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DISTRIBUTION, ABUNDANCE, COMMUNITY STRUCTURE AND TROPHIC RELATIONSHIPS OF THE NEARSHORE BENTHOS OF COOK INLET AND NEGOA

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SECTION I

DISTRIBUTION, ABUNDANCE, COMMUNITY STRUCTURE AND TROPHIC RELATIONSHIPS OF THE NEARSHORE BENTHOS OF COOK INLET AND THE NORTHEAST GULF OF ALASKA

I. SUMMARY OF OBJECTIVES, CONCLUSIONS, AND IMPLICATIONS WITH RESPECT TO OCS OIL AND GAS DEVELOPMENT

The long-term objectives of this study are: 1) a qualitative and quantitative inventory of benthic species within and adjacent to identified oil-lease sites in the northeast Gulf of Alaska (NEGOA) and lower Cook Inlet, 2) a description of spatial distribution patterns of selected species in the designated study areas, and 3) observations of biological interrelationships, specifically trophic interactions, between components of the benthic biota in designated study areas.

Forty-two widely dispersed permanent stations for quantitative grab sampling have been established in the northeastern Gulf of Alaska, and these stations represent a reasonable nucleus around which a monitoring program can be developed. Sixty-one widely dispersed stations were occupied with a van Veen grab in Cook Inlet; thirteen of these stations were ultimately selected for detailed analysis.

A pipe dredge was used in lower Cook Inlet to compliment data obtained by grab and trawl, and was also valuable for obtaining large numbers of clams used in age-growth studies.

The general patchiness of fauna initially observed at most stations in the Gulf of Alaska suggested that at least five replicates be taken per station. At least this number of replicates were taken at all stations. Analysis of grab data by the end of the project should enable us to suggest the optimum number of replicates per station for monitoring programs.

One hundred and forty stations were occupied with an otter trawl in the northeastern Gulf of Alaska. Forty-seven stations were occupied with three types of trawls in Cook Inlet.

Four hundred and fifty-seven invertebrate species were collected in the grab sampling program, and 168 invertebrate species were taken in the trawl program in the northeast Gulf of Alaska. Two hundred and eleven species have been determined from the grab sampling program, and 189 invertebrate species from the trawl and dredge programs in Cook Inlet. It is probable that all species with numerical and biomass importance have been collected in all areas of investigation and that only rare species will be added in future sampling.

Basic information on diversity, dominance and evenness is now available for all permanent stations on the NEGOA grid. Caution is indicated in the interpretation of these values until further data are available over a longer time base.

Infaunal invertebrates taken by van Veen grab in the northeast Gulf of Alaska have been used to comprehend station/species aggregations by cluster analysis. Preliminary groupings of stations into three basic clusters have been accomplished. Further understanding of station clustering has been gained by clustering species, and constructing two-way coincidence tables of species vs. station groups. By this means, specific groupings of species can be related to station clusters, and intermediate positions of stations (or clusters) can be determined by the particular groupings of species they have in common.

The joint National Marine Fisheries Service trawl charter for investigation of epifaunal invertebrates and demersal fishes in the northeast Gulf of Alaska was effective, and excellent spatial coverage was achieved. However, no seasonal information was obtained for this area. Trawl surveys in lower Cook Inlet achieved good coverage, although only limited seasonal data were obtained. Integration of information from these cruises with infaunal benthic data will enhance our understanding of these shelf ecosystems.

Information on feeding biology of species from the Gulf of Alaska is available from literature analysis and information collected on Outer Continental Shelf Environmental Assessment Program (OCSEAP) cruises. A Kodiak Island food web has been developed. The major food items in the web were polychaetes, gastropod (snails), pelecypods (clams), amphipods, hermit crabs, true crabs, and shrimps. Snow and king crabs fed heavily on benthic animals that, in turn, relied in whole or in part on sediment-associated organic material, detritus, bacteria, and benthic diatoms for food. The invertebrates in two Kodiak bays relied on a variety of feeding methods while fishes tended to be predators. The principal food groups used by the Pacific cod, Gadus *macrocephalus*, at all sites in the northeast Gulf of Alaska and the Kodiak shelf were molluscs, crustaceans, and fishes. There were some small quantities (less than 10% of the total occurrence) of annelids, euphausiids and mysids, isopods and echinoderms taken by cod. A food web, inclusive of major epifaunal species, for Cook Inlet is also available. The snow crab, *Chionoecetes bairdi*, fed, in order of decreasing importance, on clams, hermit crabs, barnacles and crangonid shrimps. King crabs, *Paralithodes camtschatica*, in Cook Inlet fed on two deposit-feeding clams, *Nuculana* and *Macoma*, and barnacles.

Clam studies in Cook Inlet have resulted in age-growth data for six species: *Nucula tenuis*, *Nuculana fossa*, *Glycymeris subobsoleta*, *Macoma calcarea*, *Tellina nuculoides* and *Spisula polynyma*. Such age-growth analyses will make available biological parameters useful for long-range monitoring programs in these areas.

Initial assessment of all data suggests that: 1) sufficient station and/or area uniqueness exists to permit development of monitoring programs based on species composition at selected stations utilizing both grab and trawl sampling techniques, and 2) adequate numbers of biologically well-known, unique, abundant, and/or large species are available to permit nomination of likely monitoring candidates for the areas once industrial activity is initiated.

11. INTRODUCTION

General Nature and Scope of Study

The operations connected with oil exploration, production, and transportation in the Gulf of Alaska 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 recorded 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 Nelson-Smith, 1973; Pearson, 1971, 1972, 1975; Rosenberg 1973, for general discussions on benthic biological investigations in industrialized marine areas). Populations of marine species fluctuate over a time span of a few to 30 years (Lewis, 1970, and 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, and personal communication).

Benthic organisms (primarily the infauna but also 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; and Rosenberg, 1973 for discussion on long-term usage of benthic organisms for monitoring pollution).

The presence of large numbers of benthic epifaunal species of actual or potential commercial importance (crabs, shrimps, snails, fin fishes) in the Gulf of Alaska further dictates the necessity of understanding benthic communities there since many commercial species feed on infaunal and small epifaunal residents of the benthos (see Zenkevitch, 1963, for a discussion of the interaction of commercial species and the benthos; also see appropriate discussions in Feder, 1977 and 1978). 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), and California (Straughan, 1971) suggests that at the completion of an initial study, selected stations should be examined regularly on a long-term basis to determine changes in species content, diversity, abundance and biomass. 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 Gulf of Alaska are essential to understand the trophic interactions involved in these areas and the changes that might take place once oil-related activities are initiated.

The benthic biological program in the northeast Gulf of Alaska (NEGOA) has emphasized development of an inventory of species as part of the examination of biological, physical and chemical components of those portions of the shelf slated for oil exploration and drilling activity. In addition, the program designed to assess assemblages (communities) of benthic species on the NEGOA shelf will expand the understanding of distribution patterns of species here. A developing investigation concerned with the biology (primarily concerned with feeding activity) of selected species on the Kodiak shelf and in Cook Inlet will further the understanding of the trophic dynamics of the Gulf of Alaska benthic system.

The study program was designed to survey the benthic fauna on the Alaska continental shelf in regions of potential *oil* and *gas* concentrations. During the first phases of research, data were obtained on faunal composition and abundance to develop baselines to which future changes can be compared. Long-term studies on life histories and trophic interactions of identified important species should define aspects of communities and ecosystems potentially vulnerable to environmental damage, and should help to determine rates at which damaged environments can recover.

Relevance to Problems of Petroleum Development

Lack of an adequate data base elsewhere makes it difficult at present to predict the effects of oil-related activity on the subtidal benthos of the Gulf of Alaska (NEGOA). However, the rapid expansion of research activities in NEGOA should ultimately enable us to point with some confidence to certain species or areas that might bear closer scrutiny if industrial activity is initiated. It must be emphasized that an extensive data base is needed to comprehend long-term fluctuations in density of marine benthic species; 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 indicator species for disturbed areas. Thus, close examination of stations with substantial complements of infaunal species is warranted (see Feder and Mueller, 1975, and NODC data on file for examples of such stations). Changes in the environment at stations with relatively large numbers of species might be refleeted by a decrease in diversity with increased dominance of a few species (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 (see Feder and Mueller, 1975; Feder, 1977; Jewett and Feder, 1976 for references to relevant stations). The potential effects of loss of species to the trophic structure in the Gulf of Alaska cannot be assessed at this time, but the problem can be better addressed once benthic food studies resulting from current projects are available (Feder, unpublished data from Cook Inlet, Bering Sea; Jewett and Feder, 1976; Feder, 1977; Feder and Jewett, 1977; Smith *et al.*, 1977).

Data indicating the effects of oil on most subtidal benthic invertebrates are fragmentary (see Boesch, *et al.*, 1974; Malins, 1977 for review; Baker, 1977 for a general review of marine ecology and oil pollution), but echinoderm 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 Gulf of Alaska (see Feder, 1977 for references to relevant stations in the northeast Gulf of Alaska), and could be affected by oil activities there. Asteroids (sea stars) and ophiuroids (brittle stars) are components of the diet of large crabs (for example king crabs feed on sea stars and brittle stars: unpub. data, Guy Powell, Alaska Dept. of Fish and Game; Feder, 1977) and demersal fishes. Snow crabs (*Chionoecetes* spp.) are conspicuous members of the shallow shelf of NEGOA and lower Cook Inlet, and support commercial fisheries of considerable importance. Laboratory experiments with this species have shown that postmolt individuals lose most of their legs after exposure to Prudhoe Bay crude oil; obviously this aspect of the biology of the snow crab must be considered in the continuing assessment of this species (Karinen and Rice, 1974). Little other direct data based on laboratory experiments are available for subtidal benthic species (see Nelson-Smith, 1973). Experimental ion on toxic effects of oil on other common members of the subtidal benthos should be strongly encouraged for the near future in OCS programs.

A direct relationship between trophic structure (feeding type) and bottom stability has been demonstrated by Rhoads (see Rhoads, 1974 for review). A diesel fuel spill resulted in oil becoming adsorbed on sediment particles with resultant mortality of many deposit feeders on sublittoral muds. Bottom stability was altered with the death of these organisms, and a new complex of species became established in the altered substratum. The most common members of the infauna of the Gulf of Alaska and the Bering Sea are deposit feeders; 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, supplemented by principal components and/or principal coordinate analysis, should provide techniques for the selection of stations useful for monitoring the infauna (see Feder, 1978; Feder and Matheke, in press) for such studies in NEGOA). In addition, these techniques should provide an insight into normal ecosystem variation (Clifford and Stephenson, 1975; Williams and Stephenson, 1973; Stephenson *et al.*, 1974). Also, intensive examination of the biology (e.g., age, growth, condition, reproduction, recruitment, and feeding habits) of selected species should afford obvious clues of environmental alteration.

III. CURRENT STATE OF KNOWLEDGE

Gulf of Alaska

Little was known about the biology of the invertebrate benthos of the northeast Gulf of Alaska (NEGOA) at the time that OCSEAP studies were initiated there, although a compilation of some relevant data on the Gulf of Alaska was available (Rosenberg, 1972). A short but intensive survey in the summer of 1975 added some benthic biological data for a specific area south of the Bering Glacier (Bakus and Chamberlain, 1975). Results of the latter study are similar to those reported by Feder and Mueller (1975) in their OCSEAP investigation. Some scattered data based on trawl surveys by the Bureau of Commercial Fisheries (National Marine Fisheries Service) were available, but much of the information on the invertebrate fauna was so general as to have little value. A summarization of existing literature is included in Feder and Mueller (1977) and AEIDC and ISEGR (1974).

In the summer and fall of 1961 and spring of 1962, otter trawls were used to survey the shellfishes and bottomfishes on the continental shelf and upper continental slope in NEGOA (Hitz and Rathjen, 1965). The surveys were part of a long-range program begun in 1950 to determine the size of bottomfish stocks in the northeastern Pacific Ocean between southern Oregon and northwest Alaska. Invertebrates taken in the trawls were of secondary interest, and only major groups and/or species were recorded. Invertebrates that comprised 27 percent of the total catch were grouped into eight categories; heart urchins (Echinoidea), snow crabs (*Chionoecetes bairdi*), sea stars (Asteroidea), Dungeness crabs (Cancer *magister*), scallops (*Pecten caurinus*), shrimps (*Pandalus borealis, P. platyceros*, and *Pandalopsis dispar*), king crabs (*Paralithodes camtschatica*), and miscellaneous invertebrates (shells, sponges, etc.) (Hitz and Rathjen, 1965). Heart urchins accounted for about 50 percent of the invertebrate catch and snow crabs ranked second, representing about 22 percent. Approximately 20 percent of the total invertebrate catch was composed of sea stars.

Further knowledge of invertebrate stocks in the north Pacific is scant. The International Pacific Halibut Commission (IPHC) surveys parts of the Gulf of Alaska annually, and records selected commercially important invertebrates; however, non-commercial species are discarded. The benthic investigations of Feder and Mueller (1975), Feder *et al.* (1976) and Matheke *et al.*, (in press), and Feder, (1977) represent the first intensive qualitative and quantitative examinations of the benthic infauna and epifauna of the Gulf of Alaska.

Data on the infauna collected in the first year (1974-1975) of the OCSEAP study in NEGOA served as a springboard and an intensive data base for the studies in 1975-1977. Information in the literature will aid in the interpretation of the biology of some dominant infaunal organisms in the Gulf of Alaska. The use of cluster and multivariate techniques for the analysis of infaunal data (now being applied to our data from the Gulf of Alaska; Matheke *et al.*, in press; Feder and Matheke, in press) has been widely used by numerous investigators examining shallow-water marine environments. Techniques are well reviewed in Clifford and Stephenson (1975).

Few data on non-commercially important benthic invertebrates of lower Cook Inlet were available until recent OCSEAP studies were initiated [Feder, 1977 and D. Lees, unpub. data and reports; draft copy of lower Cook Inlet

Synthesis Report, 1977 (Scientific Applications, 1977)]. The primary data available were principally catch and assessment records for commercial shellfish species. Based on OCSEAP feeding studies accomplished in lower Cook Inlet, NEGOA, and the Kodiak Shelf (Feder, 1977; Feder, 1978; Feder and Jewett, 1977), it is apparent that benthic invertebrates play an important role in the food dynamics of commercial crabs and demersal fishes on the Gulf of Alaska shelf.

Dennis Lees (unpub. data) suggests that the macrophytes of the intertidal and shallow subtidal regions produce materials utilized by detritivores in shallow and deep waters throughout Cook Inlet. Many of the organisms depending on these plant materials are either of commercial importance or are food items important to commercial species. In the past few years information linking the macrophyte producers to commercially important species has begun *to* emerge, but the full importance of this linkage has yet to be recognized. Many marine birds and mammals depend heavily on organisms living in the inshore areas which in turn are dependent on plant material produced by macrophytes. Studies by D. Lees and Feder (OCSEAP data) strongly suggest that the abundant deposit feeders in lower Cook Inlet are concentrated in regions of detrital accumulations (e.g. Kamashak Bay).

IV. STUDY AREAS

The established stations for the NEGOA and Cook Inlet study areas are tabulated, figured and discussed in the 1977 OCSEAP Annual Reports (Feder, 1977; 1978;). Additional stations of opportunity were established in the summer of 1978 in Port Etches (Hinchinbrook Island) and Zaikof and Rocky Bays (both on Montague Island) (locations of stations in the latter areas will be included in the NEGOA Final Report).

V. SOURCES, METHODS AND RATIONALE OF DATA COLLECTION

Lower Cook Inlet

Detailed methodology for the investigations of 1976-78 is included in Feder (1977, 1978). Sampling was accomplished with an Eastern otter trawl, try net, Agassiz trawl, pipe dredge, and van Veen grab. Preliminary workup of trawl material was accomplished onboard ship. All dredge and grab material were washed on 1.0 mm screens. All invertebrates were given tentative identifications, and representative samples of individual species preserved in 10% buffered formalin, and labeled for final identification at the Institute of Marine Science and the Marine Sorting Center, University of Alaska, Fairbanks. Stomachs of selected species (e.g. shrimps, king crabs, snow crabs, hermit crabs) were either examined on shipboard or in the laboratory. All species used in feeding studies were measured, separated by sex where readily possible (e.g., in crabs but not necessarily in shrimps), and separated into as many size groups as possible. Clams used in growth studies were separated from sediments on shipboard and in the laboratory, and measurements made on them in the laboratory.

Final analysis of material was accomplished by methods developed in past OCSEAP studies (Jewett and Feder, 1976; Feder, 1977; Feder and Jewett, 1977). All species were assigned Taxon Code numbers, and summarized according to computer programs developed for other benthic studies by Feder (for example, see Feder, 1977).

All data were summarized and analyzed with the aid of available or specially written computer programs at the University of Alaska. Growth-history analyses of clam species was applied according to techniques described in Feder and Paul (1974) and Paul *et al.* (1976).

Northeast Gulf of Alaska (NEGOA)

Sampling with a small try net was accomplished in Port Etches, Zaikof Bay and Rocky Bay (at entrance to Prince William Sound) with a try net and van Veen grab. No laboratory activities took place on this project in 1978. Most of the activities in 1978 were concerned with analysis of infaunal data to be included in the Final Report (see Feder, 1977 for methodology employed for workup of quantitative infaunal data collected on past cruises).

VI. RESULTS

Lower Cook Inlet

A Summary Report, based on some of the data collected on cruises of the NOAA Ships *Miller Freeman* and *Surveyor*, is included with this Annual Report (Summary Report, Sect. 11). All data will be included in the Final Report.

1732 specimens of juvenile king and snow crabs, and adult shrimps from lower Cook Inlet were examined for food contents in stomachs. The shrimp species and numbers of each species examined are as follows:

Pandalus goniurus (bumpy shrimp) - 176
Pandalus borealis (pink shrimp) - 257
Pandalus hypsinotus (coonstripe shrimp) - 159
PandaZus danae (no common name) - 27
Crangon dalli (sand or gray shrimp) - 858
Crangon fransciscorum (sand or gray shrimp) - 12
Crangon communis (sand or gray shrimp) - 25
Sclerocrangon boreas (no common name) - 49
Lebbeus groenlandica (no common name) - 25

108 juvenile snow crab and 35 post larval king crab are included in the above total of specimens examined. Adult snow, king and Dungeuess crab stomachs were also examined. Data and discussions are either found in Summary Report II of this Annual Report (also see Paul *et al.*, in press) or will be summarized in the Final Report.

Observations of shallow-water areas by D. Lees (subcontract to this study) will be included and discussed in the Final Report.

Northeast Gulf of Alaska (NEGOA)

Epifaunal samples were collected in Port Etches (Hinchinbrook Island) on board the R/V *Aeons* in March 1978. Additional epifaunal and infaunal samples were collected July - August 1978 in Port Etches, Zaikof and Rocky Bays (all at entrance to Prince William Sound) on the M/V *Searcher*.

Activities for the past year have consisted primarily of data analysis and manuscript preparation for the NEGOA infaunal Final Report. This report is in its final phases of preparation (Feder and Matheke, in press).

A Final Report entitled, "Distribution and Abundance of some Epibenthic Invertebrates of the Northeastern Gulf of Alaska With Notes on the Feeding Biology of Selected Species," was submitted to OCSEAP in August 1978.

Food Studies

Food studies in Cook Inlet have centered on the snow crab, *Chionoecetes bairdi*, the king crab (*Paralithodes camtschatica*), the Dungeness crab (*Cancer magister*) , shrimps of the Families Pandalidae and Crangonidae, and the known prey species taken by these organisms. The goal of these studies is to expand and make the food webs presented in previous reports more comprehensible (Feder, 1977, 1978). The results of these studies will also be useful in (1) explaining the distribution of adult and juvenile of the above species, (2) understanding the interrelationships of these species to other organisms, such as some bottom fishes, which also feed in the benthic environment, and (3) describing the effect of feeding by these species on the populations of prey species.

The results of some of the above studies are included in Feder (1977; 1978) and in the Summary Report (Summary Report, Sect. II of this Annual Report).

A master's thesis treating the feeding biology and trophic interactions of the abundant crangonid shrimp *Crangon dalli*, is in progress. Completion date for this thesis is expected to coincide with the submission period for the lower Cook Inlet Final Report.

VII. DISCUSSION

Lower Cook Inlet

A preliminary discussion of (1) important habitats for biologically important Crustacea in lower Cook Inlet, and (2) the food of snow, king and Dungeness crabs in lower Cook Inlet are included in this Annual Report as Summary Report II.

Additional food data on three crangonid shrimps (*Crangon dalli*, *C. franciscorum*, *Sclerocrangon boreas*), one species of hippolytid shrimp (*Lebbeus groenlandica*), and four species of pandalid shrimps (*Pandalus borealis* - pink, *P. goniurus* - bumpy, *P. hypsinotus* - coonstripe, and *P. danae* - no common name) will be included and discussed in the Final Report.

Additional discussions on the performance of the van Veen grab, number of grabs taken per station, station coverage, species composition, biomass, food studies, and clam studies are included in Feder (1978) and Feder and Matheke (in press).

Northeast Gulf of Alaska (NEGOA)

Data and discussions for NEGOA investigations are available in the OCSEAP Annual Reports for 1977 and 1978 (Feder, 1977, 1978) and the Final Report on the epifauna (Feder and Jewett, 1978; also see Jewett and Feder, 1976).

Activities planned for 1979 include analysis of the trawl data collected in 1978 on the M/V *Searcher* in the vicinity of Hinchinbrook Entrance and examination of stomachs of selected species of invertebrates and fishes taken on this cruise, if time permits.

A Final Report on the infauna of NEGOA will be submitted to OCSEAP shortly, and will include a discussion of species assemblages on the shelf and possible factors responsible for the maintenance of these assemblages (Feder and Matheke, in press).

VIII. CONCLUSIONS

Lower Cook Inlet

The Annual Report for 1978 (Feder, 1978) and the enclosed Summary Report for lower Cook Inlet (Summary Report in Section II of this Annual Report), summarize the benthic invertebrate work accomplished in this region through 1978. Additional data are available, but are not presented or discussed here. These data will be included with the Final Report.

Northeast Gulf of Alaska (NEGOA)

Data collected since the inception of the studies in NEGOA in 1974 have made it possible to comprehend various aspects of the distribution, abundance, and general biology of the more important invertebrate components of the shelf. Some generalizations are now possible, and are included below (also see Feder and Mueller, 1975; Feder et *al.*, 1976; Feder, 1977 for the data base used for conclusions below).

Forty-two widely dispersed permanent stations have been established to sample the infauna in the northeastern Gulf of Alaska in conjunction with the physical, chemical, heavy metals and hydrocarbon programs. These stations represent a reasonable nucleus around which a monitoring program can be developed (Feder, 1977).

The sampling device chosen, the van Veen grab, functioned effectively in all weather and adequately sampled the infauna at most stations. Penetration was excellent in the soft sediments characteristic of the majority of stations; poor penetration occurred at a few stations where the substratum was sandy or gravelly. General patchiness of many components of the infauna and quantitative field testing for optimum number of replicates per station suggest that five replicate grabs are adequate.

There is now a reasonable understanding, for grab stations occupied on the NEGOA shelf, of the invertebrate species present and general species distribution. Four hundred and fifty-seven (457) species have been identified. Fourteen marine phyla are represented in the collections. The important groups, in terms of number of species in descending order, are the polychaetous annelids, mollusca, arthropod crustaceans, and echinoderms. It is probable that all species with numerical and biomass importance have been collected and that only rare species will be added to the list in the future.

The diversity indices included in the 1976 Annual Report (Feder *et al.*, 1976), Simpson, Brillouin, and Shannon-Wiener, are complimentary since the former reflects dominance of a few species and the latter two are weighted in favor of rare species. Values calculated in the 1977 Annual Report (Feder, 1977), in general, reflect these weighings. A preliminary examination of the two measures of evenness (or equitability) indicates a reasonable relationship to the calculated diversity values. In general, high measures of evenness show numerical codominance of many species (with low Simpson index and high Shannon-Wiener and Brillouin indices) while low evenness measures imply marked dominance of a few species (high Simpson index and low Shannon-Wiener and Brillouin indices). All of these indices and measures must still be interpreted with considerable caution until more data are available. Further assessment of the meaning of the calculated values will be included in the NEGOA Final Report.

Criteria established for Biologically Important Taxa (BIT) for the grab data have delineated 95 species. Representative members of the BIT should be the organisms most intensively studied for their general biology in future work on the NEGOA shelf.

Information on feeding biology of most species has been compiled. Most of the information for the northeast Gulf of Alaska is from literature source material; it is suggested that experimental work on feeding biology of selected species be encouraged for this region (Feder and Matheke, in press).

Clustering techniques have supplied valuable insights into species distributions on the shelf of the northeast Gulf of Alaska (see Clifford and Stephenson, 1975 for review of numerical classification). The preliminary grouping of stations by three different classification schemes has delineated three basic clusters - Group I, which is characterized by a group of stations south of Prince William Sound; Group II, which generally consists of stations close to shore; and Group III, composed of stations that are at or near the shelf edge. Further insight into the meaning of stations clustered by our analysis is gained by means of the two-way coincidence table of station groups vs. species groups. Specific groupings of species can be related to station clusters, and intermediate positions of stations (or clusters) can be determined by the particular groupings of species they have in common. Some insight into the stability of the cluster groups should be gleaned by examination of clustering of the second year station data. Analysis of this data is completed, and is included in the Final Report (Feder and Matheke, in press) now ready to submit to OCSEAP (preliminary data and analysis are included as Appendix Table V in Feder, 1977).

Initial assessment of data printouts of infaunal species (data to be stored at the National Environmental Data Center) indicates that (1) sufficient station uniqueness exists to permit development of an adequate monitoring program based on species composition at selected stations, and (2) adequate numbers of unique, abundant, and/or large species are available to ultimately permit nomination of likely monitoring candidates.

The trawl survey on the NEGOA shelf for investigation of epifaunal invertebrates and demersal fishes was effective (Jewett and Feder, 1976; Feder and Jewett, 1978). The major limitations of the survey were those imposed by the selectivity of the gear used and the seasonal movements of certain species taken. In addition, rocky bottom areas were not sampled since otter trawls of the type used in the survey could only be fished on relatively smooth bottom. However, the study was effective for determining the epibenthic invertebrates and demersal fishes present on sediment bottom and for achieving maximum spatial coverage of the area. Integration of this information with data on the infaunal benthos (Feder *et al.*, 1976; Feder, 1977) should enhance our understanding of the shelf ecosystem.

To date the epifaunal investigation by OCSEAP discussed above represents the only intensive taxonomic survey of epibenthic invertebrates in the Gulf of Alaska (Feder and Jewett, 1978). Although Hitz and Rathjen (1965) surveyed invertebrates and bottom fishes on the continental shelf of the northeast Gulf of Alaska in 1961 and 1962, invertebrates taken in their trawls were of secondary interest. Only major invertebrate species and/or groups were recorded, and organisms were grouped into eight categories in descending order of importance: heart urchins (Echinoidea), snow crabs (*Chionoecetes bairdi*), scallops (*Pecten caurinus*), shrimps (*Pandalus borealis*, *P. platyceros*, and *Pandalopsis dispar*), king crabs (*Paralithodes camtschatica*), and miscellaneous invertebrates (shells, sponges, etc.). Additional data on commercially important shellfishes are available in Ronholt *et al.* (1976).

Analysis of epifaunal data from the present NEGOA investigation (Feder and Jewett, 1978) indicates that molluscs, crustaceans, and echinoderms are the leading invertebrate groups on the shelf with the commercially important crab, *Chionoecetes bairdi*, clearly dominating all other species. Furthermore, stomach analysis of the Pacific cod, *Gadus macrocephalus*, on the adjacent Kodiak shelf area, reveals that *C. bairdi* is a dominant food item of that fish. Thus, the Pacific cod, a non-commercial species which has commerical potential (Jewett, 1977; and 1978), is preying intensively on a species of great commercial significance. 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). The results of these experiments must be seriously considered as the petroleum resources in the Gulf of Alaska are developed.

Highest densities of *Chionoecetes bairdi*, *Pandalus borealis*, *Ophiura sarsi*, *Ctenodiscus crispatus*, and fishes were recorded in the vicinity of the Copper River delta southwest of Kayak Island (see Ronholt et *al.*, 1976, for distribution and density data for fishes there). Little is known about the productivity of this area, but primary and secondary production may be higher there as a result of nutrients supplied by the Copper River. Furthermore, enhanced productivity there may be related to the presence of gyres that extend vertically from the water surface to the bottom (Gait, 1976).

The biological samples now available for the eipifauna from three bays adjacent to Hinchinbrook Entrance, Prince William Sound (Port Etches, Zaikof Bay, Rocky Bay) should be useful as a data base in the event of an oil tanker accident adjacent to these sensitive areas. Furthermore, Port Etches has been suggested as a possible site to tow damaged tankers following accidents in Prince William Sound (Melteff, 1978).

Availability of many readily identifiable, biologically well-understood infaunal and epifaunal invertebrates is a preliminary to the development of monitoring programs. Sizeable biomasses of taxonomically well-known molluscs, crustaceans, and echinoderms were typical of most of our stations, and many species of these phyla were sufficiently abundant to represent organisms potentially useful as monitoring tools. The present investigation clarifies some aspects of the biology of many of these organisms, and should increase the reliability of future monitoring programs for the NEGOA shelf and lower Cook Inlet.

IX. NEEDS FOR FURTHER STUDY

The number of grab stations occupied in lower Cook Inlet and NEGOA was dictated by available ship time and funding for processing of samples. Thus, a relatively small number of stations were occupied on the extensive shelf of the northeastern Gulf of Alaska and in lower Cook Inlet. It is possible that some areas of biological importance were omitted. Additional stations should be occupied in the future to accumulate data for some of the larger unsampled areas.

All samples taken on a semi-seasonal basis in lower Cook Inlet and NEGOA should be processed, and all data made available. Analysis of all archived samples will make it possible to better comprehend the seasonality of benthic infauna.

Selected members of the infauna should be chosen for intensive study as soon as possible so that basic information can be available for monitoring programs. Specific biological parameters that should be examined for each species selected are reproduction, recruitment, growth, age, feeding biology, and trophic interactions with other invertebrates and vertebrates.

The advantage of cluster analysis techniques, used to examine infauna, is that it provides a method for delineating station groups useful for developing monitoring schemes and delimiting areas that can be used in studies of trophic interactions. It is obvious that food webs will vary in areas with differing species assemblages. An inaccurate or even erroneous description of the shelf ecosystem could occur if trophic data collected on species from one station cluster (with its complement of species) is loosely applied to another area encompassing a totally different station cluster (with its differing complement of species). Thus, continuing development of clustering and other multivariate techniques should be pursued to refine methods so that the best approach is available to an offshore monitoring program.

It appears that temporal change in species groups at stations may lead to confusion in the interpretation of station groups if stations are always pooled in time. Williams and Stephenson's (1973) technique (species x time x sites) provides an excellent solution to this problem, but it requires that a study area be completely sampled at least three times per year. Additional sampling will be necessary to understand temporal variability of infauna.

The cruises on NOAA vessels for grab-sampling and dredging, and the extensive trawl program in lower Cook Inlet and NEGOA resulted in relatively good coverage of the benthos for invertebrates. The needs for the future are (1) the development of a monitoring plan, (2) acquisition of additional data on a seasonal basis inclusive of intensive sampling of stomachs of a diversity of species, and (3) assessment of the sediment - deposit feeder - predator relationships.

It is highly recommended that serious thought be given to the development of an extensive modeling effort in the northeastern Gulf of Alaska inclusive of Kodiak and Cook Inlet. The substantial body of data on trophic interactions of organisms of the benthos, collected by Feder (1977), Feder and Jewett (1977), and Smith *et al.* (1977) for this region, suggests that a sufficiently large data base may now be available to initiate such an effort or at least to convene workshops to assess the data base available for the development of a benthic model.

X. SUMMARY OF FOURTH QUARTER OPERATIONS

A. Ship or Laboratory Activities

1. Ship or field activities:

   a. No field activities in lower Cook Inlet or NEGOA for this quarter

2. Methods, results and discussion

   a. Analysis of all grab data from NEGOA was completed, and a Final Report is in the final stages of preparation.

   b. Stomach analyses of juvenile snow and king crabs, and nine species of shrimps from Cook Inlet are in progress.

   c. A thesis on the sand or gray shrimp *Crangon dalli* is now in its final stages of preparation.

   d. A major portion of this quarter was used in the preparation of the Annual Report and developing major sections for the Final Report.

   e. A summary report by Alaska Coastal Research (subcontract to R.U. #5) is in final stages of preparation, and will be included with the Final Report.

B. Problems Encountered

No major problems were encountered during this quarter.

C. Milestones

It is intended to maintain a consistent schedule for report preparation. Some of the reports will be subdivided into sections, each section to be submitted as it is completed. The latter procedure should increase the data flow and data interpretation available to OCSEAP. The schedule for report submissions and the Final Reports submitted are as follows:

1. Kodiak (Alitak and Ugak Bays) Final Report - Submitted November, 1977.
2. Norton Sound-Chukchi Sea Final Report - Submitted February, 1977.
3. Cook Inlet Summary Report - Submitted mid-March, 1978.
4. Bering Sea Epifauna Final Report - Submitted May 1978.
5. NEGOA Epifauna Final Report. I. - Submitted August 1978.
6. NEGOA Infauna Final Report - To be submitted May 1979.
7. Bering Sea Infauna Final Report - To be submitted June 1979.
8. Cook Inlet Final Report - To be submitted December 1979.
9. NEGOA Epifauna Final Report II - To be submitted October 1979.

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SECTION II

SUMMARY REPORT

KEY ORGANISMS IN BENTHIC FOOD WEBS A-ND THEIR
RELATIONSHIP TO IMPORTANT HABITATS IN LOWER COOK INLET

I. SUMMARY OF OBJECTIVES, CONCLUSIONS, AND IMPLICATIONS WITH RESPECT TO OCS OIL AND GAS DEVELOPMENT

It was the intent of this investigation to broaden the background on composition, distribution, and biology of the infaunal and epifaunal invertebrates of lower Cook Inlet. The specific objectives were: (1) a quantitative and qualitative inventory of dominant benthic invertebrate species, (2) a description of *spatial* distribution patterns of selected species, and (3) preliminary observations of biological interrelationships between selected segments of the benthic biota.

Much of the baseline data on infaunal and epifaunal species needed prior to onset of petroleum-related activities in lower Cook Inlet is now documented. The van Veen grab, the only quantitative infaunal sampling device used, was of limited value because the high proportion of sand in sediments generally impeded grab penetration. On the other hand, a pipe dredge, also used to sample the infauna, provided valuable qualitative data. Agassiz trawls, try-nets, and Eastern otter trawls made it possible to quantitatively sample the larger, more motile species.

In general, species composition decreased with larger sampling gear. Although only 13 stations were sampled with the van Veen grab, they yielded 211 species. The number of species taken by the small Agassiz trawl (149) exceeded the number taken by large Eastern otter trawl (53).

Biomass (g/m^2) from grabs and trawls were strikingly different. Use of trawls resulted in loss of infaunal and small epifaunal organisms, important components of the benthic biomass. Therefore, the total benthic biomass value is best expressed by combining both grab and trawl values.

Seventy-four percent of the species taken by grab were polychaetous annelids and molluscs; 56% of the pipe-dredge species were polychaetes and molluscs. Snow crabs (*Chionoecetes bairdi*) dominated the catches at most trawl stations. Based on the large numbers of juvenile snow crabs taken by trawl and found in fish stomachs in the deep-water region east of Cape Douglas, it appears that this ares is a major snow crab nursery ground. The importance of this crustacean in lower Cook Inlet is further emphasized by the existence of an intensive fishery for C'. *bairdi* in lower Cook Inlet.

Food data for snow crab (*Chionoecetes bairdi*), king crab (*Paralithodes camtschatica*), Dungeness crab (*Cancer magister*), 9 species of shrimps, and 19 species of fishes are now available. The importance of deposit-feeding clams in the diet of king and snow crabs, and some bottomfishes is clear. It is suggested that comprehension of the relationship between oil, sediment, deposit-feeding clams, king and snow crabs is essential to understand the potential impact of oil on the latter two commercially important species.

Initial assessment of all data suggests that: (1) sufficient station uniqueness exists to permit development of monitoring programs based on species composition at selected stations utilizing grab, dredge, and trawl sampling techniques, and (2) adequate numbers of biologically well-known, unique, and/or large species are available to permit nomination of likely monitoring candidates once industrial activity is initiated.

II. INTRODUCTION

General Nature and Scope of Study

The operations connected with oil exploration, production, and transportation in Cook Inlet 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 of oil on the marine environment of these areas cannot be assessed, or even predicted, unless background data are recorded prior to industrial development. Insufficient long-term information about an environment, and the basic biology 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 Lewis, 1970; Nelson-Smith, 1973; Pearson, 1971, 1972; Rosenberg, 1973, for general discussions on benthic biological investigations in industrialized marine areas) .

Benthic invertebrates (primarily the infauna, and slow-moving epifauna) are 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, 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; and Rosenberg, 1973, for discussion on long-term usage of benthic organisms for monitoring pollution). The presence of numerous benthic epifaunal species of actual or potential commercial importance (crabs, shrimps, fin fishes) in lower Cook Inlet emphasizes the need to understand benthic communities there since many commercial species feed on infaunal and small epifaunal residents of the benthos (see Zenkevitch, 1963; Feder, 1977a; Feder and Jewett, 1977; Jewett, 1978; Paul *et al.*, *in* press; and this report for discussions of the interaction of commercial species and the invertebrate benthos). Any drastic changes in density of the food benthos would directly impact these commercially important species.

Experience in pollution-prone areas of England (Smith, 1968), Scotland (Pearson, 1972, 1975), and California (Straughan, 1971) suggests that at the completion of an exploratory study, selected stations should be examined regularly on a long-term basis to determine any changes in species composition, diversity, abundance and biomass. 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 lower Cook Inlet are also essential to understand trophic interactions there and to predict changes that might take place once oil-related activities are initiated.

A benthic biological program in the northeast Gulf of Alaska (NEGOA) provided a qualitative and quantitative inventory of prominent species of the benthic infauna and epifauna there (Feder *et al.*, 1976; Jewett and Feder, 1976). In addition, investigations concerned with the biology of selected benthic species from NEGOA and the Kodiak shelf (Jewett and Feder, 1976; Feder and Jewett, 1977; Jewett, 1978) have furthered our understanding of the overall Gulf of Alaska benthic system (Feder, 1977a). Initiation of a program designed to examine the subtidal benthos of lower Cook Inlet expanded coverage of the Gulf of Alaska benthic system and extended the assessment of fauna of the Gulf into little-known shallow-water benthic systems. The study reported here is a preliminary examination of the sediment-dwelling benthic fauna of lower Cook Inlet, and is intended to precede a greater overall investigation of lower Cook Inlet (Feder, 1977b).

Relevance to Problems of Petroleum Development

The effects of oil pollution on subtidal benthic systems have, until recently, been neglected, and only a few studies on such systems, conducted after serious oil spills, have been published (see Boesch *et al.*, 1974; Malins, 1977; Nelson-Smith, 1973, for reviews; Baker, 1976, for a general review of marine ecology and oil pollution). Lack of a broad data base makes it difficult to predict the effects of oil-related activity on the subtidal benthos of lower Cook Inlet. However, the rapid expansion of Outer Continental Shelf Environmental Assessment Program (OCSEAP)-sponsored research activities in this body of water should ultimately enable us to point with some confidence to certain species, biological events, and areas that might bear closer scrutiny once industrial activity is initiated. It must be reemphasized that a considerable time frame is needed to comprehend long-term fluctuations in density of marine benthic species; thus, it cannot be expected that short-term research programs will result in predictive capabilities.

As indicated previously, infaunal benthic organisms tend to remain in place and, consequently, have been useful as indicator species for disturbed areas. Thus, close examination of stations with substantial complements of infaunal species is warranted (see Feder and Mueller, 1975; National Oceanic Data Center (NODC) data on file for examples of such stations). Changes in the environment at these stations might be reflected in a decrease in diversity of species 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. The potential effects of loss of species to the overall trophic structure in lower Cook Inlet can be partially assessed on the basis of benthic food studies (e.g. see, Jewett and Feder, 1976; Feder, 1977a; Feder and Jewett, 1977).

The snow crab (*Chionoecetes bairdi*) is a conspicuous member of the shallow shelf of lower Cook Inlet, and supports a commercial fishery of considerable importance there. Laboratory experiments with this species have shown that postmolt individuals lose most of their legs after exposure to Prudhoe Bay crude oil; obviously this aspect of the biology of the snow crab must be considered in the continuing assessment of this species (Karinen and Rice, 1974). Few other direct data based on laboratory experiments are available for subtidal benthic species (Nelson-Smith, 1973; also see Malins, 1977). Experimentation on toxic effects of oil on other common members of the subtidal benthos should be strongly encouraged in lower Cook Inlet as well as for all Outer Continental Shelf (OCS) areas of investigation. In addition, potential effects of loss of sensitive species to the trophic structure of Cook Inlet must be examined.

A direct relationship between trophic structure (feeding type) and bottom stability has been demonstrated by Rhoads (see Rhoads, 1974, for review). He describes a diesel fuel spill that resulted in oil becoming adsorbed on sediment particles which in turn caused death 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 substratum. Many common members of the infauna of lower Cook Inlet are deposit feeders; thus, oil-related mortality of these species could likewise result in a changed near-bottom sedimentary regime with subsequent alteration of species composition there. In addition, the commercially important king (*Paralithodes camtschatica*) and snow crabs (*Chionoecetes bairdi*), and some bottom fishes, use deposit-feeding invertebrates as food; also, varying amounts of sediment are found in the digestive tract of snow crabs (Feder, 1977a; Feder and Jewett, 1977) and other benthic Crustacea (data in present report). Thus, contamination of the bottom by oil might directly or indirectly affect these commercial species in lower Cook Inlet.

III. CURRENT STATE OF KNOWLEDGE

A compilation of data is available on commercially important shellfish of lower Cook Inlet. The U.S. Bureau of Commercial Fisheries (National Marine Fisheries Service) have conducted distribution and abundance surveys in this area on shrimps and crabs since 1958 (see references below). More recent investigations on larval and/or adult stages of shellfish species have been carried out (Hennick, 1973; ADF&G, 1976; Feder, 1977a). A detailed examination of the food of snow crabs from lower Cook Inlet is included in Paul *et* aZ. (in press).

The snow crab, *Chionoecetes bairdi* Rathbun, a common epibenthic invertebrate found in Cook Inlet has been commerically harvested there since 1968. The annual catches for the area from 1968 to 1976 ranged from 590 to 3600 metric tons. The 1975-76 Cook Inlet catch was worth approximately 1.3 million U.S. dollars to the fisherman (catch and price data-Allen Davis, Alaska Dept. of Fish and Game, Homer, Alaska, person. commun., 1976). Approximately 55% of the snow crab caught in the Inlet came from the Kamishak Bay area, 18% from the mouth of the Inlet, and 15% from the Kachemak area.

The king crab, *Paralithodes camtschatica*, is also commercially harvested in Cook Inlet, Alaska. Approximately 69% if the king crab are caught in the Kamishak Bay area with an additional 34% in the Kachemak Bay region. The remainder are captured near the mouth of the Inlet. Catches of king crab from the Inlet averaged 1,860 metric tons during 1971-1975 (Alaska 1976 catch and production statistical leaflet No. 28).

Dungeness crab occurs primarily in Kachemak Bay. Catches of Dungeness crab from Cook Inlet averaged 141 metric tons during 1971-1975 (Alaska 1976 catch and production statistical leaflet No. 28).

Data on non-commercial, benthic invertebrates are not as extensive as that available for commercial species in lower Cook Inlet (U.S. Bureau of Commercial Fisheries, 1958, 1961, 1963 cited in U.S. Dept. Inter., 1977; Feder, 1977a). Further studies on the interactions of selected benthic invertebrate species from lower Cook Inlet are currently underway (Feder, 1977b). Littoral zone studies have been conducted (Dames and Moore, 1977) and are being continued by Lees (1977).

IV. STUDY AREA

A station grid, in addition to several stations of opportunity, were established for benthic sampling in lower Cook Inlet (see Feder, 1977b and 1978a for stations occupied in 1976; Figs. 1, 2, 3 this report for stations on this grid occupied in 1977 and 1978; data for all stations are compiled in Appendix I).

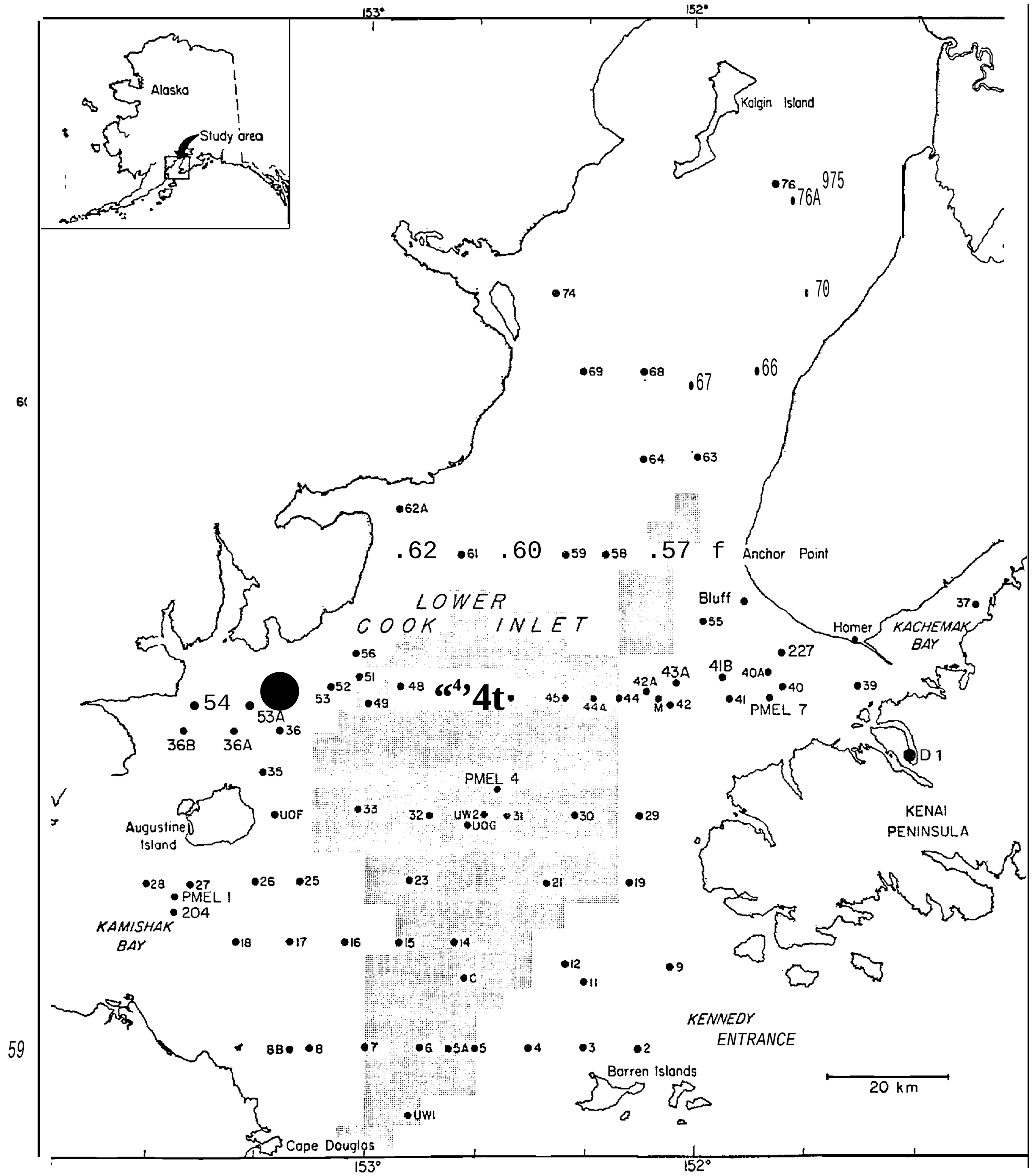


Figure 1. Lower Cook Inlet Benthic Stations occupied 1976–1978. The shaded portion represents the tract selection area.

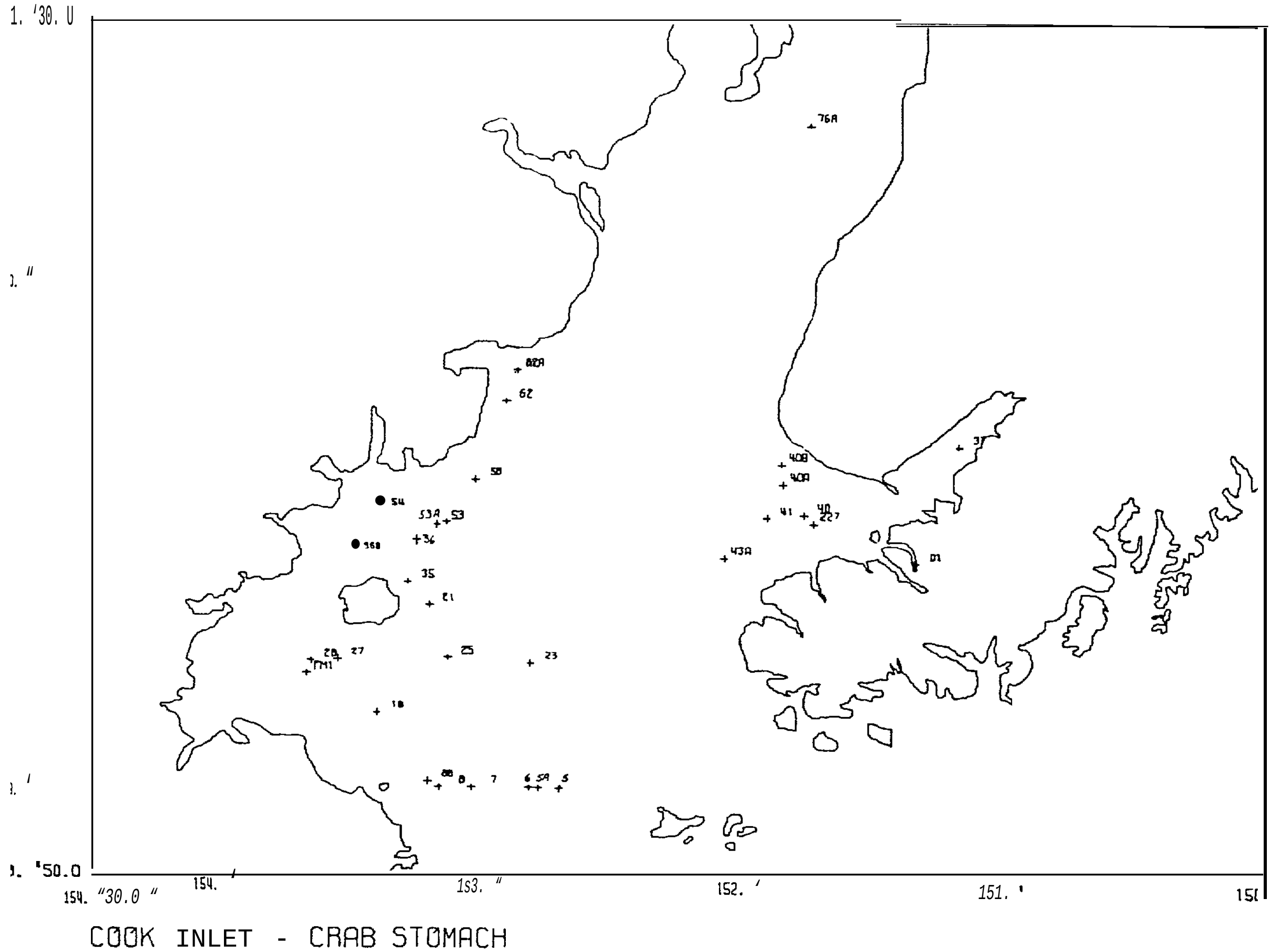
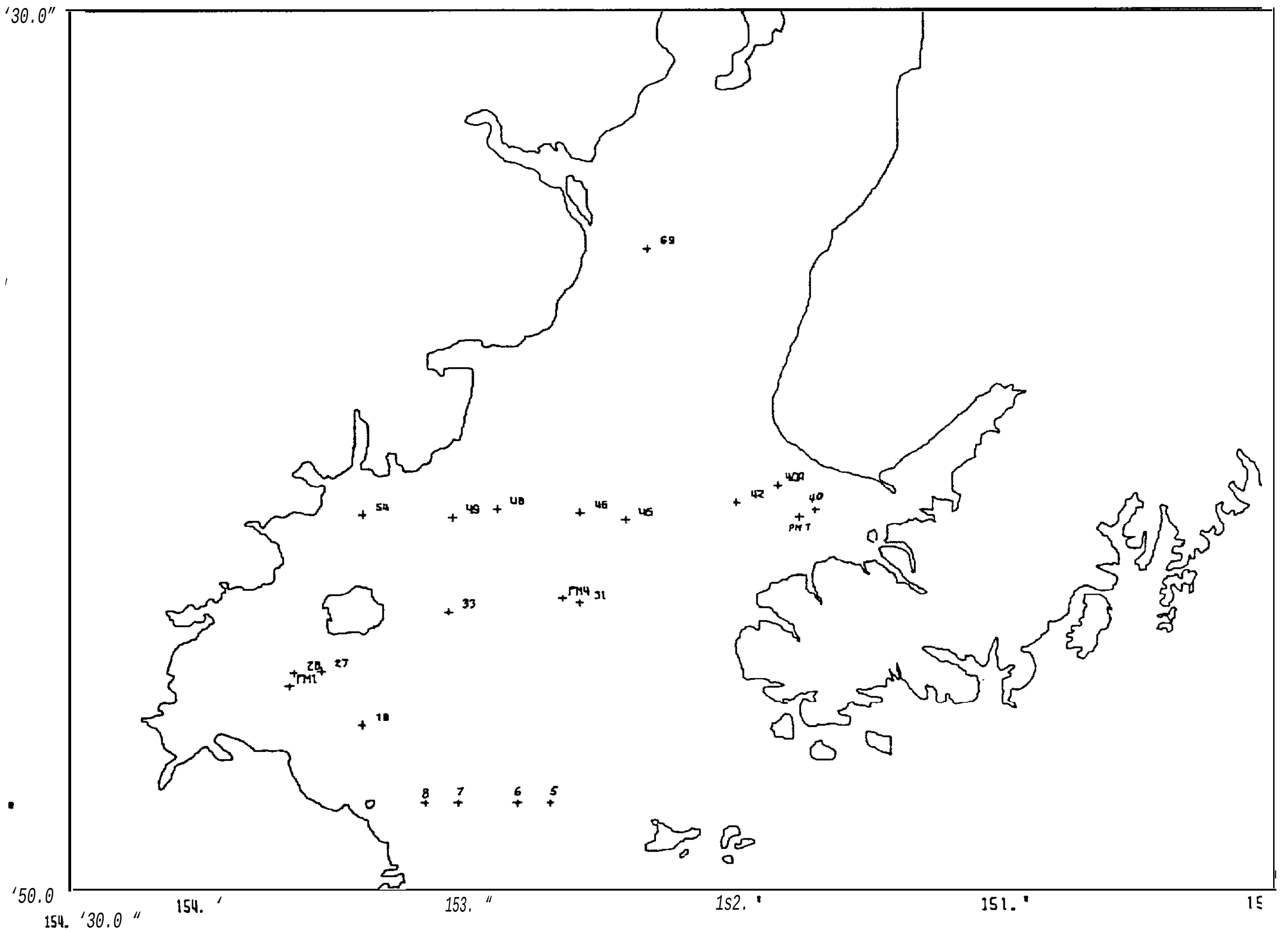


Figure 2. Locations of stations where snow crab, king crab and Dungeness crab were captured for stomach analysis.



COOK INLET - GRAB STATIONS

Figure 3. Lower Cook Inlet Grab Stations for which infaunal data available. All data will be included in Final Report.

V. SOURCES, METHODS, AND RATIONALE OF DATA COLLECTION

Benthic infauna and epifauna were collected aboard the R/V *Moana Wave* from March 30-April 15, 1976, and the NOAA Ships *Miller Freeman* and *Surveyor* on a series of cruises from October 1976 to July 1978. Sampling in 1976 was carried out using a 0.1 m^2 van Veen grab, a pipe dredge (36 x 91 cm), an Agassiz trawl (2.0 m horizontal opening), a try-net (3.7 m horizontal opening), and a clam dredge. Sampling in 1977-78 was conducted with a van Veen grab, pipe dredge, Agassiz trawl, 400-mesh Eastern otter trawl (12.2 m horizontal opening), and a clam dredge. The pipe dredge, try-net, clam dredge, and bottom skimmer were used for qualitative sampling only, while the van Veen grab, Agassiz and Eastern otter trawl data were treated quantitatively. Five or six grabs were generally obtained at selected stations. Sampling time for the Agassiz and Eastern otter trawls was usually 15 and 30 minutes, respectively.

Material from each grab was washed on a 1.0 mm stainless steel screen, and preserved in 10% formalin buffered with hexamine. Labeled samples were returned to the Marine Sorting Center, University of Alaska, where all organisms were identified, counted, and wet-weighed after excess moisture was removed.

The pipe dredge was used to, (1) determine if the van Veen grab was adequately sampling infauna; (2) provide additional infaunal data in areas where van Veen grabs could not penetrate properly; (3) provide specimens for comparison with items found in stomachs of crabs and fishes examined in feeding studies; and (4) collect large numbers of clams for age-growth investigations. Clams were removed from pipe-dredge samples, preserved in 10% buffered formalin, and shipped to the Seward Marine Station for examination. The remainder of the material from the dredge was examined in Fairbanks.

All invertebrates from trawls were sorted on shipboard, given tentative identifications, counted, weighed, and aliquot samples of individual species preserved and labeled for final identification at the Institute of Marine Science, University of Alaska.

After final identification, all invertebrate species were assigned code numbers to facilitate computer analysis of data (Mueller, 1975).

Representative and voucher samples of invertebrates were stored at the Institute of Marine Science, University of Alaska, Fairbanks, Alaska.

The crabs used for the feeding studies discussed in this report were taken by trawl from October 1976 to July 1978. Stations selected for detailed examination were those where crabs were abundant.

The stomachs of snow crab, king crab, Dungeness crab, and selected species of fishes were collected. Stomachs were removed immediately, fixed in 10% buffered formalin, and their contents examined with a dissection and/or compound microscope in the laboratory in Fairbanks. Prey organisms were counted and identified to the lowest possible taxon. If the number of prey could not be determined, contents were recorded as a single specimen of the food item. This was often the case with barnacles and occasionally bivalves. Crabs were separated by size, sex, and state of maturity. Male snow crabs with carapace widths greater than 110 mm were considered sexually mature (Brown and Powell, 1972). Female snow crabs were classified as immature (pre-reproductive) or mature (reproductive or post-reproductive) based on the enlarged abdomen, modified pleopods, and egg clutch of the adults (Yoshida, 1941). Food items were recorded as frequency of occurrence, in which prey items were expressed as the percent of the predator containing various food items relative to the total number of the predator analyzed.

The percent of fullness of snow crab stomachs was examined by injecting the stomachs with water until full, then emptying the contents into graduated centrifuge tubes, centrifuging and then determining the percent of total volume that consisted of stomach contents.

Stomach contents of snow crabs from selected stations were dried at 60°C, weighed and then digested with Potassium Hydroxide and redried to determine what percentage of the weight was animal and plant tissue (IBP Handbook 16). Next, large pieces of carapace were removed and the sample treated with concentrated hydrochloric acid to climate calcareous shell and carapace fragments. The sample was redried to determine the weight of sediments present. Sediment weight determined by this method is somewhat conservative since carbonates naturally associated with the sediment are destroyed. Snow crabs were fed live *Macoma balthica* in the laboratory to determine typical prey consumption rates.

Sampling with dredges, grabs and trawls at each station made it possible to obtain information on potential prey of snow crab, and facilitated identification of stomach contents.

In 1976 an extensive trawl survey of Cook Inlet was undertaken to determine distribution and abundance of benthic invertebrates (Feder, 1978a). This survey was utilized to determine critical habitats in the Inlet. Stations where king (*Paralithodes camtschatica*), and snow, (*Chionoecetes bairdi*), and Dungeness crabs, (*Cancer magister*), and pandalid shrimps were abundant were selected for continued study in 1977 and 1978. In addition, three stations established by Pacific Marine Environmental Laboratory (PMEL) and two by Oregon State University scientists were occupied to enable integration with these studies. The primary objective of the 1977 and 1978 trawling activities was to collect stomachs from the commercially important crustaceans and some of their major prey species. These data are necessary to determine key organisms in the benthic food web. Information on size distribution of the snow crab and the reproductive biology of this crab and other commercially important crustaceans was also obtained from the data.

The critical habitats for commercially important crustaceans include the areas where adults are captured by fisheries activities (summarized by ADF&G, 1976) and areas where juveniles, egg bearing females, and moulting individuals are found. Many of these areas were identified during the 1976, 1977-1978 surveys. However, other areas, not defined, probably exist because only a limited number of stations were occupied in the surveys.

VI. RESULTS - DISCUSSION

Important Habitats for Biologically Important Crustacea

All data reported here are primarily based on the 1977-78 survey (Feder, 1978a); some comparative data are included. Data from the 1976 surveys will be integrated with the 1977-78 survey in the Final Report.

Major concentrations of snow crabs were found primarily in the western part of lower Cook Inlet in all surveys. In terms of numbers, the largest catches occurred at stations 5(111 crab per km fished), 25

(100 per km fished), A53 (50 per km fished), 8 (43 per km fished), 18 (17 per km fished), A62 (15 per km fished) , and 27 (11 per km fished), (Table I). At all other stations in the Inlet the average number captured in all trawls was less than 10 per km fished. In Kachemak Bay, snow crabs were most abundant at stations 41 and 40 with *an* average of 8 and 5 snow crabs per km fished (Table I).

The size-distribution data for snow crabs (Table II) indicate that the areas sampled are inhabited by size segregated populations. Snow crabs less than *20 mm* carapace width were encountered primarily near the mouth of the Inlet and lower Kamishak Bay. Station 5 was the area where these small crabs were most abundant ranging from 7 to 414 per km fished. Station 8 (4 to 135 per km fished) and 25 (8 to 238 per km fished) also had significant numbers of these young crabs (Table II). The size distribution data suggest the existence of a nursery area for snow crabs that encompasses stations 5, 6, 7, 8, 18, 23, 25, 53, and A53 (Table II), and strengthens the qualitative assessment of 1976 that also indicated this region (in particular stations 5, 6, 7, and 8) to be a nursery ground for snow crabs (Feder, 1978a). Stations 6 and 23 are in the current lease area and the other stations, with the exception of 53 and A53, are directly in the path of prevailing currents which flow southward over the lease area. The absence of snow crabs less than 20 mm carapace width in the Kachemak Bay area is puzzling since the area supports a commercial fishery. Their absence in Kachemak Bay may be due to recruitment failure, or perhaps crabs move from the nursery area described above or from other nursery areas not discovered, to Kachemak Bay and other parts of the Inlet. Further observations on the distribution of these small crabs are necessary to determine the importance of nursery areas as a source of recruitment to Cook Inlet and the adjacent Gulf of Alaska.

Low numbers of sub-adult crabs 21 to 80 mm carapace widths, were encountered at all snow crab study stations (Table I). Perhaps snow crabs of this size range inhabits shallow waters not sampled. It is essential to know where this important size group of crab is located if the dynamics of this important species and its potential interaction with oil is to be comprehended.

TABLE I

MEAN NUMBER AND PERCENT OVIGEROUS KING, SNOW AND DUNGENESS CRABS CAPTURED IN ALL QUANTITATIVE TRAWLS IN 1977 AND 1978 IN LOWER COOK INLET

x = mean, km = kilometers, - = no specimens collected

Station Cook Inlet	King crab $\bar{x}$/km fished	King crab % of catch w/eggs	Snow crab $\bar{x}$/km fished	Snow crab % of catch w/eggs	Dungeness crab $\bar{x}$/km fished	Dungeness crab % of catch w/eggs
5			111	>1	1	
6			6	17		
8			43	>1	1	1
18	2	33	17	0	1	0
23	1	50	4	4		
25			100	>1		
27	8	39	11	8		
28			5	0		
35	20	7	8	0		
36	1	0	22	3		
A36			10	0		
B36	2	0	34	0		
37	2	50	3	7	3	0
38			2	0		
A38			1	0		
39	16	40	2	0		
40	2	38	5	4	13	19
A4 0	9	20	1	25	8	2
41	1	20	8	69	6	3
B41	1	0	5	0		
B43	29	18				
A47			1	0		
49			42	0		
A49			6	0		
Bluff			21	0		
53	2	78	8	4		
A53	2	50	50	1		
54	2	33	7	13		
55	2	0				
56			7	5		
A56			5	0		
62			16	20		
A62			15	2		
B62			1	0		
204			6	0		
227			3	0	2	0
PME1			11	12		
PME7	1	0	4	0	1	0

TABLE II

SIZE DISTRIBUTION OF *CHIONOECETES BAIRDI* FROM
SELECTED TRAWLS FROM COOK INLET STATIONS.
DATA FROM ALL QUANTITATIVE TRAWLS 1977 AND 1978

Data recorded as number of crabs; - = not sexed

Station	5-20 mm	21-80 mm	81+ mm	No. Male/Female Crabs 81 mm	Comments
5	1469	16	27	15/12	Large crabs have fungus growth
6	7	0	5	3/2	
8	248	0	2	2/0	
18	44	0	14		
23	22	0	3		
25	396		2		
40A	0	2	2	1/1	
41	0	"1	79	7/37	Most crabs were old shell covered with barnacles
53	81	2	30	14/4	
53A	92	0	13	1/12	
62A	32	1	105	48/57	

Female snow crabs with eggs ready to hatch, moulting individuals, and old shell individuals between clutches constituted significant percentages of the catches at the following stations on the west side of the Inlet: station 62 (20%), PMEL 1 (12%), 54 (13%), 53 (4%), and 23 (4) (see Table I). Near the mouth of the Inlet at Station 6, 17% of the snow crabs captured were females with eggs. In Kachemak Bay 25% to 69% of the snow crabs captured were females with eggs. These areas must be considered critical habitats because moulting success of snow crabs and survival of their zoea are negatively affected by crude oil (Rice *et al.*, 1978). No newly moulted females or females with hatching eggs were collected during the study period 1977-78.

On the west side of lower Cook Inlet king crabs were most abundant at stations 35 (20 per km fished), and 27 (8 per km fished; see Table I). No king crabs were captured near the mouth of the Inlet in 1977 or 1978. In Kachemak Bay, king crabs were most abundant at stations 43 (30 per km fished), 39 (16 per km fished), A40 (9 per km fished) and 40 (2 per km fished). Juvenile king crabs did not make up a significant portion of any of the catch at the stations sampled. Over 95% of the king crabs captured were sexually mature individuals. No "pods" of juveniles were encountered. Soft-shell male king crabs were encountered in March at station 41, in May at station 54, and June at station PMEL 7. One grasping pair was captured in March at station 55. Soft-shell females were observed at station 53 in June and July, and station 35 in June. By June, the majority of the crabs captured had new carapaces. King crab eggs probably hatched in Kachemak Bay in April and May (Haynes, 1977).

Dungeness crabs were captured with regularity at stations 40 (13 per km fished), A40 (8 per km fished), and 41 (6 per km fished; see Table I). Females with eggs constituted 19%, 2%, and 3%, respectively, of the catch at these same stations. In August, 64 Dungeness crabs with carapace widths of 22 to 45 mm were captured at station A40. The remainder of the Dungeness crabs captured were generally over 100 mm in carapace width. In non-quantitative trawls taken in June, 99% (n= 45 ♀♀) of the mature females examined had egg clutches. In July, only one female (n= 36 ♀♀) with eggs was observed. Kachemak Bay must be considered as the most important habitat for Dungeness crab in Cook Inlet.

The pink shrimp (*Pandalus borealis*) was encountered in the greatest abundance at station 37, inner Kachemak Bay, where catches for all trawls in 1977 and 1978 averaged 926 per km fished (Table III). Highest concentrations in outer Kachemak Bay were observed at stations 227 (278 per km fished), PMEL 7 (202 per km fished) and 40 (167 per km fished). At station 62, near the mouth of Chinitna Bay, 123 per km fished were encountered in November. No areas where pink shrimps were abundant were observed in Kamishak Bay. Near the mouth of the Inlet at stations 5, 6, and 8, pink shrimps were observed at average population densities of 9, 11, and 35 per km fished. In Kachemak Bay hatching of pink shrimp eggs probably occurs in April and May (Haynes, 1977). The results of the survey indicate Kachemak Bay to be the major habitat for pink shrimp in Cook Inlet.

Humpy shrimp (*Pandalus goniurus*) was most abundant at station 56 in northern Kamishak Bay with an average of 792 per km fished (Table III). In the same area, stations A62 and A56, the average number captured was 275 and 125 per km fished. Near the mouth of the Inlet, 166 bumpy shrimps were captured per km fished. In the Kachemak Bay area bumpy shrimps were most abundant at stations 38 (301 per km fished), A38 (224 per km fished), and 37 (171 per km fished) all in the inner bay. Few bumpy shrimps were encountered at any of the outer Kachemak Bay stations, less than 10 per km were fished. Hatching of bumpy shrimp probably occurs in April and May in Kachemak Bay (Haynes, 1977). Based on this survey the critical habitats for bumpy shrimp are northern Kamishak Bay, Chinitna Bay, and inner Kachemak Bay.

Coonstripe shrimp (*Pandalus hypsinotus*) was most abundant in inner Kachemak Bay. At stations 37, 38, and A38 catches of coonstripes averaged 176, 41 and 71 per km fished. Smaller numbers, 4 to 30 per km fished, were observed in outer Kachemak Bay. No large concentrations of coonstripe shrimps were observed at any of the other stations examined in Cook Inlet (Table III).

Sidestripe shrimp (*Pandalopsis dispar*) was also most abundant, an average of 15 per km fished, in inner Kachemak Bay station 37. Average catches of less than 10 per km fished were made in outer Kachemak Bay stations PMEL 7, 39, and station 8 near the mouth of the Inlet (Table III).

TABLE III

MEAN NUMBER OF PINK, HUMPY, COONSTRIPE AND SIDESTRIPE SHRIMPS CAPTURED IN TRAWLS IN COOK INLET, 1977 AND 1978

x = mean, km = kilometers, - = no specimens collected

Station Cook Inlet	Pink Shrimp $\bar{x}$/km fished	Humpy Shrimp $\bar{x}$/km fished	Coonstripe Shrimp $\bar{x}$/km fished	Sidestripe Shrimp $\bar{x}$/km fished
5	9	1		1
6	11			
8	35	166		9
25		4		
35		19	1	
A36		10		
37	926	171	176	15
38	65	301	41	
A38		224	71	
39	18	104	30	7
40	167	5	4	
A4 0			10	
41	1			
49		36		
A49		5		
54		9		
55			2	
56		792	12	
A56		125		
C56			3	
62	124			
A62		275		
B62	2			
227	278	3	1	
PMEL 7	202	24	19	5

Food of Snow Crab (*Chionoecetes bairdi*), King Crab (*Paralithodes camtschatica*), and Dungeness Crab (*Cancer magister*) in Cook Inlet

A detailed food survey of commercially important Crustacea and two of their major prey organisms was undertaken in order to identify the key species involved in the flow of carbon to these organisms which in turn, are utilized by man as food. The animals examined were snow, king, and dungeness crabs, hermit crabs, and pink, sidestripe, coonstripe, bumpy, and crangonid shrimps. Examination of the food requirements of zoea larvae of snow and king crabs, and pink shrimp, and post larval king crabs is in progress. Data from the latter studies will be included in the Final Report.

Stations where crab stomachs were collected are presented in Figure 2.

Snow crab

Food occurred in 772 (64%) of 1198 *Chionoecetes bairdi* examined (Tables IV - VII). In the outer Kachemak Bay area, stations 40, 40A, and 41, small clams were the most frequently encountered prey, occurring in 33% of the stomachs. The clams *Spisula polynyma*, *Nucula tenuis*, and *Macoma* spp. occurred in 16%, 6%, and 4% of the stomachs, respectively. Hermit crabs were observed in 17% of the stomachs and barnacles in 14%. All other prey categories were observed in less than 10% of the stomachs. In inner Kachemak Bay, station 37, the dominant foods were the clam *Nuculana fossa*, which occurred in 7% of the stomachs, and polychaetous annelids found in 5% of them.

In Kamishak Bay, stations 18, 25, 27, 28, 35, 53, 56, PMEL 1 and El, small bivalves occurred in 37% of the stomachs. Clams of the genus *Macoma* were the most frequently occurring clam found in 13% of the stomachs. Barnacles and hermit crabs were observed in 19% and 17% of the stomachs, respectively. All other categories of food were observed in less than 10% of the stomachs. Juvenile *Chionoecetes bairdi* were found in 4 stomachs at station 23 (Table IV).

In the outer district of the Inlet, stations 5, 5A, 8A, and 23, two food types dominated. Clams of the genus *Macoma* and hermit crabs were observed in 45% and 12% of the stomachs, respectively.

TABLE IV

FOOD OF COOK INLET SNOW CRAB, OCTOBER 1976. DATA RECORDED AS FREQUENCY OF OCCURRENCE OF FOOD ITEMS

	PREY ITEMS																						
Station	No. stomachs examined	No. stomachs with food	Polychaeta	Gastropoda	*Nucella lamellosa*	*Nuculana fossa*	*Yoldia hyperborea*	*Macoma* spp.	*Spisula polynyma*	*Tellina nuculoides*	*Serripes groelandicus*	*Astarte* spp.	Unidentified Bivalvia	Amphipoda	*Balanus* spp.	*Pandalus* spp.	Crangonidae	Paguridae	*Pagurus ochotensis*	*Chionoecetes bairdi*	Unidentified Crustacea	Ophiuroidea	Sediment
5A	38	23		1		5		19													1		
8B	24	14												4		2	2	4			1		
18	79	31				2	1	1			6				12		5	6					16
23	141	106	1					100		1		1			5			15		4			13
25	87	67	3					27				5	2		14		2	5	14	1			5
28	6	3						1										3			1		
40A	96	64	5	1	3				3				1		22			11	23			1	9
41	22	10							9						1		1						2
53	78	43	1					1					2		13		3	6	17		3		8
62A	104	54													6		14	11	30				6
76A	40	13													3		10		2				6
Total Frequency of Occurrence	715	428	10	2	3	7	1	149	12	1	6	6	5	4	76	2	37	61	86	5	6	1	65
Percent Frequency of Occurrence		60	1	0.3	0.4	1	0,1	21	2	0.1	1	1	1.	0.5	11	0.3	5	9	12	1	1	0.1	9

TAELE V

FOOD OF COOK INLET SNOW CRAR , NOVEMBER 1977. DATA RECORDED AS FREQUENCY OF OCCURRENCE OF FOOD ITEMS

Station	No. stomachs examined	No. stomachs with food	Foraminifera	Polychaeta	Unidentified Bivalvia	*Solariella* sp.*	Unidentified Gastropoda	Scaphopoda	*Nucula tenuis*	*Nuculana fossa*	*Glycymeris subobsoleta*	Mytilidae	Pectinidae	*Astarte* spp.	*Cyclocardia* spp.	*Spisula polynyma*	*Macoma* spp.	*Balanus* spp.	Amphipoda	Crangonidae	*Pagurus ochotensis*	*Pagurus capillatus*	Unidentified Paguridae	*Cancer* spp.	Unidentified Crustacea	Unidentified tissue	Unid. plant material	Teleost scales	Eggs	Sediment
										PREY ITEMS																				
5	16	15	2	4				1										5		1			3			1				8
27	6	3					1		1							1									2	1				2
35	53	53	2		4	2	3		3	4	5			4	3	2	11	39	1	1	1		22		14	2	2	1		14
40	16	16	8	2	5	1	2		2				1			2	2				1			1	3	7	2			12
53	46	45	3		7	3	1		6	13				1	1	2	17	2			2		9		13	1		1	1	20
62 & 62A	23	14										1						9			1	1	4				1			3
Total Frequency of Occurrence	160	146	15	6	16	6	7	1	12	17	5	1	1	5	4	7	35	55	1	2	5	1	38	1	32	12	5	2	1	59
Percent Frequency of Occurrence		91	9	4	10	4	4	0.6	8	11	3	1	1	3	2	4	22	34	0.6	1	3	0.6	24	0.6	20	8	3	1	0.6	37

* The genus *Margarites* occurs in the area and may be included.

TABLE VI

FOOD OF COOK INLET SNOW CRAB, MARCH 1978. DATA RECORDED AS FREQUENCY OF OCCURRENCE OF FOOD ITEMS

Station	No. stomachs examined	No. stomachs with food	Hydrozoa	Bryazoa	Polychaeta	*Solariella* sp.*	Unidentified Gastropoda	Gastropoda eggs	*Nucula tenuis*	*Nuculana fossa*	*Yoldia* spp.	*Glycymeris subobsoleta*	*Serripes groenlandicus*	*Spisula polynyma*	*Macoma* spp.	Unidentified Bivalvia	*Balanus* spp.	Crangonidae	Pandalidae	Paguridae	Unidentified Crustacea	Teleost	Plant material	Sediment
			PREY ITEMS																					
5	4	3			1	1									2									
25	23	21	1			2					1	1		1	1	2	2			3	6		1	16
56	12	10		1	1															9				5
62A	48	39	1	1			1	1		1		2	1	1	1	3	1	8	1	20	2	2	1	
E-1	4	3	1						2														1	3
Total Frequency of Occurrence	91	76	3	2	2	2	2	1	2	1	1	3	1	2	4	5	2	8	1	32	8	2	3	24
Percent Frequency of Occurrence		84	3	2	2	2	2	1	2	1	1	3	1	2	4	6	3	9	1	35	9	2	3	26

* The genus *Margarites* occurs in the area and may be included.

TABLE VII

FOOD OF COOK INLET *CHIONOECETES BAIRDI*, JULY 1979. DATA RECORDED AS FREQUENCY OF OCCURRENCE OF FOOD ITEMS

Station	No. s chs examined	No. stomachs with food	Foraminifera	Hydrozoa	Polychaeta	*Solariella* sp.*	Unidentified Gastropoda	*Nucula tenuis*	*Nuculana fossa*	*Spisula polynyma*	*Macoma* spp.	*Tellina nuculoides*	Unidentified Bivalvia	*Balanus* spp.	Cumacea	Amphipoda	*Crangon* sp.	Paguridae	*Oregonia gracilis*	*Pinnixa* sp.	Unidentified Crustacea	Ophiuroidea	Asidiacea	Unidentified tissue	Plant materia
									PREY ITEMS																
5	72	57			16	1	2		1		7					7	1	18	1		6		2	9	
27	39	8	1					2		5				2	1	1									2
37	15	9			5		2		7				2					2			2			1	
PMELI	21	17		1	4			8		9		1		1		3	1	3		1	1			1	
40	26	20	1		1	1	1	10	3	16	1			2		3		3			2	2			
41	43	8	1		1					5				4											
62A	6	3			1												1	2							
Total Frequency of Occurrence	232	122	3	1	28	2	5	20	11	35	8	1	2	9	1	14	3	28	1	1	11	2	3	11	2
Percent Frequency of Occurrence		52	1	0.4	12	0.8	2	9	5	15	3	0.4	0.8	4	0.4	6	1	12	0.4	0.4	5	0.8	0.8	5	0.8

* The genus *Margarites* occurs in the area and may be included.

Throughout Cook Inlet, snow crab stomachs with food commonly contained the remains of several barnacles or clams. In one stomach, 16 recently settled *Macoma* spp. were observed. Few stomachs contained more than one large crustacean. The total number of each prey, estimated primarily by counting hard parts of prey, is presented in Table VIII. These data must be considered qualitative since the estimates are made by counting shell and exoskeleton; soft, easily digested tissues are underestimated. Also, feeding observations in the laboratory have demonstrated that snow crabs may often eat the tissue of small bivalves without ingesting much of the shell (these observations will be discussed in more detail in the Final Report).

No difference was detected in the frequency of occurrence of prey in *Chionoecetes bairdi* of different sexes or sizes examined (Tables VIII - IX).

Barnacles, hermit crabs, crangonid shrimps, and small clams are widely distributed throughout lower Cook Inlet (see Feder, 1978a), and are fed upon by *Chionoecetes bairdi* in proportion to their abundance. Other species used for food are discontinuous in their distribution of lower Cook Inlet (Feder, 1978a). This discontinuous distribution, probably more than their acceptability as food, explains the infrequent occurrence of these species in snow crab stomachs.

Small amounts of sediment were observed in stomachs of crabs, from the three areas; however, sediment seldom contributed to more than 16% of the dried weight of stomach contents (Table X).

In the Kodiak area the most commonly encountered stomach contents were small clams, shrimps, plant material, and sediment (Feder e-t *al.*, 1977b; Feder and Jewett, 1977). In Cook Inlet plant material, possibly eelgrass, was only observed in one stomach.

Tarverdieva (1976) found in the southeastern Bering Sea that adult *C. bairdi* feed mainly on polychaetes (60-70%). Echinoderms were found in less than 10% of the stomachs, and mollusks play a large role only in feeding of the young (63%) which live separately from the adults. Commercial-size C. *opilio* feeds, as *C. bairdi*, mainly on polychaetes (more than 50% with respect to predominance), and the young and non-commercial part of the population feed on crustaceans (30-40%), polychaetes (20-30%, and mollusks 20%). Feder (1978b) reported polychaetes,

TABLE VIII

NUMBER OF PREY SPECIMENS IN SNOW CRAB STOMACHS
BY SIZE AND SEX, OCTOBER 1976

MF = mature female, MM = mature male, IF = immature female,
IM = immature male

Carapace Width	Number of Stomachs	Sex	Number of Prey in Stomachs	Number of Crab Feeding
Station 5A				
5 - 10	1	IM	Full of sediment	0
61 - 70	2	IM	No food	0
81 - 90	2	IM	Several *Nuculana fossa*	2
91 - 100	2	–	No food	0
101 - 110	2	IM	1 crustacean	1
111 - 120	6	MM	8 *Macoma* spp., 1 *Nuculana fossa*	6
121 - 130	4	MM	2 *Macoma* spp., 1 *Nuculana fossa*, 1 *Balanus* spp.	3
131 - 140	1	MM	Several *Macoma* Spp.	1
141 - 150	3	MM	No food	0
71 - 80	2	MF	Several *Macoma* Spp.	2
81 - 90	3	MF	Several *Macoma* Spp.	3
91 - 100	2	MF	2 *Macoma* spp., 1 *Nuculana fossa*	2
101 - 105	1	MF	1 *Macoma* spp.	1
81 - 90	6	IF	3 *Macoma* spp.	3
91 - 100	2	IF	2 *Macoma* spp.	2
Total	39		Total	26
Station 8B				
5 - 10	4	IM	1 amphipod, 1 crustacean, sediment	2
11 - 20	3	IM	2 tissue, sediment	2
21 - 30	3	IM	1 amphipod, 1 Crangonidae	2
81 - 90	1	IM	1 Paguridae, 1 *Macoma* spp.	1
101 - 110	1	IM	1 Crangonidae	1
5 - 10	9	IF	2 amphipods, 1 tissue, sediment	3
11 - 20	2	IF	1 Natantia, 1 amphipod	2
21 - 30	1	IF	1 Paguridae	1
Total	24		Total	14

TABLE VIII

CONTINUED

Carapace Width	Number of Stomachs	Sex	Number of Prey in Stomachs	Number of Crab Feeding
Station 18				
61 - 70	6	IM	4 *Serripes groenlandicus*	2
71 - 80	16	IM	2 *S. groenlandicus*, 2 Paguridae 3 Crangonidae, 3 *Balanus* spp., sediment	11
81 - 90	19	IM	3 S. *groenlandicus*, 4 Paguridae, 2 Crangonidae, 2 *Balanus* spp., 1 *Pectinaria* spp., sediment	13
91 - 100	13	IM	1 S. *groenlandicus*, 4 *Balanus* spp.	5
101 - 110	15	IM	1 *Macoma* spp., 1 *Nuculana* fossa, 1 Crangonidae, 3 *Balanus* spp., sediment	7
111 - 120	7	MM	No food	0
121 - 130	2	MM	No food	0
141 - 145	1	MM	No food	0
Total	79		Total	38
Station 23				
61 - 70	1	IM	2 *Macoma* spp.	1
71 - 80	9	IM	1 *Yoldia hyperborea*, 17 *Macoma* Spp .	7
81 - 90	42	IM	70 *Macoma* spp., 2 *Chionoecetes bairdi*	38
91 - 100	16	IM	13 *Macoma* spp., 1 *c. bairdi*, 1 polychaete, 2 Paguridae, sediment	16
101 - 110	11	IM	4 *Macoma* spp., 2 *Balanus* spp., sediment	7
111 - 120	9	MM	1 Paguridae, 1 *C. bairdi*, 1 *Balanus* spp. 1 Pelecypoda	4
121 - 130	7	MM	1 *Macoma* spp., sediment	1
131 - 140	1	MM	No food	0
141 - 150	2	MM	No food	0
161 - 165	2	MM	No food	0
81 - 90	17	MF	21 *Macoma* spp., 1 *Astarte* spp., 1 Pelecypoda, 1 Gastropoda, 3 Paguridae, sediment	15
91 - 100	12	Ml?	19 *Macoma* spp., 1 Pelecypoda, 1 Paguridae	9
101 - 110	3	MF	5 *Macoma* spp.	3
71 - 80	5	IF	6 *Macoma* spp.	3
81 - 90	4	IF	3 *Macoma* spp., sediment	3
Total	141		Total	107

TABLE VIII

CONTINUED

Carapace Width	Number of Stomachs	Sex	Number of Prey in Stomachs	Number of Crab Feeding
Station 25				
31 - 40	2	IM	1 *Macoma* spp.	1
61 - 70	2	IM	2 *Macoma* spp.	2
71 - 80	5	IM	1 *Macoma* spp., 1 *Astarte* spp., 1 *Pagurus ochotensis*	3
81 - 90	22	IM	7 *Macoma* spp., 6 *P. ochotensis*, 5 *Balanus* spp., 2 polychaetes, sediment	18
91 - 100	9	IM	2 *Macoma* spp., 4 *P. ochotensis*, 2 Paguridae, 2 *Balanus* spp.	10
111 - 120	3	MM	1 *P. ochotensis*, 1 Paguridae, 1 Crangonidae	3
121 - 130	5	MM	5 *Macoma* spp., 1 *Astarte* spp., 1 *Pandalus* spp., 2 amphipods, 1 polychaete	5
131 - 140	3	MM	1 *P. ochotensis*, 1 *Chionoecetes bairdi*	2
81 - 90	8	MF	2 *Macoma* spp., 1 *Astarte* spp., 1 *P. ochotensis*, 1 *Balanus* spp.	4
91 - 95	1	MF	1 Pelecypoda, sediment	1
21 - 30	3	IF	5 *Macoma* spp.	3
61 - 70	4	IF	2 *Macoma* spp., 1 *Balanus* spp., sediment	3
71 - 80	15	IF	7 *Macoma* spp., 1 *Astarte* spp., 1 Pelecypoda, 1 Paguridae, 1 *Balanus*	11
81 - 90	5	IF	24 *Macoma* spp., 1 Paguridae, 1 Crangonidae	5
Total	87		Total	71
Station 28				
91 - 100	2	IM	1 *Macoma* spp., 2 Paguridae, 1 *Balanus* spp.	2
111 - 120	4	MM	1 Paguridae	1
Total	6		Total	3

TABLE VIII

CONTINUED

Carapace Width	Number of Stomachs	Sex	Number of Prey in Stomachs	Number of Crab Feeding
Station 40A				
41 - 50	9	IM	1 Pelecypoda, 1 *Pagurus ochotensis*, 2 *Balanus* spp., 2 polychaetes, sediment	5
51 - 60	23	IM	11 *P. ochotensis*, 2 Paguridae, 5 *Balanus* spp., 2 polychaetes, sediment	18
61- 70	30	IM	2 *Spisula polynyma*, 3 *Nucella* spp., 4 *P. ochotensis*, 5 Paguridae, 9 *Balanus* spp., 1 crustacean, 1 Ophiuridae, 1 tissue	22
71 - 80	3	IM	1 *P. ochotensis*, 1 Paguridae, 1 *Balanus* spp., sediment	2
81 - 90	3	IM	1 *P. ochotensis*	1
41 - 50	13	IF	1 *P. ochotensis*, 1 Paguridae, 3 *Balanus* spp., 1 polychaete	6
51 - 60	15	IF	3 *P. ochotensis*, 2 Paguridae, 4 *Balanus* spp., 1 plant material, sediment	10
Total	96		Total	67

TAELE IX

FOOD OF COOK INLET SNOW CRAB BY SIZE OF CRAB, NOVEMBER 1977.
DATA RECORDED AS FREQUENCY OF OCCURRENCE OF FOOD ITEMS

Stations 5, 27, 35, 40, 53, 62 & 62A Size of Crab (mm)	No. stomachs examined	No. stomachs with food	Foraminifera	Polychaeta	*Solariella* sp.*	Unidentified Gastropoda	Scaphopoda	*Nucula tenuis*	*Nuculana fossa*	*Glycymeris subobsoleta*	Mytilidae	Pectinidae	*Astarte* spp.	*Cyclocardia* spp.	*Spisula polynyma*	*Macoma* spp.	Unidentified Bivalvia	*Balanus* spp.	Amphipoda	Crangonidae	*Pagurus ochotensis*	*Pagurus capillatus*	Unidentified Paguridae	*Cancer* spp.	Unidentified Crustacea	Unidentified tissue	Unid. plant material	Teleost scales	Eggs	Sediment
										PREY ITEMS																				
0.0- 9.9	7	6			2				1							3									5					4
10.0- 19.9	31	29	1		1			3	9				1	1	1	9	4	5			1		6		5	1	1	2		16
20.0 - 29.9	51	46	2	4	2	3	1	3	2	5	1		2	2	2	7	2	29	1	1	1		19		5		1			14
30.0- 39.9	18	18	3						1				2	1	1	5	2	11					7		9	1				7
40,0- 59.9	2	2							1									1								1				
60.0 - 79.9	4	4	1	1		2		1							1	3	1				1				1					4
80.0 - 99.9	25	23	4	1	1			4	2						2	7	5	6		1	1		4	1	5	2				7
100.0- 119.9	17	14	2			2		1	1							1	2	3			1	1	2		2	4	2		1	3
120.0	5	4	2																							3	1			4
Total Frequency of Occurrence	160	146	15	6	6	7	1	12	17	5	1	1	5	4	7	35	16	55	1	2	5	1	38	1	32	12	5	2	1	59
Percent Frequency of Occurrence		91	10	4	4	4	1	8	11	3	1	1	3	2	4	22	10	34	1	1	3	1	24	1	20	8	3	1	1	37

* The genus *Margarites* occurs in the area and may be included.

TABLE X

THE PERCENT FULLNESS OF STOMACH (% f), MEAN DRY WEIGHT (g) OF STOMACH CONTENTS ($\bar{x}$dw), PERCENT OF DRY WEIGHT PLANT AND ANIMAL TISSUE (%t), AND PERCENT SEDIMENT WEIGHT (%S) OF *CHIONOECETES BAIRDI*, COOK INLET, NOVEMBER 1977

Blanks indicate no specimens at size

Size of Crab	Station 5				Station 27				Station 35				Station 40				Station 53				Station 62, 62A			
(mm)	%f	$\bar{x}$dw	%t	%s	%f	$\bar{x}$dw	%t	%s	%f	$\bar{x}$dw	%t	%S	%f	$\bar{x}$dw	%t	%s	%f	$\bar{x}$dw	%t	%S	%f	$\bar{x}$dw	%t	%s
o - 9																								
10 - 19	6	.022	82	10					30	.030	60	6												
20 - 29	23	.086	85	13					40	.042	60	13												
30 - 39									35	.176	78	10												
40 - 59									11	.177	90	4												
60 - 79													30	.151	42	25								
80 - 99					8	.212	93	5					29	.213	44	31	19	.275	73	8	16	.135	59	8
100 - 119	0												78	.191	68	16	19	.284	79	10	6	.167	54	3
>120	0												13	.340	67	12	10	.114	83	2				

clams and ophiuroids as important food items for C. *opilio* in the southeastern Bering Sea.

Yasuda (1967) examined stomachs of *Chionoecetes opilio elongatus* Rathbun from Japanese waters, and found the most frequently occurring invertebrate prey to be brittle stars (*Ophiura* sp.), and young C. *opilio elongatus*, and protobranch clams. Polychaetes, shrimps, gastropod, scaphopods and flatfishes were also taken by C. *opilio elongatus*.

Polychaetes and gastropod were common in Cook Inlet but rarely preyed upon. It is possible that with a dissection microscope, often used in stomach analyses, very small polychaete fragments were not observed and that this group may occur more frequently in snow crab stomachs than reported. Brittle stars are relatively rare in the lower Cook Inlet. In Cook Inlet cannibalism was infrequent. Scaphopods and fishes were encountered in few C. *bairdi* stomachs.

A comparison of the percent fullness of stomachs of Cook Inlet snow crab at different times of day (Table XI) indicates that there are no definite day-night trends in the fullness of snow crab stomachs. These data also indicate the normal degree of stomach fullness encountered in fall, spring, and summer collections. Data on percent fullness of stomachs, average dry weight of stomach contents, and percent tissue weight of stomach contents is presented in Table X. In the laboratory, total clearance of the stomach required 3 days (Table XII). In the laboratory consumption of *Macoma balthica* tissue by snow crab averaged 4.2% and 3.4% of total live weight and total dry weight of snow crab, respectively (Table XIII). These data may be useful in indicating a change in feeding habits resulting from a change in the environment, such as the addition of oil.

King crab

A total of 117 king crab stomachs were examined from Kamishak Bay, 90% contained food. The mean carapace length of all crab examined was 105 mm with a range of 35-150 mm. The three most frequently observed individual foods were barnacles, 81%; bivalves of the family Mytilidae, probably *Modiolus* sp., 13%; and hermit crabs, 12%. In addition, 17 other categories of food items were observed ; none occurred in more than

TABLE XI

A COMPARISON OF PERCENT FULLNESS OF STOMACHS OF COOK INLET SNOW CRAB AT DIFFERENT TIMES OF CAPTURE

$\bar{x}$ = mean, N = number

Time/day	$\bar{x}$ % Fullness	Station	N
November 1977			
0130	55	53	42
0500	37	40	16
1900	34	35	47
2140	7	5	16
2140	8	27	3
2320	10	62, 62A	10
March 1978			
0000	28.6	62A	6
0335	50.0	62A	4
0740	60.0	62A	1
0815	38.1	25	21
1040	25.0	62A	1
1206	60.2	62A	6
1402	100.0	62A	1
1440	62.8	62A	2
1537	45.0	62A	2
1700	50.0	62A	2
2206	72.2	62A	3
July 1978			
0530	14	40	18
1100	5	37	6
1430	24	PMEL1	12
1800	54	62A	2
1800	15	5	46

TABLE XII

PERCENT FULLNESS OF STOMACHS OF *CHIONOECETES BAIRDI* AFTER FEEDING IN THE LABORATORY (5°C)

N = Number of specimens examined

Time After Feeding (hrs)	N	Mean Carapace Width (mm)	Mean Percent Stomach Fullness	Standard Deviation
Experiment 1				
24	5	62	11.0	6.8
32	5	51	5.6	2.4
44	5	55	6.7	5.1
56	5	53	3.4	3.2
80	5	52	1.5	0.5
Experiment 2				
24	5	47	7.3	2.3
48	5	43	4.8	2.8
72	5	45	2.4	1.1

TABLE XIII

CONSUMPTION OF *MACOMA BALTHICA* BY *CHIONOECETES BAIRDI* OVER A TWENTY-FOUR HOUR PERIOD

$\bar{x}$ = mean, N = number of specimens

$\bar{x}$ Carapace Width (mm)	N	Whole Crab Weight (g)	Mean *Macoma* Meat Weight Eaten (g)	Standard Deviation	*Macoma* Meat as X Crab Weight
Wet Weight Basis					
42	5	19.5	1.630	1.2337	8.4
50	4	35.2	0.7422	0.2672	2.1
51	5	35.2	0.9917	0.5408	2.8
72	2	107.5	3.6918	1.7976	3.4
					x 4.2
Dry Weight Basis					
42	5	5.4	0.4315	0.3266	7.9
50	4	9.3	0.0915	0.3929	1.0
51	5	10.2	0.2917	0.1591	2.9
72	2	30.1	0.5067	0.2466	1.7
					x 3.4

6% of the stomachs. Bivalves (clams), all species combined, occurred in 27% of the stomachs, and gastropod were found in 12% of the stomachs (Table XIV). In May, 41% of the crabs with empty stomachs were newly molted or molting individuals.

Stomachs from crabs in Kamishak Bay generally contained only barnacle remains. Eighteen king crabs collected at station 35 in November 1977 had full stomachs, and were feeding exclusively on the barnacles, *Balanus crenatus*. The contents of these stomachs were digested in KOH and barnacle shell weights remaining after KOH digestion and rinsing with distilled water determined. The average shell and meat weights of 100 barnacles taken from the same trawls, were determined in a similar manner. An estimation of the average number of barnacles, based on shell weight, in each stomach was made. The stomachs contained the equivalent of 11.2 (s.d. = 7.4) barnacles per crab. The average wet meat weight for the eleven barnacles would be 2g.

In Kachemak Bay, 113 king crabs were captured, 72% contained food. Bivalves, all species together, occurred in 60% of the stomachs. The clam, *Spisula polynyma*, was the most frequently occurring prey species, observed in 38% of the stomachs. Barnacles were found in 14% of the stomachs. The snail, *Neptunea lyrata*, occurred in 11% of the stomachs (Table XV). By examining shell thickness and sizes of resilium or cardinal teeth of *Spisula polynyma* shells in stomachs, it was possible to estimate sizes and age of the clams eaten (see Feder, 1978a clam-aging methodology and data). In the 43 king crab stomachs containing S. *polynyma*, 13 had large clam meats and pieces of shell 1 to 2 mm thick. *Spisula* with shells this thick would exceed 80 mm in shell length and be seven years of age or older. Shells of S. *polynyma*, probably less than 10 mm in length (young of the year or one year old clams) occurred in 30 stomachs. Pieces of *Neptunea lyrata* opercula up to 15 mm in length were found in the stomachs of adult crabs.

In contrast to Kamishak Bay, king crab in Kachemak Bay, generally contained the remains of a variety of organisms. For example, one specimen contained 21 small *Spisula polynyma*, 2 *Solariella* sp. (snail), 1 *Oenopota* sp. (snail), and *Balanus* sp. shell.

TABLE XIV

FOOD OF *PARALITHODES CAMTSCHATICA* FROM KAMISHAK BAY, COOK INLET, ALASKA.
DATA RECORDED AS FREQUENCY OF OCCURRENCE OF FOOD ITEMS

Station	Date month/year	No. stomachs examined	No. stomachs with food	Hydrozoa	Bryozoa	Polychaeta	*Solariella* sp.*	*Polinices* spp.	*Neptunea lyrata*	Unidentified Gastropoda	Gastropod eggs	*Nucula tenuis*	*Nuculana fossa*	*Glycymeris subobsoleta*	Mytilidae	*Macoma* spp.	*Tellina nuculoides*	Unidentified Bivalvia	*Balanus* spp.	Amphipoda	Paguridae	Unidentified Crustacea	Plant material
18	6/78	5	5				4	1		1		2	1	2		1			5	1	1		
27	6/78	30	30	2	1		1			1	2				14		1	1	30		9		
35	11/77	36	36			1			1	1			1	1	1				29		1		1
35	5/78	22	17										2						17				1
35	6/78	13	13	1				1		1			1					1	13		3		
36	5/78	3	1													1			1				
36B	5/78	2	0																				
53	11/77	3	3						1	1			2							1		1	
54	5/78	3	0																				
Total Frequency of Occurrence		117	105	3	1	1	5	5	5	5	2	2	7	3	15	2	1	2	95	2	14	1	2
Percent Frequency of Occurrence			90	3	1	1	4	2	2	4	2	2	6	3	13	2	1	2	81	2	12	1	2

* The genus *Margarites* occurs in the area and may be included.

TA8LE XV

FOOD OF *PARALITHODES CAMTSCHATICA* FROM KACHEMAK BAY, COOK INLET, ALASKA.
DATA RECORDED AS FREQUENCY OF OCCURRENCE OF FOOD ITEMS

Station	Date month/year	No. stomachs examined	No. stomachs with food	PREY ITENS: Foraminifera	Hydrozoa	Bryozoa	Polychaeta	*Solariella* sp.*	*Neptunea lyrata*	*Oenopota* spp.	Unidentified Gastropoda	Gastropod eggs	*Nucula tenuis*	*Nuculana fossa*	*Glycymeris subobsoleta*
.40	6/78	1	1						1		1				
40	7/78	35	29	1		1	3	6	2	9	1		3	3	
4 0A	6/78	42	36	2	8			2	8		3				1
40B	6/78	3	2		1	1	1	1	1		1	1			
41	6/78	2	2	1			1								
43A	3/78	28	10	1	8	1									
227	8/78	2	1											1	
Total Frequency of Occurrence		113	81	5	17	3	5	9	12	9	6	1	3	4	1
Percent Frequency of Occurrence			72	4	14	3	4	8	11	8	5	1	3	4	1

Station	Date month/year	*Modiolus modiolus*	*Chlamys* spp.	*Clinocardium ciliatum*	*Spisula polynyma*	*Macoma* spp.	*Tellina nuculoides*	Unidentified Bivalvia	*Balanus* spp.	Amphipoda	*Pandalus* spp.	Paguridae	Unidentified Crustacea	Ophiuroidea	Asteroidea	Unidentified tissue	Plant material
.40	6/78			1								1		5			
40	7/78	2			26	2			2	1	9	1	1				
4 0A	6/78	2	1	1	13	2		1	9				3	1		2	3
40B	6/78		1		1			1	1					1			
41	6/78				2				1			1			1		
43A	3/78	1					1	1	3			5			2		1
227	8/78				1											1	
Total Frequency of Occurrence		5	2	2	43	4	1	3	16	1	9	8	4	7	3	3	4
Percent Frequency of Occurrence		4	2	2	38	4	1	3	14	1	8	7	4	6	3	3	4

* The **genus Margarita** occurs in the area and may be included.

Sixteen king crabs were captured at station 6 near the mouth of the Inlet. In the 12 that contained food, 10 had eaten *Nuculana fossa*. These stomachs contained between 10 and 25 of these small bivalves. Clams of the genus *Macoma* occurred in 4 stomachs, and one crab had unidentifiable crustacean remains.

Tarverdieva (1976) provides information on feeding of king crabs from Bristol Bay, Alaska. There, echinoderms and molluscs were the predominant food items occurring in 50% and 35% of the stomachs respectively. Feder (1978b) observed *Chionocardium ciliatum* in 67%, *Solariella* spp. in 55%, *Naculana fossa* in 50%, *Cistenides* sp. and brittle stars of the family Amphiuridae in 35% of 124 king crab stomachs from the southeastern Bering Sea. Takeuchi (1968a, b) examined the food of king crabs from the Kamchatka region of Japan, and found that molluscs, crustaceans, and echinoderms were the main food items. Takeuchi (1967) found that the frequency of occurrence of the above prey groups in crab stomachs corresponded to the relative abundance of these organisms. In Cook Inlet, barnacles, clams, snails, and hermit crabs are widely distributed (Feder, 1978a), and are fed upon in proportion to their abundance. At the stations examined, small echinoderms were relatively rare (Feder, 1978a).

Dungeness crab

Food occurred in 331, 80%, of the 413 Dungeness crab stomachs examined (Tables XVI and XVII). The average shell width of the Dungeness crabs examined was 142 mm with a range of 22 to 210 mm. The individuals over 50 mm carapace width preyed primarily on small bivalves, barnacles, and amphipods (Table XVI). Small clams were the most important food items, present in 67% of the stomachs. The clam *Spisula polynyma* was the most frequently occurring species, observed in 48% of the stomachs. All other prey species occurred in less than 5% of the stomachs examined.

In 93% of the *Cancer magister* stomachs containing *Spisula polynyma*, the shell fragments belonged to clams probably less than 10 mm in shell length (young of the year or one-year old clams). By counting the number of umbos or hinge ligaments present, it was possible to make an estimate of the number of small S. *polynyma* present in some stomachs. The maximum

TABLE XVI

FOOD OF *CANCER MAGISTER* WITH CARAPACE WIDTH GREATER THAN 50 mm FROM COOK INLET, ALASKA

				EM																												
Station	Date month/year	No. stomachs examined	No. stomachs with food	Foraminifera	Hydrozoa	Bryozoa	Polychaeta	*Solariella* sp.*	*Natica* sp.	*Neptunea lyrata*	Unidentified Gastropoda	*Nucula tenuis*	*Nuculana fossa*	*Glycymeris subobsoleta*	*Modiolus modiolus*	*Chlamys* spp.	*Clinocardium ciliatum*	*Spisula polynyma*	*Macoma* spp.	*Tellina nuculoides*	Unidentified Bivalvia	*Balanus* spp.	Amphipoda	*Pandalus* spp.	*Crangon* spp.	Paguridae	*Chionoecetes bairdi*	Unidentified Crustacea	Ophiuroidea	Teleost	Unidentified tissue	Plant material
40	7/78	25	18						1		1		6					11	1	1	8	1			1	1			1			
40	8/78	52	40							1		10	7					33			6	1	1	1	1	1			2	1		
40A	12/77	18	12	3			2	3										9	1			2				1			2			
40A	6/78	132	104	5	1	1	5	2						3		6		80	3		5	2	10	10			1	6	3	4	2	
40A	7/78	9	5	4			1											2				3	1									
40A	8/78	6	5	1			1	1										2					2	2						1		
41	6/78	3	3															3														
41	7/78	22	21	1			1		1									9		1		10	1			2						
41	8/78	13	8	2														5			1	3			1	1						
227	8/78	6	2															1							1							
D1	6/78	63	33	1			6								7		4	13				17	6			9		4		2	6	[illegible]
Total Frequency of Occurrence		349	251	17	1	1	16	6	2	1	1	10	13	3	7	6	4	168	5	2	20	39	21	14	4	15	1	10	8	8	8	4
Percent Frequency of Occurrence			72	4.8	<1	<1	4	2	<1	<1	<1	3	4	1	2	2	1	48	1	<1	6	11	6	4	<1	4	<1	3	2	2	2	1

* The genus ites occurs in the area and may be included.

TABLE XVII

FOOD OF *CANCER MAGISTER* WITH CARAPACE WIDTHS OF 22-45 mm FROM COOK INLET, ALASKA

		RE															
Station	Date month/year	No. stomachs examined	No. stomachs with food	Foraminifera	Polychaeta	*Solariella* sp.*	Unidentified Gastropoda	*Nucula tenuis*	*Spisula polynyma*	*Tellina nuculoides*	Unidentified Bivalvia	*Balanus* spp.	Amphipoda	Paguridae	Unidentified Crustacea	Unidentified tissue	Sand
40A	8/78	64	51	23	18	2	1	1	9	1	6	18	1	8	2	2	27
Total Frequency of Occurrence		64	51	23	18	2	1	1	9	1	6	18	1	8	2	2	27
Total Frequency of Occurrence			80	36	28	3	2	2	14	2	9	28	2	13	3	3	42

* The genus *Margarites* occurs in the area and may be included.

number countable was 125 young clams. The meats of large S. *polynyma* and pieces of shell 1 to 2 mm thick were observed in 29 stomachs.

In the one sample of Cancer *magister* composed of crabs with carapace widths or 22 to 44 mm (Table XVII), the most frequently occurring animals were: Foraminifera, 36%; Polychaeta, 28; barnacles, 28%; and small clams 25%. The individuals with empty stomachs were generally in a newly molted or molting condition.

In a northern California study, the five most frequently observed categories of prey for Cancer *magister* were: clams, 35%; fishes, 24%; isopods, 17%; amphipods, 16%; and razor clams (*Siliqua patula*), 12% (Gotshall, 1977). Butler (1954) examined C. *magister* from British Columbia, Canada, and found that crustaceans (59%) and clams (56%) were the most frequently occurring food items. Butler (1954) reported fish remains in only 4 Dungeness stomachs.

The results of the previous two studies are similar to our data in that all three investigations show that clams and several kinds of crustaceans are important as prey for *Cancer magister*. The major difference between the studies is the importance of fishes in the diet of northern California Dungeness crabs, and the low frequency of occurrence of fishes in crab diets in British Columbia and Cook Inlet. Isopods or razor clams were rarely encountered in grabs or dredges in Cook Inlet. The mollusc most commonly taken by dredging and in the stomachs of other predators in the study area, was *Spisula polynyma*. Therefore, the high incidence of predation on this species is probably a reflection of its abundance.

VII. CONCLUSIONS

The trawl surveys of 1977-78 extend the data collected in 1976 for important habitats of commercially-harvested Crustacea in lower Cook Inlet (Feder, 1978a). In 1977-78, snow crabs were most abundant on the western side of the Inlet in Kamishak Bay (15 to 100 crab per km fished). Catches were less than 10 snow crab per km fished at all other stations trawled in the Inlet. Snow crabs less than 20 mm carapace width (i.e. juveniles) were found only in outer Kamishak Bay and between Cape Douglas and the Barren Islands. This apparent snow crab nursery area includes parts of the lease area. Few snow crabs of 20 to 80 mm carapace widths were captured at any of the stations occupied. The areas that this size grouping inhabit are currently unknown.

The important habitats, based on abundance, for king crabs were in Kamishak Bay Stations 35 and 27 and Kachemak Bay Stations 43, 39, 40 and A40. Dungeness crabs were observed only in mid-Kachemak Bay Stations 40, A40, and 41. With the exception of a large number of bumpy shrimp captured in northern Kamishak Bay, Station 56, the major concentrations of pink, bumpy, sidestripe and coonstripe shrimps were found in inner Kachemak Bay; lesser numbers of these shrimps were observed in mid-Kachemak Bay.

The areas discussed above must be considered among the known important habitats for commercially harvested crustaceans in Cook Inlet. Furthermore, Cook Inlet crude oil negatively affects survival of the zoea of these commercial Crustacea and the moulting success of juvenile snow crabs (Rice *et* al., 1976). Oil input in these important habitat areas could be damaging to adult stocks if a spill occurred (1) at the period of peak larval abundance in the upper layers of the water column, or (2) shortly after settlement and metamorphosis of young on the bottom.

The most frequently observed prey types in snow crab stomachs were small bivalves (especially *Macoma* spp., *Spisula polynyma, Nacula tenuis, Naculana fossa),* hermit crabs and barnacles. These same organisms as well as, mussels and the snail *Neptunea lyrata* were found to be important prey for king crabs, Dungeness crabs fed primarily on young individuals of the clam *Spisula polynyma*. The results indicate that small bivalves, barnacles, and hermit crabs are key species in the food webs of the commercially important crabs of lower Cook Inlet. No data concerning the effect of Cook Inlet crude oil on the bivalves, barnacles, and hermit crabs utilized as food by the commercially important crabs is available. Work by D. Shaw (person. commun; unpub. data), Shaw *et al* (1976), and Feder *et al.* (1976) indicate that the survival rate, condition index, filtering rate, growth, and burrowing behavior of *Macoma balthica* are negatively affected by Prudhoe Bay crude oil.

The Final Report for lower Cook Inlet will include a complete analysis of clam growth, growth history, natural mortality rates, age-size-meat weight-carbon values, and biomass by station for selected species of clams. Estimates of secondary productivity of clams were restricted to 1976 preliminary observations only; curtailment of funds and the field program in 1978-79 precluded completion of this task. Grab data including species composition, biomass and diversity will be available for 24 stations (Fig. 3). These stations are either in the current lease area, areas where commercially important benthic organisms were encountered in the trawl survey, or represent PMEL detritus-trap stations (J. Lawrence, PMEL, person. commun.). These stations will be grouped into 7 areas: inner Kachemak Bay, mid-Kachemak Bay, outer Kachemak Bay, central zone, lower Kamishak Bay, uPPer Kamishak Bay, and outer region (Fig. 4). When possible, distribution of feeding types and biomass will be integrated, with information on detrital deposition rates and bacterial activity levels available from other OCSEAP projects in lower Cook Inlet.

The trawl data will be regionalized in the same manner as the grab data (Figs. 2, 3, 4). The results of the trawl survey will include mean (and standard deviations) of numbers and weights of individuals by species for each station occupied. The data will be a summarization for all quantitative data collected at stations between April 1976 and August 1978. Information on size distribution for snow crab and distribution of egg-bearing females will be available for all commercially important crustaceans. Data on nursery areas for snow crabs located in lower Cook Inlet will also be available.

A major goal of the Final Report for lower Cook Inlet will be a description of critical habitats and periods of vulnerability of key invertebrates to oil pollution. A first assessment of some of these critical habitats is included in this Annual Report.

Food data beyond that which occurs in the Annual Report, i.e. snow crab, king crab and Dungeness crab data, will be available for six species of hermit crabs, three species of crangonid shrimps, five species of pandalid shrimps, and several species of fishes. Feeding observations will also be extended to cover the zoea larvae of king crab, snow crab, and pink shrimp in the laboratory. Relative to the latter studies, data will be available on prey concentrations necessary for successful feeding response of these zoea. These data are necessary to analyze food availability as a factor affecting survival of larvae of the above species. Information on post-larval king

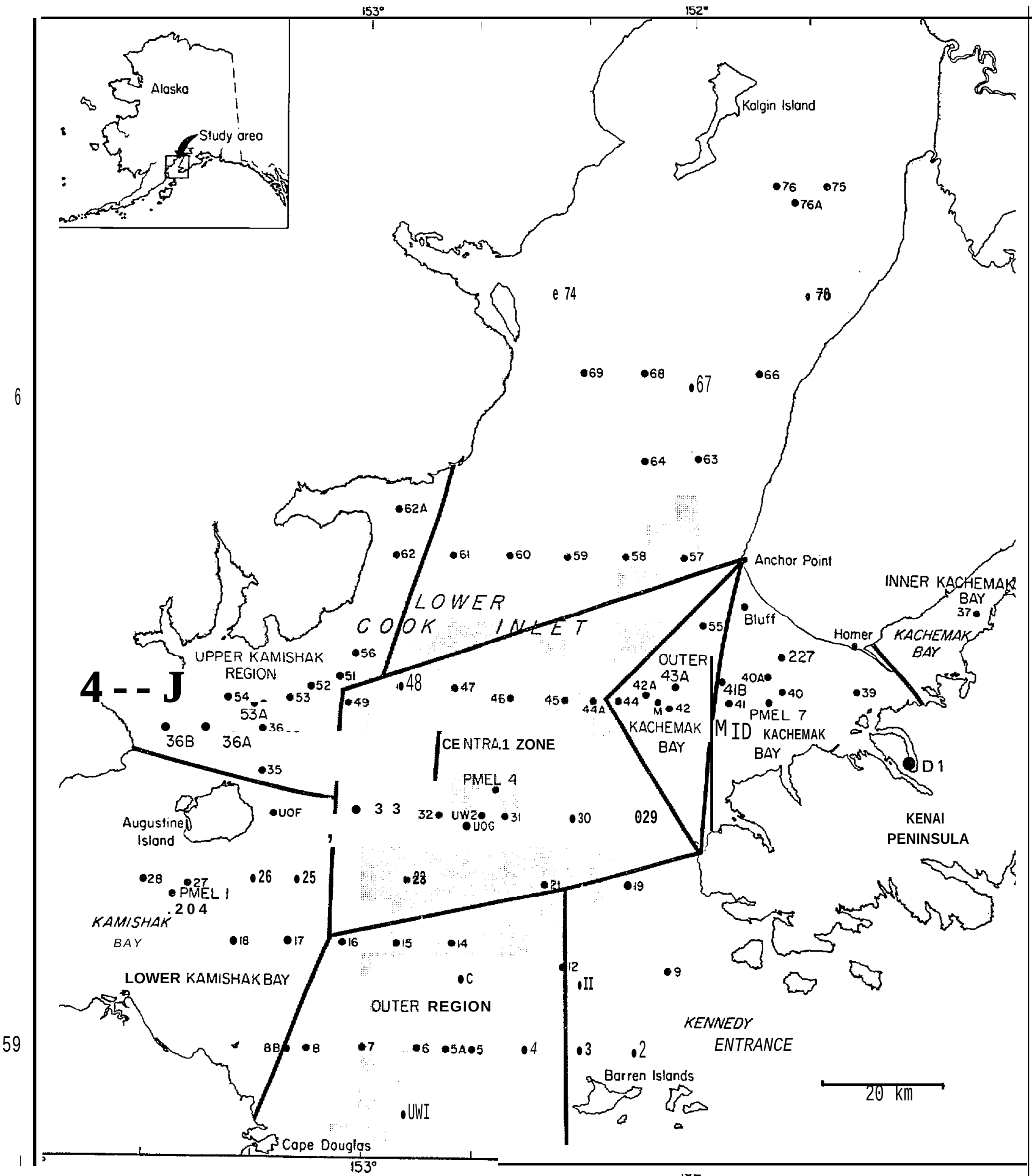


Figure 4. Lower Cook Inlet Benthic Trawl Stations and regions for grouping data for 1976, 1977 and 1978.

crab collected by Alaska Department of Fish and Game from Kachemak Bay will also be included in the Final Report.

Limited laboratory observations amd experiments on reproduction, molting, and feeding of snow and king crabs will be available. Data for this part of the study will be limited since laboratory work was eliminated from the 1978-1979 project period, and these observations and experiments were not initiated until late 1978.

VIII. NEEDS FOR FURTHER STUDIES

Suggestions for further work in Cook Inlet are included in the 1979 Annual Report, Section I of this document.

In addition, the following studies are highly recommended:

1. Examine juvenile snow crab feeding habits.
2. Find nursery areas for snow crabs on the east side of Cook Inlet.
3. Examine small bays throughout Cook Inlet for crab and shrimp distributions, abundance, and reproductive *activities.*
4. Initiate a major program to understand recruitment and natural mortalities in crab and shrimp populations in Cook Inlet.

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APPENDIX I

LOWER COOK INLET BENTHIC STATIONS OCCUPIED 1976-1978

Station Name	Latitude	Longitude	Depth (m)
2	59°00.3'	152°11.6'	117
3	59°00.3'	152°21.6'	123
4	59°0(?.3'	152°30.0'	152
5	59°00.3'	152"42.5'	166
5A	59"00.3'	152"47.5'	181
6	59°00.3'	152°49.7'	166
7	59°00.3'	153°03.1'	150
8	59"00.3'	153°10.6'	121
8B	59°01.0'	153°13.0'	111
9	59°08.4'	152°04.2'	129
11	59°06.0'	152"20.0'	116
12	59°08.9'	152°26.1'	121
14	59°10.3'	152°47.17	146
15	59°10.0'	152°54.0'	139
16	59°09.8'	153°06.9'	91
17	59°10.0'	153°13.5'	67
18	59°09.3'	153°24.8'	44
19	59''15.5'	152°10.7'	110
21	59°15.3'	152'26.6'	90
23	59°15.3'	152°49.3'	91
25	59°15.9'	153°08.5'	59
26	59°15.8'	153°20.0'	42
27	59°15.6'	153°33.8'	32
28	59°15.4'	153°40.0'	31
29	59°22.6'	152°09.4'	81
30	59°21.5'	152°24.1'	81
31	59°23,3'	152"35.7'	73
33	59°22.3'	153"05.0'	53
35	59"24.9'	153°17.7'	42
36	59°30.0'	153°15.7'	33
36B	59'28.1'	153°30.0'	
37	59"41.3'	151°11.1'	59
39	59°34.9'	151°30.4'	99
40	59°33.1'	151°46.8'	69
40A	59°36.7'	151°51.6'	31
40B	59°39.5'	151°54.6'	
41	59°32.7'	151°55.3'	35
42	59°32.1'	152°04.5'	40
42A	59°33.8'	152°12.5'	32
43A	59°28.0'	152°05.0'	
44	59°33.1'	152"13.7'	68
44A	59°33.1'	152°18.6'	61
45	59°32.7'	152°25.5'	57
46	59°33.5'	152°35.5'	81
47	59°33.9'	152"43.7'	55
48	.59"34.,0'	152°54.0'	42

CONTINUED

Station Name	Latitude	Longitude	Depth (m)
49	59″33.1′	153°04.0′	37
51	59°35.0′	153°05.0′	36
52	59°34.0′	153°10.0′	35
53	59°31.8′	153°11.0′	37
53A	59°32.0′	153°08.9′	
54	59°33.4′	153°24.5′	24
55	59°40.0′	151°59.5′	29
56	59°37.0′	153°02.0′	35
57	59°45.1′	152°03.3′	35
58	59″46.1′	152″13.0′	58
59	59°46.2′	152°23.4′	82
60	59°46.8′	152°34.7′	38
61	59°47.0′	152°43.7′	34
62	59°46.2′	152°55.0′	26
62A	59°49.8′	152″52.3′	24
63	59°55.7′	151°58.6′	31
64	59°54.9′	152°08.9′	60
66	60°03.3′	151°48.3′	44
67	60°01.5′	152°01.0′	51
68	60°02.8′	152°13.3′	60
69	60°03.3′	152°20.5′	55
70	60°10.3′	151°39.8′	41
74	60°10.0′	152°23.3′	55
75	60°20.3′	151°34.5′	27
76	60°20.0′	151°46.0′	27
76A	60°18.3′	151°45.2′	47
C	59°07.5′	152°46.1′	147
M	59°32.9′	152″08.2′	48
UWI	58°53.1′	152°51.4′	172
UW2	59°22.7′	152°42.6′	?
UOF	59°21.0′	153″15.2′	44
UOG	59°20.8′	152°43.8′	68
PMEL 1	59°14.4′	153°41.1′	
PMEL 4	59°22.3′	152″40.3′	
PMEL 7	59°33.3′	151°39.8′	
204	59°14.3′	153°38.5′	
227	59°33.4′	151°44.1′	