rep. Prin. Invest. Vol. 5. NOAA/OCSEAP, BLM. Boulder, CO.

77. Jones, R. D., Jr., and M. Kirchhoff. 1978. Avian habitats in the Yukon delta. U. S. Fish and Wild. Serv., Office of Biol. Serv., Coastal Ecosystems. Anchorage, AK. 32 p.

This report presents the results of a summer field study of the northern Yukon delta in 1977. Aerial transects were used to survey bird populations, trawl samples were collected to sample invertebrates, and soil fertility was tested. Results are presented in graphs, tables, and via an annotated bird species list, including habitat and food resource data when available. This is one of the most important biological reports available for the north delta of the Yukon River.

78. Kaplan, I. R., M. I. Venkatesan, S. Brenner, E. Ruth, J. Bonilla, and D. Meredith. 1979. Characterization of organic matter in sediments from Gulf of Alaska, Bering and Beaufort seas. Pages 597-659. In: Envir. Assess. Alaskan Cont. Shelf, Annu. Rep. Prin. Invest. Vol. 5. NOAA/OCSEAP, BLM. Boulder, CO.

These researchers analyzed sediment samples collected from several Alaskan continental shelf areas including Norton Sound. Total carbon, organic carbon, aliphatic and aromatic hydrocarbon contents of samples were determined. Norton Sound contained the highest percent terrigenous carbon of any shelf areas sampled but, as with other areas, the sediments in Norton Sound were generally unpolluted with hydrocarbons. This study has important implications for the role played by Yukon River discharge in

contributing to benthic food webs. Other useful reports of this OCSEAP-funded study (RU 480) include:

(1) Kaplan, I.R., W. E. Reed, M. W. Sandstrom, and M. I. Venkatesan. Annu. Rep. Prin. Invest. Vol. 13, 1977.

79. King , J. G., and B. Conant. 1983. Alaska-Yukon waterfowl breeding pair survey, May 16 to June 11, 1983. U. S. Fish Wildl. Serv. Unpubl. Rep. Juneau, AK. 22 p.

Over 3,000 miles of aerial survey transects were flown throughout Alaska during 1983. One hundred and forty-four of those miles were over the Yukon-Kuskokwim delta, covering all but the northernmost portion. This report presents the data from the 1983 survey, and also tables of past years' data. The authors concluded that conditions were favorable for all species of waterfowl except colonial nesting geese: emperor geese, cackling geese, dusky Canada geese and brant. As with past surveys, the major portion of the modern (northern) Yukon delta was not included in this survey. Though this paper gives a good general picture of waterfowl populations on the Yukon-Kuskokwim delta, density and abundance estimates cannot be reasonably extrapolated to our Yukon Delta study area.

80. King, J. G., and C. P. Dau. 1981. Waterfowl and their habitats in the eastern Bering Sea. Pages 739-753. In: D. W. Hood and J. A. Calder (eds.) The eastern Bering Sea shelf: Oceanography and resources. Vol. 2. NOAA/OMPA, BLM. Juneau, AK.

Available data are summarized to provide an overview of waterfowl use of eastern Bering Sea coastal habitats. The habitat types are defined and their temporal use by all species examined. Species accounts of the more abundant species are given. The great importance of the Yukon-Kuskokwim delta region is emphasized, and thus the report is of major importance to the Yukon delta characterization study. The lack of site-specific data from the modern (north) Yukon River delta region is evident; most existing data are from south of Cape Romanzof.

81. King., J. G., and C. J. Lensink. 1971. An evaluation of Alaskan habitat for migratory birds. U. S. Bur. Sport Fish. Wildl. Washington, D.C. 46 p. plus appendix

This report is based on Bureau of Sport Fisheries and Wildlife reports. It contains a two-page section on the Yukon Kuskokwim delta. Common migratory bird species are mentioned, along with a brief description of the major socio-economic factors affecting bird populations in that area--subsistence hunting and oil and gas development. Its focus is almost entirely on areas south of Cape Romanzof in the delta region, and thus outside our study area.

82. Kirchhoff, M. D. 1978. Distribution and habitat relations of pintails on the coast of the Yukon delta, Alaska. M.S. thesis, Univ. Maine at Orono. 45 p. plus appendices

The author conducted ground censuses of pintails in tidal meadows and mudflats of the northern Yukon delta, during the summer of 1977. Invertebrate organisms were sampled along transect lines. Pintail distribution was correlated to available food resources and feeding behavior, and conclusions drawn as to probable diet. Only three pintails were analyzed for digestive tract content because of the difficulty of collecting them. Carex seeds, mysids, isopods and potomageton seeds were determined to be probable major food sources. The paper includes a discussion of pintail distribution and food sources with relation to population size. This is the most important paper available on the use of tideflats and adjacent habitats by waterfowl on the north delta of the Yukon River.

83. Klein, D. R. 1966. Waterfowl in the economy of the Eskimos on the Yukon-Kuskokwim delta, Alaska. Arctic 19:319-335.

The author conducted interviews with hunters during 1964 and 1965 in 22 villages throughout the Yukon-Kuskokwim delta, including three villages on the northern Yukon delta study area. Socioeconomic and hunting data are presented for each village. Data for villages not visited were estimated from neighboring villages. For the Yukon-Kuskokwim delta as a whole, over 80,000 geese, almost 40,000 ducks, and 40,000 eggs were taken annually. This is one of the best papers on subsistence use that is available for that part of the Yukon delta in our study area.

84. Klein, D. R., and D. Seim. 1965. Spring and summer utilization of migratory waterfowl in western Alaska. Alaska Coop. Wildl. Res. Unit Quart. Rep. 16(3):14-40.

This progress report presents data collected at Yukon and Kuskokwim River delta villages on Waterfowl subsistence use. It is one of the few waterfowl investigations in the region in which data from our Yukon delta study area made an important contribution. Klein (1966) (this volume) reports on the same investigation; that report supersedes this one.

85. Klinkhart, E. G. 1966. The beluga whale in Alaska. Fed. Aid in Wild. Restor. Proj. W-6-R and W-14-R. Alaska Dept. Fish and Game. Juneau, AK. 11 p.

Based on available information up to 1966 this report summarizes beluga whale natural history and distribution in Alaska. Belugas are reported in the Yukon delta study area, as far as 60 miles upstream. This report has been superseded by several others on the same subject in recent years, and is no longer of significant importance.

86. Knebel, H. F., and J. S. Creager. 1973. Yukon River: Evidence for extensive migration during the Holocene transgression. Science 197:1230-1232.

Bathymetry and sediment core analyses, including carbon dating, are presented as evidence that the Yukon River mouth was south of Nunivak Island during the Wisconsin glacial maximum, and migrated northward during the Holocene sea level transgression. This report was not very useful for the Yukon delta characterization study.

87. Kvenvolden, K. A., G. D. Redden, D. R. Thor, and C. H. Nelson. 1981. Hydrocarbon gases in near-surface sediment of the northern Bering Sea. Pages 411-424. In: D. W. Hood and J. A. Calder (eds.) The eastern Bering Sea shelf: Oceanography and resources. Vol. 1. NOAA/OMPA, BLM. Juneau, AK.

In this study sediment samples from Norton Sound and vicinity were collected in 1976, 1977 and 1978 and analyzed for hydrocarbon gases. Methane, ethane, ethene, propane, propene, n-butane and isobutane were found to be common in these samples. At one site in Norton Sound, sediments were charged with CO_2. Results from this study have no clear value to the Yukon delta characterization study, though many of the samples were from the Yukon delta study area.

88. Kvenvolden, K. A., K. Weliky, C. H. Nelson, and D. J. Des Marais. 1979. Submarine carbon dioxide seep in Norton Sound, Alaska. Science 205:1264-1266.

These OCSEAP-sponsored authors report on biogenic and thermogenic gases in sediments of Norton Sound. The information is not useful for purposes of the Yukon delta characterization study. Related papers that resulted from the same OCSEAP research include:

(1) Kvenvolden, K. A., J. B. Rapp, and C. H. Nelson. 1978. Low modelcular-weight hydrocarbons in sediments from Norton Sound. Amer. Assn. Pet. Geol. Bull. 62:534.

(2) Kvenvolden, K. A., C. H. Nelson, D. R. Thor, C. W. Larsen, G. D. Redden, and J. B. Rapp. 1979. Biogenic and thermogenic gas in gas-charged sediment of Norton Sound, Alaska. Proc. Offshore Tech. Conf., OTC #3421:479-483.

89. LGL Alaska Research Associates, Inc. 1982. An evaluation of the environmental data base and environmental issues and concerns related to Bering Sea oil and gas exploration and development. Vol. II, Technical Report. Report to SOHIO Alaska Petroleum Company, Anchorage. 361 p.

This is a comprehensive review of physical and biological data for the Bering Sea and an analysis of potential impacts of OCS oil and gas operations. Issues, concerns and potential conflicts are discussed, as are recommendations for future actions. This is an important information sourcebook for information on Norton Sound and the Yukon delta study area (as well as for other regions in the Bering Sea).

90. Larsen, M. C., C. H. Nelson and D. R. Thor. 1979. Geologic implications and potential hazards of scour depressions on Bering Shelf, Alaska. Pages 53-154. In: Envir. Assess. Alaskan Cont. Shelf, Annu. Rep. Prin. Invest. Vol. 10. NOAA/OCSEAP, BLM. Boulder, CO.

This research on distribution and intensity of ice scour in the northeastern Bering Sea includes information on scour depression occurrence in the deeper marine areas of the Yukon delta study area. But it is relevant more to hazards to petroleum development than to ecological consequences,and has little usefulness in the Yukon delta study. Related reports include:

(1) Larsen, M. D., C. H. Nelson, and D. R. Thor. Annu. Rep. Prin. Invest. Vol. 12, 1978.

(2) Larsen, M. S., C. H. Nelson, and D. R. Thor. 1979. Geologic implications and potential hazards of scour depression on Bering Shelf, Alaska. Envir. Geol. 3:39-47.

(3) Larsen, M. C., C. H. Nelson, and D. R. Thor. 1979. Continuous seismic relfection data, S9-78-BS cruise, northern Bering Sea. USGS Open-File Rep. 79-1673. 8 p.

91. Larsen, M. C.,C. H. Nelson, and D. R. Thor. 1981. Sedimentary processes and potential geologic hazards on the sea floor of the northern Bering Sea. Pages 247-261. In: D. W. Hood and J. A. Calder (eds.) The eastern Bering Sea shelf: Oceanography and resources. NOAA/OMPA, BLM. Juneau, AK.

These authors present analyses of geophysical tracklines; bottom grab box cores and vibracore samples; and camera, hydrographic and current-meter stations of the Norton Basin region and discuss the potential geologic hazards for resource exploration in the area. They found widespread occurrence of gas-charged sediment in Norton Sound represented by thermogenic gas seeps and sea-floor cratering. In the Yukon prodelta area they found evidence of large-scale ice and current scouring; as far as 100 km from land off the delta, storm-generated bottom-transport currents had deposited thick layers of sand. This is an important paper for describing sediment transport and dynamics of seafloor change in the Yukon delta area.

92. Leendertse, J. J., and S. K. Liu. 1978. Modeling of tides and circulations of the Bering Sea. Pages 569-579. In: Envir. Assess. Alaskan Cont. Shelf, Annu. Rep. Prin. Invest. Vol. 10. NOAA/OCSEAP, BLM. Boulder, CO.

This modeling study of tides and circulations includes a Bristol Bay model and,more relevant to the Yukon delta project, a Norton Sound model. These models are three-dimensional and use fixed diffusion coefficients for the vertical and horizontal exchanges of momentum and constituent transport. Other useful published reports of this on-going OCSEAP research project (RU 435) include:

(1) Leendertse, J. J. Annu. Rep. Prin. Invest. Vol. 15, 1977.

(2) Leendertse, J. J., and S. K. Liu. Quart. Rep. Prin. Invest. Vol. 3, July-Sept., 1977.

(3) Leendertse, J. J., and S. K. Liu. Quart. Rep. Prin. Invest. Vol. 2, Oct-Dec., 1978.

(4) Leendertse, J. J., and S. K. Liu. Annu. Rep. Prin. Invest. Vol. 7, 1979.

93. Lowry, L. F., and K. J. Frost. 1971. Distribution, growth, and foods of arctic cod (Boreogadus saida) in the Bering, Chukchi, and Beaufort seas. Can. Field-Nat. 95(2):186-191.

Arctic cod were collected by trawling during 1977 and 1978. The stomach contents of the fish were analyzed. Gammarid amphipods, along with mysids, shrimps and hyperiid amphipods were found to be the major food sources for arctic cod in the Bering Sea. Data on occurrence and size of the fish are also presented. The study area included waters off the northern Yukon delta, but not Norton Sound.

94. Lowry, L. F., K. J. Frost and J. J. Burns. 1980. Feeding of bearded seals in the Bering and Chukchi Seas and trophic interactions with Pacific walruses. Arctic 33:330-342.

Stomach contents of 397 bearded seals were examined between 1975 and 1979. The authors found that shrimp, crabs and clams constituted the major food sources. Diet varied with age, location, and time of year. Data collected from Nome indicated that bearded seals were eating more clams in Norton Sound than in other areas. Competition by walrus for clams may have reduced that source of bearded seal diet in some areas. This is a very useful paper in that it suggests a hypothesis for population regulating mechanisms for seals. The hypothesis may not apply to the Yukon delta study area, however.

95. Lowry, L. F., K. J. Frost, and J. J. Burns. 1980. Variability in the diet of ringed seals, Phoca hispida, in Alaska. Can. J. Fish. Aquat. Sci. 37:2254-2261.

The stomach contents of 973 ringed seals collected from Point Hope to Nome during 1976 and 1977 were analyzed. The authors found that ringed seal diet was quite variable, depending on time of year and location. Arctic and saffron cod, hyperiid amphipods, euphasiids, mysids and some shrimp were among the most important food sources. Saffron cod made up ninety percent of the stomach contents of ringed seals collected from Nome during the summer. Winter diet included large quantities of arctic cod, and spring diet included thirty percent shrimp. Though not collected in the Yukon delta study area per se, the data presented are important to this study; they provide the best estimates available of ringed seal diets in the study area.

96. Lowry, L. F., K. J. Frost and J. J. Burns. 1981. Trophic relationships among ice-inhabiting phocid seals and functionally related marine mammals in the Bering Sea. Pages 97-142. In: Envir. Assess. Alaskan Cont. Shelf, Final Rep. Prin. Invest. Vol. 11. NOAA/OMPA, MMS. Juneau, AK.

Stomach contents from marine mammals collected from 1975 to 1980 were analyzed to determine prey species. Most specimens were obtained from subsistence hunters. Results are presented by species, and the interrelationships between the species discussed. Most of the data for this research were collected outside the Yukon delta study area, but much is applicable to mammal trophics in the study area. Preliminary reports of this study can be found in earlier OCSEAP (RU 232) annual reports, including:

(1) Lowry, L. F., K. J. Frost, and J. J. Burns. Annu. Rep. Prin. Invest. Vol. 1, 1977.

(2) Lowry, L. F., K. J. Frost, and J. J. Burns. Annu. Rep. Prin. Invest. Vol. 1, 1978.

(3) Lowry, L. F., K. J. Frost, and J. J. Burns. Annu. Rep. Prin. Invest. Vol. 1, 1979.

97. MacKinnon, J. 1977. Reconnaissance of the littoral benthos of the Yukon-Kuskokwim delta region, Appendix 1. Pages 120-125. In: Baseline/reconnaissance characterization, littoral biota, Gulf of Alaska and Bering Sea. NOAA/OCSEAP, BLM. Boulder, CO.

The purpose of this study was to qualitatively describe the macroinvertebrate fauna of the littoral zone of the Yukon and Kuskokwim deltas. The Yukon delta coastline is characterized by a low peat bluff, which grades into a fine sand and peat hummock substrate. No littoral macroinvertebrates were observed which, the author suggests, may be due to freezing and ice scouring in winter or because tide levels at the time of his observations may have been too high to view lower intertidal areas. In terms of the present project, these preliminary observations describe the Yukon delta only in very general terms.

98. Matthews, M. D. 1973. Flocculation as exemplified in the turbidity maximum of Acharon Channel, Yukon River delta, Alaska. Ph.D. Thesis, Northwestern University, Evanston, Ill. 88 p.

Beginning with field research conducted in the Yukon delta in the summer of 1969, this author investigated the dynamics of electrochemical flocculation in one of the main distributary channels. He documented the existence of a classic salt wedge extending upstream, and the associated flocculation of suspended materials, but did not report the extent of salt wedge intrusion. This is an important paper in that it is the only research done in the Yukon delta on salt wedge intrusion and associated physical-chemical processes.

99. McConnaughey, T., and C. P. McRoy. 1979. Food-web structure and the fractionation of carbon isotopes in the Bering Sea. Marine Biology 53:257-262.

The authors analyzed the ^{13}C:^{12}C ratio in marine organisms of the Bering Sea. Succesively higher trophic levels were postulated to have higher ^{13}C levels due to biomagnification. In addition to confirming this general theory, the data highlighted some interesting anomalies. Much of the benthic macrofauna appeared overly ^{13}C enriched, implying that a longer food chain supported the macrofauna than had previously been supposed.

100. McManus, D. A., V. Kolla, D. M. Hopkins, and C. H. Nelson. 1974. Yukon River sediment on the northernmost Bering Sea shelf. J. Sed. Petrology 44(4):1052-1060.

Based on analyses of about 250 bottom samples from locations in the Norton Sound, Chirikov Basin, and Bering Strait areas, these authors discussed the transport and fate of Yukon-derived sediment. They found that modern sediment derived from the Yukon is a more dominant component of bottom sediments in the Chukchi Sea than in the Bering Sea where the river debouches. The geologic history of transport and deposition of Yukon-carried sediments is discussed. This is one important paper of several that discuss the transport and fate of Yukon sediments.

101. McManus, D. A., V. Kolla, D. M.. Hopkins, and C. H. Nelson. 1977. Distribution of bottom sediments on the continental shelf, northern Bering Sea. U. S. Geol. Survey Prof. Paper 759-C. 31 p.

This report presents the results of studies conducted by the U. S. Geologic Survey in Norton Sound and the Chirikov Basin. The results of bathymetry and current measurements are presented, as well as a detailed description of bottom sediment types and locations. Some silt from the Yukon River is deposited on the delta, a little is deposited in Norton Sound, but the rest is transported through the Bering Strait into the Chukchi Sea. Most of Norton Sound is covered by a silt layer of varying depth, with fine sand found across the mouth of Norton Sound, extending northward. This relatively important paper contributes to the considerable literature that describes transport of sediment derived from the Yukon River.

102. McManus, D. A., and C. S. Smyth. 1970. Turbid bottom water on the continental shelf of the northern Bering Sea. J. Sed. Petrology 40(3):869-873.

Measures of suspended material in bottom waters of the northern Bering Sea (including locations in western Norton Sound) showed high levels of suspended material. Concentrations were highest near the Alaska mainland; the suspended material was 85 percent mineral grains. The bottom water with its high silt concentration (which was perhaps largely supplied by the Yukon River) when coupled with the prevailing northward current, appeared to be an important transport mechanism for supplying modern silt to the Chukchi Sea shelf. This is one of several papers that provide evidence that a large portion of Yukon silt is transported to and deposited in the Chukchi Sea.

103. McNutt, S. L. 1981. Remote sensing analysis of ice growth and distribution in the eastern Bering Sea. Pages 141-165. In: D. W. Hood and J. W. Calder (eds.) The eastern Bering Sea shelf: Oceanography and resources. NOAA/OMPA, BLM. Juneau, AK.

Seasonal ice thickness distribution and ice types for the eastern Bering Sea are inferred from satellite imagery and available aircraft data. Movement and generation of ice are estimated, and the location of the ice edge for different dates are plotted. Bering Sea maps of ice conditions, ice extent, ice trajectories and ice leads include Norton Sound, but no discussions focus on Norton Sound per se. This study gives a useful general picture of seasonal ice conditions and ice dynamics in the Yukon delta study area.

104. McRoy, C. P., J. J. Walsh, L. K. Coachman, J. J. Goering, and D. W. Hood. 1983. Inner shelf transfer and recycling in high latitudes (ISHTAR). Research proposal to National Science Foundation by Univ. Alaska Inst. Mar. Sci., Fairbanks, AK.

This research proposal is for a six-year interdisciplinary study of ecosystem dynamics of high-latitude shallow shelves under the influence of pristine and entrophic nutrient stimulation. In particular, it will examine the food web amplification of nutrients derived from the plume of the Yukon River on the shelves of the North Bering and Chukchi seas. The investigators propose to compare the influence of this relatively pristine river with that of a eutrophied high-latitude river (Rhine). The proposal addresses in depth the known influence of the Yukon River discharge. This is an extremely important reference and project in relation to the Yukon delta characterization study.

105. Muench, R. D., J. D. Schumacher, and R. B. Tripp. 1979. Norton Sound/ Chukchi Sea oceanographic processes. Pages 288-309. In: Envir. Assess. Alaskan Cont. Shelf, Annu. Rep. Prin. Invest. Vol. 8, Transport. NOAA/OCSEAP, BLM. Boulder, CO.

The third annual report in a series of reports dealing with circulation and tides in the northern Bering Sea and southern Chukchi Sea, this paper addresses flow through the Bering Strait system and summer circulation in Norton Sound. This research project and its reports have summarized the status of knowledge of circulation in this region and have attempted to link the regional circulation patterns here with those of the southern Bering Sea. Relying mostly on current measurements made in deeper shelf waters ($<$10 m), the project reports provide important information about circulation and water mass characteristics in Norton Sound. No measurements were made in the very shallow waters off the Yukon delta. Other improtant reports of this OCSEAP-sponsored project (RU 541) include:

(1) Coachman, L. K., R. L. Charnell, J. D. Schumacher, K. Aagaard, and R. D. Muench. Annu. Rep. Prin. Invest. Vol. 15, 1977.

(2) Coachman, L. K., K. Aagaard, and T. H. Kinder. Quart Rep. Prin. Invest. July-Sept. Vol. 2, 1978.

(3) Coachman, L. K., T. H. Kinder, K. Aagaard, R. L. Charnell, J. D. Schumacher, and R. D. Muench. Annu. Rep. Prin. Invest. Vol. 10, 1978.

106. Muench, R. D., R. B. Tripp, and J. D. Cline. 1981. Circulation and hydrography of Norton Sound. Pages 77-94. In: D. W. Hood and J. A. Calder (eds.) The eastern Bering Sea shelf: Oceanography and resources. NOAA/OMPA, BLM. Juneau, AK.

This paper summarizes observations of temperature, salinity and currents obtained in Norton Sound between 1976 and 1978. The authors found Norton Sound to be strongly two-layered in the summertime, with regard to both temperature and salinity. This layering was not apparent during the winter. The authors also observed different circulation patterns in the eastern and western parts of the Sound, which are described in detail. This paper was a valuable reference for the Yukon delta characterization study.

107. Neimark, L. M. 1979. Zooplankton ecology of Norton Sound, Alaska. M. S. thesis, Univ. Alaska, Fairbanks. 93 p.

The data for this report were obtained from coastal sampling in Norton Sound. These data were combined with OCSEAP data to provide a picture of zooplankton distribution in Norton Sound, and factors influencing that distribution. Zooplankton community structure and coastal fish feeding behavior are also discussed. Pseudocalanus species were the most common summer zooplankton in Norton Sound. The main offshore predator was the chaetognath, Sagitta sp.. Coastal fish in Norton Sound, including marine, brackish, and anadromous species, were found to have opportunistic diets. This important work is one of the few available on zooplankton in Norton Sound.

108. Neimark, L. M., R. T. Cooney, and C. R. Geist. 1979. Feeding behavior of Bering Sea coastal fish populations. Proc. 29th Alaska Science Conf:675-684.

Foreguts from 23 fish species collected along the eastern coast of Norton Sound were examined to identify major prey groups. Neomysis spp. was the most important fish food. The two most frequently captured fishes were saffron cod and rainbow smelt, both generalists in their feeding behavior. Most or all these samples were outside the study area, but given that similar types of data are almost non-existent in the study area, it seems appropriate to note this important reference here.

109. Nelson, H., and J. S. Creager. 1977. Displacement of Yukon-derived sediment from Bering Sea to Chukchi Sea during Holocene time. Geology 5:141-146.

This paper traces the recent geologic history of Yukon River sediments in the Chukchi Sea, based on a review of geologic work done in the area. Large quantities of Yukon River sediment have been carried through the Bering Strait for the last 12,000 years, at times up to as much as half of the river's total sediment load. Today it is estimated that up to one third may be being carried to the Chukchi Sea, aided by storm resuspension of sediments. This important paper agrees with several others that much of the Yukon River's silt load may end up on the Chukchi Sea shelf.

110. Nelson, H., R. W. Rowland, S. W. Stoker, and B. R. Larsen. 1981. Interplay of physical and biological sedimentary structures of the Bering continental shelf. Pages 1256-1296. In: D. W. Hood and J. A. Calder (eds.) The eastern Bering Sea shelf: Oceanography and resources. Vol. 2. NOAA/OMPA, BLM. Juneau, AK.

This study reviews what is known about the physical substrate characteristics,the benthic biota, and interactions between the two in the northern Bering Sea. A primary focus of the study is Norton Sound, where post-transgressive silty mud from the Yukon River blankets the shallow ($>$ 20 m) areas. Near the Yukon Delta fringe, sedimentary structure from physical forces (currents, ice gouging, etc.) are well-preserved; at greater distances from shore benthic animals have extensively disrupted the substrate. Almost all modern physical structures have been destroyed at depths greater than 25 m. This is an important paper that explains some of the physical and biological processes in the Yukon delta study area.

111. Nelson, C. H., D. R. Thor, and M. C. Larsen. 1979. Sediment instability, erosion,and deposition hazards of the Norton Basin seafloor. Pages 53-154. In: Envir. Assess. Alaskan Cont. Shelf, Annu. Rep. Prin. Invest. Vol. 10. NOAA/OCSEAP, BLM. Boulder, CO.

These authors used side-scan sonar data and analysis of vibracore samples at selected locations to study sea-floor sediment stability, erosion and deposition processes, and near-surface faulting in Norton Basin. Characteristics of substrates in moderately deep water immediately beyond the Yukon River prodelta indicated intense bottom current activity, intense ice gouging and near-surface faulting to be potential hazards in this area. This is a valuable study in terms of hazards to hydrocarbon exploration and development in the Yukon delta project area. Other reports on this OCSEAP-funded project (RU 429) include:

(1) Nelson, C. H. Annu. Rep. Prin. Invest. Vol. 18, 1977.

(2) Nelson, C. H., and D. R. Thor. Annu. Rep. Prin. Invest. Vol. 12, 1978.

112. Nelson, R. R. 1980. Status of marine mammal populations in the Norton Sound basin. Presentation to Norton Sound Synthesis Meeting, 28-30 Oct., 1980, Anchorage, AK. 16 p. mimeo.

This summary of available information is one of the best synopses of marine mammal use of Norton Sound and the Yukon delta study area that is available. The author discusses distributions of and habitat use by walrus, spotted seal, ringed seal, ribbon seal, bearded seal, polar bear, belukha whale, bowhead whale, gray whale, minke whale, and killer whale in the region. Based on the data presented, ringed, bearded, and spotted seals and belukha and gray whales are probably the most abundant marine mammals in the Yukon delta study area.

113. Olsen, H. W. 1980. Geotechnical characteristics of bottom sediment in the northern Bering Sea. Pages 79-244. In: Envir. Assess. Alaskan Cont. Shelf, Annu. Rep. Prin. Invest., Vol. 8. NOAA/NOS, MMS. Juneau, AK.

This is an administrative report that presents the results of the reconnaissance geotechnical studies in the northern Bering Sea and describes the work in progress on cores taken from gas-charged areas in central Norton Sound. Some of the samples were from the Yukon delta study area, but because the report's concern is related to environmental hazards and exploration potential rather than biological effects, the data have little usefulness to the Yukon delta characterization study.

114. Otto, R. S. 1981. Eastern Bering Sea crab fisheries. Pages 1037-1055. In: D. W. Hood and J. A. Calder (eds.) The eastern Bering Sea shelf: Oceanography and resources. Vol. 2. NOAA/OMPA, BLM. Juneau,AK.

This report is a review of the eastern Bering Sea crab fisheries for red and blue king crabs and Tanner crabs. The history of the fishery is reviewed, and the participation by various countries discussed. The importance of the red king crab fishery in Norton Sound is noted. This report is of relatively minor importance for purposes of the Yukon Delta characterization study, except that it identifies an important resource found in the extreme northern part of the Yukon delta study area.

115. Outer Continental Shelf Environmental Assessment Project (OCSEAP). 1978. Environmental assessment of the Alaskan continental shelf: Executive summary. NOAA/OCSEAP, BLM. Boulder, CO. 64 p.

This summary of Alaska work performed under OCSEAP sponsorship in 1977-78 includes a useful summary of Bering Sea research conducted in Fiscal Year 1978. In this summary the important physical processes occurring in Norton Sound, with particular reference to the fate of Yukon River suspended material, are discussed. This is a useful, but very brief, summary of important research findings of OCSEAP in the Yukon delta study area.

116. Pearson, C. A.,H. O. Mofjeld, and R. B. Tripp. 1981. Tides of the eastern Bering Sea shelf. Pages 11-130. In: D. W. Hood and J. A. Calder (eds.) The eastern Bering Sea shelf: Oceanography and resources. NOAA/OMPA, BLM. Juneau, AK.

Using recent pressure-gauge and current-meter data acquired on the Bering Sea shelf, these authors describe tides that occur in nearshore areas of the Bering Sea. They found that, throughout most of the shelf, the tide is of the mixed, predominantly semidiurnal type, but the diurnal tide dominates in Norton Sound. Though most discussion focused on the southeastern Bering Sea, the report was useful in giving a general picture of tides in the Yukon delta study area.

117. Pennoyer, S., K. R. Middleton and M. E. Morris, Jr. 1965. Arctic-Yukon-Kuskokwim area salmon fishing history. Alaska Dept. Fish and Game, Info. Leaflet 70. 37 p.

This report documents the history of both commercial and subsistence salmon fishing on the Yukon-Kuskokwim delta. Data are based on Alaska Dept. Fish and Game records, and are presented separately for the Yukon and Kuskokwim Rivers. A brief history of fishing regulations is followed by data on catch numbers, species and location.

118. Powell, G. C., R. Peterson, and L. Schwarz. 1983. The red king crab, Paralithodes camtschatica (Tilesius) in Norton Sound, Alaska: History of biological research and resource utilization through 1982. Alaska Dept. Fish and Game, Info. Leaflet No. 222. Dept. Comm. Fish. Kodiak, AK. 104 p.

This report is based on Alaska Department of Fish and Game research--one king crab survey of Norton Sound in 1948-49, and four between 1976 and 1981. Data for commercial crab fishing, which started in 1977, are presented, as well as data on subsistence fishing. The largest concentration of crabs was found in northwestern Norton Sound. The biology of red king crabs, including size, molting, movements, distribution, and population structure are discussed, with supporting data from Alaska Department of Fish and Game tagging and recapture efforts, sampling, and commercial catch data. This is the best and most complete report on red king crabs in our area of interest.

119. Ray, V. M., and W. R. Dupré. 1981. The ice-dominated regimen of Norton Sound and adjacent areas of the Bering Sea. Pages 263-278. In: D. W. Hood and J. A. Calder (eds.) The eastern Bering Sea shelf: Oceanography and resources. NOAA/OMPA, BLM. Juneau, AK.

In this paper the patterns of ice formation, movement, and deformation in Norton Sound and adjacent areas of the Bering Sea were studied using Landsat and NOAA satellite imagery for the years 1973-1977. Results demonstrated the significance of bathymetry and meteorology in controlling ice movement. The seasonal pattern of ice accretion, convergence and divergence, and melt in waters around the Yukon delta is described. This is an important paper that describes in detail the ice processes in the Yukon delta study area.

120. Regnart, R., and M. Geiger. 1982. Status of salmon stocks, fisheries and management programs in the Yukon River. Alaska Dept. Fish and Game. Alaska-Yukon-Kuskokwim Region, Stock Status Rep. No. 35. Anchorage, AK. 54 p.

This report is a detailed account of salmon and their management on the Yukon River, derived mainly from Alaska Department of Fish and Game annual management reports. Salmon are discussed by species, including king, chum, pink, coho and sockeye salmon. Salmon fishing and management are also discussed. Less than half the report is text, with much data presented in tables and figures. The report has a very useful discussion of salmon life history in the Yukon River and useful sets of data from the Yukon delta area.

121. Robertson,D. E., and K. H. Abel. 1979. Natural distribution and environmental background of trace heavy metals in Alaskan shelf and estuarine areas. Pages 660-698. In: Envir. Assess. Alaskan Cont. Shelf, Annu. Rep. Prin. Invest. Vol. 5. NOAA/OCSEAP, BLM. Boulder, CO.

This project analyzed sediment samples from several Alaskan continental shelf areas, including Norton Sound, for trace metal content. Considerable variability in metal content within shelf areas indicated non-uniform sediment distribution. This study, because of its subject, has little useful relevance to the Yukon delta characterization study. Further, no samples were taken in the delta shallows.

122. Sallenger, A. H., and J. R. Dingler. 1979. Coastal processes and morphology of the Bering Sea coast of Alaska. Pages 377-441. In: Envir. Assess. Alaskan Cont. Shelf, Final Rep. Prin. Invest. Vol. 2. NOAA/OCSEAP,BLM. Boulder, CO.

Focusing in the Norton Sound region primarily on the south coast of the Seward Peninsula near Nome, these authors made field studies of the effects of storm surge and normal oceanographic conditions on coastal morphology. They measured heights of debris lines above sea level, extent of tundra bluff erosion, and accretion and loss of sediments to beaches. They found that a major storm surge caused tremendous amounts of erosion locally, but that the net change was accretional. Further, coastal change continued to occur, though at a much slower rate, during non-storm conditions. These findings may or may not be relevant to the Yukon

delta. Other reports on this OCSEAP-funded project (RU 431) include:

(1) Sallenger, A. H., R. Hunter, and J. R. Dingler. Annu. Rep. Prin. Invest. Vol. 18, 1977.

(2) Sallenger, A. H., R. Hunter, and J. R. Dingler. Annu. Rep. Prin. Invest. Vol. 12, 1978.

123. Salo, S. A., J. D. Schumacher, and L. K. Coachman. 1983. Winter currents on the eastern Bering Sea shelf. NOAA Tech. Memo. ERL PMEL-45.

An analysis of 15 current records from 13 locations over the central and northern Bering Sea is presented. A few of these are located at the western edge of the Yukon delta study area at the mouth of Norton Sound. These records are very important to the Yukon delta study; they show that current speed and direction, and presumably general circulation patterns, are not greatly different in winter than they are in summer. Few other winter circulation data for this region are available.

124. Samuels, W. B., and K. J. Lanfear. 1981. An oilspill risk analysis for the Norton Sound, Alaska, (Proposed Sale 57) Outer Continental Shelf Lease area. U. S. Geological Surv., Open File Rep. 81-320. Reston, VA.

An oilspill risk analysis was conducted to determine the relative environmental hazards of developing oil in different parts of Norton Sound. The probability of spill occurrences, likely movement of oil slicks and locations of resources vulnerable to spilled oil were analyzed. Though this report was not very useful in preparing the Yukon delta characterization report, it contains the kind of information which, coupled with data on storm surge magnitude and frequency, will be extremely useful in analyzing risks to various ecological zones in the Yukon delta.

125. Sanger, G. A., and P. A. Baird. 1977. Aspects of the feeding ecology of Bering Sea avifauna. In: Envir. Assess. Alaskan Cont. Shelf, Annu. Rep. Prin. Invest. Vol. XII, Effects. NOAA/OCSEAP, BLM. Boulder, CO.

This review deals mainly with marine, cliff-nesting birds and their trophics in the Bering Sea. Because very few of these birds feed in the Yukon delta study area, and none nest there, it has only marginal relevance to the Yukon delta characterization study.

126. Schumacher, J. D., R. D. Muench, T. H. Kinder, L. K. Coachman, R. L. Charnell and K. Aagaard. 1978. Norton Sound/Chukchi Sea oceanographic processes (N-COP). Pages 860-928. In: Envir. Assess. Alaskan Cont. Shelf, Annu. Rep. Prin. Invest. Vol. 10. NOAA/OSCEAP, BLM. Boulder, CO.

This report is based on data collected during 1976 and 1977. Norton Sound was found to have a two-layered structure during the summer, with a cold saline lower layer and a warmer, less saline upper layer. Fate of Yukon River discharge, flow through the Bering Strait and tidal currents are described. The major results of this study are also presented in a subsequent paper (Hood and Calder 1981, this bibliography). This paper is a good source of basic data that help determine the spatial contribution of Yukon River water to the receiving oceans. Additional OCSEAP reports of these findings are found in Muench et al. (1979) (this volume).

127. Seaman, F. A., and J. J. Burns. 1981. Preliminary results of recent studies of belukhas in Alaskan waters. Rep. Int. Whal. Comm. 31:567-574.

The background for this paper includes personal interviews with hunters and scientists, and opportunistic field work during almost 20 years. The authors estimated total annual kill at approximately 264-319 whales. They concluded, based on the relatively old-age structure of the harvest, that present exploitation was at a low level. The data include harvests from five villages around Norton Sound. The paper also includes a discussion of the reproduction and food habits of belukhas. This is one of the few papers on belukhas that contain information from Norton Sound.

128. Sears, H. S., and S. T. Zimmerman. 1972. Alaska intertidal survey atlas. NOAA/Nat. Mar. Fish. Serv., Northwest and Alaska Fish Center, Auke Bay Lab., Auke Bay, Alaska.

This atlas contains maps of the coasts of Alaska prepared on the basis of aerial intertidal surveys during summer 1975 and 1976, and showing information on three littoral parameters: stratum composition, beach slope, and biological cover. Wildlife and vegetation characteristics are indicated. The Yukon delta coast is shown as mostly low gradient mud, with only occasional variations in gradient. The results of this survey supports findings of other more intensive observational studies related to coastal habitat descriptions of the Yukon delta area.

129. Sergeant, D. E., and P. F. Brodie. 1975. Identity, abundance and present status of populations of white whales, Delphinapterus leucas, in North America. J. Fish. Res. Board Can. 32:1047-1054.

A review of literature provides information for this summary of the status of white whales in 1975. Major emphasis is on Canadian distribution, but use of Norton Sound and the Yukon River delta is mentioned. This paper provides no information different from that contained in several other papers on white whale use of the Yukon delta study area.

130. Sharma, G. D., F. F. Wright, J. J. Burns and D. C. Burbank. 1974. Sea-surface circulation, sediment transport, and marine mammal distribution, Alaska continental shelf. Inst. Mar. Sci., Univ. Alaska, Fairbanks. 77 p.

The research for this report included detailed examination of LANDSAT imagery and ground sampling of sediment load, temperature and salinity in Alaskan waters. The report is divided into geographic regions. The section on the Bering Sea, including Norton Sound, present these data in graphic form, accompanied by a brief narrative. The report contains little information on marine mammal distribution. It does not significantly add to information presented in other papers about the physical processes and marine mammal use of the Yukon delta study area.

131. Sharma, G. D., F. F. Wright, J. J. Burns, and D. C. Burbank. 1974. Sea surface circulation, sediment transport, and marine mammal distribution, Alaskan continental shelf. Nat. Aero. and Space Adm., Final Rep. ERTS Project 110-H. 73 p.

The research for this report included detailed examination of ERTS satellite imagery, and ground sampling of sediment load, temperature and salinity in Alaskan waters. The report is divided into geographic regions. The section on the Bering Sea, including Norton Sound, presents these data in graphic form, accompanied by a brief narrative. The report contains little information on marine mammal distribution, but does discuss sea-ice.

132. Spencer, D. L., U. C. Nelson, and W. A. Elkins. 1951. America's greatest goose-brant nesting area. Trans. 16th N. Am. Wildl. Conf.:290-295.

The authors report on aerial survey and banding operations carried out by the U. S. Fish and Wildlife Service during 1949 and 1950. Species occurrence, distribution, densities and migration patterns are discussed with relation to banding and recovery data. The study area included the entire Yukon-Kuskokwim delta, but the greatest densities of birds were found between Cape Romanzof and Nelson Island. The northern portion of the region (within our Yukon delta study area) is included in a breeding distribution map of geese and brant, but it appears that nearly all the data on which the report is based came from outside the study area (south of Cape Romanzof.) This report is more valuable than most waterfowl studies conducted in the Yukon-Kuskokwim delta region, because it does include data from our study area; most studies do not.

133. Starr, S. J., M. N. Kuwada, and L. L. Trasky. 1981. Recommendations for minimizing the impacts of hydrocarbon development on the fish, wildlife and aquatic plant resources of the northern Bering Sea and Norton Sound. Prepared by the Alaska Department of Fish and Game, Habitat Division, for Alaska Department of Community and and Regional Affairs and the National Oceanic and Atmospheric Administration. 525 p.

This volume is a review of existing information about the important biota and habitats of the Norton Sound region (including St. Lawrence Island to the west) and their susceptibility to hydrocarbon development. Brief descriptions of the biota, the habitats, and the expected kinds of development activities are given. The major portion of the report addresses potential impacts and recommended mitigative actions. The report is an excellent literature review of the kinds of activities expected to accompany hydrocarbon development and the potential for the activities to adversely affect biota and habitats.

134. Stoker, S. 1981. Benthic invertebrate macrofauna of the eastern Bering/Chukchi continental shelf. Pages 1069-1090. In: D. W. Hood and J.A. Calder (eds.) The eastern Bering Sea shelf: Oceanography and resources. Vol. 2. NOAA/OMPA, BLM. Juneau, AK.

Data for this paper were collected from 1970 through 1974 in the Bering and Chukchi seas. The author presents a regional view, describing eight different faunal assemblages found in the study area. The distributions of these groups and probable causative factors are discussed. The importance of this paper in relation to the Yukon delta study is in its attempt to show a link between Yukon River discharge of detritus and the benthic productivity downstream of the Yukon delta in the Bering and Chukchi seas. This link comes via the current structure, which does not allow extensive settling of detritus from the Alaskan coastal water until current speeds decrease appreciably in the southern Chukchi Sea.

135. Straty, R. R. 1981. Trans-shelf movements of Pacific salmon. Pages 575-595. In: D. W. Hood and J. A. Calder (eds.) The eastern Bering Sea shelf: Oceanography and resources. Vol. 1. NOAA/OMPA, BLM. Juneau, AK.

The data and conclusions in this paper were based on an extensive review of available data and on work done by the Northwest and Alaska Fisheries Center. Chinook salmon were found to be the earliest migrators, during both spawning and seaward migrations, followed by sockeye, chum, pink and coho salmon, in that order. Chum, pink, and sockeye salmon were found returning to the Norton Sound area. A few chinook and coho salmon were caught in Norton Sound, but their migration routes were uncertain. The effects of temperature and food abundance on migration timing are discussed. This is the best available paper on movement of salmon beyond the natal streams and estuaries, but it includes little of significance in terms of salmon use of the Yukon River delta area.

136. Stringer, W. J. 1981. Nearshore ice characterics in the eastern Bering Sea. Pages 167-187. In: D. W. Hood and J. A. Calder (eds.) The eastern Bering Sea shelf: Oceanography and Resources. NOAA/OMPA, BLM. Juneau, AK.

This paper describes Bering Sea nearshore ice conditions on the basis of a compilation of fast-ice edge satellite data, observations of specific ice events, and results from other studies. A regional description of average nearshore ice conditions along the Bering Sea coast from Cape Prince of Wales to Cold Bay on the Alaska Peninsula is provided. Norton Sound is included in these descriptions, resulting in a discussion of the seasonal extent and characteristics of nearshore ice. A brief discussion of the normal *in situ* generation of ice in Norton Sound and ice motion on the Yukon prodelta is included.

137. Stringer, W. J., S. A. Barrett, and L. K. Schreurs. 1978. Morphology of Beaufort,Chukchi and Bering seas nearshore ice conditions by means of satellite and aerial remote sensing. 2 vols. Univ. Alaska Geophysical Institute Rep., Fairbanks.

This and various other reports dealing with remote sensing of ice conditions by the same principal author are results of research conducted under NOAA/OCSEAP Research Unit 257. Seasonal (winter/spring) change in nearshore ice cover and morphology were analyzed from LANDSAT imagery

for successive years beginning in 1973. The objective was to identify ice features that might represent hazards to OCS oil and gas exploration and development in the nearshore zone. The Yukon delta study area is included in some years of these analyses. Additional RU 257 reports are in OCSEAP volumes and include:

(1) Stringer, W. J. Annu. Rep. Prin. Invest. Vol. 14, 1976.

(2) Stringer, W. J. Annu. Rep. Prin. Invest. Vol. 15, 1977.

(3) Stringer, W. J. Annu. Rep. Prin. Invest. Vol. 10, 1978.

138. Takenouti, Y., and D. W. Hood (Convenors). 1974. Bering Sea oceanography: An update. Results of a seminar and workshop on Bering Sea oceanography, held in Fairbanks, AK, 7-11 Oct. 1974. 292 p.

This volume is a series of papers and discussions on Bering Sea oceanography. Most of the focus was in the southerly, highly productive areas of the Bering. Results of studies are presented in some papers, but not in all. The volume has limited utility for the Yukon delta study. Presentations that bear to some extent on the Yukon delta study area include:

(1) Fay, F. H. Mammals and birds. Pages 133-138.

(2) Favorite, F. Physical oceanography in relation to fisheries. Pages 157-179.

(3) Hastings, J. R. Hydrodynamical study of the eastern Bering Sea shelf. Pages 181-188.

139. Terry, J. M., R. G. Scoles and D. M. Larson. 1980. Western Alaska and Bering-Norton petroleum development scenarios: Commercial fish industry analysis. Tech. Rep. No. 51. Bureau of Land Management, Alaska O.C.S. Office, Anchorage, AK. 737 p.

This report is a socioeconomic study of the fishing industry of western Alaska. The report presents the history of the industry, and discusses the potential impacts which could result from OCS lease sales. The development of the industry in the absence of lease sales is also discussed. The report concentrates on the southeastern Bering Sea, where a much larger fishery exists, but data on the Norton Sound and Yukon River salmon fishery are included. Conclusions are that the hypothesized locations and characteristics of OCS industry activities are not expected to greatly affect the commercial fishing industry in Norton Sound. What effects there are would be near Nome, thus outside the Yukon delta region. This report had little value to the Yukon delta study.

140. Thor, D. R., and C. H. Nelson. 1979. A summary of interacting surficial geologic processes and potential geologic hazards in Norton Basin, Northern Bering Sea. Proc. Offshore Tech. Conf., Paper No. 3400: 377-381.

This paper and others described elsewhere in this volume (Larsen et al. 1979; Nelson et al. 1979) discuss the hazards to hydrocarbon development in the Norton Sound area related to ice gouging, gas-charged sediments, and other geologic phenomena. These studies have little relevance to the Yukon delta characterization study.

141. Thor, D. R. and C. H. Nelson. 1981. Ice gouging on the subarctic Bering shelf. Pages 279-291. In: D. W. Hood and J. A. Calder (eds.) The eastern Bering Sea shelf: Oceanography and resources. Vol. 1. NOAA/OMPA, BLM. Juneau, AK.

Data for this study were gathered in Norton Sound and vicinity in September 1976,July 1977, and June and July 1978 by side-scan sonar from deep- and shallow-draft vessels. In this region, the highest ice-gouge intensity on the sea floor was found in the shear zone 10-30 km off the Yukon River delta. Northeastern Norton Sound, in contrast, had minimal ice gouging. Gouging was rare anywhere in the fast-ice zone. This is an important study because much work was done very near the Yukon delta: use of a shallow-draft vessel allowed investigators to move closer to shore there than has been common in oceanographic expeditions in Norton Sound.

142. Timm, D. E. and C. P. Dau. 1979. Productivity, mortality, distribution and population status of Pacific Flyway white-fronted geese. Pages 280-298. In: R. L. Jarvis and J. C. Bartonek (eds.) Management and biology of Pacific Flyway geese. Procedings of symposium, Portland Oregon, 16 Feb. 1977. OSU Book Stores. Corvallis, OR.

This paper is based on data collected by U.S. Fish and Wildlife Service and several universities from 1920 to 1978. Productivity, sport and subsistence harvest, and band recovery data are presented. Data are generalized for the Yukon-Kuskowkim delta as a whole. The authors concluded that the Pacific Flyway white-fronted goose population had declined substantially since 1980. Most of the data are from the southern portion of the Yukon-Kuskokwim delta, south of our Yukon delt study area, but two aerial transects surveyed annually extend into the southern portion of

the study area. Though some of the data (timing of goose activities, behavior, etc.) are applicable to geese using our study area, other data (nesting density and distribution) cannot be assumed to hold for the study area.

143. USDI Bureau of Land Management. 1982. Norton Sound Final Environmental Impact Statement, proposed Outer Continental Shelf Oil and Gas Lease Sale No. 57. Alaska Outer Continental Shelf Office, BLM. 332 p. plus appendices.

This document contains a chapter, "Description of the Affected Environment" which includes a description of the biological resources of Norton Sound. The chapter is based on information from published scientific literature. The 17 page section is not very detailed, although the maps summarizing species distribution are instructive. These maps are from Recommendations for Minimizing the Impacts of Hydrocarbon Development on the Fish, Wildlife and Aquatic Plant Resources of the Northern Bering Sea and Norton Sound (Alaska Dept. Fish and Game 1981, this volume).

144. USDI Fish and Wildlife Service. 1957. Fish and wildlife resources of the lower Yukon River (Marshall to mouth). Progress Report No. IV. U.S. Fish Wildl. Serv.. Juneau, AK. 33 p.

Due to interest in the Yukon River's hydroelectric potential, the U.S. Fish and Wildlife Service inventoried its natural resources from 1955 to 1957. This report on the lower Yukon River is based on local interviews and some field work. Salmon were sampled, and interviews were used to determine the timing of runs, species presence, and wildlife harvests. Three river basins--Mountain Village River, the West Fork of Andreafski River, and the East Fork of Andreafski river--were surveyed in more detail to determine their resident fish and wildlife populations. This was a moderately useful document, because the data were collected in the study area, but sampling was sporadic and much of the information was anecdotal.

145. USDI Fish and Wildlife Service. 1980. Subsistence hunting of migratory birds in Alaska and Canada. Draft Envir. Assess. U.S. Fish Wildl. Serv. 44 p.

The United States proposed to seek amendments to migratory bird treaties with Canada, Mexico and Japan to provide a legal basis for managing subsistence hunting of migratory birds in Alaska and Canada.

This environmental impact assessment of that action includes discussions of the population status of migratory bird species, and of subsistence harvest in Alaska and Canada. The discussion of the Yukon-Kuskokwim delta is based on U.S. Fish and Wildlife reports and Klein (1966).

146. USDI Fish and Wildlife Service. 1981. White-fronted goose banding and survey data. Unpub. Rep., U. S. Fish Wildl. Serv. 16 p.

This report contains a series of figures and tables on banding, recovery and aerial surveys of white-fronted geese. The banding was done throughout Alaska, including the north delta of the Yukon River. Recovery data are from Canada, the western United States, and Mexico. Aerial survey data are from the Yukon-Kuskokwim delta (see King and Conant 1983). There is no narrative text in this report.

147. Venkatesan, M. I., M. Sandstrom, S. Brenner, E. Ruth, J. Bonilla, I. R. Kaplan, and W. E. Reed. 1981. Organic geochemistry of surficial sediments from the eastern Bering Sea. Pages 389-409. In: D. W. Hood and J. A. Calder (eds.) The eastern Bering Sea shelf: Oceanography and resources. Vol. 1. NOAA/OMPA, BLM. Juneau, AK.

The authors analyzed sediment samples taken in the southeastern Bering Sea and Norton Sound in 1975, 1976, 1977, and 1979 for hydrocarbons. Terrigenous hydrocarbons were common in Norton Sound, and were thought to have possibly been derived from Yukon River discharge. Samples collected in Norton Sound near suspected petroleum seepage contained hydrocarbons not characteristic of weathered petroleum. This paper seems to have important implications for the Yukon delta study, in that it suggests that Yukon River discharge may provide an important source of organic enrichment to Norton Sound.

148. Waldron, K. D. 1981. Ichthyoplankton. Pages 471-493. In: D. W. Hood and J. A. Calder (eds.) The eastern Bering Sea shelf: Oceanography and resources. Vol. 1. NOAA/OMPA, BLM. Juneau, AK.

This study summarizes results of ichthyoplankton studies conducted in the Bering Sea since 1955. Included is information from the Yukon delta study area and Norton Sound. Maps show the distributions of collections of the various fish families and species. The paper has moderate to low value to the Yukon delta characterization study. It gives a general idea which fishes exist as larvae in the study area region in comparison to larval fish distributions throughout the Bering Sea.

149. Wespestad, V. G. 1978. Exploitation, distribution and life history features of Pacific herring in the Bering Sea. NOAA/NMFS, Northwest and Alaska Fish. Cent. Seattle, WA 24 p.

This report presents a review of the biology of Pacific herring, based on information made available by the National Marine Fisheries Service and the Alaska Department of Fish and Game. It includes a discussion of the history of exploitation, the distribution of Pacific herring, and data from Japanese harvests. Three stocks of herring are described in Norton Sound; these spawn in the St. Michael's area, the Cape Denbigh area, and the Golovnin Bay area. It was not known if these stocks migrate to other areas to winter. This is a moderately important paper; when coupled with several other papers it gives a summary of current information on one of Norton Sound's most important marine fishes.

150. Wespestad, V. G., and L. H. Barton. 1981. Distribution, migration and status of Pacific herring. Pages 509-526. In: D. W. Hood and J. A. Calder (eds.) The eastern Bering Sea shelf: Oceanography and resources. Vol. 1. NOAA/OMPA, BLM. Juneau, AK.

This report is a summary of current knowledge of the biology of Pacific herring, based on an extensive literature review and the authors' professional backgrounds. The life history, food habits, distribution and abundance of Pacific herring, as well as a description of the Pacific herring fishery, are presented. Norton Sound is described as a minor spawning area,and a potential wintering site for local and migratory herring stocks. This is a valuable summary paper of the knowledge of herring in the vicinity of the Yukon delta study area.

151. Williamson, F. S. L. 1957. Ecological distribution of birds in the Napaskiak area of the Kuskokwim River delta, Alaska. Condor 59:317-338.

This paper is based on field work in the Napaskiak area, eight miles southwest of Bethel, during the summers of 1955 and 1956. The author describes vegetation types and their occurrence. An annotated species list and tables record the association of bird species with vegetation types. Although the study area is several hundred miles south of the Yukon River delta, and includes vegetation types not present in the delta, many of the vegetation types and bird species are similar.

152. Wise, J. L.,A. L. Comiskey and R. Becker. 1981. Storm surge climatology and forecasting in Alaska. Alaska Council on Science and Technology, Alaskan Natural Hazards Research. 45 p.

This project summarizes historical storm surge events and applies this to forecasting such events in Alaskan coastal areas. Of particular interest to the Yukon delta project is an appendix listing case histories of storm surge flooding. Included are brief descriptions of the effects on habitats and biota (mainly birds) of storm surges in the Yukon-Kuskokwim delta region. This report has great potential value in further analyzing the potential for storm surge damage to habitats and biota in the north Yukon delta.

153. Wolotira, R. 1980. Fishery resources of Norton Basin, their distribution, abundance and utilization. Rep. by Nat. Mar. Fish. Serv., Northwest and Alaska Fish Center, Kodiak, AK. 47 p.

This report examines three categories of fishery resources in Norton Sound (but excluding the Yukon delta): demersal fishes, pelagic fishes, and invertebrates. In general, the densities of fishery resources with a commercial value are substantially lower than occurs in the eastern Bering Sea or northeastern Gulf of Alaska. Norton Sound represents a region of transition between Arctic and subarctic boreal fish species; the invertebrates, however, are primarily Pacific boreal with an absence of arctic species (probably because of the prevailing northward ocean currents in this region). General descriptions of major fish and invertebrate species in Norton Sound are presented. Although this report excludes discussion of the Yukon delta, it presents a useful review of species which utilize the delta at some stages in their life cycle.

154. Wolotira, R. (Chief Scientist). 1983. Cruise results: Cruise No. MF-82-3 NOAA R/V Miller Freeman. Prelim. Mimeo. Rep. 12 p.

This brief summary of the 1982 cruise of the R/V Miller Freeman discusses the itinerary, areas surveyed, methods, and general preliminary results of the cruise. The primary survey region included the waters of Norton Sound; secondarily, the waters between St. Matthew, Nunivak, and St. Lawrence islands were surveyed. Primarily, work in Norton Sound included a demersal trawl survey for crabs and groundfish, measurements of water quality, and collections of plankton samples. Results are being analyzed. This appears to be a moderately important research effort conducted partly in the Norton Sound waters of the study area.

155. Wolotira, R. J., T. M. Sample, and M. Morin. 1979. Baseline studies of fish and shellfish resources of Norton Sound and the southeastern Chukchi Sea. Pages 258-572. In: Envir. Assess. Alaskan Cont. Shelf, Final Rep. Prin. Invest. Vol. 6. NOAA/OCSEAP, BLM. Boulder, CO.

This study represents one of the most thorough surveys and analyses of Norton Sound fishes and shellfishes in existence. The primary data sources were (1) an intensive six-week trawl and gillnet survey of fish and shellfish fauna in Norton Sound, the southeastern Chukchi Sea and adjacent waters and (2) a review of existing data. Biomass estimates of species captured were considerably lower than had been reported for the southeastern Bering Sea. Most species studied were found in highest relative abundance in shallow, warm-water regions. Of the areas studied, Norton Sound had greatest abundances of most species (especially for young-aged fishes). Earlier reports for this work unit (RU 175) include:

(1) Pereyra, W. T., and R. J. Wolotira. Annu. Rep. Prin. Invest. Vol. 8, 1977.

156. Wolotira, R. J., T. M. Sample, and M. Morin. 1977. Demersal fish and shellfish resources of Norton Sound, the southeastern Chukchi Sea, and adjacent waters in the baseline year 1976. U. S. Dept. Comm., NOAA, Nat. Mar. Fish. Serv., Northwest and Alaska Fish. Cent. Seattle, WA. 300 p.

This report presents data from a BLM/OCS project, comparing the results of this study with a similar study done the year before (1975) on the resources of the eastern Bering Sea. The Norton Sound-Chukchi Sea region was found to have less than 25% of the biomass per area of the eastern Bering Sea, and a much larger percentage of the biomass was non-commercial starfish and other invertebrates (75%). The authors also present data on variation within the study area with regard to species occurrence, abundance, and physical parameters such as depth and temperature. This report represents one of the few extensive fisheries surveys undertaken in Norton Sound, and this is important in relation to deeper waters of the Yukon delta study area. The same information has been presented in various OCSEAP reports (see Wolotira et al. 1979, this volume).

157. Woodby, D., and G. Divoky. 1982. Bird use of coastal habitat in Norton Sound. Pages 196-704. In: Envir. Assess. Alaskan Cont. Shelf, Final Rep. Prin. Invest. Vol. 18, Biological Studies. NOAA/NOS, MMS. Juneau, AK.

This report is based on surveys of Norton Sound coasts during the summers of 1980 and 1981. The authors found that wet tundra areas supported major bird populations. Bird use of Norton Sound (except near cliff colonies) was sparse. Results are presented by bird groups, followed by a discussion of trophic inter-relations. This is a particularly valuable paper that shows the generally poor feeding environment that Norton Sound waters offer to birds. The environments in the immediate vicinity of the Yukon river delta are not discussed.

158. Zimmerman, S. T. (ed.) 1982. The Norton Sound environment and possible consequences of planned oil and gas development. Proc. of a Synthesis Meeting, Anchorage, Alaska, 28-30 Oct. 1980. NOAA/OMPA, BLM. Juneau, AK.

The conclusions of interdisciplinary discussion groups composed of leading researchers in the Norton Sound area are presented in this report. One group discussed the impacts of oil development on the Yukon delta, another the impacts of oil development on Norton Sound, and the third discussed the hazards of oil development. The meeting which this report documents included presentation by many of the major researchers on the Norton Sound region. However, since these presentations were similar to papers published in Hood and Calder (1981) (this volume), they were not published in this volume. This was perhaps the most useful document reviewed in terms of its utility to the Yukon delta characterization study.

159. Zimmerman, S., J. Gnagy, N. Calvin, J. MacKinnon, L. Barr, J. Fujioka, and T. Merrell. 1977. Baseline/reconnaissance characterization, littoral biota, Gulf of Alaska and Bering Sea. BLM/NOAA, OCSEAP. Boulder,CO. 8:1-228.

A section of this report (authored by L. Barr) describes the biota observed along subtidal surveys in Norton Sound. Locations surveyed by SCUBA divers were adjacent to the shorelines of Stuart Island, Egg Island, Cape Denbigh, Cape Darby, Rocky Point, Bluff, Cape Nome and Sledge Island. Surface waters to 20 feet were warmer (55-65 F) and less turbid (15-20 ft. visibility) than deeper waters (40-56° F, 2-4 ft. visibility).

Shallow-water substrates were typically medium to large boulders in gravel and sand; fine sand, clay and silt were more abundant in deeper waters. Dominant organisms were mussels, barnacles, filamentous red algae, and caprellid amphipods. The larger kelps were generally absent. In study areas, annelid worms, clams and sand dollars were abundant. Common fishes were cottids, stichaeids, gadids, and agonids. While the habitats examined during this survey are probably not representative of those occurring in the Yukon delta, the information contributes towards a characterization of adjacent waters.

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PART 2. INTERVIEWS

Barton, L. Alaska Dept. Fish and Game, Fairbanks. Interviewed by J. Truett, 4 August 1983.

Louis Barton has worked extensively with marine fish (primarily herring) and anadromous species in the Norton Sound and Yukon delta areas. He discussed distribution of and habitat use by herring and salmon and other anadromous fish. He noted that the Yukon River contributes more biomass and variety of anadromous fish to the Bering Sea than perhaps any other river. Salmon and other anadromous fishes are extremely important to a large number of subsistence users. He thought that a major information gap with respect to potential effects of oil development was the distribution and residence time of all fish species and their trophic relations in the Yukon delta estuary. Indices of abundance to non-salmonid anadromous species and sampling programs to determine peaks and duration of salmon smolt residence in the Yukon estuary are needed. Fishes are probably very susceptible to impacts from oil and gas development in this environment. Mr. Barton provided several useful leads on published and unpublished fisheries data.

Branson, J. North Pacific Fisheries and Management Council. Interviewed by M. Raynolds, 22 August 1983

Jim Branson gave assistance in reviewing the information already collected on marine and anadromous fishes in the Norton Sound area to determine if the North Pacific Fisheries and Management Council had additional data. He saw no obvious missing information in what had already been collected. He pointed out that much work has been done south of Norton Sound in the Bering Sea on commercial fish species, but little in the Yukon delta study area. He saw a growing interest in forage fishes in the northern Bering Sea including Norton Sound, but so far little money for research. He suggested other individuals that might have additional information.

Burns, J. Alaska Dept. Fish and Game, Fairbanks. Interviewed by J. Truett, 4 August 1983.

John Burns, marine mammal biologist with ADF&G who has worked for a number of years in the Norton Basin area, discussed marine mammal (and to a lesser extent fisheries) issues and provided pertinent unpublished reports. He believed the marine mammal species of concern in the Yukon delta study area to be ringed, spotted, and bearded seals and belukhas. Important prey of these mammals in the area is infauna (bearded seals) and herring, capelin, salmon, saffron cod, sand lance, and (for ringed seal) zooplankton. He discussed seasonal movements of mammals and their prey, general abundance of mammals, issues of primary concern to ADF&G, and principal data gaps related to potential OCS oil and gas impacts. Subsistence issues are of primary concern in the delta area. Key research needs were seen to include:

(1) An integrated study to predict impacts on marine mammals and other resources, using Alaska North Slope and Canadian Beaufort Sea experiences as a basis for deriving sensible approaches.

(2) A thoroughly objective study to evaluate the impacts of current and expected subsistence use on animal populations.

(3) Studies on transport such that sites of deposition of nutrients, organics, and pollutants can be defined.

Coachman, L. K., Dept. of Oceanography, Univ. of Washington, Seattle. Interviewed by J. Truett, 19 July 1983.

Dr. Coachman, oceanographer with extensive experience in the western Norton Sound and adjacent Bering Strait region, discussed general background of oceanographic work in the region and gave his opinions about needed physical process research. He described general circulation patterns in western Norton Sound and places and seasons where data were lacking. He suggested key literature references and additional people to interview about physical/biological information from the Yukon delta study area. He discussed an important proposal currently being considered to the National Science Foundation (Inner Shelf Transfer and Recycling Study, ISHTAR) and suggested Dr. P. McRoy of the University of Alaska as a further source of information regarding this proposal. He noted that the level of effects and the time-dependent behavior of the Yukon River discharge on receiving waters is virtually unknown. He stressed the need for mapping techniques to detect events such as reverses in the normal northward transport of Yukon River and Alaskan Coastal water.

Dau, C. U. S. Fish and Wildlife Service, Izembek National Wildlife Refuge, Alaska. Telephone conversation with J. Truett, 4 August 1983, and with S. R. Johnson, several dates.

Dr. Chris Dau has worked extensively on waterfowl in the Yukon delta area. He discussed important issues related to ducks and geese in the vicinity of the north delta of the Yukon, provided maps showing important zones for waterfowl feeding along the delta front, and sent photographs showing sloughs and adjacent habitats important to waterfowl near the coast of the north delta. Dr. Dau pointed out that some of the best waterfowl habitats on the north delta are near the coast in the northern parts near Kotlik; eroding beaches farther south make habitat less valuable there. The extent of inland intrusion by storm tides is very important for helping to evaluate potential impacts from oil spills. Creation of bird habitat is occurring as the delta front advances due to geologic accretion. The most important data gaps are in the intertidal zone, especially the clear-water areas between delta distributaries. A second important information gap is the summer and fall distribution of waterfowl and seabirds in Norton Sound waters off the delta coast. Molting and possibly even wintering birds (e.g. spectacled eider) assemble there but little is known of their numbers or distribution.

Derksen, D. U. S. Fish and Wildlife Service, Anchorage, Alaska. Interviewed by J. Truett, 29 July 1983.

Derk Derksen, recognized waterfowl authority on arctic Alaskan habitats, discussed briefly the current status of waterfowl research being conducted by the Fish and Wildlife Service in the Yukon delta region. He gave his views on the most important expected impacts of OCS development and on new research needed; he suggested several unpublished reports on birds that should be reviewed. Dr. Derksen noted that the Fish and Wildlife Service is currently looking at the effects of increased subsistence harvests on waterfowl, particularly colonial geese, and that they believe this to be a prime development-related threat to the waterfowl resource of the Yukon-Kuskokwim delta region. Major additional research needed is to evaluate, by new and innovative approaches, existing data on spring subsistence harvest of waterfowl, and to project what increased development in the area would do to the existing trend. The second priority for research is to conduct local distributional and life-history studies of geese, in order of priority as follows: white-fronted goose, black brant, lesser Canada goose, emperor goose, and cackling Canada goose.

Dupré, W. University of Houston Department of Geology. Telephone conversation with J. Truett, October 1983.

Dr. william Dupré has conducted the only thorough surficial geologic analysis and mapping work that exists for the north Yukon delta. He provided little additional data from that in his reports and publications, which are very thorough. But he gave leads to other individuals who might have important information on hydrologic processes in the delta, specifically M. D. Matthews (thesis described in this Annotated Bibliography) and R. Gibbs (Matthews' thesis director, see Gibbs in "Interviews" section of this Annotated Bibliography.)

Gibbs, R. University of Delaware, College of Marine Studies. Telephone conversation with J. Truett, October 1983.

Dr. Ron Gibbs directed the doctoral studies by M. D. Matthews (see description of thesis, this Annotated Bibliography) on flocculation in the salt wedge of Acharon Channel, Yukon River delta. This is the only work available on this important phenomenon in the Yukon delta. Dr. Gibbs discussed the likely seasonal changes in extent of salt wedge intrusion; he believed that salt wedge intrusion might be very small or non-existent during peak river discharge, but might extend far upstream at low-flow times. (Matthews' thesis did not describe extent of intrusion.) He admitted that, to his knowledge, virtually nothing is known of this phenomenon in the Yukon River delta, other than the work done by Matthews.

Gill, R., and C. Handel. U. S. Fish and Wildlife Service, Anchorage, Alaska. Interviewed by M. Raynolds, 15 August 1983.

Bob Gill and Colleen Handel have conducted much of the recent research on shorebirds in the Yukon-Kuskokwim delta region. They suggested reports and publications that should be consulted relative to the Yukon delta study and pointed out what needs to be done in the Yukon delta study area relative to potential effects on shorebirds of OCS oil and gas development. Almost no research has been done in the north delta region; the existing work has been concentrated farther south in the Yukon-Kuskokwim delta area, or in parts of Norton Sound away from the north delta. Studies of species distribution and abundance in time and space, food dependencies, and habitat use and migration patterns are needed. Zonation of bird use in the north delta is unknown, but might be similar in general to what has been documented (in terms of bird distribution by habitat) south of Cape Romanzof in the Yukon-Kuskokwim delta.

Ingraham, J. National Marine Fisheries, Northwest and Alaska Fisheries Center, Seattle, Washington. Interviewed by J. Truett, 21 July 1985.

James Ingraham is currently involved in modeling and describing physical parameters, mainly temperatures and salinities, in the Bering Sea. He provided an overview of his work and of what is generally known about temperature-salinity regimes in the northern Bering Sea. He supplied some of the most recent reports of the Northwest and Alaska Fisheries Center summarizing seasonal temperature and salinity patterns in the region of the Yukon delta study area and elsewhere in the Bering Sea.

Jewett, S. University of Alaska Institute of Marine Science, Fairbanks. Interviewed by J. Truett, 4 August 1983.

Steve Jewett, biologist who has authored or co-authored many of the useful invertebrate reports on Norton Sound, discussed the state of knowledge and importance of invertebrates. There is little information available on invertebrate distribution in Norton Sound other than that assembled by Steve Jewett and Howard Feder. Jewett noted that the lowest biomass of commercially important invertebrates in the Bering Sea is in Norton Sound; the area of western Norton Sound under the influence of the Yukon River plume is particularly depauperate in commercially important species. Copepods in Norton Sound may be an important food source for outmigrating salmon smolts, but data to show this are not available. Neomysis spp. (mysids) appear to be important foods to nearshore fishes and perhaps waterfowl; preliminary evidence shows them to be abundant in the Yukon delta littoral zone (between distributaries) in summer. Most of the invertebrate work in Norton Sound has been conducted in the deeper waters; invertebrate biota of the shallows, particularly in front of the Yukon delta, is poorly known.

Jones, R. D. U. S. Fish and Wildlife Service (retired). Anchorage, Alaska. Interviewed by J. Truett, 28 July 1983.

Dr. Jones, one of the few biologists who have conducted research on the north portion of the Yukon delta, provided important information on avifaunal use, bird habitats, and other biota of the coastal delta area as follows.

Pintails are perhaps the most numerous of the ducks and geese that use the north delta; their young are hatched near delta distributaries and large numbers feed on epibenthic invertebrates in the intertidal zone. Emperor geese and swans appear to nest mainly below the shrub (willow) zone on the delta; cackling Canada and white-fronted geese are more widely distributed. One of the great advantages that geese find for hatching and rearing young in the delta is the protection its many distributaries provide from mammalian predators (foxes, etc.). The clear-water zone in the mud-flat front of the delta appears very important for feeding pintails and to a lesser extent other ducks; causes of this zone are unclear. In terms of fishes, very little is known of ciscoes, sheefish, and other anadromous species in the delta, but these fish are very abundant and important for subsistence in the area. Research is badly needed on ciscoes and other non-salmonid anadromous species and their invertebrate food sources. Great hazards to waterfowl habitats are a potential if oil should come ashore during large storm surges in late summer or early fall.

King, J. U. S. Fish and Wildlife Service, Juneau, Alaska. Interviewed by J. Truett, 25 July 1983.

Dr. James King is a waterfowl biologist with years of experience in the Yukon-Kuskokwim delta region. He provided, to the best of his knowledge, a verbal overview of waterfowl use of the study area, and suggested further sources of information. He noted that the entire intertidal zone of the north Yukon delta south to beyond the Kuskokwim delta is important to vast numbers of pintails in late summer and early fall. Some waterfowl, notably some of the geese, are highly traditional in their use of specific sites for nesting and feeding, and may not shift their use of habitats even should habitat quality change. Storm surges in fall come inland far beyond major nesting areas for some species; the surge effect may be greater upriver than at the coast. Tidal fluctuation is larger on the west side of the delta than on the north side. There are no good existing maps that show inland extent of storm surge. Factors that regulate waterfowl productivity in the delta region include timing of spring thaw (late spring can reduce production drastically), subsistence hunting, and occasionally summer flooding by storm surge. Research needed would relate to productivity of mudflats off the north delta and its use by shorebirds, diet of pintails feeding in mudflat areas, and general vulnerability of mudflat habitats to pollution by oil.

Laevastu, T. National Marine Fisheries Service, Northwest and Alaska Fisheries Center, Seattle, Washington, Interviewed by J. Truett, 20 July 1983.

Dr. Laevastu, marine fisheries biologist and oceanographer with extensive experience in the Bering Sea, discussed the general state of knowledge of commercial fisheries and provided introductions to several fisheries authorities on his staff. Individuals of his staff who were particularly helpful were Richard Major and James Ingraham, interviews with whom are discussed separately in this volume. Dr. Laevastu also provided useful and relevant publications by the Northwest and Alaska Fisheries Center. He suggested that new research, to reflect the desires of users, would best concentrate on species used by man, but deferred to his staff for specific suggestions.

Lensink, C. U. S. Fish and Wildlife Service, Anchorage, Alaska. Interviewed by J. Truett, 27 July 1983.

Dr. Lensink is recognized for his outstanding work on waterfowl in Alaska. In an interview he discussed at length the status of waterfowl in the Yukon delta area and the current research in the area. The Fish and Wildlife Service has done extensive waterfowl research south of Cape Romanzof, and continues to do so. Most of this work is outside the Yukon delta study area. Studies are planned for the future on the north delta, within our study area. Maps of vegetation/habitat zones in the north delta region have been started but are not yet completed. The geographic area in the Yukon-Kuskokwim delta that is most in need of research is the north delta that is the main focus of our study. Needed in this area is research to define the density distribution of waterfowl species from late April to early October. This area may be as important to staging waterfowl as it is for nesting waterfowl. Impacts of oil on both staging and nesting waterfowl could be quite severe.

Major, R. National Marine Fisheries Service, Northwest and Alaska Fisheries Center, Seattle,Washington, Interviewed by J. Truett, 20 July 1983.

Richard Major, salmon fisheries specialist with extensive experience in the Bering Sea, provided information on salmon in the marine environment. He believed that the time when salmon are most stressed and thus most vulnerable to pollution that might be caused by OCS oil and gas development is when they first reach the estuarine environment as smolts. He pointed out the most critical data gaps in knowledge of the marine life of salmon. He provided useful reports and suggested others. He suggested that Ron Regnart of the Alaska

Department of Fish and Game and Richard Straty of the National Marine Fisheries Service Auke Bay Laboratory would have better information than he about salmon in and near fresh water. (Interviews with these individuals are abstracted under their names.)

Muench, R. D. SAI Northwest, Seattle, Washington. Telephone contact by J. Truett, 18 July 1983.

Dr. Muench, one of the few individuals with considerable oceanographic experience in Norton Sound proper, did not have time for a lengthy interview, but during a phone call provided suggestions for data sources. He had little to add to information contained in recommended literature.

Regnart, R. Alaska Department of Fish and Game, Anchorage, Alaska. Interviewed by J. Truett, 28 July 1983.

Ron Regnart supervises commercial and anadromous fisheries programs for ADF&G. He provided important unpublished reports and verbal discussions related to the state of knowledge of anadromous and freshwater fishes in the Yukon delta region. He also suggested other individuals in the ADF&G who might have additional information, and gave his opinions on needed research. He believed the ADF&G recent status reports (which he provided) to be the best current information on Yukon delta fisheries. He believed one of the major data gaps related to potential effects of OCS oil development to be the temporal and spatial distribution of juvenile salmon in the Yukon delta and Norton Sound. More information is needed on the temporal and spatial distribution of the marine forage fish (herring, capelin) resource. Subsistence use levels on non-salmonid anadromous and freshwater fishes needs to be better evaluated. Finally, basic surveys of distribution, abundance, and life histories of these non-salmonids are needed.

Schumacher, J. National Oceanic and Atmospheric Administraton, Pacific Marine Environmental Laboratory, Seattle, Washington, Interviewed by J. Truett, 22 July 1983.

James Schumacher, oceanographer with extensive recent experience in the Norton Sound region, provided information and suggested publications and research needs related to physical oceanographic processes in the area of study. He stressed that local field measurements of wind (not extrapolations from existing statistics) will be needed before accurate projections of estuarine water movement patterns and storm surge in the Yukon delta can be made. He discussed the current state of knowledge of water mass movement in western Norton Sound and vicinity. He pointed out some of the more important publications about transport in this region, and named other individuals who should be contacted. He offered possible explanations for the interdistributary clear water zone that has been observed at the Yukon delta front. The most important general research need he saw was a highly coordinated, interdisciplinary study of the very shallow water zone of the Yukon delta.

Straty, Richard. Northwest and Alaska Fisheries, Auke Bay Laboratory, Auke Bay, Alaska. Interviewed by J. Truett, 26 July 1983.

Dr. Straty has worked extensively with the salmon resource of the Bering Sea. He discussed the general information available on salmon in the marine environment, but suggested that other individuals (he recommended Louis Barton of ADF&G) would have better knowledge of salmon in estuarine and freshwater environments of the Yukon delta region. He suggested other individuals in the Auke Bay Laboratory who would be able to provide us with recent reports on north Bering Sea fisheries biology and responses of fish to oil contamination. He also mentioned literature available elsewhere and individuals in other agencies that should be able to provide assistance. Dr. Straty suggested that, of the total marine mortality of salmon, most probably occurs in estuaries near river mouths, where out-migrating smolts adjust to the marine environment. This suggested a site where additional stress offered by OCS oil and gas development might be critical.

Trasky, L. Alaska Department of Fish and Game, Anchorage, Alaska. Interviewed by J. Truett, 28 July 1983.

Lance Trasky supervises environmental impact assessment affairs for the ADF&G. He pointed out the impact analysis work that has been done in the Yukon delta area by the state, and provided copies of important reports. He believed that the most significant impacts to occur because of oil and gas development will be a direct result of increased local populations and income, which will promote changes in human life styles and changes in resource use. The most important information needed is knowledge of how these social changes will affect the biota.

Wolfe, R. Alaska Dept. Fish and Game, Bethel. Telephone conversation with J. Truett, 2 August 1983.

Bob Wolfe is currently involved in subsistence-based economics studies in the Yukon River delta area. He pointed out that subsistence issues are of primary concern to the State of Alaska in the Yukon delta. Subsistence studies in progress are descriptive in nature; what is needed is an impact study to evaluate the effects of subsistence on the biota, and thereby to predict what changes in effects would be caused by OCS petroleum development. He suggested that a good approach to devising such studies would be to first compare the Alaskan North Slope development experience with that of the Canadian Beaufort Sea, then decide where the most likely areas of impact would be and thus where studies should focus.

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