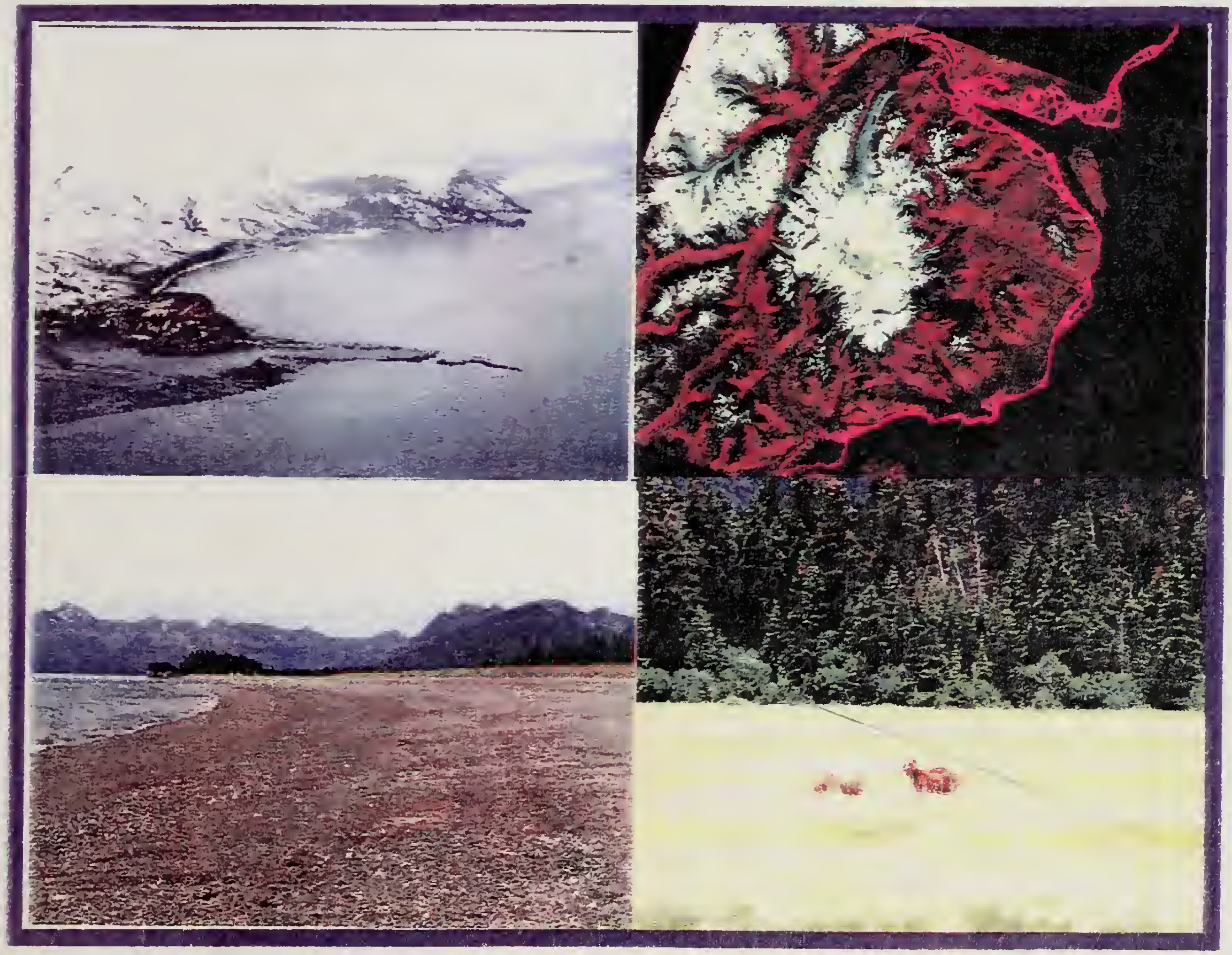
Physical & Biological Resource Inventory of the Lake Clark National Park-Cook Inlet Coastline, 1994-96



Lake Clark National Park & Preserve

Kenai Coastal Office

Physical & Biological Resource Inventory of the Lake Clark National Park-Cook Inlet Coastline, 1994-96

by

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ABSTRACT

Lake Clark National Park and Preserve contains 200 km of marine coastline in Western Lower Cook Inlet. During 1994-96, surveys were conducted to obtain basic data on intertidal habitats, and distributions and abundances of marine and near-coastal vertebrates and invertebrates. The goal of this project was to gain an understanding of the Park's coastal ecosystem and biotic processes.

Intertidal shoreline habitats were classified at a minimum spatial scale of 10 m horizontally. The shoreline was partitioned into 338 upper, 246 middle, and 207 lower intertidal polygons with homogeneous morphodynamic attributes such as wave runup, substrate character, slope angle, and aspect. The attributes of each polygon were described and quantified allowing for statistical calculations for parametric or spatial distribution modeling of nearshore habitats.

Salt marshes (32 km^2) were delineated and mapped at a scale of 1:12,000. Five attributes were interpreted for each of 1,286 map polygons: Physiographic Location - 4 classes; Site Moisture - 2 classes; Vegetation Type -27 classes; Growth Form - 8 classes; and Landscape Feature - 13 classes. These attributes may be treated as independent variables or in combination for analysis of salt marsh vegetation communities.

During spring migration, 86,000 to 122,000 shorebirds, primarily western sandpipers and dunlin, use intertidal mud flats in Tuxedni and Chinitna Bay. Density (birds/km^2) of dabbling and diving ducks in intertidal habitats was 158 ± 117 and 378 ± 178 during May respectively. Sea ducks, primarily surf and white-winged scoters, were the most numerous marine waterbirds and occurred at densities of 308 ± 171 in the intertidal and reached peak numbers (18,500) during August. Canada geese occurred only in Tuxedni Bay during September and numbered 4,400. Mallards, American Wigeon, trumpeter swans, and Barrows goldeneye constituted 40%, 16%, 14%, and 13% of the resident breeding population of waterfowl respectively. Annual reproductive rates were obtained for 10 species and ranged from 4.79 for mallards to 0.16 for arctic loons. Seven seabird colonies were identified, the largest was in Tuxedni Channel and contained 2,700 black-legged kittiwakes.

Harbor seal numbers peaked during July, 244 ± 90 animals, and 3 haulout sites (Tuxedni Bay, Chinitna Bay and Johnson River) accounted for 96% of haulout sightings. Beluga whales seasonally occurred off the mouths of glacial rivers in both bays and were most numerous (160-200 animals) during September. An average of 67 brown bears were sighted during aerial surveys of salt marshes (May-July). Brown bear density (bears/km^2) in salt marshes was 7.1 at Glacier Spit marsh in Chinitna Bay and 5.2 in marshes on the south side of Tuxedni Bay.

Intertidal mud flats in Chinitna and Tuxedni Bays supported large to moderate standing crops of suspension and deposit feeding invertebrates. Eighteen species of Polychaeta, 7 species of Mollusca and 12 species of Crustacea were identified in the samples from Chinitna Bay. Infauna in both bays was dominated by the clam <u>Macoma balthica</u>. Density (animals/m^2) of <u>M. balthica</u> in Chinitna Bay exceeded 3,500 individuals west of Seal Spit and averaged 2,033 on mud flats throughout the bay. The trophic relationship between shorebirds, sea ducks, diving ducks and <u>Macoma</u> may be the most significant near coastal predator-prey linkage along the Lake Clark National Park-Cook Inlet Coastline.

New and existing coastal resource data was compiled into a digital database/geographical information system (GIS) on CD-ROM. Data layers developed and projected for Lake Clark National Park-Cook Inlet Coastline GIS include: land status, bathymetry, topography, surface hydrology, nearshore rocks, intertidal shoreline segments, geomorphology, salt marsh vegetation, beach profile transects, invertebrate sample sites, waterbird density, raptor nests, seabird colonies, and harbor seal haulouts.

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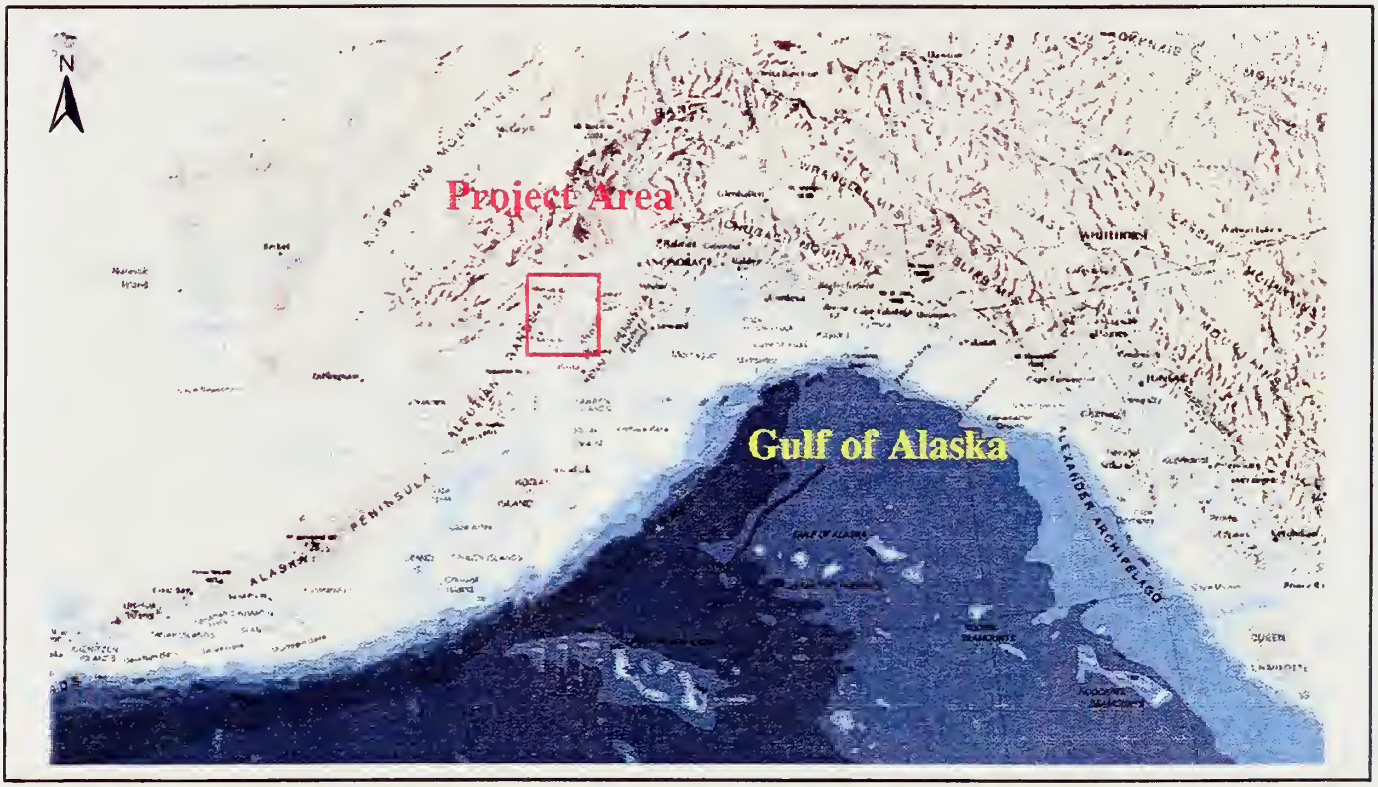


Lake Clark National Park-Cook Inlet Study Area

INTRODUCTION

Lake Clark National Park and Preserve (LACL) is approximately 1.4 million hectares and was established in 1980 by the Alaska National Interest Lands Conservation Act (Lands Act). It is located on the Alaska Peninsula along the western shore of Cook Inlet. The marine shoreline of the Park extends north from Chinitna Bay approximately 200 km to Redoubt Point (Figure 1a). This segment of coastline and near-shore islands (Chisik, Duck, & Gull Islands which are managed by the U.S. Fish & Wildlife Service) are among the most important and biologically productive ecosystems in the Gulf of Alaska (Hood and Zimmerman 1986).

Bird and mammal populations, coastal habitats and ecology of the Lake Clark coastline are poorly understood. LACL did not experience direct contamination from the 1989 Exxon Valdez Oil Spill, and consequently received no post-spill damage assessment or resource inventories. Previous survey work has been limited to intertidal invertebrates, coastal geomorphology, and archeology. No systematic surveys have been conducted for birds, terrestrial mammals, or marine mammals. One of the purposes for the establishment of LACL as stated in the 1980 Lands Act was "....to protect populations and habitats of brown/grizzly bears, bald eagles, peregrine falcons, sockeye salmon....." (Section 201(7a) ANILCA).

Available information suggests that the vast intertidal mud flats that characterize much of the Lake Clark coastline are of great importance to resident and migratory birds. A survey conducted in 1980 revealed that Tuxedni Bay had the second highest bird density (332 birds/km^2) in Lower Cook Inlet (Arneson 1980). Shorebirds accounted for 56 percent of these birds during spring migration. Chisik and Duck Islands which lie two km off the LACL coast supports 20,000 black-legged kittiwakes (<u>Rissa tridactyla</u>) and is the largest seabird colony in Cook Inlet (Slater et al. 1995). The LACL coastline also supports nesting seabirds and is a major feeding area for the Chisik Island colonies.

Salt marshes at the heads of Chinitna and Tuxedni Bays are rated as critical spring habitat for brown bears (<u>Ursus arctos</u>) (Hamilton et al. 1980). Although no formal population surveys have been conducted, densities appear high, with as many as 34 brown bears observed at one time in western Tuxedni Bay during July 1992 (LACL unpubl. records).

Marine mammals known to use the LACL coastline include harbor seals (<u>Phoca vitulina</u>), Steller's sea lions (<u>Eumetopias jubatus</u>), killer whales (<u>Orcinus orca</u>), minke whales (<u>Balaenoptera acutorostrata</u>), and beluga whales (<u>Delphinapterus leucas</u>). Steller's sea lions are threatened and harbor seals are a candidate for threatened status due to sustained population

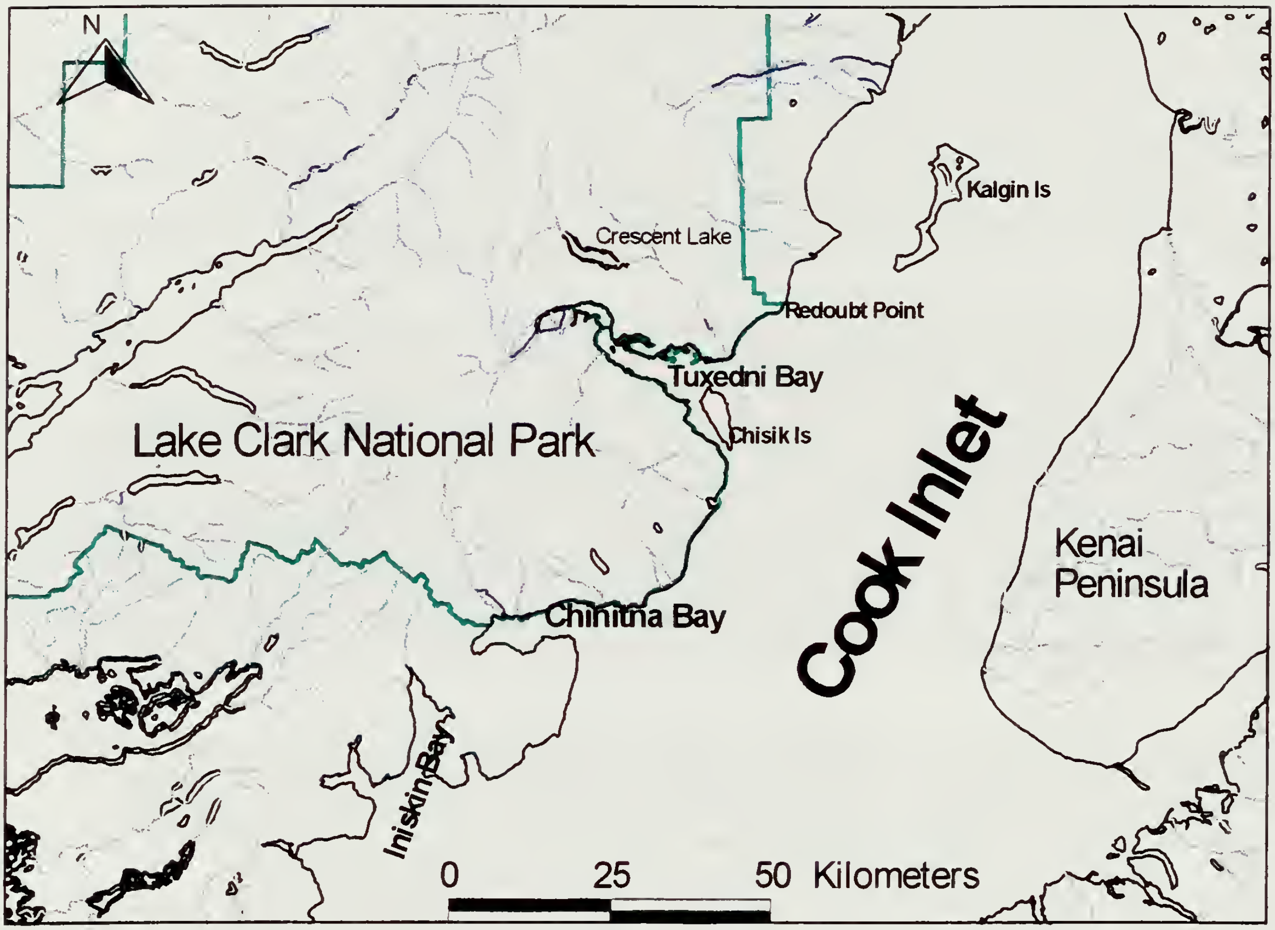


Figure 1a. Coastline of Lake Clark National Park.

declines. Terrestrial mammals that commonly forage in intertidal and coastal habitats include brown bear (Ursus arctos), black bear (U. americanus), mink (Mustela vison), and river otter (Lutra canadensis).

Cook Inlet currently supports Alaska's largest developed oil field outside of the Kuparuk and Prudhoe Bay fields on the Beaufort Sea. Existing and proposed petroleum development pose an extreme risk to coastal birds and mammals in lower Cook Inlet. Potential hazards include drilling platforms, offshore tanker loading, refineries, tanker traffic, oil storage, and fishing fleets. Because much of the LACL coast is characterized by embayed or protected shorelines, 52% has been classified as highly vulnerable to oil spill damage (Michel et al. 1978).

Mt. Redoubt and Mt. Iliamna are part of an active chain of volcanoes in LACL. From December 1989 to April 1990 volcanic explosions from Mt. Redoubt produced pyroclastic flows that swept across the Redoubt's heavily glaciated north slope. The resulting debris flow down the Drift River threatened the Drift River Marine Terminal. This onshore facility is 24 km north of the Park's boundary and stores 1.4 million barrels of crude oil.

Land status along the LACL coastline is complex because large blocks of land were conveyed to native corporations under the Lands Act (Figure 1b). In 1997, native village corporations will begin logging 10 million board feet of timber from the Crescent River drainges. To support this operation, a large marine log transfer facility will be constructed within the intertidal zone of Squarehead Cove, Tuxedni Bay. Development of a gold and copper mine on a private inholding at the headwaters of the Johnson River may occur within the next 5 years. This project has the potential to become the largest commercial mining operation within an Alaskan Park. Due to the proximity of the mine and support network of roads and ore stockpiles to the Johnson River, there is a high potential for contaminants to reach the Johnson River estuary and from there be transported along the coastline by prevailing tidal currents.

The LACL coast is known to support numerous summer resident and overwintering species that are vulnerable to oil spills and other environmental contaminants including grebes (Podiceps sp.), cormorants (Phalacrocorax sp), loons (Gavia sp), harlequin (Histrionicus histrionicus) and scoter ducks (Melanitta sp.), pigeon guillemots (Cepphus columba), horned puffins (Fratercula corniculata), black oystercatchers (Haematopus bachmani), black-legged kittiwakes and bald eagles (Haliaeetus leucocephalus). These species are at high risk because they feed extensively in intertidal habitats or consume mussels and other invertebrates that become contaminated with oil (EVOS 1992). Post-spill studies from the Exxon Valdez Spill revealed that harlequin and scoter ducks used intertidal and shallow subtidal habitats that

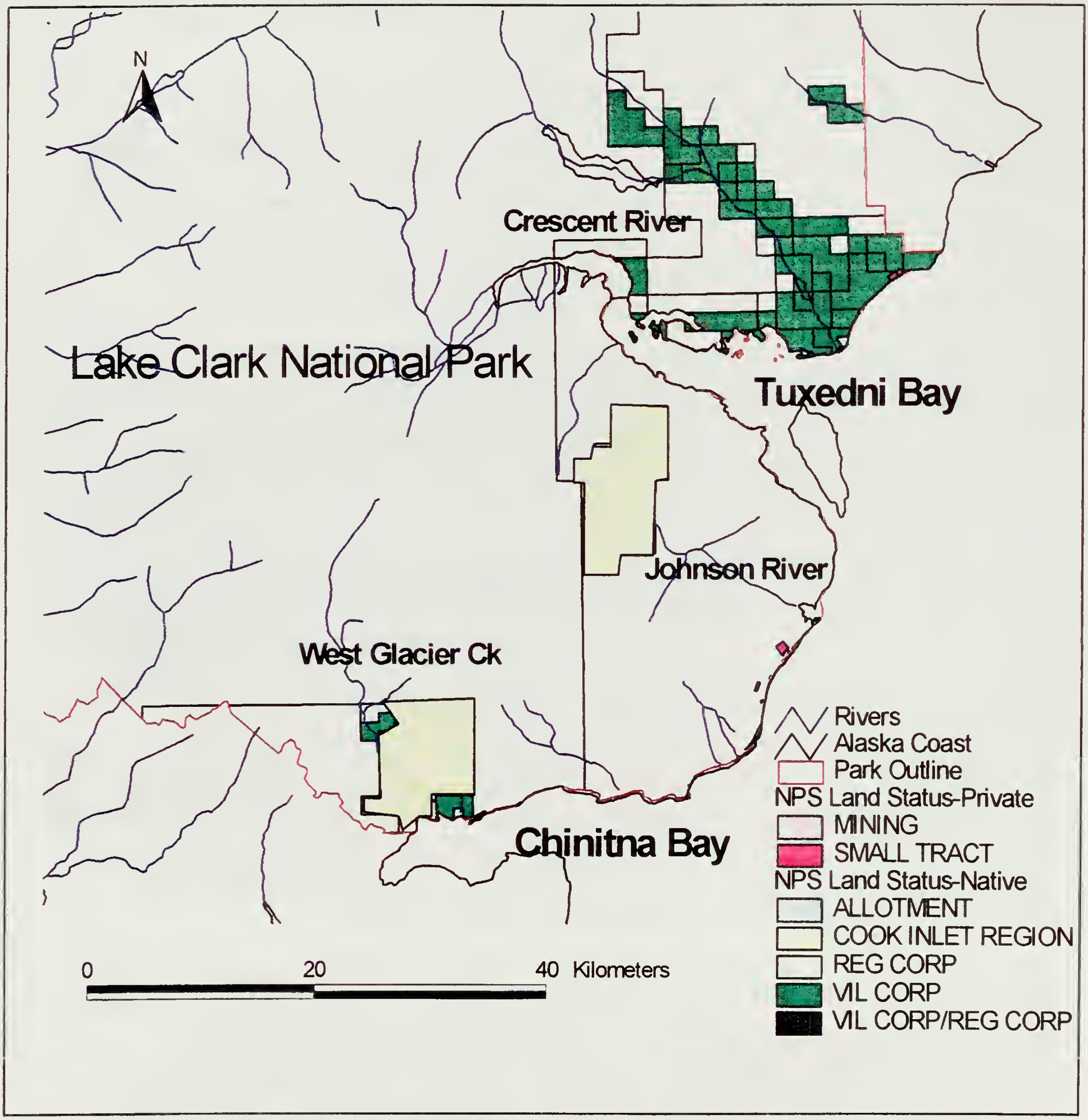


Figure 1b. Land status along the Lake Clark National Park-Cook Inlet coastline.

were most heavily affected by the spill. As a result, harlequin ducks have exhibited population declines and reproductive failure throughout the spill area (Crowley 1991).

The benthic bivalves Mytilis and Macoma are major foods of shorebirds and sea ducks in the Cook Inlet area, and both have been shown to concentrate hydrocarbons in unusually high levels. An oil spill during periods of peak migration could directly oil thousands of shorebirds. Black-legged kittiwakes are experiencing reproductive failure throughout their range in Alaska (Hatch et.al. in press). The proposed tidewater loading site for the Johnson River Mine is directly adjacent to the kittiwake nesting colony.

The objectives of this project were to (a) collect baseline data on bird, mammal and invertebrate species composition, distribution, seasonal abundance, annual productivity, and classify intertidal habitats along the LACL coastline; and (b) to compile new and previously collected data into a single coastal resource data base. This data base will be used to assign sensitivity values and priorities for containment and cleanup in the event of an oil spill, and to support the development of long term population monitoring programs for high risk species and habitats.

PROJECT AREA

Cook Inlet is a large tidal estuary with a length of 280 km and a width ranging from 20 to 90 km. Water depth averages about 60 m with a maximum of about 100 m near the entrance to less than 20 m near the head of the estuary. It is bordered on the west and northwest by the Alaska Range, on the northeast by the Talkeetna Mountains, on the southwest by the Aleutian Range, and on the southeast by the Kenai-Chugach Mountains. Cook Inlet can be divided into three distinct regions: the head, consisting of Knik and Turnagain Arms; upper Cook Inlet, extending from the Forelands to Point Woronzof; and lower Cook Inlet, from the Forelands to the Gulf of Alaska.

Cook Inlet is an extremely dynamic, high-energy estuarine environment. The tides in the inlet are characterized by two highs and lows of unequal height in each period of approximately 25 hours (Dames and Moore, 1978). The normal tidal cycle, completed in just over 12 hours, has an average height ranging from about 5.5 m in Kachemak Bay to 8.8 m at Anchorage. Extreme high tides can be in excess of 11 m, making the tidal ranges in Cook Inlet among the largest in the world (Britch 1976; Brower et al 1988).

Assuming an average tide of about 7 m in upper Cook Inlet, the total amount of water flushing into upper Cook Inlet from lower Cook Inlet during the tidal flow, and then flushing out past the Forelands during the ebb tide, is about 5.7 X 1012 liters. This tremendous, twice-daily tidal flux produces very strong tidal currents. Currents of 8 to 12 knots are common near the Forelands, while 1- to 2-knot currents prevail in the southern part of upper Cook Inlet (MMS 1984). Greater velocity for ebbing tides is caused by asymmetry of the tidal cycle and greater velocities necessary to move the same volume of water in a thin and narrow water column rather than in a thick and wide water column.

The Aleutian low pressure system prevails over the North Pacific from October to March and dominates the weather patterns of southcentral Alaska. This semi-permanent feature accounts for the numerous storms that traverse the Gulf of Alaska. Gales blow 10-15% of the time during November and December and may have sustained winds of 60-70 knots. Deep water wave heights can reach 6-9 meters in November, the stormiest month. Three or four winter storms per month move from the Asian mainland towards the Aleutians and into the Bering Sea or the Gulf of Alaska. From April to September the Aleutian Low gradually weakens. Storms still occur but are less frequent and intense. Winds of gale force can be expected twice a month (Brower et al.,1977).

The North Pacific Current flows east from the north coast of

Japan. In the vicinity of British Colombia this current splits with a north flowing component following the coast in a counterclockwise rotation around the Gulf of Alaska. At Hinchinbrook Entrance, the Alaska Current remains offshore continuing the counterclockwise rotation around the Gulf (Reed et al., 1986). In Prince William Sound, the Alaska Coastal Current flows southwest and is thought to be driven by massive amounts of fresh water runoff from the numerous rivers and glaciers flowing into the Gulf (Royer et al., 1989). The coastal current exits Prince William Sound between Montague Island and Latouche Island, and follows the coast westward through Shelikof Strait with a branch flowing north into Cook Inlet.

Cook Inlet is located in southcentral Alaska and is exposed to the Gulf of Alaska and the severe maritime weather generated in the North Pacific Ocean . The Coastal Section includes all of the western shoreline of Cook Inlet, from Kamishak Bay at the south boundary to Knik Arm at the north. This is primarily a linear coast broken by numerous fjords, bays and inlets. The mean surface water temperature ranges from a high of 11.7 degrees (C) in July to 0.7 degrees (C) in January. The local weather is strongly influenced by the adjacent Chigmit Mountains and Aleutian Range.

Dominant winds through Shelikof Strait and Cook Inlet are generally aligned with the trend of the shoreline (SW to NE) and no one direction prevails (NOS, 1987). Northeast winds generally bring rain and heavy weather, but winds of greater force come from the southwest and bring clear weather. Gales in this region generally last from 1-3 days without intermission. Seas and winds are generally much higher and stronger on the western side of the inlet particularly in the vicinity of the numerous capes and headlands (NOS, 1987).

Two major estuarine systems lie within the coastal bounds of the park. These partition the project area into four marine domains. The estuarine heads of Tuxedni Bay and Chinitna Bay receive a large volume of fresh water that significantly alters the nearshore community structure. The remaining coastline is dominated by marine habitats exposed to the prevailing waves and currents of Cook Inlet.

The velocity of the currents in the inlet fluctuates with wind speed and direction but averages 1.5 knots in a counterclockwise direction (Reed et al. 1986). The mixed semi-diurnal tides along the western shore fluctuate approximately 7 meters (NOS, 1987). The tide range is amplified by the length and configuration of Cook Inlet, creating a harmonic oscillation resulting in tidal amplitudes exceeding 10 meters at the head of the inlet.

The major sources of freshwater and sediment (from glacial erosion) to Upper Cook Inlet are the Susitna, Knik, Chakachatna, Matanuska, Eagle, and Little Susitna Rivers (Sharma 1979). The rivers contributing the most freshwater and suspended matter to the lower Inlet are the Kenai and Drift Rivers. Rainfall is another source of freshwater to the Inlet and several volcanoes contribute ash to the estuary. Freshwater flow into Cook Inlet varies seasonally. It is low in the winter and reaches a peak in July and August.

Currents in Cook Inlet are dominated by tidal flows and the water circulates in a counter-clockwise gyre. High-salinity oceanic water flows into the lower Inlet primarily through the Kennedy Entrance. It moves northward along the east coast of the Inlet and mixes with the river inputs from the head of the Inlet. Low-salinity water from the upper Inlet then flows south along the west side of the Inlet. An individual parcel of water will tend to follow a circular path, flowing north during the incoming tide and south during the ebb tide (Dames and Moore 1978). There is a small net southward tidal component, 10 to 15 percent of the speed of the tidal currents, that flushes water gradually out of upper Cook Inlet. An indication of the rate of this non-tidal current can be gained by the movements of winter ice in upper Cook Inlet. Sharma (1979), for example, estimated that it takes winter ice flows about 28 days to drift through upper Cook Inlet into lower Cook Inlet.

Because of the high tidal-current speeds, and resulting turbulent mixing, the waters of Cook Inlet are well mixed vertically. However, there are horizontal gradients of salinity and temperature. Salinity of Cook Inlet waters in the summer during maximum river flow ranges from about 32 parts-per-thousand (ppt) at the entrance to 27 ppt at the Forelands, and 8 ppt at Anchorage (Kinney et al. 1970). Seawater salinity tends to be lower in the western Inlet than in the eastern Inlet.

The rivers emptying into Cook Inlet carry very high loads of suspended sediments, mainly fine glacial flour. The high tidal currents and turbulent mixing of the waters of the inlet prevent most of these suspended sediments from settling to the bottom. As a result, concentrations of suspended sediments in the waters of upper Cook Inlet are very high. Average concentrations of suspended sediments are about 200 mg/l with maximum concentrations in excess of 2,000 mg/l (Sharma and Burrell 1970, Feely and Massoth 1982). There is little net deposition of these fine-grained suspended sediments in the upper Inlet. While the benthos may remain relatively unaffected by sediments that remain suspended, filter feeding organisms and juveniles feeding on suspended particular matter may be more sensitive. Fine-grained sediments are carried south through the lower Inlet and into Shelikof Strait and the outer continental shelf of the Gulf of Alaska. Some of the suspended sediments are deposited along the way in shallow coastal areas, such as Kamishak Bay.

Bottom sediments in the head of the estuary are primarily unconsolidated muds. In upper Cook Inlet, offshore sediments are dominated by sand (Sharma and Burrell 1970). Protected coastal embayments, representing about 38 percent of the inlet, often have finely-mixed sediments (O'Clair and Zimmerman 1986). Extensive, broad, intertidal flats with mixed sand/mud substrate occur in the south, particularly in Kamishak Bay and Kachemak Bay.

Cook Inlet is an extremely harsh and variable estuarine environment. Because of high suspended-sediment loads, and physical disturbances to the sea floor due to current scour, subtidal benthic communities in parts of Cook Inlet may be absent or present at very low densities and diversities. Despite these adversities, a large variety of marine and estuarine plants and animals live in Cook Inlet. The rocky intertidal zone is dominated by a Fucus (algae)/Mytilus (mussel)/barnacle assemblage similar to that found throughout southern Alaska (Stoker et al. 1993). Intertidal sand flats in some locations support dense populations of mollusc bivalves, including razor, littleneck, and soft-shell clams. Intertidal salt marshes and shallow subtidal eelgrass and kelp beds are extensive in some coastal areas and provide important nursery habitat for several fish species. Several types of commercially important fishes and crustaceans reside in, or visit seasonally, the offshore coastal waters and anadromous streams of Cook Inlet. Several species of marine mammals and seabirds also inhabit the Inlet permanently or intermittently and feed on its biota.

There are 15 offshore oil and gas production platforms in Cook Inlet, three of which have been shut down. All oil and gas production platforms except NCITJ Tyonek A, and all treatment facilities are located in the southern part of upper Cook Inlet. The Tyonek A platform is located slightly north of the other platforms. Onshore production facilities are located at Granite Point, Trading Bay, and East Foreland.

A total of 277 oil and gas wells have been drilled in upper Cook Inlet. An additional 14 exploratory were drilled in federal waters of lower Cook Inlet between 1975 and 1985. None of the wells in lower Cook Inlet were developed and all oil and gas production today is in upper Cook Inlet. An exploratory well, Sunfish No. 1, was drilled in upper Cook Inlet, approximately 53 km southwest of Anchorage, during the summer of 1991 (Franqis and Giichter 1992). The well resulted in the first oil and gas discovery in Cook Inlet since 1965 . ARCO and Phillips Petroleum expect to further evaluate the discovery in the future.

Two oil refineries and two gas-processing facilities are located in Nikishka, but one was shut down in 1991. There are two oil terminals, both south of the Forelands at Nikishka and Drift River, where crude and refined oil are transferred between shore facilities and oil tankers. Pipelines connect the offshore platforms to shoreline treatment facilities and oil terminals and there are two pipelines from Nikishka to Anchorage (one for natural gas and one for product). There is a major oil tanker route that enters lower Cook Inlet at Kennedy Entrance and extends up along the eastern side of the sound to Nikishka.

There are a variety of oil-industry-related activities that can result in permitted or fugitive discharges resulting in adverse effects on the biota of Cook Inlet. Such discharges include: accidental spills of crude and refined oil from tankers, pipelines, and well blowouts; permitted discharges of treated produced water at offshore platforms and shore treatment facilities; permitted discharges of drilling muds and work-over fluids during drilling and servicing of wells; permitted discharges of waste water from the oil refinery; water discharge from storage tanks and ballast; and chronic leakage of oil from storage tanks and pipelines. Oil release may also occur via discharge from municipal treatment plants, commercial and sport fishermen, and merchant ships. Natural oil seeps are also potential sources of petroleum hydrocarbons to the Cook Inlet environment.

Geomorphology

Coastal geomorphology is the most basic information layer relevant to shoreline management and the monitoring of biological resources. Seasonally differentiated baseline data on coastal habitats is crucial in the Cook Inlet region because of its relative inaccessibility, extreme tidal range of over 10 meters, and the harsh nine month sub-arctic winters which make routine in situ monitoring by resource managers unfeasible for most of the year. The ecology, geomorphology and coastal processes along the Gulf of Alaska are not well documented or understood. Ecological functions of the Cook Inlet tidelands are complex and dynamic.

Steps in the nearshore habitat classification for LACL included: (1.) acquisition of ground control points for aerial photography; (2.) classification of the nearshore habitats; (3.) surveys of across-shore profiles at selected shoreline types; (4.) collection of biotic transect data at selected intertidal sites; (5.) development of a statistical model to extrapolate the biotic information over a broad scale; and 6. validating the model results.

The categorization of wave power for segmenting exposure regions was based on the prevailing wave climate defined by locally generated wave heights and periods, and the relative exposure to deep water waves. Wave power estimates therefore integrate the effects of the deep water wave climate and the local wave climate on the nearshore habitat.

Only generalized information on wave heights was available for the study area, so wave power estimates relied primarily upon fetch distance and geomorphic proxies as indicators. For example, assessments of geomorphological indicators such as slope angle, particle size and roundness, and geomorphic forms and processes such as storm berms, were used to differentiate relatively exposed from protected segments (at a scale of 1 - 10 km).

Using a constant wave power chart, significant deep water wave heights and periods were estimated for verification with deep water wave information obtained from the NDBC buoy at position 56^{0}N 148^{0}W in the Gulf of Alaska, and also from estimates of deep water wave heights in Cook Inlet. For the sheltered portions of the coast (Chinitna and Tuxedni Bays), locally generated wind wave heights were estimated from fetch distance measurements.

Forty-three percent of the LACL coastline is either very protected or protected from high energy waves (Figure 2). Over half of this length includes the salt marshes of Tuxedni and

Chinitna Bays. Note that no part of the study area is fully exposed to the wave climate of the Gulf of Alaska, however, southeast storm swells from the Gulf penetrate into Lower Cook Inlet during the winter months. These events cause very large berms to develop on boulder beaches in the semi-exposed regions.

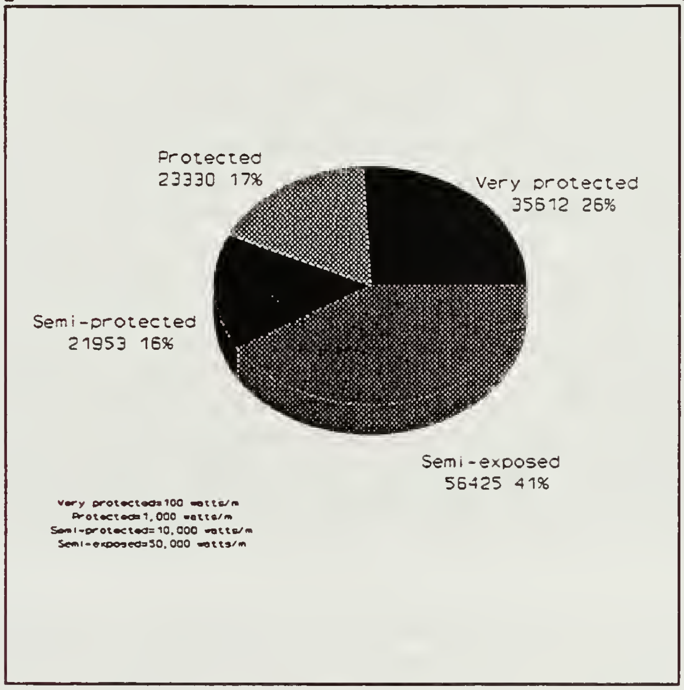


Figure 2. Wave power distribution with respect to shoreline length, Lake Clark National Park-Cook Inlet Coastline.

Twenty-six <u>Shoreline Segments</u> were delineated according to geomorphological shoreline type, Iribarren number (a surf similarity parameter developed by Battjes 1974; low angle shorelines correspond to low Iribarren numbers), and the sediment transport regime. Preliminary stereo-image photogrammetric interpretation identified twelve dominant shoreline types prior to ground surveys in 1994 (Figure 3). Salt marsh accounts for 22% of the total project length and 42% of the total area (Table 1). Salt marsh is restricted to sheltered areas of low wave energy. The combined soft substrates account for 90% of the total length and 98% of the total area. Combinations of rocky shores (ramps, platforms, cliffs) are therefore a very small percentage of the total habitat type in the project area.

Iribarren numbers were calculated for each shoreline segment based on the representative significant deep water wave height and period for the prevailing wave power categories. Values for the slope angle of the shoreline were calculated from the average width and height of the exposed intertidal zone on aerial photography flown at MLLW.

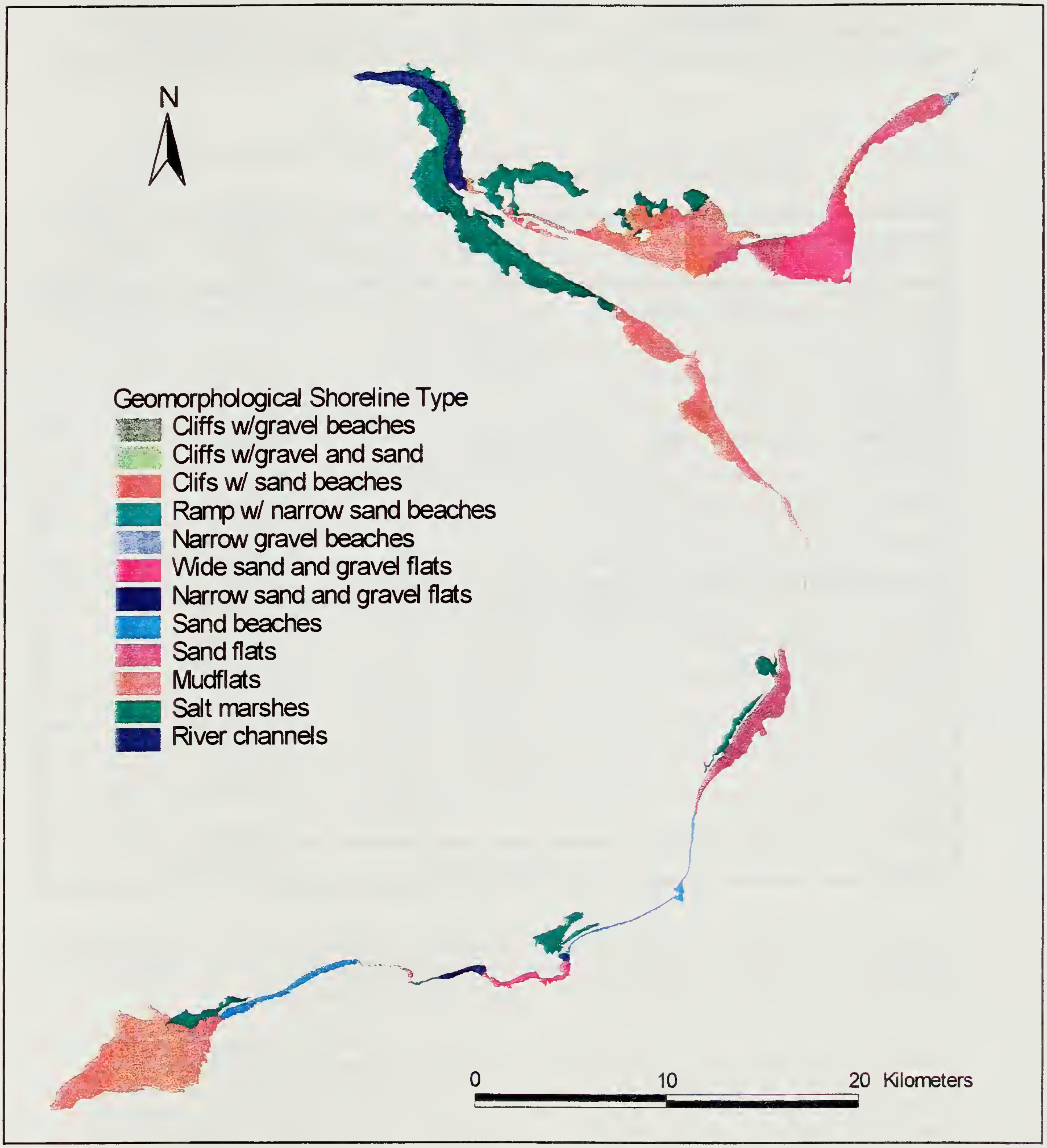


Figure 3. Spatial distribution of shoreline types along the Lake Clark National Park-Cook Inlet Coastline.

Across-shore profiles at representative shoreline types were surveyed using third order leveling techniques. Slope and volumetric changes and particle size distribution analyses from

Table 1. Length and area of shoreline types along the coast of Lake Clark National Park.

SEGMENT TYPE	**LENGTH (m)**	**% TOTAL**	**AREA (m^2)**	**% TOTAL**
Cliffs w/ narrow gravel beach	2802	2	27738	<1
Cliffs w/ narrow sand & gravel	8247	6	65190	1
Cliffs w/ narrow sand beach	1360	1	80490	1
Ramp w/ narrow sand beach	2007	1	14039	<1
Gravel aluvial fan	3657	3	188089	1
Wide sand and gravel flat	9491	7	1240764	10
Narrow sand & gravel flat	3693	3	83219	1
Wide sand beach	20752	15	392463	3
Wide sand flat	24176	15	1565149	12
Wide mud flat	30063	22	2978329	24
Salt marsh	31075	22	5320286	42
River channel			644496	5
Total	137322		12600253	

these shore-normal transects provided information on the sediment transport regime including erosion/accretion, rate of change, sediment sources and relative sediment abundance.

At Spring Point, a wave power category 4 (semi-exposed) cobble beach demonstrates a relatively stable backshore (Figure 4). Summer storm berm shifting accounts for the majority of moved sediment. The particle size analysis of this transect reveals that the winter storm berm is composed of rounded cobbles and boulders, and the summer berms are primarily rounded cobbles.

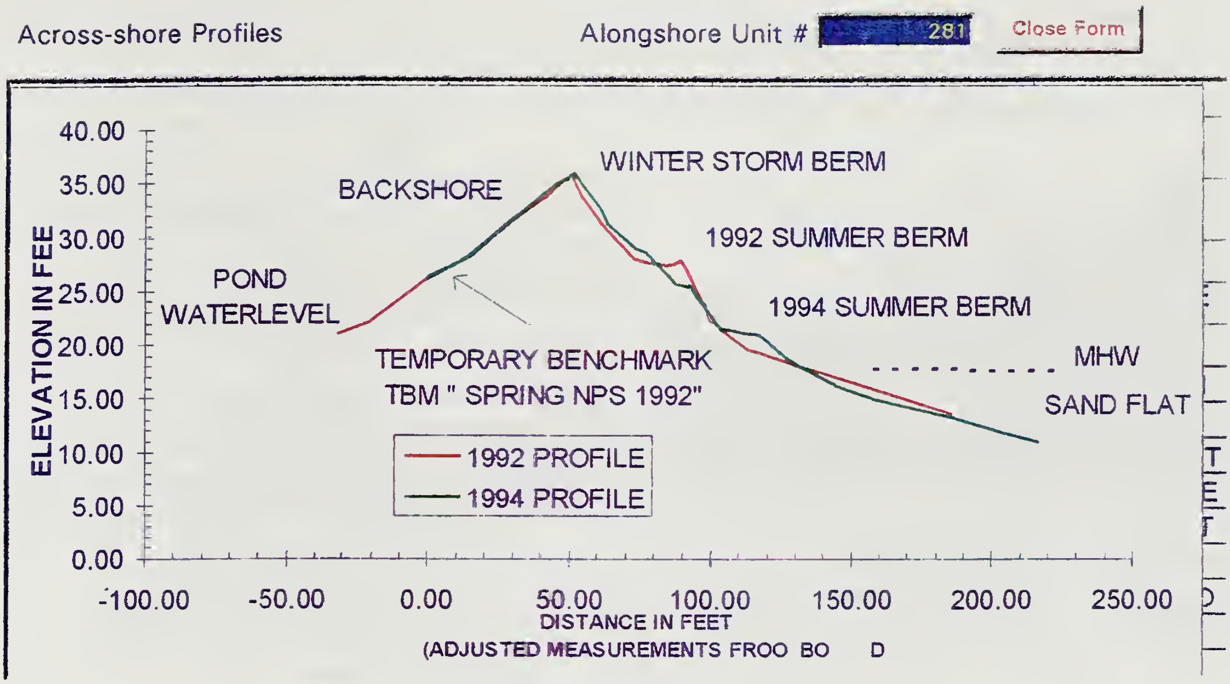


Figure 4. Shoreline profile at Spring Point, Lake Clark National Park-Cook Inlet Coastline, 1992-94.

Air photo interpretation and ground observations of beach ridges, turbidity plumes, and spit development indicate the direction of the net alongshore sediment transport along each shoreline segment. The general transport direction is south with a counterclockwise transport in Tuxedni and Chinitna Bays.

Ground surveys in 1994 resulted in the delineation of 338 alongshore units. Criteria for field delineation were primarily aspect, substrate size and roundness, dynamism, wave runup estimates and slope angle for each across-shore zone. When any of these attributes changed for any of three across-shore zones (upper, middle, or lower intertidal), a new alongshore unit was demarcated.

Across-shore zones were characterized at specific elevations: 0, 2.5, and 5 meters (above MLLW, based in part on predicted tide heights). Horizontal and vertical delineation of the across-shore polygons was facilitated by aerial photo basemaps. Because of differences in alongshore unit elevations, not all have the complete array of across-shore zones. For example, alongshore units in salt marshes have only upper intertidal zones while other units may have only upper and middle zones.

A total of 338 upper, 246 middle, and 207 lower intertidal polygons were delineated. Polygon attributes are stored in a database that is linked to the coastal GIS (Figure 5). Within each unit, all of the across-shore zone attributes were categorized. Units were not shorter than 10 m, but were often longer than 100 m. The longest units, not including the salt marshes, were the sandy beaches between the Johnson River mouth and Spring Point.

Maximum wave runup was surveyed in the field for each upper intertidal zone based on the height of the vegetation line above extreme high water, the height of storm berms or drift piles, the upper extent of marine organisms, or the lower extent of blue-green algae *verrucaria* on rocky shores (Table 2). Iribarren numbers were calculated for each across-shore zone using the wave height and period values estimated from wave power as before, but incorporating slope angles for each across-shore zone. Then the maximum wave runup and the new Iribarren number were used to calculate the significant wave height for the upper zone. Finally, the significant wave height and the Iribarren number were used with empirical coefficients for C (Van der Meer and Stam 1992) to calculate the mean wave runup for each across-shore zone, thus taking into account the roughness and permeability for each zone.

Spring Point lies within the semi-exposed region of the study area (Figure 6). The significant deep water wave height used for the calculations was 2 meters with a period of 8 seconds.

Lake Clark National Park and Preserve, Alaska
Cook Inlet Shoreline Segments

Alongshore Unit # 20   Segment ?

Latitude: 60 15 31   Longitude: 152 31 00 W

Shoreline Type: wide sand flat (28)

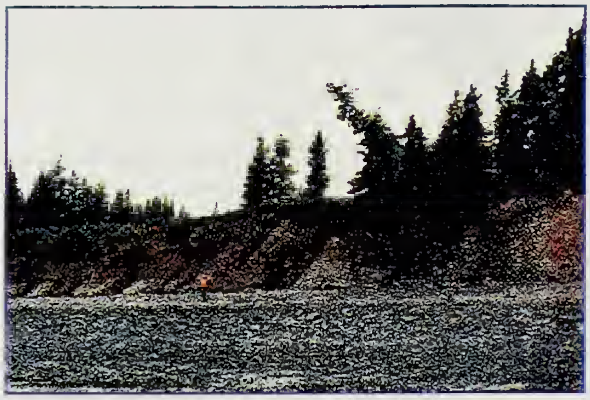
Wave Power: semi-exposed (Hs=2, T=8)

Area (square m) : 2674207   Width (m): 790

Unit Aspect: southeast   Length (m): 3038

Debris Volume: scattered (5 - 25%)

Transects: geomorphic (see profile)



Across-shore Zones

Upper   Middle   Lower

Data Options

Print   Next   Profiles   More Photos   Previous

MIDDLE INTERTIDAL ZONE (MSL 2.5 METERS)
SUBSTRATE CHARACTERISTICS

Close Form

Alongshore Unit	20	Habitat Type:	7b
Habitat:	7 - stable, moderate energy, boulders and cobbles		
Unit Aspect	southeast	Length (meters)	930
Runup	1.0 - 2.0 meters	Width (meters)	9
Slope	5 -15 degrees	Area (meters sq.	8367
Dynamism:	moderate		
Roughness	gnarled		
Size (p)	boulders		
Size (s)	pebbles/granules		
Roundness (p)	well rounded		
Roundness (s)	well rounded		
Permeability	moderate		

Print Record

Sampled Habitat Type   Characteristic Species

1d = 38	6u = 322
1e = 52	6v = 328
1g = 58, 95	7k = 216, 220,
1i = 155, 162,	7o = 280, 28
1j = 191, 197	9i = 184
1x = 350, 3	9t = 306,

Figure 5. Example of data attributes for shoreline segement no. 20, Lake Clark National Park-Cook Inlet Coastline.

The mean wave runup for this polygon was calculated to be 2.2 meters, which corresponds to category 4 (2 - 3 meters runup).

Twenty-one percent of the upper intertidal polygons have wave runup greater than 3 meters, while 31% of the middle intertidal polygons and only 13% of the lower intertidal polygons have runup in the same range. This can be attributed to the higher slope angle of the upper polygons.

The Spring Point area demonstrates a relatively steep profile in the upper section and flatter profile in the lower zones (Figure 7).

Table 2. Intertidal wave runup distribution along the Lake Clark National Park-Cook Inlet coastline, 1994-96.

Upper Intertidal Polygons		
WAVE RUNUP	LENGTH (m)	%
< 1 m	122021	55
1 - 2 m	23732	11
2 - 3 m	29613	13
3 - 4 m	34966	16
> 4 m	10072	5
Totals	**220403**	
Middle Intertidal Polygons		
WAVE RUNUP	LENGTH (m)	%
< 1 m	24277	23
1 - 2 m	19955	19
2 - 3 m	27619	27
3 - 4 m	30556	30
>4 m	1293	1
Totals	**103700**	
Lower Intertidal Polygons		
WAVE RUNUP	LENGTH (m)	%
< 1 m	13890	16
1 - 2 m	54014	62
2 - 3 m	7789	9
3 - 4 m	10875	12
> 4 m	1295	1
Totals	**87864**	

Due to the higher slope angle, the substrate of the upper polygons is considerably more dynamic while the lower polygon substrates are relatively stable. The changes in beach profile for Spring Point between 1992 and 1994 (Figure 4) suggest the large volumes of sediment transport characteristic of these steeper profiles.

Fifty-five percent of the upper intertidal polygons show less than 1 meter runup. This is due to the extensive salt marshes which are all above 5 meters in elevation. Predicting the

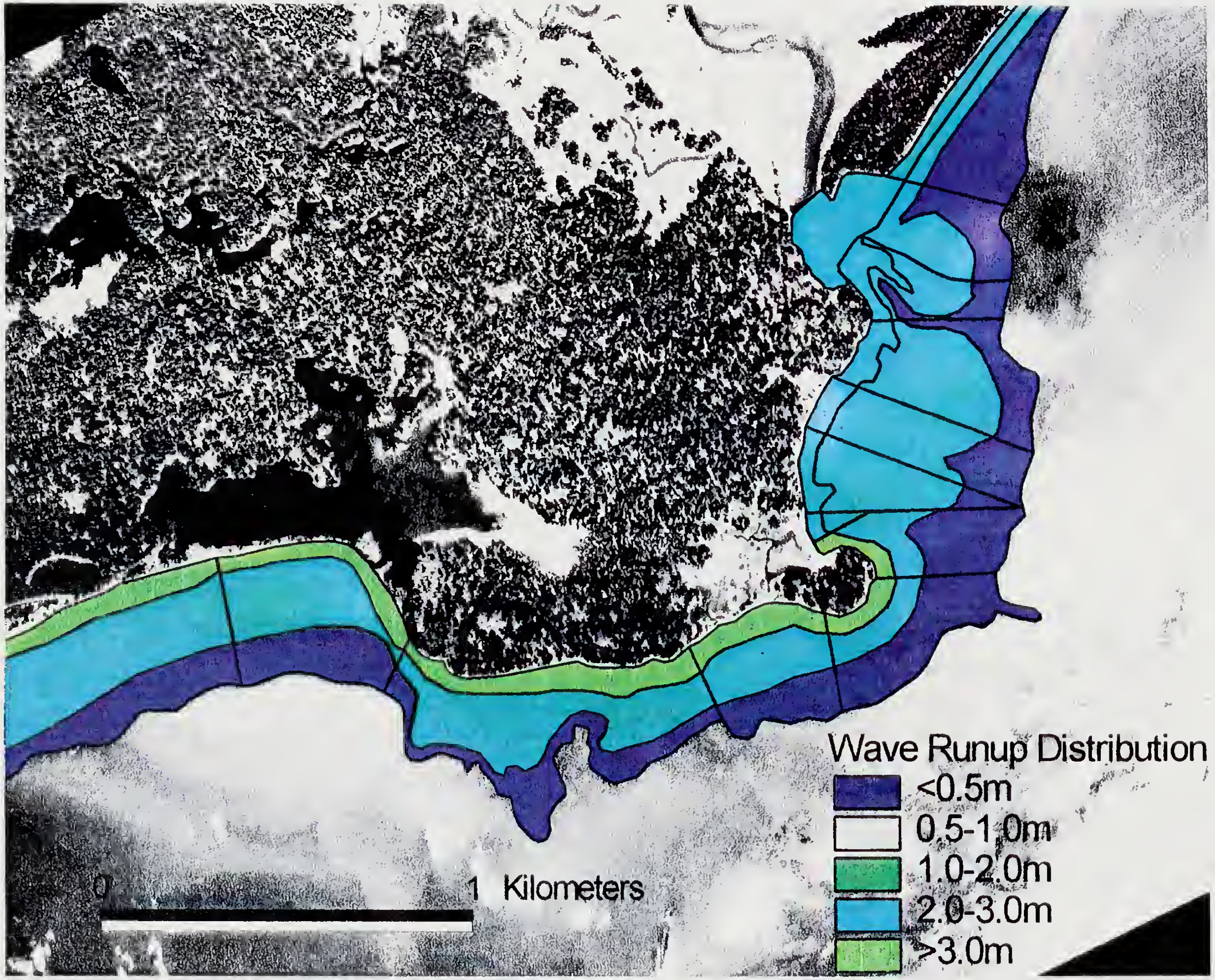


Figure 6. Wave runup categories at Spring Point, Lake Clark National Park-Cook Inlet Coastline.

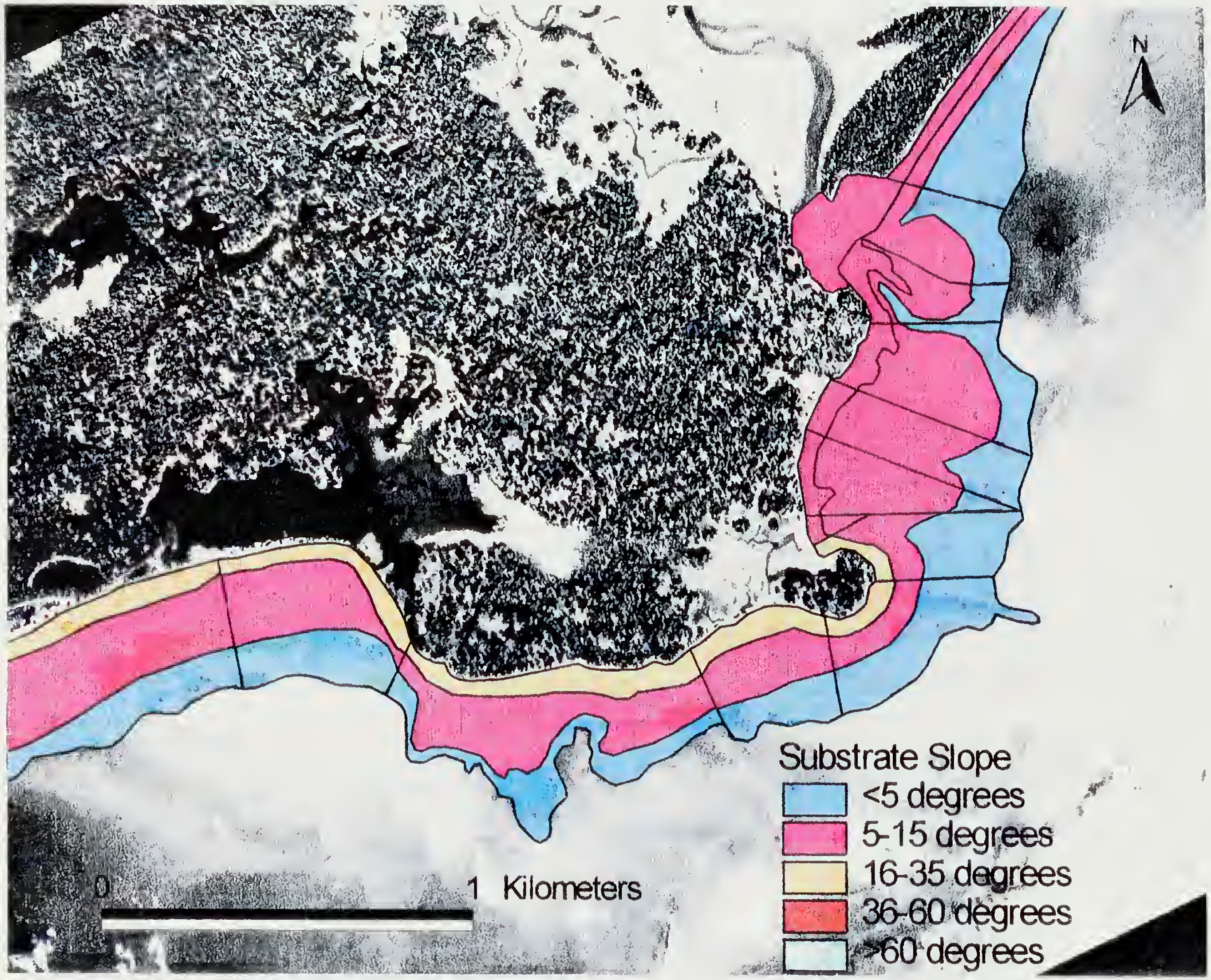


Figure 7. Substrate slope at Spring Point, Lake Clark National Park-Cook Inlet Coastline.

responses of ecosystems to perturbations requires experimentation to determine causal factors. Ecosystem experimentation is inherently observational due to the multitude of uncontrolled factors. Replicability is problematic because of the difficulty in locating exact replicates in nature. One of the applications for a classification system is the grouping of habitat types for ecosystem modelling.

Lake Clark National Park requires a broad scale inventory of intertidal fauna and flora communities. Horizontal and vertical (spatial) variability of both species composition and abundance is primarily a function of substrate type, shoreline gradient, and exposure or wave energy. Due to the difficulty and expense of a synoptic quantitative inventory, a habitat model was developed based on the preceding classification. Intertidal communities are strongly influenced by particle size and solar insolation. Wave runup, dynamism, primary particle size, and secondary particle size from the preceding classification were

Table 3. Intertidal habitat attributes measured along the Lake Clark National Park-Cook Inlet Coastline, 1994-96.

Upper Intertidal Habitats						
Habitat #	Dynamism	Runup	Size 1	Size 2	Description	Sampled Units
1	0	2	5	5	very stable, low energy, bedrock	170
2	0	5	5	5	very stable, high energy, bedrock	
3	4	3	2	4	loose, moderate energy, pebbles and boulders	313
4	2	1	1	1	stable, low energy, sand and silt	58,95,100,155,
5	2	3	4	4	stable, moderate energy, boulders	218,220,248,280
6	1	3	1	1	stable, moderate energy, sand and silt	337
7	5	2	1	1	very loose, low energy, sand and silt	306
8	3	3	4	3	loose, high energy, boulders and cobbles	
9	3	5	3	3	loose, very high energy, cobbles	286
10	2	1	4	2	stable, low energy, boulders and pebbles	184

Middle Intertidal Habitats						
Habitat #	Dynamism	Runup	Size 1	Size 2	Description	Sampled Units
1	4	1	1	1	loose, low energy, sand and silt	
2	1	1	1	1	stable, low energy, sand and silt	58,52,51,39,170,179,191,197
3	0	4	4	5	very stable, high energy, boulders and bedrock	
4	3	1	1	5	loose, low energy, sand and bedrock	
5	1	3	4	2	stable, moderate energy, boulders and pebbles	
6	4	3	2	1	loose, moderate energy, pebbles and sand	
7	2	3	4	3	stable, moderate energy, boulders and cobbles	216,220,248,280,286
8	4	3	2	4	loose, moderate energy, pebbles and boulders	
9	0	1	5	5	very stable, low energy, bedrock	184,306,313
10	4	1	4	3	loose, low energy, boulders and cobbles	

Lower Intertidal Habitats						
Habitat #	Dynamism	Runup	Size 1	Size 2	Description	Sampled Units
1	3	3	4	4	loose, moderate energy, boulders	
2	4	1	1	1	loose, low energy, sand and silt	191,197,321,329
3	4	1	1	3	loose, low energy, sand and cobbles	39
4	4	3	2	2	loose, moderate energy, pebbles	
5	0	2	5	5	very stable, low energy, bedrock	306
6	4	1	4	1	loose, low energy, boulders and sand/silt	184,216,
7	3	3	1	4	loose, moderate energy, sand and boulders	248,
8	5	1	2	1	very loose, low energy, pebbles and sand/silt	
9	3	1	1	5	loose, low energy, sand and bedrock	313
10	2	1	4	4	stable, low energy, boulders	220,280,286

clustered using a hierarchical algorithm to determine the number of principal cluster groups.

The ecological communities of 10 intertidal habitat types were quantified. Thus, for each across-shore elevation, the attributes were clustered into 10 groups, each group representing a habitat type (Table 3). Since each across-shore elevation was clustered independently, the resulting three groups of 10 habitat types are not related, e.g. habitat #5 in the middle zone is not the same combination of attributes as habitat #5 in the lower zone. The alongshore units were selected at random for biological sampling. Spring Point demonstrates the distribution of the habitat types for each elevation by shoreline length, area, and count respectively (Figure 8).

The number of habitat types within shoreline classes varies considerably. For example, only two habitat types occur in the salt marsh class, and one of these represents less than 2% of the total shoreline length. Shoreline Type 29 (wide mud flats) has the highest variance in the upper zone with 9 habitat types represented. Shoreline Type 13 (cliffs with narrow sand and gravel beaches) has the highest variance for the lower zone with 8 habitat types represented.

This study focused on developing a systematic procedure to define and inventory nearshore habitats at multiple spatial scales by partitioning shoreline segments with generally homogenous abiotic characteristics. These segments are characterized using a suite of physical factors, thus differentiating horizontal (among-segment) characteristics and vertical (within-segment) characteristics. Small scale applications of this habitat distribution model suggest that shoreline segments with similar characteristics can be statistically clustered in groups of like habitats with specific biotic associations.

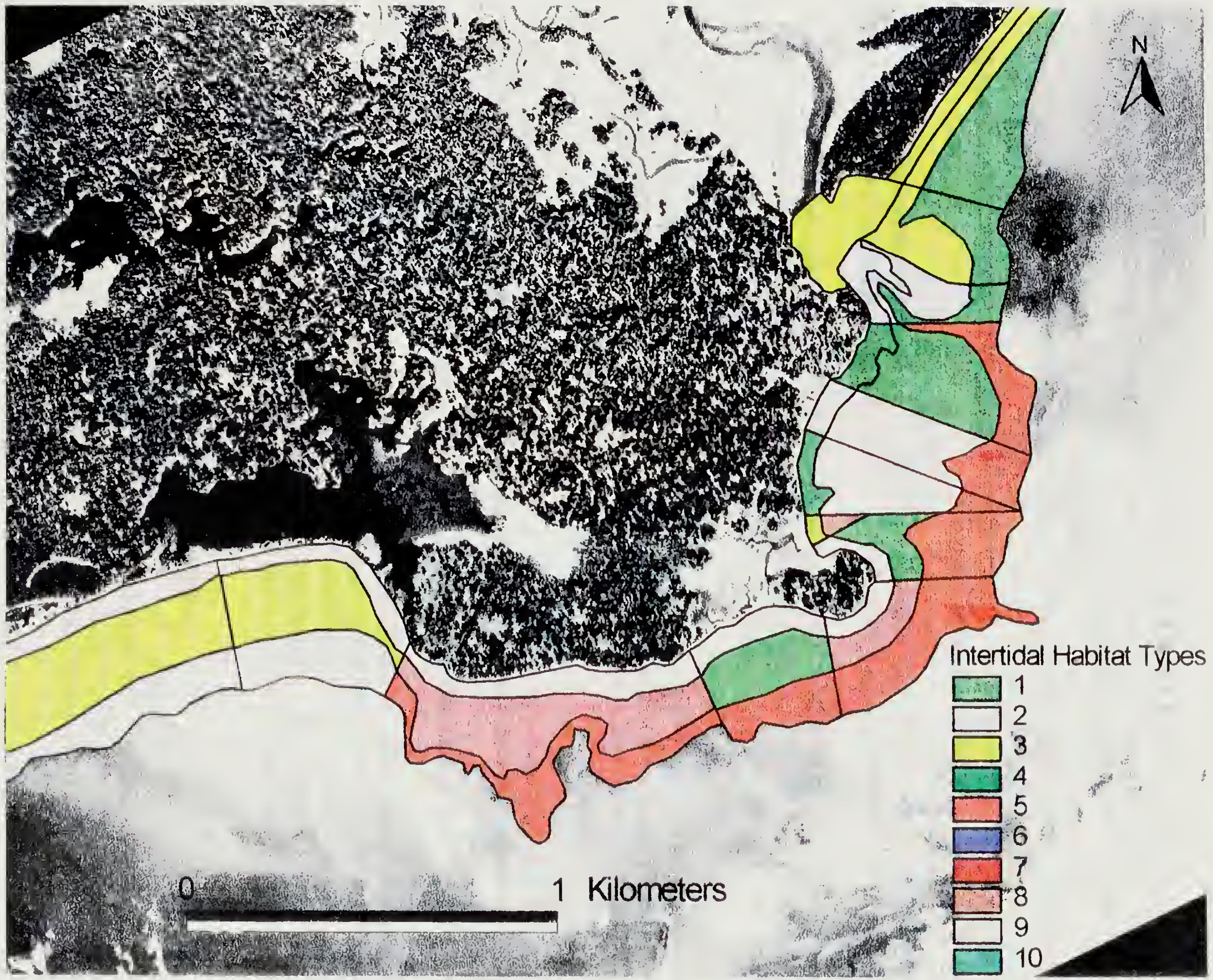


Figure 8. Distribution of intertidal habitat types at Spring Point, Lake Clark National Park-Cook Inlet Coastline.

Salt Marsh Vegetation Classification and Inventory

The objectives of the salt marsh vegetation classification were to:

1. Delineate and identify vegetation types on mylar overlays of 1:12,000-scale, black and white, digitally-enhanced and registered aerial photography.

2. Develop a vegetation cover map classification.

3. Conduct field studies to ground-truth air photo delineations and vegetation determinations.

4. Prepare and provide these airphoto delineations and vegetation determinations in a GIS, digitizing-ready format.

5. Describe the species composition and physical site characteristics of the various vegetation types within the study area.

Eight marshes totaling 32 km^2 (12 mi^2) occur along the coastline of Lake Clark National Park and Preserve in western Cook Inlet between Tuxedni Bay and Chinitna Bay (Figure 9). From north to south, these include:

1) Tuxedni Bay marshes on the southern shoreline of Tuxedni Bay;
2) Horsefly marsh near Magnetic Island on the northern shoreline of Tuxedni Bay;
3) Squarehead Cove marsh on the northern shoreline of Tuxedni Bay;
4) Bear Creek marsh west of Chisik Island;
5) Silver Salmon Creek marsh near Silver Salmon Lakes;
6) Shelter Creek marsh at Herb's Lagoon;
7) Glacier Spit marsh on the northern shoreline of Chinitna Bay;
8) Clearwater Creek marsh on the west side of Chinitna Bay.

METHODS

<u>**Photo interpretation**</u>- Digitally-enhanced and rectified 1:12,000-scale black and white aerial photography was used as a basemap for this investigation. These images were in an 11x17 format blown up from a 1:24,000-scale. The photography was already in use for prior-year investigations and served as the map base for the coastal GIS.

Eighteen photos from 1993 were delineated and classified before the 1995 field season. Prior to interpretation, work areas were delimited on stable-base acetate overlays registered to the

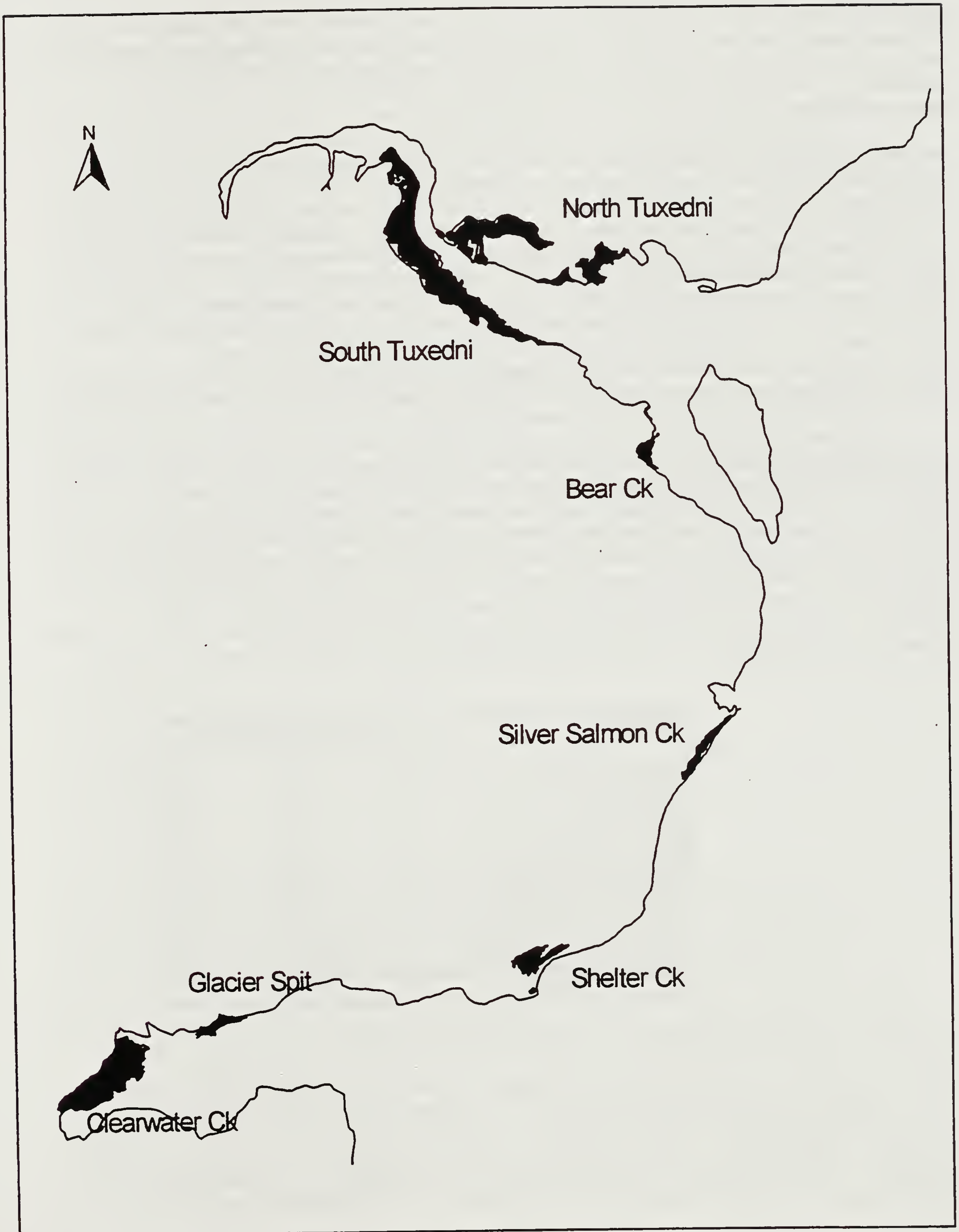


Figure 9. Major salt marshes along the Lake Clark National Park-Cook Inlet Coastline.

photos according to standard photo interpretation procedures (Avery 1968, Markon 1980). Interpretations were completed with waterproof black ink utilizing a 4x0 pen point to adhere to currently accepted mapping standards (NWI-FWS 1985, 1986) and insure crisp linework for GIS digitization.

General photo interpretation ("first cut") separated lakes, ponds, rivers and mudflats from vegetated units. Within vegetated units, large types and complexes were delineated based on vegetation and physical features such as levee systems and interlevee basins. Secondary photo interpretation ("second cut") was refined to a minimum map unit size of 2 ha (5 A) for water bodies and vegetation units. Larger types and complexes were subdivided to vegetation covertypes based on tonal and textural qualities of the photos and 1995 vegetation field data. Delineations were further refined for consistency, polygons were closed and edges were matched to "tie" adjacent photos together for a final GIS digitizing-ready product.

Field classification- A helicopter was used to visit study sites between July 9 and July 16, 1995. A skiff was also used to sample wetland sites that were accessible from the water. Sampling intensity varied between marshes based on priorities determined by Park personnel; size of individual marshes; vegetation complexity; and ground-truthing needs relating to the quality of the digitally-enhanced aerial photography. One hundred ninety-nine releves (sample plots) were completed for 114 sites; a breakdown of sites and releves by coastal marsh is as follows:

MARSH	SITES	RELEVES
Tuxedni Bay	35	61
Horsefly	16	29
Squarehead Cove	6	12
Bear Creek	8	13
Silver Salmon	19	29
Shelter Creek	12	26
Glacier Creek	7	10
Clearwater Creek	11	23
Total	114	199

Photos and photo signatures were prioritized to insure that a maximum number of different areas could be visited across north-south and east-west gradients given the short field season, field logistics and unpredictable weather conditions of the coast. Study sites were selected across moisture, elevation and physical gradients. Sites were concentrated in the coastal zone; however, sites were also selected from airphotos representing a transect extending inland and upstream from coastal estuarine areas to upland areas of tall shrubland. Weather conditions and fuel cache logistics limited sampling intensity in the extreme south portion of the study area.

Vegetation and physical site characteristics were described from the air and on the ground. The percentage cover of each vegetation type within delineated photo signatures was visually estimated, recorded and described. Photos were taken of each site from approximately 110 m (400 ft) altitude, and at ground level. Several photos were taken in complex vegetation units. Airphoto signatures were reviewed at each site with regard to location and relationship of tone to vegetation communities. All 35 mm photos were recorded in a field notebook and referenced to each site, photo signature and vegetation type.

Rapid survey techniques were employed to minimize helicopter operating costs and to maximize data collection. Detailed ground observations were made at most sites. Site visits of less than nine minutes (economical time to shut down helicopter) were called "Extensive Sites" and were generally visited to verify similar photo signatures and vegetation types. "Intensive Sites" were visited for 10-45 minutes or more. All vegetation descriptions were made on 6 m^2 releves using the releve techniques and cover-scale values of Mueller-Dombois and Ellenberg (1974):

Plant Cover Class

t trace
1 individual
2 <5 (few, seldom)
3 <5 (many indiv.)
4 6-25%
5 26-50%
6 51-75%
7 76-100%

In areas with homogenous vegetation that appeared to be representative of the photo signature, visual estimates of dominant growth forms and percentage cover for all dominant plants were made, associated species noted, and physical site characteristics described. The latter included descriptions or scale values for terrain; physiographic features; distribution patterns; site moisture; flooding conditions; and animal, bird and human activity. These are summarized in Appendix A.

<u>**Laboratory analysis**</u>- Vascular plant identifications and verifications were completed and a species list for the study area was compiled from field data, previous field studies and a literature review. Vegetation data were summarized daily while in the field and analyzed to develop a draft vegetation covertype classification composed of vegetation communities that were

readily identifiable on the photographs. After the field season, the releves were grouped into vegetation types based on site moisture, dominant plant species, physiognomy and physiographic location.

Releves were sorted: 1) into Dry, Moist, Wet and Aquatic moisture classes; 2) within moisture classes to Growth Form class; and 3) within Growth Form classes to species dominance using a modified Zurich-Montpelier releve sort (Mueller-Dombois and Ellenberg 1974) and COENOS computer program (Ceska 1987). These were then used to develop a final covertype classification system in conjunction with the final photo interpretations.

Mapping and classification techniques, conventions and procedures were modified from Alaskan vegetation studies which have been ongoing for many years (Tande and Boggs 1995, Tande and Jennings 1986, Walker et al. 1979, 1980; Walker and Acevedo 1986; Walker and Lederer 1983). The LACL coastal marsh classification system satisfies the following mapping and classification criteria, is expandable to accommodate further vegetation studies in the Park, and will allow comparison of Park vegetation types to other parts of Cook Inlet and Alaska.

These criteria are based upon study objectives, budget, time and staffing considerations, and the complexity of the vegetation encountered during photo interpretation and field studies:

1. Mapping units should describe holistic, repeating ecological units that as a minimum consider vegetation, landforms, and hydrologic features, since these features interact to influence the use of wetlands and uplands by wildlife.

2. Nomenclature should be based primarily on plant growth forms and vegetation physiognomy, since habitat is essentially a vegetational phenomenon (Egler 1977).

3. Map information should be uniform in reliability and intensity.

4. The resulting system should contain enough information to allow for the eventual segregation of habitat types that may have different values to waterbirds and other wildlife.

5. The legend should be structured, as much as possible, on the characteristics that can be recognized and mapped with 1:12,000 digitally-enhanced, black and white photography provided by NPS. It should also be part of a hierarchical scheme that permit descriptions at several scales.

6. At lower levels, the classification should be consistent yet flexible enough to describe the great variety of plant communities. At the community level, it should be open-ended

so that units may be readily added to the system, or so that those that do not accurately describe the vegetation of a given area need not be applied.

7. It should be possible to group lower-level units into higher-level units with a minimum of overlap so that there is a clear compatibility between levels (i.e., community level description to growth form, if possible).

The following five attributes were interpreted for each map polygon and may be treated as independent variables for GIS analysis purposes:

1. Physiographic Location
2. Site Moisture
3. Vegetation Type by Species Dominance
4. Vegetation Growth Form
5. Landscape Descriptor

Map polygons were classified to dominant vegetation types even though vegetation complexes are common in coastal marshes where minimal changes in elevation, and hence moisture, lead to subtle changes in vegetation over short distances. These vegetation units were described with three independent attributes arranged in this sequence: 1) a site moisture term, 2) dominant plant taxa and 3) a dominant plant growth form.

Site moisture was described as Dry, Moist, Wet, or Aquatic (Raup 1969). These terms were derived from prompts used in the field to rapidly and consistently assess site/soil moisture at the end of the growing season (Appendix A). Plant communities were named by dominant plant taxa, one or more from each of the representative layers. The number of taxa was kept to the minimum required to adequately distinguish between types; the total did not exceed six.

The dominant growth forms could be any of the following: 1) Trees (>3 m), 2) Tall Shrub (1.5-3 m), 3) Low Shrub (0.2-1.5 m), 4) Dwarf Shrub (<0.2 m), 5) Sedge, 6) Grass, 7) Graminoid (5+6), 8) Forb, and 9) Moss. The term Graminoid was used when two or more of the dominant grass-like plants were from different families. Only growth forms contributing more than 30 percent of the readily visible ground cover were included in the type name. The term Barren was used for areas where vegetation could not be detected on the aerial photos.

Landscape attributes are general, subjective terms describing landscape features associated with coastal marshes (e.g., Panne, Mudflat, Interlevee Basin), vegetation physiognomy (e.g., Meadow) and surface patterns (e.g., Eroding Levee, Interlevee Ponded Basin). They are provided to help the data user gain a mental image of the terrain the vegetation type is associated with, as viewed from the ground. Definitions follow Batten et al. (1978), Gabriel and Talbot (1984), National Wetlands Working Group (1988) and Watt (1982). Large ponds and lakes were interpreted and identified by landscape descriptor attributes (Pond, Lake, Interlevee Ponded Basin) and will serve as an indicator of open water which may prove useful for modeling waterbird habitat.

An example of a typical complete polygon attribute description might read:

> "Wet, *Puccinellia phryganodes* (Creeping Arrowgrass), *Hippuris tetraphylla* (Four-leaf Mare's-Tail) Grass Forb (type)(on) Coastal Low-Marsh Mudflats and Pannes."

The classification system was applied to the interpreted imagery on a photo-by-photo basis starting on the coast and working inland. Photo signatures were compared with site classifications for all study sites on a photo. Special attention was paid to tones, textures, patterns and associations, noting similarities and differences among sites. Polygon codes were developed and then applied to all map polygons across the study area.

Final classification data and mapping linework were automated by Carl Schoch, Oregon State University, utilizing ARCVIEW GIS software of the Environmental Systems Research Institute (ESRI). The process of automation involved digitizing the aerial photo linework; entering attribute data for all polygons; computer and manual verification for map accuracy; generation of intermediate test products; and finally, the production of a completed database for the Park.

RESULTS AND DISCUSSION

Vegetation Cover Type Classification- Digitizing-ready photo interpretations were completed for vegetation and physical site characteristics of eight coastal marshes of LACL at a scale of 1:12,000 with a minimum map unit size of 2 ha (5 A). Data analysis and photo interpretation resulted in the following attribute file for the five major features interpreted for each map polygon:

Physiographic Location

1. Coastal Low Marsh
2. Coastal Mid Marsh
3. Coastal High Marsh
4. Upland

Site Moisture

1. Wet

2. Moist

Vegetation Type by Species Dominance

1. Barren
2. *Puccinellia phryganodes*
3. *Puccinellia phryganodes/Hippuris tetraphylla*
4. *Puccinellia phryganodes-Triglochin palustre*
5. *Puccinellia phryganodes-Puccinellia* red-*Puccinellia* Tall-*Triglochin maritimum*
6. *Puccinellia grandis/Plantago maritima*
7. *Carex ramenskii-Triglochin maritimum*
8. *Carex ramenskii-Triglochin maritimum-Puccinellia phryganodes/Plantago maritima*
9. *Carex ramenskii*
10. *Leymus mollis/Argentina egedii*
11. *Carex ramenskii-Hordeum brachyantherum/Argentina egedii*
12. *Carex ramenskii-Hordeum brachyantherum/Argentina egedii - Plantago maritima*
13. *Carex glareosa-Carex ramenskii-Hordeum brachyantherum-Calamagrostis deschampsioides-Poa eminens/Argentina egedii*
14. *Carex lyngbyei/Comarum palustre*
15. *Carex ramenskii-Carex glareosa/Argentina egedii*
16. *Carex ramenskii-Carex mackenziei-Calamagrostis deschampsioides/Argentina egedii*
17. *Carex ramenskii-Carex mackenziei*
18. *Carex ramenskii/Hippuris tetraphylla*
19. *Carex ramenskii-Eleocharis palustris/Hippuris tetraphylla*
20. *Calamagrostis canadensis-Poa eminens/Lathyrus palustris-Lathyrus japonicus var. maritimus*
21. *Carex lyngbyei-Carex pluriflora-Carex ramenskii-Calamagrostis deschampsioides/Argentina egedii*
22. *Carex lyngbyei-Carex mackenziei*
23. *Carex lyngbyei-Carex pluriflora/Salix fuscescens-Myrica gale/* Moss spp.
24. *Carex lyngbyei/Argentina egedii*
25. *Carex lyngbyei*
26. *Carex lyngbyei-Calamagrostis canadensis/Comarum palustre*
27. *Sparganium* spp.-*Potamogeton* spp.-*Utricularia* spp.

Growth Form

1. Sedge
2. Sedge Forb
3. Grass
4. Grass Forb
5. Graminoid
6. Forb
7. Graminoid Forb
8. Sedge Low-Shrub Moss

Landscape Descriptor

1. Mudflat
2. Panne
3. Mudflat and Panne
4. Tidal Stream Bench
5. Levee
6. Levee Meadow
7. Eroding Levee Meadow
8. Interlevee Basin Meadow
9. Interlevee Basin and Channel Bank
10. Interlevee Ponded Basin
11. Interlevee Pond
12. Meadow
13. Pond/Lake

Sedge is the dominant growth form in salt marshes along the LACL-Cook Inlet Coastline (Figure 10). In Tuxedni Bay, monotypic stands of *Carex ramenskii* comprise 41 percent of the sedge commmunity and the remainder is a complex of *C. ramenskii*, forbs, and grasses such as *Hordeum brachyantherum-Calamagrostis deschampsioides-Poa eminens/Argentina egedii*. Farther inland these stands become expansive meadows, spreading out from shallow narrow drainageways. These communities are rarely flooded, though frequent rain and spring thaws keep the silty soils and peaty substrate continuously saturated.

In Chinitna Bay vast meadows of a nearly pure community of *Carex lyngbyei* cover much of the Clearwater Creek marshes. This sedge community occurs over a flat, shallow gradient between grass forb levees, and extends inland from grass forb communities of mudflats and pannes along Chinitna Bay. Pure *Carex lyngbyei* communities also are found on ice-heaved margins of large brackish lakes at Clearwater Creek.

Triglochin maritimum - Puccinellia phryganodes/Plantago maritima graminoid forb community are common in all marshes except Bear Creek and Clearwater Creek. It is the dominant vegetation type at Squarehead Cove marsh, and on the south half of Silver Salmon marsh. This covertype is also an important mid-marsh community in Tuxedni and Horsefly marshes around Bear and Magnetic islands. Sites are flooded by daily tides or may only be occasionally inundated by high tides depending on the marsh. Landscapes are flat to undulating with shallow depressions and rises. A dense network of microdrainages is common in this type in Squarehead marshes. Silty soils are generally saturated and frequently have lower microsites that are semipermanently flooded especially after heavy rains, high tides or spring thaws.

Nine vegetation types constitute 82% of the salt marsh area. Most of the marshes appear to be significantly different with

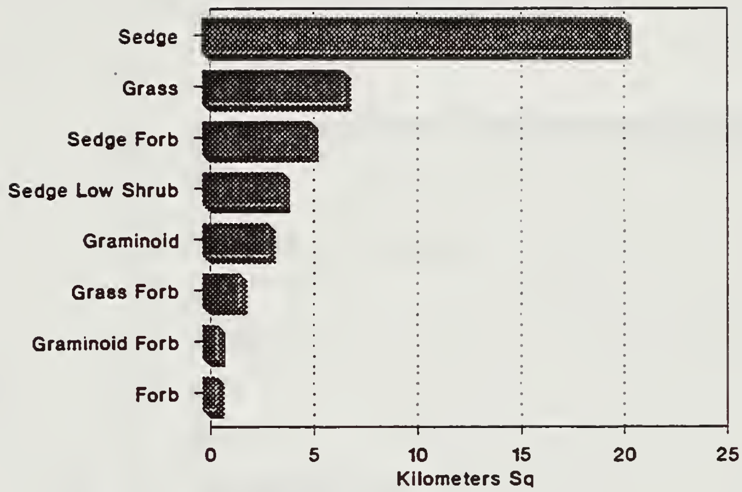


Figure 10. Composition of salt marsh community types along the LACL-Cook Inlet Coastline.

only a few vegetation types common with each other up and down the length of the coast (Figure 11). For example, Type 4 in which *Triglochin palustre* is the dominant species, occurs only in Tuxedni Bay where its distribution is limited to the southcentral region east of Open Creek. Brown bears and white-fronted geese graze heavily on *Triglochin* and their distribtuion in Tuxedni Bay conforms to the presence of this species.

Field data indicate a gradient of change from the coast inland related to the degree of tidal flooding. In most cases, this is reflected in very abrupt vegetation changes, while in other instances it can be gradual over long distances. The most seaward vegetation type(s) are the SPARSE HALOPHYTIC VEGETATION types consisting of *Triglochin palustre*, *Triglochin maritimum* and *Plantago maritima*. It eventually grades to *Carex ramenskii* meadows where *Puccinellia* may also form pure communities on pannes within the *Carex ramenskii* type. At Clearwater Creek marsh, it is associated with a *Hippuris tetraphylla* meadow community. Soils are saturated, and frequently have small pannes and microdrainages that are semipermanently flooded by daily tides.

Carex ramenskii forms extensive, monotypic meadows and lines the banks of tidal guts and streams. It is found on all marshes of the study area. The largest meadows occur in lower Tuxedni Bay upstream to Bear Island. Here, it occurs between barren mudflats

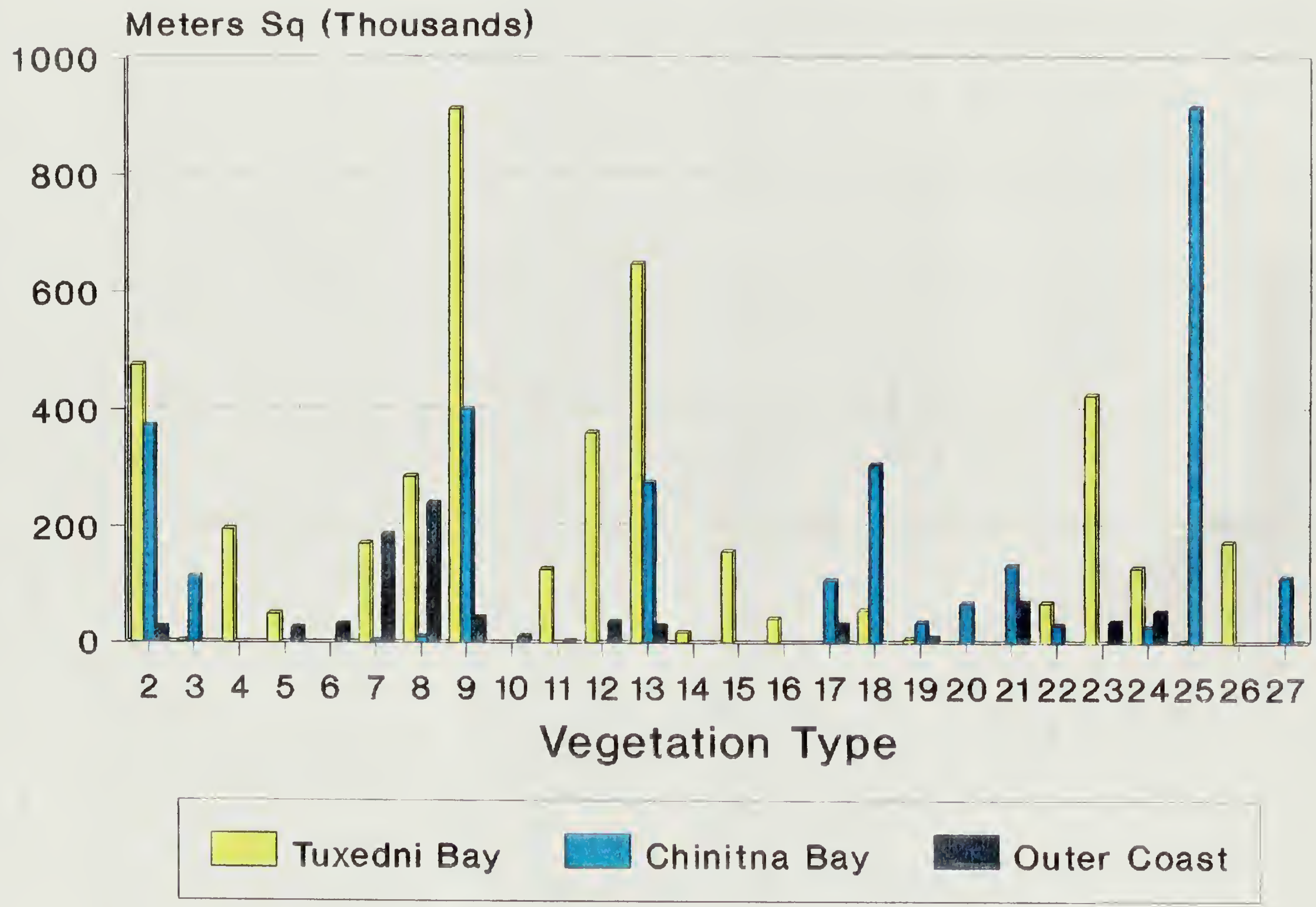


Figure 11. Area and composition of salt marsh vegetation types, Lake Clark National Park-Cook Inlet Coastline.

and the narrow *Puccinellia phryganodes* community, and the upland that rises abruptly off the marshes. The vast, low-gradient marshes of the western two thirds of the Clearwater Creek marshes are also predominantly pure Carex *ramenskii*. Winds periodically knock down swaths of sedges partially explaining the mottled tone on airphotos.

Carex lyngbyei/Argentina egedii communities form large meadows far inland and upstream in Tuxedni Bay and Horsefly marshes. They also occur near shorelines and behind old beach ridges at Squarehead and Shelter Creek marshes. Terrain is undulating to hummocky; sites are flooded by high tides. Silty soils are saturated and support a dense, tall (0.75 m), nearly pure cover of *Carex lyngbyei* and an open understory of *Argentina egedii*. Few associated species were observed to recur between marshes.

Lakes and ponds of mappable extent occur at Silver Salmon Creek, Glacier Creek, and Clearwater Creek marshes. Floating and rooted aquatic species of shallow water zones include: *Sparganium* spp., *Potamogeton* spp., *Utricularia* spp. and *Myriophyllum* spp. Extensive beds of *Sparganium angustifolium* extend from the shorelines of the large lakes at Clearwater Creek marshes and are evident on the 1:12,000-scale aerial photography.

This GIS saltmarsh vegetation database is both powerful and versatile; these attributes may be treated as independent variables (total of 54) or as any combination of variables for analysis purposes. In addition, these attributes may be integrated with other coastal data sets, such as geological features, or bird and animal densities for habitat investigations.

Floristics

A list of vascular plants reported to occur in southcentral Cook Inlet was prepared for the study. Limited vascular plant collections were made; these were verified by Jerry Tande and Mike Duffy, botanist, Antioch College, Keene, NH. A set of voucher specimens was prepared and deposited at Park Headquarters (c/o Park Curator Laurel Bennett). This collection includes specimens of *Eleocharis kamtschatica*, a species designated as G4S2 by the Alaska Natural Heritage Program (an affiliate of The Nature Conservancy) which tracks rare species in the state. *Eleocharis kamtschatica* was observed and collected at Shelter Creek marsh, and in the elbow of the upper Tuxedni River.

Texts used in identifications included Argus (1973), Hitchcock and Cronquist (1973), Hulten (1968), Porsild and Cody (1980), Viereck and Little (1972) and Welsh (1974). Nomenclature conforms with national standards of accepted taxonomic names established by NRCS/BNAP (1994). The reader is referred to this publication for acceptable common names and a crosswalk to older scientific names.

Table 4 contains a summary of the vegetation cover map classification developed for the study area. The table is arranged along a generalized gradient from coastal low-marsh types to more inland high-marsh types. Biophysical descriptors present useful images of the ecological characteristics of the coastal vegetation of LACL. The vegetation attributes are representative vegetation types that were described in the field; however, they may not necessarily include all of the species that were dominant from one location to another. Complex vegetation patterning is accentuated in marsh systems where minimal changes in elevation, and hence moisture, lead to subtle changes in vegetation over short distances (Figure's 12 and 13).

Implications for Monitoring- Salt marshes are a vital component of the LACL coastal ecosystem. Organic material originating in salt marshes is responsible for the high productivity of benthic invertebrates in adjacent mud flats and tidal sloughs (Warwick and Price 1975). Thus salt marshes contribute indirectly to food resources in all coastal habitats. Wildlife populations and coastal ecosystem processes will be effected by successional change in salt marshes. For example, reductions in the volume and spatial distribution of Type 4, *Puccinellia phryganodes-Triglochin palustre* will reduce foraging opportunities for brown bears, Canada geese, and white-fronted geese.

The sensitivity of salt marsh vegetation species to alterations in marsh hydrology results in changes to the direction and rate of succession and community composition (Reed 1995). Natural processes such as glacial melt, sea-level rise, and hydrostatic uplifting of coastal estuaries; and anthropogenic disturbances such as near coastal logging and road construction, effect tidal regimes and depositional processes. During 1997-2002, 10 million board feet of lumber will be removed from forested areas on the north side of Tuxedni Bay. Construction of roads and causeways across intertidal areas will probably increase intertidal sediment accretion rates. Thilenius (1995) demonstrated that increased sediment accretion promoted the spread of shrubs onto levees and the conversion of herbaceous meadow to shrubland.

Quantitative measurements of salt marsh vegetation communities are needed over time to assess changes in community composition, volume, and spatial patterns. Salt marsh monitoring along the LACL coastline needs to examine micro-elevation, substrata, tidal regime, and vegetation parameters such as taxa composition and coverage.

Table 4. Salt marsh vegetation cover types along the Lake Clark National Park-Cook Inlet coastline.

Photo Code	New Code	Physiographic Location	Site Moisture	Vegetation Type by Species Dominance	Growth Form	Landscape Descriptor
0	1		Wet			Mudflat
1	2	Coastal Low Marsh	Wet	*Puccinellia phryganodes*	Grass	Mudflat and Panne
2	3	Coastal Low Marsh	Wet	*Puccinellia phryganodes/Hippuris tetraphylla*	Grass Forb	Mudflat and Panne
3	4	Coastal Low Marsh	Wet	*Puccinellia phryganodes-Triglochin. palustre*	Graminoid	Mudflat and Panne
5	5	Coastal Mid Marsh	Wet	*Puccinellia phryganodes-Puccinellia red-Puccinellia tall-Triglochin maritimum*	Graminoid	Panne
6	6	Coastal Low Marsh	Wet	*Puccinellia grandis/Plantago maritima*	Graminoid Forb	Tidal Stream Bench
9	7	Coastal Mid Marsh	Wet	*Carex ramenskii-Triglochin maritimum*	Graminoid	Interlevee Ponded Basin
10	8	Coastal Mid Marsh	Wet	*Carex ramenskii-Triglochin maritimum-Puccinellia phryganodes/Plantago maritima*	Graminoid Forb	Interlevee Basin Meadow
11	9	Coastal Low & Mid Marsh	Wet	*Carex ramenskii*	Sedge	Interlevee Basin & Channel Bank
15	10	Coastal Mid Marsh	Moist	*Leymus mollis/Argentina egedii*	Grass Forb	Levee
16	11	Coastal Mid Marsh	Moist	*Carex ramenskii-Hordeum brachyantherum/Argentina egedii*	Graminoid Forb	Levee
17	12	Coastal Mid Marsh	Moist	*Carex ramenskii-Hordeum brachyantherum/Argentina egedii - Plantago meritima*	Graminoid Forb	Eroding Levee Meadow
21	13	Coastal High Marsh	Moist	*Carex glareosa-Carex ramenskii-Hordeum brachyantherum-Calamagrostis deschampsioides-Poa eminens/Argentina egedii*	Graminoid Forb	Levee Meadow
21a	14	Coastal High Marsh	Wet	*Carex lyngbyei/Comarum palustre*	Sedge Forb	Levee
22	15	Coastal High Marsh	Wet	*Carex ramenskii-Carex glareosa/Argentina egedii*	Sedge Forb	Interlevee Basin Meadow
23	16	Coastal High Marsh	Wet	*Carex ramenskii-Carex mackenziei-Calamagrostis deschampsioides/Argentina egedii*	Graminoid Forb	Interlevee Basin Meadow
24	17	Coastal High Marsh	Wet	*Carex ramenskii-Carex mackenziei*	Sedge	Interlevee Ponded Basin
26	18	Coastal Low & Mid Marsh	Wet	*Carex ramenskii/Hippuris tetraphylla*	Sedge Forb	Interlevee Ponded Basin
27	19	Coastal Mid Marsh	Wet	*Carex ramenskii-Eleocharis palustris/Hippuris tetraphylla*	Sedge Forb	Interlevee Pond
28a	20	Coastal High Marsh	Wet	*Calamagrostis canadensis-Poa eminens/Lathyrus palustris-Lathyrus japonicus var. maritimus*	Grass Forb	Levee Meadow
28	21	Coastal Mid Marsh	Wet	*Carex lyngbyei-Carex pluriflora-Carex ramenskii-Calamagrostis deschampsioides/Argentina egedii*	Graminoid Forb	Meadow
30a	22	Coastal High Marsh	Wet	*Carex lyngbyei-Carex mackenziei*	Sedge	Interlevee Ponded Basin
32	23	Coastal High Marsh	Wet	*Carex lyngbyei-Carex pluriflora/Salix fuscescens-Myrica gale/Moss sp.*	Sedge - Low Shrub - Moss	Meadow
35	24	Coastal High Marsh	Wet	*Carex lyngbyei/Argentina egedii*	Sedge Forb	Meadow
36	25	Coastal High Marsh	Wet	*Carex lyngbyei*	Sedge	Meadow
37	26	Coastal High Marsh	Wet	*Carex lyngbyei-Calamagrostis canadensis/Comarum palustre*	Graminoid Forb	Meadow
38	27	Coastal High Marsh	Wet	*Spargenium sp.-Potamogeton sp.-Utricularia sp.*	Forb	Pond or Lake
U	28	Upland	Moist			

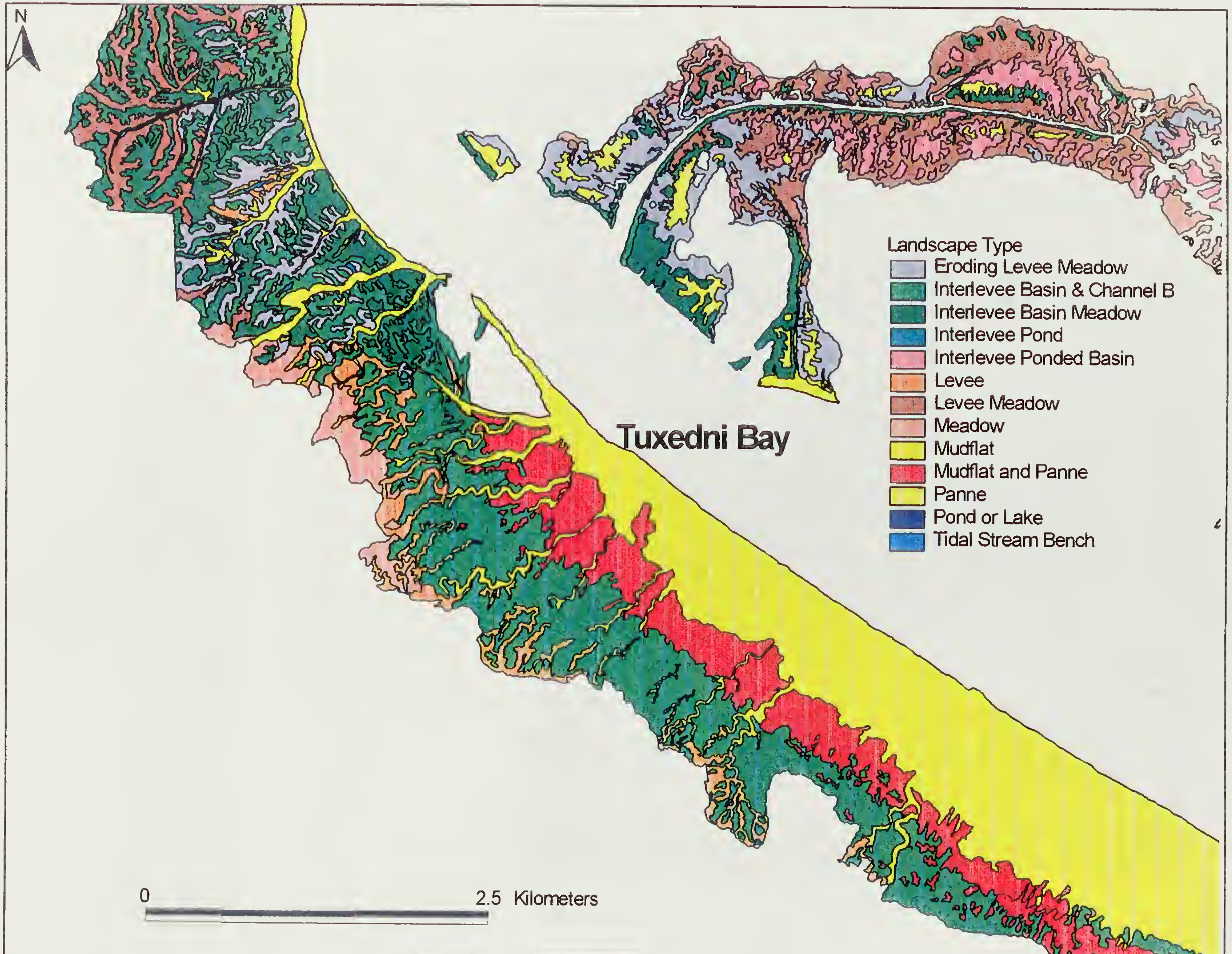


Figure 12. Landscape attributes of salt marshes in Tuxedni Bay, Lake Clark National Park-Cook Inlet Coastline.

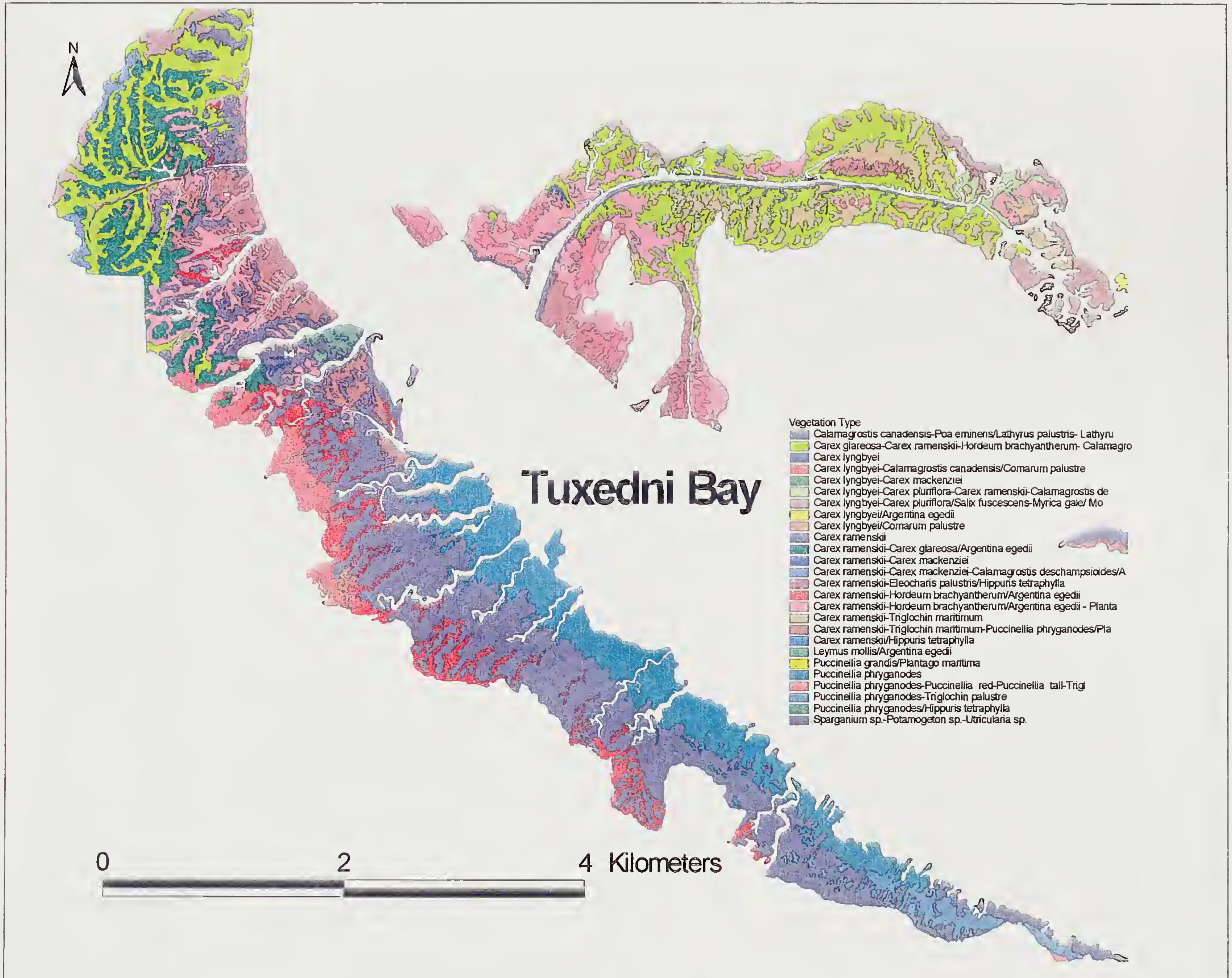


Figure 13. Salt marsh vegetation types in Tuxedni Bay, Lake Clark National Park-Cook Inlet Coastline.

Shorebirds

Methods- Shorebird abundance and distribution was estimated in spring by aerial surveys of the intertidal zone between Redoubt Point and West Glacier Creek. A Piper PA-18 aircraft with a pilot and observer experienced in aerial survey procedures conducted each survey. The aircraft was operated at 30 m above ground at approximately 100 km/hour ground speed as described by Gill and Jorgensen (1979). The number of shorebirds in each of 3 size classes was estimated while flying the coastline 1-2 hours before high tide or after a height of 14.0 feet is reached in Tuxedni Channel. This tide level was the minimum necessary to flood the vast mud flats in Squarehead Cove and at the mouth of Bear Creek and concentrate shorebirds. A systematic search pattern was flown over any expanses of intertidal flats that remained exposed. Observations were recorded on tape recorders and locations of large flocks (>1,000 birds) plotted on 1:20,000 scale maps.

Where possible, ground transects were conducted to determine relative numbers, species composition, habitat use, and to provide a comparison of air:ground estimates of shorebird numbers. Ground transects sampled each of the major substrate types, i.e. mud, sand, and gravel. Geographical landmarks and habitat similarities were used to divide the survey route into segments. Ground transect counts were conducted daily and aerial population surveys at 2-day intervals in spring and 4-day intervals in fall. Major survey periods were 1-20 May and 10-30 August.

Abundance- Shorebirds were surveyed daily along the LACL coast during spring migration (1994-96). Shorebirds began arriving during the final days of April (<500 birds) and reached peak numbers during 7-13 May. Peak daily counts occurred on 9 May 1994 (62,600); 10 May 1995 (24,500); and 14 May 1996 (23,400). After 16 May <1,000 shorebirds were observed during all years. These counts are unadjusted for visibility bias and represent minimum estimates. Air:ground comparisons revealed that aerial counts underestimated flock sizes by 20%. In addition, flocks seen by observers on the ground were sometimes missed by observers in the aircraft.

The earliest arrivals were common snipe (Gallinago gallinago), short-billed dowitchers (Limnodromus griseus), and semipalmated plovers (Charadrius semipalmatus). Western sandpipers (Calidris mauri) and dunlins (C. alpina) comprised 63 and 28 percent of the all shorebirds respectively. Least sandpipers (C. minutilla) were the third most abundant species accounting for 4 percent of the sightings. Little variation (<5 percent) was observed in composition among years. Other major species (>200 birds) included sanderlings (C. alba), red knots (C. canutus), pectoral sandpipers (C. melanotos), Hudsonian godwits (Limosa haemastica), and whimbrels (Numenius phaeopus).

In 1995-96, 80 western sandpipers (WESA's)/year were radio-tagged on the Frazer River Delta, British Columbia, and Stikine River Delta in southeastern Alaska in a joint effort between the USFWS, Canadian Wildlife Service, U.S. Forest Service (FS) and the Copper River Delta Institute (CRDI). LACL personnel monitored for these radio-tagged birds during all survey flights.

During both years 5 radio-tagged WESA's were located along the LACL coastline. None of these radio-tagged birds remained >24 hours and 2 departed within 12 hours of detection. These observations along with wide daily variation in the number of shorebirds sighted suggests a high rate of population turnover. During high tide cycles (>17 feet) that flood over 90% of the available mud flat in Chinitna and Tuxedni Bays, virtually all WESA's and dunlins were observed leaving the area and moving northeast (up Cook Inlet). Assuming that a complete daily population turnover occurs, 86,000 to 122,000 shorebirds stop along the LACL coastline during spring migration (1994-96).

No shorebird concentrations were observed during the fall migration. Small flocks of shorebirds, primarily western sandpipers, began appearing along the coast in early July and scattered flocks were observed passing through the area until early September. At no time during the fall migration were more than 500 shorebirds observed during an aerial survey.

The LACL coastline is not a major shorebird breeding area (LACL unpubl, records 1992-93). Black oystercatchers (Haematopus bachmani) and black turnstones (Arenaria melanocephala) were observed nesting on Chisik Island in 1994 and used portions of the mainland coast.

Distribution- Small shorebirds were primarily associated with the vast intertidal mudflats of Tuxedni and Chinitna Bay's. Western sandpipers occurred almost exclusively on very fine mud and clay substrates whereas dunlin were more widespread and also occurred on transition zones between mud and sand flats and along the seaward edge of salt marshes. Squarehead Cove on the northern shore of Tuxedni Bay, accounted for 61% of the shorebirds sighted during all years (Figure 14). Large shorebirds occurred primarily in tidal estuaries and on river deltas. Although flocks of shorebirds were observed in flight along the outer coast, few were sighted on the ground. Shorebird distribution varied between surveys but seasonal patterns of distribution were similar among years.

While monitoring for radio-tagged WESA's, I estimated shorebird abundance throughout western Lower Cook Inlet from Kustatan to Augustine Island/Bruin Bay twice/year (1995-96). These aerial surveys were timed to coincide with peak counts along the LACL coastline (7-13 May). These observation provide an index to the relative importance of various sites to shorebirds during spring migration. Redoubt Bay and the LACL coastline accounted for 65% and 23% of the shorebirds sighted respectively (Figure 15).

Although ground composition counts were not obtained outside of the LACL coastline, numbers of small shorebirds (presumably Caladrids) were relatively scarce south of the Iniskin Peninsula. Augustine Island, which supports relatively little intertidal mud and sand flat habitat, had the highest number of medium and large shorebirds.

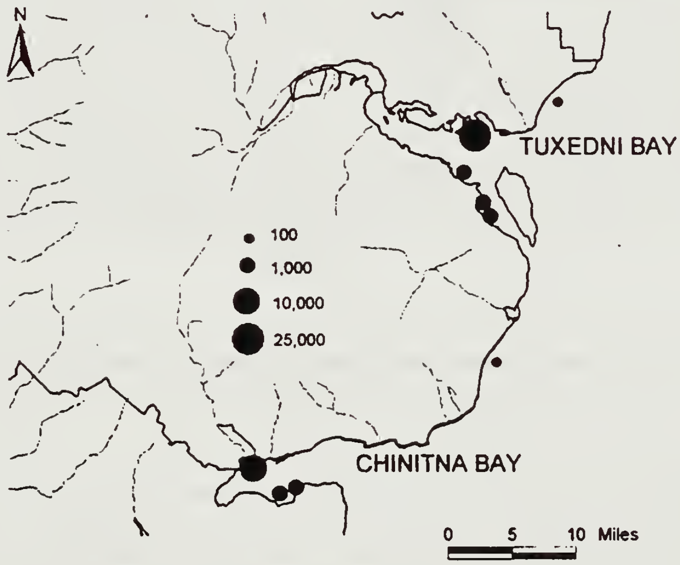


Figure 14. Distribution of shorebirds along the LACL Cook Inlet coastline during spring migration 1994-96.

<u>Inventory & Monitoring Implications</u>- Intertidal mud flats in Chinitna, Tuxedni, and Redoubt Bays are an important link in the annual cycle of shorebirds. Shorebird feeding on these mud flats are acquiring energy reserves that are critical for the completion of migration and reproductive success. Destruction or contamination of intertidal invertebrate resources could adversely impact a significant proportion of the Western sandpiper population and Western Alaska subspecies of the dunlin.

Aerial shoreline surveys conducted within 2 hours of high tide are considered to be the most accurate and efficient means of estimating shorebird abundance over vast areas of tidal flat along the northern Gulf of Alaska (Bishop and Green 1993-94).

Despite their value to the conservation of migratory birds, data from shorebird surveys exhibit appreciable variation that makes meaningful analysis difficult (Colwell and Cooper 1993).

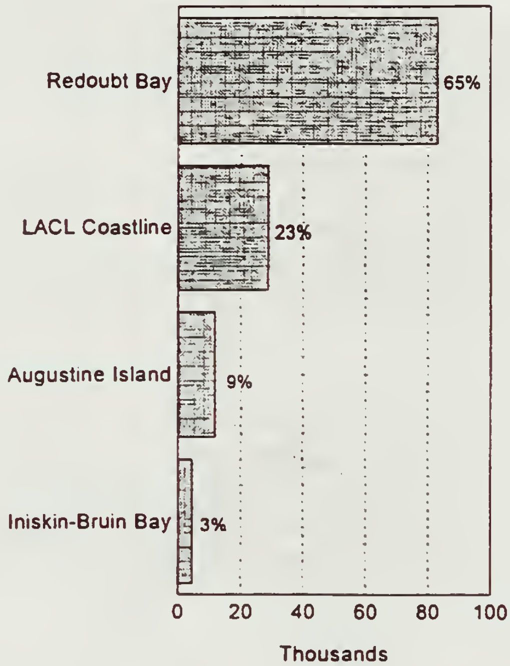


Figure 15. Distribution of shorebirds in Western Lower Cook Inlet during spring migration, 1995-96.

Shorebird migration monitoring along the LACL coast is confounded by weather-induced observation bias, the interaction between weather and tidal inundation and its influence on shorebird movements, and yearly variation in migration chronology. Shorebirds displaced from foraging habitat by rising tides along the LACL coastline move up the Inlet. Only when weather conditions are adverse for migration, dense fog or NE winds >25 km/hr, do shorebirds remain and concentrate on the upper exposed tidal flats of Tuxedni and Chinitna Bays.

Despite detailed knowledge of local tidal regimes, it is difficult to predict shorebird movements in Tuxedni and Chinitna Bays. Scheduling counts to consistently coincide with optimum observation conditions is next to impossible. Redoubt Bay, a vast 30 mile-long tidal flat located 7 miles north of the LACL coastline, may be the best site in western lower Cook Inlet for shorebird migration monitoring. Redoubt Bay supports the largest concentration of shorebirds in lower Western Cook Inlet during spring migration (Gill & Tibbitts 1993, Bennett this study 1996) and is less prone to foul weather that hampers surveys south of Chisik Island.

Waterfowl

<u>**Methods**</u>- Migratory waterfowl numbers and distribution were determined weekly from 15 April to 20 May and 15 August to 15 October by aerial surveys of bays, tidal estuaries and the outer coast. Winter surveys were conducted monthly (December-March) to examine overwinter use by diving and sea ducks. Survey timing and frequency were often adjusted depending upon ice conditions, migration chronology, and tides. Aerial surveys were conducted from a fixed-wing aircraft operated at an altitude of 30-40 m and a ground speed of 100-130 km/hour. Transect width on the outer coast was 0.5 km, bays were systematically surveyed. The same pilot and observer and the same flight procedures were used during all 3 years of the survey.

Early (June) and late summer (July-August) surveys were used to measure production of local breeding species. Waterfowl production surveys of freshwater lakes/ponds were conducted with a Bell 206B jetranger helicopter. Production surveys of the coastline were conducted from a 22 foot aluminum skiff powered by twin 50 hp outboards during 1994. A skiff operator piloted the vessel near the coastline, islands and off-shore rocks, and in intertidal estuaries. One or more observers used 8-10X binoculars to determine species, age, numbers of birds sighted, and location.

Productivity surveys were also be conducted for trumpeter swans and common loons because they forage extensively in coastal habitats before and after the breeding season. Swan and loon surveys were conducted once during incubation and again prior to the chicks fledging to measure breeding effort and breeding success. Most surveys were conducted using a helicopter. If a loon or swan was sighted on a water body, the shoreline and islands were searched for nests. All water bodies known to be active nesting territories were checked for young during the second survey. Waterbird brood surveys were only conducted during periods of peak brood activity (early morning) on clear days when wind velocity was low to avoid wave action in ponds.

<u>**Seasonal abundance and composition**</u>: Aerial waterfowl surveys were conducted within 1 hour of low tide, 2-4 times/month from 1 April to 30 September each year. Survey frequency and coverage were often limited by weather conditions. Efforts to survey waterfowl during October were entirely unsuccessful due to unfavorable weather conditions.

Dabbling ducks were most numerous during spring and fall migration and reached peak abundance during late April (3,450) and early September (4,200). Mallards (<u>Anas platyrhynchos</u>) accounted for 57% of the dabbling ducks observed during spring migration. Other species included Northern pintail (<u>A. acuta</u>)

28%; green-winged teal (A. crecca) 7%; American wigeon (A. americana) 4%; and Northern shoveler (A. clypeata) 3%. In fall the proportion of mallards and green-winged teal increased (64 and 10% respectively) and pintails declined (21%.). Species composition varied weekly in response to individual migration chronology. Composition among years was similar except for spring 1995 when pintails comprised 41% of the dabblers.

Diving ducks reached peak abundance (16,400 birds) in mid-May (Figure 16). Diver numbers declined throughout May and did not exceed 1,000 birds during the remainder of the year. Unlike dabbling ducks, divers do not stage along the Lake Clark

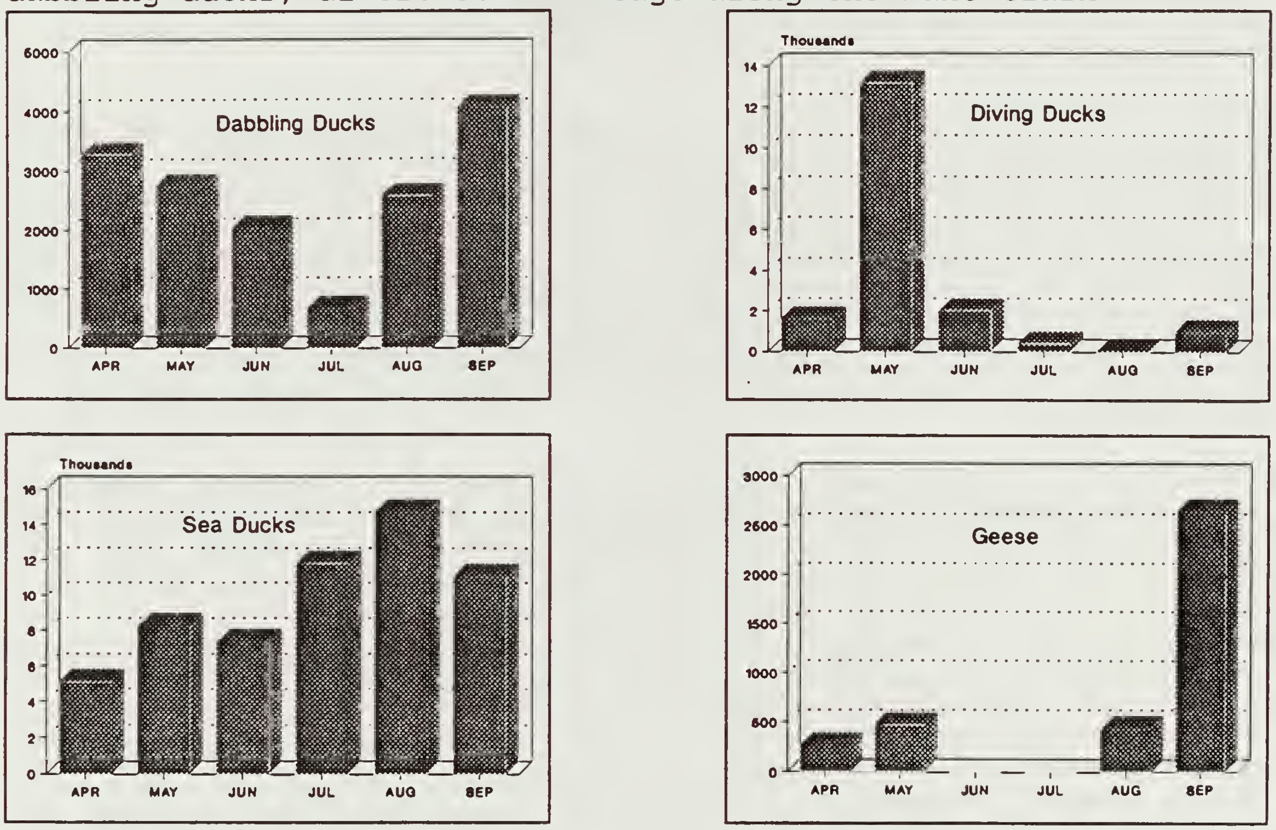


Figure 16. Monthly abundance of waterfowl, Lake Clark-Cook Inlet Coastline, 1994-96.

coastline during fall migration. Greater scaup (Aythya marila) and lesser scaup (A. affinis) accounted for 98% of the diving ducks. Other diving ducks (less than 200 individuals/survey) included ringneck (A. collaris) and canvasback (A. valisineria).

Sea ducks were the most abundant waterfowl during all months except May. Sea duck numbers steadily increased during spring and early summer and peaked in mid-August when 18,500 were observed (1994). Scoters (Melanitta sp.) comprised 96% of the sea ducks during all months except April.

Scoter composition was determined monthly in Tuxedni and Chinitna Bays by fixed-point ground counts. Surf scoter (M. perspicillata) were the dominant species and represented 67% of all scoters sighted (1994-96). However, scoter composition varied spatially and temporally along the LACL coastline. Surf scoters were the dominant species in Tuxedni Bay whereas white-winged scoters (M. fusca) were the most abundant species in Chinitna Bay (Figure 17). Black scoters (M. nigra) were scarce in both bays and represented <5% of the scoters. White-winged scoters increased during mid and late summer while surf and black scoter declined.

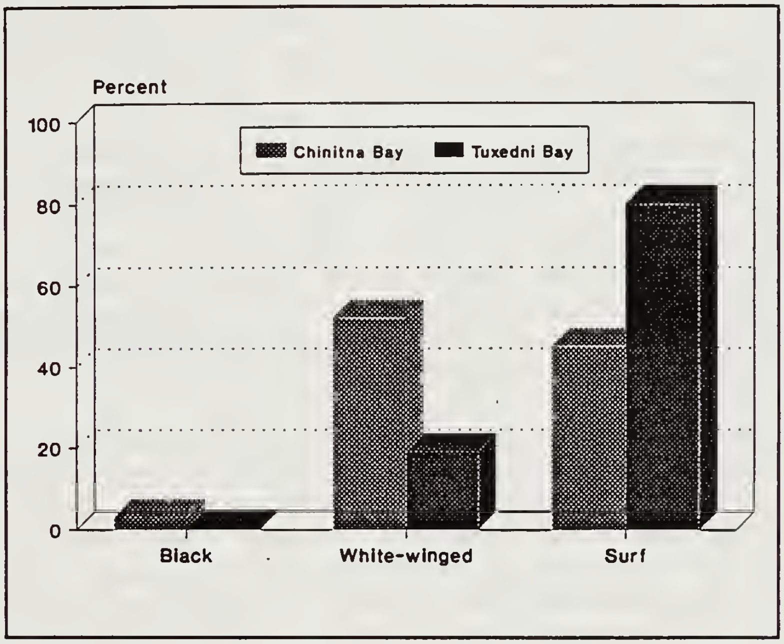


Figure 17. Composition of scoters in Tuxedni and Chinitna Bays, Lake Clark National Park-Cook Inlet Coastline, 1994-96.

Scoter species were unequally distribution within bays. Surf scoters favored the heads of the bays while white-winged scoters primarily occurred near the mouth. Scoters do not nest in coastal waters of LACL but rather concentrate for molting and feeding.

Oldsquaws appeared on the LACL coastline as early as 6 April and were the first migratory waterbirds to arrive in spring. Oldsquaws were the second most abundant sea duck in April and May (1,486±492 birds, 1994-96) but were not sighted during the remainder of the year. Common eider occurred in all months but were most numerous during June (280±91 birds, 1994-96). Common eider nests were detected on Chisik Island and adult females with young were sighted in nearshore waters of Tuxedni Bay.

Aerial counts did not provide a meaningful estimate of harlequin ducks because they were relatively inconspicuous from the air and widely distributed in small groups ($\leq$10 birds). Harlequin abundance was estimated by skiff counts in 1994 and by walking selected coastline segments in 1995-96. An estimated 140-200 harlequin ducks were sighted during May 1994-96. Harlequin ducks were scarce or absent in Tuxedni Bay and the upper half of Chinitna Bay. Most harlequins (64%) occurred along a 28 km section of outer coast between Shelter Creek and Horn Creek. Within this area, harlequins concentrated at the mouths of Shelter, Spring, East Glacier, and Horn Creeks, and near an offshore reef at Clam Point. Linear density of harlequin ducks (3.3 ducks/km) in this section of coastline was similar to that reported on Kodiak Island (Zwiefelhofer 1995).

Barrows goldeneye (Bucephala clangula) and common goldeneye (B. islandica) were common in nearshore waters during spring (355$\pm$190 birds, 1994-96) but absent during summer and fall. Although goldeneye were one of the species most easily counted from the air, species could not be identified. Ground surveys revealed that Barrows goldeneye accounted for 97% of the goldeneyes. Bufflehead (B. albeola) occurred during spring migration but were relatively uncommon (<50 birds).

Common mergansers (Mergus merganser) and red-breasted mergansers (M. serrator) constituted 63 and 37% of the mergansers identified during costal surveys respectively. Mergansers were most abundant in April and May (486$\pm$211 birds, 1994-96) when they concentrated within the mouths of rivers in response to the availability of anadromous fish prey. Red-breasted mergansers, which primarily occurred in pairs and small groups, were probably underestimated.

Geese occurred almost exclusively in Tuxedni Bay and primarily during fall migration when 4,400 Canada geese (Branta canadensis) were observed. In spring, goose numbers peaked at 500 birds during the last week of April. Canada and white-fronted geese (Anser albifrons) comprised 88 and 12 percent of the geese in spring respectively. Tuxedni Bay may not attract large numbers of geese in spring because most tidal marshes in upper Tuxedni Bay remain frozen and snow-covered until after most migrating geese have left the Cook Inlet region. Other geese sighted in Tuxedni Bay throughout the survey period (<25 birds) included brant (Branta bernicla) and emperor geese (Chen canagica).

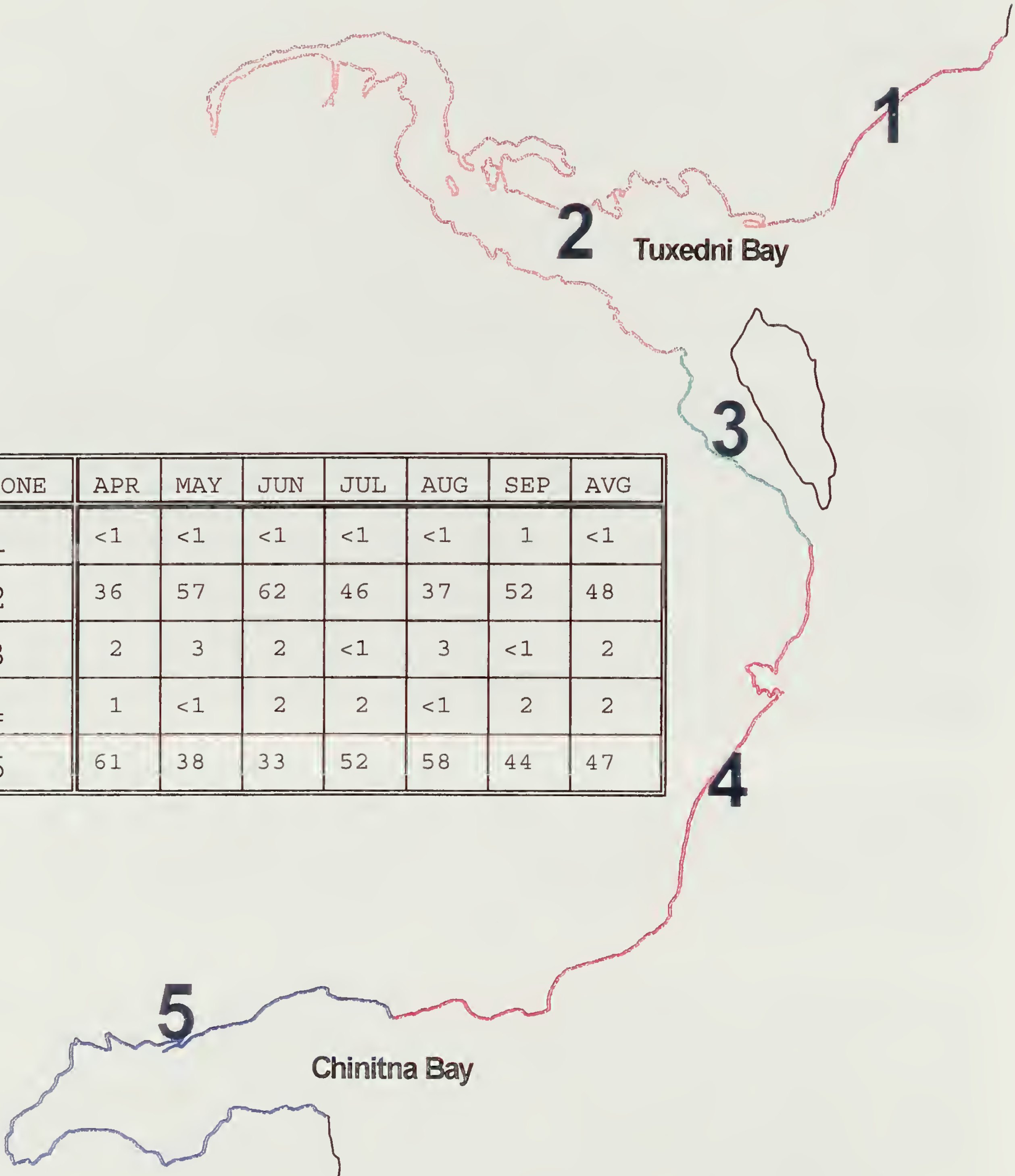
Loons (Gavis sp.) were most abundant during fall in marine subtidal waters (2.8$\pm$3.0 birds km^2). All three species of loons observed on near-coastal freshwater ponds in the study area during the nesting season were in mature breeding (definitive alternate) plumages, were in pairs and were on territories. Red-throated loons (G. stellata), which occurred exclusively in beaver flowages within the Red River and West Glacier Creek valleys, accounted for 67% of all breeding loons. There were no groups of non-breeding loons that congregated on freshwater ponds during June-August.

Distribution- Eighty-six percent of the waterfowl use occurred in Chinitna and Tuxedni Bays (Figure 18). Although use of specific sites within bays was not quantitatively measured, distribution was disproportionate. In Tuxedni Bay, scaup and scoters favored the southern edge of the bay between Difficult Creek and Fossil Point (73% of all sightings). Few waterfowl of any species were sighted west of Magnetic Island. In Chinitna Bay, scaup and scoters concentrated between the mouth of Clearwater Creek and Seal Spit on the southwest end of the bay. Most geese (92%) occurred in salt marshes on the south side of Tuxedni Bay. Sighting of geese in Chinitna Bay normally involved white-fronts and in flocks numbering <100 birds.

Habitat affiliation and density of waterbirds varied among the major groups. Density of dabbling ducks was greatest along the mouths of rivers and intertidal slough-mud flats (Table 5). In Chinitna Bay, the lower mainstem and sloughs of Clearwater Creek accounted for 88% of the dabbling duck use in spring and fall. Diving ducks occurred almost exclusively in the intertidal zone of bays within 100 m of the waters edge. Like dabblers, divers frequently occurred in long linear rafts that paralleled the edges of wide mud flats. Sea ducks occurred in both the intertidal and subtidal zones. At low-mid tidal levels sea ducks occurred in oval-shaped rafts within 0.5 km of the waters edge. In Tuxedni Bay, which has extensive off-shore bars, scoters were more widely distributed and often moved toward the mouth of the bay during ebb tides.

Productivity: Resident waterfowl and loon populations and production were measured by aerial counts of breeding adults in late May and adults and young in early August (1994-96). Both surveys were accomplished with a helicopter and covered all freshwater lakes, ponds, and streams within the coastal study area.

An average of 186 breeding pairs of waterfowl and loons were counted annually (range=168-231). This count was not corrected for visibility bias and represents a minimum estimate of the breeding population. Sightability widely varied between highly conspicuous species such as swans and loons and inconspicuous species such as mergansers. Mallards, American Wigeon, trumpeter swans, and Barrows goldeneye constituted 40%, 16%, 14%, and 13% of the breeding population of waterfowl and loons respectively. Other breeders represented by $\geq$ 5 pairs included Northern pintail, red-breasted mergansers, and red-throated loons.



ZONE	APR	MAY	JUN	JUL	AUG	SEP	AVG
1	<1	<1	<1	<1	<1	1	<1
2	36	57	62	46	37	52	48
3	2	3	2	<1	3	<1	2
4	1	<1	2	2	<1	2	2
5	61	38	33	52	58	44	47

Figure 18. Monthly distribution of waterfowl among survey zones (percent), Lake Clark National Park-Cook Inlet coastline, 1994-96.

Table 5. Density (birds/km²) of the most common waterbird groups in coastal habitats of Chinitna and Tuxedni Bays, Lake Clark-Cook Inlet coastline, April -September 1994-96.

Bird Group	Season	Subtidal	Intertidal	River Mouth	Salt Marsh
Dabbling Ducks	Spring	0	158.1±116.7	29.4±22.1	6.8±4.3
	Summer	0	10.0±8.8	[illegible].2±4.7	10.1±8.8
	Fall	0	142.6±98.7	33.9±24.4	5.3±3.2
Diving Ducks	Spring	33.3±38.0	378.6±177.8	27.1±11.9	0
	Summer	0	0.9±4.6	0	0
	Fall	0	4.8±3.7	0	0
Sea Ducks	Spring	46.0±20.7	55.8±32.1	0	0
	Summer	283.1±111.6	308.0±171.3	[illegible].6±8.1	0
	Fall	136.1±98.2	76.4±67.4	2.2±0.9	0
Geese	Spring	0	0.6±0.7	0	8.1±6.6
	Summer	0	0	0	0
	Fall	0	4.2±3.6	2.1±3.8	67.7±36.4
Loons	Spring	0.7±3.6	0.3±0.3	0	0
	Summer	0.6±0.7	0	0	0
	Fall	2.8±3.0	0.1±0.3	0	0
Cormorants	Spring	0.1±0.6	2.9±2.0	7.1±4.9	0
	Summer	0.7±3.3	3.8±3.6	1.3±2.2	0
	Fall	1.1±2.5	2.9±5.1	0.5±0.2	0

Waterfowl brood visibility was considered low because many wetlands, especially beaver flowages, were partially forested. Gabor et al. (1995) recommended visibility correction factors of 2.09 for helicopter surveys of broods in boreal forested wetlands. Because of the low and variable sighting rates of broods, productivity is expressed as reproductive rates, i.e., the number of fledged first-year birds alive in late summer per adult female alive and present in spring. Mean annual reproductive rates ranged from 4.79 for mallards to 0.16 for Pacific loons (G. pacifica) (Table 6). However, statistically meaningful sample sizes only existed for the 5 most numerous species.

Production rates for dabbling ducks in forested wetlands adjacent to Cook Inlet are unknown. Reproductive rates of northern pintails within the study area (3.4-4.3) were greater than those reported by Flint and Grand (1996) for the Yukon-Kuskokwin Delta (3.3-3.5). Reproductive rates of trumpeter swans along the LACL coastline were greater than the Alaska-wide average (0.90-0.97, 1991-94; Conant and Groves 1994), while rates for red-throated loons were in the low range of those reported elsewhere (0.35-0.86; Dickson 1992).

Productivity of harlequin ducks was not determined because no effective techniques exist for counting broods of this species in forested riparian habitats. Harlequin broods were observed in the Crescent River during August in 1994-95. Adults and young

Table 6. Reproductive rate[1] of waterbirds along the Lake Clark National Park-Cook Inlet Coastline, 1994-96.

Species	1994	n=pairs	1995	n=pairs	1996	n=pairs	Avg
COLO	1.50	n=2	0.50	n=2	0	n=0	0.66
PALO	0	n=4	0.50	n=2	0	n=0	0.16
RTLO	0.25	n=8	0.20	n=5	0.50	n=6	0.32
TMSW	1.18	n=28	1.11	n=27	1.07	n=25	1.12
MALL	4.55	n=91	5.66	n=64	4.16	n=69	4.79
AMWI	2.41	n=46	4.07	n=15	3.25	n=31	3.24
NOPI	3.66	n=6	4.33	n=3	3.50	n=12	3.83
RNDU	2.20	n=14	5.14	n=7	2.33	n=5	3.22
BAGO	3.16	n=28	4.04	n=27	2.91	n=17	3.37
RBME	3.00	n=4	6.11	n=9	4.00	n=3	4.37

1/ Reproductive rate is the number of fledged, first-year birds alive in late summer (August) per adult female alive and present in spring (May).

were not sighted during coastal surveys in August and September, which suggests that broods do not descend the river systems until October or later.

Implications for monitoring: Birds that use the Lake Clark-Cook Inlet Coastline are at high risk from both acute and chronic oil spills. Pollution that interferes with the production of organic detritus which supports filter and deposit-feeding fauna, could have more serious long term consequences to the birds than oiling. In terms of biomass, the trophic relationship between sea and diving ducks and bivalves such as M. balthica, may be the most significant predator-prey linkage for this coastline. The daily food consumption (minus shell) of adult scoters is approximately 196g/day (Vermeer 1981). At that rate, 10,000 scoters could consume 2 metric tons of mollusk meat daily. Dabbling ducks, like divers and sea ducks, also forage primarily within the intertidal zone.

Among resident breeding species, Barrows goldeneye are an excellent species to monitor because they feed on mussels while in coastal habitats (Verneer 1981) and are the fourth most numerous species. Near-coastal breeding red-throated loons feed primarily on marine forage fish (Eriksson et al. 1990) and are highly sensitive to changes in coastal habitats. Dabblers probably exploit the plethora of prey available on river deltas and intertidal mud flats including gammarid amphipods, polychaetes, gastropods, and bivalve mollusks. Because they breed locally, ubiquitous species such as mallards may be useful bioindicators of hydrocarbon pollution.

Skiff surveys, used in 1994, proved impractical for counting waterbirds along the LACL coast. Due to shallow near-shore waters and navigation hazards such as rocks and sandbars, skiff surveys had to be conducted at $\geq$5 m tidal heights. Even at this level, shorelines in upper Tuxedni Bay could not be approached closer than 0.5 km. Because of the narrow survey window ($\pm$2 hours of high tide) it required 2 days to complete the survey. Large rafts of sea and diving ducks were difficult to count from a skiff. Both groups of birds often flushed at distances of >1 km which lead to "double counting" and forced observers to simultaneously estimate birds in the air and on the water. At high tide, ducks enter flooded intertidal mud flats and are widely dispersed. Visibility is often impaired by rough seas, rain and the low sighting angle of the observers with respect to the horizon.

Tidal levels $\leq$0 are optimum for aerial surveys of all waterfowl species along the LACL coastline. At a -1 tidal level, surface water area in Chinitna and Tuxedni Bays declines by 31% and 52% respectively. During low tide, sea and diving ducks concentrate and loaf in relatively large and compact rafts. At high tide they widely disperse over shallow intertidal flats and dive to forage on benthic invertebrates. Dabbling ducks concentrate along the waters edge on intertidal mud flats during low tide where they are highly visible and are easily counted. At high tide they disperse into salt marsh ponds and sloughs and near-coastal emergent wetlands.

Chinitna and Tuxedni Bays represent a relatively small proportion of the habitat available to scoters in lower Cook Inlet. However, Angler et al. (1994) estimated 50-70,000 scoters in lower Cook Inlet during 1993. Based on this survey, the Lake Clark Coastline supports 20-30% of this population. It is unknown whether scoters exhibit seasonal or annual fidelity to specific regions of Cook Inlet. Periodic aerial surveys of the region between the West Forelands and Kamashak Bay suggest that seasonal shifts in distribution are common. For example, the lowest June-July 1996 counts of scoters in Tuxedni Bay coincided with the highest counts in Redoubt Bay 35 km to the north. Meaningful population monitoring of scoters in lower Cook inlet requires broader coverage than the LACL coastline.

Existing knowledge of the distribution and abundance of prey species of benthic feeding ducks is inadequate to determine availability and importance to birds. Studies are needed in western Cook Inlet to determine feeding habits of diving and sea ducks concurrently with sampling of the epibenthos and infauna within the -2 to +5 m tidal range.

Raptors - Bald Eagle

<u>Methods</u>- Fixed-wing aircraft and skiff surveys were used to search for raptor nest sites. The survey effort sampled the entire 192 km of coastline, all major coastal rivers, and all near-coastal lake shore habitat below 3,000 feet elevation. An "Early Occupancy Survey" (EOS) was flown after most of the eggs were laid and before the majority of nests failed (late May-early June). A "Late Productivity Survey" (LPS) was flown when young were large enough to be seen from the air, but before they had fledged (5-9 weeks-late July). Only those nests that were considered active or occupied during the EOS were surveyed during the LPS.

All data were collected and recorded following United States Fish and Wildlife protocols (Bowman 1992) and entered into the Alaska state-wide database. Terminology for productivity followed Bowman (1992) and Postupalsky (1974). Productivity is expressed as percent nest success (number of successful nests per total number of active and occupied nests), percent of active nests successful, number of young per occupied nest, and number of young per successful nest. Only those nests with data from both surveys were used for productivity measurements.

Aerial surveys for raptors were supplemented with ground surveys on foot or boat because in some situations aircraft did not permit prolonged viewing or access to nest sites. A skiff or helicopter was used to place observers at sites with good vantage points from which raptors can be detected or monitored. Because falcons and other raptors respond vocally to intruders in their nesting territories, listening for defensive calls or courtship calls is often an effective survey technique.

Nest site locations were plotted on 1:63,000 USGS topographic maps and recorded using a Global Positioning System (GPS) receiver. Raptor numbers, productivity, and nest site characteristics will be entered on raptor observation data sheets and transferred into the Parks natural resources database and coastal GIS.

<u>Distribution, Abundance and Productivity</u>- Survey dates for the EOS and LPS varied depending on annual fluctuations in bald eagle breeding phenology, localized weather conditions, and availability of pilots and observers. The same pilot and observer conducted all surveys and both were experienced in bald eagle nest surveys.

Early Occupancy Surveys in 1994 and 1996 were conducted during required dates of mid to late May. However, the EOS in 1995 was conducted later in the breeding season and may have resulted in an underestimate of occupied and active nests. Results from this survey should not be used to estimate 1995 bald eagle productivity. However, this information can be used to look at broad changes in productivity and bald eagle presence/absence at particular nest sites.

Forty-five, 48, and 50 nests were known in 1994, 1995, and 1996, respectively (Figure 21). Of these, 3 of 45 (7.0%) in 1994, 1 of 48 (2.0%) in 1995, and 4 of 50 (8.0%) in 1996 were not found during the EOS. Nineteen, 14, and 22 nests in 1994, 1995, 1996, respectively, were found empty during the EOS and not checked during the LPS.

Ninety-one percent of nests along the outer coastline were constructed in Sitka spruce (Picea sitkensis), whereas 84% of nests located inland along coastal rivers were constructed in cottonwood (Populus balsamifera). Most nests (94%) were situated within 100 m of shorelines. Two nests along the outer coast were constructed on the ground at the edge of cliffs.

Breeding chronology appeared to be influenced by snowcover, temperature and the availability of prey, primarily waterfowl and marine forage fish. In Chinitna Bay and along the outer coast, reestablishment of territories and nest construction began in late April. Farther inland up the Johnson and Crescent River valley's, arrival on territories and nest construction often did not occur until early May. During all years, incubation peaked on 15 May and most young fledged by 15 August.

Mean bald eagle productivity from 1994-1996 was 0.8 young fledged/occupied nest and 1.44 young fledged/successful nest, 56% of occupied nests were successful (success rate) and 60% of active nests produced one or more chicks (Table 7). Sprunt et al. (1973) determined that a bald eagle population should have at least a 50% success rate and 0.7 young fledged/occupied territory to remain stable. The success rate on the Lake Clark National Park coastline exceeded those figures for all 3 years studied and was similar to those of other areas in Alaska (Sprunt et al. 1973, Hansen 1987, Tetreau 1991, Kralovec and Yerxa 1995).

Table 7. Bald eagle productivity along the Lake Clark National Park-Cook Inlet Coastline, 1994-1996.

Year of Survey	No. Occupied and Active Nests	% Occupied Nests Successful	% Active Nests Successful	No. Young/ Occupied Nest	No. Young/ Successful Nest
1994	21	52.0	52.0	0.81	1.55
1995	30	63.0	66.0	0.80	1.26
1996	19	53.0	63.0	0.79	1.50

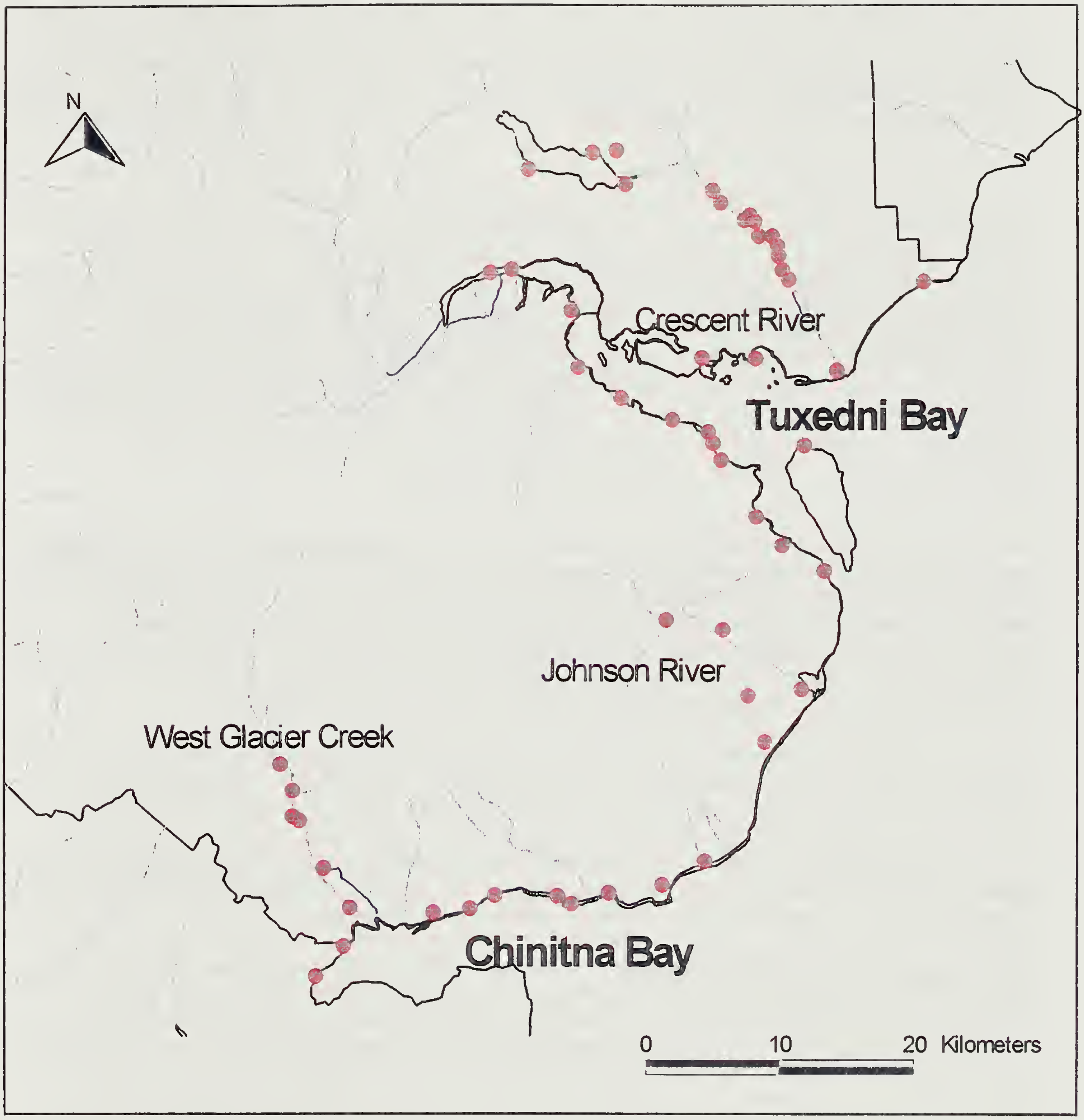


Figure 19. Distribution of bald eagle nests along the Lake Clark National Park-Cook Inlet coastline, 1994-96.

The number of occupied and active nests increased from 1994 (n =21) to 1995 (n = 30), but declined again in 1996 (n = 19). Nest success appeared to follow the same trend, with more occupied and active nests successful in 1995 than either 1994 or 1996. It is likely that nest success was high in 1995 because the EOS survey was flown late in the breeding season. Even though overall nest success was higher in 1995 than 1994 or 1996, the number of young fledged per occupied nest remained relatively consistent (Table 7).

Fifty-five and 50% of the successful nests in 1994 and 1996, respectively, produced 2 fledglings/nest. In 1995, only 26% of the successful nests produced 2 fledglings/nest. On the other hand, 74% of the 1995 successful nests produced 1 fledgling/nest. Several factors; including food supply, environmental conditions, and human disturbance around individual nests could have contributed to this discrepancy between years. Hansen (1987) found that in areas of the Chilkat River where food was limited fewer nests were successful than in those areas where food was abundant. More likely it is a natural fluctuation in the breeding cycle caused by more viable eggs and young produced in 1994 and 1996.

The spatial distribution of eagle nests along the LACL coastline has shifted during the past 5 years. Since 1991, the number of nests along the outer coast has declined while the number of nests inland along coastal rivers has increased. Occupied territories between Clam Cove and Spring Point declined from 5 in 1991 to 0 in 1995 whereas the number of territories on the Crescent River increased from 5 in 1991 to 9 in 1995.

Post-breeding concentrations of bald eagles occurred along several coastal rivers. On 10 December 1994, 260 bald eagles were counted along the Johnson River and in late December 1995, 190 bald eagles were counted along West Glacier Creek. Eagles are attracted by the availability of chum salmon (Oncorhynchus keta) and silver salmon (O.kisutch) in these river systems which often do not completely freeze until mid-January.

Implications for Monitoring- Bald eagle populations along the Lake Clark National Park coastline are at risk from oil spills, logging, road construction and mining. These activities can eliminate existing and potential nesting habitat and contaminate food sources. Of immediate concern is the logging of 10 million board feet of timber on native lands within the Crescent River valley. This region supports 40% of the bald eagle nests along the LACL coastline and displacement of these eagles could have a adverse ripple effect on the entire population. The construction of a 25 km road across Park Lands to support the operation of the CIRI-Johnson River Mine could impact nesting within the road corridor and displace eagles that concentrate in this valley to feed on late runs of salmon.

Five or more years of bald eagle productivity data are necessary to identify significant change in reproductive success. Year-to-year fluctuations in reproductive success and productivity are common in raptors and short-term decreases do not affect the long-term stability of populations. At LACL, the first aerial surveys of bald eagle reproduction began in 1983, however, surveys were often sporadic and incomplete and the methods were not standardized. Since 1992, standard USFWS survey protocols have been used and the results are entered into the Alaska Statewide bald eagle database. This systematic approach to monitoring productivity is needed so that results can be compared between years and geographic regions.

In addition, an understanding about bald eagle use of the Lake Clark National Park coastline is currently incomplete. Further work on food habits, identification of foraging areas, human disturbance near nest sites, and breeding phenology could contribute to a better understanding about bald eagles in the Lake Clark National Park ecosystem.

Peregrine Falcons

Distribution and Abundance- In 1994-96, peregrine falcon eyries, fledgling young, or adults exhibiting breeding behavior were observed at 6 sites along the Lake Clark National Park coastline and one site on Chisik Island adjacent to Tuxedni Channel (Table 8). In 1996, 7 adults and 6 fledgling falcons were observed at 5 different cliffs. These sites included a small cliff (elevation = 94 m) at the north end of the West Glacier Spit Bear Meadow, Chinitna Bay; a cliff (elevation = 141 m) on the south end of Tuxedni Channel and three sites in Tuxedni Bay; mouth of Difficult Creek, mouth of Tuxedni River and the west side of Squarehead Cove (elevations = 60-94 m).

Most peregrine falcon breeding sites were located directly adjacent to sea bird colonies and falcons were commonly observed preying on black-legged kittiwakes, gulls and young cormorants. Productivity was not obtained for falcon nests. Five of 6 cliffs with falcons were located in the Tuxedni Bay/River drainage. Fledglings (n = 6) were observed or heard at 4 of the 6 cliffs. This suggests that this area supports several active eries. Reasons for this are currently unknown, but could be related to adequate nesting habitat, large food supply, or both.

The youngest nestlings were approximately 20 days old and the oldest nestlings were approximately 40 days old during the surveys in late July. By using the observed age of nestlings to calculate the range in nesting phenology, initiation of egg laying occurs during 15-31 May, hatching occurs during 15 to 30 June, and fledging occurs from 20 July to 15 August (Figure 22).

Table 8. Location of peregrine falcon nest sites on the coastline of Lake Clark National Park and Preserve, 1994-96.

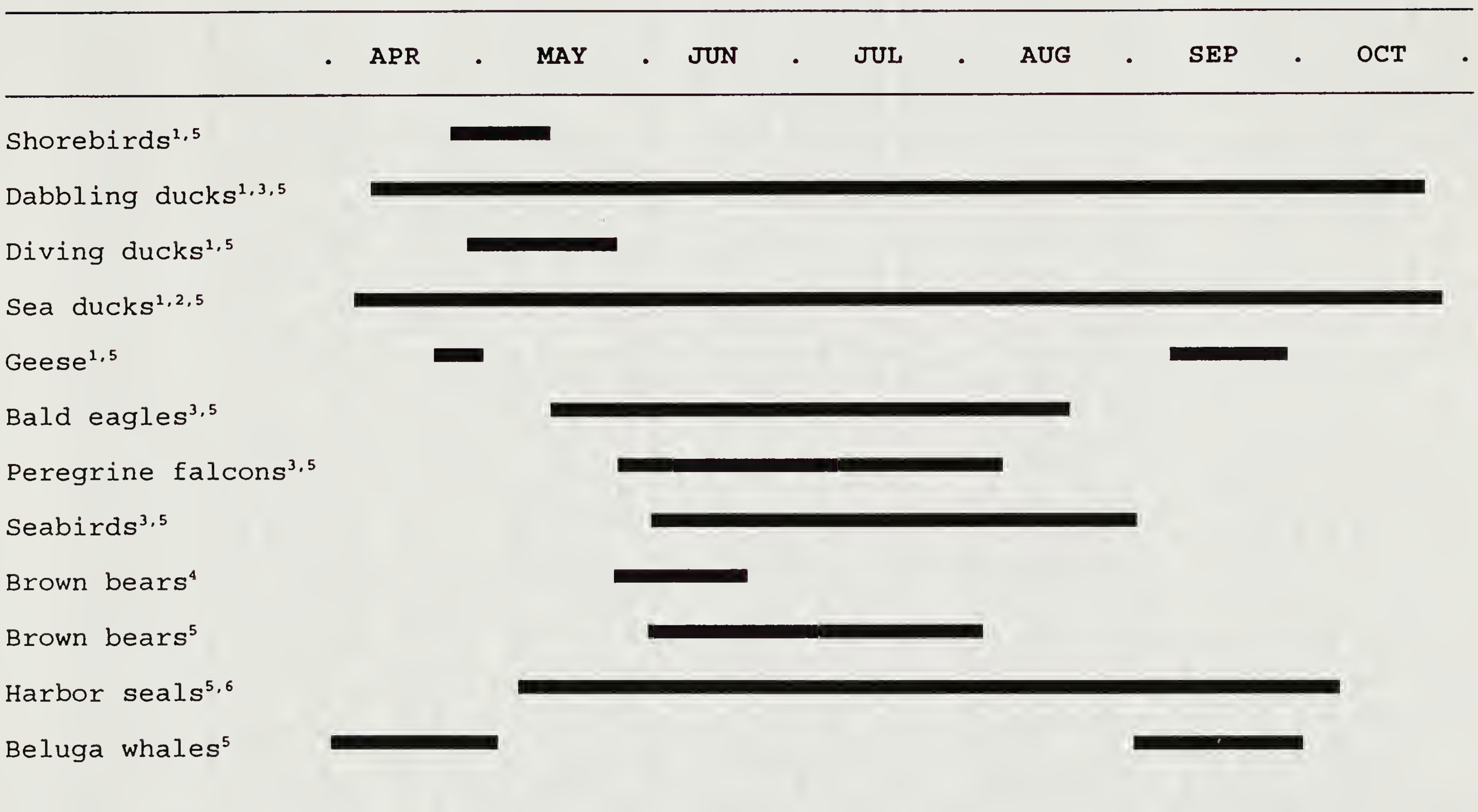
Nest No.	Latitude	Longitude	General Description
PEFA 001	59° 52.23	152° 06.83	Northwest West Glacier Spit Bear Meadow
PEFA002	60° 05.02	152° 34.83	Northeast Slope Mt.
PEFA003	60° 07.03	152° 36.15	Southwest Chisik Is.
PEFA004	60° 11.15	152° 45.25	Northwest of Difficult Creek
PEFA005	na	na	Squarehead Cove
PEFA006	60° 15.63	152° 53.25	West Tuxedni River

<u>Implications for Monitoring</u>- The mean height for cliffs with falcons along the Lake Clark National Park coastline was 100 m. This suggests that peregrine falcons in this area nest at relatively low elevations. Some peregrine falcons nesting in interior Alaska nest as low as 15 m above the riverbed (C. McIntyre, NPS, pers. comm.). Based on this, we suggest selecting cliffs < 150 m when surveying for peregrine falcon presence.

Little is known about the breeding phenology of falcons along the Lake Clark National Park coastline. Surveys for determining peregrine falcon presence should be conducted in late May to early June, when adults are laying eggs, or late July to early August, when young are near fledging or have already fledged. During these periods adults and young are vocal and can be detected easily. A minimum of 3 hours should be spent surveying the cliff face. On one occasion we observed a cliff for 2 hours before a fledgling peregrine was heard calling.

When determining falcon productivity, cliff surveys should take place in early June during the egg laying period and again in late July, before fledging. In early June a minimum of 4 hours should be spent observing a cliff in order to determine the eyrie location and reproductive status. In late July, enough time should be spent to identify the number of nestlings.

Figure 22. Annual Chronology of Peak Bird and Mammal Use, Lake Clark National Park-Cook Inlet Coastline



Codes: 1=staging/migration; 2=molting; 3=nesting; 4=mating; 5=foraging; 6=haulout

Seabirds

Methods- Seabird survey efforts focused on identifying nesting colonies on the LACL coastline and determining the size and productivity of these colonies. Black-legged kittiwake (*Rissa tridactyla*) adult and nest counts were conducted in mid to late June when most adults had laid eggs but before many nests had failed. Chick counts were conducted in late July to early August when chicks are large enough to identify but before fledging. To facilitate counting and insure continuity between years cliff faces were divided into individual plots based on geomorphic characteristics.

Results were compared after each observer had completed their count. Counting continued until each observers total was within 5% of each other. If after 5 attempts the counts were still not within 5% the counts were averaged. An occupied nest was any nest with an adult nearby and fresh nesting material present. Five photographic adult counts of all plots were taken and these photographs were compared to visual counts of adults.

Chick counts were conducted by each observer on one plot at a time. At the end of the count results were compared and if not in complete agreement a recount was made of the same plot. Because chicks are difficult to identify and fewer in number than adults and nests, counts were repeated of the same plot until we were in total agreement. Productivity is expressed as the number of occupied nests, nunber of young/occupied nest, and percent nest success (no. of successful nests/no. of occupied nests).

Adult Double-crested cormorant (*Phalacroconax auritus*) and glaucous-winged gulls (*Larus glaucescens*) were counted from a skiff while navigating in front of the colonies. Counts for adults and nests were conducted in mid-June when eggs had been laid, but before most nests had failed. Two observers silently counted at the same time, with one observer counting adults and the other nests. Only those adults that were perched near or on a nest or in an incubating posture were counted. An occupied nest was designated as one with an adult near or observed in an incubating posture (Postupalsky 1974).

Horned puffins (*Fratercula corniculata*) and pigeon gullimots (*Cepphus columba*) were counted from a skiff during the incubation period (mid-June to mid-July). Counts were conducted at high tide during the early morning hours (Sanger and Cody 1994). The objective of puffin and guillemot surveys was to identify the location and size of colony sites. No efforts were made to search for nests or count young.

Numbers and productivity of seabirds on Chisik Island, a unit of the Alaska Maritime National Wildlife Refuge, was determined during a comprehensive survey effort in 1993 (L. Slater, USFWS, pers. comm.). Because most seabirds that frequent the LACL coastline breed on Chisik Island, no effort was made to obtain a population estimate in near-coastal waters.

__Distribution and Abundance__- Seven seabird colonies were identified along the LACL coastline in 1994. All seabird colonies were surveyed throughout the breeding season in 1995-96 to determine the number of adults and young. Except for a colony of black-legged kittiwakes on the south end of Tuxedni Channel, colonies contain <100 breeding birds (Table 9).

Table 9. Location, size and breeding effort of seabird colonies along the Lake Clark National Park-Cook Inlet Coastline, 1995-96.

Colony No.	Location	Species	No. Adults		No. Young	
			1995	1996	1995	1996
1	Squarehead Cove - Tuxedni Bay	PIGU	7	11	NA	
2	Squarehead Cove - Tuxedni Bay	HOPU	20	10	NA	
3	Tuxedni River	DCCO GWGU	50 35	59 82	30 20	71 NA
4	Fossil Point, Tuxedni Channel	PIGU	12	13	NA	
5	Tuxedni Channel	BLKI HOPU	1612 9	2726 0	NA NA	91
6	Slope Mountain	GWGU	40	37	38	NA
7	Clam Point	PIGU	9	6	NA	

In recent years, numbers and productivity of black-legged kittiwakes have been declining in various areas of the Cook Inlet ecosystem (J. Piatt, NBS, pers. comm.). The United States Fish and Wildlife Service (USFWS) has started a long term study in this area to identify potential causes for the decline. In Lake Clark National Park and Preserve, the black-legged kittiwake colony at Slope Mountain has been monitored sporadically. In 1996, a more systematic approach, developed by the USFWS, (J. Piatt, NBS, pers. comm., R. Yerxa, NPS, pers. comm.) was used to determine productivity and obtain a adult population estimate.

The Slope Mountain black-legged kittiwake colony was divided into 13 plots and photographs were taken of each plot. These photographs can be used, in the following years, to identify plot locations. Using the same plots from year to year will result in a more systematic approach to counting. The results can then be compared to look at annual and seasonal variation.

Two counts of occupied nests were conducted on 13 and 17 June 1996 and 2 counts of adults on 17 June and 30 July 1996. The adult count on 30 July 1996 was used to compare parental attendance after some nests had failed and when young were close to fledging. Three observers, using binoculars, counted on 13 and 17 June 1996; while 2 observers conducted the counts on 30 July 1996. The first count on 13 June 1996 was conducted at mean high tide to get as close to the colony as possible. Sea conditions in this area made counting difficult, therefore all subsequent counts were conducted at mean low tide. In addition to visually counting adults we also obtained a photographic record of all adults on 17 June and 30 July 1996. These photos were then used to compare a photographic count with visual counts.

The mean number of occupied nests for all plots was 2,260, with 2,726 adults and 94 chicks counted (Table 10). The number of nests/plot ranged from 8 to 338. Those plots towards the middle of the cliff appeared to have the highest number of adults and

Table 10. Mean number of nests/plot, adults/plot, and chicks/plot counted at the Slope Mountain black-legged kittiwake colony, Lake Clark National Park-Cook Inlet Coastline, 1996.

Plot No.	No. Nests	No. Adults	No. Chicks
1	28.4	28.3	3.0
2	97.0	120.0	0.0
3	125.8	136.0	0.0
4	211.3	254.5	4.0
5	338.3	423.0	18.0
6	156.5	215.0	6.0
7	322.3	341.0	5.0
8	303.5	376.0	35.0
9	249.5	286.0	14.0
10	244.6	350.5	6.0
11	79.3	86.0	3.0
12	7.5	7.0	0.0
13	96.5	103.0	0.0
Total	2260.3	2726.3	94.0

nests. This is likely due to increased vegetation towards the ends of the cliff and, in turn, poorer nesting habitat.

Adult numbers appeared to decline from 2,726 on 17 June 1996 to 2,020 on 30 July 1996. This may be a result of adults associated with failed nests leaving the colony permanently or for extended periods of time. In 1995, 1,612 adults were counted on 7 July. The discrepancy between 1995 and 1996 may be due to differences in counting methodology, observer experience, time of year, and weather conditions. Kittiwakes from this colony did appear to expand from 1995 to 1996 as no kittiwakes were observed nesting on Plot 13 in 1995.

The Slope Mountain kittiwake colony experienced a 4.2% nest success with 0.04 young/occupied nest. These figures appear to be relatively low. Variables such as experience of the observers, weather and water conditions, and tidal height could have biased the results. However, because there is little data available on this colony it is difficult to make any comparisons.

Productivity was also obtained for a double-crested cormorant colony present on a cliff on the Tuxedni River. Counts for adults and nests were conducted in mid-June when eggs had been laid, but before most nests had failed. Productivity estimates were based on 4 separate counts of adults and nests. Three counts were completed on 17 June 1996 and one on 18 June 1996.

Adult cormorant numbers ranged from 56 to 62 with a mean of 59 adults. Occupied nest numbers ranged from 39 to 50 with a mean of 39 nests. Counts of adults and occupied nests in 1995 were 50 and 30, respectively. However, several factors may have contributed to this including: experience of observers, difference in counting methodology, and weather conditions. Only through continued monitoring of this colony can an accurate assessment of cormorant numbers be determined. In 1996, the mean number of chicks/occupied nest was 1.6. No figures are available from 1995 on the number of chicks observed at this colony. On Chisik Island, double-crested cormorants have declined since the early 1970's (Slater et al. 1995).

Glaucous-winged gull nests ranged from 35 to 39 (Mean 34) at the Tuxedni River colony and 37 to 42 (mean 37) at the Slope Mountain colony. Fledging rates of glaucous-winged gull chicks was not determined.

Three pigeon guillemot colonies were active during each year of the survey (Table 9). Guillemot colony size averaged 10 birds which is typical for colonies in Prince William Sound (Sanger and Cody 1994). Studies of guillemot colony attendance patterns have demonstrated that numbers can fluctuate daily (Nelson 1987), consequently these counts should be considered minimum estimates of breeding population size for the LACL coastline. Pigeon guillemots have not been detected breeding on Chisik Island (Slater et al. 1995).

Horned puffins nest on a small island in Squarehead Cove, Tuxedni Bay. Numbers of adults that were observed loafing on the water in front of this colony ranged from 43 in 1994 to 10 in 1996. Wide intertidal mud flats counfounded access to this site and no attempt was made to estimate the breeding population.

Implications for monitoring- Oil spills affect seabirds through direct or indirect mortality, lowered reproductive performance, and changes in habitat that lead to altered populations size and status (Weins et al. 1993). To demonstrate that populations or reproductive output have been altered, there must be sufficient prespill data. Affected populations may remain stable if immigration has occurred and has balanced spill-related mortality.

Seabird monitoring is most effective when it incorporates planned comparisons (Hatch et al. 1993). Ideally, species should be monitored at many dispersed colonies at frequent intervals. Changes in demographic parameters of small colonies, such as those at LACL, may provide early indications of natural or anthropogenic changes to the marine ecosystem. For example, species such as pigeon guillemots that forage within 5 km of their colonies and do not breed in large dense colonies, are one of the best-suited avian species for monitoring nearshore marine ecosystem health (Duffy et al. 1995).

A key requirement of seabird monitoring is that observations are replicated over time and are made with sufficient precision and accuracy to permit the meaningful analysis of variability and trends. Consequently, seabird monitoring at LACL should be a joint venture under the direction of the seabird study group of USGS-BRD or USFWS.

Marine Mammals

Harbor seals

Methods- Minimum population estimates of harbor seals were determined from aerial surveys using visual counts, photographs (Pitcher and Calkins 1979) and videography of animals on haul-out sites. A Piper PA-18 aircraft with a pilot and observer experienced in aerial survey procedures conducted each survey. The aircraft was operated 500 m above ground at approximately 100 km/hour ground speed. Harbor seal surveys were conducted on ebbing tides (within 2 hours of low water) when the maximum number of animals were expected to be visible. Seal herds containing >25 animals were photographed with a 35 mm camera equipped with an 80-200 mm lens. Aerial photographs of seals on land or ice haul-outs were used to determine adult:pup ratios. Survey frequency was directed at obtaining a minimum seasonal population estimate, identification of preferred haul-out sites, and the location of pup rearing areas.

Abundance and Distribution- Two to 4 surveys/month were conducted for harbor seals from 1 April to 30 September. Monthly abundance is expressed as the average number of animals estimated during that period. In 1994-95 independent visual estimates were made by the pilot and observer and all groups of seals >50 were photo-censused. Visual estimates fell within 4 ± 1.3% of counts obtained by photo-censusing. In 1996, only visual estimates were obtained.

Three major seal haulout sites were identified: (1) Upper Tuxedni Bay; (2) Johnson River delta; and (3) Upper Chinitna Bay/Clearwater Creek. These sites accounted for 96% of all seal haulout sightings. The primary haulout in Upper Tuxedni Bay occurs at the mouth of a deeply cut slough bank 2.2 miles east of Open Creek. A second Tuxedni Bay haulout site, used only in 1994, occurs on a mid-channel bar 2 miles north of Open Creek. Both sites are on intertidal mudflat. At the Johnson River delta, seals haulout on a series of sandbar islands within the intertidal zone at the mouth of the river. In Chinitna Bay, seals haulout along the mouth of Clearwater Creek within the middle intertidal.

Monthly abundance at harbor seal haulout sites ranged from 78-244 animals (Table 11). Numbers peaked at all haulouts during July when up to 280 animals were sighted. Seal numbers at haulouts were most stable during June and July and little variation occurred among years; 244 in 1994, 181 in 1995, and 218 in 1996. Use of haulouts declined rapidly during mid-August. No seals were sighted at the Johnson River haulout after early July. Human disturbance, primarily air and boat traffic associated with the operation of several nearby lodges and commercial fishing sites, may affect use of this area.

Although survey frequency was not sufficient to define pupping dates, most pupping had occurred by 10 June. Seal pups were not present at haulouts during most aerial photo-surveys and proved

Table 11. Monthly abundance of harbor seals at haulout sites along the coast of Lake Clark National Park-Cook Inlet Coastline, 1994-96.

Haulout Site	April	May	June	July	Aug	Sept
Tuxedni Bay	20 15-25	72 68-75	132 132-140	184 125-243	97 85-110	62 62-75
Johnson River	43 20-65	40 35-45	46 8-80	8 0-16	0	0
Chinitna/ Clearwater	15 11-20	43 40-50	57 48-60	52 42-62	36 30-40	52 52-90
Totals	78 52-106	155 146-173	235 136-280	244 167-243	133 127-140	114 122-177

values = mean and range respectively

difficult to count from a skiff. A minimum estimate of 8 pups was made on 8 June, 1994. In 1995, an aerial count was obtained in Tuxedni Bay during optimal survey conditions and a -5 tide level. This tide level afforded the opportunity to see most of the pups and obtain adult/pup ratios. Three groups of seals were counted containing 108 adults and 17 pups, 0.16 pups/adult. Maternal seals did not linger in the upper Bay after pupping and few were observed after 15 July.

No seals were sighted during mid-winter surveys (Dec-March) which suggests that harbor seals leave Chinitna and Tuxedni Bays entirely. Winter distribution is probably controlled by the lack of forage availability and ice conditions in this area of the Inlet. Seal appearance in spring coincides with the arrival of migratory prey species.

Long-time Chinitna Bay residents W. Beyers and R. Haeg (pers comm.) have witnessed a major decline in harbor seals since the 1970's. Calkins (1979) observed 400 harbor seals in Chinitna Bay during a haulout survey in 1976. During 1994-96, 46 $\pm$ 18 seals were estimated in this bay and the highest single count was 90 animals.

Implications for Monitoring- Harbor seals occupy shallow near-coastal waters where they opportunistically prey on invertebrates and fish including herring, salmon, eulachon, and cephalopods (Pitcher and Calkins 1979). They are relatively sedentary and exhibit high fidelity to haulout sites which are important during pupping and molting (Pitcher and Calkins 1979). The EVOS caused population declines and sublethal injuries to harbor seals throughout Prince William Sound (EVOS Trustee Council 1994). Organochlorines, which are resistant to biochemical breakdown (Hansen 1985), may be influencing long term recovery of this species.

Harbor seals select haulouts that afford protection from predators, access to deep water, proximity to food, and protection from strong winds and high surf (Hoover-Miller, A.A. 1994). The strong fidelity to haulout sites observed along the LACL coastline suggests that preferred sites are few in number. This highlights the need to protect haulout sites and monitor changes in use by harbor seals.

Aerial harbor seal counts at haulout sites provide an index to population status (Pitcher and Calkins 1979). Their position in the food chain, site fidelity, and visibility make harbor seals an excellent candidate for monitoring change in coastal ecosystems. The survey protocol for harbor seal haulout counts at LACL will involve: an aerial survey of Tuxedni Bay for adult/pup ratios during 1-10 June during a -2 or lower tide cycle and two aerial surveys for adults on or near 10 July and 10 August; visual estimates by pilot and observer and photo estimates of groups >50; survey within the tidal window of low ± 90 minutes and prior to mid-day (0600-1200 hrs); survey altitude > 300 m.

Beluga whales and other marine mammals

Methods- Seasonal presence of beluga whales was noted during weekly aerial or ground surveys of the coastline. When beluga whales were present, numbers were estimated using an aerial photo-survey. This survey was conducted at low tide when whales were concentrated in shallow water. Other marine mammals, such as sea otter, Steller's sea lions, killer whales and humpback whales, intermittently occur along the LACL coastline but were not abundant enough to support a systematic survey effort. Records were maintained of all marine mammal species sighted in conjunction with aerial and ground surveys.

Abundance and distribution- Surveillance for beluga whales occurred during all aerial surveys of the coast. When whales were sighted, the group was circled until counts were completed and video or still photographs were collected. By watching the group for several minutes and noting the locations of turbulence and mud plumes, a relatively accurate group estimate could be obtained. Counts were usually obtained at minus tide levels when whales were in very shallow water (<5 m) at the heads of bays. Adult/calf ratios were not obtained during the counts.

Beluga were first sighted in Tuxedni Bay on 5-10 April. At this time ice normally covers up to 60 percent of the Bay and whales concentrate near the entrance adjacent to the mouth of the Crescent River. A maximum of 120 individuals was sighted at this location on 8 April 1994. A similar concentration of 135 belugas was observed in Chinitna Bay on 14 April 1995. Beluga whale numbers steadily declined throughout April and no whales were sighted from 1 May to late-August 1994-96. During 10-30 September, 160-200 beluga whales were sighted in Tuxedni and Chinitna Bays each year. Belugas were usually feeding when sighted in near-coastal waters. The animals were in a compact cluster and randomly aligned with respect to one another.

The Cook Inlet population of belugas is currently estimated at 1,000 animals (R. Morris, pers comm.) and up to 20% of this population uses the LACL coastline. Dense concentration of prey are believed to be essential for successful foraging by belugas (Hazard 1988). The arrival of belugas in Tuxedni and Chinitna Bays appeared to coincide with large runs of eulachon (Thaleichthys pacificus) that spawn in lower reaches of glacial rivers in May and June. Belugas may also be attracted to these bays by in spring by outmigrating smolts and in fall by downstream drift of spawned-out adult salmon (Oncorhynchus sp.).

Other marine mammal sightings included Steller's sea lions, harbor porpoise, and sea otters. Sea lions (10-25 animals) were sighted each year during May but were most numerous during May and early June 1996. A minimum of 100 sea lions were counted between the Red River and Ilimana Point on 17 May 1996. Sea lions move northward along the LACL coastline passing through Tuxedni Channel but do not haulout. Harbor porpoises (2-5 animals/observation) were sighted along the coast throughout the summer. One sea otter, the only sighting for this species, was observed on 22 June 1994 adjacent to the mouth of the Crescent River. Sea otters are common south of Chinitna Point and on 12 May 1996, 215 were counted in Iniskin Bay, 30 km south of the LACL coastline.

Implications for monitoring- Because the beluga whale population in Cook Inlet appears to be a small geographically isolated population, they are vulnerable to human-induced perturbations especially off-shore oil and gas development (NMFS 1992). However, independent counts of beluga whales along the LACL coastline are of limited use in monitoring the Inlet-wide status of this species. Current research by the National Marine Fisheries Service employing the use of satellite telemetry (R. Morris, pers comm.) will hopefully define distribution patterns and identify estuaries of special significance. This data will provide a context for refining survey protocols for this species.

Other marine mammals do not occur in sufficient numbers to warrant consideration for monitoring. Incidental observations of these species should be recorded and will be useful in identifying range expansions of sea otters and other species.

Terrestrial Mammals

Brown Bears

Methods- Weekly aerial surveys were used to index brown bear distribution, relative abundance, and seasonal use patterns in coastal salt marshes. The survey route paralleled the coast and sampled 32 km^2 of salt marsh between the Crescent River and Clearwater Creek in Chinitna Bay. Ground observations from skiffs and field camps were be used to determine sex-age composition and general feeding behavior at all known brown bear concentration sites such as Glacier Spit Marsh in Chinitna Bay, Open Creek Marsh in Tuxedni Bay, and Herbs Lagoon at Shelter Creek. At these sites bears forage on grasses and sedges in tidal marshes and can be readily viewed from fixed observation points. Binoculars and spotting scopes were used to identify and examine bears.

On their initial sighting, each bear was photographed and described with respect to physical characteristics (i.e., color, relative size, scars, behavioral peculiarities). Physical descriptions will usually be detailed enough to allow recognition of individual bears on subsequent visits. Sex of bears was subjectively identified based on behavior and physical characteristics. Field observers were trained in the recognition of sows and boars and viewed video tapes that demonstrated most aspects of brown bear behavior. Age of cubs were estimated by size and when possible all bears were classified as adults or subadults. Monitoring of concentrations sites occurred during 1 June to 31 August.

Distribution and abundance- Brown bears began appearing on tidal marshes in early May and numbers steadily increased throughout that month. The chronology of brown bear use of salt marshes conformed to vegetation phenology. Bear sightings peaked during late June and early July when an average of 67 bears were sighted/aerial survey (Figure 21). A peak count of 87 bears was obtained on 11 July 1995. Bear sightings abruptly declined in early August and after 1 September <5 bears were sighted/survey.

Ground observations of brown bears at Glacier Spit Marsh (GSM) were made a minimum of twice/week from 1 June to 10 August. During 1995-96, 23 and 25 individual bears were identified in this 0.9 km^2 salt marsh. Comparison of daily 24-hour ground counts at GSM with aerial counts indicated that an average of 29% of the bears using this marsh were detected on aerial surveys during June-July. Adjustment of aerial counts in all salt marshes by this sighting rate yields an estimate of 180-234 brown bears, 1994-96.

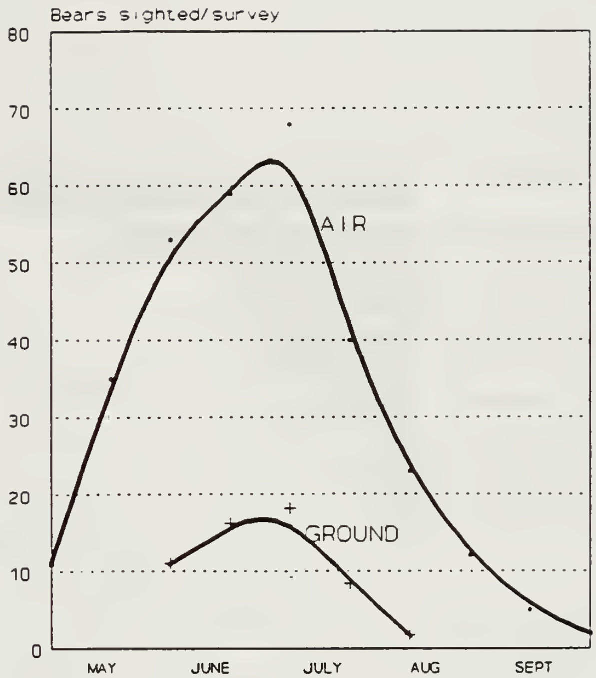


Figure 21. Monthly chronononology of brown bear use of salt marshes, Lake Clark National Park-Cook Inlet Coastline, 1994-96.

Adult brown bears exhibited high early summer fidelity to salt marshes. Eight individual bears or family groups were observed weekly at GSM during 2 June to 10 August 1996. Duration of use for adult boars averaged 50 days (r=34-65, n=3) and sows with cubs 55 days (r=40-59, n=5). These observations represent minimum periods of use because no ground observations were conducted during May. Two subadult bears of unknown sex were sighted ≤20 days.

Bear distribution and abundance varied spatially among and within salt marshes. The south side of Tuxedni Bay accounted for 46-59% of the bears sighted (1994-96). Although Glacier Spit Marsh in Chinitna had the greatest overall density (Figure 22), local density of foraging bears exceeded 11 animals/km^2 in a sub-region of Tuxedni Bay between Open and Difficult Creeks. In contrast, brown bear use of Clearwater Creek was widely distributed and no concentration areas were detected. Bear Creek Marsh in Tuxedni Channel, while comprising 8% of the salt marsh area, supported <0.5% of the observed brown bear use.

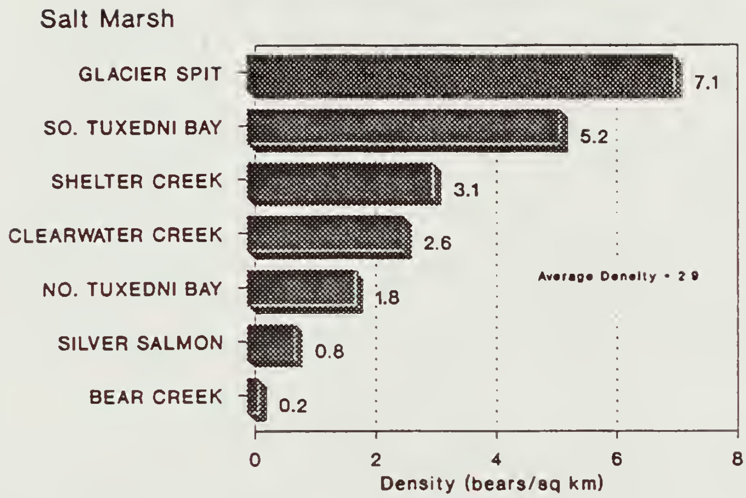


Figure 22. Brown density among salt marshes, Lake Clark National Park-Cook Inlet Coastline, 1994-96.

Miller (1993) used measured densities of ≥175 bears/1,000 km^2 to define high density brown bear habitat in Alaska. Although habitat variability prevents any meaningful extrapolation of salt marsh densities to the entire coastline, LACL clearly supports high density coastal brown bear habitat.

Although many variables may have influenced brown bear distribution during a singe survey, such as exposure to human disturbance and weather conditions, seasonal distribution patterns observed over the course of this three year study are considered to reflect habitat preferences, specifically salt marsh vegetation composition, and salt marsh proximity to travel corridors and escape cover. Consequently, observed densities (Figure 22) represent an index to the relative importance of LACL salt marshes to brown bears.

Observations of brown bear foraging revealed heavy exploitation of the leaves, roots, and tubers of little arrowgrass Triglochin palustre. This species is not widely distributed and occurs primarily in low-marsh mud flats and pannes on the south side of Tuxedni Bay. Vegetation communities comprised of Alkali grass Puccinella phryganodes with clones or patches of Raminski sedge (Carex raminskii) little and big arowgrass (T. palustre and T.

Maritimum) received the most intensive use by brown bears. Brown bear use of salt marsh varied in response to plant phenology, vigor and growth stage. In late June 1994, bears abandoned most saltmarshes in response to unseasonably hot and dry weather which defoliated the outer tips of sedges and grasses. Fine sedges, such as Raminiski sedge, did not appear to recover if heavily grazing early in the growing season.

Sex composition of brown bears using tidal marshes varied temporally. Adult boars frequented salt marshes primarily during the mating season in early June and were largely absent during July-August. Sows with cubs of the year were the last cohort to appear on the tidal marshes, and often did not appear until early July. Boar:sow ratios were greatest in May and June (43:57) and lowest in July and August (34:66). Sixty-three percent of the cubs were sighted 10-31 July. Average sighting rate/survey for cub age classes during 1995 was: cubs/year = 5.5; 1.5 year/olds = 8.5; and 2.5 year/olds = 2.0. Cub age class composition was not obtained in 1994 and 1996.

Black bears were sighted infrequently and involved <10 animals/survey. Because black bears primarily forage in forested or forest edge habitats, aerial surveys of tidal marshes are not a useful index to distribution or abundance. Most black bears (68%) were sighted in Tuxedni Channel, Silver Salmon Lakes, and the Johnson River Delta.

Implications for monitoring- Salt marshes may be the most important habitat component for brown bears along the LACL coastline. Above-ground standing biomass of sedges in Cook Inlet saltmarshes exceeds 460 g m^2 (Vince and Snow 1984) and provides a rich forage resource for bears. Unlike brown bear populations south of Cape Douglas, the Lake Clark population has not been observed foraging on intertidal marine fauna/flora such as clams, cockles, barnacles and kelp. Instead, they forage exclusively on salt marsh vegetation from den emergence (April) until the arrival of salmon and ripening of the berry crop in late July.

LACL coastal salt marshes occur as narrow linear patches which follow the shoreline. Consequently, these areas are easily accessible to humans in boats, aircraft, or on foot. Guided bear viewing-photography in Chinitna and Tuxedni Bay is increasing rapidly as bear watchers unable to obtain McNeil River permits seek alternate destinations. A growing number of air taxi operators are flying clients into the area for "aerial bear watching." If human disturbance displaces bears from salt marshes, adverse impacts to fitness of the population, behavior, and reproductive success can be expected. In addition, offshore oil development, large-scale pulp logging and mineral exploration and development within and adjacent to LACL could affect brown bears.

Direct measurement of brown bear population trends through annual aerial surveys is difficult (Harris 1986). However, an immediate need exists to examine whether: (a.) human disturbance is displacing brown bears from foraging and breeding sites; (b.) shifts in spatial or temporal distribution patterns is occurring; and (c.) to define minimum "response distances" exhibited by bears which are displaced when approached by humans. In addition, air and ground surveillance is needed to estimate brown bear visitation rates and sex-age composition; and ground observation are needed to describe general movement patterns, foraging preferences, and to determine the extent to which bears feed in intertidal habitats. The existing salt marsh vegetation classification and inventory will provide a valuable tool for examining foraging preferences of brown bears.

Other Mammals

River otters (Lutra canadensis) were commonly sighted and appear to be abundant along the LACL coastline. Otter sign and sightings were most numerous along the outer coast between the Red River and Chinitna Bay. Otter sign was common in sand flat and rocky intertidal zones indicating that they forage extensively in the marine environment. River otters were often observed feeding on razor clams (Siliqua patula) and pinkneck clams (S. polynyma) on sand flats near the mouths of East Glacier and Spring Creeks.

Because river otters are top trophic-level carnivores and long-lived (Larsen 1984) and can occur at densities of 0.2-0.8 animals/km of shoreline in the Gulf of Alaska (Testa et al. 1994), they are an excellent species to monitor for assessing the effects of marine pollution. Otter have large home ranges (Bowyer et al. 1995), and hence may integrate the effects of pollution over wide areas. For example, river otters in EVOS oiled areas exhibited significantly lower body mass than did otters inhabiting oil-free areas (Duffy et al. 1993).

Marine Invertebrates

Infauna

<u>Methods</u>- Occurrence, density and biomass of infauna was measured at -0.6 and +1.2 m (-2.0 and +4.0 ft) elevations along randomly placed transects. Thirteen transects were sampled in Tuxedni Bay in early June 1994 (Figure 23) and 6 transects sampled in Chinitna Bay in late May 1995. Sample elevations were determined with the program TIDE.1/Rise & Fall (Micronautics Inc., Rockport, ME) and sample locations physically marked in the field and referenced by GPS. A float-equipped helicopter (Bell 206B jetranger) was used to access sample sites and to transport personnel and equipment. At each site, a minimum of 3 replicate core samples measuring 7 cm in diameter (1994) and 10 cm square (1995) x 8 cm deep was collected. Replicates were spaced 10 m apart. Samples were sieved in the field through a 1.0 mm sieve and preserved in buffered formalin until sorting.

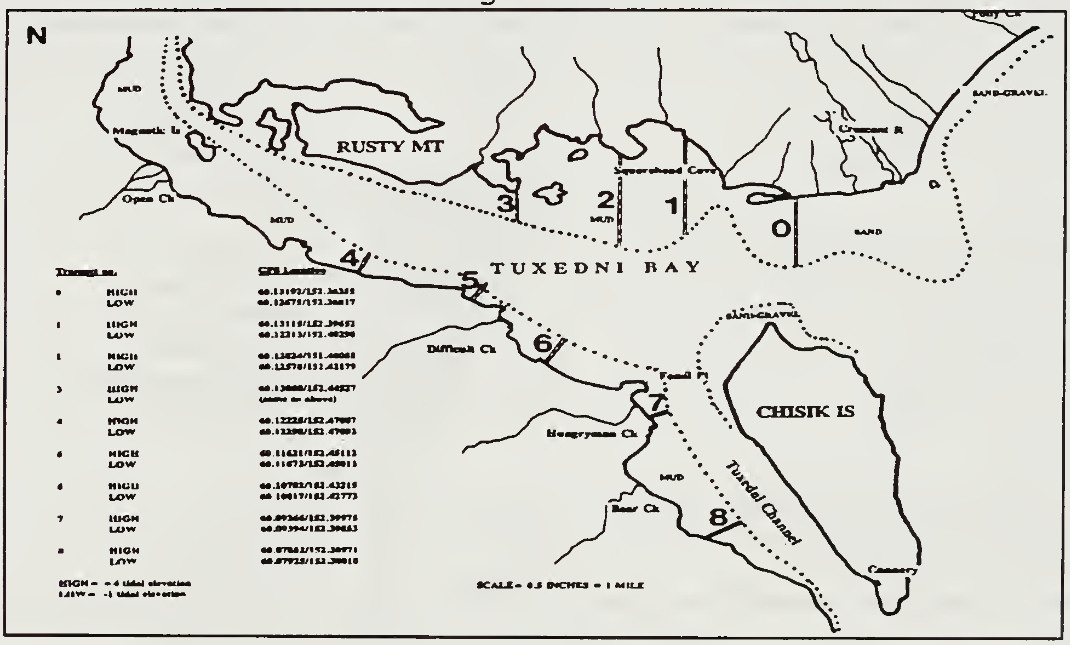


Figure 23. Location of invertebrate sampling sites in Tuxedni Bay and Tuxedni Channel, Lake Clark National Park, 1994.

<u>Distribution and abundance</u>- Intertidal mud flats at Chinitna and Tuxedni Bays supported large to moderate standing crops of suspension and deposit feeders and had high species richness (Table 12). Eighteen species of Polychaeta, 7 species of Mollusca and 12 species of Crustacea were identified in the samples from Chinitna Bay. Infauna at both sites was dominated by the clam <u>Macoma balthica</u>, which comprised >60% of the individuals and 83% of the wet biomass, mean 735.2 g m^2 in Chinitna Bay and 141.6 g m^2

in Tuxedni Bay. Other conspicuous and numerically important species included the large polychaetes Nephtys cacea and Polydora brachycephala, and the molluscs Mysella tumida and Mya arenaria.

Table 12. Intertidal mud flat infauna assembledge in Chinitna Bay, LACL-Cook Inlet Coastline, 1995.

	Elevation (ft)	
Taxa	+4.0	-2.0
POLYCHAETA		
Aiaricidea lopezi	Frequent	Frequent
Capitella capitata complex		Present
Eteone longa	Frequent	
Harmothoe imbricate		Present
Leitoscoloplos pugeftensis		Present
Nephtys caeca	Dominant	Dominant
Nephtys cornuta	Present	Present
Polydora brachycephala	Sub-dominant	Sub-dominant
Pygospio elegans	Frequent	Frequent
Sabellidae sp. lndet.	Present	Present
Spio filicornis	Seasonal	Seasonal
Spiophanes bombyx	Present	Present
MOLLUSCA		
Clinocardium nuftalli	Present	Present
Macoma balthica	Dominant	Dominant
Melanochlamys diomedea	Present	Present
Mya arenaria	Present	Present
Myselia tumida	Sub-dominant	Sub-dominant
Retusa obtusa	Frequent	Frequent
CRUSTACEA		
Rhepoxynius heterocuspidatu	Seasonal	
Solidobalanus hesperius	Seasonal	Seasonal
Wecomedon wecomus	Seasonal	Seasonal

Clams dominated the assembledge at Chinitna Bay with respect to abundance and biomass whereas in Tuxedni Bay polychaetes dominated in abundance and clams dominated in biomass (Figure 24). Density of M. balthica in Chinitna Bay ranged from 300 individuals/m^2 at transects near Horn Creek to 3,500 individuals/m^2 at transects west of Seal Spit (mean density 2,033/m^2). In Tuxedni Bay, M. balthica density ranged from 40 individuals/m^2 in the upper bay to 1,100 individuals/m^2 in Tuxedni Channel (mean density 880/m^2). Dames and Moore (1980) observed an average density of 4732.4/m^2 in April 1977 and 2282.3/m^2 in May 1978 for Macoma at Glacier Spit in Chinitna Bay.

Juvenile Clinocardium occurred at most sample sites in Chinitna

Bay (1-3 individuals/sample) but none occurred in Tuxedni Bay. Wayne Byers (pers comm.) contends that adult cockles were abundant at Glacier Spit prior to the uplift resulting from the 1964 earthquake.

Polychaete species richness and biomas varied among sample locations. Thirteen species in Tuxedni Bay exhibited densities >100 individuals/m^2 compared to 8 species in Chinitna Bay. However, mean polychaete biomass in Chinitna Bay (3.95 g m^2) was greater than in Tuxedni Bay (1.59 g m^2). All of the polychaetes except Nephtys and Polydora were more numerous in Tuxedni Bay. Spoonworms Echiurus sp. were not present in samples from Chinitna Bay. Dames and Moore (1980) reported that this species was common among the infauna assembledge at Glacier Spit in 1976-77. Samples of the clam worm Nephtys contained specimens up to 10 cm in length, but was largely comprised of small, presumably young animals.

Although seasonal differences in timing of sampling limits comparisons between the two bays, Tuxedni Bay mud flats also appeared to support greater densities of gammarid amphipods and isopods.

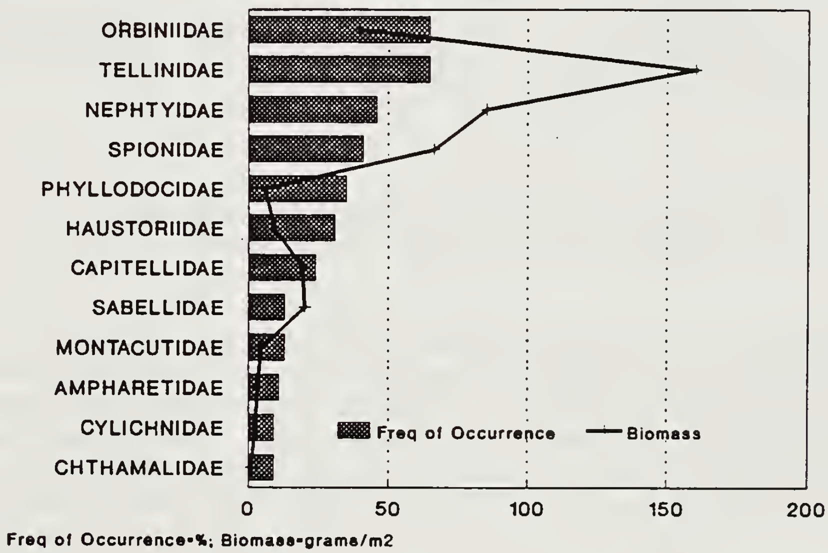


Figure 24. Frequency of occurrence and biomass of major infauna taxa in Tuxedni Bay, LACL-Cook Inlet Coastline, 1994.

Physical and biological factors are important in determining the distribution and density of the organisms living in Cook Inlet mud flats (Dames & Moore 1980). Heavy rates of sedimentation, unstable substrate, temperature and salinity fluctuations, and ice scouring and crushing adversely effect survival. Infauna biomass varied spatially within both bays. In Tuxedni Bay, biomass was greatest near the mouth of bay and lowest near the head of the Bay (Figure 25). Spatial variation was also observed in length frequencies of Macoma. In Chinitna Bay, mean length frequency ranged from 7.8 mm on the north side of the Bay to 12.2 mm on the south side of the Bay and in Tuxedni Bay ranged from 7.7 mm in the upper Bay to 13.5 mm in Tuxedni Channel.

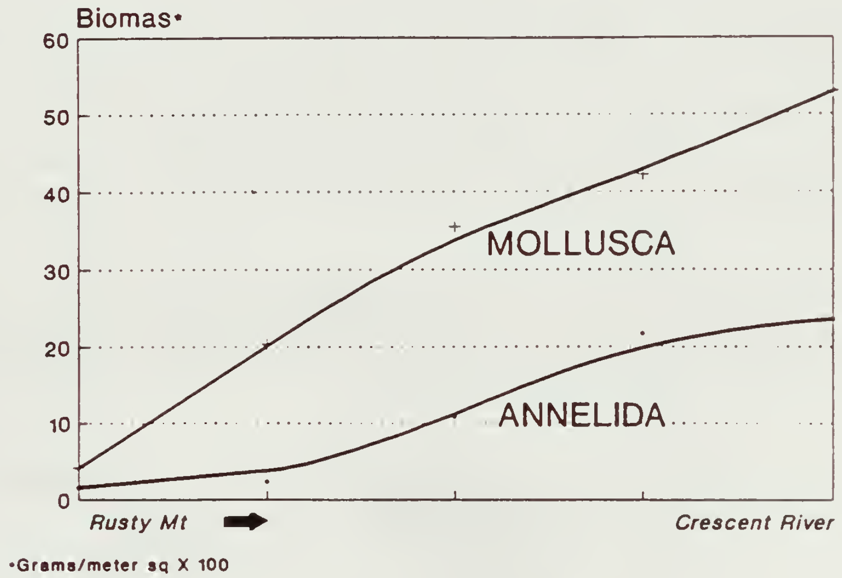


Figure 25. Spatial relationship of infauna biomass within Tuxedni Bay, LACL-Cook Inlet Coastline.

Biomas and species richness was greatest at sites were the substrate was relatively firm and stable. Such sites were slightly raised in elevation, had a high clay content, and characteristically appeared bluish-gray. Mud flats adjacent to the mouth of West Glacier Creek in Chinitna Bay and in upper and middle Tuxedni Bay are highly dynamic. In these areas, the location and configuration of braided stream channels is in constant flux, changing monthly and even weekly in response to freshwater runoff, siltation, tide cycles, and wave dynamism. Infauna at these sites are often excavated by surface flow during low tide or inundated with a thick layer (>25 cm) of soft flocculent silt. This harsh environment may explain why polychaete biomass is lower in the study area than that reported for other locations. Piersma et al. (1993) compared polychaete biomass in muddy intertidal substrates worldwide and reported an average of 4.48 g; range 0.09-16.57 g m^2.

Predation may exert a strong influence on the density of several species, such as Macoma, especially in the spring when maximum densities of young clams are concentrated in the upper few centimeters of sediment. Sea ducks, diving ducks, shorebirds and gulls are major predators on clams and polychaetes. Diving ducks and shorebirds are known to concentrate feeding efforts on Macoma and Mya during spring migration (Sanger et al. 1979). Dames and Moore (1980) observed reductions of nearly 50 percent and 70 percent in the densities of Macoma and Mya, respectively, between April and July at sites where bird predation was intense.

The trophic structure of intertidal mud flats in Chinitna and Tuxedni Bays appears to be based on detrital material from marine and terrestrial systems. It is considerably more diverse than that reported for Cook Inlet sand flats (Hood and Zimmerman (1986). Dames and Moore (1980) indicate that bacterial flora observed in the water column suggests that terrestrial plants may be a major source of organic debris on the west side of the inlet. The detritus, associated inorganic particles, bacteria, and protozoans are ingested by suspension and deposit feeders (Green 1968). Nearly all of the infaunal animals collected along the LACL coast were detritivores. Deposit feeders were common but suspension feeders dominated at all sample sites.

Implications for monitoring- Mud flats in Chinitna and Tuxedni Bays are at greatest risk for damage from crude oil spills (Michel, et al. 1978). The clams Mya arenaria and Macoma balthica are known to be sensitive to crude oil and refined products. Numerous burrows would permit large amounts of oil to penetrate deeply into the substrate. Direct mortality of animals constructing the burrows, such as Echiurus and Mya, would lead to destruction of the burrows and seal the oil in the sediments. Ensuing anaerobic conditions would result in very slow weathering rates for the oil and long-term disruption of the mud flat assemblage. Considering the high productivity of the mud flat assemblages and the dependence of many bird and fish populations on these assemblages, such a condition could be devastating to the LACL coastal ecosystem. The trophic relationship between shorebirds, sea ducks, diving ducks and Macoma may be the most significant near-coastal predator-prey linkage along the Lake Clark-Cook Inlet Coastline.

Macoma can live up to 15 years (Green 1969) and they are an excellent candidate species for monitoring change in intertidal mud flats. In 1996, Macoma samples from Chinitna and Tuxedni Bays were analyzed for total hydrocarbons (as extractable organic material), percent lipids, and polycyclic aromatic hydrocarbons (PAHs), including alkylated PAHs and heterocyclics. Physiological condition was also be measured to obtained a "Bivalve Condition Index" (BCI) which is an indicator of organismal responses to disease or unfavorable environmental conditions. The results of this investigation is presented in Appendix B.

Unfortunately, efforts to measure density, biomass, and seasonal variability of infauna were confounded by wide spatial variability in distribution, especially in Tuxedni Bay. "Patchy distribution" of Macoma and other infauna may be related to physical conditions, such as ice scouring and crushing (which can be severe near the water-sediment interface) temperature or salinity fluctuations, and predation. Research is needed to: (1.) determine the number of spatial array of replicate samples needed to produce a quantitative measurement of infauna density; (2.) measure temporal variation in density, biomass and size frequency; (3.) design monitoring protocols for Macoma and other dominant infauna and physical parameters that may influence infauna distribution and abundance.

Additional studies are needed to establish a better understanding of mud flat energy pathways and their relative importance along the LACL-Cook Inlet Coastline. For example, measurements of benthic prey organisms needs to be conducted throughout the year to evaluate harvestable food resources with respect to seasonality in recruitment, growth, and survival. Research is also needed on the effects of various types of oil and dispersants on mud flat assemblages. Laboratory simulations cannot duplicate the faunal and structural complexity of natural mud flats of lower Cook Inlet. Long term effects of chronic exposure to refined or crude oil products such as inhibition of growth rates, reproduction, recruitment, carcinogenesis and mutagenesis are unknown.

COASTAL GEOGRAPHIC INFORMATION SYSTEM

Background- Coastal resource management and protection at Lake Clark National Park requires a geographic information system (GIS) for habitat sensitivity analysis. Effective management of the coastal zone is dependent on the availability of accurate information on the distribution of natural resources in both space and time. A coastal resource GIS can provide this function and has the potential for significantly enhancing most aspects of coastal management by accessing information to address issues concerning resource identification, location and seasonal variability. A GIS can provide multi-variate assessments of coastal ecosystems and can analyze critical linkages between natural resources, cultural resources and social infrastructures. Access to current and accurate resource inventories can benefit resource managers in monitoring habitat trends in response to natural and anthropogenic disturbances by identifying critical habitats for coastal dependent species, for natural resource damage assessment and for habitat sensitivity analyses.

The objectives for this component of the project were to develop and assemble a library of GIS data layers pertinent to the needs of this park. A GIS is an assemblage of computer hardware and software designed to collect, organize, manipulate, interpret and display geographically referenced information. It provides a means of creating, storing and accessing data layers, and examining relationships among data layers. The most significant difference between a GIS and a conventional database management system (DBMS) is the added attribute of spatial reference linked to each feature. Computer analysis of spatial data is the primary function of a GIS. Examples of analysis within a data layer include calculating mean density and area of a habitat. Analysis between layers include calculations of specific areas, mathematical overlay of different features, the production of composite databases and calculating the proximity of different attributes (such as measuring the distances between seabird colonies, their feeding grounds, and commercial development activities). These types of analyses distinguish a GIS from a computer mapping system.

An important first step for data layer development was to define the spatial and attribute characteristics most suitable to the needs of the park. These included map projection; georeferencing system; geocoding system; data collection units; attribute classification; scale; and ground resolution.

Brookes (1985) describes how map projections are calculated mathematically or constructed geometrically to represent the curved earth surface as a planar feature on a map sheet. The standard adopted by state and federal agencies in Alaska is the

Albers Conical Equal Area projection. It is mathematically based on a cone that is conceptually secant on two parallels. This projection has the property of equal area and the standard parallels are correct in scale and correct in every direction. Hence, there is no angular distortion along the standard parallels and properties at various scales are retained. This allows for individual sheets to be joined along the edges which produces very accurate area and distance measurements.

Data Layer Development- USGS maps are based on a datum derived from a reference ellipsoid. USGS 15 minute topographic maps for Alaska define the corners using the North American Datum 1927 (NAD 27), based on the Clarke 1866 ellipsoid (the NAD 27 is taken from an initial point in Meades Ranch, Kansas, and other points are referenced to it). This datum was used for the rectification of the aerial photography because it was the most accurate for the area.

Field data collected for the coastal information database was geocoded with latitude and longitude coordinates determined by the Global Positioning System (GPS). The raster based digital imagery encodes each pixel with coordinates during the rectification pre-processing phase of image enhancement. The primary data collection unit for the nearshore data layer are polygons delineating the across-shore zones for each alongshore unit. The polygons represent the lower, middle and upper intertidal zones, and have a minimum length of 10 meters. The polygon attributes include the nearshore classification data based on the geomorphological criteria discussed in the previous section.

A GIS is scale-independent in that each data layer is registered to others by a standard coordinate system (e.g., latitude and longitude). Map scale specifies the relationship between distance on a map derived from the data layer and distance on the ground or over the water. For a printed USGS 15 minute topographic map (1:63,360), 1 inch equals exactly 1 mile on-the-ground. The amount of detail shown on a map is in proportion to the scale of the map (the larger the scale the greater the detail). Much more detail is available on maps at a 1:24,000 scale than maps at 1:100,000 scale. This project used the aerial photos for basemaps for field delineation of alongshore units. The original scale of the photography was 1:24,000, but digital enlargement provided 11 x 17 basemaps of 1:12,000 scale.

Resolution refers to the size of the minimum spatial unit on the basemap. For analysis of spatial features in a GIS, accuracy depends on resolution. For example, an accurate measure of the area of a polygon depends on the detail at which the polygon was digitized from aerial photos or other sources (i.e., its resolution). The aerial photography was scanned at a resolution of 600 lpi for a file size of about 14 megabytes. The pixel size at this resolution is approximately 1 x 1 meter which was adequate for the designed objectives. The photos were scanned as a 256 step greyscale and formatted in an uncompressed tagged image file (TIFF).

The scanned imagery was used as a basemap for digitizing the MHHW shoreline, the horizontally homogenous shoreline segments, the segment polygons to MLLW and the intertidal zones within the polygons. Stereo-image pairs were also used for shoreline classification by identifying prevailing coastal processes of progradation and degradation, net shore drift and sediment transport patterns.

Documentation was generated for each data layer. The source, types of analysis and reformatting, the projection and resolution is contained in a metadata file (Figure 26). This will allow the end-user to make informed decisions concerning the usefulness of a particular data layer in a map. Appendix C contains the metadata files for this project and Table 13 lists the coverage types developed for this project.

Queries of a geographic database will frequently involve combinations of three functions: search, measurement, and comparison. With any of these analyses, the locational data are manipulated in concert with the descriptive data belonging to that location. The search capability reads a database of geographic information and retrieves any required data by location, attribute or specific attribute value. Measurement functions include a count of points, lines, nodes and arcs. Other measurement functions include calculations of area, perimeter, distance and direction. Comparison is probably the most powerful of GIS functions. It is defined as the use of the descriptive or locational data to determine relationships based on criteria from one or both types of data. The two basic comparative techniques are overlaying or composing, and inferential statistics such as regression and correlation.

Management Applications- The coastal information system for Lake Clark National Park will provide resource managers with a tool for: (1. data management; (b) inventory of integrated coastal resource information; (c) monitoring spatial and temporal changes in habitats and flora/fauna communities; (d) designing mitigation plans for development projects; and (e) management of anthropogenic disturbance to natural systems. Ideally, this database will be integrated with other data sets for Cook Inlet to support ecosystem level monitoring.

The primary application of the database will be to develop and analyze linkages between geomorphologically defined nearshore habitats and nearshore fauna/flora assemblages for the specific purpose of identifying sensitive habitats for Natural Resource Damage Assessments (NRDA). Additionally, the database can aid in:

A. Determination of brown bear distribution and abundance
B. Determination of fluctuations and trends in background petroleum hydrocarbon concentrations in sediments and water column
C. Inventory and monitoring of coastal raptor populations
D. Inventory and monitoring of coastal shorebird populations and habitat
E. Inventory and monitoring of resident and migratory waterfowl populations
F. Inventory and monitoring of anadromous fish species, movements and habitat use
G. Environmental impact assessment and monitoring of coastal development
H. Determination of seasonal beach deposition and erosion rates

Data layers may be associated in the GIS to produce maps with a variety of themes (Table 13 and Figure 27). For example, seabird distribution in May with respect to bathymetry and distance from colonies. Other data layers that might be included to put the primary theme in perspective are the shoreline and beach type. Such maps are prepared in the GIS by assembling several pertinent data layers. Themes are not typically associated in a particular data layer, although this can be done; each data layer is distinct and can be overlaid (associated) with any other data layer.

Data Layer Title and Code:
Description:
Suggested Application/ Cautions:
Feature Type(s) Present: arcs points lines polygons
Topology Present: yes no
Precision of coordinates (number of decimal places):
Projections and Parameters:
Name:
Units:
Spheroid (if other than Clarke 1866):
Datum: 1927 1983
Standard Parallel #1 (lat/long):
Standard Parallel #2 (lat/long):
Latitude of origin:
Longitude of Origin:
False Easting (X coordinate manipulation):
False Northing (X coordinate manipulation):
Other Parameters:
Data Source:
Principal Investigator:
PI Affiliation/Phone:
When, Where, and How was Data Collected?:
Data Layer Preparer:
Date Prepared as Data Layer:
Data Source Medium: paper mylar disk/tape
Scale of Data Source:
Data Source Projection and Parameters:
Who Digitized: Phone
Version Date:
Date Last Revision:

Processing Notes:

Comments:

Figure 26. GIS data layer documentation for Lake Clark National Park

Table 13. Data layers developed or projected for Lake Clark National Park-Cook Inlet Coastal GIS.

Features	Type	Attributes
Bathymetry	line	depth
Topography	line	elevation
Nearshore rocks	point	location
Intertidal zone	polygon	length, width, area
Geomorphology	polygon	intertidal habitat attributes
Transects	line	topographic profiles
		horizontal profiles
		photo transacts
		biotic sampling transects
Salt marshes	polygon	vegetation types
Streams	line	discharge volume
		water quality parameters
		fish populations
Waterbird Density	line	population/distribution
Eagle Nests	point	productive history
Vegetation Types	polygon	species classification
Seabird Colonies	point	productive history
Marine Mammals	point	species
		population history
EVOS	polygon	stranded oil location
		persistence history
		cleanup history
		threatened populations
		oiled surface area
Inholdings	polygon	deeded lands
		shore fishery sites
Cabins	point	structures
Cultural Resources	point	archeological inventories

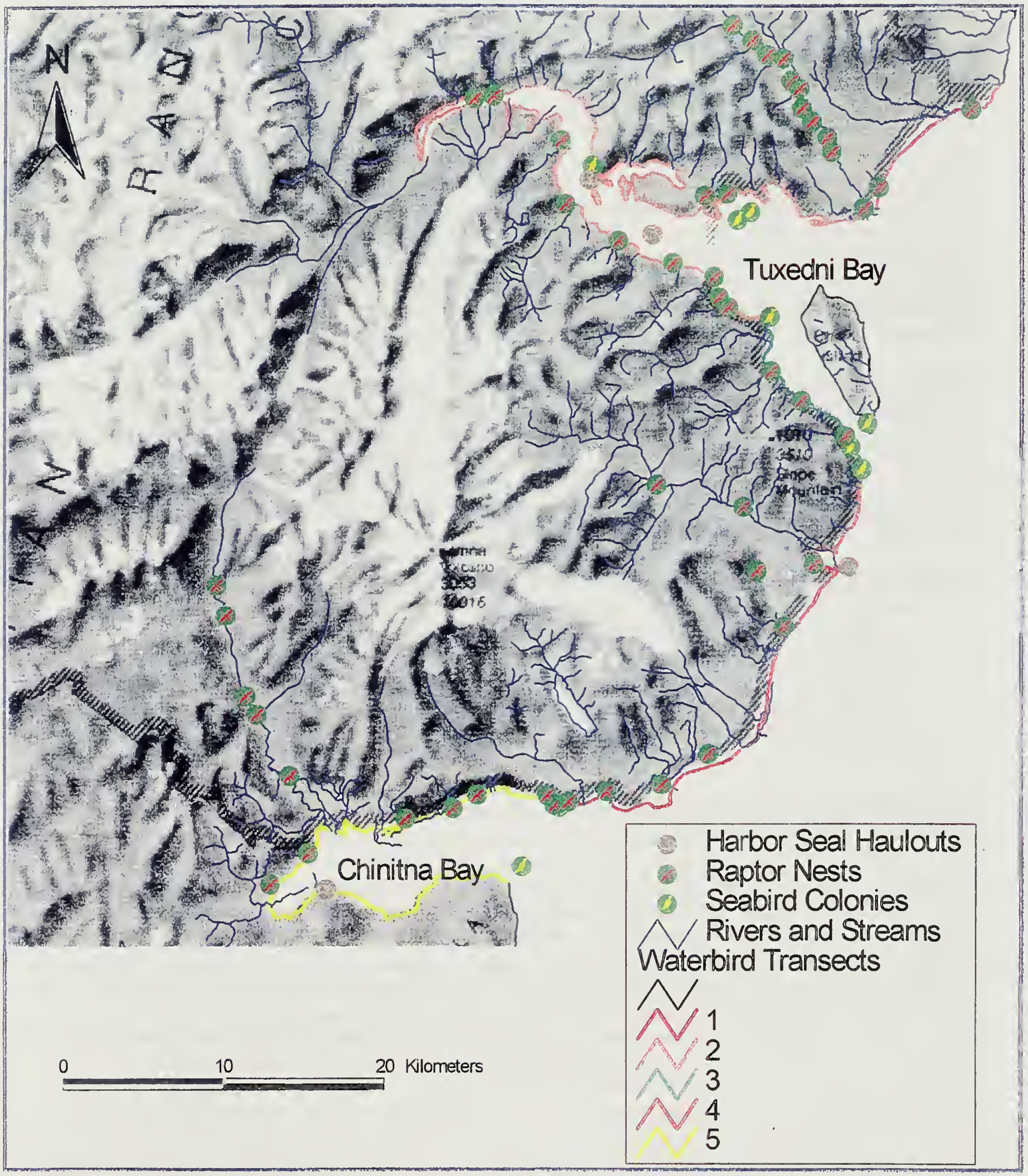


Figure 27. Example of GIS data layers, Lake Clark National Park-Cook Inlet Coastline.

Mud Flat Infauna Assembledge- Preliminary sampling during 1994-96 revealed that the vast intertidal mud flats in Chinitna and Tuxedni Bays support large standing crops of suspension and deposit feeders. Dominant organisms include the clam Macoma balthica, the polychaete Nephtys, and the echiurid Echiurus. This infauna resource is the prey base for large numbers of birds including up to 60,000 migratory shorebirds and 16,000 diving ducks during May; and 18,500 sea ducks during July-August (LACL records 1994-96). Macoma densities in areas of Chinitna and Tuxedni Bays exceed 3,000/meter^2 (LACL 1994-95) and are greater than densities reported elsewhere in Cook Inlet. The trophic relationship between shorebirds, sea ducks, diving ducks and Macoma may be the most significant near-coastal predator-prey linkage along the Lake Clark Cook Inlet Coastline.

Unfortunately, efforts to measure density, biomass, and seasonal variability of infauna were confounded by wide spatial variability in distribution, especially in Tuxedni Bay. Patchy distribution of Macoma and other infauna may be related to physical conditions, such as ice scouring and crushing (which can be severe near the water-sediment interface) temperature or salinity fluctuations, and predation.

Research/monitoring needs: (1.) Determine the number of spatial array of replicate samples needed to produce a quantitative measurement of infauna density. (2.) Measure temporal variation in density, biomass and size frequency. (3.) Design monitoring protocols for Macoma and other dominant infauna and physical parameters that may influence infauna distribution and abundance.

Salt Marsh Foraging Ecology of Brown Bears- The LACL coastline contains 52 km^2 of salt marsh, primarily at the heads of Chinitna and Tuxedni Bay. Brown bears are attracted to these tidal salt marshes in early summer to mate and forage on grasses and sedges. From May-July the average number of brown bears sighted/aerial survey of the tidal marshes between Crescent River and Clearwater Creek (a linear distance of 110 km) is 44 (LACL records 1993-96). In July 1995, 78 brown bears were observed in 34 km^2 of salt marsh (2.3 bears/km^2) and in two areas, Glacier Spit Marsh and Open creek Marsh, brown bear densities exceeded 4 bears/km^2 during June and July. This represents one of the largest concentrations of brown bears in Alaska, and one of only a few sites where bears congregate in the absence of a salmon run.

Unlike brown bear populations south of Cape Douglas (Katmai National Park), the Lake Clark population does not forage on intertidal marine fauna and fauna such as clams, cockles, barnacles and kelp. Instead, they forage exclusively on salt marsh vegetation from den emergence (April) to the arrival of salmon and ripening of the berry crop in late July.

A detailed classification and delineation of LACL salt marsh vegetation types was conducted in 1995. Twenty-eight salt marsh types were identified based on physiographic location, site moisture, vegetation class by species dominance, vegetation growth form, and landscape descriptor.

Aerial brown bear survey data and vegetation survey transects have suggested that bears are selecting specific salt marsh plants and vegetation types for foraging. This pattern of habitat exploitation accounts for a patchy distribution of brown bears with 31% of area supporting 88% of the use. In proportion to their availability, brown bears exhibit the greatest selection for arrowgrass (Triglochin sp.) vegetation types. This species has a narrow distribution occurring primarily on low-marsh mud flats and pannes on the south side of Tuxedni Bay. Successional trends suggest that this species is being replaced by Carex sp. communities as a result of physical processes such as geologic uplifting or tidal sedimentation.

Research/monitoring Needs: (1.) Determine salt marsh vegetation foraging preferences of brown bears; (2.) Develop a salt marsh vegetation monitoring strategy capable of detecting the rate and magnitude of change in salt marsh type composition.

Sand Flat Infauna Community Composition- Wide sand flats comprise 27% of the shoreline type along LACL. These intertidal sand flats support populations of mollusc bivalves, including razor, littleneck, soft-shelled clams, polychaetes and gammarid amphipods. Intertidal sand flats were not examined during the LACL coastal inventory (1994-96). This habitat type was sampled by Gail Irvine in 1992 but no data was reported.

Baseline information on marine infauna community composition will be entered into the LACL intertidal spatial distribution model for intertidal habitats. Key species, such as razor clams, will be targeted for long term monitoring on established transects. LACL supports the most extensive razor clam beds in Cook Inlet and clam beds have been commercially harvested almost continuously since 1919. Polly Creek and other sites also receives heavy use by recreational clammers.

Several techniques have been used in Cook Inlet to estimate razor clam populations. Dames and Moore (1980) used a visual count of clam "shows" at Polly Creek. However, surf clams and cockles are also present in some razor clam beds, and Nelson (Unpubl) has speculated that clam shows vary with the weather and may increase with the incoming tide. The Alaska Department of Fish and Game has adopted a technique for east side Cook Inlet beaches developed by Suarzi (1991) which utilizes a hydraulic pump with a random stratified sampling design. The Washington Department of Fish and Wildlife will probably adapt this technique also.

Research/monitoring needs: (1.) Examine sand flat infauna community composition to include: species richness, biomass, zonation, and seasonal patterns of abundance; (2.) Develop a workable, cost effective technique for estimating and monitoring razor clam populations along the LACL/KATM coastlines.

Population Parameters of Anadromous and Nearshore Forage Fish- Seasonal coastline surveys (LACL 1994-96) suggest that the presence and distribution of beluga whales, harbor seals, seabirds, mergansers, loons and bald eagles is closely related to the presence of nearshore forage fish, such as hooligan, herring, Pacific sand lance, and Dolly Varden. Knowledge of this prey resource is fundamental to the long-term monitoring of predatory species and is a crucial element in understanding annual variations in productivity of diving and surface-feeding birds.

Research/monitoring Needs: (1.) Determine composition, seasonal distribution, run timing, and abundance (biomass) of anadromous hooligan and other near-shore forage fish.

Temporal and Spatial Analysis of Shoreline Morphology- Sediment transport influences shoreline morphology and dynamism which in turn effects the composition, distribution and abundance of intertidal flora and fauna. Shoreline change is measured over time with beach surveys or periodical photogrammetric analysis of the net sediment transport direction and shoreline profiles. In August 1992, 9 shoreline profile transects were established along the LACL coast. While this was an important first step, additional measurements are necessary to document seasonal dynamism. Beach profiles can undergo dramatic transformations in lower Cook Inlet between winter and summer.

In addition to natural precesses, human-related activities such as logging and mining may be affecting coastal sediment transport regimes. For example, logging will commence on 168 km^2 of Native Village Corporation lands along the Crescent River and northern shore of Tuxedni Bay in 1996.

Research/monitoring needs: (1.) Examine temporal and spatial dynamics of shoreline morphology at established shoreline profile transects; (2.) Design and integrate measurements of shoreline dynamism into the biophysical monitoring program for LACL.

__Food habits of dabbling, diving, and sea ducks in intertidal and subtidal coastal habitats__- Intertidal mud flats in upper and lower western Cook Inlet attract high densities of migratory and resident dabbling, diving and sea ducks. Measured densities of these species in intertidal habitats of Chinitna and Tuxedni Bays during 1994-96 exceeded 700 birds/km^2. These two bays support 40,000 scoters, scaup, and mallards annually. Although food habits of sea ducks have been studied in Katchmak Bay (Dames and Moore 1980, Sanger et al. 1979), food habits of dabbling and diving ducks in intertidal mud flats are unknown. Dabblers probably exploit the plethora of prey available in coastal estuaries and intertidal mud flats including gammarid amphipods, polychaetes, gastropods, and bivalve mollusks. Because they breed locally, ubiquitous species such as mallards may be useful bioindicators of hydrocarbon pollution.

Mud flats in western Cook Inlet are at greatest risk for damage from crude oil spills (Michel, et al. 1978). The clams _Mya arenaria_ and _Macoma balthica_ are known to be highly sensitive to crude oil and refined products. Numerous burrows would permit large amounts of oil to penetrate deeply into the substrate. Direct mortality of animals constructing the burrows, such as _Echiurus_ and _Mya_, would lead to destruction of the burrows and seal the oil in the sediments. Ensuing anaerobic conditions would result in very slow weathering rates for the oil and long-term disruption of the mud flat assemblage and recovery would be slow. Considering the high productivity of the mud flat assemblages and the apparent dependence of many bird and fish populations on these assemblages, such a condition could be devastating to the LACL coastal ecosystem.

Research/monitoring Needs: (1.) Determine the foods eaten by dabbling, diving and sea ducks that forage in the intertidal and near-coastal subtidal habitats of Tuxedni, Chinitna and Redoubt Bays in Western Lower Cook Inlet; (2) Examine seasonal shifts in diet or foraging sites and determine prey availability.

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APPENDIX A

SALT MARSH VEGETATION TYPES FOR LAKE CLARK NATIONAL PARK & PRESERVE COASTAL INFORMATION SYSTEM

Type 1. Mud flat

Extensive, regularly flooded, unvegetated mudflats are exposed to the moderate-energy wave action along the shorelines of Tuxedni Bay, Squarehead, Bear and Clearwater Creek marshes. Unvegetated mudflats also occur along the channels of rivers, streams and tidal guts exposed at ebb tides in all marshes of the study area.

Type 2. *Puccinellia phryganodes* Community

A nearly pure grass community of *Puccinellia phryganodes* occurs inland from barren mudflats. From the air, this type appears as a light-green, mowed lawn. Extensive, mappable stands occur in all marshes except Horsefly where it is limited to tidal banks and scattered pannes. The *Puccinellia phryganodes* type is less extensive at Silver Salmon and Shelter Creek marshes.

At the upper, more inland margins of the community, it is associated with raised microsites supporting clones or patches of *Carex ramenskii, Triglochin palustre, Triglochin maritimum* and *Plantago maritima*. It eventually grades to *Carex ramenskii* meadows where *Puccinellia* may also form pure communities on pannes within the *Carex ramenskii* type. At Clearwater Creek marsh, it is associated with a *Hippuris tetraphylla* meadow community. Soils are saturated, and frequently have small pannes and microdrainages that are semipermanently flooded by daily tides.

Type 3. *Puccinellia phryganodes/Hippuris tetraphylla* Community

A grass forb community dominated by *Puccinellia phryganodes* and *Hippuris tetraphylla* forms an extensive plant community at Clearwater Creek marsh. Here, it occurs between major tidal guts, occupying the lower marsh bordering nonvegetated mudflats of Chinitna Bay. Dominant species form a mosaic consisting of pannes of *Hippuris tetraphylla* and slightly raised microsites of pure *Puccinellia phryganodes*. The latter grades coastally to a *Puccinellia phryganodes* community and inland to a *Carex ramenskii - Hippuris tetraphylla* type. Occasional associated species include *Triglochin palustre*, and clones of *Carex ramenskii* and *Carex lyngbyei*.

Vegetation serves as a sediment trap over a shallow gradient. Plants are coated with silt from daily tidal flooding. The fine silts rarely dry out and the type is difficult to traverse due to the mucky nature of the substrate.

Type 4. *Puccinellia phryganodes - Triglochin palustre* Community

This type is of limited, mappable extent in the study area. It occupies low-marsh mudflats and pannes on the south end of Tuxedni Bay near the mouth of the Tuxedni River.

Triglochin palustre is the dominant, characteristic species and is heavily grazed by brown bears. The codominant species at most sites is *Puccinellia phryganodes.* This type was observed to occur upstream to Bear Island, occupying small, unmappable, shallow depressions within the extensive, pure *Carex ramenskii* meadows. Soils are saturated; frequent lower microsites occur with standing water due to daily tidal flooding.

Type 5. *Puccinellia phryganodes* - *Puccinellia* red - *Puccinellia* tall - *Triglochin maritimum* Community

A distinct but less wide-spread graminoid community of *Puccinellia phryganodes - Puccinellia* red - *Puccinellia* tall - *Triglochin maritimum* occupies large pannes in interlevee basins at Horsefly marsh and channel banks near the mouth of Silver Salmon marsh. At Horsefly, these shallow, concave catchments appeared to be infrequently flooded after heavy rains and during spring thaws. There was standing water to 2 cm deep when these sites were visited during a heavy rain. The substrate is a hard panne of silt displaying a cracked, semipermeable surface from exposure to sunnier, drier conditions.

Total vegetation cover is sparse. The lower, decumbent *Puccinellia phryganodes* is complimented by *Triglochin maritimum,* and the dominant unidentified *Puccinellias* which give the pannes a distinct, taller physiognomy (30-45 cm) and red color on the ground and from the air. Associated species include: *Glaux maritima* and *Atriplex gmelinii.* This community is surrounded by interlevee basin meadows of *Carex ramenskii - Triglochin maritimum - Puccinellia phryganodes/Plantago maritima* (Type 8) and eroding levee meadows of *Carex ramenskii - Hordeum* brachyantherum/Argentina egedii - Plantago maritima (Type 12).

Type 6. *Puccinellia grandis/Plantago maritima* Community

The *Puccinellia grandis/Plantago maritima* grass forb community is of limited mappable extent in the study area, occurring on tidal stream benches of Shelter Creek marsh. These narrow, flat to undulating benches occur between the banks of steep tidal guts,*Carex ramenskii* sedge levees or upland dune communities.

The *Puccinellia grandis/Plantago maritima* type is flooded by monthly high tides. Saturated but firm, silty soils may be mixed with beach sands and gravels. The latter have been washed upstream from the coast, or eroded from a series of old beach ridges in the complex Shelter Creek marsh system, and then mixed to give some sites coarser-textured, better-drained substrates.

An open cover of the dominant species *Puccinellia grandis* and *Plantago maritima* is complimented by a mix of *Stellaria humifusa, Puccinellia phryganodes, Carex ramenskii* and Triglochin maritimum.

Type 7. *Carex ramenskii - Triglochin maritimum* Community

A *Carex ramenskii - Triglochin maritimum* graminoid plant community occupies mid-marsh, flooded, interlevee basins at Horsefly, Silver Salmon, and Glacier Creek marshes. Very extensive at Horsefly, this type is also common on the northern portion of Silver Salmon but of relatively small extent at Glacier Creek. It is permanently flooded to approximately 30 cm and is associated with generally unmappable open bodies of water. The substrate is an undecomposed, vegetative fibrous sedge peat supporting the dominant plant species.

The most common associated species is *Carex mackenziei*. *Hippuris tetraphylla, Eleocharis palustris* and *Sparganium* spp. are important where ponds are present, while levee species such as *Carex glareosa* and *Argentina egedii* increase in importance toward surrounding levees.

Type 8. *Carex ramenskii - Triglochin maritimum - Puccinellia phryganodes/Plantago maritima* Community

Vast, interlevee basin meadows dominated by a wet *Carex ramenskii - Triglochin maritimum - Puccinellia phryganodes/Plantago maritima* graminoid forb community are common in all marshes except Bear Creek and Clearwater Creek. It is the dominant vegetation type at Squarehead Cove marsh, and on the south half of Silver Salmon marsh. This covertype is also an important mid-marsh community in Tuxedni and Horsefly marshes around Bear and Magnetic islands.

Sites are flooded by daily tides or may only be occasionally inundated by high tides depending on the marsh. Landscapes are flat to undulating with shallow depressions and rises. A dense network of microdrainages is common in this type in Squarehead marshes. Silty soils are generally saturated and frequently have lower microsites that are semipermanently flooded especially after heavy rains, high tides or spring thaws.

The *Carex ramenskii - Triglochin maritimum - Puccinellia phryganodes/Plantago maritima* plant community occurs inland from the *Puccinellia phryganodes* covertype. Vegetation physiognomy varies from an open to a closed canopy. Species dominance is quite variable from site to site due to minimal changes in elevation and moisture. This may vary from a full compliment of the dominant species found on most marshes to nearly pure stands of *Triglochin maritimum* at Squarehead Cove. Variations in this covertype could not be differentiated on available photography. Associated species and relative cover values are listed below.

Type 9. *Carex ramenskii* Community

Carex ramenskii forms extensive, monotypic meadows and lines the banks of tidal guts and streams. It is found on all marshes of the study area. The largest meadows occur in lower Tuxedni Bay upstream to Bear Island. Here, it occurs between barren mudflats and the narrow *Puccinellia phryganodes* community, and the upland that rises abruptly off the marshes. The vast, low-gradient marshes of the western two thirds of the Clearwater Creek marshes are also predominantly pure Carex *ramenskii*.. Winds periodically knock down swaths of sedges partially explaining the mottled tone on airphotos.

The landscape is flat to slightly undulating with shallow depressions, gradually sloping inland. Silty soils and a dense, fibrous, sedge peat are saturated and frequently have semipermanently-flooded topographic depressions. These pannes are dominated by *Puccinellia phryganodes - Triglochin palustre* graminoid and *Puccinellia phryganodes/Hippuris tetraphylla* graminoid forb communities. Most sites are regularly inundated well inland by tides. *Carex ramenskii* sedge communities are generally dense and robust growing to 30-50 cm high. They grade inland through the mid-marsh zone to a variety of *Carex lyngbyei* types. *Carex ramenskii* cover is nearly pure with low or trace amounts of the associated species noted below.

Type 10. *Leymus mollis/Argentina egedii* Community

Small, linear, raised microsites occur within interlevee basin meadows of *Carex ramenskii - Triglochin maritimum - Puccinellia phryganodes/Plantago maritima* at Silver Salmon and Shelter Creek marshes. These low, levee-like features, dominated by a *Leymus mollis/Argentina egedii* plant community, are rarely large enough to map. Associated species are *Puccinellia phryganodes*, *Plantago maritima* and *Stellaria humifusa*. Physical site features are similar to surrounding types.

Type 11. *Carex ramenskii - Hordeum brachyantherum/Argentina egedii* Community

This community occurs on mid-marsh, less developed, and less well-drained levees close to the mouths of tidal guts and channels. Soils are saturated and sites are generally only inundated by high tides. Mappable units were limited to lower Tuxedni Bay and Squarehead Cove marshes.

The vegetation is characterized by a low, open canopy of *Argentina egedii* and the taller *Carex ramenskii* and *Hordeum brachyantherum*. Associated species include *Poa eminens*, *Triglochin maritimum* and *Festuca rubra*.

Type 12. *Carex ramenskii - Hordeum brachyantherum/Argentina egedii - Plantago maritima* Community

A *Carex ramenskii - Hordeum brachyantherum/Argentina egedii - Plantago maritima* plant community occurs inland and parallel to the larger streams and tidal guts in the study area. Silty soils are saturated and flooded regularly by tides. Large volumes of water in these waterways have eroded banks and adjacent levees causing the latter to slump away and form slightly lower terraces. An uneven, sometimes blocky substrate is characterized by a relatively dense and complex network of microdrainages, topographic depressions and flats.

These areas support a vegetation between interlevee basin meadows of *Carex ramenskii - Triglochin maritimum - Puccinellia phryganodes/Plantago maritima*; various levee types; and *Carex ramenskii* sedge communities lining the tidal guts. The diagnostic species are the forbs *Plantago maritima* and *Argentina egedii* in association with the graminoids *Hordeum brachyantherum* and *Carex ramenskii*. Other associated species of the cover type are noted below.

Type 13. *Carex glareosa-Carex ramenskii-Hordeum brachyantherum-Calamagrostis deschampsioides-Poa eminens/Argentina egedii* Community

Mid- to high-marsh tidal guts and stream levees support a graminoid forb community of *Carex glareosa-Carex ramenskii-Hordeum brachyantherum-Calamagrostis deschampsioides-Poa eminens/Argentina egedii*. As one moves inland, these levees become expansive meadows, spreading out from shallow, narrow drainageways. This type is rarely flooded, though frequent rain and spring thaws keep the silty soils and peaty substrate continuously saturated.

Vegetation physiognomy varies from a closed canopy to a relatively open canopy with exposed soil. Species dominance is quite variable from site to site due to minimal changes in elevation and moisture, leading to subtle changes in species composition and cover over short distances. Characteristic dominant species of mid- and upper-marsh levee communities are *Carex glareosa, Hordeum brachyantherum* and *Calamagrostis deschampsioides* complementing the ubiquitous *Carex ramenskii* and *Argentina egedii*. Conspicuous associated species include *Dendranthema arcticum, Poa eminens* and *Festuca rubra*. Variations in this cover type could not be differentiated on available photography.

Type 14. *Carex lyngbyei/Comarum palustre* Community

Mappable units of a *Carex lyngbyei/Comarum palustre* sedge forb community occur in Tuxedni Bay marshes and were observed in lesser amounts in all marshes of the study area. This type is found at the upper edge of high-marsh on sites partially affected by ground water seepage near abrupt upland borders, and on outwash plains of freshwater streams entering the coastal marsh system. It may also form shoreline mats of inland lakes and ponds. This type is perhaps more widespread but could not be identified and mapped confidently with available photography.

Sites are flat to undulating with a deep, tangled growth of undecomposed fibrous sedge peat. Frequent depressions are semipermanently flooded to 50 cm; however, the plant community is rarely affected by tidal waters. *Myrica gale, Carex aquatilis* and *Epilobium palustre* may be associated with the nearly pure cover of *Carex lyngbyei* and *Comarum palustre*.

Type 15. *Carex ramenskii - Carex glareosa/Argentina egedii* Community

Large meadows of *Carex ramenskii - Carex glareosa/Argentina egedii* occur between mid- to high-marsh levees, and slope gently to upland cliffs bordering the marsh. These shallow, concave catchments have saturated, silty soils. Slightly lower microsites may be flooded after heavy rains and spring breakup but no permanent ponding occurs.

Vegetation is similar to *Carex glareosa - Carex ramenskii - Hordeum brachyantherum - Calamagrostis deschampsioides - Poa eminens/Argentina egedii* levees with the notable exception of the slightly raised and drier levee site species. *Carex glareosa* is dominant closer to levees while *Argentina egedii* and *Carex ramenskii* increase in importance to the center of the interlevee basins.

Type 16. *Carex ramenskii - Carex mackenziei - Calamagrostis deschampsioides/Argentina egedii* Community

A *Carex ramenskii* - *Carex mackenziei* - *Calamagrostis deschampsioides/Argentina egedii* graminoid forb community occupies interlevee basins close to steep upland margins of the high-marsh zone. A dense, saturated, peaty mat surrounds shallow, permanently-flooded depressions dominated by the yellow-green *Carex mackenziei*. These species-rich meadows are predominantly *Carex ramenskii, Calamagrostis deschampsioides* and *Argentina egedii*. Sites are influenced by ground water seepage from surrounding uplands and may rarely be affected by extremely high tides.

Type 17. *Carex ramenskii - Carex mackenziei* Community

A pure sedge community of *Carex ramenskii* - *Carex mackenziei* is associated with a strangmoor vegetation pattern where it occupies the shallow, permanently-flooded depressions (flarks) between higher, parallel ridges (strangs) of graminoid forb levees and old beach ridges. Flarks are 10-40 cm deep and 3-8 m wide. This pattern is prevalent at Bear Creek, Shelter Creek and Glacier Creek marshes. *Carex ramenskii* - *Carex mackenziei* communities also occur in the vicinity of high-marsh ponds in a zone immediately shoreward of barren mud and *Hippuris tetraphylla* communities. Especially large meadows occur at Clearwater Creek marsh where they occupy shallow depressions seaward of lakes and ponds.

Zones of the *Carex ramenskii* - *Carex mackenziei* covertype are readily identifiable from a distance in the field by the pale, yellow-green color and creeping, spreading habit of *Carex mackenziei*. The most conspicuous associated species is *Hippuris tetraphylla*.

Type 18. *Carex ramenskii/Hippuris tetraphylla* Community

A sedge forb community dominated by *Carex ramenskii* and *Hippuris tetraphylla* occurs adjacent to the mudflats of Chinitna Bay in Clearwater Creek marshes, and below upland cliffs in Squarehead Cove marshes. Topography is flat, with numerous, shallow depressions or pannes that are semipermanently flooded.

Pannes are covered by *Hippuris tetraphylla*, and surrounded by dense *Carex ramenskii*. Sediment deposition coats stems and leaves of the vegetation indicating frequent inundation by tides.

Type 19. *Carex ramenskii - Eleocharis palustris/Hippuris tetraphylla* Community

A wet sedge forb community of *Carex ramenskii, Eleocharis palustris* and *Hippuris tetraphylla* is associated with small ponds that are generally not large enough to map at a scale of 1:12,000 in the study area. This type was observed in all marshes; however, it was of less extent at Silver Salmon and Horsefly Creek marshes. It is the dominant, emergent vegetation type forming shoreline mats around mid- and high-marsh ponds. Sites are shallow (10-20 cm deep) and permanently flooded.

Type 20. *Calamagrostis canadensis - Poa eminens/Lathyrus palustris - Lathyrus japonicus var. maritimus* Community

This type occurs on high-marsh levees of Clearwater Creek marshes. The substrate is a dense, saturated, hummocky tangle of fibrous peat supporting a rank, species-rich association of grasses, sedges and forbs (see below). Narrow, deep tidal guts are lined and concealed by *Carex lyngbyei*. Type 20 grades coastally into pure *Carex lyngbyei* meadows. Shrub species such as *Myrica gale* and Salix *ovalifolia* become important inland.

Type 21. *Carex lyngbyei -Carex pluriflora- Carex ramenskii - Calamagrostis deschampsioides/Argentina egedii* Community

A complex community dominated by *Carex pluriflora, Carex lyngbyei, Carex ramenskii, Calamagrostis deschampsioides* and *Argentina egedii* makes up a mid-marsh transitional zone from coastal *Carex ramenskii - Argentina egedii* communities to those dominated by *Carex lyngbyei*. The type is indicated by the predominance of *Carex pluriflora* and a general absence of a shrub component. Species dominance is quite variable from site to site due to minimal changes in elevation and moisture, leading to subtle changes in species composition and cover over short distances.

Variations in the covertype could not always be differentiated on available photography. Mappable units occur at Glacier Creek and Shelter Creek marshes. Silty soils are saturated, ground water is at or near the surface, and lower areas with ponded water frequently are present. Sites are only rarely affected by extremely high tides.

Type 22. *Carex lyngbyei - Carex mackenziei* Community

A relatively minor sedge community dominated by *Carex lyngbyei* and *Carex mackenziei* occurs far upstream in the Tuxedni Bay marshes. An uneven surface within a flooded and sometimes ponded, interlevee basin supports an alternating distribution of these species.The rare plant *Eleocharis kamtschatica* was found in this cover type.

Type 23. *Carex lyngbyei - Carex pluriflora/Salix fuscescens- Myrica gale/Moss* spp. Community

Inland, high-marsh levees and meadows are dominated by a *Carex lyngbyei - Carex pluriflora/Salix fuscescens - Myrica gale*/Moss spp. community. They extend out from forested borders and occur inland from the graminoid forb inner-marsh transitional Type 21. Type 23 differs significantly from Type 21 by the addition of low shrubs less than 0.5 m high and a moss layer.

Myrica gale and *Salix fuscescens* are conspicuous additions complementing an increase in *Carex lyngbyei* and a decrease in the importance of *Carex pluriflora*. Coastal and upland species mix on these sites; species dominance and cover are variable between areas due to subtle changes in elevation, and thus moisture. Flat to undulating terrain may be hummocky with seasonally flooded depressions much like one would encounter in a boreal bog.These meadows and levees are rarely flooded by high tides.

Type 24. *Carex lyngbyei/Argentina egedii* Community

Carex lyngbyei/Argentina egedii communities form large meadows far inland and upstream in Tuxedni Bay and Horsefly marshes. They also occur near shorelines and behind old beach ridges at Squarehead and Shelter Creek marshes. Terrain is undulating to hummocky; sites are flooded by high tides. Silty soils are saturated and support a dense, tall (0.75 m), nearly pure cover of *Carex lyngbyei* and an open understory of *Argentina egedii*. Few associated species were observed to recur between marshes.

Type 25. *Carex lyngbyei* Community

Vast meadows of a nearly pure community of *Carex lyngbyei* cover much of the Clearwater Creek marshes. This type occurs over a flat, shallow gradient between Type 20 grass forb levees, and extends inland from Type 2 *Puccinellia phryganodes - Hippuris tetraphylla* grass forb communities of mudflats and pannes along Chinitna Bay. Pure *Carex lyngbyei* communities also are found on ice-heaved margins of large brackish lakes at Clearwater Creek.

Carex lyngbyei communities are indicated by a mottle of circular, gray tones and textures on the 1:12,000-scale aerial photos. This is a result of blown down swaths of this tall sedge; tidal sediments coating stems and leaves of the vegetation; and the circular clones characteristic of the growth habits of *Carex lyngbyei*. Associated species are related to raised microsites where levee species have begun to establish.

Type 26. *Carex lyngbyei - Calamagrostis canadensis/Comarum palustre* Community

A marsh fringe community of *Carex lyngbyei - Calamagrostis canadensis/Comarum palustre* occurs along the bases of abrupt, rocky, upland cliffs. This type is affected by groundwater seepage and runoff from these neighboring uplands significantly diluting the brackish conditions of more coastal salt marshes. Soils are saturated, ground water is at or near the surface, and lower microsites and hummocky depressions with ponded water are frequently present. Sites are rarely inundated by high tides.

The dominant grass, *Calamagrostis canadensis*, and sedge, *Carex lyngbyei*, may be 1-1.5 m high, and surround flooded mats of *Comarum palustre*. Associated species include: *Menyanthes trifoliata, Equisetum fluviatile, Cicuta virosa* and *Myrica gale*.

Type 27. *Sparganium* spp. - *Potamogeton* spp. - *Utricularia* spp. Community

Lakes and ponds of mappable extent occur at Silver Salmon Creek, Glacier Creek, and Clearwater Creek marshes. Floating and rooted aquatic species of shallow water zones include: *Sparganium* spp., *Potamogeton* spp., *Utricularia* spp. and *Myriophyllum* spp. Extensive beds of *Sparganium angustifolium* extend from the shorelines of the large lakes at Clearwater Creek marshes and are evident on the 1:12,000-scale aerial photography.

Upland

Upland plant communities were not mapped and described in this study. Coastal marshes are generally bordered by mixed forests of *Picea sitchensis* and *Populus balsamifera ssp. trichocarpa*; tall shrub thickets of *Alnus viridis* ssp. *sinuata* , and coastal, grass-forb beach ridge and dune communities.

APPENDIX B

HYDROCARBON ANALYSIS OF SEDIMENTS AND BIVALVE MOLLUSKS FOR LAKE CLARK NATIONAL PARK & PRESERVE COASTAL INFORMATION SYSTEM

COOK INLET REGIONAL CITIZENS ADVISORY COUNCIL
1996 LAKE CLARK NATIONAL CLARK BIVALVE STUDY
DATA REPORT AND DATABASE DESCRIPTION

This data submittal contains information concerning the Cook Inlet Regional Citizens Advisory Council (CIRCAC) 1996 Lake Clark National Park (LCNP) Bivalve Study. This document is intended solely as an interpretive data deliverable and not as a comprehensive project report. This deliverable includes a summary of the analytical methods used, laboratory results including quality control results, a general interpretation of the results, and a database. Also included is a description of the database structure with information necessary to identify samples in the database, including information concerning the abbreviations which have been used in the database to encode items such as stations names, analysis types, and other parameters. This database is consistent with the structure developed for CIRCAC under their 1995 Environmental Monitoring Program (EMP; KLI 1995) and can be appended to those data.

SAMPLE COLLECTION AND DESIGNATION

Sampling for the 1996 Bivalve Study was performed in early June by LCNP staff during a single survey, Survey 1. Sampling was performed at nine sites in two different bays (Tuxedni and Chinitna) on the west side of Cook Inlet. Each site was assigned a five-character abbreviation as described in the following table. At each station, one bivalve tissue sample was collected for each analytical parameter. Samples were collected from the intertidal zone using a hand-corer. The chemistry samples from CHB-4 were not subject to analysis due to the lack of adequate sample material.

Sampling Location	Abbreviation	Latitude (N)	Longitude (W)	Sample Date	Sample Time
Chinitna Bay #1	CHB-1	59° 51' 26.4"	153° 07' 27.63"	6/3/96	10:26
Chinitna Bay #2	CHB-2	59° 49' 34.31"	153° 09' 08.26"	6/3/96	10:00
Chinitna Bay #3	CHB-3	59° 49' 31.89"	153° 08' 08.31"	6/3/96	10:33
Chinitna Bay #4	CHB-4	59° 50' 08.80"	153° 06' 34.43"	6/3/96	10:48
Chinitna Bay #5	CHB-5	59° 49' 48.82"	153° 06' 34.43"	6/3/96	10:42
Tuxedni Bay #1	TXB-1	60° 12' 38.07"	152° 41' 46.87"	6/4/96	10:35
Tuxedni Bay #2	TXB-2	60° 09' 17.98"	152° 39' 41.61"	6/4/96	10:00
Tuxedni Bay #3	TXB-3	60° 09' 06.63"	152° 39' 07.10"	6/4/96	10:00
Tuxedni Bay #4	TXB-4	60° 08' 19.35"	152° 38' 54.57"	6/4/96	10:00

Samples were collected for a variety of analytical parameters. In the field, each sample was assigned a unique identifier, called a SAMP_ID. Each SAMP_ID begins with the project designation "LCL" followed by the program year "96". The remainder of the SAMP_ID contains an abbreviation representing the type of analysis pertaining to the sample, as described in the following table, and a consecutive number to make each SAMP_ID unique.

Type of Analysis	Abbreviation	Matrix	Example SAMP_ID
Bivalve condition index	BCI	Bivalve	LCL96BCI0001
Polycyclic aromatic hydrocarbons (PAH) and their alkylated homologues	TIS	Bivalve	LCL96TIS0001
Trace metals analysis	TMT	Bivalve	LCL96TMT0001

LABORATORY ANALYSIS

Laboratory analyses for PAH and trace metals were performed by the Geochemical and Environmental Research Group (GERG) Laboratory of Texas A&M University in College Station, Texas. Laboratory analysis for bivalve condition index was performed by Kinnetic Laboratories, Inc. in Santa Cruz, California.

Samples were analyzed following GERG Standard Operating Procedures (SOPs) or protocols such as those listed below.

Procedure	GERG SOP No.
Sample receipt/sample preparation	SOP-9225
Percent moisture determination (tissue)	SOP-8903
Tissue extraction	SOP-8903
Polycyclic aromatic hydrocarbon determination	SOP-8905
Weighing lipids (percent lipid determination)	SOP-9231
Trace metals (tissue digestion)	SOP-ST07
Trace metals (tissues by graphite furnace)	SOP-ST10
Trace metals (tissues by inductively coupled plasma)	Draft ICP SOP (based on EPA Method 1620)

PAH Analysis

The extraction and analyses of bivalve tissue for PAH were conducted in accordance with GERG standard operating procedures. Extraction of the tissues was carried out using methylene chloride, and extracts were processed with alumina column and silica gel purification, as described in GERG SOP-8903, Revision 3. Polycyclic aromatic hydrocarbons and their alkylated homologues were determined using a gas chromatograph/mass spectrometry (GC/MS) technique in the selected ion monitoring (SIM) mode as described by GERG SOP-8905, Revision 2. Gas chromatographic (GC) separation was accomplished on a fused-silica capillary column with a DB-5 bond phase. The GC column fed directly into the ion source of the mass spectrometer (MS) operating in the SIM and electron-impact ionization mode. A computer system interfaced with the MS continuously acquired and stored all mass-spectral data during the analysis. This system also allowed display of a GC/MS data file for ions of specific mass and plotting ion abundances versus time or scan number. All PAH data were reviewed for quality and met the quality assurance (QA) criteria as specified in the PAH analysis SOP, GERG SOP-8905, Revision 2.

Extracts were spiked with internal standard solutions containing fluorene-d_{10} and benzo(a)pyrene-d_{12} prior to analysis. Internal standards of were used. In addition, matrix spike standard solutions consisting of 2 to 5-ring PAHs were used for quality control matrix spike samples. In addition, QC samples (duplicates, procedural blanks, matrix spike and spike duplicates, standard reference material [SRM], and reference oil samples) were included in each batch as reported below.

Results for each tissue PAH analyte were reported in nanograms/gram (ng/g) in dry weight, or parts per billion (ppb). Method detection limits (MDLs) for each PAH analyte, defined as the lowest concentration of analyte that a method can reliably detect, were calculated by performing analyses on pre-extracted clean tissue following procedures outlined in the Federal Register 40 CFR Part 136, Appendix B (1986). MDLs were estimated for analytes not available in the spike solution or in the actual matrix by using the closest related compound. Results that are below the MDL are qualified with a "J"; analytes not detected during the analysis are qualified with "ND". Measurements falling outside QA limits are qualified with a "Q".

Trace Metals Analysis

The digestion and analyses of bivalve tissues for trace metals were conducted in accordance with the GERG SOPs. Tissues were freeze dried, homogenized, and heated with nitric acid until digestion was complete following the procedures outlined in GERG SOP-ST07, Revision 2. Analysis by graphite furnace atomic absorption (GFAA) was carried out following GERG SOP-ST10, Revision 3. This GFAA method involves using passing an electrical current through a graphite tube injected with the sample to evaporate water, remove interfering species, and finally atomize the analyte of interest into the light path of an absorption spectrophotometer. Various wavelengths correspond to each element (metal). Matrix modifiers are added to the samples to help either remove or greatly diminish interferences. A matrix spiking solution is added to a sample in each batch of samples analyzed to help determine possible interferences. Analysis by inductively induced plasma (ICP) spectrometer followed procedures in GERG Draft SOP for ICP which is based upon EPA Method 1620. In addition, QC samples (duplicates, SRM, matrix spike and spike duplicate, and blank spike) were included in each sample batch as reported in the QC results section below.

The trace metal concentrations are reported in micrograms per gram (µg/g), or parts per million (ppm), on a dry weight basis. Results falling below the MDL are qualified in the tables with a "J". Those analytes that were not detected during the analysis are qualified with "ND", while measurements that are out of QA limits are qualified with "Q".

Bivalve Condition Index Analysis

Biological condition index of *Macoma* spp. and other bivalve individuals were determined by measuring the dry weight in grams (g) of the bivalve tissue, dividing it by the shell volume in cubic centimeters (cc), and multiplying by 100. This followed the formula developed by Haven (1962) and that used on the previously for CIRCAC on their EMP (KLI 1995).

LABORATORY RESULTS AND DISCUSSION

PAH Analysis

Complete listings of PAH results with individual analyte concentrations are presented in the appendix along with the PAH fingerprints from each station. In general, total PAH (TPAH) results were fairly uniform between sites and within each site. A summary of the TPAH results is presented in the table below. TPAH ranged from 271.1 ng/g at CHB-2 to 407.9 ng/g at TXB-4. The mean TPAH at the four Tuxedni Bay stations was 359.5 ng/g, and the mean TPAH at the four Chinitna Bay stations was 333.3 ng/g.

	Station							
	CHB-1	CHB-2	CHB-3	CHB-5	TXB-1	TXB-2	TXB-3	TXB-4
TPAH (ng/g)	311.2	271.1	348.6	402.4	295.5	371.5	362.9	407.9
Average	359.5				333.3			

A review of the LCNP data indicates that, although many PAH components were below MDLs, the PAH fingerprints showed a petrogenic signature. The source of the petroleum hydrocarbons is probably relatively fresh, as indicated by the prevalence of naphthalenes in the samples. The source may include refined petroleum product such as diesel fuel, as indicated by the relative lack of the chrysenes, particularly at the Tuxedni Bay stations.

Comparison of these data with other studies in the area is impossible at this time due to the lack of comparable data. Recent studies conducted in the area, including the recent MMS study (MMS 1995), included the chemical analysis of the mussel *Mytilus edulis* rather than the clam *Macoma*. These different species of bivalves have completely different feeding strategies, and the analytical results are not comparable. That is, the clams sampled for the LCNP program are sediment-dwelling organisms that actually ingest organic particles and sediments on which chemical contaminants such as trace metals and PAHs may be adsorbed. Mussels are filter-feeders which ingest smaller particles of sediment and organic material that are suspended in the water column.

The 1993 Pilot Program conducted by CIRCAC included the analysis of hydrocarbons in six *Macoma* tissue samples collected from subtidal areas in Kamishak and Kachemak Bays. Total PAHs reported by this study were considerably lower than the LCNP values, ranging from 36 to 79 ng/g (Arthur D. Little 1995). Aside from the fact that these bivalves were collected from subtidal rather than intertidal habitats, as on the LCNP program, the extraction and analysis procedures used for these samples were different from those used on the LCNP program, rendering these results unsuitable for comparison.

Trace Metals Analysis

Trace metals results by station are summarized in the following table. Complete listings of the trace metals data can be found in the appendix. Metals results were consistent both between sites and within each site. This lack of variability indicates a fairly uniform exposure to trace metals throughout the study area. Although several of the elements showed fairly high concentrations (e.g., aluminum), these results are most likely due to the ingestion and uptake of glacially-derived sediments given the extremely high suspended sediment concentrations in the water column within the study area (MMS 1995). Cook Inlet sediments analyzed during the 1995 MMS program showed high levels of aluminum (26,400 to 74,300 μg/g) as well as iron, but all metals analyzed for the MMS program were found to be within the range reported elsewhere in Alaska and globally (MMS 1995). Some of the LCNP trace metals values could have been reduced if a pre-analysis depuration was performed on individual bivalves; however, this procedure is not routine for this type of monitoring program. The depuration procedure would eliminate sediment particles from the stomachs of the clams prior to analysis to allow an assessment of the bioaccumulation of the metals within the animal tissues themselves.

Station	Trace Metals (µg/g) Dry Weight												
	Al	As	Ba	Cd	Cr	Cu	Ni	Pb	Se	V	Zn	%Solids	Dry Wt. (g)
CHB-1	7,261	7.43	53.9	0.050 J	8.46	31.6	15.80	2.44	3.00	27.5	202	21.2	0.201
CHB-2	5,589	9.32	48.2	0.060 J	6.85	23.7	13.24	1.98	3.22	21.5	156	24.7	0.199
CHB-3	8,985	9.93	57.6	0.067 J	9.19	37.2	7.24	1.95	3.40	35.5	207	20.7	0.202
CHB-5	8,847	9.23	58.3	0.124	9.13	35.0	8.46	2.19	2.15	33.0	202	20.1	0.196
TXB-1	5,597	15.23	59.8	0.049 J	9.13	28.6	8.03	2.52	3.49	22.5	198	20.9	0.202
TXB-2	8,283	15.39	74.6	0.058 J	11.82	27.3	9.84	2.52	3.61	29.4	215	19.8	0.206
TXB-3	6,039	16.04	57.3	0.063 J	8.65	28.9	15.63	2.54	4.38	20.9	242	18.9	0.200
TXB-4	9,396	15.23	89.2	0.058 J	12.09	30.0	16.13	3.41	3.59	31.7	215	20.3	0.205

J = below MDL

Comparison of the trace metals tissue results with other programs is impossible at this time due to the lack of comparable data from the study area. As indicated above, the recent MMS study performed in the area did not include the analysis of clam tissue as part of the study plan. The 1993 CIRCAC Pilot Program did not include the analysis of trace metals.

Bivalve Condition Index

The small size of the individuals collected on this program (≈ 10 - 20 mm) made the measurement of BCI difficult, particularly with respect to shell volume. Shell volumes could vary quite a bit depending on how the meniscus was interpreted. To minimize this effect, a low viscosity liquid (ethanol) was used, and the same analyst was used for every shell volume measurement. This index is normally carried out on much larger individuals where volume discrepancies are not as high a percentage of the total measurement. This limitation should be considered when reviewing the data.

The BCI values for the *Macoma balthica* individuals collected ranged from a low of 3.33 (CHB-4) to a high of 34.56 (TXB-1). The mean BCI for *Macoma* was 17.15 (n=171) with a standard deviation of 4.7. The range for mean BCI observed (12 - 22) between stations was very similar to the range observed on the 1995 CIRCAC EMP (10 - 20; KLI 1995) as well as on the CIRCAC Pilot Program (12 - 23; Arthur D. Little 1995) and probably reflects the normal range of this parameter.

QUALITY CONTROL RESULTS

PAH Quality Control Results

All tissue analyses for PAH met or exceeded QA criteria with the few exceptions listed below. Any subsequent action taken by the laboratory or analyst with regard to QA variances is also provided.

The entire batch of tissue samples was reextracted due to a power outage that occurred at the laboratory during the middle of the GC analysis. Although this outage may not have affected the final results, the decision was made to reextract the remaining material and rerun the entire batch of samples.

The recovery of the surrogate deuterated perylene was outside the QA limits (40% -120%) for sample LCL96TIS0009. Deuterated perylene is routinely low in samples having low concentrations of lipids. The recovery of deuterated perylene is advisory and only used to calculate the concentration of perylene. In addition, perylene is not included as part of the total PAH. This surrogate recovery was reported with the QA qualifier "Q", and no further action was taken.

The matrix spike and blank spike analyses passed all QA criteria for spike recovery. The average percent recovery for the matrix spike sample was 104%. All duplicate analysis passed QA criteria for relative percent difference (RPD). Calculation of the RPD between matrix spike and matrix spike duplicate samples could not be performed since not enough sample was available to run the matrix spike duplicate. This lack of sample material was due to the reextraction procedure explained above.

No analytes were measured at levels greater than three times the MDL in the procedural blanks. The SRM (NIST 1974a; GERG ID Q14014) had high recovery for 2-methylnaphthalene. No interferences could be found by the analyst. The certified analyte concentration was less than the MDL, and no further action was taken. The Reference Oil analysis passed the QC criteria.

Trace Metals Quality Control Results

All tissue analyses for trace metals met or exceeded QA criteria with the few minor exceptions listed below. Any subsequent action taken by the laboratory or analyst with regard to QA variances is also listed.

Nickel and chromium were initially to be analyzed by GFAA. The nickel data was reported from the ICP data when the concentrations that were measured were well above the detection limits for the ICP. Chromium was run on both the GFAA and ICP. Since the ICP and the GFAA data for chromium were comparable, and the ICP results were acceptable (above the ICP detection limits), the ICP data were reported for this element as well.

The concentration of chromium and lead for the SRM NRCC DOLT-2 (GERG ID 1665) were high. However, the concentration for both were less than 10 times the detection limits, and no further action was taken. The matrix spike/matrix spike duplicate and blank spike analyses passed all QA criteria for spike recovery. All duplicate analysis passed QA criteria for % RPD. No analytes were measured greater than MDL in the procedural blank.

DATABASE DESCRIPTION

Included as part of the database deliverable are several pieces of information. These include a database description, an Entity Relationship Diagram (ERD) which depicts the database structure, and a disclaimer, describing the intended limitations and uses of the database. In this description and the accompanying information, certain conventions are used. Table names indicate what type of data each table contains and are typed in upper case (e.g., STATION). Field names are generally abbreviated, are typed in upper case, and often include an underscore, such as SURVEY_ID. Tables can be thought of as data files that contain both records and fields. In general, a record may be defined as one line of data in a table, while a field may be considered a column. In this database, all fields are character-based to maintain simplicity. Fields that are null are either empty or are filled with ".NULL."

The database design is relational in nature. In this type of design, the data are broken into separate tables, as indicated by the ERD and database description, to reduce redundancy and provide an efficient means of handling large amounts of data. The database consists of nine tables that are related using fields called common keys, also called "foreign" keys. These common keys are used to relate data in one table to corresponding data in another table. For example, the sample identification number (SAMP_ID) may be found in five of the nine tables, and this provides a common link between these tables. Primary keys are also used and are defined as keys that, when combined, identify a unique record in a table. For example, in the ANALYSIS table, combining SAMP_ID, LABSAMP_ID, and ANAL_TY provides a means to identify a unique record.

When querying or handling the data, it may be necessary to join certain tables, or certain fields of interest from two or more tables, in order to obtain the information that is needed. For example, sampling information, analytical methods used, and results for a particular sample from the STATION, SAMPLE, and RESULT tables may be joined to provide a better view of the data of interest. All extraneous information can be omitted from the table join so that only the fields that are needed are present. This means that processing speed and ability to review (browse) or query large volumes of data are greatly enhanced.

Tables relate to one another in several different types of relationships. A one-to-many relationship indicates that a common key that is unique in one table will be represented many times in another table. That is, for every station there are many samples, for every sample there are many analysis types, and for every analysis type there are many results. The common key is used to link the tables, while the primary keys are used to determine unique records in the table showing many instances of that common key. For example, the SAMP_ID field exists as a unique field in the SAMPLE table, meaning each SAMP_ID exists only once. The same SAMP_ID, however, exists for numerous records in the ANALYSIS table, because it is repeated each time a different analysis type (ANAL_TY) is reported in this table. This demonstrates the one-to-many condition, which is indicated on the ERD as a double arrow.

In addition to the eight tables linked by common keys, an additional table is part of this database. This table, called a valid values table (VALIDVAL), provides information about the appropriate codes, units, and other data that exist in the database. For example, this table provides definitions and descriptions of certain encoded values that might exist in the

ANALYSIS table, such as "PAH" as the ANAL_TY for polycyclic aromatic hydrocarbons. This table can be used as a lookup table to help with abbreviations, acronyms, and codes used in other tables in the database.

The accompanying database description provides more detailed information concerning each table in the database, including what each field in that table contains. Additional information on specific fields within the tables may be found in the VALIDVAL table. In brief, the tables include:

STATION	field sampling information on a by-station basis
SAMPLE	field sampling and sample shipment information on a by-sample basis
ANALYSIS	analytical method and handling data on a by-sample and analysis basis, for field-collected samples
RESULT	analytical results on a by-sample, analysis type, and individual analyte basis, for field-collected samples
QCANAL	analytical method and handling data on a by-sample and analysis basis, for quality control samples originating in the laboratory
QCRESULT	analytical results on a by-sample, analysis type, and individual analyte basis, for quality control samples originating in the laboratory
COC	chain of custody (COC) data on a COC basis
COC_XFER	COC information on a COC, relinquish date, and time basis
VALIDVAL	provides valid values that may be found for different types of fields in the other tables

DISCLAIMER

This database has been prepared by Kinnetic Laboratories, Inc. (KLI) under a contract with the Cook Inlet RCAC and is being provided solely to make public the data obtained under the contract. Conclusions or opinions that database users may reach from the data are solely their own and may not be attributed to KLI or Cook Inlet RCAC. KLI may provide subsequent data to the Cook Inlet RCAC that is not included in this database. The information in this draft database was gathered in accordance with generally-accepted scientific practices and procedures. KLI and Cook Inlet RCAC make no warranties or representations, express or implied, as to the suitability of the data for any purpose other than educational or research purposes.

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APPENDIX C

META-DATA FOR LAKE CLARK NATIONAL PARK & PRESERVE COASTAL GEOGRAPHIC INFORMATION SYSTEM

C.1 Data Layer Title and Code: cabins

Description: Point coverage of occupied/unoccupied cabins located along the coast
Suggested Application/ Cautions: cultural development, population monitoring
Feature Type(s) Present: points
Topology Present: no
Precision of coordinates (number of decimal places): 0.1m

Projections and Parameters
Name: Albers Conical Equal Area
Units: meters
Spheroid: Clarke 1866
  Datum: NAD1927 Alaska
  Standard Parallel #1 (lat/long): 55N
  Standard Parallel #2 (lat/long): 65N
  Latitude of origin: 50N
  Longitude of Origin: 154W

Data Source: Aerial photography and ground location
Principal Investigator: G.C. Schoch/Alan Bennett
PI Affiliation/Phone: Oregon State University, College of Oceanic and Atmospheric Sciences, 503-737-2360
Data Layer Preparer: G.C. Schoch
Date Prepared as Data Layer: May 10, 1995
Data Source Medium: screen
Scale of Data Source: 1:1000
Data Source Projection and Parameters: Albers Conical Equal Area
Who Digitized: G.C. Schoch **Phone**: 503-737-2360
Version Date: April 20, 1995
Date Last Revision: October 10, 1995

Processing Notes:

Comments:

C.2 Data Layer Title and Code: index

Description: Polygon coverage of aerial photo locations along the LACL coast
Suggested Application/ Cautions: visual reference to aerial photo locations
Feature Type(s) Present: polygons
Topology Present: yes
Precision of coordinates (number of decimal places): 0.1m

Projections and Parameters
Name: Albers Conical Equal Area
Units: meters
Spheroid: Clarke 1866
  Datum: NAD1927 Alaska
  Standard Parallel #1 (lat/long): 55N
  Standard Parallel #2 (lat/long): 65N
  Latitude of origin: 50N
  Longitude of Origin: 154W

Data Source: Scanned aerial photography corner coordinates
Principal Investigator: G.C. Schoch/Alan Bennett
PI Affiliation/Phone: Oregon State University, College of Oceanic and Atmospheric Sciences, 503-737-2360
Data Layer Preparer: G.C. Schoch
Date Prepared as Data Layer: prepared from digital aerial photography
Data Source Medium: screen
Scale of Data Source: 1:50,000
Data Source Projection and Parameters: Albers Conical Equal Area
Who Digitized: G.C. Schoch **Phone**: 503-737-2360
Version Date: April 20, 1995
Date Last Revision: October 10, 1995

Processing Notes:

Comments:

C.3 Data Layer Title and Code: lacl01al - lacl38al

Description: 38 grid coverages of geometrically corrected scanned grey scale aerial photo imagery
Suggested Application/ Cautions: backdrop for vector layers, resource inventory and monitoring, habitat modelling
Feature Type(s) Present: raster imagery
Topology Present: no
Precision of coordinates (number of decimal places): 0.1m

Projections and Parameters
Name: Albers Conical Equal Area
Units: meters
Spheroid: Clarke 1866
Datum: NAD1927 Alaska
Standard Parallel #1 (lat/long): 55N
Standard Parallel #2 (lat/long): 65N
Latitude of origin: 50N
Longitude of Origin: 154W

Data Source: 1:24,000 aerial photography
Principal Investigator: G.C. Schoch/Alan Bennett
PI Affiliation/Phone: Oregon State University, College of Oceanic and Atmospheric Sciences, 503-737-2360
Data Layer Preparer: G.C. Schoch
Date Prepared as Data Layer: September 30, 1994
Data Source Medium: scanned
Scale of Data Source: 1:24,000
Data Source Projection and Parameters: none
Who Digitized: G.C. Schoch **Phone**: 503-737-2360
Version Date: April 20, 1995
Date Last Revision: October 10, 1995

Processing Notes: Images were geometrically corrected using ground control points with GPS coordinates. Additional points were acquired from scanned topographic quadrangles. Images were corrected from north to south, thus images are intended to overlap in that order, with images to the south overlapping adjacent images to the north to ensure matching of the shorelines at scales > 1:10,000.
Comments:

C.4 Data Layer Title and Code: laclgeo

Description: Polygon coverage of homogenous intertidal morphodynamic units
Suggested Application/ Cautions: habitat classification, spatial analysis, modelling
Feature Type(s) Present: polygons
Topology Present: yes
Precision of coordinates (number of decimal places): 0.1m

Projections and Parameters
Name: Albers Conical Equal Area
Units: meters
Spheroid: Clarke 1866
  Datum: NAD1927 Alaska
  Standard Parallel #1 (lat/long): 55N
  Standard Parallel #2 (lat/long): 65N
  Latitude of origin: 50N
  Longitude of Origin: 154W

Data Source: delineations digitized from aerial photography, data from ground surveys
Principal Investigator: G.C. Schoch/Alan Bennett
PI Affiliation/Phone: Oregon State University, College of Oceanic and Atmospheric Sciences, 503-737-2360
Data Layer Preparer: G.C. Schoch
Date Prepared as Data Layer: September 14, 1995
Data Source Medium: screen
Scale of Data Source: 1:4,000
Data Source Projection and Parameters: Albers Conical Equal Area
Who Digitized: G.C. Schoch **Phone**: 503-737-2360
Version Date: April 20, 1995
Date Last Revision: October 10, 1995

Processing Notes:

Comments:

C.5 Data Layer Title and Code: laclhase

Description: Point coverage of harbor seal haulouts
Suggested Application/ Cautions: population monitoring, spatial analysis, modelling
Feature Type(s) Present: points
Topology Present: no
Precision of coordinates (number of decimal places): 0.1m

Projections and Parameters
Name: Albers Conical Equal Area
Units: meters
Spheroid: Clarke 1866
Datum: NAD1927 Alaska
Standard Parallel #1 (lat/long): 55N
Standard Parallel #2 (lat/long): 65N
Latitude of origin: 50N
Longitude of Origin: 154W

Data Source: locations based on aerial reconnaisance, points digitized from aerial photography
Principal Investigator: G.C. Schoch/Alan Bennett
PI Affiliation/Phone: Oregon State University, College of Oceanic and Atmospheric Sciences, 503-737-2360
Data Layer Preparer: G.C. Schoch
Date Prepared as Data Layer: March 30, 1995
Data Source Medium: screen
Scale of Data Source: 1:4,000
Data Source Projection and Parameters: Albers Conical Equal Area
Who Digitized: G.C. Schoch **Phone**: 503-737-2360
Version Date: April 20, 1995
Date Last Revision: October 10, 1995

Processing Notes:

Comments:

C.6 Data Layer Title and Code: laclhydr

Description: Line coverage of significant rivers and streams
Suggested Application/ Cautions: spatial analysis, intertidal habitat modelling
Feature Type(s) Present: lines
Topology Present: no
Precision of coordinates (number of decimal places): 0.1m

Projections and Parameters
Name: Albers Conical Equal Area
Units: meters
Spheroid: Clarke 1866
  Datum: NAD1927 Alaska
  Standard Parallel #1 (lat/long): 55N
  Standard Parallel #2 (lat/long): 65N
  Latitude of origin: 50N
  Longitude of Origin: 154W

Data Source: hydrological significance based on volume and proximity to intertidal habitats, lines digitized from aerial photography
Principal Investigator: G.C. Schoch/Alan Bennett
PI Affiliation/Phone: Oregon State University, College of Oceanic and Atmospheric Sciences, 503-737-2360
Data Layer Preparer: G.C. Schoch
Date Prepared as Data Layer: April 18, 1995
Data Source Medium: screen
Scale of Data Source: 1:12,000
Data Source Projection and Parameters: Albers Conical Equal Area
Who Digitized: G.C. Schoch **Phone:** 503-737-2360
Version Date: April 20, 1995
Date Last Revision: October 10, 1995

Processing Notes:

Comments:

C.6 Data Layer Title and Code: laclmllw

Description: Line coverage of Cook Inlet bathymetric contours adjacent to LACL shoreline
Suggested Application/ Cautions: intertidal habitat modelling
Feature Type(s) Present: lines
Topology Present: no
Precision of coordinates (number of decimal places): 0.1m

Projections and Parameters
Name: Albers Conical Equal Area
Units: meters
Spheroid: Clarke 1866
Datum: NAD1927 Alaska
Standard Parallel #1 (lat/long): 55N
Standard Parallel #2 (lat/long): 65N
Latitude of origin: 50N
Longitude of Origin: 154W

Data Source: National Ocean Service Hydrographic Chart for Cook Inlet: Anchor Point to Kalgin Island
Principal Investigator: G.C. Schoch/Alan Bennett
PI Affiliation/Phone: Oregon State University, College of Oceanic and Atmospheric Sciences, 503-737-2360
Data Layer Preparer: G.C. Schoch
Date Prepared as Data Layer: March 22, 1995
Data Source Medium: digitizing tablet
Scale of Data Source: 1:100,000
Data Source Projection and Parameters: Mercator, NAD 1983
Who Digitized: G.C. Schoch **Phone:** 503-737-2360
Version Date: April 20, 1995
Date Last Revision: October 10, 1995

Processing Notes: bathymetry digitized include the 0, 1, 5, 10, 20, and 30 fathom (6 feet) lines

Comments:

C.7 Data Layer Title and Code: laclrock

Description: Point coverage of Cook Inlet submerged rocks adjacent to LACL shoreline
Suggested Application/ Cautions: intertidal habitat modelling
Feature Type(s) Present: points
Topology Present: no
Precision of coordinates (number of decimal places): 0.1m

Projections and Parameters
Name: Albers Conical Equal Area
Units: meters
Spheroid: Clarke 1866
Datum: NAD1927 Alaska
Standard Parallel #1 (lat/long): 55N
Standard Parallel #2 (lat/long): 65N
Latitude of origin: 50N
Longitude of Origin: 154W

Data Source: National Ocean Service Hydrographic Chart for Cook Inlet: Anchor Point to Kalgin Island
Principal Investigator: G.C. Schoch/Alan Bennett
PI Affiliation/Phone: Oregon State University, College of Oceanic and Atmospheric Sciences, 503-737-2360
Data Layer Preparer: G.C. Schoch
Date Prepared as Data Layer: March 22, 1995
Data Source Medium: digitizing tablet
Scale of Data Source: 1:100,000
Data Source Projection and Parameters: Mercator, NAD 1983
Who Digitized: G.C. Schoch **Phone**: 503-737-2360
Version Date: April 20, 1995
Date Last Revision: October 10, 1995

Processing Notes: all submerged rocks in depths less than 10 fathoms (60 feet) were digitized

Comments:

C.8 Data Layer Title and Code: lacltics

Description: Point coverage of ground control points used for geometric correction of the scanned aerial photography
Suggested Application/ Cautions: aerial photo rectification
Feature Type(s) Present: points
Topology Present: no
Precision of coordinates (number of decimal places): 0.1m

Projections and Parameters
Name: Albers Conical Equal Area
Units: meters
Spheroid: Clarke 1866
Datum: NAD1927 Alaska
Standard Parallel #1 (lat/long): 55N
Standard Parallel #2 (lat/long): 65N
Latitude of origin: 50N
Longitude of Origin: 154W

Data Source: Corrected GPS coordinates of annotated photo-basemap features, additional features acquired from 1:63,360 USGS topographic quadrangles, all features relocated on scanned aerial imagery
Principal Investigator: G.C. Schoch/Alan Bennett
PI Affiliation/Phone: Oregon State University, College of Oceanic and Atmospheric Sciences, 503-737-2360
Data Layer Preparer: G.C. Schoch
Date Prepared as Data Layer: March 22, 1995
Data Source Medium: screen
Scale of Data Source: 1:4,000
Data Source Projection and Parameters: Albers Conical Equal Area
Who Digitized: G.C. Schoch **Phone**: 503-737-2360
Version Date: April 20, 1995
Date Last Revision: October 10, 1995

Processing Notes: at least 4 ground control points per aerial image

Comments:

C.9 Data Layer Title and Code: lacltopo

Description: Line coverage of 100m topographic contours to 500m
Suggested Application/ Cautions: nearshore habitat modelling
Feature Type(s) Present: lines
Topology Present: no
Precision of coordinates (number of decimal places): 0.1m

Projections and Parameters
Name: Albers Conical Equal Area
Units: meters
Spheroid: Clarke 1866
  Datum: NAD1927 Alaska
  Standard Parallel #1 (lat/long): 55N
  Standard Parallel #2 (lat/long): 65N
  Latitude of origin: 50N
  Longitude of Origin: 154W

Data Source: scanned USGS 1:63,360 topographic quadrangles
Principal Investigator: G.C. Schoch/Alan Bennett
PI Affiliation/Phone: Oregon State University, College of Oceanic and Atmospheric Sciences, 503-737-2360
Data Layer Preparer: G.C. Schoch
Date Prepared as Data Layer: February 15, 1995
Data Source Medium: screen
Scale of Data Source: 1:4,000
Data Source Projection and Parameters: Albers Conical Equal Area
Who Digitized: G.C. Schoch **Phone**: 503-737-2360
Version Date: April 20, 1995
Date Last Revision: October 10, 1995

Processing Notes: 5 lines at 100m intervals each

Comments:

C.10 Data Layer Title and Code: raptors

Description: point coverage of 1994 bald eagle and peregrine falcon nest locations
Suggested Application/ Cautions: resource inventory and monitoring
Feature Type(s) Present: points
Topology Present: no
Precision of coordinates (number of decimal places): 0.1m

Projections and Parameters
Name: Albers Conical Equal Area
Units: meters
Spheroid: Clarke 1866

- **Datum**: NAD1927 Alaska
- **Standard Parallel #1 (lat/long)**: 55N
- **Standard Parallel #2 (lat/long)**: 65N
- **Latitude of origin**: 50N
- **Longitude of Origin**: 154W

Data Source: aerial surveys and annotated aerial photo basemaps
Principal Investigator: G.C. Schoch/Alan Bennett
PI Affiliation/Phone: Oregon State University, College of Oceanic and Atmospheric Sciences, 503-737-2360
Data Layer Preparer: G.C. Schoch
Date Prepared as Data Layer: February 15, 1995
Data Source Medium: screen
Scale of Data Source: 1:4,000
Data Source Projection and Parameters: Albers Conical Equal Area
Who Digitized: G.C. Schoch **Phone**: 503-737-2360
Version Date: April 20, 1995
Date Last Revision: October 10, 1995

Processing Notes:

Comments:

C.11 Data Layer Title and Code: seabirds

Description: point coverage of 1994 seabird (kittiwakes, puffins) colonies
Suggested Application/ Cautions: resource inventory and monitoring
Feature Type(s) Present: points
Topology Present: no
Precision of coordinates (number of decimal places): 0.1m

Projections and Parameters
Name: Albers Conical Equal Area
Units: meters
Spheroid: Clarke 1866
    Datum: NAD1927 Alaska
    Standard Parallel #1 (lat/long): 55N
    Standard Parallel #2 (lat/long): 65N
    Latitude of origin: 50N
    Longitude of Origin: 154W

Data Source: aerial and vessel surveys and annotated aerial photo basemaps
Principal Investigator: G.C. Schoch/Alan Bennett
PI Affiliation/Phone: Oregon State University, College of Oceanic and Atmospheric Sciences, 503-737-2360
Data Layer Preparer: G.C. Schoch
Date Prepared as Data Layer: February 15, 1995
Data Source Medium: screen
Scale of Data Source: 1:4,000
Data Source Projection and Parameters: Albers Conical Equal Area
Who Digitized: G.C. Schoch **Phone**: 503-737-2360
Version Date: April 20, 1995
Date Last Revision: October 10, 1995

Processing Notes:

Comments:

C.12 Data Layer Title and Code: status

Description: polygon coverage of non-federal lands within LACL boundaries
Suggested Application/ Cautions: resource inventory and monitoring
Feature Type(s) Present: polygons
Topology Present: yes
Precision of coordinates (number of decimal places): 0.1m

Projections and Parameters
Name: Albers Conical Equal Area
Units: meters
Spheroid: Clarke 1866
Datum: NAD1927 Alaska
Standard Parallel #1 (lat/long): 55N
Standard Parallel #2 (lat/long): 65N
Latitude of origin: 50N
Longitude of Origin: 154W

Data Source: 1:63,360 analog maps and ownership data provided by the NPS Regional Lands Office
Principal Investigator: G.C. Schoch/Alan Bennett
PI Affiliation/Phone: Oregon State University, College of Oceanic and Atmospheric Sciences, 503-737-2360
Data Layer Preparer: G.C. Schoch
Date Prepared as Data Layer: April 30, 1995
Data Source Medium: digitizing tablet
Scale of Data Source: 1:63,360
Data Source Projection and Parameters: Transverse Mercator, NAD 1927
Who Digitized: G.C. Schoch **Phone**: 503-737-2360
Version Date: April 20, 1995
Date Last Revision: October 10, 1995

Processing Notes:

Comments:

C.13 Data Layer Title and Code: transects

Description: line coverage of intertidal transects supporting biological and geomorphological assessment studies adjacent to LACL
Suggested Application/ Cautions: resource inventory and monitoring
Feature Type(s) Present: lines
Topology Present: no
Precision of coordinates (number of decimal places): 0.1m

Projections and Parameters
Name: Albers Conical Equal Area
Units: meters
Spheroid: Clarke 1866
Datum: NAD1927 Alaska
Standard Parallel #1 (lat/long): 55N
Standard Parallel #2 (lat/long): 65N
Latitude of origin: 50N
Longitude of Origin: 154W

Data Source: annotated aerial photo basemaps
Principal Investigator: G.C. Schoch/Alan Bennett
PI Affiliation/Phone: Oregon State University, College of Oceanic and Atmospheric Sciences,. 503-737-2360
Data Layer Preparer: G.C. Schoch
Date Prepared as Data Layer: April 5, 1995
Data Source Medium: screen
Scale of Data Source: 1:4,000
Data Source Projection and Parameters: Albers Conical Equal Area
Who Digitized: G.C. Schoch **Phone:** 503-737-2360
Version Date: April 20, 1995
Date Last Revision: October 10, 1995

Processing Notes:

Comments:

C.14 Data Layer Title and Code: marsh

Description: Polygon coverage of salt marsh vegetation types
Suggested Application/ Cautions: habitat classification, spatial analysis, modelling
Feature Type(s) Present: polygons
Topology Present: yes
Precision of coordinates (number of decimal places): 0.1m

Projections and Parameters
Name: Albers Conical Equal Area
Units: meters
Spheroid: Clarke 1866
Datum: NAD1927 Alaska
Standard Parallel #1 (lat/long): 55N
Standard Parallel #2 (lat/long): 65N
Latitude of origin: 50N
Longitude of Origin: 154W
Data Source: delineations digitized from aerial photography, data from ground surveys
Principal Investigator: Jerry Tande/G.C. Schoch/Alan Bennett
PI Affiliation/Phone: Oregon State University, College of Oceanic and Atmospheric Sciences, 503-737-2360
Data Layer Preparer: G.C. Schoch
Date Prepared as Data Layer: September 14, 1995
Data Source Medium: screen
Scale of Data Source: 1:4,000
Data Source Projection and Parameters: Albers Conical Equal Area
Who Digitized: G.C. Schoch **Phone**: 503-737-2360
Version Date: April 20, 1995
Date Last Revision: October 10, 1995

Processing Notes:

Comments: