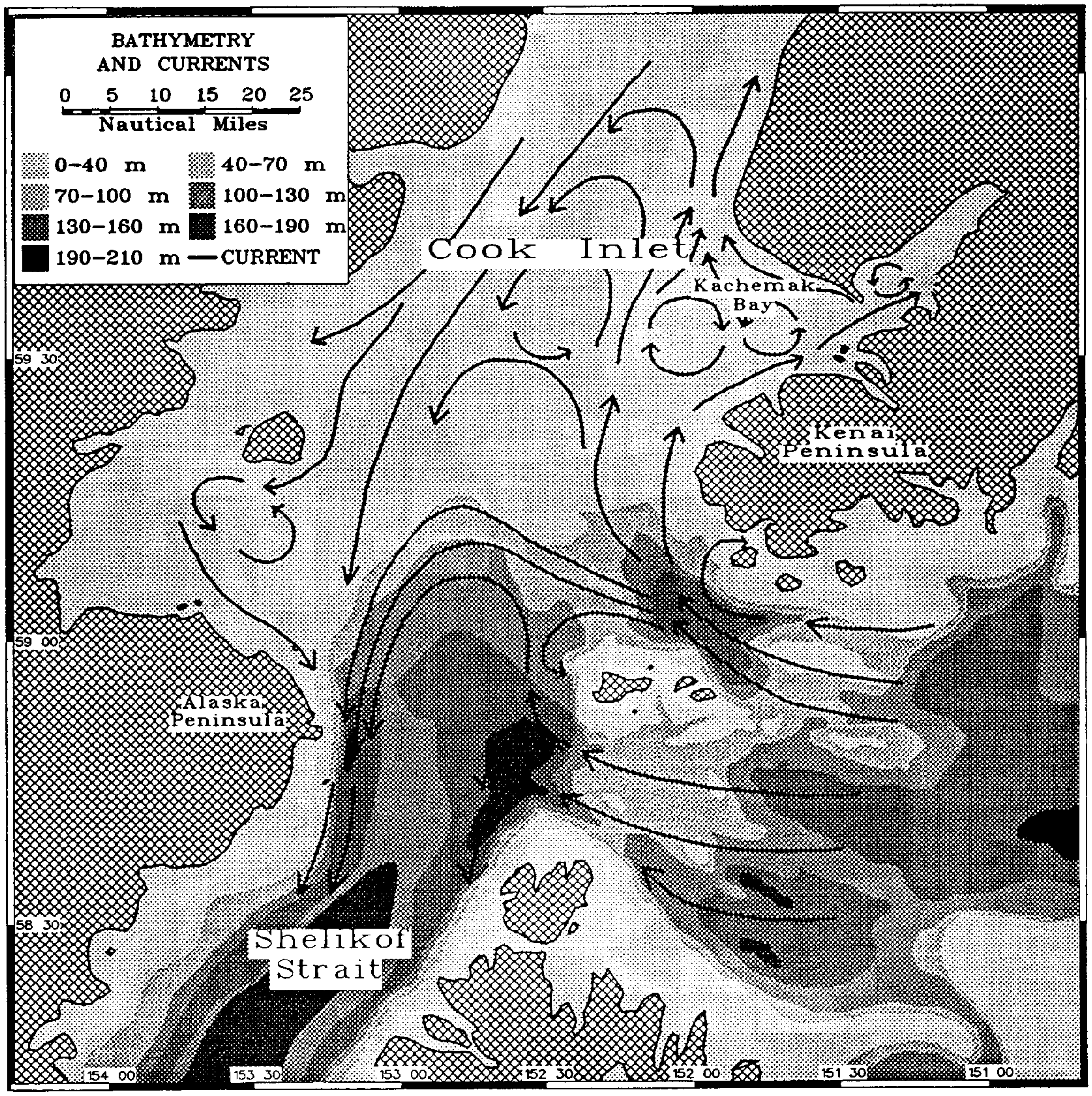

MONITORING SEABIRD POPULATIONS IN AREAS OF OIL AND GAS DEVELOPMENT ON THE ALASKAN CONTINENTAL SHELF

Oceanic, Shelf and Coastal Seabird Assemblages at the Mouth of a Tidally-Mixed Estuary (Cook Inlet, Alaska)

OCS Study MMS 93-0072
Final Report to Minerals Management Service
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ABSTRACT

Surveys were conducted in July, 1992 to study the distribution and abundance of seabirds in a 12,500 km^2 area of lower Cook Inlet, Alaska. Seabirds at the sea surface, fish below the surface (estimated acoustically), and sea surface temperature and salinity were recorded on 415 ten-minute transects covering 1225 linear km. Sea temperature and salinity (CTD) profiles of the water column and zooplankton tows were obtained on stations crossing the entrance to Cook Inlet.

Observed temperature and salinity patterns were consistent with well-known oceanographic features of the area Low-salinity Alaska Coastal Current (ACC) waters hugs the coast of the Kenai Peninsula and enters Cook Inlet after flowing north around the Barren Islands-- which rise from the middle of a relatively deep (130 m) shelf that connects the Kenai Peninsula with Shuyak Island in the Kodiak Archipelago. More saline, oceanic water from the Alaska Stream enters south of the Barren Islands and is steered bathymetrically in a counterclockwise fashion around the mouth of Cook Inlet and then southwest into Shelikof Strait. Most water in lower Cook Inlet is well-mixed by upwelling and tidal action at the mouth of this shallow estuary.

Zooplankton were most abundant (ea. 60-80 mg/m^3) on the northeast side of the entrance to Cook Inlet, but there was little variation in species composition across the entrance. Fish biomass was also highest (ea. 4-8 g/m^3) on the northeastern side, especially in shallow coastal waters near the Kenai Peninsula. Fish biomass in more oceanic water south of the Barrens was generally low (0-0.5 g/m^3) except in shallow coastal waters around Shuyak Island.

Despite extensive vertical mixing of waters in lower Cook Inlet, weak property gradients across the entrance, and lack of segregation of zooplankton communities, there was marked segregation of seabird assemblages. Species (e.g., murres, murrelets, gulls) that feed mostly on fish in coastal and shelf habitats were abundant (50-300 bird/km^2 northeast of the Barrens and in coastal waters of the Kenai Peninsula and Shuyak Island. Nekton-feeding species (e.g., fulmars, storm-petrels, phalaropes) that typically forage in oceanic and shelf-edge habitats were most numerous (100-540 birds/km^2) in higher-salinity oceanic water located south of the Barrens. Species (e.g., shearwaters, Tufted Puffins) with mixed plankton and fish diets, and which may forage in both oceanic and shelf environments, were concentrated (500-2500 birds/km^2 near the Barren and Shuyak islands in cool upwelled waters.

Overall, an estimated 2 million seabirds foraged within 50 km of the Barren Islands in July, and these waters supported an average seabird biomass of 89.8 kg/km^2. Transient shearwaters (64.4 kg/km^2) comprised most of this standing biomass, but coastal/shelf species (12.8 kg/km^2) and oceanic species (6.5 kg/km^2) contribute to make lower Cook Inlet one of the most productive areas for seabirds in Alaska (compare with 17.1 kg/km^2 in Bering Strait, or 36.1 kg/km^2 on the outer shelf of the southeast Bering Sea). Seabird densities were highest in the vicinity of the Barren and Shuyak islands and their associated shelf environments-- revealing the importance of islands in creating productive local foraging habitat for seabirds.

INTRODUCTION

During the past two decades, the distribution of seabirds in relation to water masses, fronts, and prey aggregations has been well-described in several ocean areas (see reviews by Brown 1980, 1988; Hunt and Schneider 1987, Hunt 1990). It has often been observed that some seabird species have remarkably well-defined distributional boundaries because of strong associations with prey patches (Piatt 1990, Hunt et al. 1990a, 1993), or a variety of oceanographic features. At small spatial scales (1-100 km), seabirds may aggregate where food is concentrated at fronts (e.g., Brown and Gaskin 1988, Piatt et al. 1991, Schneider et al. 1990), which may be defined as areas of high spatial gradient in thermodynamic properties such as temperature, density, or velocity (Schneider 1990a). At both small and medium (100-1000 km) spatial scales, seabird species or "assemblages" may not necessarily be concentrated at fronts, but rather be segregated into different water masses which are themselves demarcated by fronts (Schneider et al. 1986, 1987; Gould and Piatt 1993).

In any case, it appears that fronts often play a key role in structuring marine habitat for seabirds. Strong fronts may attract more seabirds than weak fronts (Schneider et al. 1987), seabird abundance may be correlated with the spatial extent or frequency of fronts (Haney 1985), and strongly demarcated water masses may promote greater segregation of seabird species than weakly defined ones (Elphick and Hunt 1993). Indeed, it has been suggested that seabirds largely ignore weakly defined habitats at small (<100 km) spatial scales (Hunt et al. 1990b, Elphick and Hunt 1993). Whereas this hypothesis has proven to be generally true in Alaska, I will show in this report that despite being well-mixed by tidal and upwelling processes, marine waters of lower Cook Inlet support distinct and segregated assemblages of coastal, shelf, and oceanic seabirds.

Compared to other marine areas of Alaska, seabirds in lower Cook Inlet and the Barren Islands have been little studied with regard to their pelagic ecology. The geographic distribution and abundance of species has been described on a gross scale from aerial and shipboard surveys (Erickson 1977, Gould et al. 1982). These surveys showed that lower Cook Inlet is a regional "hotspot" supporting 100's to 1000's of birds/km^2 during spring and summer. Population surveys (Bailey 1976, Sowls et al. 1978), and studies of breeding biology and diets of species nesting on the Barren Islands were conducted in the 1970's (storm-petrels and puffins; Manuwal and Boersma 1977, Boersma et al. 1980, Wehle 1980) and in 1989-1992 following the "Exxon Valdez" oil spill (principally murres, Nysewander et al. 1992, Boersma et al. 1993).

Here I present results of a pelagic survey of lower Cook Inlet conducted in summer, 1992. Seabirds were censused at sea in a 50 km radius grid around the Barren Islands. During these transects, the biomass of fish below the surface was measured hydroacoustically and sea-surface temperatures and salinities were recorded continuously. Temperature and salinity profiles of the water column and zooplankton samples were obtained at stations on 3 cross-sections of lower Cook Inlet.

STUDY AREA

Cook Inlet is a broad (ca. 80 km), shallow (ca. 60 m depth) tidal estuary that extends 350 km northeastward from the Gulf of Alaska continental shelf. The mouth of the inlet is bounded by an escarpment that arcs westward from the tip of the Kenai Peninsula to the Alaska Peninsula (Fig. 1). On the eastern side of the entrance to Cook Inlet, some low salinity Alaska Coastal Current (ACC) water follows the coast and moves north into Cook Inlet, but most ACC water is steered bathymetrically in a counterclockwise fashion around the mouth of the inlet and into the northern end of Shelikof Strait (Burbank 1977, Muench et al. 1978). The flow of ACC water north into Cook Inlet is weak and variable. Some of this water circulates in Kachemak Bay where it mixes with low salinity glacial river outflows, and some proceeds north. Much of this northward flow is swept to the west where it is entrained in a strong southward flow of very dilute water from upper Cook Inlet that joins the ACC as it enters Shelikof Strait.

About 70 km southwest of the Kenai Peninsula, the Kodiak Archipelago serves to funnel water from the Gulf of Alaska into lower Cook Inlet and Shelikof Strait. Mid-way in this strait lie the Barren Islands, which sit astride a bridge at 130 m that connects the Kenai Peninsula and the Kodiak Archipelago, and is surrounded by deep troughs to the east and west (Fig. 1). This local area is highly productive and the Barren Islands host the largest seabird colonies in the region, including historical (Bailey 1976, Sowls et al. 1978, Boersma et al. 1980) breeding populations of approximately 300,000 Fork-tailed Storm-petrels (*Oceanodroma furcata*), 90,000 Common Murres (*Uria aalge*), 200,000 Tufted Puffins (*Fratercula cirrhata*), and 34,000 Black-legged Kittiwakes (*Rissa tridactyla*). Lower Cook Inlet is also an important foraging area during summer for a variety of locally non-breeding species like shearwaters (*Puffinus* spp.) and Northern Fulmars (*Fulmarus glacialus*). The regional importance of the area for seabirds was underscored during the *Exxon Valdez* oil spill, when the highest mortalities of seabirds, particularly murres, occurred in this area (Piatt et al. 1990).

The area also supports ecologically and economically important populations of demersal, pelagic and anadromous fish populations (SAI 1979, Blackburn et al. 1983, Dames and Moore 1983, Rogers 1986, Rogers et al. 1986). Numerically dominant species include pink (*Oncorhynchus gorbuscha*) and sockeye (*O. nerka*) salmon, walleye pollock (*Theragra chalcogramma*), capelin (*Mallotus villosus*), and Pacific sandlance (*Ammodytes hexapterus*). Salmon migrate through the lower Cook Inlet basin in summer en route to the mouths of natal spawning streams along the coast. Forage fishes such as sandlance and capelin occupy suitable coastal and shallow offshore habitats.

METHODS

Surveys were conducted in Kachemak Bay and lower Cook Inlet between 10-15 July, 1992, from the U.S. Fish and Wildlife Service (USFWS) vessel *M/V Tiglax*. The survey started in Kachemak Bay, and was planned to include a series of east-west transects that would provide spatial coverage of up to about 50 km in every direction from the Barren Islands, with more detailed coverage near the islands. Weather, sea conditions and time constraints forced modification of the planned route, but coverage was nonetheless fairly complete (Fig. 2). Transects covered 1225 km of linear distance and sampled an approximately circular area centered on the Barren Islands of about 12,500 km^2. In addition to the east-west tracks, two diagonal transects were run to obtain CTD (Conductivity [salinity], Temperature, Depth) profiles of entrances to lower Cook Inlet (Fig. 2). Observations of bird abundance at the sea surface, fish below the surface (hydroacoustically estimated), and sea surface temperature and salinity were taken on 415 ten-minute transects that were conducted from dawn to dusk on each day. Fig. 2 shows the real-time track of the vessel, and there are no breaks in data on these track-lines.

Seabird surveys were conducted according to protocols developed by the USFWS (Gould et al. 1982, Gould and Forsell 1989). In brief, seabirds were censused in a 300 m-wide strip forward of the ship's center line and over a 10-min time interval (a transect). All swimming birds were tallied by species. Instantaneous counts of flying birds were made 3 times during a 10-min transect, which combined with swimming birds, provided the total numbers of birds per transect with which to calculate densities (birds/km^2). Areas were determined from time travelled and ship speed. Ancillary data on bird behavior, weather, sea conditions, position, etc., were collected on each transect.

Hydroacoustic surveys were conducted simultaneously with 390 bird transects using a BIOSONICS Model 102 Echosounder and a hull-mounted 120 kHz transducer located 4 m below the sea surface. Transmit power was set at 217 dB, gain at -125.4 dB, bandwidth at 5 kHz, trigger interval at 0.5 s, and pulse width at 0.5 ms for all surveys. Fish and plankton echosignals were integrated in real time over 1 min time intervals (10 per transect) and over 5, 10, 25, or 50 m depth strata using a BIOSONICS Model 121 Digital Echo Integrator with 20 LogR amplification. Signals were integrated over each time/depth block and later converted to biomass densities (g/m^3) using estimated target strengths and equipment calibration constants. In the absence of sampling, I assumed a target strength of -64 dB/g, which was calculated from regression equations for fish with closed swimbladders (Foote 1987, Piatt et al. 1991). The contribution of zooplankton to echosignals was assumed to be neglible. The accuracy of calculated biomass is therefore approximate, but estimates serve as precise relative measures of fish biomass.

On all transects, sea surface (3 m) temperatures (SST) and salinities (SSS) were monitored using a continuously recording thermosalinograph (Tsurumi Seiki Model 305861, Yokogawa Hokushin Electric Co. Ltd., Yokohama, Japan). On CTD transect lines (Fig. 2), water column profiles were obtained using a Seacat 19-03 Conductivity - Temperature - Depth recorder (Sea-Bird Electronics Inc., Bellevue WA).

The distribution and abundance of zooplankton were determined from 14 plankton tows at 7 stations (Fig. 2). Replicate vertical tows were made with a 1-m, 505 micron mesh plankton ring net. Most tows were made from 100 m depth. Zooplankton were identified to the lowest taxon possible in the laboratory. Biomass was determined from numbers using conversion factors for each species (Lubny-Gerzik 1953).

Analyses and mapping of seabird distribution, and sea surface temperature and salinity were accomplished with CAMRIS (Computer Aided Mapping and Resource Inventory System; Copyright 1987, 1988 by R. Glenn Ford, Ecological Consulting Inc.). For calculations of seabird population abundance in the study area, all transect data were binned into 70 contiguous 10 min latitude-longitude blocks and total populations were extrapolated using the average density ($\pm$ s.d.) from all blocks containing data within the survey area (ca. 12,500 km^2). A measure of error ($\pm$ %) around the population estimate was calculated as $\pm$ 2 s.e., which closely approximates the 95% confidence limits when n>30 (Sokal and Rohlf 1981). These confidence limits may be biased because sampling was not random, bird abundance on consecutive transects may be autocorrelated, and transects may not be of the appropriate measurement scale (Sokal and Rohlf 1981, Schneider 1990b, Piatt and Ford 1993). In effect, however, all 70 blocks were sampled and weighted equally in calculating confidence limits, and 10-min blocks likely encompass the scale of most seabird foraging aggregations in Alaska (Hunt and Schneider 1987). Assuming no bias, the confidence limits are conservative because of the reduction in sample size from 415 to 70 measurement blocks. For mapping, transects were first grouped and averaged over 5 min latitude-longitude blocks (Piatt and Ford 1993). Density polygons were generated from blocked data, and missing blocks were filled using algorithms that extrapolate from densities of adjacent blocks.

RESULTS

Oceanography

Conductivity-temperature-depth (CTD) profiles of the water column in lower Cook Inlet showed that only waters in Kachemak Bay were strongly stratified, with a strong thermocline at about 10 m depth (Fig. 3). Lower Cook Inlet waters from Shuyak Island and Cape Douglas to the Kenai

Peninsula were well-mixed, with little gradient in temperature or salinity from the surface to deeper layers (Figs. 3 and 4). Pycnocline gradients were weak throughout the area, and the difference in density from bottom to surface waters seldom exceeded 0.5-1.5 kg/m^3 (Fig. 4). Although weak, stratification was persistent along the Kenai Peninsula owing to fresh water input (Burbank 1977), and lowest sea-surface salinities were observed (Fig. 5) in a broad band nearshore (<20-30 km). Surface salinities were also low on the west side of Cook Inlet owing to fresh water output from upper Cook Inlet (Fig. 1, Burbank 1977). Higher-salinity oceanic water remained on the south side of the Barren Islands and was diluted upon passage through Stevenson Entrance (Figs. 2 and 5).

As currents squeezed water through Stevenson and Kennedy entrances (Fig. 1), upwelling occurred in front of the Barren Islands (Shuyak Is. CTD line, Fig. 4), and along the escarpment at the mouth of Cook Inlet (Cape Douglas CTD line, Fig. 4). Sea surface temperatures (not illustrated) also reflect these upwelling processes. Surface temperatures were 1-2° C cooler around and north of the Barren Islands (8-9.5° C) and all along the 130 m shelf (9-10° C) that connects the Kenai Peninsula with Shuyak Island, compared to surface temperatures in the Gulf of Alaska (10-11.5° C) or Kachemak Bay (11.5-15° C). High salinity water in central lower Cook Inlet (Fig. 5) resulted from the upward transport and thorough mixing (Kachemak Bay CTD line, Fig. 4) of upwelled waters onto the escarpment (Burbank 1977, Muench et al. 1978).

Zooplankton and Fish

Zooplankton biomass was dominated by calanoid copepods. Out of 43 taxa identified, 18 were copepods and *Pseudocalanus minutus* and *P. newmani* were most common (Fig. 6). Zooplankton densities were highest at two stations (Fig. 2): Barren Islands East and Kenai Peninsula West. Analysis of variance (ANOVA) revealed no significant variation (F=1.03, $df_{7,13}$, NS) in total zooplankton biomass across the entrance to Cook Inlet (three locations: northeast, central, or southwest), between areas of low ($\leq$31.4 ppt) or high (>31.4 ppt) sea surface salinity, or between replicate tows (n=2) at each station. Of 16 major taxa examined individually with ANOVA, only five varied significantly with location or salinity. For example, *Acartia longiremis* was common (0.4-1.4 mg/m^3) at all stations, but generally more abundant (F=8.33, $df_{7,13}$, $p<0.05$) in the southwestern portion of lower Cook Inlet (including Shuyak Island). Similarly, *Centropages* spp. (F=5.72, $df_{7,13}$, $p<0.05$), *Cladocera* spp. (F=23.3, $df_{7,13}$, $p<0.001$), Euphausiid furcilia (F=4.68, $df_{7,13}$, $p<0.05$), and Appendicularia (F=32.5, $df_{7,13}$, $p<0.001$) were all more abundant at southwestern stations and in higher salinity water. In contrast, the abundance of many common taxa including *Calanus marshallae* (0.1-4.8 mg/m^3), *Eucalanus bungii* (0.1-3.4 mg/m^3), *Metridia pacifica* (0.04-0.56 mg/m^3), *Pseudocalanus minutus* (3-73 mg/m^3), decapods, and pteropods did not vary significantly among locations or water types. Amphipods, predominantly *Parathemisto pacifica*, were common (0.3-1.1 mg/m^3) at all stations.

I examined the distribution of fish biomass only in the upper 100 m of the water column because fish at greater depths are beyond the normal foraging range of diving seabirds (usually 10-60 m, see Piatt and Nettleship 1984, Burger 1990). The highest average densities (2-8 g/m^3) of fish biomass in the upper 100 m of the water column were observed within 15-20 km of the Kenai Peninsula and near the northwest corner of Shuyak Island (Fig. 7). Moderate densities (0.5-2 g/m^3) were found in waters north of the Barren Islands, whereas the lowest densities (0.0-0.5 g/m^3) were observed in oceanic waters to the south. These densities are averaged over large areas and depths. Maximum densities in sampled cells (n=3855) ranged up to 100's g/m^3 (Table 1). Only 6.1% of the total biomass (200 mt/km^2) was found in the upper (5-15 m) water column (Table 1), and most of this biomass was located immediately north of the Barren Islands and along the Kenai Peninsula. About 30% of total biomass was located at intermediate depths (15-50 m) where maximum cell biomass densities ranged from 120-650 g/m^3 (Table 1). Most of this biomass was distributed close to the Kenai Peninsula and Shuyak Island (Fig. 7). Most biomass (64%) was located at depths of 50-100 m and found on the Kenai Peninsula shelf, in deep oceanic waters east of Shuyak Island, or along the edge of the Cook Inlet escarpment.

Overall fish biomass in the 5-100 m stratum was not significantly correlated with sea surface salinity (Spearman r_s=0.05, NS, n=388) but biomass was higher in waters with surface salinities less than 31.4 ppt (Wilcoxon rank sum test, z= -1.96, $p<0.05$, low salinity n=155, high salinity n=235). Fish biomass at 5-100 m was not significantly correlated with sea surface temperature (r_s=-0.02, NS, n=379) or bottom depth (r_s=-0.02, NS, n=383). Fish biomass in the upper water column (5-30 m) was higher in low-salinity waters (r_s=-0.12, $p<0.05$, n=388). Biomass in the uppermost stratum (5-10 m) was negatively correlated with sea surface temperature (r_s=-0.13, $p<0.01$), but deeper strata (10-15, 15-20, 20-30 m) were positively correlated (r_s=0.08-0.13, $p<0.05$) with temperature. Overall, these results indicate a weak tendency for fish biomass in near-surface strata to be concentrated in warm, low-salinity coastal and shelf waters in lower Cook Inlet.

Seabirds

About 87,000 seabirds were censused on transects, and an estimated 2.2 million seabirds foraged within the area (ca. 12,500 km^2) surveyed in lower Cook Inlet during July (Table 2). Shearwaters, mostly (99.9%) Short-tailed Shearwaters *Puffinus tenuirostris*, comprised the majority (66%) of birds observed. Other abundant species included Fork-tailed Storm-petrel (7.3%), phalaropes (6.6%; 99% of which were Red-necked Phalaropes *P. lobatus*), Northern Fulmar (5.6%), Tufted Puffin (5.5%), murres (3.6%; 99% of which were Common Murres *U. aalge*), Black-legged

Kittiwake (2.0%), and murrelets (1.6%; about equal numbers of Marbled and Ancient murrelets). The remaining 2.3% of birds were comprised of 18 other uncommon species including loons, cormorants, scoters, jaegers, gulls, terns, guillemots, auklets, and puffins.

Species were grouped according to the type of habitat in which they generally prefer to forage (Table 2). Species that normally forage on fish in coastal (C) and coastal/shelf (C/S) habitats (e.g., murres, *Brachyramphus* murrelets and kittiwakes), were most abundant (Fig. 8) in relatively shallow waters (Table 3) along the Kenai Peninsula and around the Barren and Shuyak islands. Because of the high abundance of murres and their preference for shelf habitat, the pattern of distribution of C/S species (Fig. 8) is largely a reflection of murre distribution. In contrast to strictly coastal species, shelf species were i) not correlated with sea surface salinities, ii) negatively correlated with sea surface temperatures, and, iii) positively correlated with fish biomass (Table 3). Shelf species were not segregated among low- ($\leq$31.4 ppt) or high-salinity (>31.4 ppt) water masses (Wilcoxon rank sum test, z= -0.88, NS, low salinity n=177, high salinity n=235). Species that were distributed widely on the shelf, and coastally, included gulls, kittiwakes, and Horned Puffins. The distribution of Marbled Murrelets (*B. marmoratus*, Fig. 9) is typical of C/S species with an affinity (Table 3) for warm, low-salinity coastal waters (e.g., Pigeon Guillemot, Kittlitz's Murrelet *B. brevirostris*, Rhinoceros Auklet). In contrast to shelf species, coastal species showed a marked preference for low-salinity ($\leq$ 31.4 ppt) waters (Wilcoxon z=5.19, p<0.0001, low salinity n=177, high salinity n=235).

Oceanic or shelf-edge (O/E) species that feed at or near the surface on small nektonic prey (e.g., storm-petrels, phalaropes, fulmars) were correlated (Table 3) with deep, higher-salinity waters south and southwest of the Barren Islands (Fig. 10). These taxa were concentrated along deep canyon slopes and near the Barren and Shuyak islands, and showed strong segregation into high-salinity (>31.4 ppt) waters (Wilcoxon z=-9.19, p<0.0001, low salinity n=177, high-salinity n=235). The pattern of distribution of Fork-tailed Storm-petrels (Fig. 11) exemplifies the distribution of O/E species (Fig. 5). Phalaropes were almost as abundant as storm-petrels, but were concentrated more along visible convergence slicks near Shuyak Island, and over deep waters west of the Barren Islands (reflected in Fig. 10). Large, persistent convergence slicks are common in lower Cook Inlet (Burbank 1977, Muench et al. 1978). Fulmars were most abundant immediately south of the Barren Islands, and along the 130 m contour lines east and west of the Barrens.

Species with mixed diets (e.g., shearwaters, Tufted Puffins) that may forage in either oceanic or shelf (O/S) environments were aggregated around the Barren and Shuyak Islands (Fig. 12). In contrast to O/E species, mixed O/S species were correlated with shallow water, cool surface temperatures and high fish biomass (Table 3), which may indicate a preference for productive upwelling areas near islands. Overall, mixed O/S species were segregated into oceanic (>31.4 ppt) waters (Wilcoxon z=-4.90, p<0.0001, low salinity n=177, high salinity n=235). Figure 12 reflects largely the distribution of shearwaters, which were super-abundant. Tufted Puffins comprised 88%

of non-shearwater species in the O/S group, and were highly concentrated around the Barren Islands (Fig. 13), as were Parakeet Auklets. Ancient Murrelets were widely distributed over the deep canyon west of the Barren Islands, near Shuyak Island, and to a lesser degree along the Kenai Peninsula.

In general, C/S, O/E, and O/S species were highly segregated (Figs. 8,10,12), even in relatively small geographic areas where all groups were very concentrated (e.g., Shuyak Island). In terms of biomass density, O/S species were dominant (70.4 kg/km^2), largely because of the super-abundance of shearwaters (64.4 kg/km^2). Excluding shearwaters, the area supported moderate densities (6.0 kg/km^2) of other O/S species. Although O/E species were much more numerous than C/S species, they are also typically much smaller in size, so that C/S species (12.8 kg/km^2) ocurred in much higher biomass densities than O/E species (6.5 kg/km^2).

DISCUSSION

All of our oceanographic observations were consistent with previous, more detailed studies of lower Cook Inlet (Burbank 1977, Muench et al. 1978, SAI 1979, Reed and Schumacher 1986). Surface-salinities and vertical densities were similar to those found in previous studies, but surface-temperatures were somewhat higher (by 1-2° C). Strong tidal flow in and out of the Cook Inlet estuary, and upwelling around Barren and Shuyak islands, along the Kenai Peninsula, and along the escarpment at the entrance to Cook Inlet, all serve to vertically mix waters in lower Cook Inlet. Weak stratification occurs along the Kenai Peninsula owing to freshwater runoff, and the Alaska Coastal Current is distinguished by its low surface-salinities. South-flowing waters near the Alaska Peninsula are also weakly stratified owing to freshwater output in upper Cook Inlet. Because of all these processes, a well-defined dome of higher-density water can be found in the middle of lower Cook Inlet in July (see Fig. 2 in SAI 1979) supporting a counterclockwise baroclinic current. The current is also steered in this direction by bathymetric features (see Fig. 1).

Both horizontal and vertical property gradients are rather weak in lower Cook Inlet. Outside of Kachemak Bay, which is protected from strong mixing forces, vertical density differences from the surface to 50 m barely exceed 0.5 sigma-t (kg/m^3) except near the coasts. Beyond about 5-10 km of the Kenai Peninsula, surface salinities range over only 0.8 ppt (31.2-32.0 ppt), with a weak front occurring at about the 31.5 ppt isohaline that more or less divides waters north and south of the Barren Islands into coastal and oceanic habitats, respectively (Fig. 5). Because of topographic control of the current regime, these water masses are also loosely defined by the bathymetry, especially west and southeast of the Barren Islands.

The distribution and abundance of zooplankton in lower Cook Inlet was similar to that observed in other areas of the Gulf of Alaska (Cooney 1986). Copepods dominated zooplankton biomass in lower Cook Inlet, and species which are typically associated with oceanic (*Eucalanus* *bungii, Metridia pacifica*), shelf (*Calanus marshallae*), and coastal (*Acartia longiremis*) environments were found at all stations sampled in lower Cook Inlet. For these and other taxa, there was little significant variation in abundance across habitats in lower Cook Inlet. Similarly, Cooney (1986) observed that the composition of zooplankton communities in the Gulf of Alaska display a homogeneity of species across oceanic, shelf, coastal, and inside waters. This reflects "both the influence of the open ocean on the shallower, protected environments and the highly advective nature of the overall system" (Cooney 1986).

Hydroacoustically-determined fish biomass in shallow (<50 m) strata tended to be concentrated in warm, low-salinity coastal and shelf waters in lower Cook Inlet. Highest concentrations were observed on the shelf near the Kenai Peninsula and Shuyak Island. In the absence of sampling, I can only speculate that many of the large fish observed on echosounder traces were salmon (*Onchorhynchus* spp.), particularly pink and sockeye salmon, which are abundant in lower Cook Inlet in July (SAI 1979, Rogers 1986, Rogers et al. 1986). During the course of surveys, we frequently saw salmon leaping from the water, particularly near the Barren Islands and Kenai Peninsula. Other large fish could have been adult walleye pollock.

Dense concentrations of small, pelagic fishes were frequently observed on echosounder traces obtained in shelf (<100 m) waters, and these probably consisted mostly of forage fish such as sandlance (*Ammodytes hexapterus*), capelin (*Mallotus villosus*), or juvenile walleye pollock (*Theragra chalcogramma*; SAI 1979, Blackburn et al. 1983, Dames and Moore 1983), all of which are important prey for piscivorous seabirds such as murres, kittiwakes, and murrelets (Sanger 1986, Piatt et al. 1991, Springer 1991, Piatt unpubl. data). Because the hydroacoustic signals from all fish were integrated, it is impossible to distinguish between forage fish and larger species. This probably accounts for the relatively low correlations in spatial distribution of seabirds and fish biomass (Table 3). In any case it is clear that, in contrast to zooplankton, fish biomass was not randomly distributed in lower Cook Inlet. Rather, fish were concentrated on shelves (<100 m) and in Alaska Coastal Current waters.

Despite extensive vertical mixing of waters in lower Cook Inlet, weak property gradients across the entrance, and lack of segregation of zooplankton communities, there was marked segregation of seabird assemblages in lower Cook Inlet. Species (e.g., murres, murrelets, gulls) that feed largely on fish in coastal and shelf habitats (Schneider et al. 1986, 1987; Springer et al. 1984, Piatt et al. 1991, Piatt and Ford 1993) were most abundant (50-300 birds/km^2) northeast of the Barrens and in warm, low-salinity coastal waters of the Kenai Peninsula and Shuyak Island. Nekton-feeding species (e.g., fulmars, storm-petrels, phalaropes) that typically forage in oceanic and shelf-edge habitats (Gould et al. 1982, Schneider et al. 1986, 1987; Piatt et al. 1991) were most numerous (100-540 birds/km^2) in higher-salinity oceanic water located south of the Barrens. Species (e.g., shearwaters, Tufted Puffins) with mixed plankton and fish diets, and which may forage in both oceanic and shelf environments (Gould et al. 1982, Piatt et al. 1991), were concentrated (500-2500 birds/km^2) near the Barren and Shuyak islands in cool upwelled waters.

Evidence to date suggests that seabirds largely ignore weakly defined gradients (Elphick and Hunt 1993). Studies in the Bering and Chukchi seas have shown that marked segregation of seabirds occurs between well-defined water masses separated by strong fronts, and often containing distinct zooplankton and fish communities. For example, vertical differences in density from bottom to surface layers regularly exceed 2-4 kg/m^3 in statified Alaska Coastal and Bering Shelf waters of <50 m depth, which may be adjacent to mixed Anadyr Current waters with little or no vertical density gradient (Haney 1991, Piatt et al. 1992). Horizontal changes in salinity across these three water masses in the Bering Strait (ca. 80 km) may exceed 3-6 ppt, with strong gradients at fronts only a few kilometers in width (Coachman et al. 1975, Piatt et al. 1992). Correspondingly, zooplankton (Springer et al. 1989) and planktivorous auklets (Piatt et al. 1992, Schauer 1992) are well-segregated among water masses in Bering Strait, and can be strongly associated with zooplankton concentrations in stratified water. Similarly, zooplankton and seabird communities in the southeastern Bering Sea are segregated by relatively strong fronts between the inner, middle, and outer domains of the Bering Shelf (Schneider 1982, Cooney and Coyle 1982, Kinder et al. 1983, Schneider et al. 1987).

Although weak, vertical and horizontal property gradients in lower Cook Inlet were apparently still of sufficient magnitude to demarcate marine habitats for fish and seabirds. However, the abundance of seabirds was often as well correlated with bottom depth as with sea-surface salinity or temperature. This is probably due in part to the topologically-controlled flow of currents in lower Cook Inlet, but may also relate to benthic substrate and corresponding habitat for fish (e.g., sandlance). Prey distribution often explains more variance in seabird distribution than oceanographic features such as fronts or vertical stratification (Schneider 1990a) and vice-versa (Hunt and Harrison 1990). As fronts, vertical stratification, currents, prey aggregations, and bottom topography are all inter-related, it is not surprising that any one feature cannot explain more than a small part of the overall variation in distribution of species or species assemblages. Furthermore, the importance of any one factor probably varies among species.

For example, Fork-tailed Storm-petrels were strongly associated with high-salinity oceanic water (Fig. 5 and 11), as were most of the plankton-feeding oceanic/shelf-edge assemblage (Table 3), despite the fact that appropriate zooplankton prey (principally copepods and amphipods, Boersma et al. 1980, Vermeer and Devito 1988) were distributed widely in all waters. In contrast, the distribution of shelf species was independent of salinity, but signifcantly correlated with bottom depth and fish biomass. Shearwaters, a mixed oceanic/shelf species, were most strongly associated with cool, upwelled waters.

Owing to the complex oceanography of the area, three different seabird assemblages are found in close proximity to each other in lower Cook Inlet and this results in both high diversity and abundance of seabirds in a relatively small area (see also Gould et al. 1982). An estimated 2 million seabirds foraged within 50 km of the Barren Islands in July, and these waters supported an average seabird biomass of 89.8 kg/km^2. Transient (non-breeding) shearwaters (64.4 kg/km^2) comprised most of this standing biomass, but coastal/shelf species (12.8 kg/km^2) and oceanic species (6.5 kg/km^2) contribute to make lower Cook Inlet one of the most productive areas for seabirds in Alaska (compare with 17.1 kg/km^2 in Bering Strait, or 36.1 kg/km^2 on the outer shelf of the southeast Bering Sea). Seabird densities were highest in the vicinity of the Barren and Shuyak islands and their associated shelf environments-- revealing the importance of islands in creating productive local foraging habitat for seabirds (see also Kinder et al. 1983, and Piatt et al. 1992)

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Table 1. Estimated fish biomass in different depth strata as determined from hydroacoustic surveys. (Estimates of biomass accurate on a relative scale only, see Methods).

Depth stratum (m)	n*	Biomass density (g/m^3)			Total biomass	
		mean	+ s.d.	maximum	mt/km^2	% total
5-10	3855	1.46	+ 5.14	164.5	7.30	3.7
10-15	3855	0.95	+ 2.76	77.3	4.75	2.4
15-20	3855	1.17	+ 8.14	448.7	5.85	2.9
20-30	3839	1.48	+ 6.84	239.3	14.7	7.4
30-40	3745	1.93	+11.5	648.2	18.7	9.4
40-50	3635	2.11	+ 6.02	122.2	19.9	9.9
50-75	3500	2.19	+ 6.67	127.1	49.7	24.8
75-100	3012	4.05	+35.8	1670.0	79.1	39.5

* n = number of (1-min)*(depth stratum) cells sampled by the echointegrator. One minute of survey corresponds to about 300 m of distance traveled by the vessel.

Table 2. Species composition, number observed, mean density, and estimated population abundance of seabirds observed on 415 transects in lower Cook Inlet, July, 1992. Densities and population estimates were calculated after data were grouped into 70 10-min latitude-longitude blocks (see Methods).

Habitat type*	Species	Scientific name	No. observed	Density: no./km² ±s.d.	Density: kg/km²	Population estimate (no. ± %)
	All species total		86,969	174.20 ±356.00	89.80	2,169,000 ±49
O/E	Northern Fulmar	(*Fulmarus glacialis*)	4,880	7.05 ± 13.40	4.37	87,970 ±45
O/S	All Shearwaters	(*Puffinus* spp.)	57,808	105.50 ±337.70	64.40	1,313,000 ±77
O/E	Fork-tailed Storm-petrel	(*Oceanodroma furcata*)	6,319	22.05 ± 42.29	1.46	276,500 ±46
C/S	All Cormorants	(*Phalacrocorax* spp.)	43	0.05 ± 0.20	0.09	620 ±96
O/E	All Phalaropes	(*Phalaropus* spp.)	5,775	12.50 ± 44.13	0.69	155,900 ±84
C/S	Glaucous-winged Gull	(*Larus glaucescens*)	480	0.92 ± 1.82	1.01	11,460 ±47
C/S	Black-legged Kittiwake	(*Rissa tridactyla*)	1,752	4.61 ± 12.11	1.94	57,130 ±63
C/S	All Murres	(*Uria* spp.)	3,135	8.41 ± 14.43	8.24	103,900 ±41
C	Pigeon Guillemot	(*Cepphus columba*)	50	0.22 ± 1.10	0.12	2,720 ±119
C	*Brachyramphus* murrelets	(*Brachyramphus* spp.)	423	1.49 ± 2.60	0.35	18,430 ±42
O/S	Ancient Murrelet	(*Synthliboramphus antiquus*)	478	1.18 ± 1.94	0.38	14,730 ±20
O/S	Parakeet Auklet	(*Cyclorrhynchus psittacula*)	169	0.23 ± 0.70	0.07	2,890 ±73
C	Rhinoceros Auklet	(*Cerorhinca monocerata*)	69	0.28 ± 1.62	0.18	3,410 ±138
O/S	Tufted Puffin	(*Fratercula cirrhata*)	4,823	6.97 ± 13.57	5.58	86,780 ±47
C/S	Horned Puffin	(*Fratercula corniculata*)	107	0.42 ± 0.78	0.21	5,170 ±44
C/S	Other species total		658	2.23 ± 4.13	0.67	27,480 ±44

* Type of foraging habitat typically used: O/E- oceanic and shelf-edge, C- coastal, C/S- coastal and shelf, O/S- mixed habitat, including oceanic, shelf-edge, and shelf.

Table 3. Spearman rank correlation between seabirds in different assemblages and sea surface salinity, sea surface temperature, bottom depth, and fish biomass density (at 5-100 m) in lower Cook Inlet.

Parameter	n	Oceanic		Mixed (O/S)		Shelf		Coastal	
		r	p<	r	p<	r	p<	r	p<
Salinity	409	0.50	0.0001	0.28	0.0001	0.06	NS	-0.28	0.0001
Temperature	396	0.05	NS	-0.34	0.0001	-0.22	0.0001	0.13	0.01
Depth	412	0.36	0.0001	-0.10	0.001	-0.36	0.0001	-0.26	0.0001
Fish density	390	-0.01	NS	0.19	0.0001	0.16	0.001	-0.03	NS

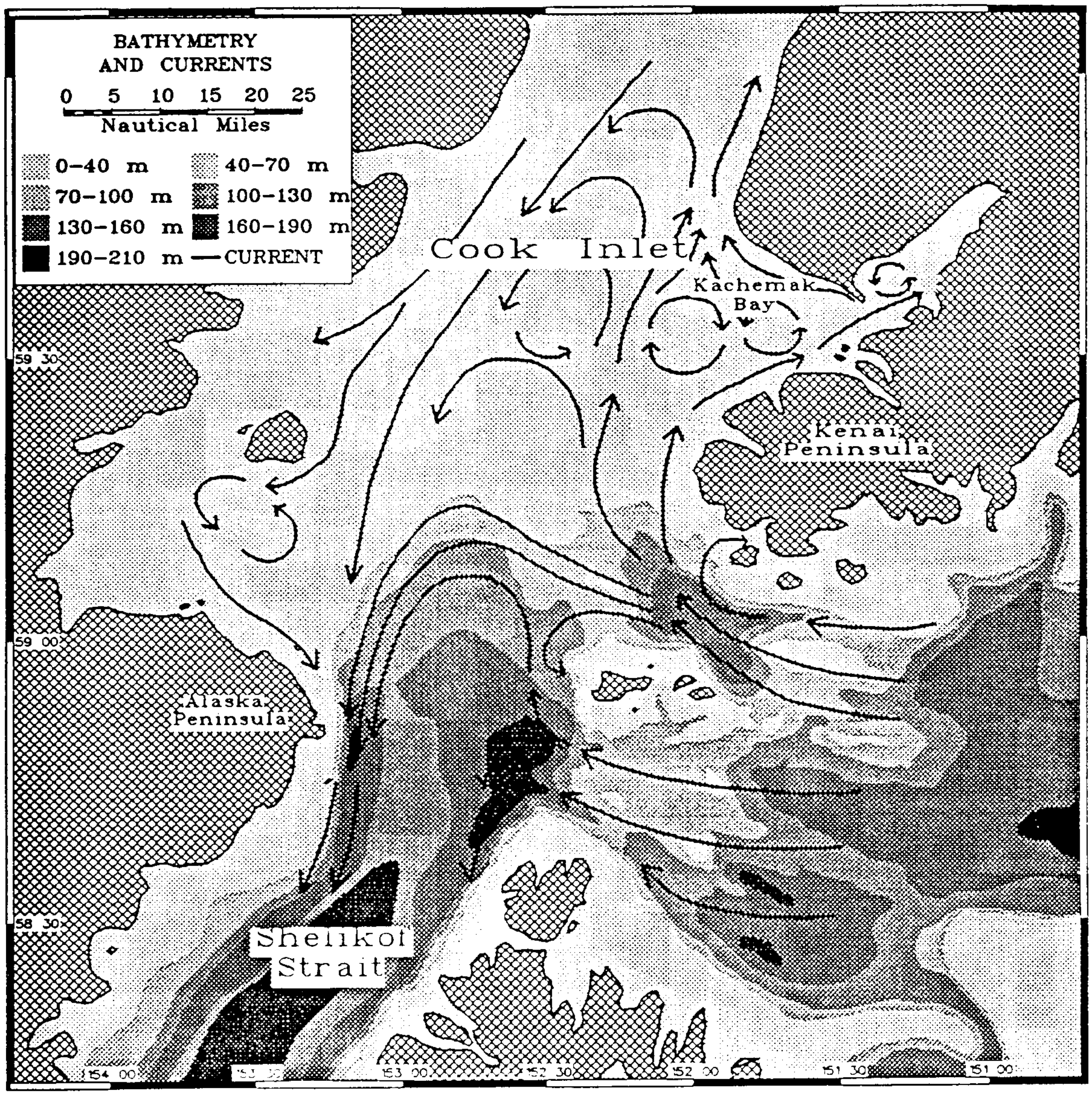


Fig. 1. Bathymetry and currents in lower Cook Inlet (currents after Burbank 1977, Muench et al. 1978).

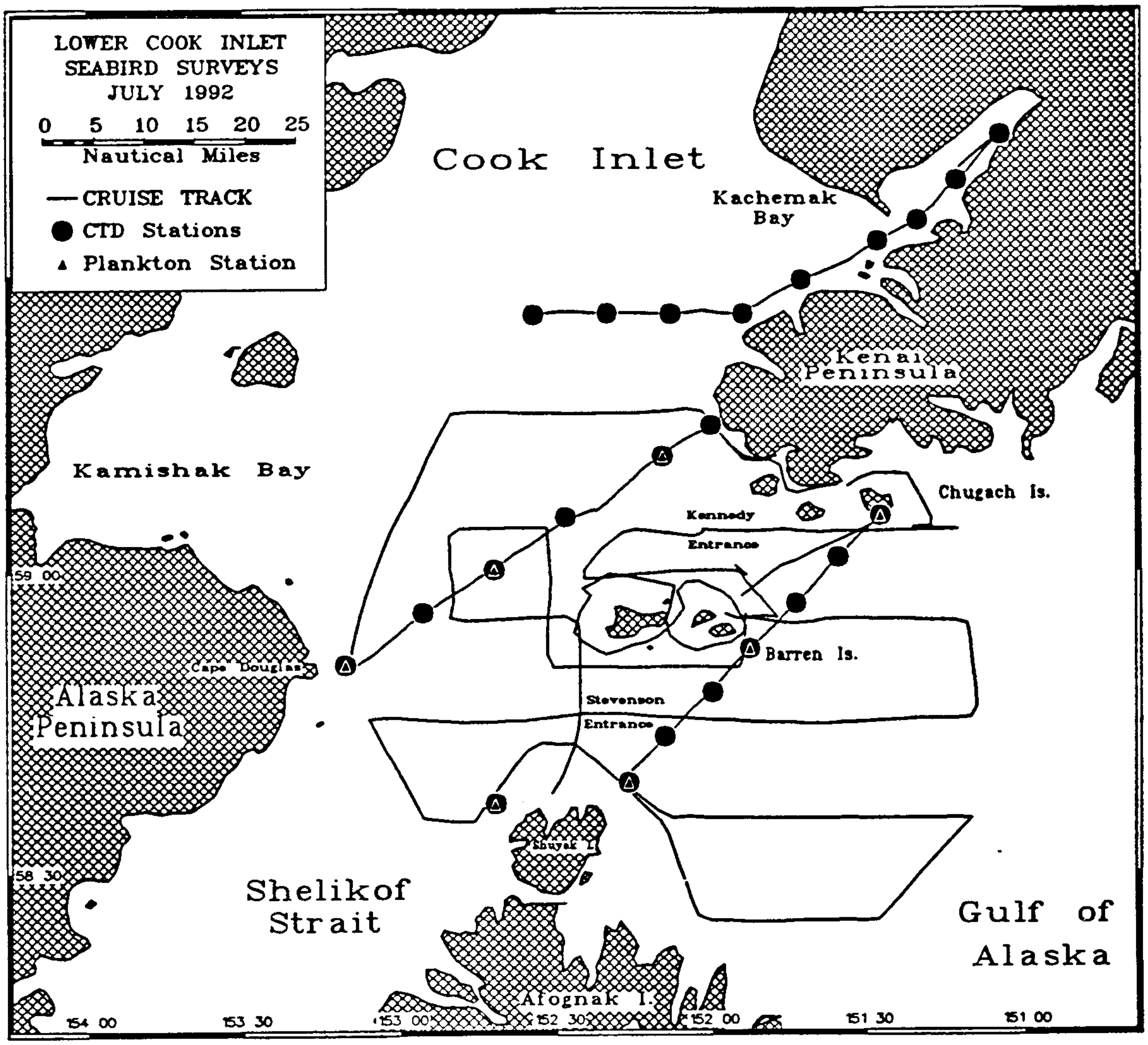


Fig. 2. Cruise track, sampling stations, and place names in lower Cook Inlet. Note that only cruise track lines on which data were collected are illustrated, and position of the lines are exactly as indicated by satellite navigation equipment (± 200 m).

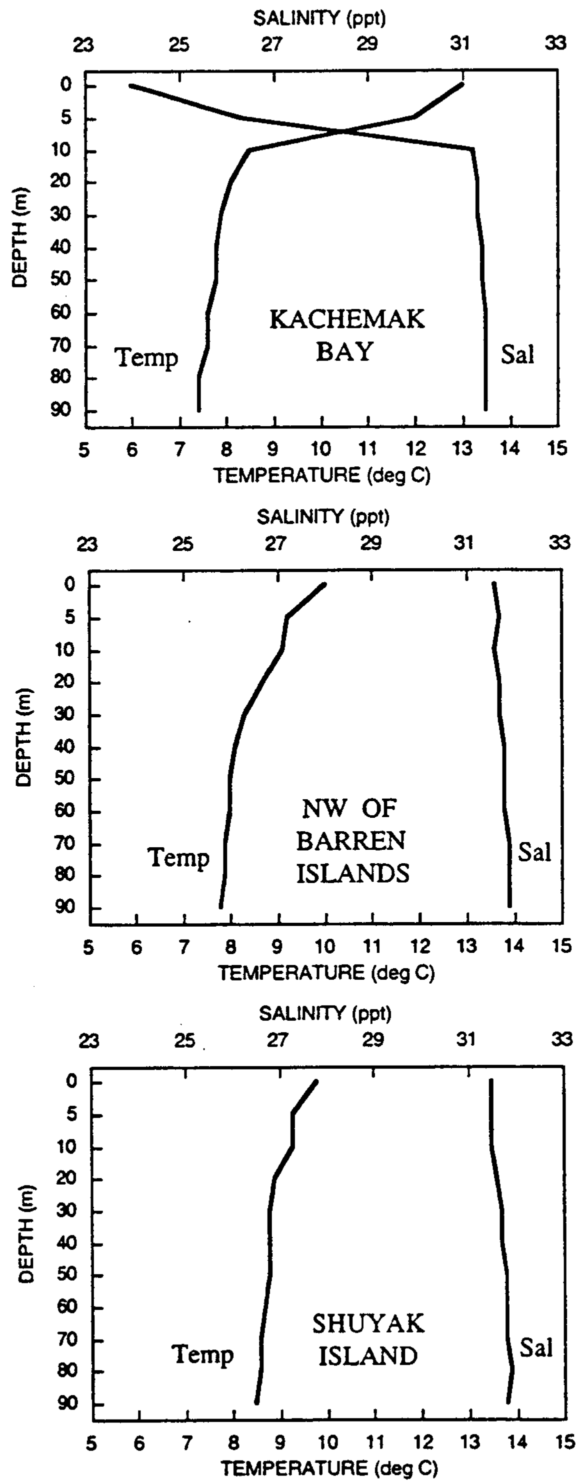


Fig. 3. Temperature and salinity profiles obtained from CTD casts at three stations in lower Cook Inlet (see Fig. 2).

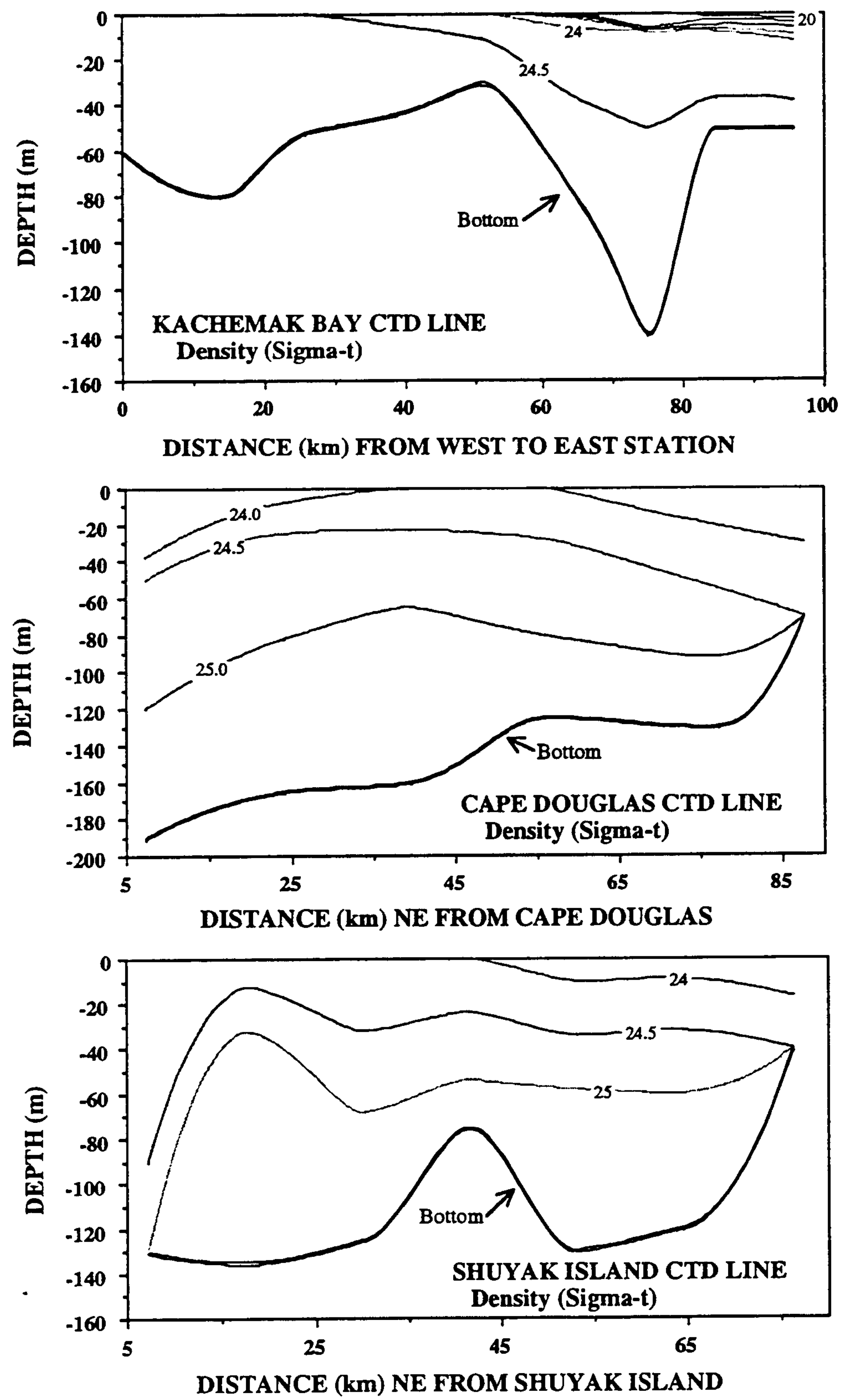


Fig. 4. Density (sigma-t, kg/m^3) profiles of the water column on three CTD lines crossing lower Cook Inlet (see Fig. 2).

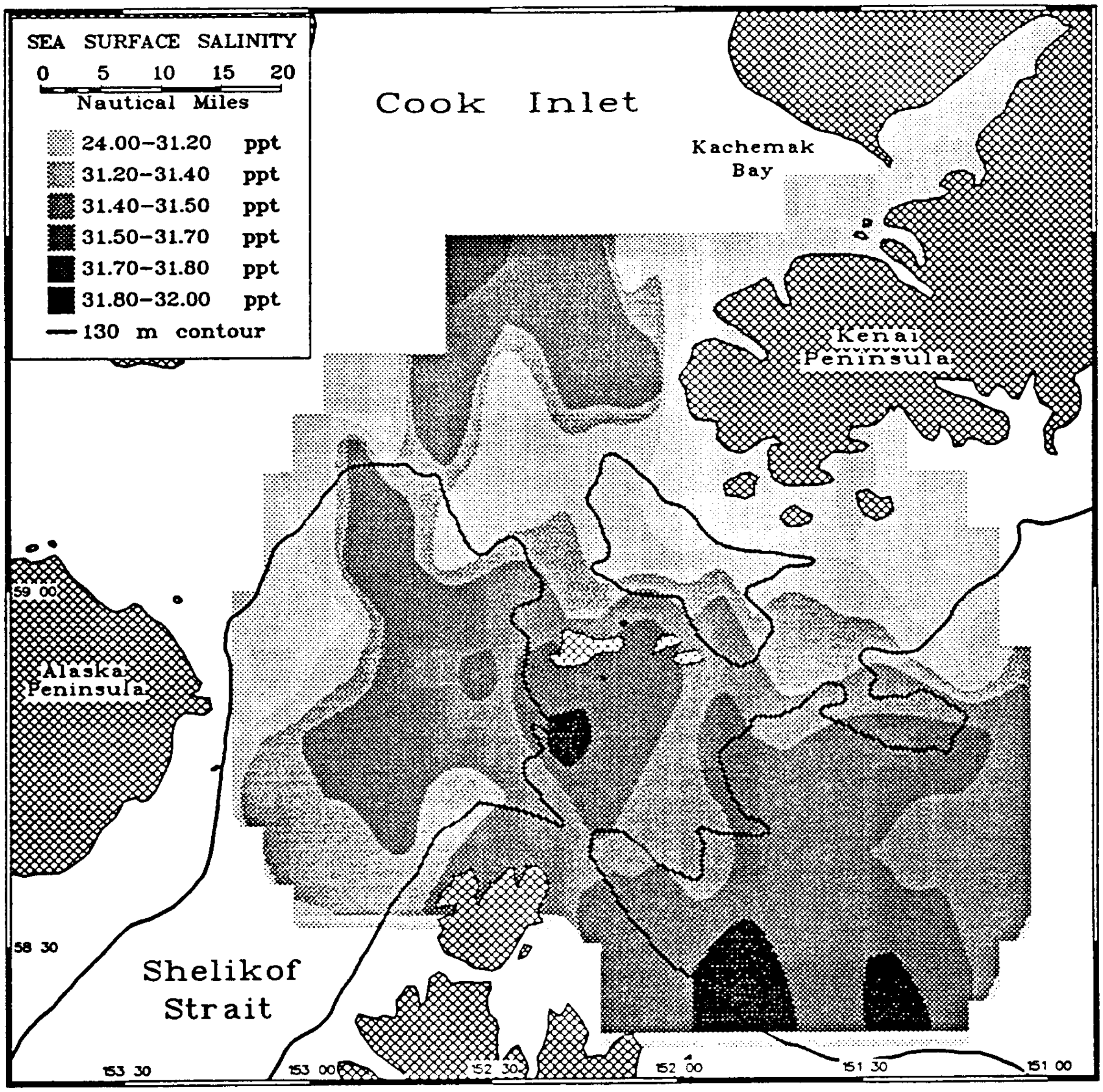


Fig. 5. Sea-surface salinity pattern in lower Cook Inlet, July, 1992. (See Methods for details of mapping).

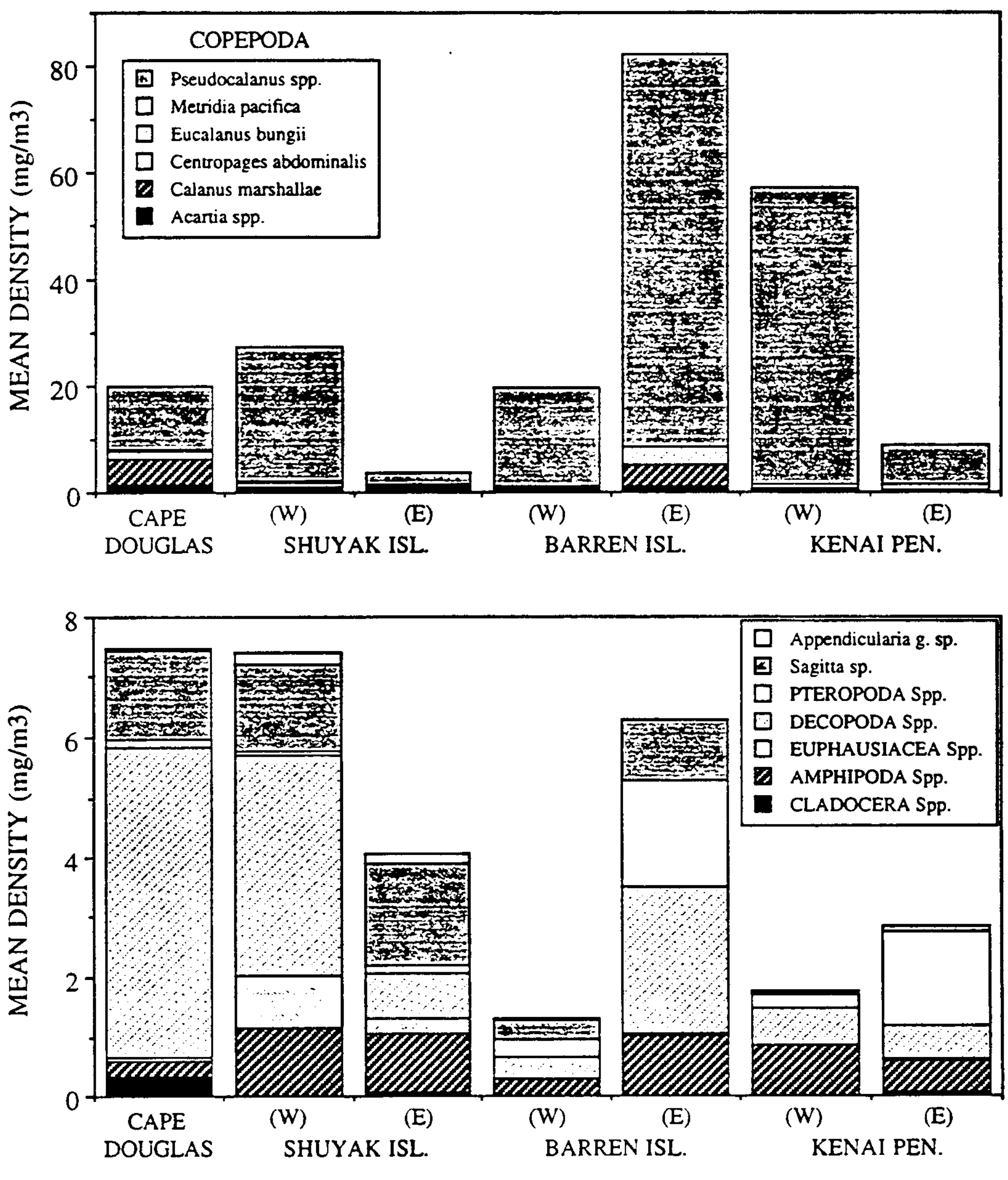


Fig. 6. Zooplankton biomass densities and species composition on tows conducted in lower Cook Inlet, July, 1992 (see Fig. 2). Only most abundant taxa are illustrated: Copepods (upper panel) and other major taxa (lower panel).

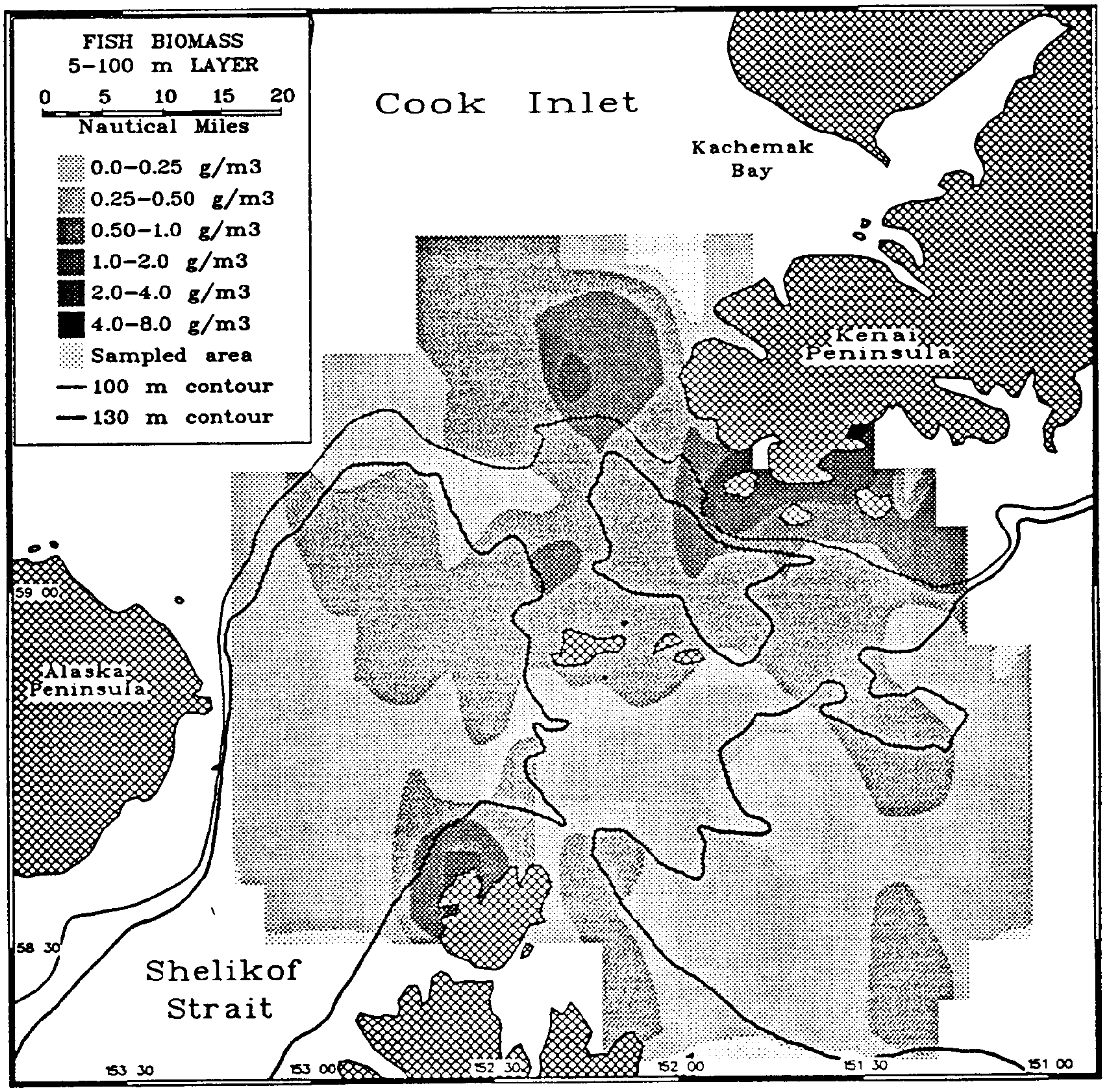


Fig. 7. Distribution of hydroacoustically determined fish biomass (integrated over 5-100 m) in lower Cook Inlet, July, 1992. (See Methods for assumptions and methods of calculating biomass).

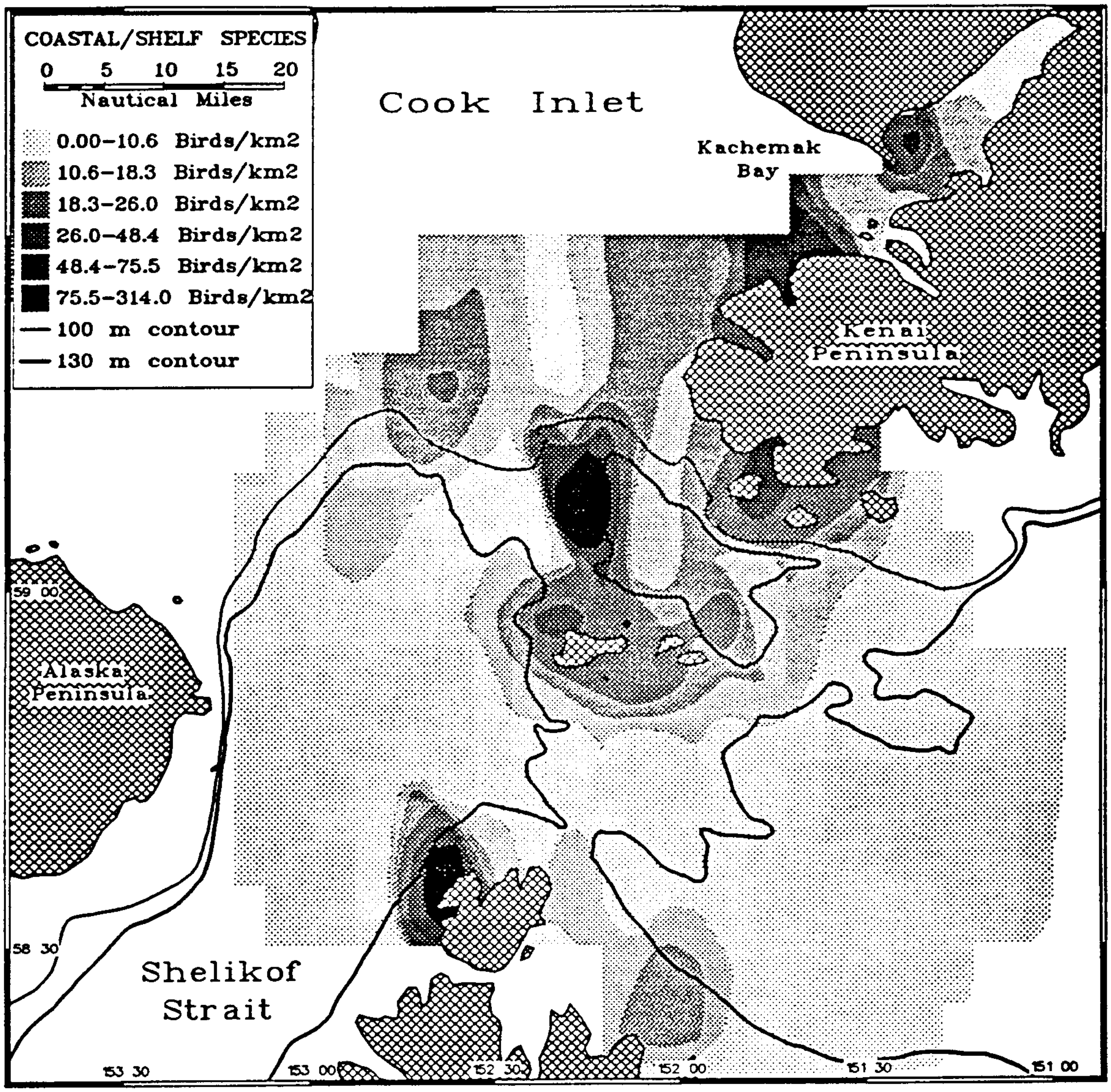


Fig. 8. Distribution and abundance of coastal (C) and coastal/shelf (C/S) seabird species in lower Cook Inlet, July, 1992. See Table 2 for species composition of the C/S assemblage. Note this map largely reflects the distribution of murres (see Discussion).

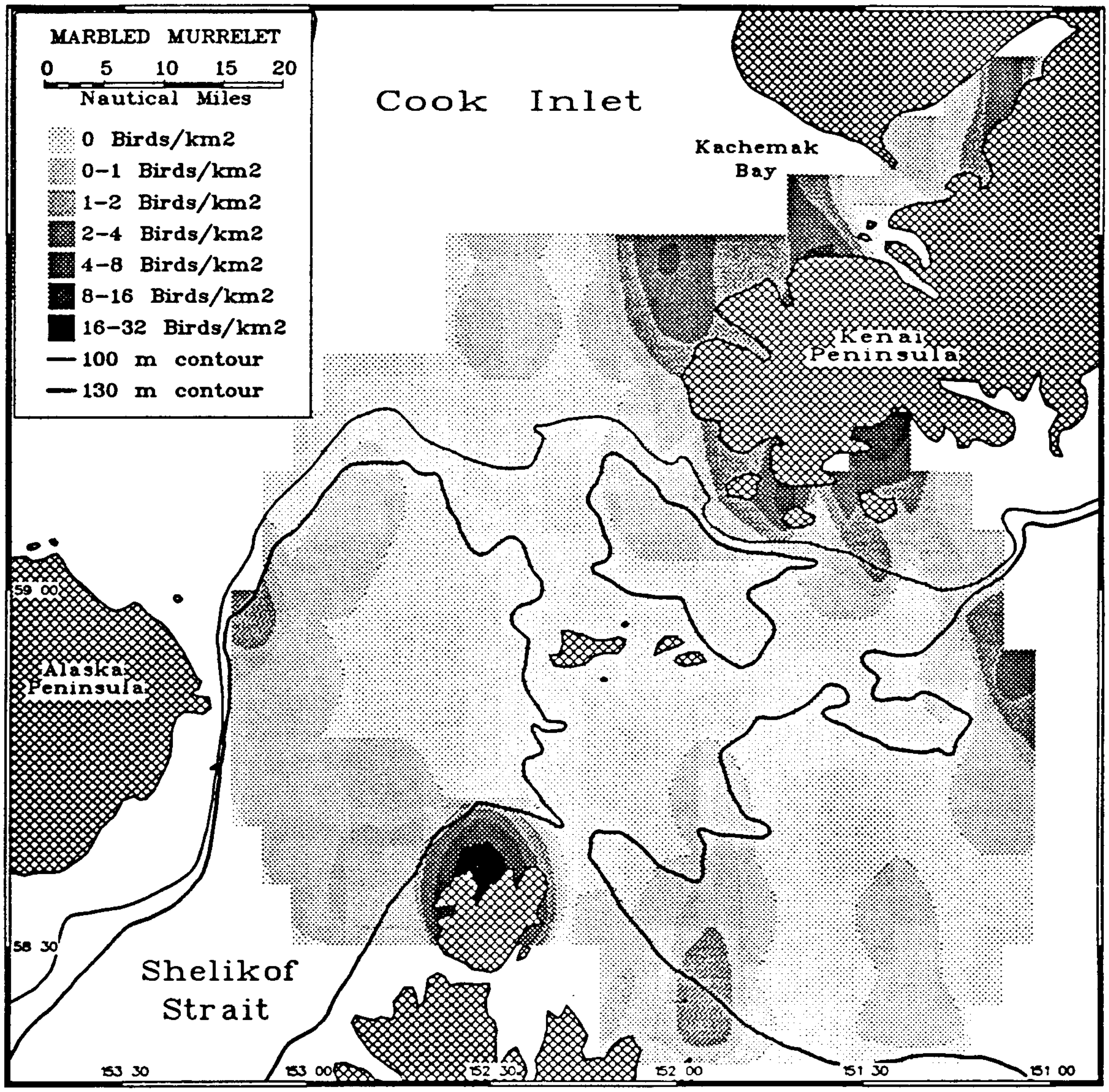


Fig. 9. Distribution and abundance of Marbled Murrelets, a typical coastal species, in lower Cook Inlet, July, 1992.

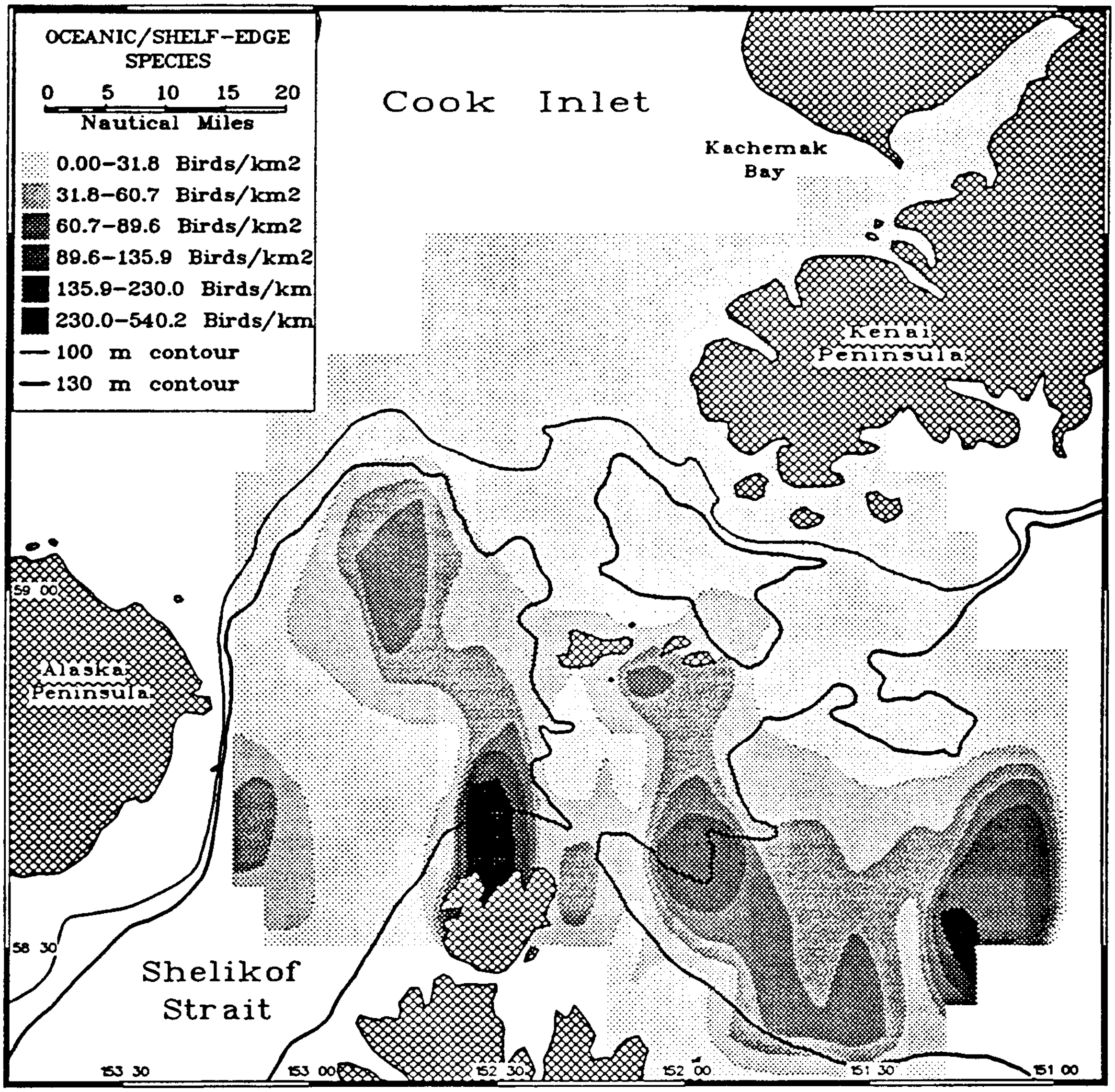


Fig. 10. Distribution and abundance of oceanic and shelf-edge (O/E) seabird species in lower Cook Inlet, July, 1992. See Table 2 for species composition of the O/E assemblage.

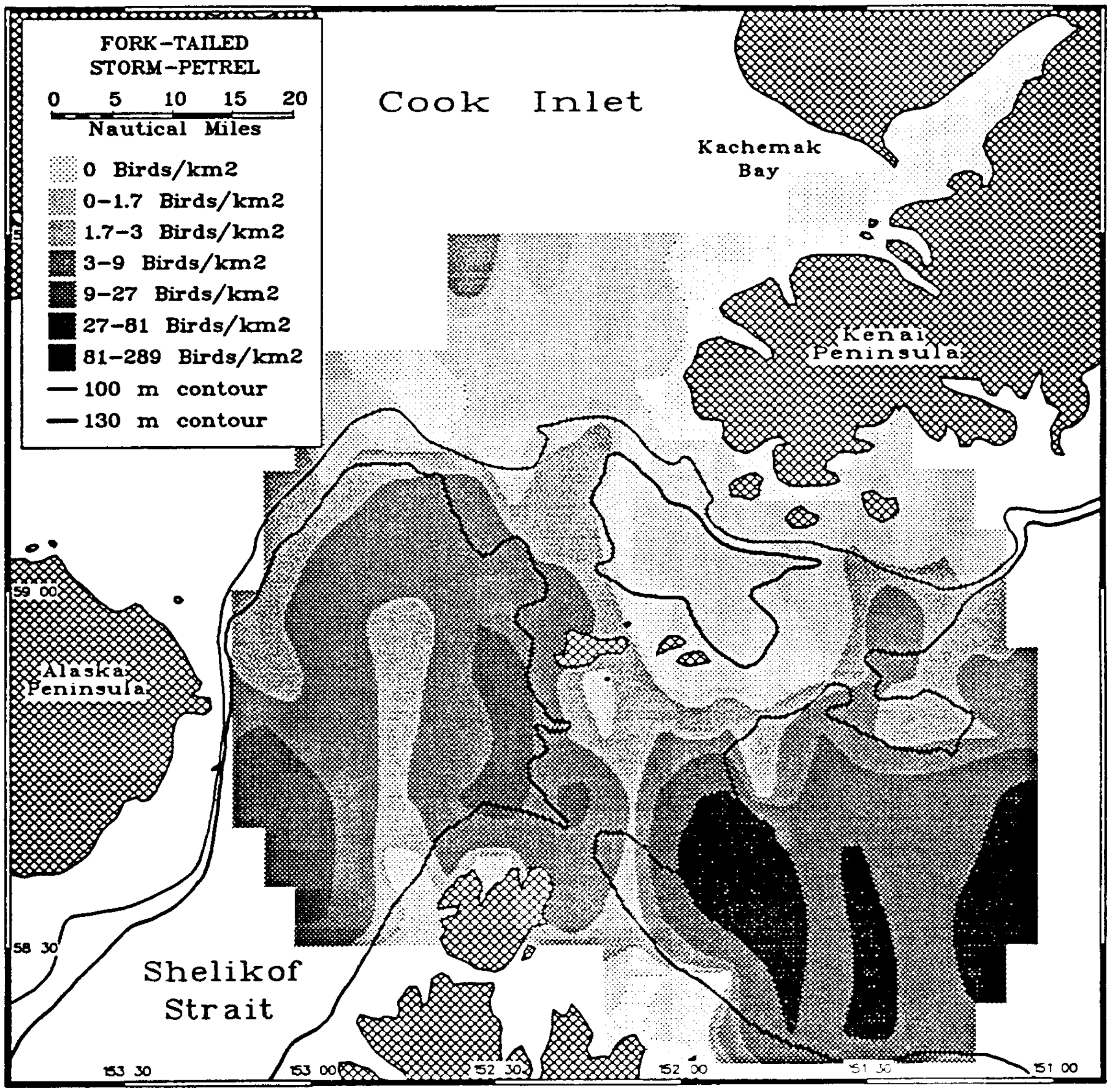


Fig. 11. Distribution and abundance of Fork-tailed Storm-petrels, a typical oceanic/shelf-edge species, in lower Cook Inlet, July, 1992.

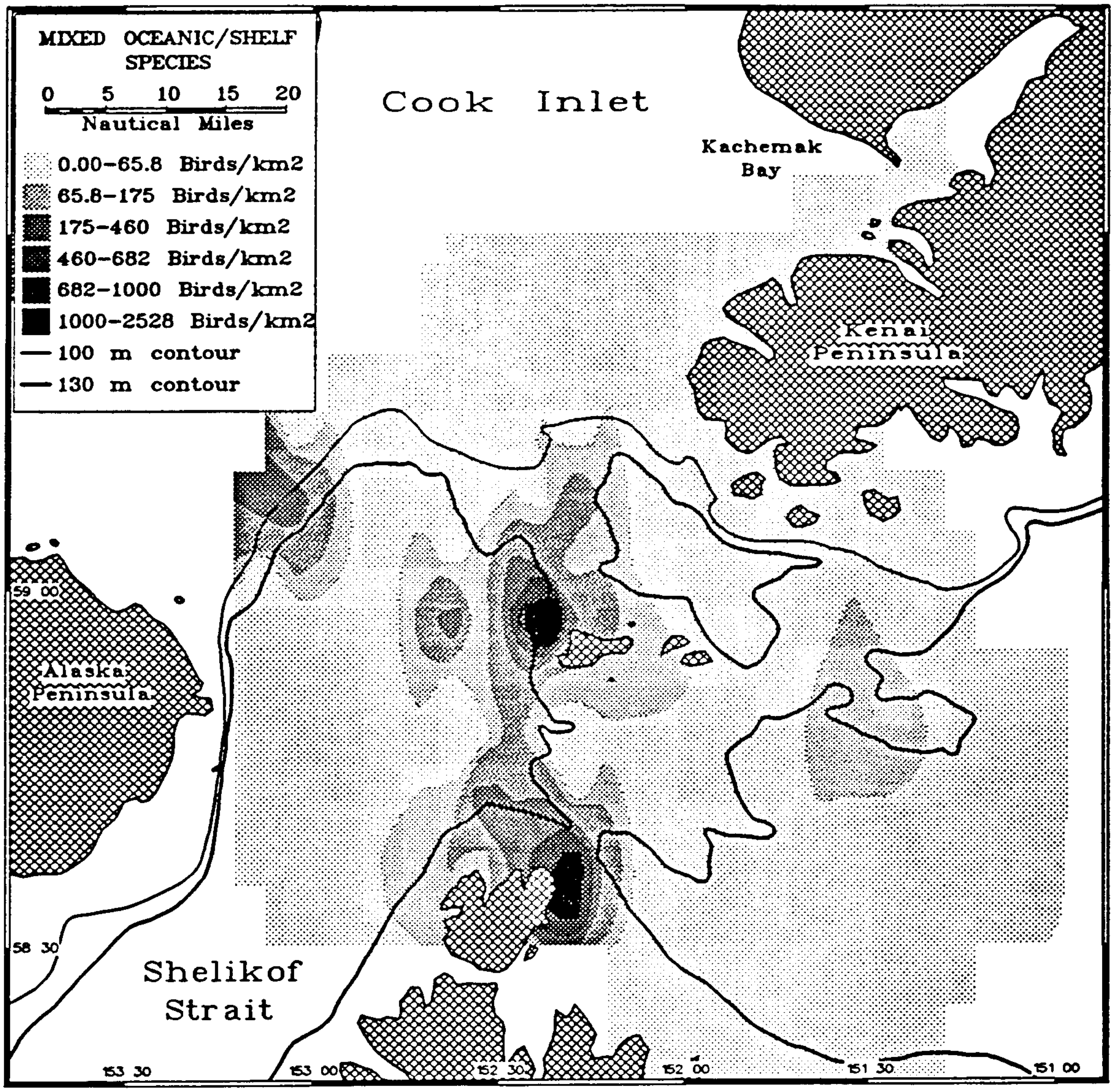


Fig. 12. Distribution and abundance of mixed oceanic and shelf (O/S) seabird species in lower Cook Inlet, July, 1992. See Table 2 for species composition of the O/S assemblage.

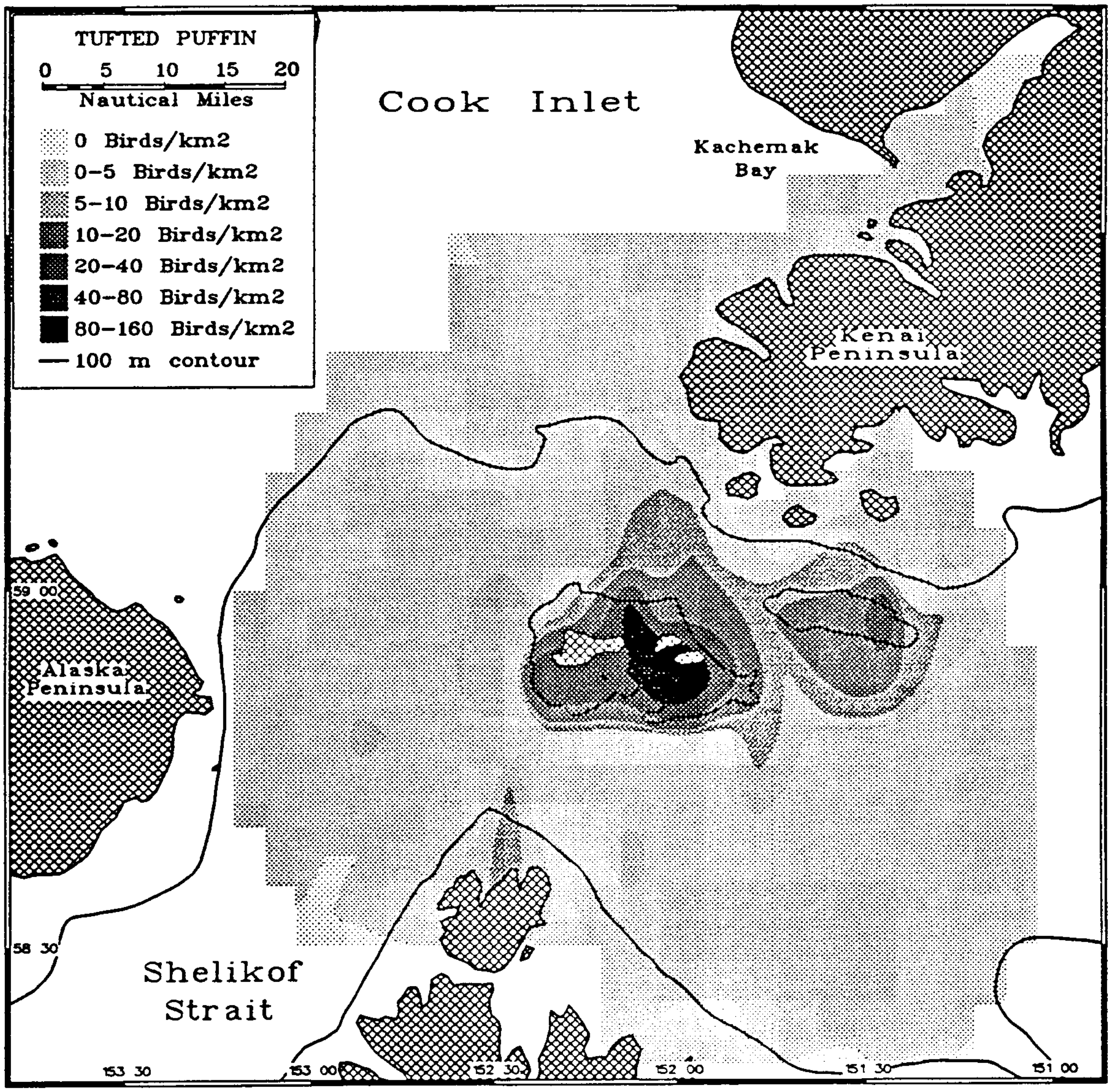


Fig. 13. Distribution and abundance of Tufted Puffins, a typical mixed oceanic/shelf species, in lower Cook Inlet, July, 1992.

APPENDICES

Appendix 1. Zooplankton composition and biomass at seven stations in lower Cook Inlet, July, 1992.

GROUP	SPECIES	SEX	1a	1b	2a	2b	3a	3b	4a	4b	5a	5b	6a	6b	7a	7b
HYDROZOA	*Aequorea victoria*															
Hydrozoa	*Aglantha digitale*															
Hydrozoa	*Eutonina indicans*															
Hydrozoa	*Hybocodon prolifer*															
Hydrozoa	*Hydrozoa g. sp. (juv.)*															
Hydrozoa	*Neoturris breviconis*															
Hydrozoa	*Phialidium gregarium*															
Hydrozoa	*Proboscidactyla flavicirrata*															
Hydrozoa	*Rathkea octopunctata*															
Hydrozoa	*Sarsia princeps*															
Hydrozoa	*Sarsia sp. (juv.)*															
Hydrozoa	*Tiaropsis multicirrata*															
POLYCHAETA	*Polychaeta g. sp. (larv.)*			0.1111	0.0741	0	0	0	0.0741	0	0	0.037	0	0.1481	0.0741	0.037
COPEPODA	*Acartia clausi*	F	39.4	16	0	0	0	0	0	0	0	0	0.4	0	0	0
Copepoda	*Acartia clausi*	M	4.4	6.75	0	0	0	0	0	0	0	0	0	0	0	0
Copepoda	*Acartia longiremis*	F	103.6	78.789	40.87	36.468	8.7544	61.281	40.87	61.691	107.95	43.772	70.035	46.673	1.7509	3.6518
Copepoda	*Acartia longiremis*	M	13.1	16.05	2.9	4.35	0	8.75	8.75	20.4	7.3	11.65	29.15	11.65	0.75	1.5
Copepoda	*Acartia sp. (juv.)*		1.2	0	0	0	0	0	0	0	2.4	4.8413	0	0	0	0
Copepoda	*Calanus marshallae 1*															
Copepoda	*Calanus marshallae 2*															
Copepoda	*Calanus marshallae 3*		7	7.75	0.75	3.5	0.5	4	11	16.5	4.25	0.5	4	3	0.5	0
Copepoda	*Calanus marshallae 4*		37.509	48.012	2.2506	0.7502	1.5004	6.0015	3.0008	4.5011	2.2506	0	57.014	18.005	3.0008	0
Copepoda	*Calanus marshallae 5*		234.53	301.3	1.6287	11.401	6.5147	6.5147	6.5147	9.772	8.1433	1.6287	254.07	149.84	6.5147	4.886
Copepoda	*Calanus marshallae 6*	F	130.01	161.21	10.4	5.2002	10.4	7.8003	0	0	0	0	62.402	52.002	2.6001	0
Copepoda	*Calanus marshallae 6*	M	9.1996	13.799	0	4.5998	0	0	0	0	0	0	9.1996	0	0	0
Copepoda	*Centropages abdominalis*	F	2	0.9091	0.9091	0.5455	0	0	21.273	42.364	42.364	2.3636	2.1818	1.8182	0	0.1818
Copepoda	*Centropages abdominalis*	M	1.2	0.84	0.24	0	0	0	21.001	35.041	17.521	10.44	0	0.96	0	0
Copepoda	*Centropages abdominalis (juv.)*		4.5999	2.2999	4.5999	0.0793	0	0	9.2791	13.879	30.058	0.7931	0	0.3172	0.1586	0
Copepoda	*Epilabidocera amphitrites 3*															
Copepoda	*Epilabidocera amphitrites 5*															
Copepoda	*Epilabidocera amphitrites*	F														
Copepoda	*Epilabidocera amphitrites*	M	0	0.9001	0	0	0	0	0	1.8002	0	0	0	0	0	0
Copepoda	*Eucalanus bungii 2*															
Copepoda	*Eucalanus bungii 3*		2.551	2.551	4.2517	11.054	18.707	30.612	1.7007	0	0.8503	0	35.714	54.422	3.4014	7.6531
Copepoda	*Eucalanus bungii 4*	F	8	34	8	20	12	32	0	0	0	2	80	32	4	6
Copepoda	*Eucalanus bungii 4*	M	12	22	8	6	20	40	0	0	2	4	72	0	8	16
Copepoda	*Eucalanus bungii 5*	F	30.837	66.079	4.4053	8.8106	0	0	8.8106	0	0	4.4053	0	0	0	0
Copepoda	*Eucalanus bungii 5*	M	26.432	44.053	13.216	0	0	17.621	0	0	4.4053	0	70.485	105.73	4.4053	4.4053
Copepoda	*Eucalanus bungii 6*	F	24.59	0	0	0	0	8.1967	0	0	0	0	32.787	0	0	0
Copepoda	*Eucalanus bungii 6*	M	0	0	0	0	8.1967	0	0	0	0	0	0	0	0	0
Copepoda	*Eurytemora sp. (juv.)*							0.12		0.12						
Copepoda	*Eurytemora herdmani*	F								0.12						
Copepoda	*Eurytemora pacifica*	F														
Copepoda	*Eurytemora pacifica*	M														
Copepoda	*Harpacticoida g. sp.*															
Copepoda	*Metridia pacifica (juv.)*		62.8	22.6	1.4	20.4	8	7.2	1.2	1.2	23.4	5.6	0.8	4.8	2.6	6
Copepoda	*Metridia pacifica*	F	20.906	6.0976	0	0.8711	3.4843	3.4843	0.8711	1.7422	4.3554	3.4843	0.8711	1.7422	0	0.8711
Copepoda	*Metridia pacifica*	M	0	0	0	0	0	0	0.16	0	1.28	1.12	0	0	0	0.16
Copepoda	*Neocalanus cristatus 3*		0	1.7999	0	0	0	0	0	0	0	0	0	0	0	0
Copepoda	*Neocalanus cristatus 4*		0	0	0	7.5988	0	0	0	0	0	0	0	0	0	0
Copepoda	*Neocalanus cristatus 5*		0	0	0	0	0	17.301	0	0	0	0	0	0	0	0

Appendix 1. Zooplankton composition and biomass at seven stations in lower Cook Inlet, July, 1992.

GROUP	SPECIES	SEX	1a	1b	2a	2b	3a	3b	4a	4b	5a	5b	6a	6b	7a	7b
Copepoda	*Neocalanus plumchrus 3*		0	0	0	0	0.6001	0	0	0	0	0	0	0	0	0
Copepoda	*Neocalanus plumchrus 4*		0.6998	0	0	0	0.6998	0	0	0	0	0	0.6998	0	0	0
Copepoda	*Neocalanus plumchrus 5*		33.598	3.0544	0	0	0	0	0	0	6.1087	0	9.1631	12.217	0	0
Copepoda	*Neocalanus plumchrus*	F	0	0	0	0	0	0	0	0	3.5002	10.501	0	0	0	0
Copepoda	*Neocalanus plumchrus*	M	0	0	0	0	0	0	0	0	2.7005	2.7005	0	0	0	0
Copepoda	*Neocalanus tenuicornis*	F	0.6001	0	0	0	0	1.2001	0	0	0	0	0	0	0	0
Copepoda	*Neocalanus tenuicornis*	M	0	0.4	0	0	0	0	0	0	0	0	0	0	0	0
Copepoda	*Oithona sp.*		0.9	1.5103	0.6	2.1103	1.8103	3.6206	0	0	0.3	0.3	0.2896	0.0828	0.2483	0.4034
Copepoda	*Pseudocalanus minutus*	F	815.66	981.92	1363.6	1561.7	3076.9	7062.9	1142.2	2191.1	36.162	7.4925	3916.1	6445.3	181.52	164.64
Copepoda	*Pseudocalanus newmani*	F	114.01	105.19	96.474	84.753	43.779	157.78	93.468	169.51	354.54	68.123	175.32	23.342	11.721	18.333
Copepoda	*Pseudocalanus spp.*	M	90.996	79.392	133.09	191.44	175.11	98.039	186.71	312.77	25.69	4.6419	28.011	74.67	16.006	14.646
Copepoda	*Pseudocalanus spp. (juv.)*		98	79.26	128.32	116.64	230.96	294	135.36	144.64	56	32.64	121.36	112	9.36	18.64
Copepoda	*Scolecitricella minor*	F	0	0	0.16	0.16	0.16	1.28	0	0	0.8	0	0	0	0.16	0
Copepoda	*Scolecitricella minor (juv.)*															
Copepoda	*Tortanus discaudatus 3*															
Copepoda	*Tortanus discaudatus*	F	0.14	0.14	0	0	0	0	0	0	0	0	0	0	0	0
Copepoda	*Tortanus discaudatus*	M	0.14	0.07	0	0	0	0	0	0	0	0	0	0.07	0	0
CLADOCERA	*Evadne nordmanii*		0	0	0	0	0	0	0	0.06	0.8701	2.6103	0	0	0.9001	1.0201
Cladocera	*Podon leuckartii*		27.301	40.031	0.0936	0.0936	0	0	0.1248	0.2496	9.1108	3.6505	0.2496	0.2496	0.156	1.092
CIRRIPEDIA	*Cirripedia g. sp. (nauplii)*		0.87	0.29	0.28	0	0.02	0	1.17	2.92	3.79	1.17	0	0	0.01	0
Cirripedia	*Cirripedia g. sp. (cypris)*		0.18	0.12	0	0	0	0	0.24	0	0	0.06	0.48	0	0	0
AMPHIPODA	*Cyphocaris challengeri*															
Amphipoda	*Parathemisto pacifica*		20	32	22	34	20	152	116	84	132	116	72	80	26	6
EUPHAUSIACEA	*Euphausiacea g. sp. (calypt.)*		0.54	0.3	0.48	0.84	0.24	0	21	41.999	40.259	19.26	1.92	0.72	0.12	0
Euphausiacea	*Euphausiacea g. sp. (furcil.)*		5.6001	4.8433	0.6054	0.7566	0.1514	1.2108	19.979	70.683	4.9947	0.9081	1.2108	0.6054	0.3027	0.3027
Euphausiacea	*Thysanoessa sp. (cyrtopia)*		0.6667	0.3333	0	0	0	0	0	0	0.3333	0	0	0	0	0
DECAPODA	*Crangonidae g. sp. larv. 2*															
Decapoda	*Hyppolitidae g. sp. larv. 1*															
Decapoda	*Hyppolitidae g. sp. larv. 2*															
Decapoda	*Hyppolitidae g. sp. larv. 3*															
Decapoda	*Hyppolitidae g. sp. larv. 4*															
Decapoda	*Hyppolitidae g. sp. larv. 5*															
Decapoda	*Pandalidae g. sp. (larv. 6)*															
Decapoda	*Majidae g. sp. (zoea)*		380.02	223.23	23.917	21.26	21.26	53.149	90.353	55.807	108.96	21.26	37.204	65.039	7.9724	5.3149
Decapoda	*Majidae g. sp. (megalopa)*		18.302	10.981	3.6603	0	0	14.641	21.962	29.283	0	3.6603	36.603	186.68	3.6603	10.981
Decapoda	*Atelecyclidae g. sp. (zoea)*		2.6603	0	2.6603	0	2.6603	10.641	164.94	175.58	15.962	2.6603	7.9808	0	0	0
Decapoda	*Atelecyclidae g. sp. (megalopa)*		3.6603	10.981	0	3.6603	0	0	7.3206	0	14.641	0	0	0	0	0
Decapoda	*Paguridae g. sp. (zoea)*		276.96	103.86	5.3262	2.6631	2.6631	10.652	63.915	26.631	15.979	0	0	10.652	2.6631	2.6631
Decapoda	*Paguridae g. sp. (glaucotea)*															
Decapoda	*Anomura g. sp. (zoea)*		2.6603	0	5.3206	2.6603	0	2.6603	0	0	2.6603	2.6603	0	0	0	0
PTEROPODA	*Clione limacina*		15.2	15.2	15.2	45.6	45.6	0	0	0	15.2	15.2	182.4	75.999	60.8	30.4
Pteropoda	*Limacina sp.*		0.64	0.42	0.12	0.58	0.04	0.24	3.5	11.66	0	0.56	0.08	0.08	0	0.02
CHAETOGNATHA	*Sagitta elegans*		170.01	122.06	30.514	34.874	4.3592	4.3592	156.93	95.902	183.09	239.76	95.902	56.67	4.3592	0
Chaetognatha	*Sagitta scripsae*															
APPENDICULARIA	*Appendicularia g. sp.*		1.76	7.56	3.3	4.66	3.12	3.5	5.84	23.34	22.76	21	0.08	0	0.32	0.68
PISCES	*Pisces g. sp. (larv.)*															

Appendix 1. Zooplankton composition and abundance at seven stations in lower Cook Inlet, July, 1992.

GROUP	SPECIES	SEX	1a	1b	2a	2b	3a	3b	4a	4b	5a	5b	6a	6b	7a	7b
Copepoda	*Neocalanus plumchrus 3*						2									
Copepoda	*Neocalanus plumchrus 4*		1				1						1			
Copepoda	*Neocalanus plumchrus 5*		11	1							2		3	4		
Copepoda	*Neocalanus plumchrus*	F									1	3				
Copepoda	*Neocalanus plumchrus*	M									1	1				
Copepoda	*Neocalanus tenuicornis*	F	2					4								
Copepoda	*Neocalanus tenuicornis*	M		2												
Copepoda	*Oithona sp.*		87	146	58	204	175	350			29	29	28	8	24	39
Copepoda	*Pseudocalanus minutus*	F	8167	9829	13650	15633	30800	70700	11433	21933	382	75	39200	64517	1817	1650
Copepoda	*Pseudocalanus newmani*	F	1138	1050	963	846	437	1575	933	1692	3539	680	1750	233	117	183
Copepoda	*Pseudocalanus spp.*	M	1137	992	1663	2392	2188	1225	2333	3908	321	58	350	933	200	183
Copepoda	*Pseudocalanus spp. (juv.)*		1225	991	1604	1458	2887	3675	1692	1808	700	408	1517	1400	117	233
Copepoda	*Scolecitricella minor*	F			1	1	1	8			5				1	
Copepoda	*Scolecitricella minor (juv.)*		3								2					
Copepoda	*Tortanus discaudatus 3*		2		1											
Copepoda	*Tortanus discaudatus*	F	1	1												
Copepoda	*Tortanus discaudatus*	M	2	1										1		
CLADOCERA	*Evadne nordmanii*									2	29	87			30	34
Cladocera	*Podon leuckartii*		875	1283	3	3			4	8	292	117	8	8	5	35
CIRRIPEDIA	*Cirripedia g. sp. (nauplii)*		87	29	28		2		117	292	379	117			1	
Cirripedia	*Cirripedia g. sp. (cypris)*		3	2					4			1	8			
AMPHIPODA	*Cyphocaris challengeri*										1					
Amphipoda	*Parathemisto pacifica*		10	16	11	17	10	76	58	42	66	58	36	40	13	3
EUPHAUSIACEA	*Euphausiacea g. sp. (calypt.)*		9	5	8	14	4		350	700	671	321	32	12	2	
Euphausiacea	*Euphausiacea g. sp. (furcil.)*		37	32	4	5	1	8	132	467	33	6	8	4	2	2
Euphausiacea	*Thysanoessa sp. (cyrtopia)*		2	1							1					
DECAPODA	*Crangonidae g. sp. larv. 2*										1					
Decapoda	*Hyppolitidae g. sp. larv. 1*		3	1		1	1	2	14	38	10	1	12	12	7	15
Decapoda	*Hyppolitidae g. sp. larv. 2*					3			34	60	6	4	2	1		1
Decapoda	*Hyppolitidae g. sp. larv. 3*			5					6	32	6	2				
Decapoda	*Hyppolitidae g. sp. larv. 4*		1	1					2							
Decapoda	*Hyppolitidae g. sp. larv. 5*		2													
Decapoda	*Pandalidae g. sp. (larv. 6)*			2				1					1	1		
Decapoda	*Majidae g. sp. (zoea)*		143	84	9	8	8	20	34	21	41	8	14	32	3	2
Decapoda	*Majidae g. sp. (megalopa)*		5	3	1			4	6	8		1	10	51	1	3
Decapoda	*Atelecyclidae g. sp. (zoea)*		1		1		1	4	62	66	6	1	3			
Decapoda	*Atelecyclidae g. sp. (megalopa)*		1	3		1			2		4					
Decapoda	*Paguridae g. sp. (zoea)*		104	39	2	1	1	4	24	10	6			4	1	1
Decapoda	*Paguridae g. sp. (glaucotea)*		2													
Decapoda	*Anomura g. sp. (zoea)*		1		2	1		1			1	1				
PTEROPODA	*Clione limacina*		1	1	1	3	3				1	1	12	5	4	2
Pteropoda	*Limacina sp.*		32	21	6	29	2	12	175	583		29	4	4		1
CHAETOGNATHA	*Sagitta elegans*		39	28	7	8	1	1	36	22	42	55	22	13	1	
Chaetognatha	*Sagitta scripsae*											1				
APPENDICULARIA	*Appendicularia g. sp.*		86	379	165	233	156	175	292	1167	1138	1050	4		16	34
PISCES	*Pisces g. sp. (larv.)*		10	17	5	5	2	4			57	45	20	28	1	
	date		7.11	7.11	7.11	7.11	7.11	7.11	7.13	7.13	7.14	7.14	7.14	7.14	7.14	7.14
	time		1445	1445	520	520	2030	2030	2015	2015	1610	1610	1800	1800	2100	2100
	depth (m)		100	100	100	100	100	100	87	87	125	125	74	74	29	29

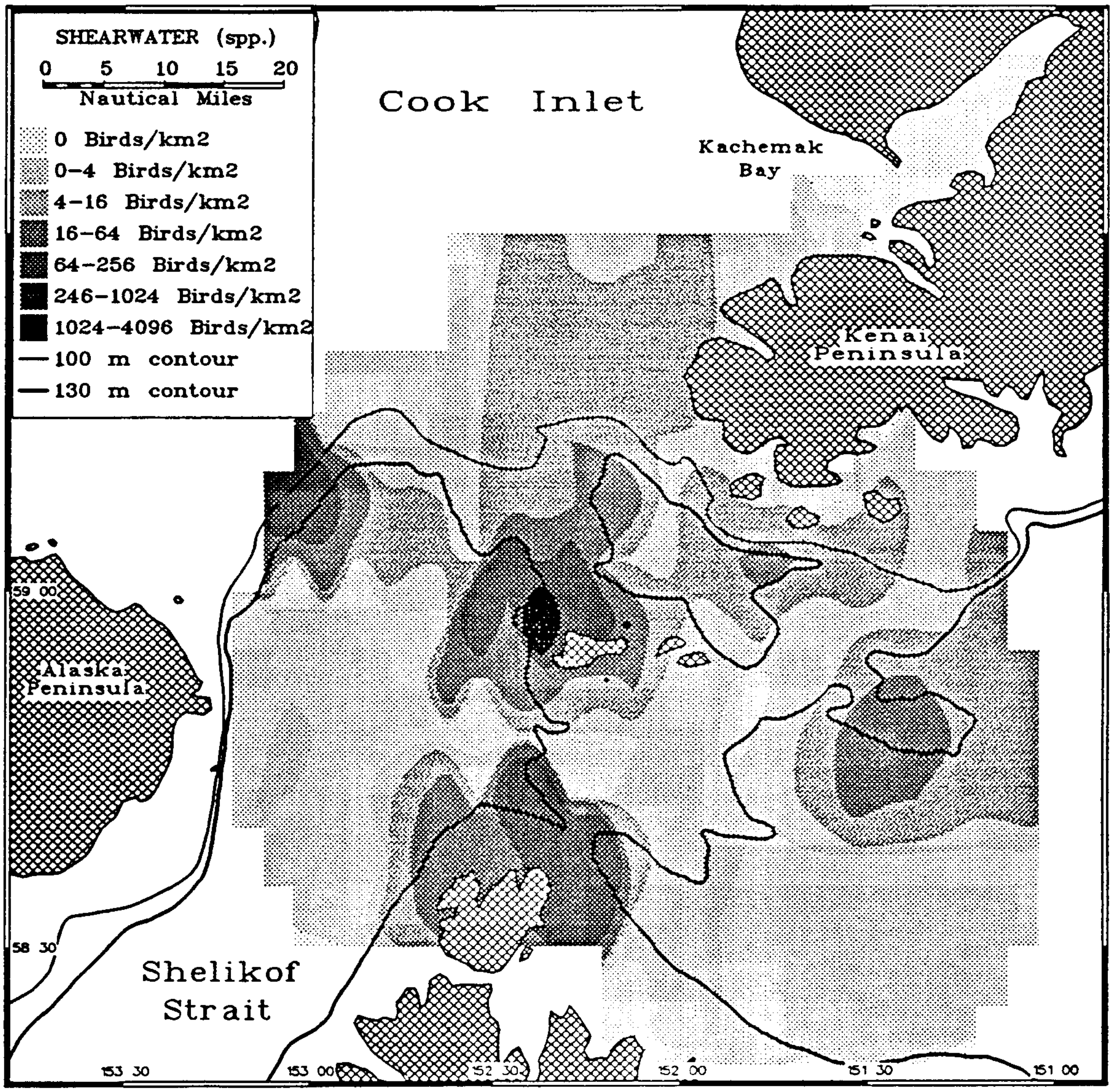
Appendix 1. Zooplankton composition and abundance at seven stations in lower Cook Inlet, July, 1992.

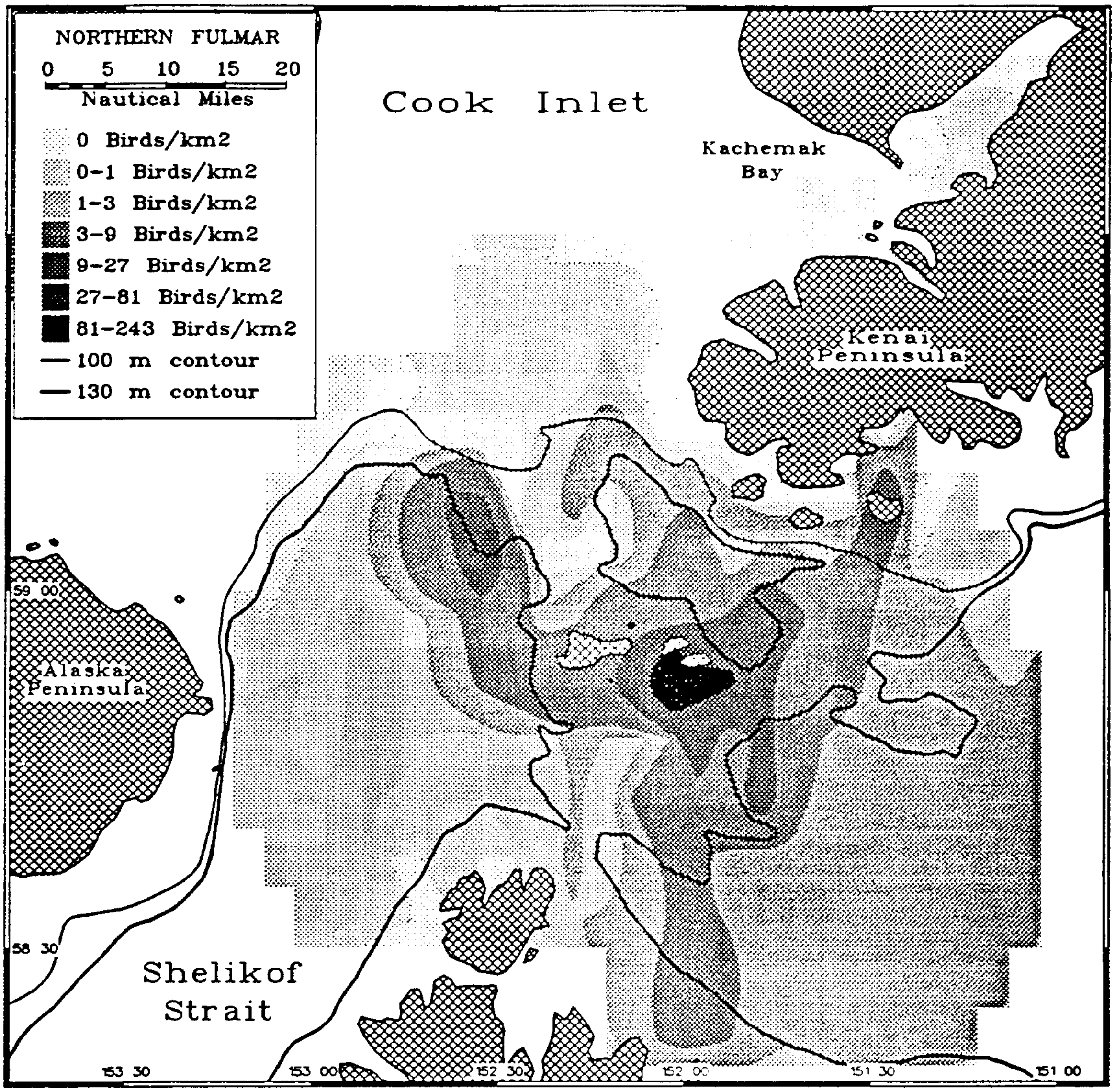
GROUP	SPECIES	SEX	1a	1b	2a	2b	3a	3b	4a	4b	5a	5b	6a	6b	7a	7b
HYDROZOA	*Aequorea victoria*													1		
Hydrozoa	*Aglantha digitale*		5	6	1	1			1	2	2	6				
Hydrozoa	*Eutonina indicans*			1												
Hydrozoa	*Hybocodon prolifer*			1												
Hydrozoa	*Hydrozoa g. sp. (juv.)*					5		1				10				
Hydrozoa	*Neoturris breviconis*		1													
Hydrozoa	*Phialidium gregarium*				1			1				1	3	4	2	
Hydrozoa	*Proboscidactyla flavicirrata*								2			1			1	
Hydrozoa	*Rathkea octopunctata*										2	22				
Hydrozoa	*Sarsia princeps*											1				
Hydrozoa	*Sarsia sp. (juv.)*		2						1							
Hydrozoa	*Tiaropsis multicirrata*		2													
POLYCHAETA	*Polychaeta g. sp. (larv.)*			3	2				2			1		4	2	1
COPEPODA	*Acartia clausi*	F	788	320									8			
Copepoda	*Acartia clausi*	M	88	175												
Copepoda	*Acartia longiremis*	F	2071	1575	817	729	175	1225	817	1633	2158	875	1400	933	35	73
Copepoda	*Acartia longiremis*	M	262	321	58	87		175	175	408	146	233	583	233	15	30
Copepoda	*Acartia sp. (juv.)*		29								58	117				
Copepoda	*Calanus marshallae 1*		28		29											
Copepoda	*Calanus marshallae 2*		146	58	6	9	4	4	467	525	53	9	16		1	1
Copepoda	*Calanus marshallae 3*		28	31	3	14	2	16	44	66	17	2	16	12	2	
Copepoda	*Calanus marshallae 4*		50	64	3	1	2	8	4	6	3		76	24	4	
Copepoda	*Calanus marshallae 5*		144	185	1	7	4	4	4	6	5	1	156	92	4	3
Copepoda	*Calanus marshallae 6*	F	50	62	4	2	4	3					24	20	1	
Copepoda	*Calanus marshallae 6*	M	4	6		2							4			
Copepoda	*Centropages abdominalis*	F	11	5	5	3			117	233	233	13	12	10		1
Copepoda	*Centropages abdominalis*	M	10	7	2				175	292	146	87		8		
Copepoda	*Centropages abdominalis (juv.)*		58	29	58	1			117	175	379	10		4	2	
Copepoda	*Epilabidocera amphitrites 3*			1	1						1					
Copepoda	*Epilabidocera amphitrites 5*									4						
Copepoda	*Epilabidocera amphitrites*	F							2							
Copepoda	*Epilabidocera amphitrites*	M		1						2						
Copepoda	*Eucalanus bungii 2*						2	4		2			4			
Copepoda	*Eucalanus bungii 3*		3	3	5	13	22	36	2		1		42	64	4	9
Copepoda	*Eucalanus bungii 4*	F	4	17	4	10	6	16				1	40	16	2	3
Copepoda	*Eucalanus bungii 4*	M	6	11	4	3	10	20			1	2	36		4	6
Copepoda	*Eucalanus bungii 5*	F	7	15	1	2			2			1				
Copepoda	*Eucalanus bungii 5*	M	6	10	3			4			1		16	24	1	1
Copepoda	*Eucalanus bungii 6*	F	3					1					4			
Copepoda	*Eucalanus bungii 6*	M					1									
Copepoda	*Eurytemora sp. (juv.)*							2		2						
Copepoda	*Eurytemora herdmani*	F								2						
Copepoda	*Eurytemora pacifica*	F														
Copepoda	*Eurytemora pacifica*	M														
Copepoda	*Harpacticoida g. sp.*										1					
Copepoda	*Metridia pacifica (juv.)*		314	113	7	102	40	36	6	6	117	28	4	24	13	30
Copepoda	*Metridia pacifica*	F	24	7		1	4	4	1	2	5	4	1	2		1
Copepoda	*Metridia pacifica*	M							1		8	7				1
Copepoda	*Neocalanus cristatus 3*			1												
Copepoda	*Neocalanus cristatus 4*					1										
Copepoda	*Neocalanus cristatus 5*							1								

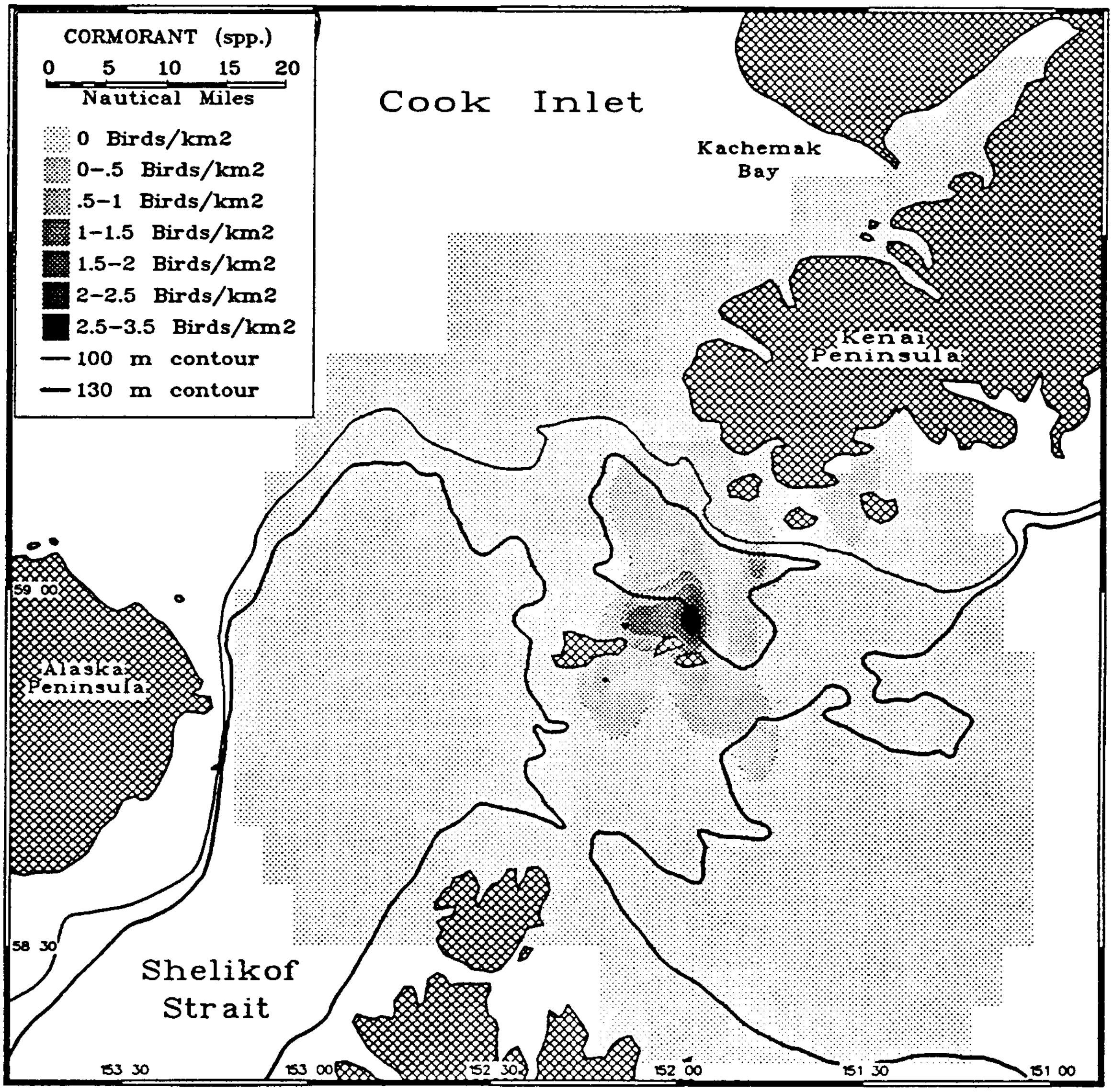
Appendix 2. Species composition and numbers of seabirds and marine mammals observed on 415 transects in lower Cook Inlet, July, 1992.

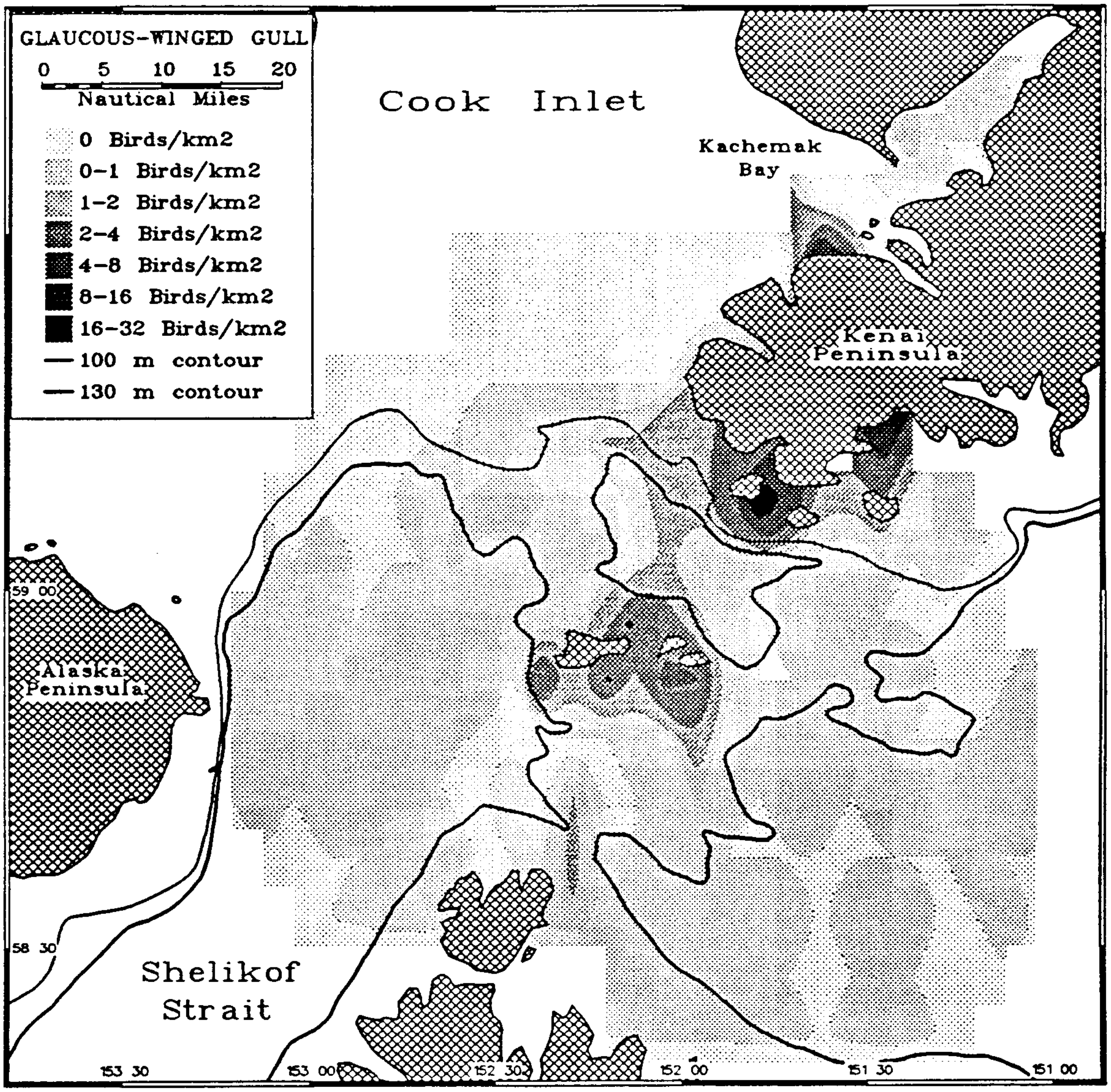
Species	Scientific Name	No. Observed	% Total
All bird species total		86969	100.0
Unidentified bird		8	<0.1
Pacific Loon	(*Gavia pacifica*)	1	<0.1
Northern Fulmar	(*Fulmarus glacialis*)	4880	5.6
All Shearwaters	(*Puffinus* spp. total)	57808	65.5
Sooty Shearwater	(*Puffinus griseus*)	13	-
Short-tailed Shearwater	(*Puffinus tenuirostris*)	181	-
Unidentified storm-petrel	(*Oceanodroma* spp.)	2	<0.1
Fork-tailed Storm-petrel	(*Oceanodroma furcata*)	6319	7.3
Leach's Storm-petrel	(*Oceanodroma leucorhoa*)	1	<0.1
All Cormorants	(*Phalacrocorax* spp. total)	43	<0.1
Double-crested Cormorant	(*Phalacrocorax auritus*)	5	-
Pelagic Cormorant	(*Phalacrocorax pelagicus*)	33	-
Unidentified scoter	(*Melanitta* spp.)	2	<0.1
Surf Scoter	(*Melanitta perspicillata*)	3	<0.1
White-winged Scoter	(*Melanitta fusca*)	8	<0.1
All Phalaropes	(*Phalaropus* spp.)	5775	6.6
Red-necked Phalarope	(*Phalaropus lobatus*)	1961	-
Red Phalarope	(*Phalaropus fulicaria*)	24	-
Pomarine Jaeger	(*Stercorarius pomarinus*)	10	<0.1
Parasitic Jaeger	(*Stercorarius parasiticus*)	10	<0.1
Unidentified gull	(*Laridae*)	1	<0.1
Herring Gull	(*Larus argentatus*)	1	<0.1
Glaucous-winged Gull	(*Larus glaucescens*)	480	0.6
Black-legged Kittiwake	(*Rissa tridactyla*)	1752	2.0
Sabine's Gull	(*Xema sabini*)	14	<0.1
Unidentified tern	(*Sterna* spp.)	2	<0.1
Arctic Tern	(*Sterna paradisaea*)	23	<0.1
Aleutian tern	(*Sterna aleutica*)	14	<0.1
Unidentified alcid	(Alcidae)	45	<0.1
All Murres	(*Uria* spp. total)	3135	3.6
Common Murre	(*Uria aalge*)	1589	-
Thick-billed Murre	(*Uria lomvia*)	20	-
Pigeon Guillemot	(*Cepphus columba*)	50	<0.1
Unidentified murrelet	(Alcidae)	505	0.6
All *Brachyramphus*	(*Brachyramphus* spp. total)	423	0.5
Marbled Murrelet	(*Brachyramphus marmoratus*)	309	-
Kittlitz's Murrelet	(*Brachyramphus brevirostris*)	52	-
Ancient Murrelet	(*Synthliboramphus antiquus*)	478	0.5
Cassin's Auklet	(*Ptychoramphus aleuticus*)	8	<0.1
Parakeet Auklet	(*Cyclorrhynchus psittacula*)	169	0.2
Rhinoceros Auklet	(*Cerorhinca monocerata*)	69	<0.1
Tufted Puffin	(*Fratercula cirrhata*)	4823	5.5
Horned Puffin	(*Fratercula corniculata*)	107	0.1
Sea Otter	(*Enhydra lutris*)	16	
Northern Fur Seal	(*Callorhinus ursinus*)	9	
Harbor Seal	(*Phoca vitulina*)	2	
Killer Whale	(*Orcinus orca*)	4	
Harbor Porpoise	(*Phocoena phocoena*)	2	
Dall Porpoise	(*Phocoenoides dalli*)	95	
Minke Whale	(*Balaenoptera acutorostrata*)	4	
Humpback Whale	(*Megaptera novaeangliae*)	42	
Unidentified baleen whale	(*Balenoptera* spp.)	26	

Appendix 3. Maps of seabird, marine mammal, and fish distributions in lower Cook Inlet in July, 1992.

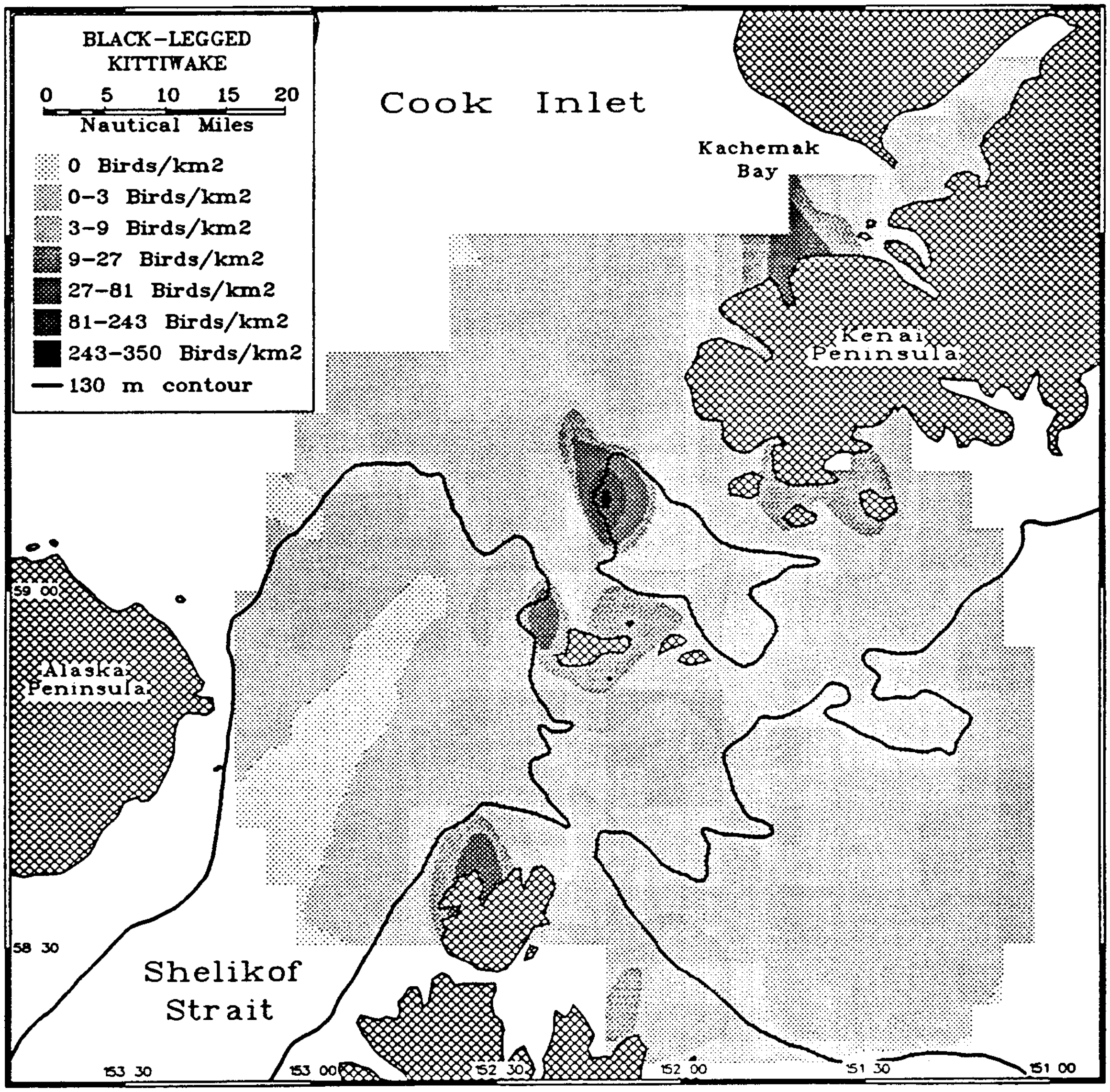

SHEARWATER (spp.)
0 5 10 15 20
Nautical Miles
0 Birds/km2
0-4 Birds/km2
4-16 Birds/km2
16-64 Birds/km2
64-256 Birds/km2
246-1024 Birds/km2
1024-4096 Birds/km2
100 m contour
130 m contour
Cook Inlet
Kachemak Bay
Kenai Peninsula
Alaska Peninsula
Shelikof Strait
59 00
58 30
153 30
153 00
152 30
152 00
151 30
151 00

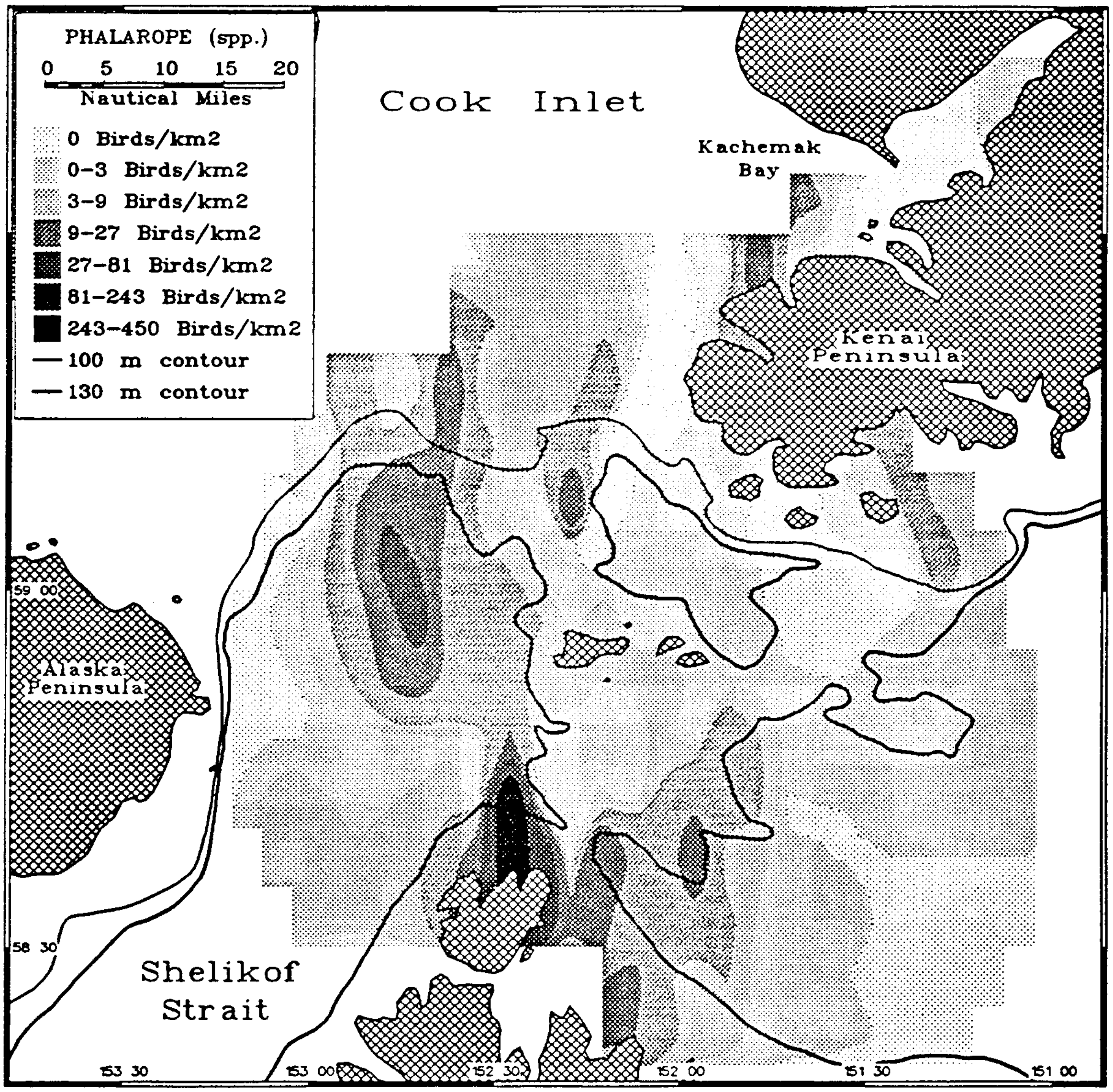

NORTHERN FULMAR
0 5 10 15 20
Nautical Miles
0 Birds/km2
0-1 Birds/km2
1-3 Birds/km2
3-9 Birds/km2
9-27 Birds/km2
27-81 Birds/km2
81-243 Birds/km2
100 m contour
130 m contour
Cook Inlet
Kachemak Bay
Kenai Peninsula
Alaska Peninsula
Shelikof Strait
59 00
58 30
153 30
153 00
152 30
152 00
151 30
151 00


CORMORANT (spp.)
0 5 10 15 20
Nautical Miles
0 Birds/km2
0-.5 Birds/km2
.5-1 Birds/km2
1-1.5 Birds/km2
1.5-2 Birds/km2
2-2.5 Birds/km2
2.5-3.5 Birds/km2
100 m contour
130 m contour
Cook Inlet
Kachemak Bay
Kenai Peninsula
Alaska Peninsula
Shelikof Strait
59 00
58 30
153 30
153 00
152 30
152 00
151 30
151 00

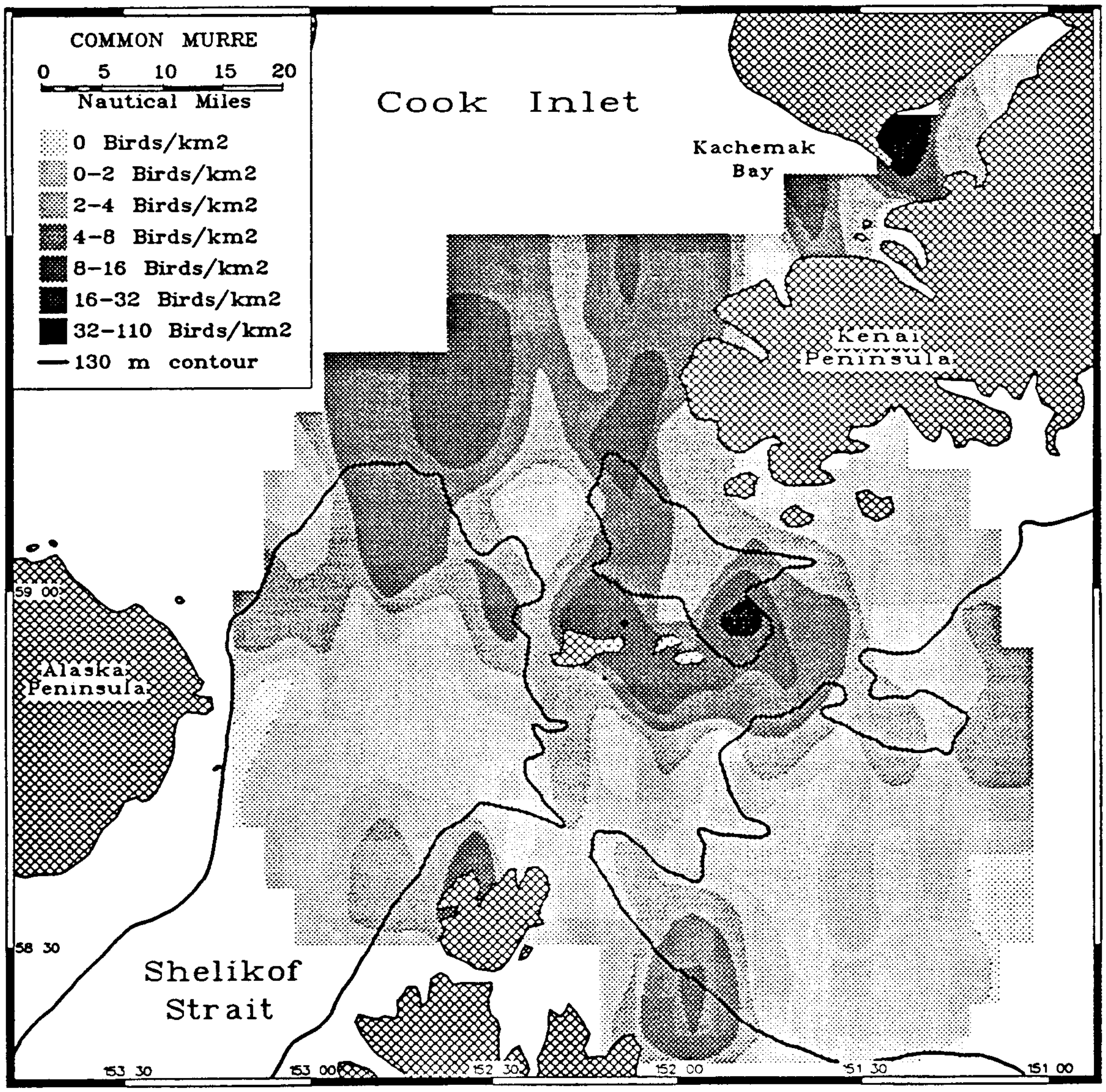


GLAUCOUS-WINGED GULL
0 5 10 15 20
Nautical Miles
0 Birds/km2
0-1 Birds/km2
1-2 Birds/km2
2-4 Birds/km2
4-8 Birds/km2
8-16 Birds/km2
16-32 Birds/km2
100 m contour
130 m contour
Cook Inlet
Kachemak Bay
Kenai Peninsula
Alaska Peninsula
Shelikof Strait
59 00
58 30
153 30
153 00
152 30
152 00
151 30
151 00

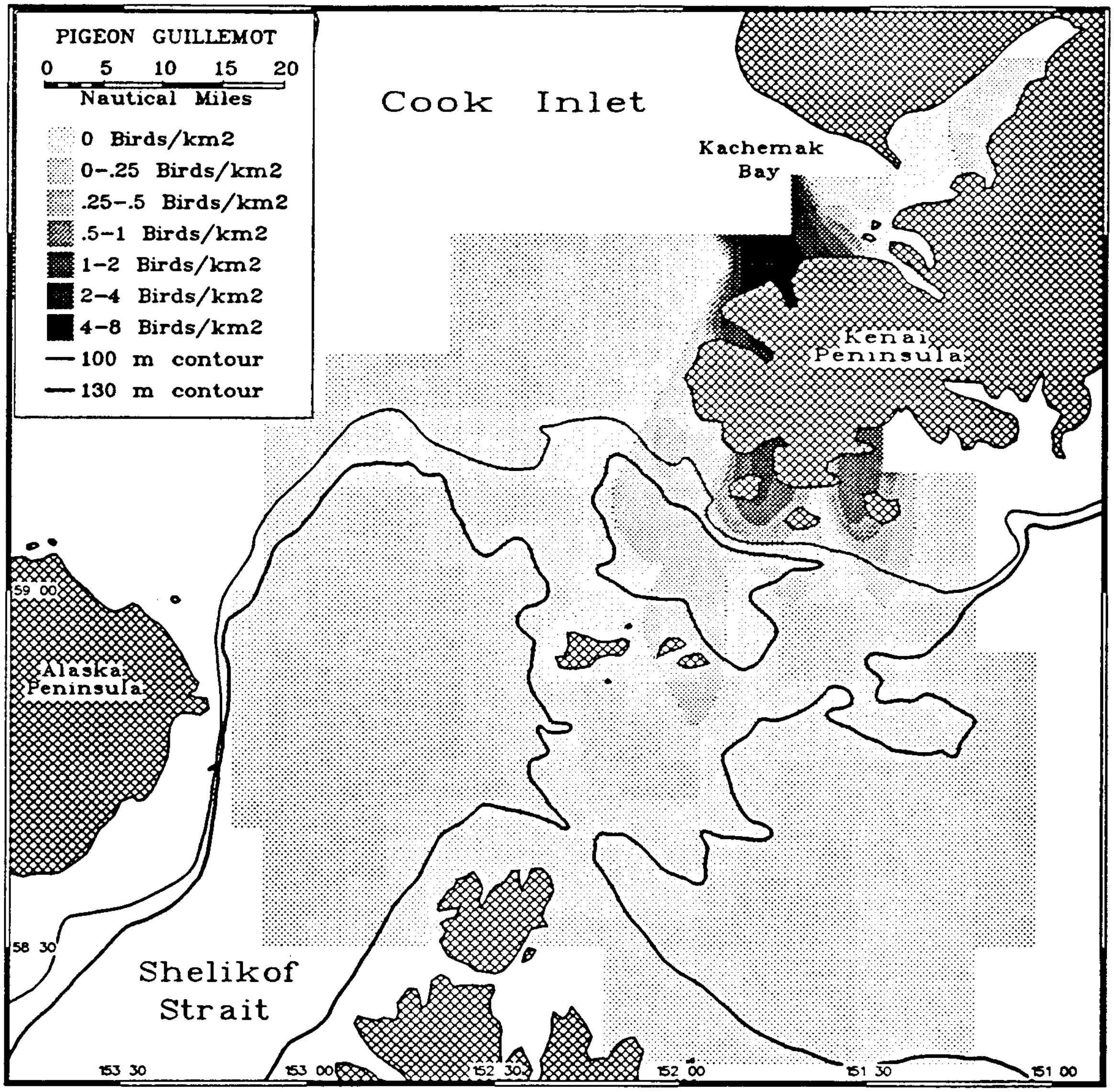

BLACK-LEGGED
KITTIWAKE
0 5 10 15 20
Nautical Miles
0 Birds/km2
0-3 Birds/km2
3-9 Birds/km2
9-27 Birds/km2
27-81 Birds/km2
81-243 Birds/km2
243-350 Birds/km2
130 m contour
Cook Inlet
Kachemak
Bay
Kenai
Peninsula
Alaska
Peninsula
59 00
58 30
Shelikof
Strait
153 30
153 00
152 30
152 00
151 30
151 00

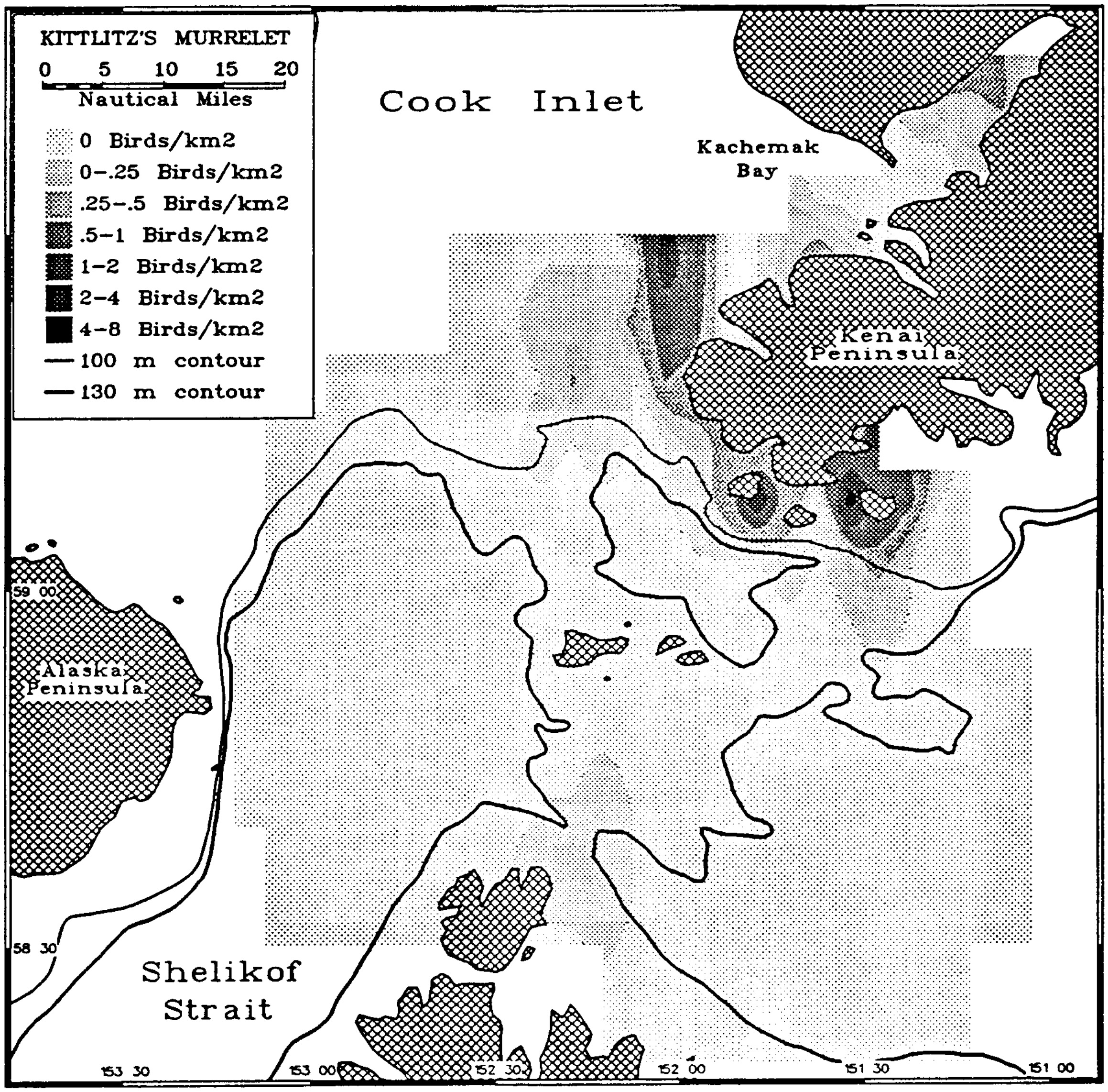


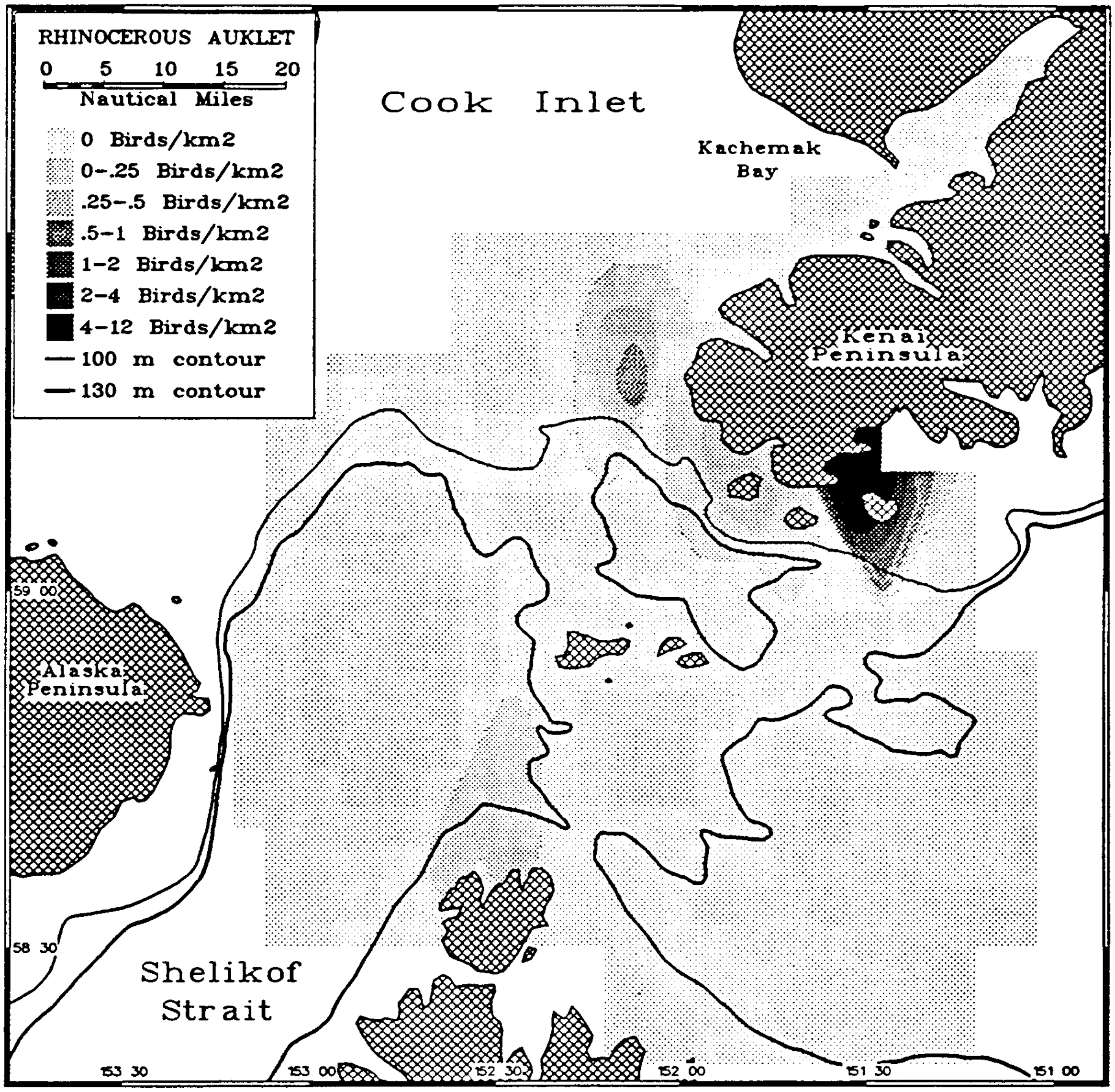
PHALAROPE (spp.)
0 5 10 15 20
Nautical Miles
0 Birds/km2
0-3 Birds/km2
3-9 Birds/km2
9-27 Birds/km2
27-81 Birds/km2
81-243 Birds/km2
243-450 Birds/km2
100 m contour
130 m contour
Cook Inlet
Kachemak Bay
Kenai Peninsula
Alaska Peninsula
Shelikof Strait
59 00
58 30
153 30
153 00
152 30
152 00
151 30
151 00



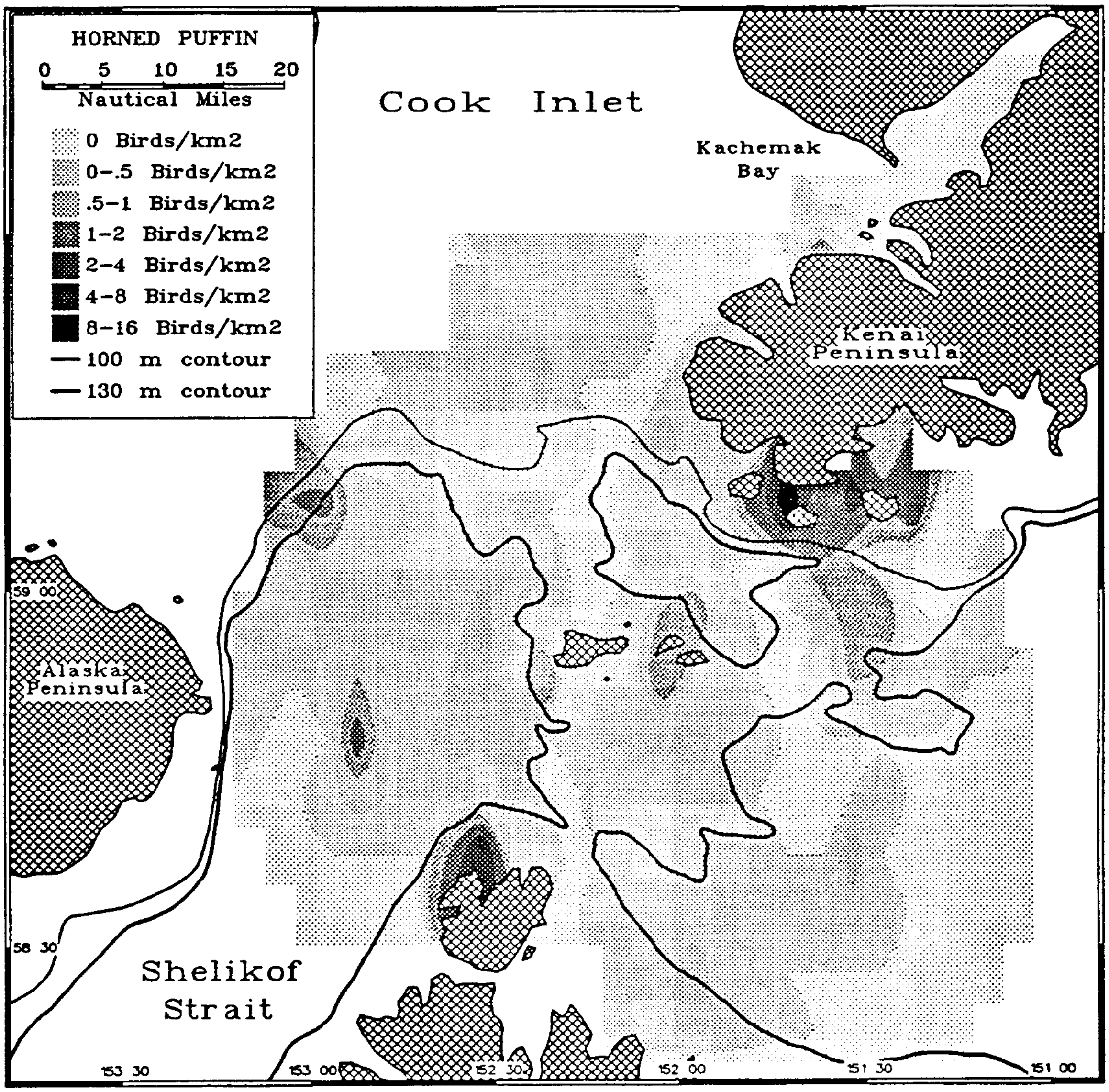
COMMON MURRE
0 5 10 15 20
Nautical Miles
0 Birds/km2
0-2 Birds/km2
2-4 Birds/km2
4-8 Birds/km2
8-16 Birds/km2
16-32 Birds/km2
32-110 Birds/km2
130 m contour
Cook Inlet
Kachemak Bay
Kenai Peninsula
Alaska Peninsula
Shelikof Strait
59 00
58 30
153 30
153 00
152 30
152 00
151 30
151 00

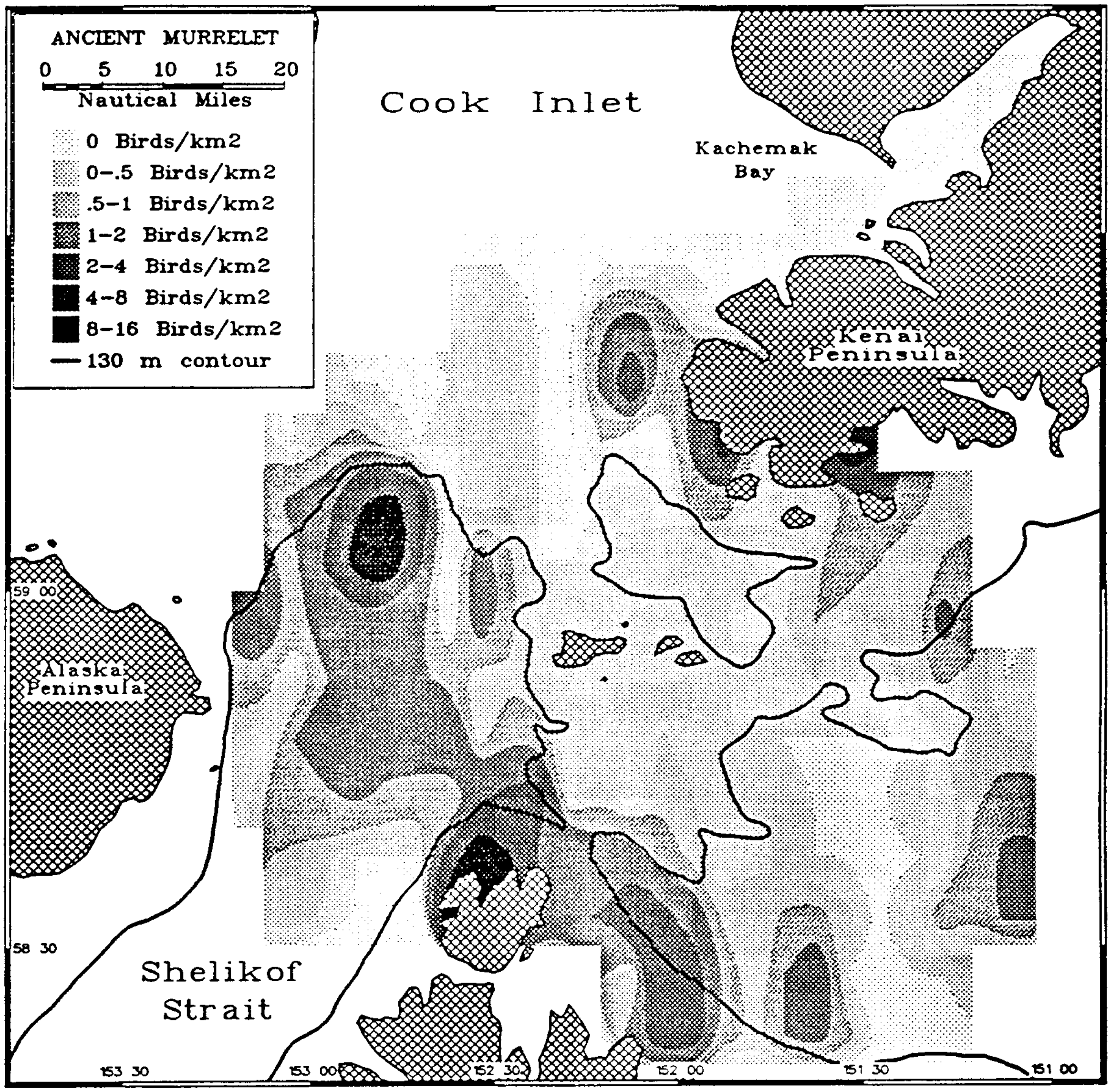

PIGEON GUILLEMOT
0 5 10 15 20
Nautical Miles
0 Birds/km2
0-.25 Birds/km2
.25-.5 Birds/km2
.5-1 Birds/km2
1-2 Birds/km2
2-4 Birds/km2
4-8 Birds/km2
100 m contour
130 m contour
Cook Inlet
Kachemak Bay
Kenai Peninsula
Alaska Peninsula
Shelikof Strait
59 00
58 30
153 30
153 00
152 30
152 00
151 30
151 00


KITTLITZ'S MURRELET
0 5 10 15 20
Nautical Miles
0 Birds/km2
0-.25 Birds/km2
.25-.5 Birds/km2
.5-1 Birds/km2
1-2 Birds/km2
2-4 Birds/km2
4-8 Birds/km2
100 m contour
130 m contour
Cook Inlet
Kachemak Bay
Kenai Peninsula
Alaska Peninsula
Shelikof Strait
59 00
58 30
153 30
153 00
152 30
152 00
151 30
151 00

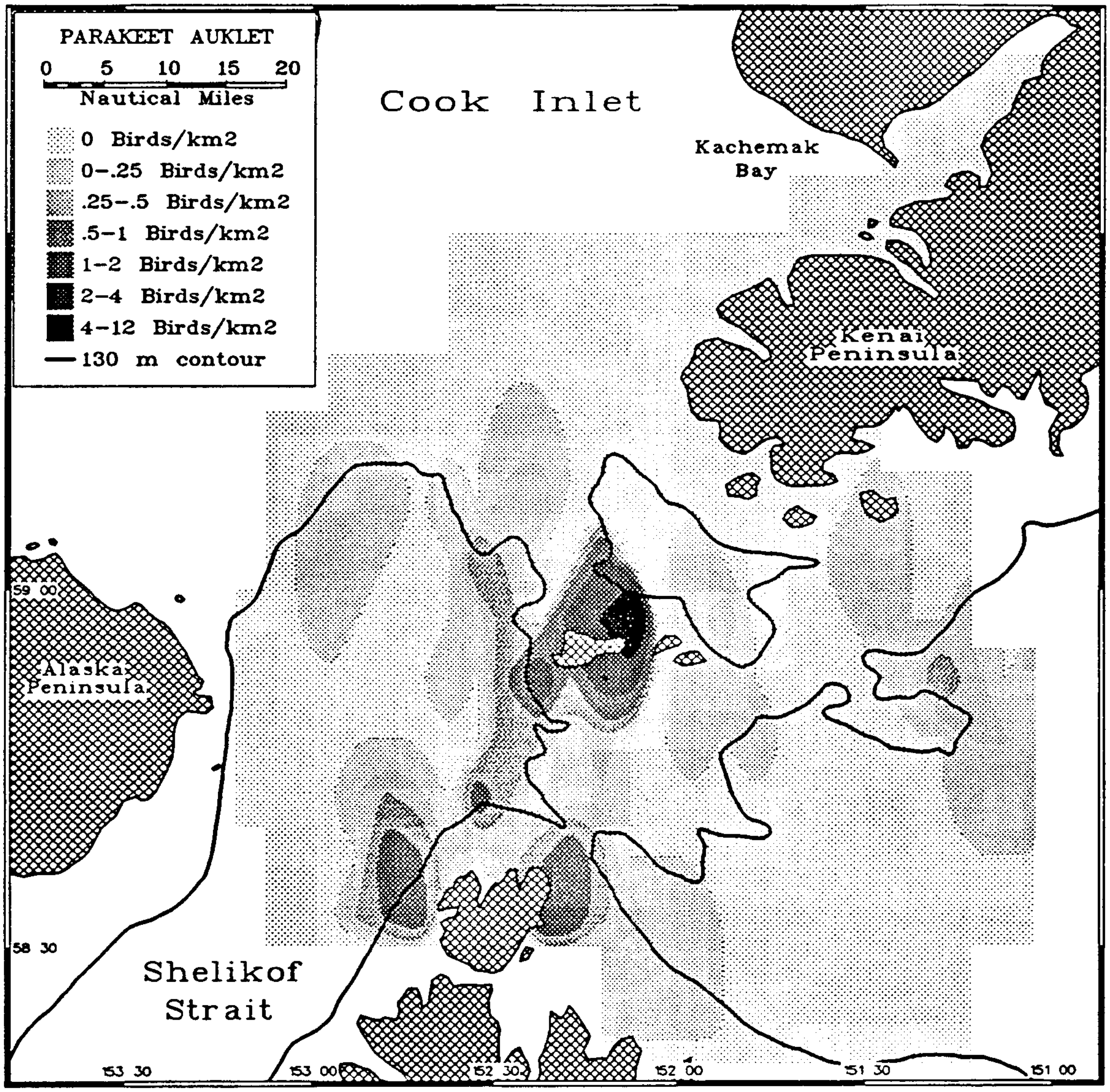


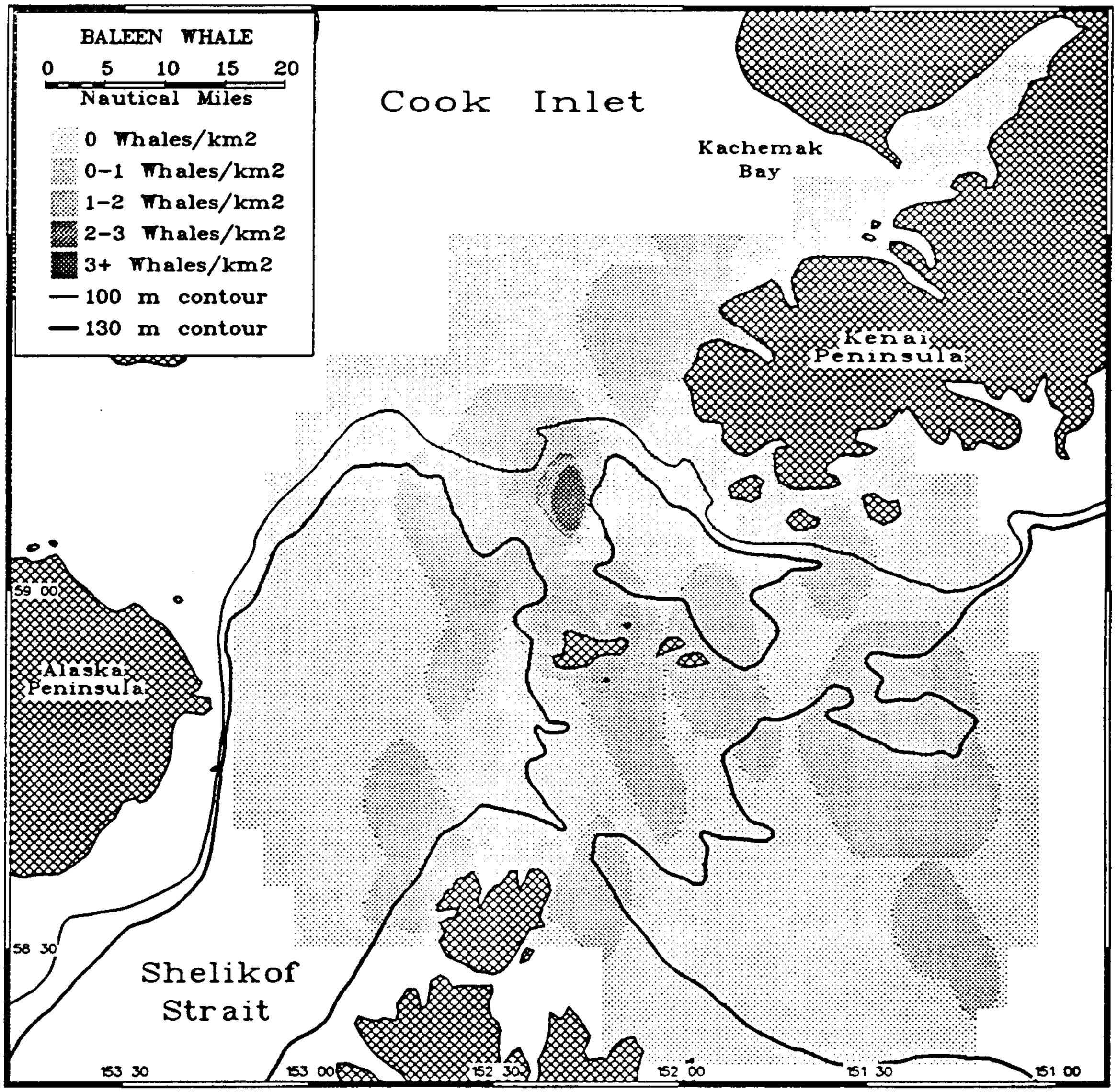
RHINOCEROUS AUKLET
0 5 10 15 20
Nautical Miles
0 Birds/km2
0-.25 Birds/km2
.25-.5 Birds/km2
.5-1 Birds/km2
1-2 Birds/km2
2-4 Birds/km2
4-12 Birds/km2
100 m contour
130 m contour
Cook Inlet
Kachemak Bay
Kenai Peninsula
Alaska Peninsula
Shelikof Strait
59 00
58 30
153 30
153 00
152 30
152 00
151 30
151 00

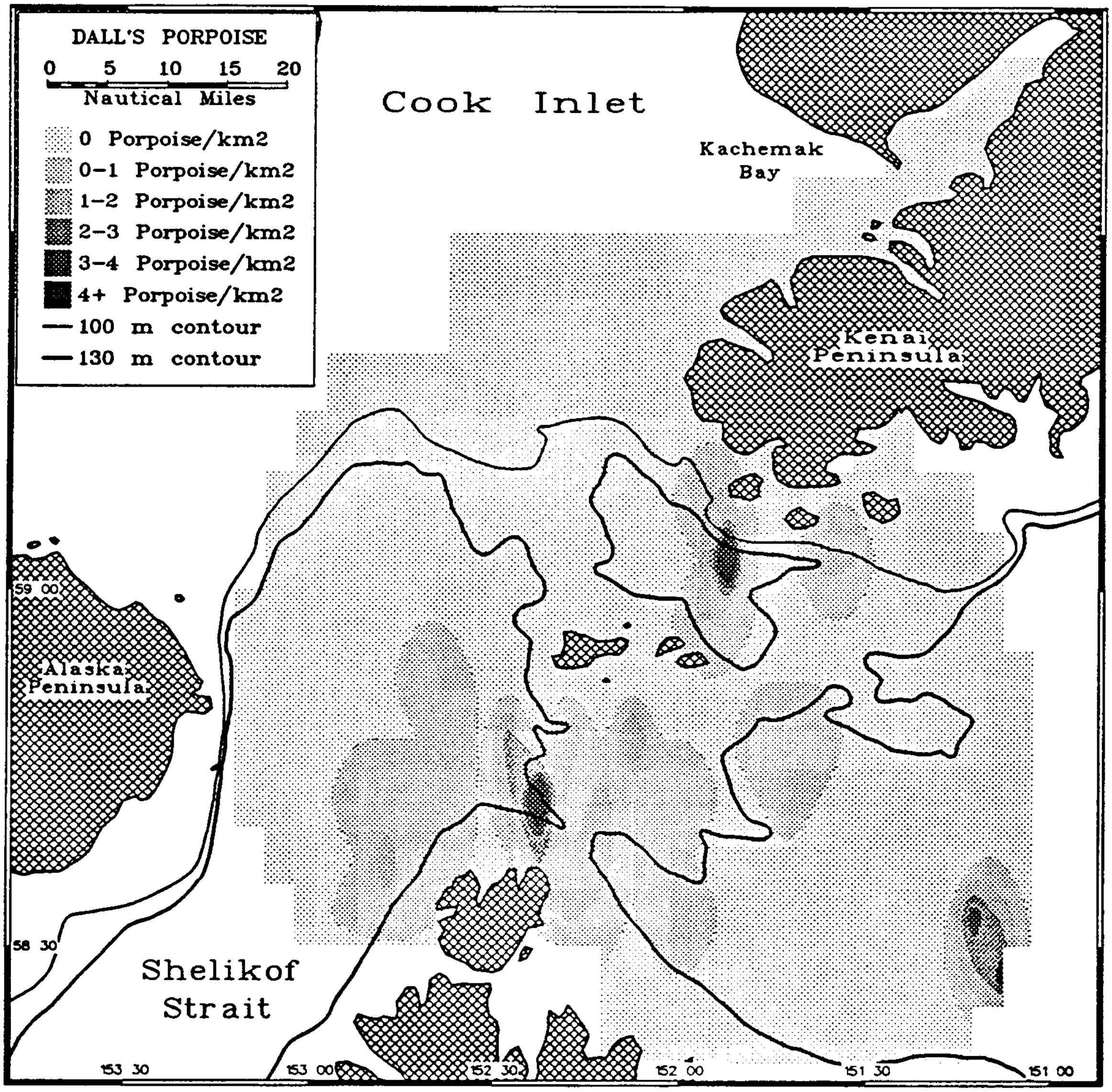

HORNED PUFFIN
0 5 10 15 20
Nautical Miles
0 Birds/km2
0-.5 Birds/km2
.5-1 Birds/km2
1-2 Birds/km2
2-4 Birds/km2
4-8 Birds/km2
8-16 Birds/km2
100 m contour
130 m contour
Cook Inlet
Kachemak Bay
Kenai Peninsula
Alaska Peninsula
Shelikof Strait
59 00
58 30
153 30
153 00
152 30
152 00
151 30
151 00

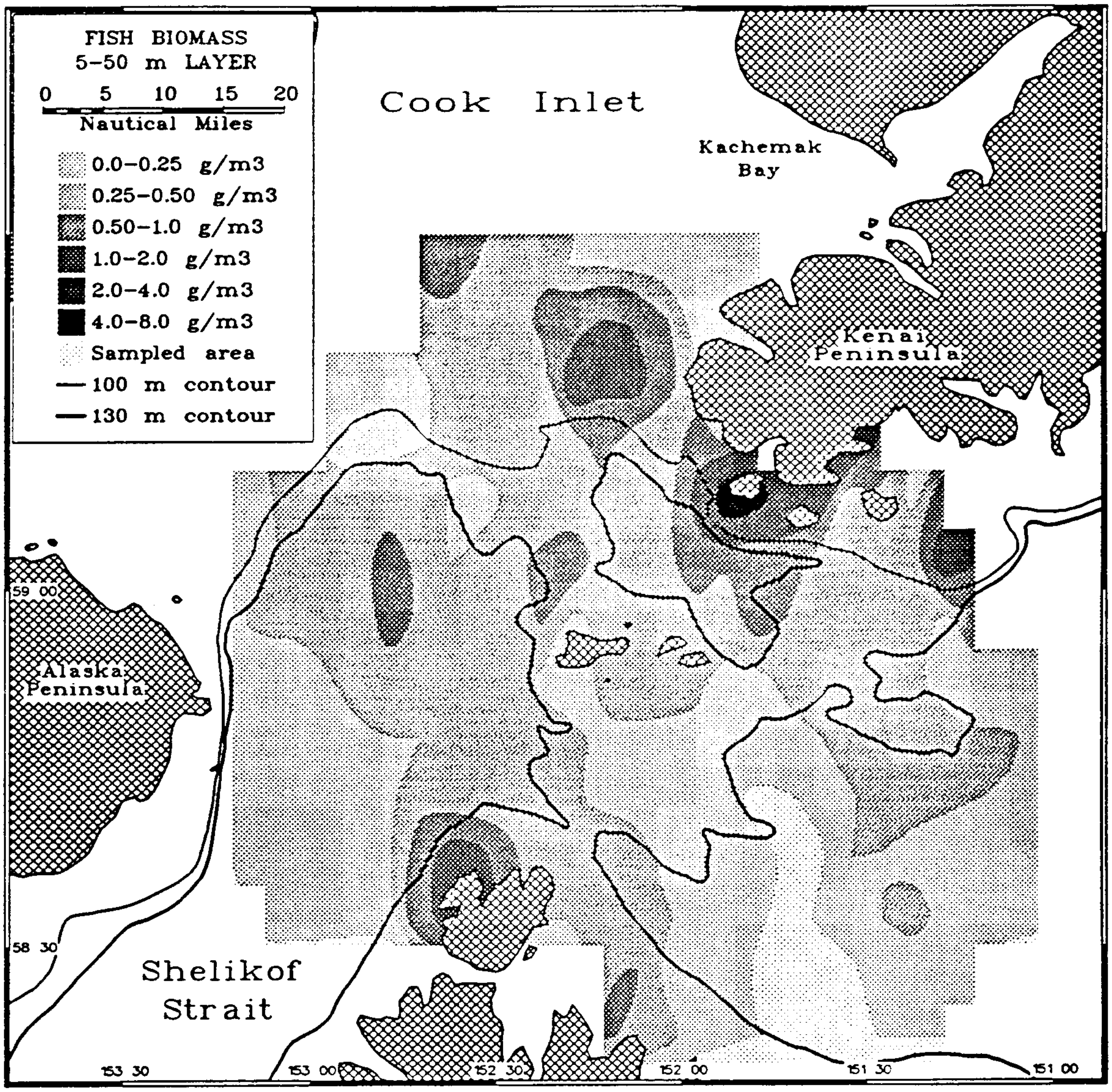


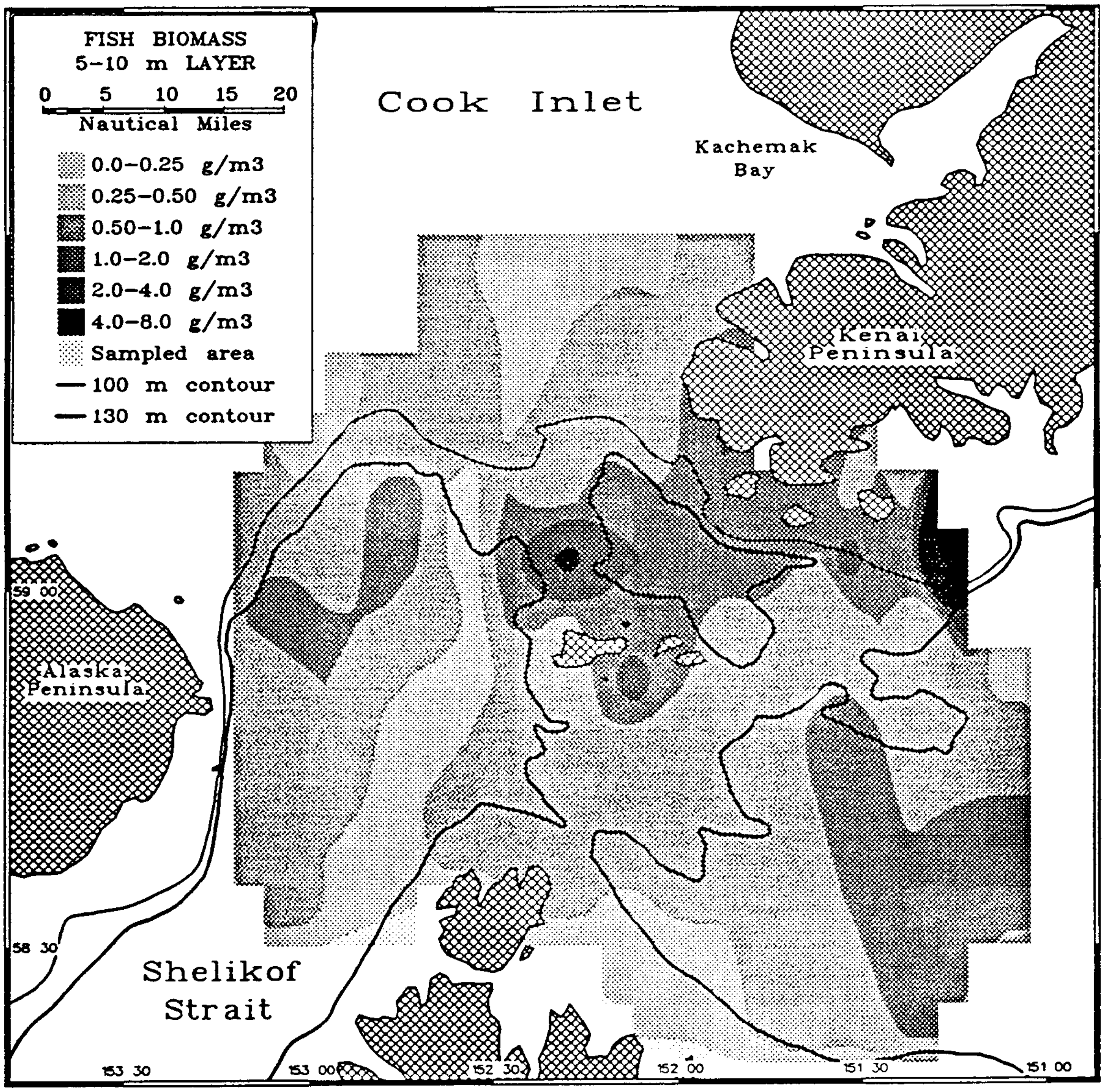
ANCIENT MURRELET
0 5 10 15 20
Nautical Miles
0 Birds/km2
0-.5 Birds/km2
.5-1 Birds/km2
1-2 Birds/km2
2-4 Birds/km2
4-8 Birds/km2
8-16 Birds/km2
130 m contour
Cook Inlet
Kachemak Bay
Kenai Peninsula
Alaska Peninsula
Shelikof Strait
59 00
58 30
153 30
153 00
152 30
152 00
151 30
151 00


PARAKEET AUKLET
0 5 10 15 20
Nautical Miles
0 Birds/km2
0-.25 Birds/km2
.25-.5 Birds/km2
.5-1 Birds/km2
1-2 Birds/km2
2-4 Birds/km2
4-12 Birds/km2
130 m contour
Cook Inlet
Kachemak
Bay
Kenai
Peninsula
Alaska
Peninsula
Shelikof
Strait
59 00
58 30
153 30
153 00
152 30
152 00
151 30
151 00

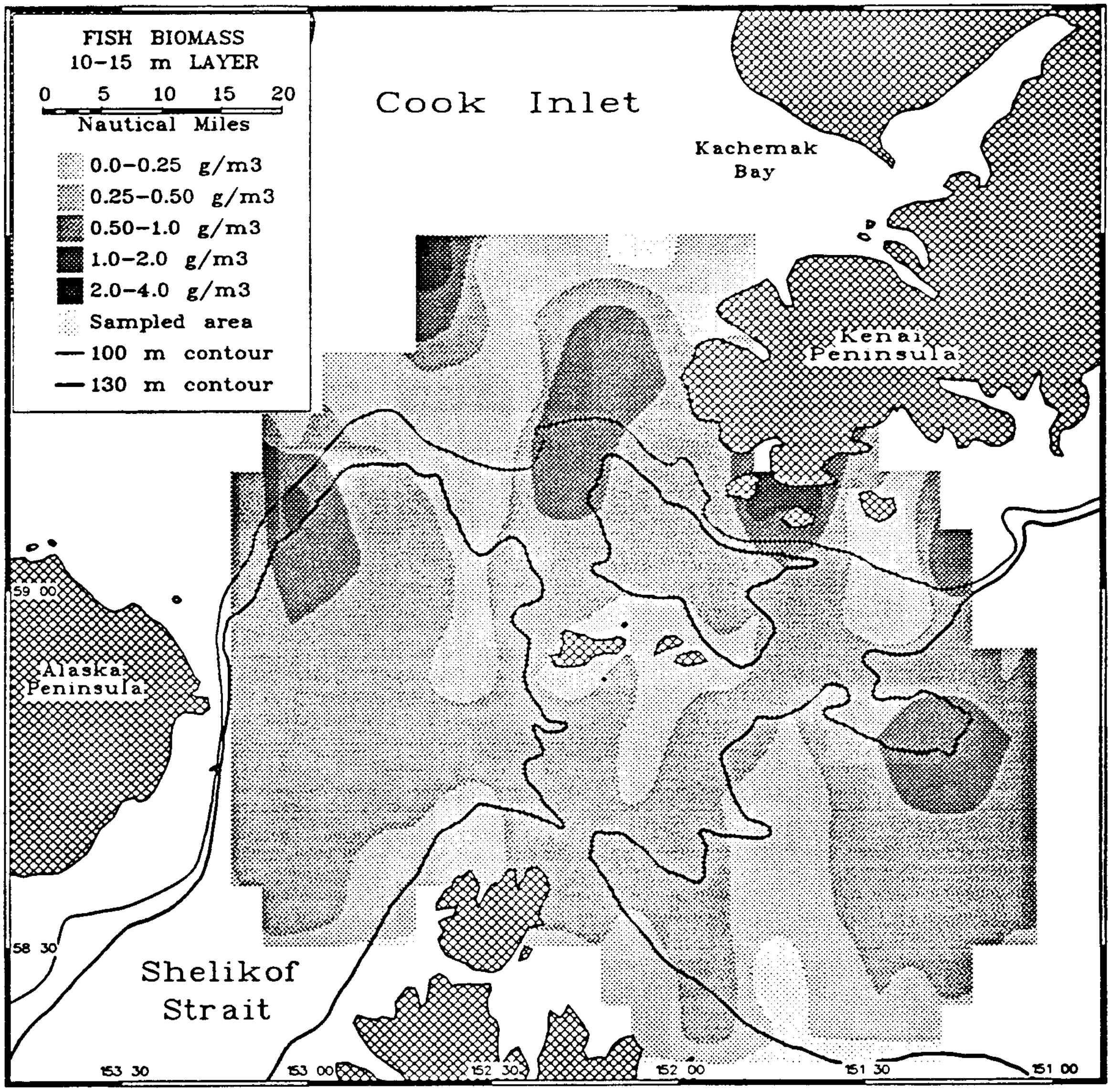

BALEEN WHALE
0 5 10 15 20
Nautical Miles
0 Whales/km2
0-1 Whales/km2
1-2 Whales/km2
2-3 Whales/km2
3+ Whales/km2
100 m contour
130 m contour
Cook Inlet
Kachemak Bay
Kenai Peninsula
Alaska Peninsula
Shelikof Strait
59 00
58 30
153 30
153 00
152 30
152 00
151 30
151 00

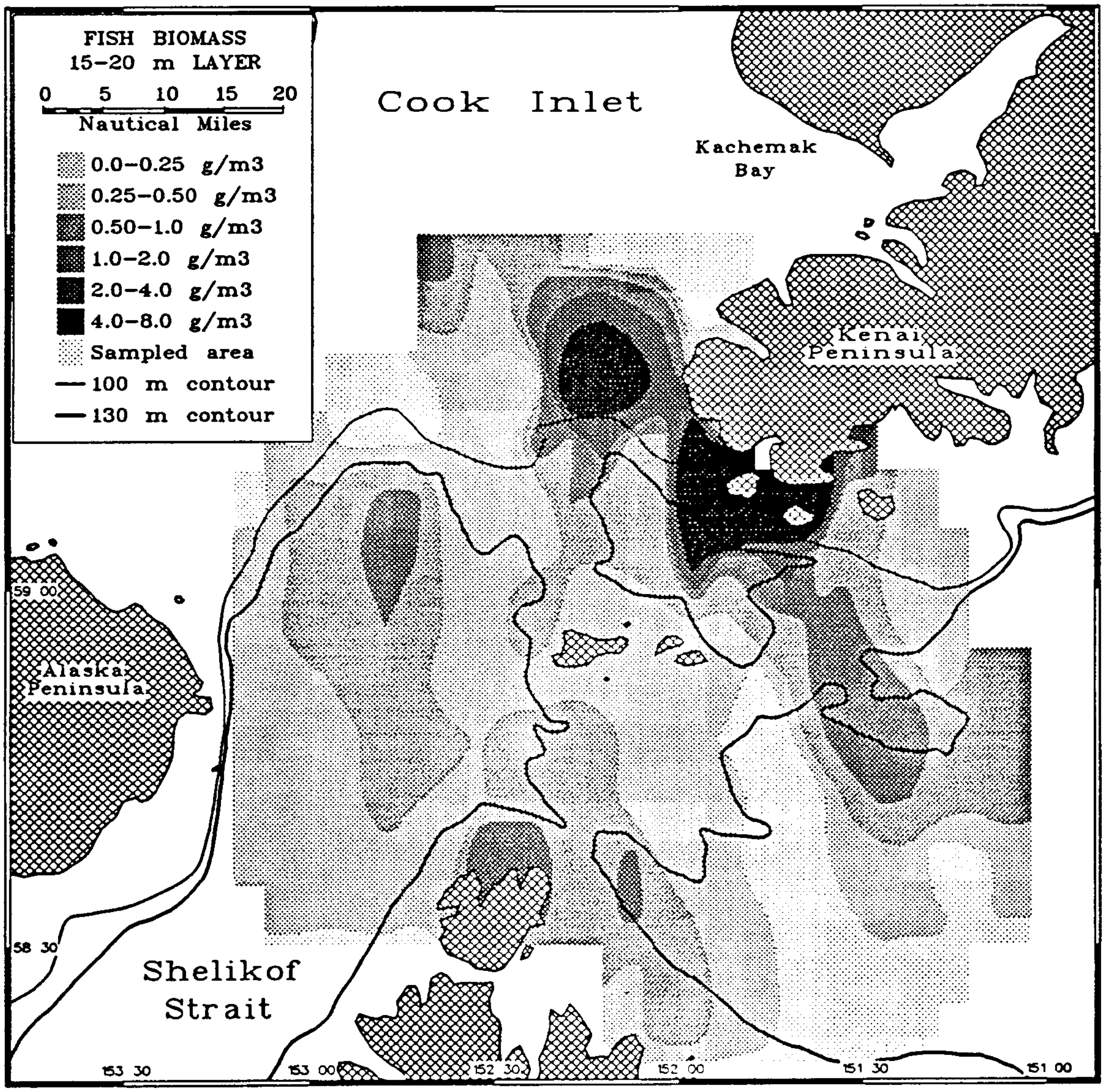

DALL'S PORPOISE
0 5 10 15 20
Nautical Miles
0 Porpoise/km2
0-1 Porpoise/km2
1-2 Porpoise/km2
2-3 Porpoise/km2
3-4 Porpoise/km2
4+ Porpoise/km2
100 m contour
130 m contour
Cook Inlet
Kachemak Bay
Kenai Peninsula
Alaska Peninsula
59 00
58 30
Shelikof Strait
153 30
153 00
152 30
152 00
151 30
151 00

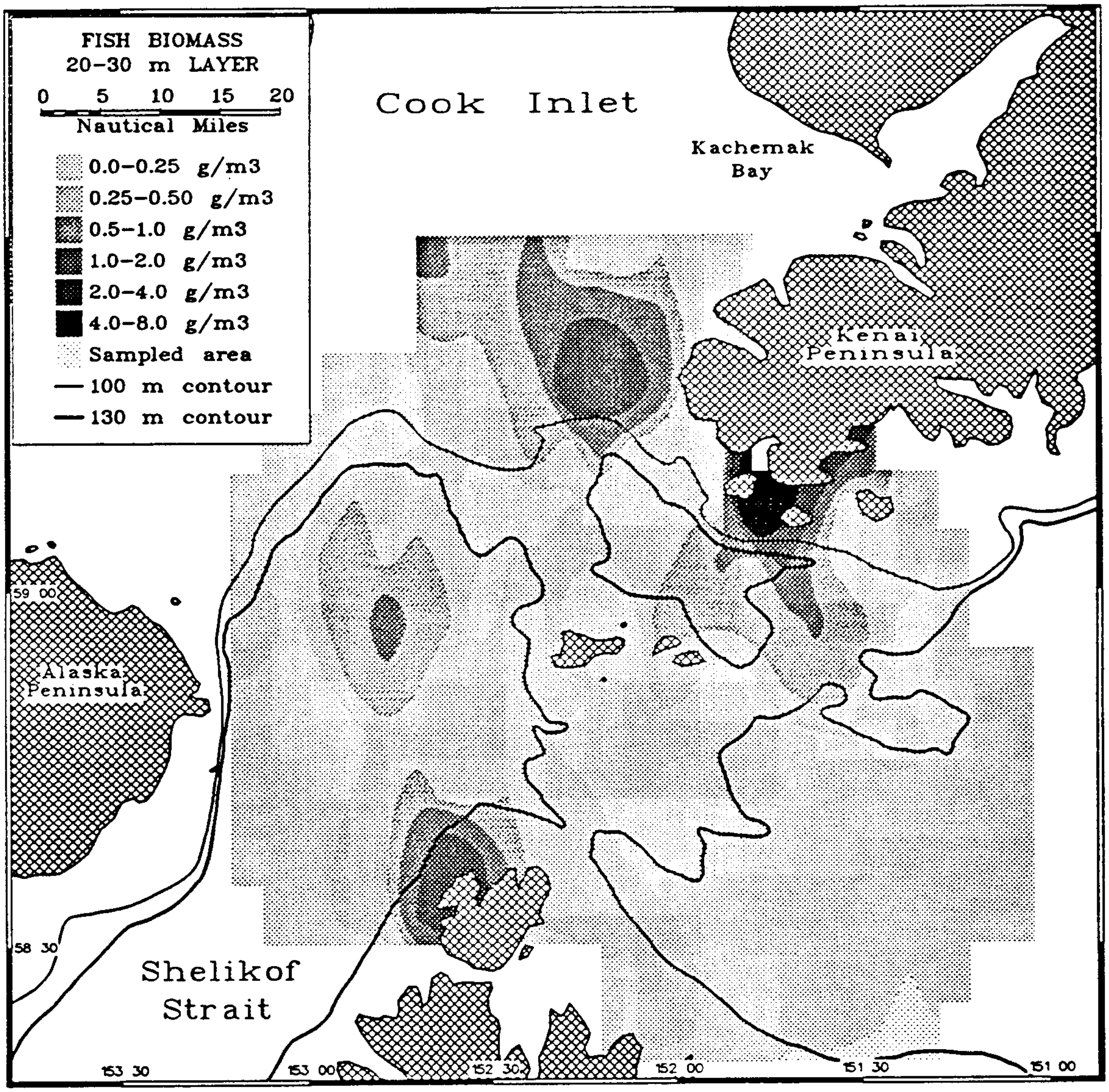

FISH BIOMASS
5-50 m LAYER
0 5 10 15 20
Nautical Miles
0.0-0.25 g/m3
0.25-0.50 g/m3
0.50-1.0 g/m3
1.0-2.0 g/m3
2.0-4.0 g/m3
4.0-8.0 g/m3
Sampled area
100 m contour
130 m contour
Cook Inlet
Kachemak
Bay
Kenai
Peninsula
Alaska
Peninsula
59 00
58 30
Shelikof
Strait
153 30
153 00
152 30
152 00
151 30
151 00

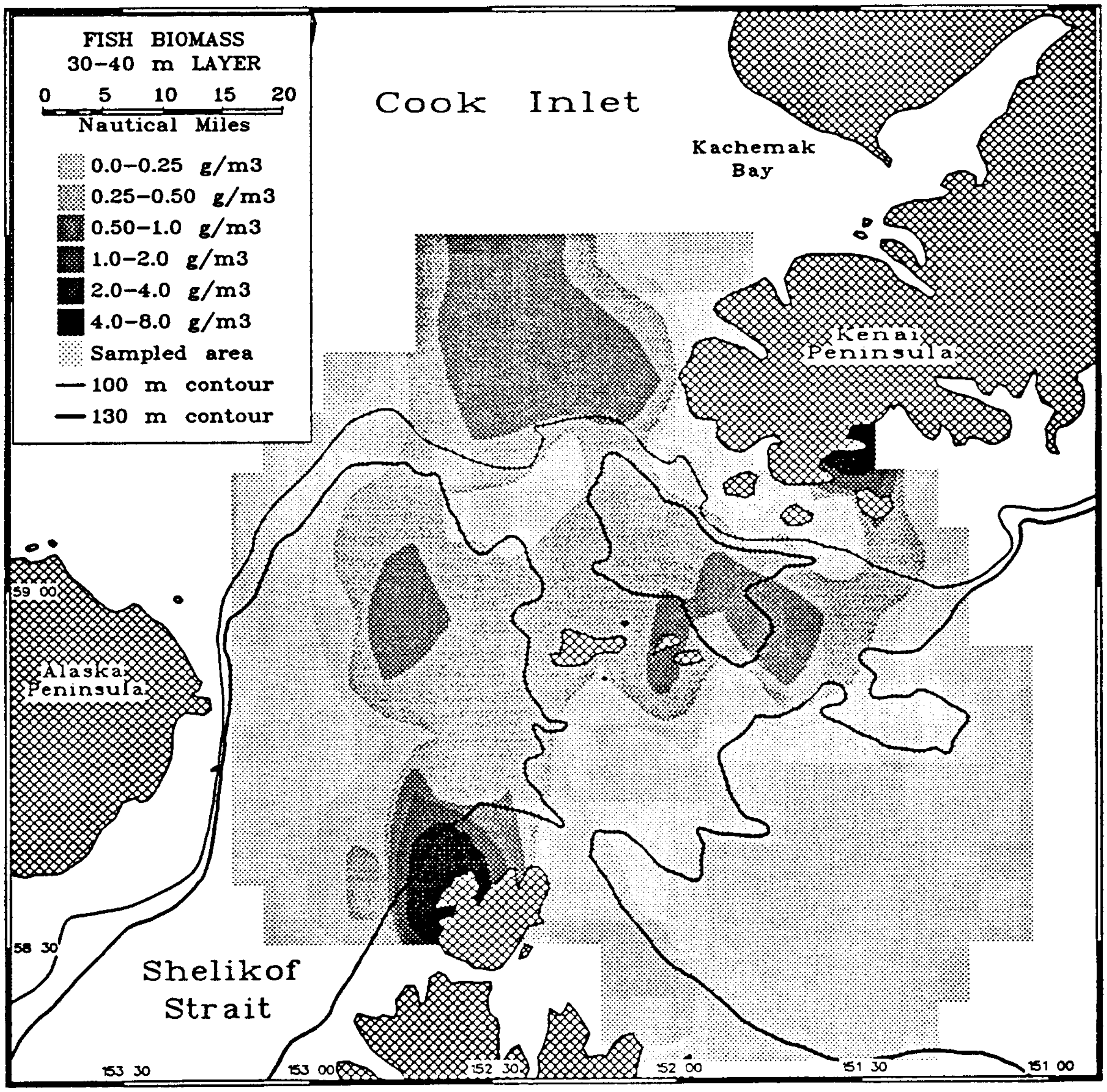


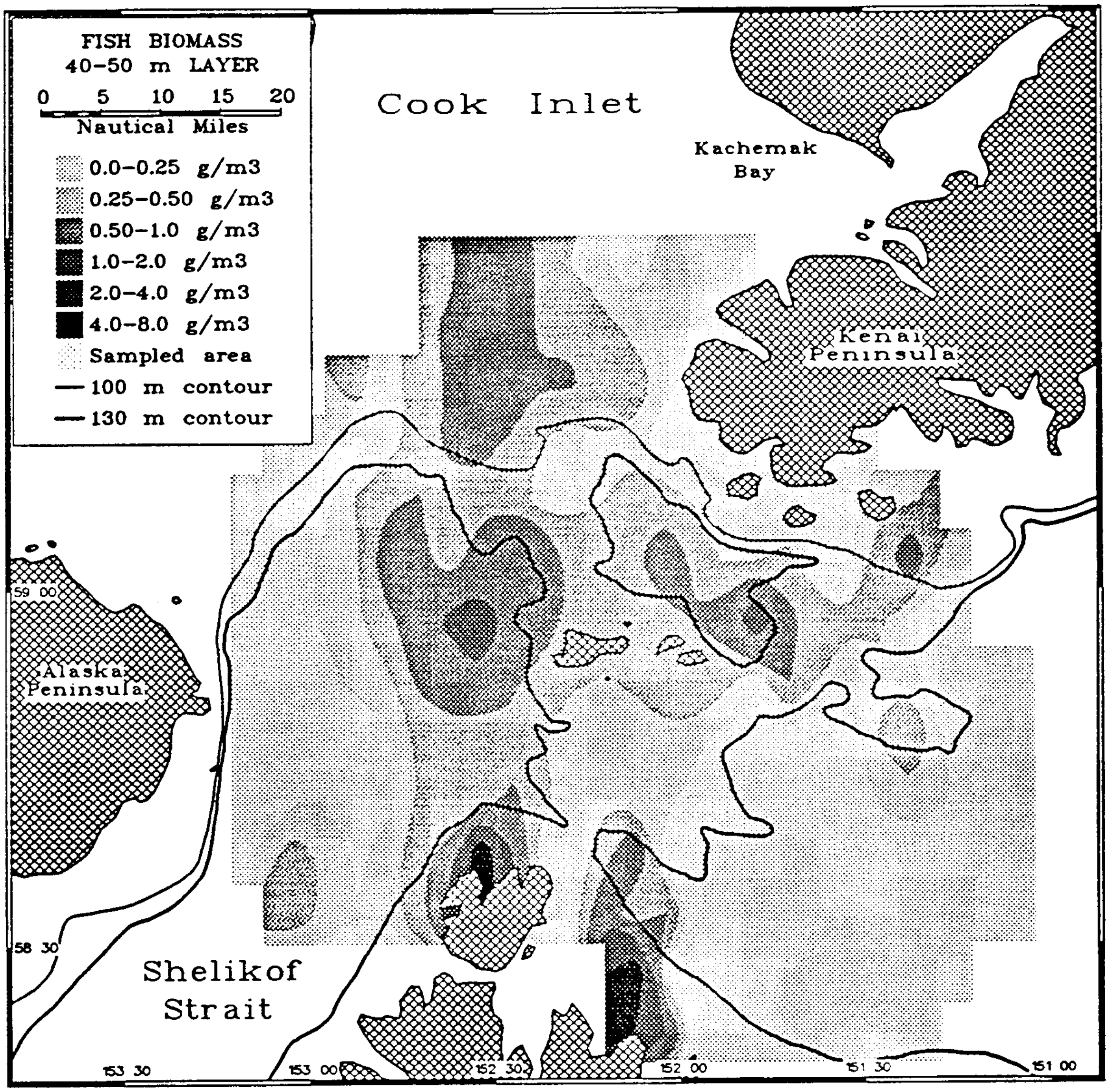
FISH BIOMASS
5-10 m LAYER
0 5 10 15 20
Nautical Miles
0.0-0.25 g/m3
0.25-0.50 g/m3
0.50-1.0 g/m3
1.0-2.0 g/m3
2.0-4.0 g/m3
4.0-8.0 g/m3
Sampled area
100 m contour
130 m contour
Cook Inlet
Kachemak Bay
Kenai Peninsula
Alaska Peninsula
Shelikof Strait
59 00
58 30
153 30
153 00
152 30
152 00
151 30
151 00

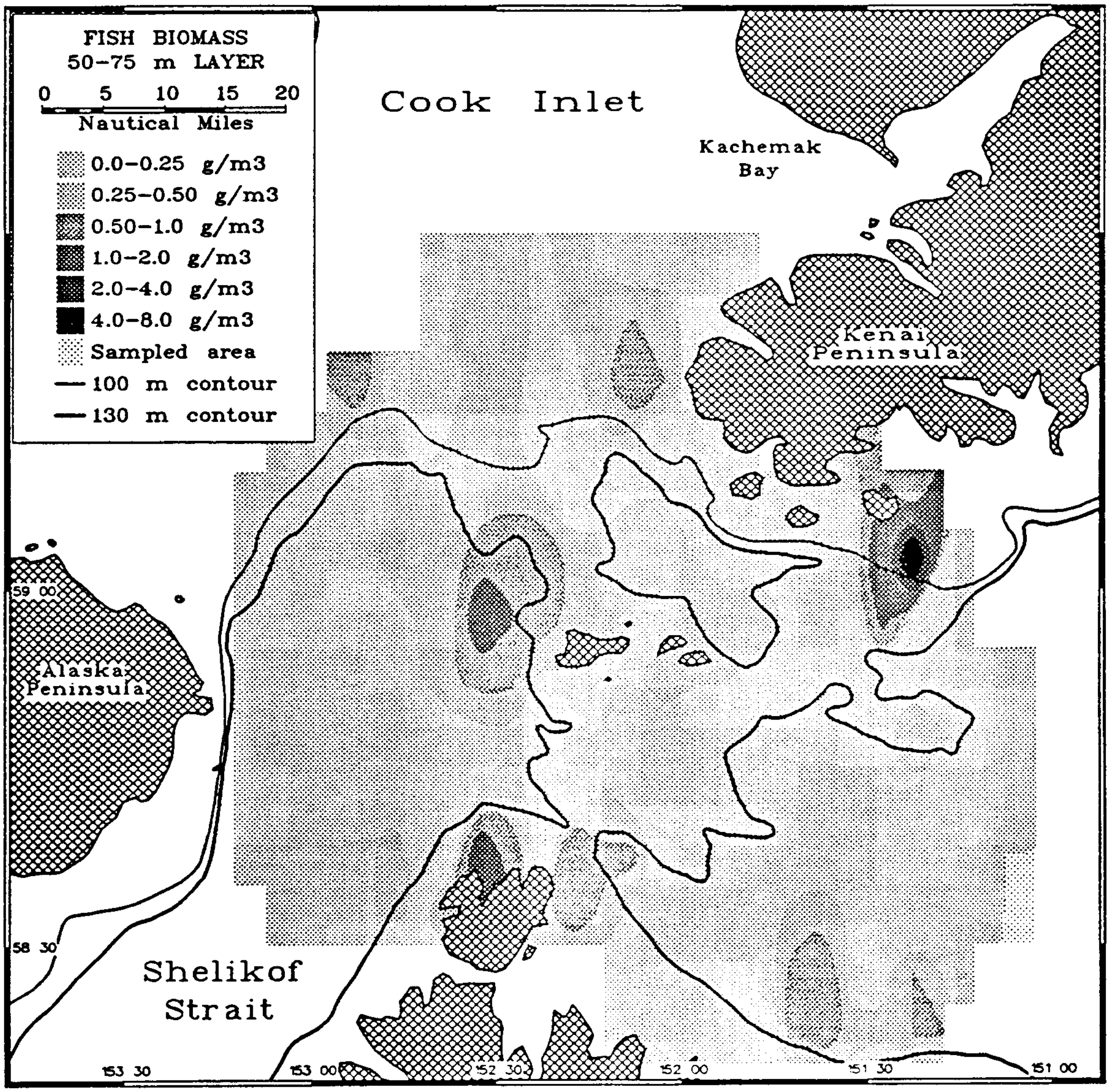

FISH BIOMASS
10-15 m LAYER
0 5 10 15 20
Nautical Miles
0.0-0.25 g/m3
0.25-0.50 g/m3
0.50-1.0 g/m3
1.0-2.0 g/m3
2.0-4.0 g/m3
Sampled area
100 m contour
130 m contour
Cook Inlet
Kachemak Bay
Kenai Peninsula
Alaska Peninsula
Shelikof Strait
59 00
58 30
153 30
153 00
152 30
152 00
151 30
151 00


FISH BIOMASS
15-20 m LAYER
0 5 10 15 20
Nautical Miles
0.0-0.25 g/m3
0.25-0.50 g/m3
0.50-1.0 g/m3
1.0-2.0 g/m3
2.0-4.0 g/m3
4.0-8.0 g/m3
Sampled area
100 m contour
130 m contour
Cook Inlet
Kachemak
Bay
Kenai
Peninsula
59 00
Alaska
Peninsula
58 30
Shelikof
Strait
153 30
153 00
152 30
152 00
151 30
151 00

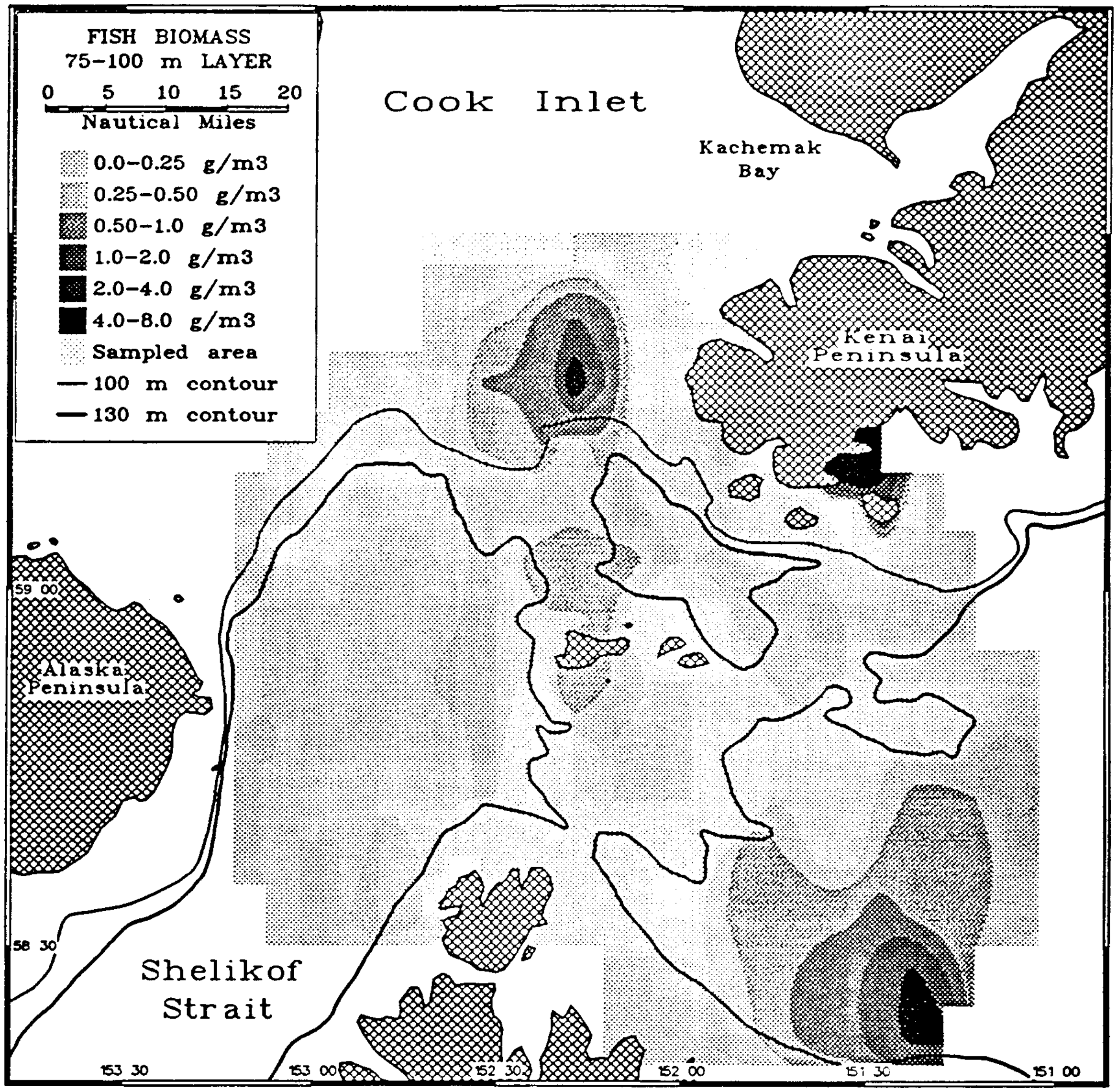

FISH BIOMASS
20-30 m LAYER
0 5 10 15 20
Nautical Miles
0.0-0.25 g/m3
0.25-0.50 g/m3
0.5-1.0 g/m3
1.0-2.0 g/m3
2.0-4.0 g/m3
4.0-8.0 g/m3
Sampled area
100 m contour
130 m contour
Cook Inlet
Kachemak Bay
Kenai Peninsula
Alaska Peninsula
Shelikof Strait
59 00
58 30
153 30
153 00
152 30
152 00
151 30
151 00


FISH BIOMASS
30-40 m LAYER
0 5 10 15 20
Nautical Miles
0.0-0.25 g/m3
0.25-0.50 g/m3
0.50-1.0 g/m3
1.0-2.0 g/m3
2.0-4.0 g/m3
4.0-8.0 g/m3
Sampled area
100 m contour
130 m contour
Cook Inlet
Kachemak Bay
Kenai Peninsula
Alaska Peninsula
Shelikof Strait
59 00
58 30
153 30
153 00
152 30
152 00
151 30
151 00

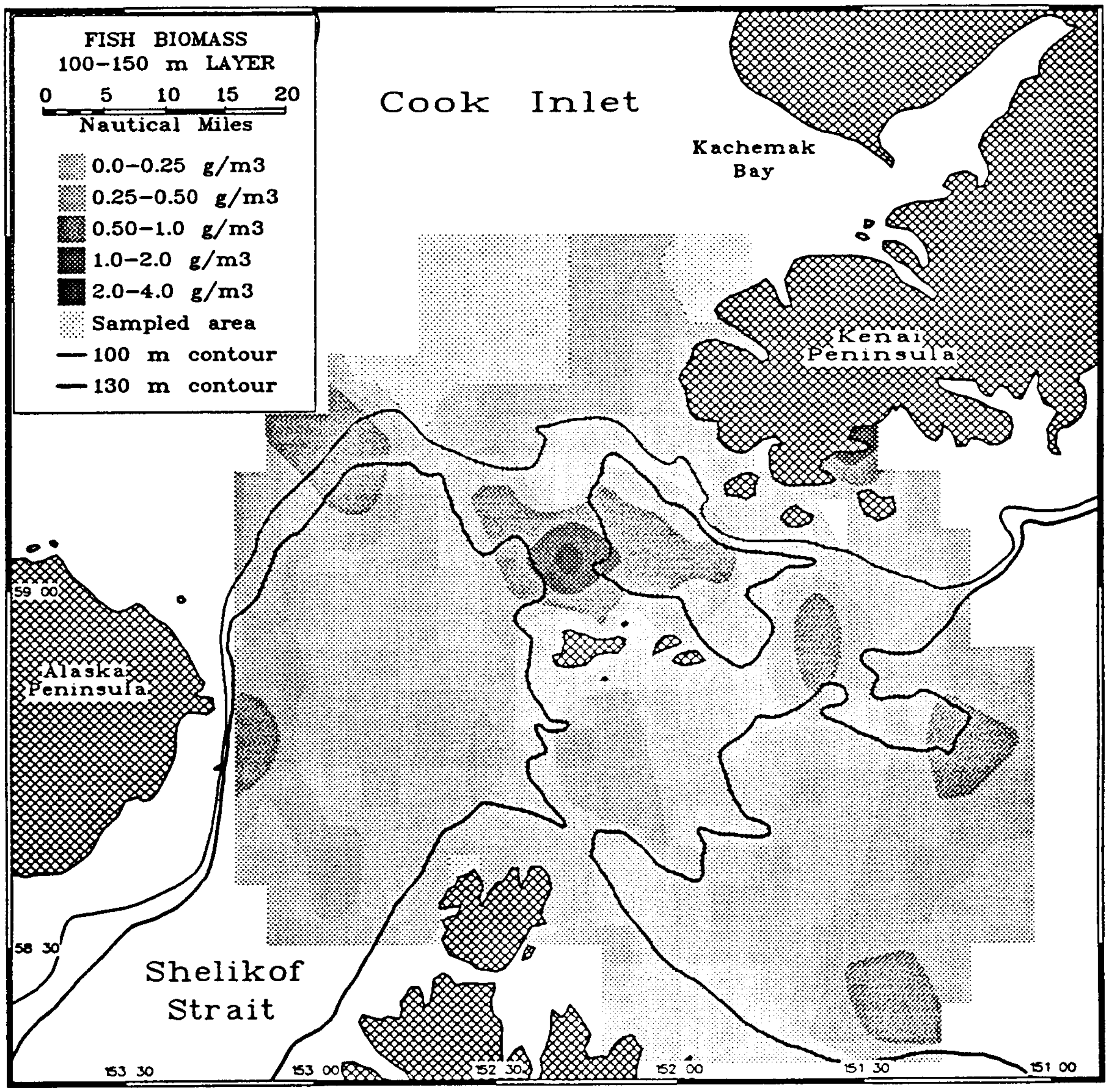

FISH BIOMASS
40-50 m LAYER
0 5 10 15 20
Nautical Miles
0.0-0.25 g/m3
0.25-0.50 g/m3
0.50-1.0 g/m3
1.0-2.0 g/m3
2.0-4.0 g/m3
4.0-8.0 g/m3
Sampled area
100 m contour
130 m contour
Cook Inlet
Kachemak Bay
Kenai Peninsula
Alaska Peninsula
Shelikof Strait
59 00
58 30
153 30
153 00
152 30
152 00
151 30
151 00

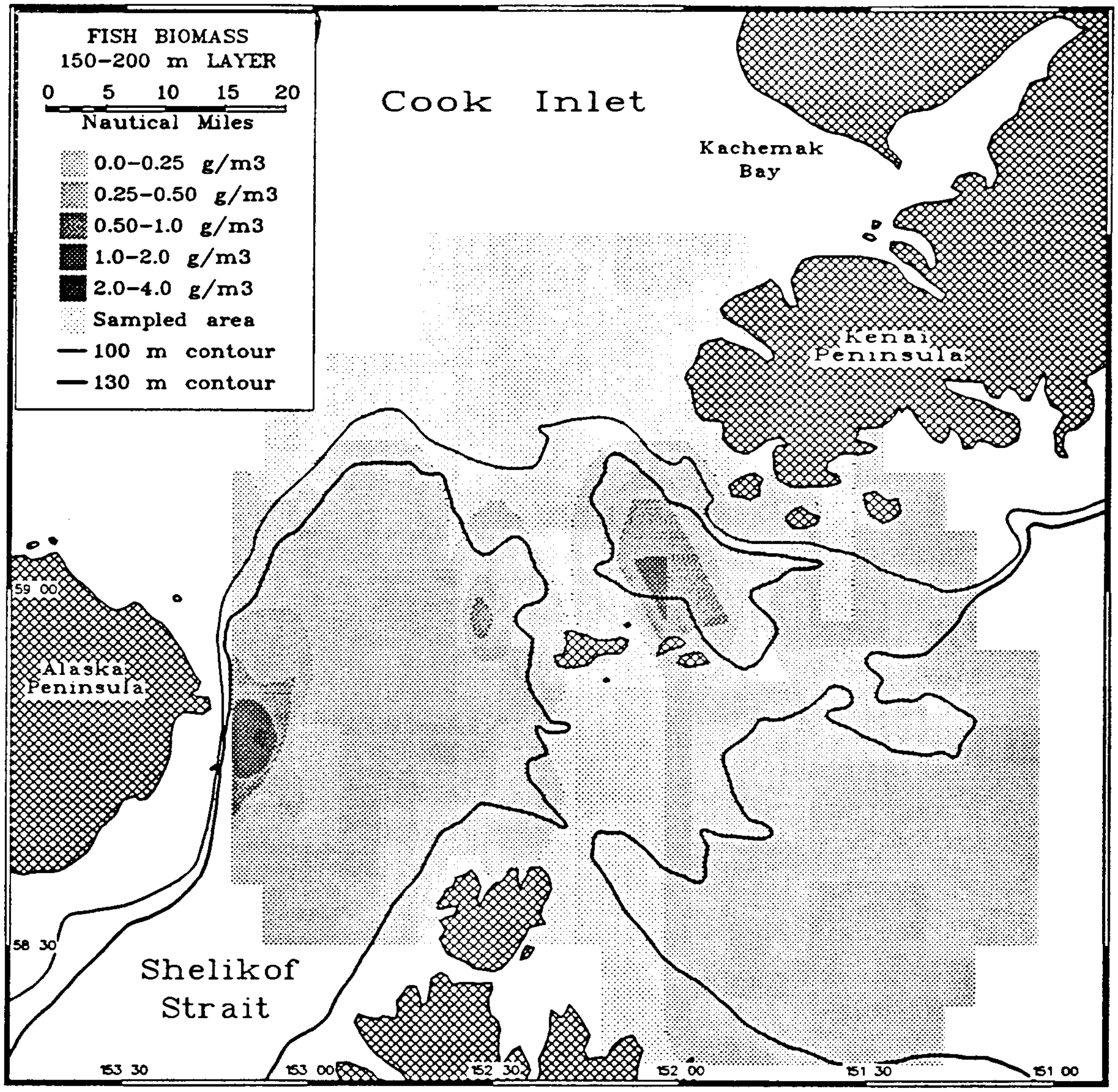


FISH BIOMASS
50-75 m LAYER
0 5 10 15 20
Nautical Miles
0.0-0.25 g/m3
0.25-0.50 g/m3
0.50-1.0 g/m3
1.0-2.0 g/m3
2.0-4.0 g/m3
4.0-8.0 g/m3
Sampled area
100 m contour
130 m contour
Cook Inlet
Kachemak Bay
Kenai Peninsula
Alaska Peninsula
Shelikof Strait
59 00
58 30
153 30
153 00
152 30
152 00
151 30
151 00



FISH BIOMASS
75-100 m LAYER
0 5 10 15 20
Nautical Miles
0.0-0.25 g/m3
0.25-0.50 g/m3
0.50-1.0 g/m3
1.0-2.0 g/m3
2.0-4.0 g/m3
4.0-8.0 g/m3
Sampled area
100 m contour
130 m contour
Cook Inlet
Kachemak Bay
Kenai Peninsula
Alaska Peninsula
Shelikof Strait
59 00
58 30
153 30
153 00
152 30
152 00
151 30
151 00


FISH BIOMASS
100-150 m LAYER
0 5 10 15 20
Nautical Miles
0.0-0.25 g/m3
0.25-0.50 g/m3
0.50-1.0 g/m3
1.0-2.0 g/m3
2.0-4.0 g/m3
Sampled area
100 m contour
130 m contour
Cook Inlet
Kachemak Bay
Kenai Peninsula
Alaska Peninsula
Shelikof Strait
59 00
58 30
153 30
153 00
152 30
152 00
151 30
151 00


FISH BIOMASS
150-200 m LAYER
0 5 10 15 20
Nautical Miles
0.0-0.25 g/m3
0.25-0.50 g/m3
0.50-1.0 g/m3
1.0-2.0 g/m3
2.0-4.0 g/m3
Sampled area
100 m contour
130 m contour
Cook Inlet
Kachemak Bay
Kenai Peninsula
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59 00
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153 30
153 00
152 30
152 00
151 30
151 00