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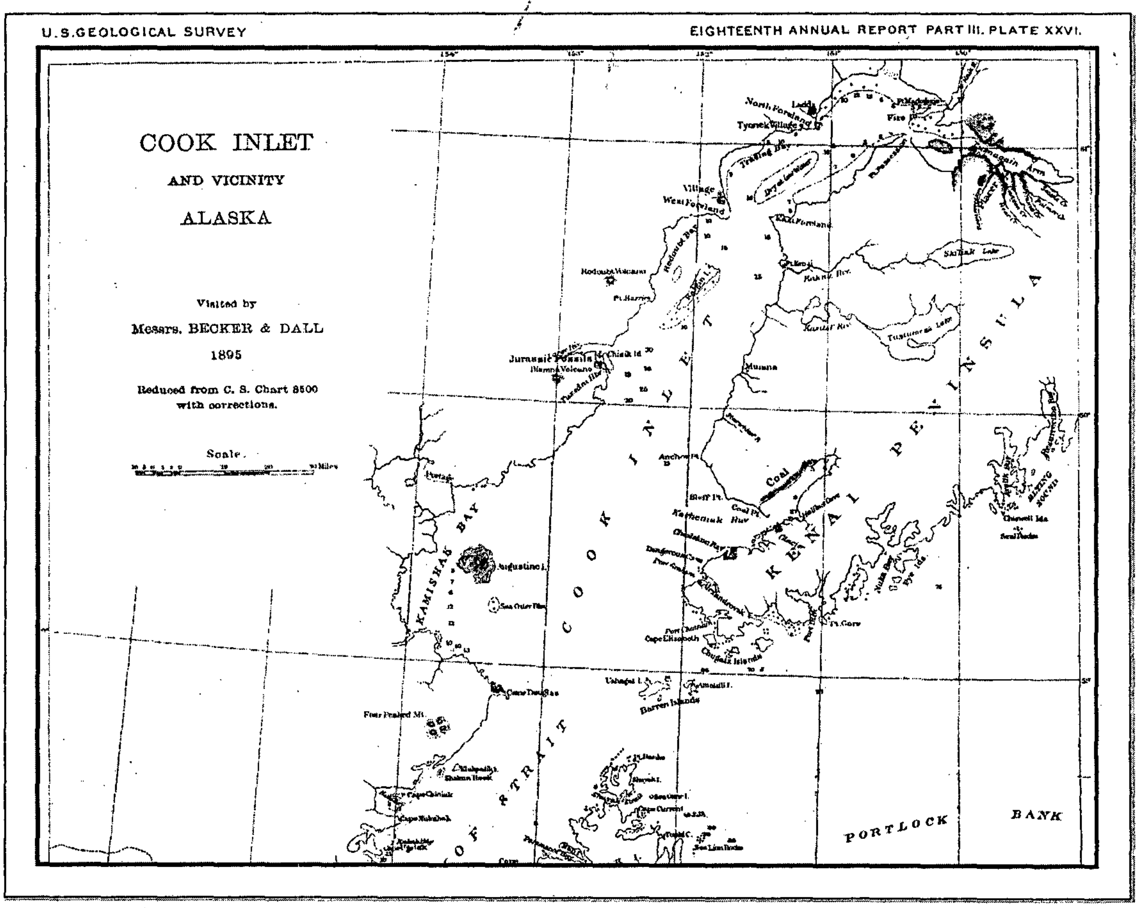
SEASONAL SHOREBIRD USE OF INTERTIDAL HABITATS OF COOK INLET, ALASKA



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Biological Resources Division

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FINAL REPORT

SEASONAL SHOREBIRD USE OF INTERTIDAL HABITATS OF COOK INLET, ALASKA

by

Robert E. Gill, Jr., and T. Lee Tibbitts

Prepared by

the
U.S. Geological Survey
Biological Resources Division
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in support of
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Alaska OCS Region

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This research addresses an information need identified by the U.S. Department of the Interior's Minerals Management Service, Alaska OCS Region, Anchorage, Alaska.

DISCLAIMER

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SUMMARY

Seasonal shorebird use of intertidal habitats of Cook Inlet, Alaska, was studied from February 1997 to February 1999 using aerial surveys as the principal method of assessment. On-ground studies were conducted to validate aerial survey results and to assess shorebird use of vegetated habitats, especially during the breeding season. Twenty-eight species of shorebirds were recorded using the area, ranging from all being present during spring to a single species present during winter. The annual pattern of use was characterized by the sudden occurrence and rapid increase in numbers of birds during early May and their abrupt departure in mid- to late-May. During this period, survey totals frequently exceeded 150,000 birds per day. Comparatively little use occurred during summer and autumn, but use was significant from late autumn to early spring when Rock Sandpipers (*Calidris ptilocnemis*) resided in the Inlet. A single species, the Western Sandpiper (*C. mauri*), was by far the numerically dominant shorebird, accounting for three-fourths of all birds recorded. The Pacific flyway population of this species numbers 2-3 million birds of which we estimated 20-47% used Cook Inlet embayments, especially southern Redoubt Bay. Cook Inlet also supported between 11 and 21% of the Pacific flyway population of Dunlin (*C. alpina pacifica*) and what may be the entire population (ca. 20,000 birds) of the nominate race of the Rock Sandpiper (*C. p. ptilocnemis*). Several areas along the west side of Cook Inlet proved to be extremely important to shorebirds. Southern Redoubt Bay supported 73% of all shorebirds during spring (average 32,000 per day) while Susitna Flats accounted for 82% of use during winter (8,400 per day). International criteria used to assess the conservation importance of particular wetland sites to shorebirds not only place Cook Inlet at the highest level of recognition but afford similar recognition to several individual embayments therein. The large human population and the extent of oil and natural gas production facilities occurring in the Cook Inlet region potentially pose serious risks to shorebirds and intertidal habitats.

Key words: *shorebirds, seasonal occurrence, abundance, migration, wintering, Western Sandpiper*, Calidris mauri, *Rock Sandpiper*, Calidris ptilocnemis, *Cook Inlet, Alaska*.

INTRODUCTION

Cook Inlet represents the last significant expanse of ice-free littoral habitat available to birds migrating in spring to breeding areas in arctic and subarctic regions of Alaska and eastern Asia. These habitats are known to be extremely important to migratory waterfowl in both spring and autumn (Raveling 1978, Butler and Gill 1987, Robertson and Hupp 1992), but considerably less is known about their importance to other groups of waterbirds, particularly shorebirds.

Prior to this study we suspected that Cook Inlet was potentially an important site for shorebirds. We based this largely on: 1) the Inlet's proximity (400 km) to the Copper River Delta (CRD), a renowned spring stopover site for migrating shorebirds, and 2) its position between the CRD and major shorebird breeding areas in western Alaska and eastern Asia (Gill et al. 1994, Page and Gill 1994, Gill 1996, Warnock and Bishop 1998, Bishop and Warnock 1998). As many as 3 million Western Sandpipers and 500,000 Dunlin migrate along the coast of the Gulf of Alaska each spring (see Appendix A for scientific names). Recent studies involving radio-marked Western Sandpipers provide direct evidence that birds nesting in western Alaska stop en route at sites along the south-central Alaska coast, especially the CRD and embayments along the west side of Cook Inlet (Iverson et al. 1996, Warnock and Bishop 1998, Bishop and Warnock 1998).

Infrequent observations since the mid-1970s point to often significant use of Cook Inlet embayments by shorebirds. Along the east side of Cook Inlet, Upper Kachemak Bay would appear to be particularly important to birds in spring. For example, an observation of 1-2 million "small shorebirds" there on 11 May 1976 (*in* Erickson 1977) is likely an overestimate, but would nevertheless suggest an unusually large concentration of birds, probably in the hundreds of thousands. Over 60,000 small sandpipers (mostly Westerns) were found there during the second week of May 1977 (Krasnow and Halpin 1981), and over 100,000 Western Sandpipers were recorded there in early May 1993 (Gill and Tibbitts 1993).

Earlier studies also suggested that the embayments along the west side of Lower Cook Inlet (LCI) are used regularly by shorebirds during migration. Single aerial surveys of this region flown during each of the four seasons in 1976 revealed a total of 20,000 shorebirds, 80% of which occurred during spring (Erickson 1977). In early May 1993 over 115,000 small sandpipers, again mostly Western Sandpipers, were recorded on southern Redoubt Bay (Gill and Tibbitts 1993). And a more recent series of aerial surveys of Tuxedni and Chinitna bays indicated that between 86,000 and 122,000 shorebirds used these two areas each spring from 1994 to 1996 (Bennett 1996).

While most of these observations concern embayments in LCI and point to major use during some years, less clear is the importance of Upper Cook Inlet (UCI) intertidal areas to shorebirds. Spring aerial surveys in the mid-1980s, of primarily waterfowl in UCI, revealed several tens of thousands of shorebirds using both unvegetated and vegetated intertidal habitats from Redoubt Bay north to upper Knik Arm (Butler and Gill 1987; R. Gill unpubl. data).

In northern UCI, on-ground observations of shorebirds on Susitna Flats in early May 1996 revealed densities of 350-2,000 birds/km^2 during single-day surveys of vegetated intertidal plots (R. Gill, unpubl. data). The two most abundant species recorded were Western Sandpipers and Long-billed Dowitchers. Previous studies on the Susitna and Knik River flats found almost 1,000 shorebirds/km^2 (small sandpipers, yellowlegs of unknown species, and Red-necked Phalaropes) on salt marshes in July (Sellers 1979). Seasonal densities such as these and the extent of habitat in UCI suggest that a few to several hundred thousand shorebirds may use UCI habitats between May and October.

Most shorebirds in Alaska depend on littoral habitats during some portion of their annual cycle (Gill and Handel 1990) and any human activities that displace or alter such habitats could put shorebird populations at risk. Because Alaska's largest human population center lies in UCI, the potential for such disturbance or alteration is very real. In addition, the extent of oil and natural gas production facilities in this area is second only to those occurring on Alaska's North Slope. Indeed, almost 300 oil and natural gas wells have been drilled in Cook Inlet, including 15 offshore oil and gas production platforms, 13 of which are currently active and located in UCI between the Forelands and Tyonek (*in* Bennett 1996). Onshore production facilities are located at Granite Point, Trading Bay, and the East Forelands. Oil refineries and gas-processing facilities are located in Nikiski and oil terminals with facilities for transferring oil from shore to oil tankers are located at Nikiski and Drift River. A deepwater shipping channel is maintained throughout the Inlet north to Anchorage where additional oil storage facilities are located.

Cook Inlet has recently been the focus of oil and gas lease sales (Federal sale No. 149 and State of Alaska Cook Inlet areawide sale). The Final Environmental Impact Statement (FEIS) for Sale No. 149 expressed concern for the potential adverse effects of an oil spill on habitats seasonally occupied by shorebirds (MMS 1996). Furthermore, oil spill risk analysis indicated that if an oil spill occurred in the lease sale area, intertidal habitats along the west side of the Inlet from Kalgin Island to Kamishak Bay would likely be contaminated. A more recent oil spill model (Pearce et al. 1997) indicated that a spill of any appreciable size anywhere in Cook Inlet would eventually result in oil coming ashore along the west side of the Inlet, but particularly near the Beluga River and in southern Trading and Redoubt bays.

Because of the potential impacts to shorebirds from OCS oil and gas development and the need for current information for environmental risk assessment, the Minerals Management Service (MMS) identified a study of Cook Inlet shorebirds as a national need. In response to that need, the Alaska Biological Science Center initiated a study to provide resource managers with current information on seasonal shorebird use of Cook Inlet intertidal habitats. Within this guideline, the study addressed these specific objectives:

° Identify stopover areas in Cook Inlet that support substantial concentrations of shorebirds during spring and autumn migration.

° Document seasonal timing and magnitude of shorebird use of Cook Inlet embayments.

° Obtain detailed information on abundance, species composition, and habitat use through on-site studies at selected areas in Cook Inlet.

° Determine seasonal patterns of movement by shorebirds among Cook Inlet estuaries.

° Synthesize historical and current information, making appropriate recommendations for oil spill cleanup procedures and priorities.

PROJECT AREA

Cook Inlet is a long (280 km), relatively narrow (20-90 km) waterbody that extends along a north-south axis from its mouth on the northwest Gulf of Alaska near Kodiak Island to Anchorage at the head of the Inlet (Figure 1). The Cook Inlet drainage basin encompasses an area equal in size to the state of Pennsylvania and is bordered on the southwest by the Aleutian Range, on the west by the Alaska Range, on the northeast by the Talkeetna Mountains, and on the southeast by the Kenai-Chugach Mountains. The Susitna, Little Susitna, Matanuska, Knik, Eagle, and Kenai rivers provide most freshwater input to the Inlet, but numerous lesser discharges occur throughout the Inlet basin. The Inlet can be divided into three distinct physiographic regions: the head, consisting of Knik and Turnagain arms; Upper Cook Inlet, extending from the Forelands near Kenai north to points Woronzof and MacKenzie; and Lower Cook Inlet, from the Forelands to the Gulf of Alaska. Water depths average about 60 m throughout the Inlet, ranging from a maximum of about 100 m near the mouth to less than 10 m at the head. Much of the Inlet is bordered by extensive intertidal mud and sand flats that grade into equally extensive vegetated tidal and supratidal wetlands.

A combination of physiography, tides, currents, and meteorology makes Cook Inlet one of the most dynamic, high-energy estuaries in the world. The diurnal range of tides in Cook Inlet extends from about 5.5 m near Seldovia in LCI to over 10 m along Turnagain Arm in UCI. Indeed, the range of tides in Cook Inlet is second only in the Western Hemisphere to that in the Bay of Fundy, Nova Scotia.

Currents in Cook Inlet are also extreme, averaging about 1.5 knots (Reed and Schumaker 1986) but exceeding 4 knots at several places, especially near the Forelands where currents in excess of 8-12 knots have been recorded. The overall pattern to Cook Inlet currents is driven by tidal flow and circulates in a counter-clockwise gyre. High salinity oceanic water enters Cook Inlet primarily through Kennedy Entrance and moves northward along the east side of the Inlet where it mixes with input from several rivers at the head of the Inlet. Low-salinity water from the upper Inlet then flows south along the Inlet's west side and back into Shelikof Strait near Kodiak Island and eventually back into the Gulf of Alaska (Dames and Moore 1978). The overall effect of tides and currents is a net southward movement of water at a rate about 10-15% of the speed of the tidal currents. Thus in winter it takes about 28 days for ice to move from upper to lower Cook Inlet (Sharma 1979).

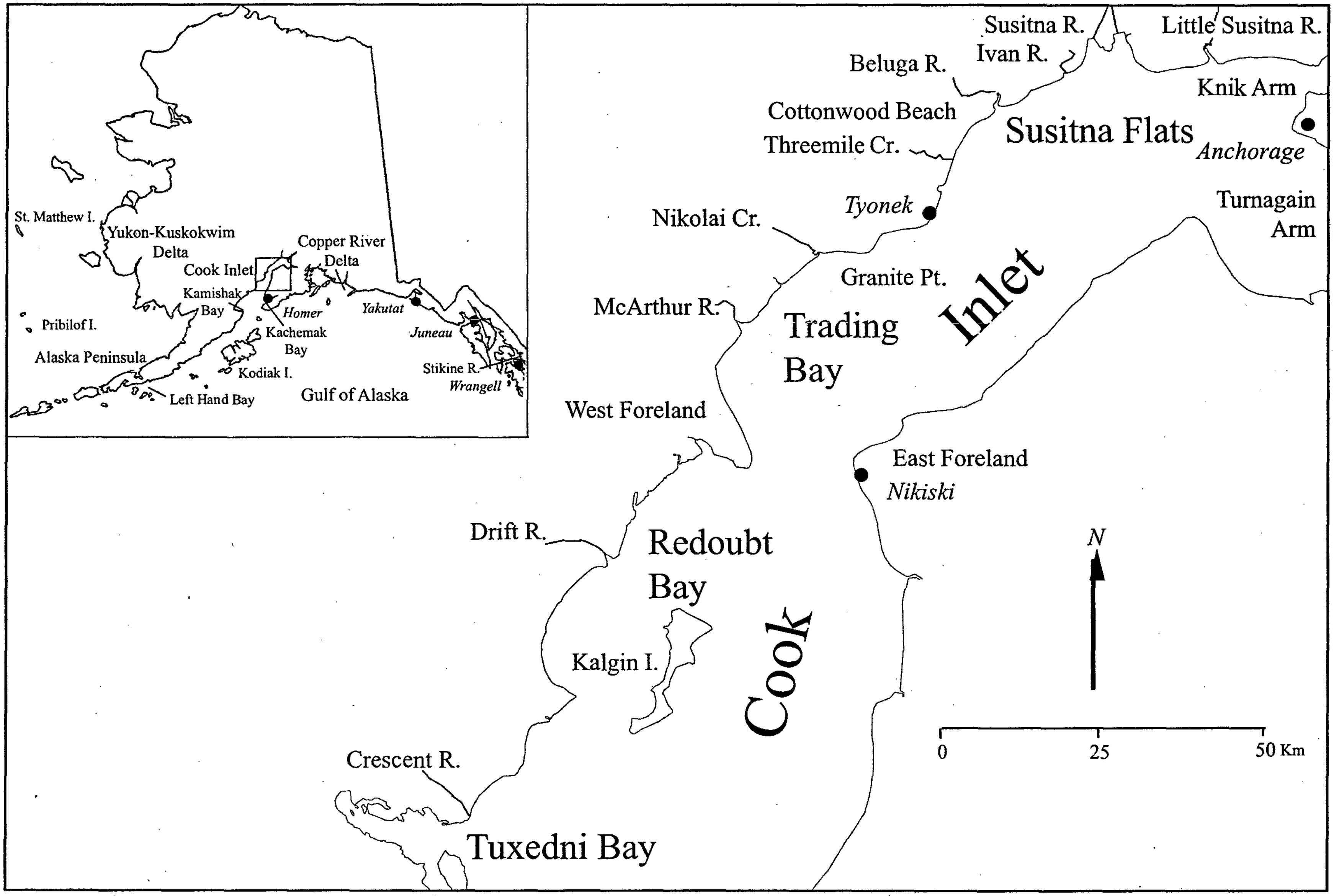

Figure 1. Upper Cook Inlet study area showing principal embayments and place names mentioned in the text.

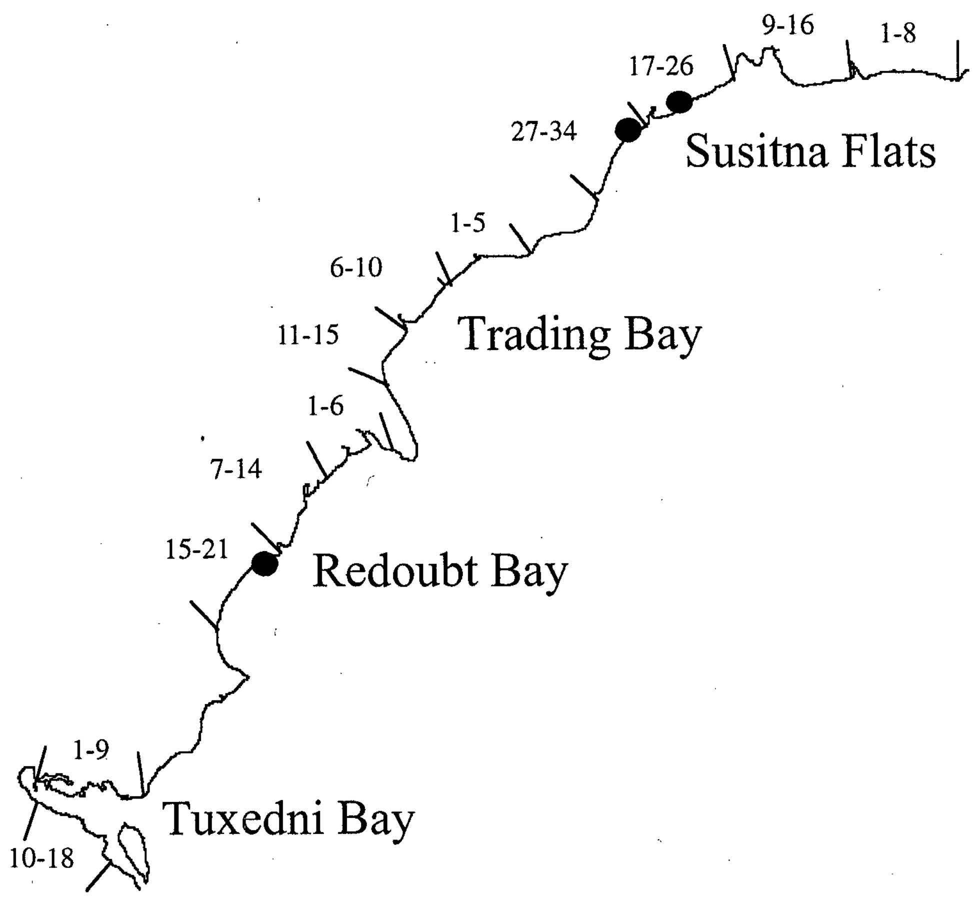

Figure 2. Location of subareas within embayments of Cook Inlet. Numbers refer to inclusive 1.5-km-wide aerial survey segments comprising each subarea. Filled circles denote locations of on-ground study plots. See Appendix B for descriptions of each subarea.

METHODS

Aerial surveys

The most effective means of assessing the distribution and abundance of shorebirds over an area the size of Cook Inlet is through aerial surveys. Aerial surveys, however, inherently come with several constraints that must be overcome depending on anticipated objectives when using this survey methodology. The distribution of birds can readily be assessed through adequate spatial and temporal coverage of an area. Deriving estimates of absolute abundance, however, requires some measure of counting error, being able to identify birds to species or obtaining a measure of species composition, and assessing length-of-stay (LOS) or how long birds use a particular area.

Two factors dictated the size of the area we studied: 1) we wanted to include most of the unvegetated intertidal habitat within the Inlet, and 2) we needed to be able to survey this area from the air during a single tidal cycle. We were fortunate on both accounts in that most of the Inlet's unvegetated and vegetated intertidal habitats occur in the upper half and, with Anchorage as a base of operations, we could survey this area during a single flight of about two hours duration.

In order to learn if shorebird use varied over different portions of Cook Inlet, we divided the overall survey area by principal embayments, including Susitna Flats, Trading Bay, Redoubt Bay, and Tuxedni Bay (Figure 2). We then subdivided each of these areas into uniquely numbered 1.5-km-wide segments that extended perpendicular from the shore.

Previous studies of waterbirds in Cook Inlet (Butler and Gill 1987) revealed that most shorebirds pass through the area during a relatively brief 3-4 week period in spring (late April to mid-May) and then over a much more protracted period in summer and autumn (late June to mid-September). Further, the magnitude of use appears to be much greater during the shorter spring period (i. e., shorter LOS) than during the longer post-breeding period. To assess this differential use we varied the frequency of aerial surveys according to season. In spring 1997, surveys were scheduled every fifth day between 25 April and 20 May; in 1998 we increased the frequency to every third day during the same period in order to get a better assessment of movement of birds through the various embayments. During the breeding and postbreeding periods from late May through late September we attempted to survey at two-week intervals. During winter (October-March) we surveyed the entire study area at monthly intervals except over the Susitna Flats and occasionally upper Trading Bay where we maintained more frequent surveys to document use of these particular areas by Rock Sandpipers.

The general survey protocol over the two years involved single-engine aircraft, usually a Cessna 172, but occasionally a Cessna 185 or 206, or a PA 18. Surveys were flown at about 40-60 m above ground level and at ground speeds of between 150 and 190 km/h. Speed varied depending on season and observation conditions; slower speeds were usually used in spring when large numbers of birds were present.

Surveys were scheduled to be completed within a two-hour period either before or after high tide. We generally avoided high slack tides unless the height was among the lower in the series and considerable unvegetated flats remained exposed. The configuration of Cook Inlet produces marked temporal delays in any given tide, however, even between areas only a few dozen kilometers apart. Thus, not all areas could be surveyed under similar tidal conditions. We discovered that the most uniform coverage occurred by beginning a survey at Tuxedni Bay near high tide and working north as the tide flooded the Inlet. However, the time difference between high tide at Tuxedni Bay and Anchorage is about four hours. Thus, since it only took two hours to survey between Tuxedni Bay and Anchorage, comparably more flats were usually exposed in UCI on any given survey. This occasionally necessitated our flying figure "S" patterns over the Susitna River flats to assure adequate coverage of this area.

Usually a single observer sat in the right front seat and surveyed and recorded information. During each survey the aircraft was positioned about 100 m inboard of the tide line or, on the few occasions during which we surveyed from north to south, the plane was positioned over the water just outboard of the tide line. Such positioning was in response to two factors: 1) surveys conducted during late flooding or early ebbing tides assured that we would encounter most birds at or near the tide line, and 2) since low-flying aircraft invariably cause some birds to take flight, such positioning assured that most birds that were flushed flew into view of the observer and not under the plane. Nevertheless, the pilot regularly looked for large concentrations of birds visible only on the left side of the plane and notified the right-seat observer when seen.

We attempted to identify all shorebirds to species, but during certain periods and under certain observing conditions we assigned birds to categories of unidentified small, medium, or large shorebirds. We also assigned each observation to a location within one of the uniquely coded 1.5-km-wide survey blocks. To facilitate data presentation for this report we established subareas within each embayment by combining survey blocks (Figure 2). Observations were recorded onto cassette tape and later transcribed onto maps of the study area. The principal observer during aerial surveys (REG) regularly assessed the precision of his estimates of flock size (particularly of Rock Sandpipers) by comparing them with counts of the same flocks derived from aerial photographs (see Data Analysis).

Ground-based Studies

Use of unvegetated intertidal habitats by shorebirds was assessed on census plots established on areas known to be major stopover sites during migration periods. On these plots we focused on determining temporal change in species composition. Two methods were employed to assess shorebird use of vegetated intertidal habitats. Census plots were used to derive seasonal measures of species diversity and relative abundance, while location mapping of marked individuals provided information on localized use of intertidal habitats by breeding birds.

Census plots in the unvegetated intertidal zone

Field work on unvegetated intertidal habitats was done primarily to ground-truth aerial survey results, specifically species composition and abundance. In 1997 this entailed two visits to the Drift River area of Redoubt Bay, the principal area used by shorebirds during spring migration. At Drift River we randomly scanned portions of large assemblages and determined the proportions of various species within samples of the first 50 birds seen. In 1998 we expanded this effort by establishing three large census plots (500 m X 500 m) on mudflats just south of the mouth of the Drift River (Figures 1 and 2). On 7 of 11 days in spring we sampled the proportions of the predominant species of birds classified as "peeps." We did this by scanning concentrations of birds and randomly selecting groups of 50 birds from which we identified individuals to species. As a rule we tried to sample at least 10% of the birds in any one concentration.

Census plots in the vegetated intertidal zone

Census plots ($n = 11$), ranging in size from 2.0 to 9.8 ha each (total 41.1 ha), were clustered in three areas based principally on access (Figure 2): Cottonwood Beach south of the mouth of the Beluga River and off the Ivan and Lewis river roads. At each site plots were set up to encompass portions of three principal habitat types that run the length of the intertidal gradient: 1) salt-grass meadow adjacent to unvegetated intertidal mudflats and dominated by *Triglochin maritimum* and *Plantago maritima*; 2) short-sedge marsh characterized by stands of *Carex ramenskii* and *C. mackenziei;* and 3) tall-sedge marsh of predominantly pure stands of *C. lyngbyaeii*. However, we found that most plots contained patches of more than one habitat type and that differences between short- and tall-sedge marshes were minimal until mid-June, by which time vegetation was fully emerged but most migrant shorebirds had departed the area. Thus, we do not distinguish shorebird use by specific habitat type but rather over the entire vegetated intertidal community.

Each plot was censused seven times during spring (3-20 May 1997) and five times during summer (21 May-9 July 1997). All plots were censused at high tide by an observer standing on a truck or a tower and counting all shorebirds on the plot (flying birds were excluded).

Tracking marked individuals

Beginning in 1995 as part of another study and continuing through 1998 as part of this study we color-banded individuals of four species of shorebirds breeding locally in Cook Inlet (Lesser Yellowlegs, Greater Yellowlegs, Short-billed Dowitcher, and Hudsonian Godwit). Adults were captured with mist nets while on nests or as they flew towards observers while defending broods. Total numbers of adults of each species banded at Susitna Flats and throughout the Anchorage Bowl, respectively, were: Lesser Yellowlegs, 120 and 53; Greater Yellowlegs, 2 and 1; Short-billed Dowitchers, 27 and 4; and Hudsonian Godwits, 12 and 2. In addition, numerous chicks (mostly Lesser Yellowlegs) were also banded and their locations noted once they fledged. We searched for banded individuals during regular visits to coastal salt marshes and upland breeding habitats from mid-April to late 1997. We marked the location of each resighting on a color infrared photo and used behavioral cues to determine each individual's breeding status (e.g., courting, incubating, paired with brood, failed nester). We used the distance between an individual's breeding and foraging site to estimate home range size.

Assessment of Rock Sandpiper occurrence and abundance

With the discovery of large numbers of Rock Sandpipers using Cook Inlet in winter we conducted special aerial and on-ground surveys to assess their numbers, use of areas, and taxonomic affinities. Aerial surveys in winter differed from those during other seasons in that we regularly photographed concentrations of Rock Sandpipers following the initial surveys in February 1997. Photos were later projected and individuals counted to compare with ocular estimates made by observers at the time of the surveys. On four occasions we observed Rock Sandpipers from the ground during which we collected specimens and assessed the subspecific composition of flocks. The latter was done by determining ratios of light and dark birds (*C. p. ptilocnemis* vs. either *C. p. couesi* or *C. p.*

tschuktschorum) from among samples of 100 birds (without replication) selected randomly from larger flocks of birds.

The accuracy of our aerial estimates of large flock sizes (≥ 500 birds) was assessed from a series of photographs taken from the air of flocks during surveys.

DATA ANALYSIS

Studies of shorebird use of migratory staging and stopover sites have used various measures to present results, including relative and absolute counts, lineal and areal densities, and bird-days of use, to name a few. In order to allow greater comparison of results between this and other studies we present our findings in four ways: 1) bird-days of use derived from aerial surveys, 2) lineal density per kilometer of unvegetated shoreline derived from aerial surveys, 3) areal density per hectare of vegetated intertidal habitat derived from ground census plots, and 4) high counts of all taxa or of individual species.

Assessments of relative use of various nonvegetated intertidal areas were based on complete aerial surveys (n = 50) of the study area (Appendix D). Numbers of individual species are based on total numbers of birds recorded on complete aerial surveys and include those identified to species plus proportions initially lumped among categories (small, medium, large) of unidentified shorebirds. To obtain information at the species level from these categories of unidentified shorebirds we followed a two-step procedure. First, we determined the proportion of birds identified to species during each seasonal period within a year (spring migration, breeding, autumn migration, and winter), and then we applied these proportions to the cohort of unidentified birds recorded on each survey that season. The resulting values were then combined with those for birds originally identified to species.

To compare use of different study area embayments by shorebirds we estimated the average number of birds that occurred each day by linear interpolation between surveys. The interpolated daily estimates of bird use were summed and divided by the total number of days within each period. This method was preferable to calculating a straight average of all surveys within a season because the surveys were concentrated during periods of peak use. The winter period was shortened for both 1997-98 and 1998-99 to include only the days encompassed by the first and last surveys of the study, respectively.

To compare use of different areas within bays we combined 1.5-km-wide survey blocks according to major drainages, resulting in each bay having between two and four distinct subareas (see Appendix B for specific demarcations of each). We calculated the average daily number of birds using each bay within each season over the three years. Next we calculated the proportion of birds using each subarea of a bay by season across all years. We then multiplied these proportions by the average daily use for each bay to obtain an estimate of the average number of birds using each subarea for each season.

Calculations of lineal densities were derived using values for average number of birds per day over a given area divided by the length (km) of shoreline within that area (Appendix B).

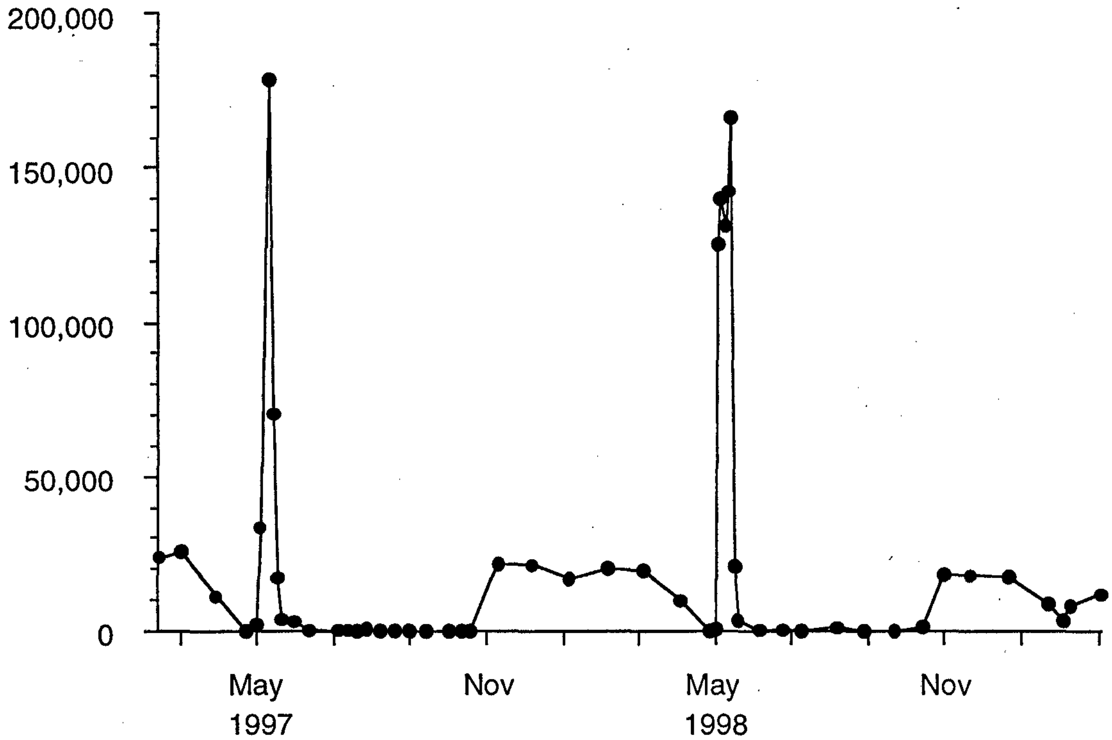

Figure 3. Seasonal occurrence and abundance of shorebirds recorded on aerial surveys ($n = 50$) of Cook Inlet, 1997-1999.

To test the accuracy of our estimates of larger flock sizes, especially those of Rock Sandpipers, we first calculated the correlation coefficient between our estimates and actual counts from photographs, forcing the relationship through the origin. We then calculated the ratio between the estimated and actual number of birds in the flocks. We calculated confidence intervals of the ratio (Cochran 1977) to determine if it differed significantly from one.

All values are expressed as mean ± SD unless stated otherwise.

RESULTS

Use of unvegetated intertidal habitats

Seasonal occurrence

Shorebirds used Cook Inlet in a very pronounced seasonal pattern throughout the study (Figure 3). Spring migrants arrived during the last week of April both years and rapidly built in numbers, reaching a peak of about 175,000 birds during the second week of May. Beginning in mid-May use declined as abruptly as it had increased and remained relatively low at less than a thousand birds throughout summer and into early autumn, declining to a few hundred birds by late September. Following a brief two- or three-week period from late September to early October when virtually no birds were recorded on the area, numbers once again began to increase as Rock Sandpipers moved into the area to spend the winter. By early November their population had reached its maximum of about 18,000 birds, a level that was sustained throughout winter and early spring (but see beyond). During late

March and early April Rock Sandpipers gradually departed the area, the last birds leaving about two weeks prior to the arrival of other spring migrant shorebirds, which began the cycle anew.

Seasonal occurrence by species

The greatest diversity of shorebirds occurred on the area during spring when all 28 species recorded throughout the study period were present. During summer and autumn, 16 and 18 species, respectively, were recorded on the area (Table 1). A single species, the Rock Sandpiper, was present during winter. Use of the area in spring was by a combination of passage migrants (e. g., Black-bellied Plover, Whimbrel, Western Sandpiper, and Dunlin) and local breeders (e. g., Short-billed Dowitcher, Hudsonian Godwit, and Greater and Lesser yellowlegs). Table 2 presents information on the percent composition of species or species groups in each season as recorded during aerial surveys. Western Sandpipers were by far the most common species in spring, accounting for 89% of all birds recorded, with Dunlin a distant second at 8%. Fifteen other species comprised the remaining 3% of birds recorded that season. Eighty-one percent of all birds were recorded during spring, followed by 18% in winter, and less than 1% each in summer and autumn (Table 2).

Compared to spring, few shorebirds used unvegetated intertidal areas in summer (Table 2). Migrant Western Sandpipers still comprised most (39%) of the birds recorded, but several other species were well represented, including migrant Whimbrel (8%) and Black-bellied Plover (4%), and both locally breeding (Short-billed only) and migrant (mostly Short-billed) Dowitcher (23%) and Hudsonian Godwit (22%). Use during autumn was also characterized by comparatively small numbers of birds and was represented by migrant species such as Black-bellied Plover (11%), but also included locally breeding species such as (Short-billed) Dowitcher spp. (7%) and yellowlegs spp. (4%). The large proportion of Rock Sandpipers (35%) recorded during autumn (Table 2) reflects a single flock of 1,200 birds that was recorded on the last day (14 October) of the autumn survey period and that represented the vanguard of the population that wintered in the area. The large proportion (33%) of unidentified small sandpipers recorded during this period was most likely Western Sandpipers, but we lacked ground data from which to verify species composition. With exceptions of a single yellowlegs (probably Greater) and two Dunlin, all birds recorded during winter were Rock Sandpipers.

Seasonal abundance and use of embayments

Yearly and seasonal use of the four principal embayments, and the subareas within each, are shown in Table 3, Figure 4, and Appendix C. Throughout an annual cycle almost 3.5 million bird-days of shorebird use were recorded for the study area. Use was highest during spring when almost 44,000 birds were present each day. During summer and autumn use declined markedly to fewer than 1,000 birds per day, but use in winter was surprisingly high at over 10,000 birds per day. Seasonal patterns of use varied across embayments and also across specific areas within each embayment. These patterns highlighted the seasonal importance of several key areas to shorebirds (Table 3, Figure 4). Redoubt

Table 1. Seasonal status and relative abundance of shorebirds using Cook Inlet, 1997-1999.[1]

Species	Spring		Summer		Autumn		Winter	
	Status	No. of birds	Status	No. of birds	Status	No. of birds	Status	No. of birds
Black-bellied Plover	M	f 1,000	m	s 100	m	f 100		
American Golden-Plover	m	f 10			m	f 10		
Pacific Golden-Plover	m	f 10	m	f 10	m	f 10		
Semipalmated Plover	m, B	f 100	B	f 100	m	f 100		
Greater Yellowlegs	m, b	f 100	B	f 100	m	f 100		
Lesser Yellowlegs	m, b	s 100	B	s 100	m	s 100		
Solitary Sandpiper	b	f 10	b	f 10	m	f 10		
Whimbrel	m	s 100	m	s 100	m	s 100		
Hudsonian Godwit	M, B	s 100	B	s 100	m	s 100		
Bar-tailed Godwit	m	f 10						
Marbled Godwit	m	f 10						
Ruddy Turnstone	m	f 10						
Black Turnstone	m	f 100						
Surfbird	m	s 100						
Red Knot	m	f 100						
Sanderling	m	f 10						
Semipalmated Sandpiper	m	s 100	m	f 100				
Western Sandpiper	M	s 100,000	M	s 1000	M	s 1000		
Least Sandpiper	m, b	s 1000	b, m	f 1000	m	f 1000		
Baird's Sandpiper	m	f 100						
Pectoral Sandpiper	m	s-f 1000	m	f 100	m	f 100		
Rock Sandpiper	m	f 100			m	f 100	R	s 1000
Dunlin	M	s 10,000			m	f 100		
Ruff	v							
Short-billed Dowitcher	M, B	s 1000	B, M	s 1000	M	s 1000		
Long-billed Dowitcher	M	s 1000	m	f 100	m	f 10		
Common Snipe	b	s 100	b	s 100	m	s 100		
Red-necked Phalarope	m	s 100	b	s 100	m	s 100		

[1] Status and abundance determined from both aerial and ground observations. M = migrant, B = breeds locally, R = resident, V = vagrant (distinctions between upper and lower case "M" denote major and minor occurrences relative to the species' flyway population; for "B" distinction is made relative to breeding populations throughout south-central Alaska), s = several, and f = few. Seasons as follows: Spring (16 Apr - 19 May), Summer (20 May - 14 Jul), Autumn (15 Jul - 14 Oct), Winter (15 Oct - 15 Apr).

Table 2. Percent composition by season of shorebirds recorded on aerial surveys (n = 50) of Cook Inlet unvegetated intertidal habitats, 1997-1999.

	Spring		Summer		Autumn		Winter	
Taxa	%	Number	%	Number	%	Number	%	Number
Black-bellied Plover	<1	4,504	4	160	11	393		
Golden-Plover spp.	<1	10	<1	4				
Semipalmated Plover	<1	3						
Yellowlegs spp.	<1	48	<1	2	4	131	<1	1
Whimbrel	<1	766	8	351	3	87		
Hudsonian Godwit	<1	3,933	22	972	5	157		
Bar-tailed Godwit	<1	23						
Marbled Godwit	<1	2						
Black Turnstone	<1	9						
Surfbird	<1	1,127						
Red Knot	<1	341						
Sanderling	<1	60						
Pectoral Sandpiper	<1	15	1	30				
Rock Sandpiper	<1	2			35	1,224	100	237,862
Dowitcher spp.	2	17,361	23	1,039	7	238		
Red-necked Phalarope					<1	8		
Unid. small shorebird[2]					33	1,163		
Western Sandpiper	89	926,844	39	1,758				
Dunlin	8	80,992	3	153	2	80	<1	2
Total	100	1,036,040	100	4,466	100	3,481	100	237,865

[1] Total surveys include 16 during two spring periods, 7 during two summer periods, 12 during two autumn periods, and 15 during three winter periods. Note that numbers of birds recorded include multiple counts of same individuals on repeated surveys during seasonal periods.

[2] We do not show categories of unidentified medium and large shorebirds because we were able to allocate all of these to species based on the composition of birds that were identified to species on the aerial surveys. Birds classified as unidentified small shorebirds on aerial surveys were allocated based on ratios derived from ground observations (see methods) except during autumn, when ground observations encompassed only a portion of the season. Most of the small sandpipers recorded as unidentified in autumn were likely Western Sandpipers.

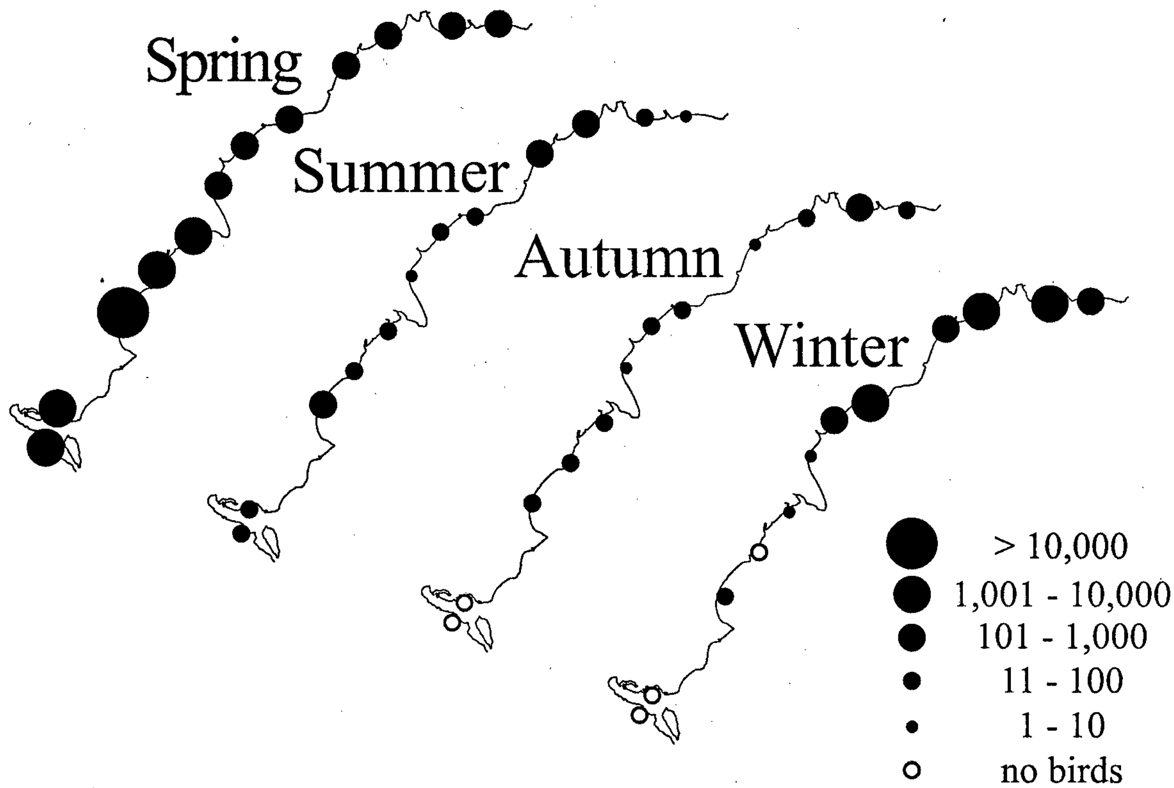

Figure 4. Average number of shorebirds per day using subareas of each embayment during four seasonal periods, 1997-1999.

Bay, for example, accounted for 73% of all birds recorded on the study area in spring while Susitna Flats supported 82% of all birds during winter.

The importance to shorebirds of specific subareas within bays was most apparent during spring. Indeed, even within subareas particular segments were used differentially. Most striking was a 7-km-long segment (areas 7-15; Figures 2 and 4, Appendix C) of southern Redoubt Bay (= 5% of the study area shoreline), which supported over 24,000 birds per day, or 55% of the daily average for the entire study area that season. Other measures of shorebird use also pointed to the importance of this segment of Redoubt Bay: the highest single count of shorebirds (163,000) occurred here, over twice that of any count elsewhere, and the highest value of birds present per kilometer of shoreline (2,308) was also recorded here (Appendix C). This was double that of the next highest value, which was also recorded in Redoubt Bay on an adjacent area. The next highest bird use occurred at northern Tuxedni Bay, where an average of 6,325 birds occurred per day in spring. Other subareas that supported over 1,000 birds per day in spring included the north half of Redoubt Bay and the north and south halves of Tuxedni Bay. The remaining subareas of the study area (all in Trading Bay and Susitna Flats) supported

Table 3. Comparison of measures to assess seasonal use by shorebirds of Cook Inlet embayments, 1997-1999[1].

Measure/embayment	Spring	Summer	Autumn	Winter
Mean no. birds per day				
Susitna Flats	1,831	488	200	8,414
Trading Bay	1348	105	74	1,871
Redoubt Bay	31,883	300	730	21
Tuxedni Bay	8,602	102[2]	0	0
Mean no. birds per km shoreline per day				
Susitna Flats	36	10	4	165
Trading Bay	49	4	3	68
Redoubt Bay	1,012	10	2	1
Tuxedni Bay	319	4[2]	0	0
High count				
Susitna Flats	6,687	2,637	1,126	25,350
Trading Bay	73,970	120	302	15,300
Redoubt Bay	162,250	440	449	980
Tuxedni Bay	64,790	0[2]	0	0

[1] Values are season averages over the entire study period (two spring periods, two summer, two autumn, and three winter). Total complete surveys for the combined seasons = 16 spring, 7 summer, 12 autumn, and 15 winter.
[2] Even though no birds were recorded using Tuxedni Bay during summer surveys, estimated values for mean number birds per day and birds per km shoreline per day reflect values interpolated from the last day of the previous survey period (see Methods and Data Analysis).

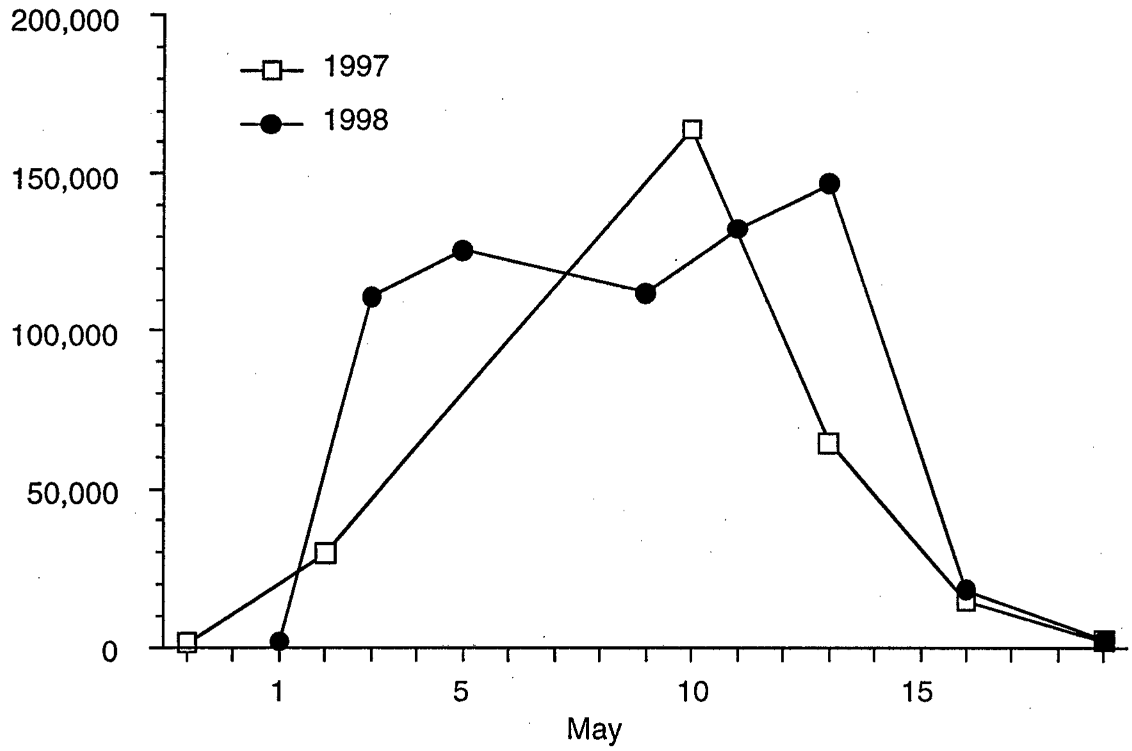

Figure 5. Abundance of Western Sandpipers recorded on spring aerial surveys of Cook Inlet, 1997-1998. Survey totals have been adjusted according to the species composition of small sandpipers recorded from on-ground observations (see Methods).

between 100 and 1,000 birds per day during spring (Appendix C).

During summer and autumn no one bay or subarea therein stood out from the others in terms of average daily use, all being comparatively low with most supporting fewer than 100 birds per day. Surprisingly, we recorded very few shorebirds in Tuxedni Bay in summer and none during autumn (Figure 4, Table 3).

Use of the study area by shorebirds in winter was almost entirely by Rock Sandpipers (see below) and confined almost exclusively to Susitna Flats and Trading Bay where an average of 8,414 and 1,871 birds per day, respectively, occurred throughout the season (Table 3, Figure 4). Within each embayment birds exhibited preferences for certain subareas over others, apparently in response to changing environmental conditions (see Discussion). At Susitna Flats birds favored the area about and just west of the mouth of the Little Susitna River and the area between the Ivan and Beluga rivers. Rock Sandpipers also favored Trading Bay, especially the northernmost area about the mouth of Nikolai Creek. Rock Sandpipers made little or no use of Redoubt or Tuxedni Bay during winter (but see Discussion).

Abundance of key species

Three species, Western Sandpiper, Dunlin, and Rock Sandpiper were the most abundant throughout the study and merit more detailed analyses.

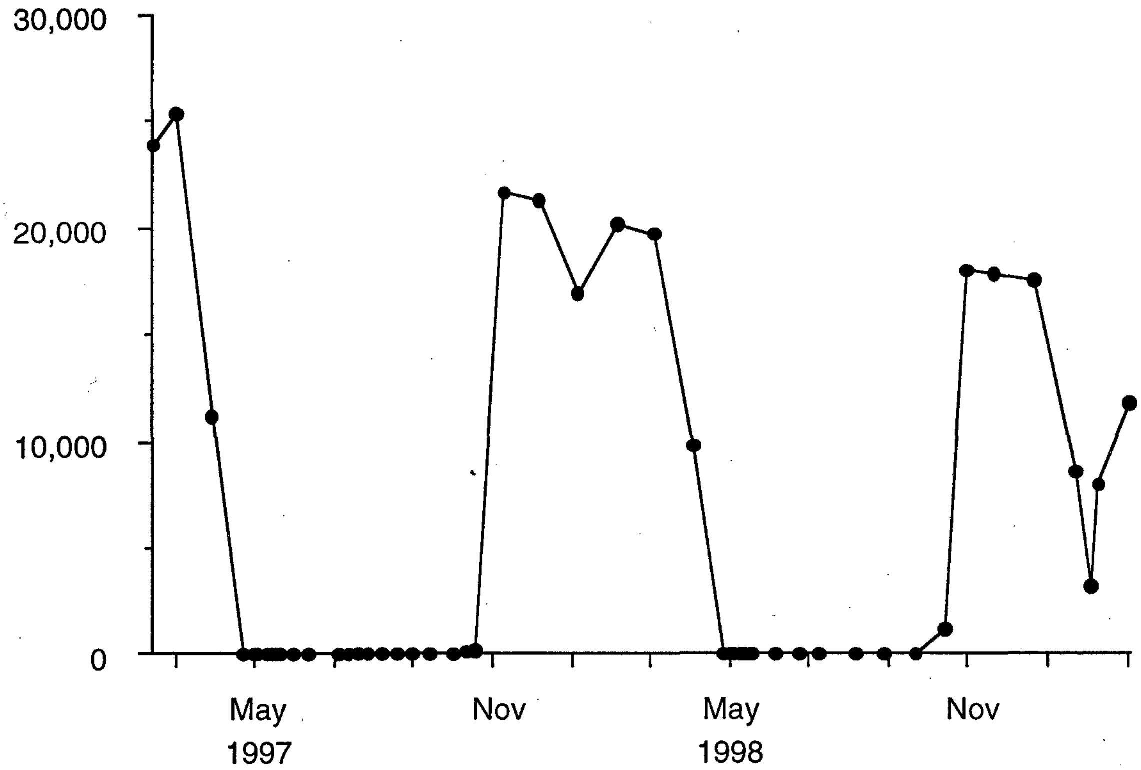

Figure 6. Abundance of Rock Sandpipers recorded on aerial surveys of Cook Inlet, 1997-1999.

Western Sandpiper and Dunlin.—In both 1997 and 1998 we recorded more than 100,000 small sandpipers during aerial surveys in May when numbers were at their peak (Figure 5). From on-ground evaluations of species composition of these large flocks we determined that 92% and 91% of these birds were Western Sandpipers in 1997 and 1998; Dunlin comprised the remaining 8% and 9% in those years.

Rock Sandpiper. —The study period encompassed one complete and two partial winter periods (Appendix D). The mean count of Rock Sandpipers on aerial surveys (n = 13) during periods of peak occurrence in all three winter periods was 17,530 ± 6,579 (r = 3,182 - 25,350) (Figure 6). Estimated sizes of large flocks of Rock Sandpipers (≥ 500 birds) counted during aerial surveys were highly correlated with the actual flocks sizes as determined from photographs (r = 0.98, n = 25, P < 0.001). Counting errors of individual flocks ranged from underestimates of 34% to overestimates of 41%. Among all photographed flocks, the ratio between estimated and actual flock sizes was 1.12 ± 0.05. This ratio was significantly different from 1.0 (P < 0.05), suggesting we generally overestimated flocks of more than 500 birds by 12%.

Rock Sandpipers tended to be highly concentrated during most surveys with 47% of all birds recorded in flocks of 1,000 or more. On a few occasions the entire population of 15,000-20,000 birds was found in one or two flocks spread

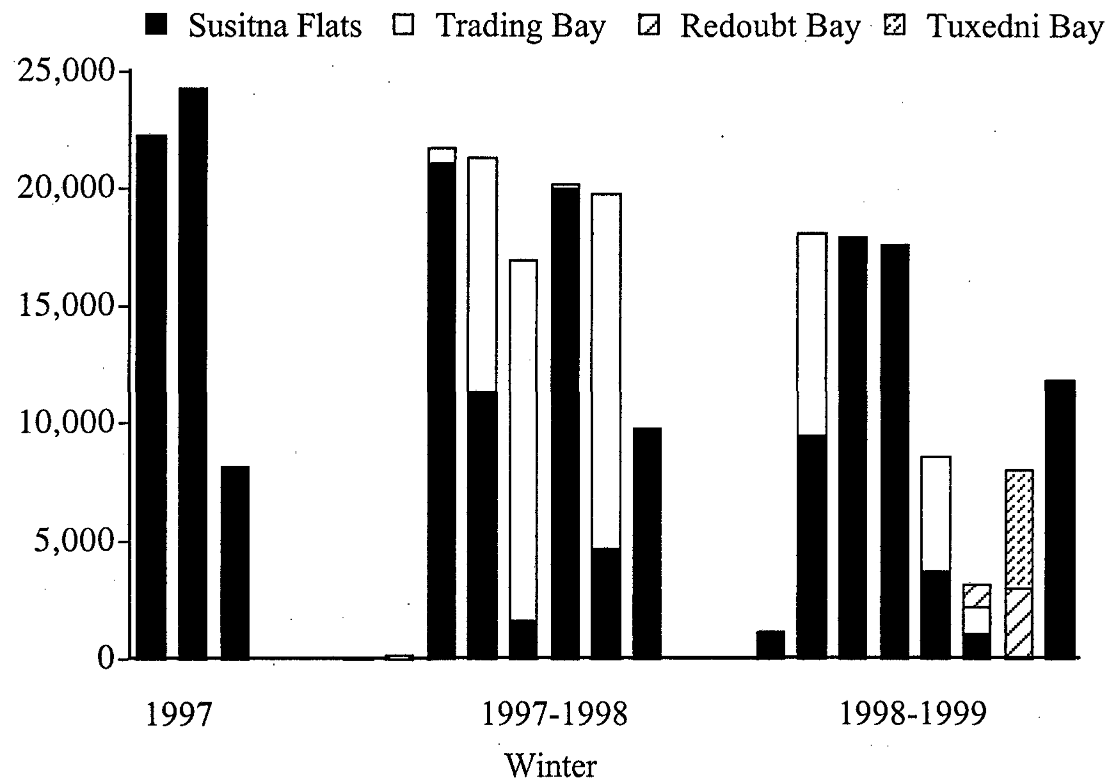

Figure 7. Comparative use of embayments by Rock Sandpipers recorded on aerial surveys during winter, 1997-1999.

along 2-5 km of shoreline of western Susitna Flats (Appendix D).

Once birds arrived in UCI in early winter they were detected continuously throughout the period, at either Susitna Flats or northern Trading Bay depending on ice conditions (Figure 7; but see Discussion). This pattern was found during the 1996-1997 and 1997-1998 winters and into early winter 1998-1999.

Use of vegetated intertidal and adjacent habitats

Abundance on vegetated intertidal plots

A total of 17 species of shorebirds (8 migrants, 9 local breeders) was observed on vegetated census plots during the study (Table 4). As with use of unvegetated intertidal habitats, species richness and abundance were greater during spring migration than during summer (Table 5). The total number of shorebirds on plots (all plots combined for each season) averaged 245 ± 88 and 20 ± 8 during spring and summer, respectively. Their average densities (5.95 ± 2.12 and 0.49 ± 0.20 birds/ha) also reflected a marked shift in use between the two periods. Short-billed Dowitcher was the most abundant species in spring, followed by Pectoral Sandpiper, Least Sandpiper, Western Sandpiper, and Red-necked Phalarope

Table 4. Percent species composition of shorebirds using vegetated intertidal study plots on Susitna Flats, 1997. See Figure 2 for location of plots.

Species	Spring[1] (%)	Summer[1] (%)
Black-bellied Plover	<1	
American Golden-Plover	<1	
Semipalmated Plover	1	
Greater Yellowlegs	<1	14
Lesser Yellowlegs	1	30
Solitary Sandpiper	<1	
Whimbrel	1	21
Hudsonian Godwit	3	2
Semipalmated Sandpiper	<1	
Western Sandpiper	14	
Least Sandpiper	17	8
Pectoral Sandpiper	18	14
Dunlin	<1	
Short-billed Dowitcher	25	8
Long-billed Dowitcher	2	
Common Snipe	2	
Red-necked Phalarope	13	4
Unidentified small sandpipers	1	

[1] Total birds sampled for spring = 1,713; for summer = 101.

(Table 4). Much less common were Common Snipe, Hudsonian Godwit, Long-billed Dowitcher, Lesser Yellowlegs, Whimbrel, and Semipalmated Plover. Fewer than 10 individuals of the remaining six species were counted on the plots during spring. Six of nine species that nested locally were seen regularly but in low numbers on plots during summer (Table 4). In addition, several individuals of two species (Pectoral Sandpiper and Whimbrel) that were common migrants in early spring, lingered in UCI into early June well after most other migrants had passed through.

IMPORTANCE OF INTERTIDAL HABITATS TO LOCAL BREEDERS

Greater and Lesser yellowlegs, Hudsonian Godwits, and Short-billed Dowitchers relied on food obtained at intertidal foraging sites to sustain them during courtship, incubation, and brood rearing.

Courtship.—Upon arrival at Susitna Flats, all species spent the majority of their time either foraging or resting in vegetated intertidal habitats. Within days of arrival and continuing for the next two weeks birds performed flight displays. These were all over vegetated intertidal habitats regardless of whether or not birds eventually nested inland or along the coast.

Incubation.—Males and females of the species that nested inland at Susitna Flats took incubation breaks and flew to coastal foraging sites that were disjunct and often distant from nesting sites. Incubation breaks lasted up to several hours based on the timing of resightings of individuals at foraging sites. Mean distance moved between breeding and foraging sites for Lesser Yellowlegs was 4.1 ± 2.3 km (r = 1.6 - 9.9, *n* = 14 pairs), for Short-billed Dowitcher 2.7 ± 0.2 km (r = 2.5 - 3.0, *n* = 6 pairs), and for Hudsonian Godwit 2.9 ± 0.2 km (r = 2.7-3.1, *n* = 5 pairs). A single pair of Greater Yellowlegs nested 2.1 km inland from its coastal foraging site. These data likely underestimate home range size because we only color-marked individuals within about 5 km of available roads; birds that nested farther inland (and potentially traveled greater distances during breaks) were not sampled. A related study in Anchorage showed that individual Greater and Lesser yellowlegs traveled up to 13 km one way during incubation breaks. Such foraging trips usually ceased at hatch, but for one species (Hudsonian Godwit) females continued to make foraging trips to intertidal flats during the brood-rearing period.

Brood-rearing.—Beginning the day after hatch, some pairs of Lesser Yellowlegs that nested inland at Susitna Flats began leading their precocial chicks to coastal sedge-marsh sites, often traversing distances of more than 3 km. Interestingly, species that nested in spruce bogs (Greater Yellowlegs, Hudsonian Godwit, Short-billed Dowitcher) did not move their broods to the coast but remained with them on the nesting areas. Within these areas, however, they tended to move their broods similar overall distances as did Lesser Yellowlegs. After departing brood-rearing areas, Lesser Yellowlegs spent from 1 to 10 days at coastal sedge-marsh sites before autumn migration (Tibbitts, unpubl.).

Breeding area fidelity.—Forty-eight percent of marked Lesser Yellowlegs (*n* = 29) returned to nest at Susitna Flats in consecutive years, as did all Greater Yellowlegs (*n* = 3) and Hudsonian

Table 5. Seasonal abundance of shorebirds using vegetated intertidal plots on Susitna Flats, May-July 1997.

Season/date[1]	Number of species	Number of shorebirds	Birds per hectare[2]	Number of plots with birds
Spring				
3-4 May	8	223	5.4	6
5-6 May	11	119	2.9	9
7-8 May	10	345	8.4	9
13-14 May	7	207	5.0	5
15-16 May	13	332	8.1	7
17-18 May	10	171	4.2	7
19-20 May	10	316	7.7	7
Mean ± SD		245 ± 88	6.0 ± 2.1	
Summer				
29 May	3	17	0.4	2
8-9 June	5	23	0.6	2
18-19 June	6	32	0.8	5
28-19 June	4	19	0.5	2
9 July	3	10	0.2	2
Mean ± SD		20 ± 8	0.5 ± 0.2	

[1] Inclusive dates for spring period defined as 16 Apr - 19 May; for summer (breeding) 20 May - 14 July.
[2] Individual plots (n = 11) ranged in size from 2.0 to 9.8 ha (total = 41 ha).

Godwits ($n = 3$). In Anchorage, 81% ($n = 88$) of marked Lesser Yellowlegs were seen 1-3 years after banding. Many birds that returned to nest on the Susitna Flats did so within 10 km of their previous sites, but regardless of whether or not they had shifted nest sites they tended to use the same intertidal foraging sites each year.

Natal philopatry.—Lesser Yellowlegs was the only species in which locally produced birds were documented returning to their natal site to nest. In the Anchorage area 19% (7/27) of Lesser Yellowlegs marked as chicks were sighted within 10 km of their natal sites the subsequent one or two years after fledging. At least three of these birds nested within 8-12 km of their natal sites. It is likely that other species exhibit similar levels of philopatry but we didn't band enough of their chicks to determine this.

DISCUSSION

Our results clearly show Cook Inlet to be extremely important to both migrant and winter resident shorebirds, supporting major portions of the population of one of North America's most (Western Sandpiper) and least (Rock Sandpiper) abundant species (see beyond). That shorebird use of this magnitude and importance occurs on one of the most active gas and oil exploration and development areas of the continent should be of major concern to conservation planners.

At the same time our study failed to document any significant autumn migration of shorebirds through this portion of south-central Alaska. Such disparate seasonal use by shorebirds of Cook Inlet is in keeping with our knowledge of patterns of shorebird use at all major stopover or staging sites in Alaska, namely that they are either important in spring or autumn but not both seasons. Such a pattern is understandable for sites in western Alaska in spring where freezing conditions persist into early May and preclude most shorebirds from using the extensive intertidal substrates in this region. Less clear is why shorebirds on their return migration in autumn generally do not use the same sites that they used during spring or, if they do use the same area, why overall numbers are markedly lower in autumn. This pattern is well established for all major spring stopover sites along the Gulf of Alaska coast including the Stikine River Delta, Yakutat Forelands, the Copper River Delta, and now Cook Inlet (Isleib and Kessel 1973, Isleib 1979, Patten 1982, Petersen et al. 1991, C. Iverson pers. comm., M. Bishop unpubl., this study). The ultimate reason for the markedly different seasonal migration strategies exhibited by shorebirds transiting the Pacific Flyway of North America, especially in autumn, likely revolves around factors such as molt schedules and predictability of weather to aid migration.

SIGNIFICANCE OF COOK INLET AS A SPRING STOPOVER SITE FOR MIGRATING WESTERN SANDPIPERS AND DUNLIN

Among the 75 species of shorebirds that occur in North America, the Western Sandpiper is but one of a half dozen having populations in excess of a million individuals (Morrison et al., unpubl.; Rose and Scott 1997). Recently, Bishop (pers. comm.) determined that the Pacific Flyway population of this species numbers between 2.0 and 3.3 million birds. The Dunlin is another species whose continental population probably exceeds a million birds, but whose Pacific Flyway population numbers only about 450,000 birds (Page and Gill 1996, Page pers. comm.). Because we were able to determine species composition of birds using Cook Inlet embayments in spring, we can, using length-of-stay (LOS) values, derive an estimate of the total population of Western Sandpiper and Dunlin using the study area during spring.

Recent studies by Warnock and Bishop (1998) and Bishop and Warnock (1998) used radio-telemetry to determine that Western Sandpipers stopped on the Copper River Delta for an average of 2.2 ± 1.1 days (n = 90 birds) during spring migration. A subset of their data involving many fewer birds (n = 3) suggested even shorter (1.7 ± 1.1 days) LOS for birds stopping at sites in Cook Inlet. Applying the former LOS values to the interpolated bird-days of use recorded from our aerial surveys (Figure 5, Appendix D), produces conservative population bounds of between 600,000 and 775,000 Western Sandpipers for the area in 1997 and between 750,000 and 950,000 in 1998. In terms of overall numbers during the study period, Cook Inlet (primarily southern Redoubt Bay), supported between 20 and 47% of the Pacific Flyway population of Western Sandpipers each spring.

We are aware of no similar LOS data for Dunlin at spring migration stopover sites along the Pacific Flyway. For this exercise we assume a LOS similar to that of Western Sandpipers based on almost identical migration chronology, use of the same migration stopover sites in spring, and timing of arrival on largely sympatric breeding areas. Applying the above LOS values to the interpolated bird-days of use recorded from our aerial surveys in 1997 and 1998 (Appendix D), we estimate that between 50,000-65,000 and 72,000-94,000 Dunlin used Cook Inlet embayments in 1997 and 1998, respectively, or between 11 and 21% of the flyway population.

Significance of Cook Inlet as a wintering area for Rock Sandpipers

The Rock Sandpiper is a Beringian shorebird having four recognized subspecies, all with breeding and most nonbreeding populations confined to Alaska and northeast Asia (Conover 1944, AOU 1957, Hopkins 1982). The total population of all forms probably does not exceed 200,000 birds (Gill, unpubl.; P. Tomkovich, pers. comm.). The largest-bodied and probably least numerous of the forms (*C. p. ptilocnemis*) breeds on Bering Sea islands (Pribilofs, St. Matthew, and Hall Is., Figure 1), but heretofore has had a largely unknown distribution during the nonbreeding season (Conover 1944). This subspecies does not occur on its breeding grounds during winter (contra Paulson 1993), but it has been seen for brief periods and in relatively small numbers along the west coast of Alaska and the Alaska Peninsula in autumn among flocks of predominantly *C. p. couesi* (Conover 1944; Gill et al. 1981; Tibbitts et al. 1996; Gill, unpubl.). It is also known to occur in winter along the coast of southeast Alaska as far south as Juneau and Wrangell (AOU 1957), but nowhere has it been found outside the breeding season in appreciable numbers.

The occurrence of Rock Sandpipers in UCI has been known to biologists since at least the mid-1980s when small numbers were seen on late autumn and early spring aerial surveys of waterfowl

(Butler and Gill 1987; W. Eldridge, pers. comm.; Gill, unpubl.). It was assumed these were migrants, either birds passing through in late autumn or early spring, but certainly not individuals that intended to reside or had resided throughout the winter. In LCI Rock Sandpipers have been regularly recorded in winter, especially at Homer (Christmas Bird Count data), but the first evidence that the species occurred in UCI in winter came from an aerial survey during which "a few thousand small shorebirds" were seen on a mid-Inlet shoal (just south of West Foreland) in February 1996 (D. Erickson, unpubl.). With our first aerial survey in February 1997 we noted large flocks of small sandpipers in extreme UCI about the mouth of the Beluga River. Subsequent on-ground observations confirmed these were flocks entirely of Rock Sandpipers. Birds assessed to subspecies (n = 1,100 sampled) and specimens (n = 40) revealed >99% to be the nominate subspecies (*fide* D. Gibson, University of Alaska Museum). Continued aerial and ground observations through early February 1999 confirmed a resident winter population in UCI of about 18,000 birds (see Results).

Logical questions pertaining to this discovery are: 1) is this use a recent occurrence or has it just gone unnoticed? 2) what proportion of the species and subspecies population do the Cook Inlet birds represent? and 3) why do birds choose to winter in UCI instead of central and southern Cook Inlet where conditions are presumably more favorable? In answer to the first question, it appears Rock Sandpipers have been using the Inlet in winter for some time. Our results indicate that Erickson's February observation of "small shorebirds" could only have been Rock Sandpipers. Shortly after the initial discovery we learned that on several occasions over the previous 10 years other observers had reported "large flocks of sandpipers" along the extreme north shore of Cook Inlet in winter (A. Bennett, in litt.). Bennett's observations were made from the air when inclement weather forced him to fly close to the ground along the shore en route to Anchorage from Port Alsworth. And finally, several records of over 1,000 Rock Sandpipers seen at Kachemak Bay in LCI on Christmas Bird Counts (1982-1996) prompted REG to look at photographs of Rock Sandpipers taken there in previous years (1982 and 1984). In these images are several examples of *C. p. ptilocnemis* among the more abundant and much darker and smaller *C. p. couesi* or *C. p. tschuktschorum*. This prompted us to visit Kachemak Bay in March 1998 during which all but one of the 951 Rock Sandpipers found there were identified as the *C. p. ptilocnemis* subspecies (Gill, unpubl.).

The question of what proportion of the population of the *C. p. ptilocnemis* subspecies of Rock Sandpiper occurs in Cook Inlet in winter is a bit more problematic, but evidence points to Cook Inlet supporting the majority of the population. The insular nature of the breeding grounds of this subspecies and the available habitats on the islands obviously limit the size of this population, but there have been no dedicated assessments of breeding ground requirements of this subspecies from which to compare nesting densities and population figures from Cook Inlet. What is known is that the number of Rock Sandpipers in Cook Inlet is more than double that reported previously for the species in general (Gill 1997; Gill and Tibbitts, unpubl.) and five times greater than any other known concentration of the *C. p. ptilocnemis* subspecies. Only along the coast of the Yukon-Kuskokwim River Delta and at certain Alaska Peninsula estuaries have concentrations in excess of 5,000 birds been reported for any subspecies (Gill et al. 1981; Gill and Handel 1990; Tibbitts et al. 1996; Gill and Tibbitts, unpubl.).

From an ecological standpoint the intriguing questions to us are why do Rock Sandpipers concentrate in such large numbers in UCI? And why and how do these concentrations persist throughout winter when conditions in UCI can be quite severe? At present we have several working hypotheses that may help answer these questions, but these remain largely speculative without further study.

The fundamental basis for residency of any wildlife population must be an ample food supply. For Rock Sandpipers wintering in UCI this food supply is the small bivalve *Macoma balthica*, which was almost the exclusive item present in all 40 stomachs examined to date. Our preliminary analyses of the distribution and density of these clam stocks indicates that they are prevalent along the entire west side of UCI from Ivan River to Redoubt Bay and in densities from 2,000-3,000 per square meter (Gill and Tibbitts, unpubl.). Indeed, such densities apparently allow Rock Sandpipers to maintain on average 20 ± 4 % (r = 13 - 27, n = 20) total body fat during winter (R. Gill and T. Piersma, unpubl.).

This rather high body fat content poses another series of questions related to the existence of these birds in UCI in winter. How, for instance, are birds obtaining these clams when they are a probing species and the littoral substrates over which they feed are either covered to a large extent by grounded Inlet ice or, if not covered by ice, literally flash frozen for prolonged periods when receding water exposes them to subzero air temperatures? Throughout most of the winter from November to March ambient air temperature over UCI remains below freezing, but for a few periods each winter there usually are prolonged periods of extreme cold. Such conditions occurred three times during this study, once in late December 1997-early January 1998, again in February 1998, and in January 1999, when daytime high temperatures remained below -22° C for periods ranging from 5 to 20 days. How do these extreme conditions affect the overall distribution of Rock Sandpipers in UCI?

What we have pieced together to date suggests that birds prefer the Beluga-Ivan River portion of the Susitna Flats (Areas 17-34, Figure 2) because 1) overall densities of clams are high in this area, and 2) tidal currents in this portion of the Inlet affect benthic community productivity through ice scour. Further, the sandpipers have evolved certain foraging behaviors associated with this ice scour that allow them to reside in this region of the Inlet during all but the most severe conditions. For example, in early winter before major ice formation in Cook Inlet and again in late winter after ice has begun to disperse, birds can profitably forage on exposed mudflats during most tidal cycles. With the beginning of major ice formation in UCI in December, most littoral substrates become covered with ice that becomes grounded by combinations of tides and winds. The exception appears to be the upper and middle band of intertidal flats about the Beluga-Ivan rivers, which are kept relatively free of grounded ice by the strong sweeping currents along this portion of the Inlet shore. The ice that does occur over these flats leaves pronounced tracks in the substrate as it is moved along by tidal current, especially on receding tides. These tracks vary in length from a few to several hundred meters, in width from one to several meters, and in depth from a fraction to several centimeters.

Our on-ground observations to date suggest Rock Sandpipers have evolved an association with this ice scour that helps sustain them over this portion of UCI during all but the few periods of extreme conditions that occur each winter. They do this in two ways. First, we have observed birds arriving over recently exposed flats and concentrating along scour tracks where they appeared to be foraging on clams brought to the surface by the scouring action. These appeared to be both clams that had been killed by the scouring action and ones either killed or incapacitated by exposure to subfreezing ambient temperature.

This scouring action appears to aid Rock Sandpiper foraging in yet another way. In January 1998 we observed birds from the ground near Beluga when ambient air temperatures were -8 to -10° C and a thin layer of surface mud became frozen within minutes of exposure to the air. However, scour tracks of any appreciable depth retained receding tidal water that remained unfrozen for a longer period. It was in these tracks that birds concentrated their feeding.

Apparently once birds are well established in Cook Inlet during winter, they only abandon the Beluga-Ivan River area during periods of extreme and prolonged freezing conditions. Such movements occurred during the harsh cold spells of December 1997-January 1998 and late February 1998 when the majority of the population moved from the Susitna Flats and took up residence in the north part of Trading Bay (Areas 1-5, Figure 2). An even more pronounced shift was documented in January-February 1999 beginning about the mid-point of a record-setting cold spell when only about half (9,000 birds) of the regular wintering population could be found in UCI on a 22 January survey (Figure 2). About two-thirds fewer total birds (3,000) were found on a survey two weeks later — all being distributed about equally along Susitna Flats, Trading Bay and Redoubt Bay. A week after this, on 8 February, following 20 continuous days of –20° C temperatures, we surveyed the entire UCI north from Tuxedni Bay and Clam Gulch (Note: these data and those from surveys in March and April 1999 were not collected in time to be included in this report and are presented here only in the Discussion). On the 8 February survey no birds were found in the Beluga-Ivan River area and only a few hundred were present in Trading Bay. Most had, instead, moved farther south with about equal numbers (4,000) found in southern Redoubt Bay and Tuxedni Bay (Areas 1-9 Tuxedni Bay and 15-21 Redoubt Bay; Figure 2, Appendix B). Prior to this survey we had not recorded Rock Sandpipers in Tuxedni Bay in winter despite repeated survey conditions of little or no ice or frozen mudflats at this site. On the 8 February 1999 survey we did encounter considerable ice in Tuxedni Bay and over some littoral areas, but the flats (Areas 3-6, Figure 2) being used most heavily by Rock Sandpipers appeared to be unfrozen and striated with both numerous old and fresh ice scour tracks.

We include a few final observations as this report goes to the printer. With the amelioration of harsh winter conditions in south-central Alaska beginning mid-February 1999, Rock Sandpipers did return to UCI, but only in numbers about half of what was recorded prior to January. During a 4 March survey 11,768 birds were recorded, all on the Susitna Flats near the Beluga River, while on a 2 April survey 9,600 were found in the same area. On neither of these surveys did we find Rock Sandpipers south of this area. The reason for the decline in the Rock Sandpiper population during the second half of the 1998-1999 winter is unclear, but two factors seem likely: birds either emigrated from the area and/or suffered unusually high mortality due to the prolonged harsh conditions.

If birds did move south of their normal range it is unclear where. There were no reports of unusually large numbers of Rock Sandpipers in Kachemak Bay or Kodiak Island during the 1998-1999 winter (West 1999). It is possible they moved farther south along the Alaska Peninsula, but previous winter surveys of the entire south side of the peninsula (Arneson 1980) recorded shorebirds at only four sites, and two of these were in LCI (Tuxedni and Iniskin bays). At none of these four sites did densities exceed 10.1-100 birds/km^2, while densities at two of the four sites were <1 bird/ km^2. Though Arneson did not identify these birds to species, we presume they were Rock Sandpipers. That the nominate form of Rock Sandpiper occurs in winter along the south Alaska Peninsula was recently confirmed by C. Dau (pers. comm.) who found a small flock of this subspecies in Left Hand Bay on 11 February 1999. Finally, Arneson's surveys were conducted during normal to mild winters, thus his results may not be indicative of Rock Sandpiper occurrence along the Alaska Peninsula during harsh winter conditions, especially if birds in Cook Inlet respond to these conditions by moving.

What puzzles us about the issue of movement is why numbers of Rock Sandpipers in March and April 1999 remained low whereas in past winters when birds shifted south they eventually returned north to their pre-shift population levels. We can only speculate that mortality may also have been a factor in the population decline detected in UCI in 1999, but resolution of this will only come from additional study.

The Importance of Cook Inlet to Nesting Shorebirds

In terms of overall numbers of shorebirds recorded among the four seasons (Table 2, Figure 4), the summer or breeding period accounted for relatively few individuals. Nevertheless, we did establish clear links between shorebirds that nested around the periphery of Cook Inlet and their use of adjacent vegetated and unvegetated intertidal habitats. Not only did nesting birds travel several kilometers from inland nesting sites to feed on intertidal areas, but they also moved their young chicks to intertidal habitats where they remained throughout the brood-rearing period.

For one species in particular, the Hudsonian Godwit, Cook Inlet may be critical to a major portion of the continental population. Hudsonian Godwits have a disjunct breeding distribution with populations distributed over two or more areas of Canada and in south-central and western Alaska (AOU 1998). Western North American breeding godwits, including those in Alaska, have recently been shown to be genetically distinct from populations breeding in eastern Canada (Haig et al. 1998). The species' overall population is estimated at about 50,000 birds (Morrison et al., unpubl.), based on counts during migration, which would presumably include birds enroute to or from Alaska. What proportion the Alaska birds represent of this figure is unclear, but certainly less than 10-15%. For example, away from Cook Inlet concentrations of godwits have been reported only on the Yukon-Kuskokwim Delta; these were in autumn and consisted of flocks of only a few hundred birds (Williamson and Smith 1964, Seppi 1995). In Cook Inlet our high counts on surveys in spring frequently numbered several hundred birds (highest 786 but >1,500 when adjusted for proportions among unidentified large shorebirds; Table 3, Appendix D). The final destination of godwits using intertidal habitats in Cook Inlet in spring is unknown. Many nest locally and we suspect the majority remains within the Cook Inlet drainage basin, which supports the largest tract of this species' preferred nesting habitat within the state.

Conservation implications of Cook Inlet as a stopover site for shorebirds

Most shorebirds are migratory and rely on a series of stopover sites during their migrations (Senner and Howe 1984; Myers et al. 1987a, b; Morrison and Myers 1987, 1989; Morrison and Ross 1989). Thus, effective conservation of their populations depends on the identification of these sites and an assessment of the critical periods when they are used. All sites within a species' migratory flyway need to be identified and preserved, since the removal of one key site could disrupt the entire system.

Morrison (1983, 1984) first proposed an international system of linked reserves to protect important sites required by shorebirds throughout their ranges. This led to the establishment of the Western Hemisphere Shorebird Reserve Network (WHSRN), which stimulates development of the Network, gathers information on potential sites, and ratifies their inclusion in the WHSRN System (Myers et al. 1987a, b). To date the Network has been very successful, mainly due to voluntary and collaborative efforts among the various countries and organizations having jurisdiction over linked sites.

The WHSRN program carries no legislative or statutory provisions for the protection of a particular site. Instead, it promotes recognition of sites through designation by local, state, provincial, or national conservation units such as National Wildlife Areas (Parks, Refuges, Preserves), international treaty or convention (e.g., "Ramsar" site; Table 6), or through "stewardship" with private groups or individuals. Federal, provincial, state, or private organizations as appropriate may manage these in turn. Through 1999, WHSRN has officially recognized 14 Hemispheric sites (8 in North America), 12 International sites (10 in North America), and 5 Regional sites (4 in North America). These include only two sites in Alaska, the Copper River Delta, a Hemispheric Reserve, and Kachemak Bay in LCI, an International Reserve.

Categories of WHSRN sites.—Four categories of sites are recognized under the WHSRN system:

Hemispheric Sites: support at least 500,000 shorebirds annually, or 30% of a species' flyway population. Hemispheric sites are intended to include areas supporting major concentrations of shorebirds, with daily totals reaching about 50,000 birds during migration;

International Sites: support at least 100,000 shorebirds annually, or 15% of a species' flyway population;

Regional Sites: support at least 20,000 shorebirds annually, or 5% of a species' flyway population; and

Endangered Species Sites: are critical to the survival of endangered species (no minimum number of birds is required).

Findings from our study clearly demonstrate the importance of Cook Inlet to migratory and wintering shorebirds, with all four major embayments (and several subareas therein) qualifying for various WHSRN designations (Table 6). Two areas stand out among all. Southern Redoubt Bay qualifies as a WHSRN Hemispheric Reserve based on the total number of shorebirds it supports and in both the number of individuals and percent of the population of Western Sandpipers it supports in spring (1 million individuals and 30-50% of the Pacific Flyway population). The other principal area of hemispheric importance to Cook Inlet shorebirds is the Susitna Flats where what appears to be the vast majority of the population of the *C. p. ptilocnemis* subspecies of Rock Sandpiper resides throughout winter. Similar hemispheric designations, however, are also warranted for Trading and Tuxedni bays based on their use by Rock Sandpipers. Whether bays are considered individually or as a unit, the unmistakable conclusion is that Cook Inlet is a site of significant importance to both Pacific Flyway and North American shorebirds.

POTENTIAL EFFECTS ON SHOREBIRDS FROM OIL AND GAS EXPLORATION AND DEVELOPMENT IN COOK INLET

Without question Cook Inlet is a major site for oil and gas exploration and development in Alaska (MMS 1996, ADNR 1999). Most of LCI was included within a recent federal lease sale (Lease Sale 149) while in 1999 the State of Alaska proposed a much larger Cook Inlet sale (formerly Lease Sale 85) that includes all state lands (upland, tidelands, and submerged lands) adjacent to and north of the Sale 149. Development of new oil production facilities and associated modifications to existing facilities greatly increase the chances of direct and indirect impacts to shorebirds and the habitats on which they rely.

Shorebirds are most likely to be adversely affected by such development in three ways: 1) by disturbance during critical periods of use, 2) by direct contamination from pollutants, and 3) both directly and indirectly through elimination or contamination of benthic food supplies. Disturbance would have the greatest adverse effect if it were to occur on or adjacent to important spring stopover sites, such as southern Redoubt Bay during late April or May. At such areas shorebirds forage intensively, not only to replace energy reserves expended on flights to reach a site such as Cook Inlet, but also to fuel flights to succeeding sites along their migration route. Cook Inlet is a special case in that

Table 6. Cook Inlet embayments as sites of conservation importance for shorebirds.

			WHSRN qualification[2]		Ramsar qualification[3]	
Site	Species/group	WHSRN category[1]	Number	%	Number	%
Susitna Flats						
	Rock Sandpiper	H		x	x	x
	Rock Sandpiper	R	x			
	Hudsonian Godwit					x
	All shorebirds	R	x		x	
Trading Bay						
	Rock Sandpiper	H		x		x
	Western Sandpiper	I	x			
	All shorebirds	I	x		x	
Redoubt Bay						
	Rock Sandpiper	H		x		x
	Western Sandpiper	H	x	x	x	x
	Dunlin	I	?	x	x	x
	All shorebirds	H	x		x	
Tuxedni Bay						
	Rock Sandpiper	H		x		x
	Western Sandpiper	I	x	x		x
	All shorebirds	I	x		x	

[1] See Discussion for detailed descriptions of WHSRN (Western Hemisphere Shorebird Reserve Network) categories: H = Hemispheric, I = International, R = Regional.

[2] See Discussion for detailed descriptions of WHSRN criteria for each category.

[3] Ramsar is an international convention whereby governments agree upon common standards for the conservation and wise use of wetlands (Rose and Scott 1997). The most frequently applied "Ramsar Site" criteria are that a site must regularly support at least 20,000 birds (of all species) and/or that when data on populations are available, the site regularly supports 1% of the individuals in a population of one species or subspecies.

for the most abundant species using the area, the Western Sandpiper, it represents the last stopover site for birds before they depart directly to their breeding grounds (Bishop and Warnock 1998). Unless adequate energy reserves are obtained at stopover sites, especially penultimate sites such as Cook Inlet, it becomes problematic whether birds will be able to complete these flights or arrive with sufficient reserves to begin nesting. Thus, any activity that would potentially disrupt foraging for even periods of a few days could significantly alter energy intake and affect other subsequent life cycle events.

Most wildlife that depends on littoral ecosystems is potentially at risk from direct contamination from pollutants associated with gas and oil exploration and development in marine systems (Rice et al. 1996). Findings from past studies indicate that shorebirds as a group respond differently than other groups of birds affected by oil spills (Chapman 1984;Larsen and Richardson 1990; Burger 1997a, b). For example, they tend to suffer proportionately less direct contamination from oil. Their comparative rates of mortality, however, are harder to assess. This is because they often depart areas soon after oil has come ashore or, because of their smaller size, they are not found as readily as larger birds. Such is not the case with the benthic foods upon which shorebirds depend. Indeed, intertidal invertebrates as a group usually suffer the greatest damage and have some of the longest recovery times of organisms affected by spilled oil (e. g., Chasse 1978, Teal and Howarth 1984, Highsmith et al. 1996). Oil-Spill-Risk-Analyses (OSRA) for Cook Inlet (MMS 1996) indicates a high (27-72%) probability of there being major spills associated with gas and oil exploration and development in this region. Further, intertidal mud and sand flats are considered among the most sensitive of shoreline habitats in the region. A "base-case" spill in LCI, for example, is estimated to contact about 50% of all intertidal and shallow subtidal habitat and to have lethal or sublethal effects on 40-60% of all marine invertebrates (= 20% of all infauna within the region). Recovery times for these populations, especially those occurring in low energy habitats such as intertidal flats, have been estimated at greater than seven years (MMS 1996).

No similar OSRA has been done in UCI that we are aware of but, depending on the source and season of the spill, one could expect similar or even higher rates of contact and effects on benthos, not only because of the greater extent of intertidal habitats in UCI but because of the more dynamic influence of tides and currents in the region (Pearce et al. 1996). For Dunlin and Rock Sandpipers, which feed almost exclusively on small clams (i. e., *Macoma balthica*) while in Cook Inlet (Gill, unpubl.), loss of or sublethal effects to their food sources could have major consequences on the viability of their populations.

For Rock Sandpipers, in particular, an oil spill in winter could have severe consequences. Presumably birds are most stressed during this season because of the cold and the difficulty in obtaining food, especially during the few periods of extreme conditions that occur each winter. This is also the time when weather-induced accidents are most likely to occur and with little chance of rapid clean-up (MMS 1996). This combination of factors would make Rock Sandpipers highly vulnerable, both from direct oiling and indirectly through loss or reduction of their food supply.

Recommended protective measures

Added recognition should be given to several areas of Cook Inlet identified in this report as being of hemispheric and international importance to shorebirds. In general this would include the entire west side of Cook Inlet from Pt. MacKenzie to southern Tuxedni Bay. Within this region four sites should be designated as environmental resource areas or areas of special biological sensitivity (MMS 1996). These include western Susitna Flats from the Susitna River to Threemile Creek (Susitna subareas 9-16, 17-26, and 27-34, Appendix B), north Trading Bay (Trading Bay subareas 1-5 and 6-10), Redoubt Bay (Redoubt. Bay subareas 15-21), and Tuxedni Bay (Tuxedni Bay subareas 1-9). Within these areas conservation administrators with Federal, State, and local agencies should consider placing seasonal restrictions on certain activities (e. g., exploratory drilling and seismic activity). Critical seasonal periods would include late April to late May for Redoubt and Tuxedni bays and November through April for northern Trading Bay and western Susitna Flats.

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LITERATURE CITED

Alaska Department of Natural Resources. 1999. Cook Inlet areawide 1999 oil and gas lease sale: final finding of the director. Vol. 1. Department of Natural Resources, Division of Oil and Gas, Anchorage, AK. 275 pp.

American Ornithologists' Union. 1957. Check-list of North American Birds. Fifth edition. American Ornithologists' Union, Port City Press, Baltimore, MD.

American Ornithologists' Union. 1998. Check-list of North American Birds. 7th edition. American Ornithologists' Union, Washington, D.C.

Arneson, P. 1980. Identification, documentation and delineation of coastal migratory bird habitat in Alaska. Pp. 1-363 *in* Environmental Assessment of the Alaska Continental Shelf, Final Reports of Principal Investigators, Vol. 15. NOAA Environ. Res. Lab., Boulder, CO.

Bennett, A. J. 1996. Physical and biological resource inventory of the Lake Clark National Park-Cook Inlet coastline, 1994-1996. Unpubl. rpt., National Park Service, Kenai, AK. 137 pp.

Bishop, M. A., and N. Warnock. 1998. Migration of Western Sandpipers: links between their Alaskan stopover areas and breeding grounds. Wilson Bull. 110: 457-462.

Burger, J. 1997a. Effects of oiling on feeding behavior of Sanderlings and Semipalmated Plovers in New Jersey. Condor 99: 290-298.

Burger, J. 1997b. 1997. Oil spills. Rutgers Univ. Press, Piscataway, NJ.

Butler, W. I., Jr., and R. E. Gill, Jr. 1987. Spring 1987 aerial surveys of geese and swans staging in Upper Cook Inlet, Alaska. Unpubl. rpt., U.S. Fish and Wildlife Service, Anchorage, AK.

Chasse, C. 1978. The ecological impact on and near shores by the *Amoco Cadiz* oil spill. Marine Pollution Bull. 9: 298-301.

Chapman, B. R. 1984. Seasonal abundance and habitat-use patterns of coastal bird populations on Padre and Mustang Island barrier beaches (following Ixtoc I oil spill). U. S. Fish and Wildlife Service. FWS/OBS-83/31. 73 pp.

Cochran, W. G. 1977. Sampling techniques. John Wiley and Sons, New York, NY.

Conover, H. B. 1944. The North Pacific allies of the Purple Sandpiper. Field Museum of Natural History, Zoological Series 29: 169-179.

Dames and Moore. 1978. Drilling fluid dispersion and biological effects study for Lower Cook Inlet C.O.S.T. well. Unpubl. rpt. to Atlantic Richfield Co., Anchorage, AK. 309 pp.

Erickson, D. 1977. Distribution, abundance, migration, and breeding locations of marine birds, Lower Cook Inlet, Alaska, 1976. *In* Environmental studies of Kachemak Bay and Lower Cook Inlet (L. Trasky, L. Flagg, and D. Burbank, eds.). Unpubl. rpt., Alaska Dept. Fish and Game. 181 pp.

Gill, R. E., Jr. 1996. Alaska shorebirds: status and conservation measures at a terminus of the East Asian-Australasian Flyway. Pp. 21-42 *in* Conservation of migratory waterbirds and their wetland habitats in the East Asian-Australasian Flyway (D. R. Wells and T. Mundkur, eds.). Wetlands International-Asia Pacific, Kuala Lumpur, Publ. No. 116, and International Waterfowl and Wetlands Research Bureau-Japan Committee, Tokyo.

Gill, R. E., Jr. 1997. Rock Sandpiper, Pp. 786-787. *In* Alaska Region (T.

G. Tobish, ed.). Field Notes 51: 785-788.

Gill, R. E., Jr., R. Butler, P. S. Tomkovich, T. Mundkur, and C. M. Handel. 1994. Conservation of North Pacific Shorebirds. Trans. N. Am. Wildl. Nat. Resour. Conf. 59: 63-78.

Gill, R. E., Jr., and C. M. Handel. 1990. The importance of subarctic intertidal habitats to shorebirds: a study of the central Yukon-Kuskokwim Delta, Alaska. Condor 92: 709-725.

Gill, R. E., Jr., M. R. Petersen, and P. D. Jorgensen. 1981. Birds of the northcentral Alaska Peninsula. Arctic 34: 286-306.

Gill, R. E., Jr., and T. L. Tibbitts. 1993. Trip report: aerial surveys of shorebirds in Kachemak Bay and Upper Cook Inlet, Alaska, 5-14 May 1993. Unpubl. rpt., U.S. Fish and Wildlife Service, Alaska Research Center, Anchorage, AK.

Haig, S. M., C. L. Gratto-Trevor, T. M. Mullins, and M. A. Colwell. 1997. Population identification of Western Hemisphere shorebirds throughout the annual cycle. Molecular Ecology 6: 413-427.

Highsmith, R. C., T. L. Rucker, M. S. Stekoll, S. M. Saupe, M. R. Lindberg, R. N. Jenne, and W. P. Erickson. 1996. Impact of the *Exxon Valdez* oil spill on intertidal biota. Pp. 212-237 *in* Proceedings of the Exxon Valdez oil spill symposium (S. D. Rice, R. B. Spies, D. A. Wolfe, and B. A. Wright, eds.). American Fisheries Symposium 18.

Hopkins, D. M., J. V. Matthews, Jr., C. E. Schweger, and S. B. Young (eds.). 1982. Paleoecology of Beringia. Academic Press, New York, NY. 489 pp.

Isleib, M. E. 1979. Migratory shorebird populations on the Copper River Delta and eastern Prince William Sound. Studies in Avian Biol. 2: 125-129.

Isleib, M. E., and B. Kessel. 1973. Birds of the North Gulf Coast - Prince William Sound Region, Alaska. Biol. Papers Univ. Alaska 14.

Iverson, G. C., S. E. Warnock, R. W. Butler, M. A. Bishop, and N. Warnock. 1996. Spring migration of Western Sandpipers (*Calidris mauri*) along the Pacific Coast of North America: a telemetry study. Condor 98: 10-21.

Krasnow, L. D., and M. A. Halpin. 1981. Potential impacts of the Bradley Lake hydroelectric project on birds: a preconstruction survey. Unpubl. rpt., U. S. Fish and Wildlife Service, Anchorage, AK. 61 pp. plus Appendices.

Larson, E. M. and S. A. Richardson. 1990. Some effects of a major oil spill on wintering shorebirds at Grays Harbor, Washington. Northwestern Naturalist 71: 88-92.

Minerals Management Service. 1996. Cook Inlet Planning Area Oil and Gas Lease Sale 149. Final Environmental Impact Statement, Vol. 1, OCS EIS/EA, MMS 95-0066. USDI, MMS, Alaska OCS Region, Anchorage, AK.

Morrison, R. I. G. 1983. A hemispheric perspective on the distribution and migration of shorebirds in North and South America. Pp. 84-94 *in* First western hemisphere waterfowl and waterbird symposium (H. Boyd, ed.). Canadian Wildlife Service, Ottawa.

Morrison, R. I. G. 1984. Migration systems of some New World shorebirds. Pp. 125-202 *in* Behavior of marine birds, Vol. 5, Shorebirds: breeding behavior and populations (J.

Burger and B. Olla, eds.). Plenum Press, New York, NY.

Morrison, R. I. G., and J. P. Myers. 1987. Wader migration systems in the New World. Pp. 57-69 *in* The Conservation of international flyway populations of waders (N. C. Davidson and M. W. Pienkowski, eds.). Wader Study Group Bull. 49, suppl.

Morrison, R. I. G., and J. P. Myers. 1989. Shorebird flyways in the New World. Pp. 85-96 *in* Flyways and reserve networks for water birds (H. Boyd and J.-Y. Pirot, eds.). IWRB Special Publ. No. 9. Canadian Wildlife Service, Ottawa.

Morrison, R. I. G., and R. K. Ross. 1989. Atlas of Nearctic shorebird distribution on the coast of South America. 2 vols. Canadian Wildlife Service Special Publication, Ottawa.

Myers, J. P., P. D. McLain, R. I. G. Morrison, P. Z. Antas, P. Canevari, B. A. Harrington, T. E. Lovejoy, V. Plulido, M. Sallaberry, and S. E. Senner. 1987a. The Western Hemisphere Shorebird Reserve Network. Pp. 122-124 *in* The Conservation of international flyway populations of waders (N. C. Davidson and M. W. Pienkowski, eds.). Wader Study Group Bull. 49, suppl.

Myers, J. P., R. I. G. Morrison, P. Z. Antas, B. A. Harrington, T. E. Lovejoy, M. Sallaberry, S. E. Senner, and A. Tarak. 1987b. Conservation strategy for migratory species. American Scientist 75: 12-26.

Page, G. W., and R. E. Gill, Jr. 1994. Shorebirds in western North America: late 1800s to late 1900s. *In* A century of avifaunal change in western North America (N. K. Johnson and J. R. Jehl, Jr., eds.). Studies Avian Biol. 15: 147-160.

Patten, S. M., Jr. 1982. Seasonal use of coastal habitat from Yakutat Bay to Cape Fairweather by migratory seabirds, shorebirds, and waterfowl. Pp. 295-603 *in* Environmental Assessment of the Alaska Continental Shelf, Final Reports of Principal Investigators, Vol. 16. NOAA Environ. Res. Lab., Boulder, CO.

Paulson, D. 1993. Shorebirds of the Pacific Northwest. University of Washington Press, Seattle, WA. 406 pp.

Pearce, B. R., D. Jones, and H. McIlvaine. 1997. A Cook Inlet oil spill model. P. 21 *in* Watershed '97: water, people, and wildlife. The Cook Inlet Symposium. Anchorage, AK.

Petersen, M. R., J. C. Gerilich, and N. M. Harrison. 1991. Spring and fall migration, and habitat use by waterbirds in the Yakutat Forelands, Alaska — 1980. Unpubl. rpt., U.S. Fish and Wildlife Service, OBS, Anchorage, AK.

Raveling, D. G. 1978. Spring surveys of geese and swans in Cook Inlet, Kvichak Bay, Nushagak Bay, Kuskokwim Bay to Hazen Bay and Innoko River, Alaska, 3-7 May 1978. Unpubl. rpt., Univ. of California, Davis. 5 pp.

Reed, R. K., and J. D. Schumaker. 1986. Physical oceanography. Pp. 57-76 *in* Gulf of Alaska, Physical Environment and Biological Resources (D. Hood and S. Zimmerman, eds.). NOAA and MMS, Washington, D.C.

Rice, S. D., R. B. Spies, D. A. Wolfe, and B. A. Wright (eds.). 1996. Proceedings of the *Exxon Valdez* oil spill symposium. American Fisheries

Society Symposium 18, Bethesda, MD.

Robertson, D. G., and J. W. Hupp. 1992. Spring migration ecology of Lesser Snow Geese in Upper Cook Inlet—1992. Unpubl. rpt., U.S. Fish and Wildlife Service, Anchorage, AK. 12 pp.

Rose, P. M., and D. A. Scott. 1997. Waterfowl population estimates, 2nd edition. Wetlands International Publication 47. Wetlands International, The Netherlands. 106 pp.

Sellers, R. 1979. Waterbird use of and management considerations for Cook Inlet state game refuges. Unpubl. rpt., Alaska Dept. Fish and Game, Anchorage, AK. 42 pp.

Senner, S. E., and M. A. Howe. 1984. Conservation of Nearctic shorebirds. Pp. 379-421 *in* Behavior of marine birds, Vol. 5, Shorebirds: breeding behavior and populations (J. Burger and B. Olla, eds.). Plenum Press, New York, NY.

Seppi, B. 1995. Hudsonian Godwit migration at Carter Spit, Alaska. Western Birds 26: 167.

Sharma, G. D. 1979. The Alaska Shelf: hydrographic, sedimentary and geochemical environment. Springer-Verlag, New York. 338 pp.

Teal, J. M., and R. W. Howarth. 1984. Oil spill studies: a review of ecological effects. Environmental Management 8: 27-44.

Tibbitts, T. L., R. E. Gill, Jr., and C. P. Dau. 1996. Abundance and distribution of shorebirds using intertidal habitats of Izembek National Wildlife Refuge, Alaska. Unpubl. rpt., USGS, Alaska Science Center, Anchorage, AK. 38 pp.

Warnock, N., and M. A. Bishop. 1998. Spring stopover ecology of migrant Western Sandpipers. Condor 100: 456-467.

Williamson, F. S. L., and M. A. Smith. 1964. The distribution and breeding status of the Hudsonian Godwit in Alaska. Condor 66: 41-50.

West, G. 1998. Southcoastal Alaska Christmas Bird Counts – 1998. Kachemak Bay Bird Watch No. 36. 24 pp.

Appendix A. English and scientific names of shorebirds recorded on the Cook Inlet study area, 1997-1999.

English name	Scientific name
Black-bellied Plover	*Pluvialis squatarola*
American Golden-Plover	*P. dominica*
Pacific Golden-Plover	*P. fulva*
Semipalmated Plover	*Charadrius semipalmatus*
Greater Yellowlegs	*Tringa melanoleuca*
Lesser Yellowlegs	*T. flavipes*
Solitary Sandpiper	*T. solitaria*
Whimbrel	*Numenius phaeopus*
Hudsonian Godwit	*Limosa haemastica*
Bar-tailed Godwit	*L. lapponica*
Marbled Godwit	*L. fedoa*
Ruddy Turnstone	*Arenaria interpres*
Black Turnstone	*A. melanocephala*
Surfbird	*Aphriza virgata*
Red Knot	*Calidris canutus*
Sanderling	*C. alba*
Semipalmated Sandpiper	*C. pusilla*
Western Sandpiper	*C. mauri*
Least Sandpiper	*C. minutilla*
Baird's Sandpiper	*C. bairdii*
Pectoral Sandpiper	*C. melanotos*
Rock Sandpiper	*C. ptilocnemis*
Dunlin	*C. alpina*
Ruff	*Philomachus pugnax*
Short-billed Dowitcher	*Limnodromus griseus*
Long-billed Dowitcher	*L. scolopaceus*
Common Snipe	*Gallinago gallinago*
Red-necked Phalarope	*Phalaropus lobatus*

Appendix B. Descriptions of subareas within embayments of the Cook Inlet study area, 1997-1999 (see Figure 2). Place names appear on USGS 1:63 360 maps.

Bay and subarea	Length of shore (km)[1]	Description
Susitna Flats	51.0	West from Pt. MacKenzie at the head of Knik Arm to 1.5 km south of Threemile Creek.
Areas 1-8[2]	12.0	From Pt. MacKenzie west to the west bank of the mouth of the Little Susitna River.
Areas 9-16	12.0	From Little Susitna River west to the center of Big Island in the mouth of the Susitna River.
Areas 17-26	15.0	From Big Island southwest to mid-channel of the Beluga River.
Areas 27-34	12.0	From Beluga River to 1.5 km south of Threemile Creek.
Trading Bay	22.5	From Granite Pt. south to the Trading Bay production facility at the south end of Trading Bay.
Areas 1-5	7.5	From Granite Point southwest to Middle River.
Areas 6-10	7.5	From Middle River to mid-channel of the McArthur River.
Areas 11-15	7.5	From above south along the shore to opposite the Trading Bay production facility.

Appendix B. Continued.

Bay and subarea	Length of shore (km)[1]	Description
Redoubt Bay	31.5	From the village of Kustatan south to the mouth of Katchin Creek.
Areas 1-6	9.0	From the village of Kustatan south 2.7 km past the mouth of Johnson Slough.
Areas 7-14	12.0	From 2.7 km south of Johnson Slough south to the south bank of the mouth of Drift River.
Areas 15-21	10.5	From Drift River south to the mouth of Katchin Creek.
Tuxedni Bay	27.0	From the mouth of Crescent River west along the shore to Magnetic Point, then across Tuxedni River to the mouth of Open Creek and then east along the south side of the bay 3.0 km east of Bear Creek.
Areas 1-9	13.5	From the mouth of Crescent River west along the shore to Magnetic Point.
Areas 10-18	13.5	From Magnetic Point to 3.0 km east of Bear Creek.

[1] Equal straight line distance along the smoothed contour of the shoreline.
[2] Refers to inclusive aerial survey segments, each a rectangle with a 1.5-km-wide base at the unvegetated-vegetated interface and extending perpendicular to the farthest intertidal flats exposed at mean lower-low water.

Appendix C. Comparison of measures to assess seasonal use by shorebirds of the principal embayments and subareas therein, Cook Inlet, 1997-1999[1].

Measure/embayment/subarea	Spring	Summer	Autumn	Winter
Average no. birds per day				
Susitna Flats (all)	1,831	488	200	8,414
1-8[2]	220	10	20	259
9-16	110	88	138	2,848
17-26	842	234	36	4,789
27-34	659	156	6	518
Trading Bay (all)	1,348	105	74	1,871
1-5	867	81	56	1,322
6-10	329	23	16	450
11-15	152	1	2	99
Redoubt Bay (all)	31,883	300	730	21
1-6	2,232	33	37	3
7-14	5,420	24	24	0
15-21	24,231	242	12	18
Tuxedni Bay (all)	8,602	102[3]	0	0
1-9	6,325	90	0	0
10-18	2,277	12	0	0
Average no. birds/km shoreline/day				
Susitna Flats (all)	36	10	4	165
1-8	18	1	2	22
9-16	9	7	12	237
17-26	56	16	2	319
27-34	55	13	1	43
Trading Bay (all)	49	4[3]	3	68
1-5	116	11	7	176
6-10	44	3	2	60
11-15	20	0	0	13
Redoubt Bay (all)	1,012	10	2	1
1-6	248	4	4	0
7-14	452	2	2	0
15-21	2,308	23	1	2

Appendix C. Continued.

Measure/embayment	Spring	Summer	Autumn	Winter
Average no. birds/km shoreline/day				
Tuxedni Bay (all)	319	4[3]	0	0
1-9	469	7	0	0
10-18	169	1	0	0
High count				
Susitna Flats (all)	6,687	2,637	1,126	25,350
1-8	1,985	10	15	3,500
9-16	640	292	1,125	17,500
17-26	2,289	1,337	196	20,000
27-34	1,772	934	12	22,230
Trading Bay (all)	73,970	120	302	15,300
1-5	8,554	97	144	15,000
6-10	35,421	62	75	8,500
11-15	38,595	8	87	11,500
Redoubt Bay (all)	162,250	440	449	980
1-6	10,358	66	329	30
7-14	28,324	25	120	6
15-21	162,500	205	100	950
Tuxedni Bay (all)	64,790	0	0	0
1-9	47,225	0	0	0
10-18	40,720	0	0	0

[1] Refers to inclusive number of 1.5-km-wide segments of shoreline within each subarea of each embayment (see Figure 2).

[2] Values are seasonal averages over the entire study period (2 spring periods, 2 summer, 2 autumn, and 3 winter). Total complete surveys for the combined seasons = 16 spring, 7 summer, 12 autumn, and 15 winter.

[3] Even though no birds were recorded using Tuxedni Bay during summer surveys, values for average birds/day and birds per km/shoreline reflect interpolated values between the last spring survey and first summer surveys (see Methods and Data Analysis).

Appendix D. Numbers of individuals recorded by species or species group during aerial surveys of Cook Inlet, 1997-1999. See Figure 2 and Appendix B for locations and descriptions of bays and subareas within bays.

		Susitna Flats				
Survey/taxa	All bays	1-8	9-16	17-26	27-34	Total
11-Feb-97						
Rock Sandpiper	23,861			1,631	22,230	23,861
28-Feb-97						
Rock Sandpiper	25,350			6,000	19,350	25,350
28-Mar-97						
Rock Sandpiper	11,147				11,147	11,147
21-Apr-97						
None	0					
29-Apr-97						
Black-bellied Plover	111		2		2	4
Yellowlegs spp.	13			7	6	13
Hudsonian Godwit	12		5	2		7
Dowitcher spp.	47		8	10	29	47
Unid. small shorebird	1,601		6	75	63	144
2-May-97						
Black-bellied Plover	88		14		2	16
Yellowlegs spp.	14		1		13	14
Whimbrel	11			3	3	6
Hudsonian Godwit	295		2	31	13	46
Surfbird	1			1		1
Dowitcher spp.	656			254	92	346
Unid. small shorebird	32,263	5	42	900	75	1,022
10-May-97						
Black-bellied Plover	43					
Whimbrel	96					
Hudsonian Godwit	52			7	1	8
Bar-tailed Godwit	2					
Dowitcher spp.	393					
Unid. large shorebird	11					
Unid. med. shorebird	26			1		1
Unid. small shorebird	177,950			50	350	400
13-May-97						
Black-bellied Plover	26					
Golden-Plover spp.	4					
Whimbrel	102			3	2	5
Hudsonian Godwit	12			4	2	6
Black Turnstone	8					
Red Knot	60					
Sanderling	25					
Dowitcher spp.	496			80	127	207
Unid. med. shorebird	7					
Unid. small shorebird	69,704		50	250		300

Trading Bay				Redoubt Bay				Tuxedni Bay		
1-5	6-10	11-15	Total	1-6	7-14	15-21	Total	1-9	10-18	Total
					47	60	107			
1			1		4		4			
	360		360	200	647	250	1,097			
27			27		41	2	43	2		2
5			5							
5	32	74	111		130	8	138			
17	25	18	60		250		250			
3,600	1,250	359	5,209	3,695	14,910	7,353	25,958	48	26	74
						43	43			
		15	15			76	76		5	5
14	8	12	34			10	10			
		2	2							
	2	36	38			55	55	300		300
		1	1							
						25	25			
	40	1,353	1,393			162,291	162,291	8,350	5,516	13,866
12			12		5	9	14			
					4		4			
					24	73	97			
4			4						2	2
								8		8
	25		25	20		15	35			
								25		25
2			2	29	118	15	162		125	125
					7		7			
1,800	1,200	5,025	8,025	5,284	5,560	38,035	48,879	10,500	2,000	12,500

Appendix D. Continued.

Survey/taxa	All bays	Susitna Flats 1-8	9-16	17-26	27-34	Total
16-May-97						
Black-bellied Plover	39	18				18
Semipalmated Plover	3					
Whimbrel	187					
Hudsonian Godwit	28				3	3
Red Knot	5					
Sanderling	11					
Pectoral Sandpiper	15					
Dowitcher spp.	230			6	150	156
Unid. large shorebird	12			12		12
Unid. med. shorebird	549			125		125
Unid. small shorebird	16,062	50			10	60
19-May-97						
Black-bellied Plover	10			1	3	4
Yellowlegs spp.	10				10	10
Whimbrel	41		4			4
Hudsonian Godwit	133			1	6	7
Red Knot	157		5		70	75
Sanderling	24			1	8	9
Dunlin	397	2		10	115	127
Dowitcher spp.	540		20	60	255	335
Unid. med. shorebird	105			5	100	105
Unid. small shorebird	2,340			600	80	680
30-May-97						
Black-bellied Plover	2		1			1
Golden-Plover spp.	1					
Whimbrel	49	5	2	10	18	35
Hudsonian Godwit	513	46	166	71	125	408
Pectoral Sandpiper	28			28		28
Dowitcher spp.	476	15	80	248	116	459
Unid. large shorebird	2					
Unid. med. shorebird	95		40	30	25	95
Unid. small shorebird	1,813	8	3	950	650	1,611
10-Jun-97						
Whimbrel	63		5	45		50
Hudsonian Godwit	96		59	18	2	79
Pectoral Sandpiper	2					
Dowitcher spp.	233		125	20	62	207
Unid. med. shorebird	2					
3-Jul-97						
Black-bellied Plover	39		39			39
Whimbrel	171					
Hudsonian Godwit	5					
Unid. small shorebird	32		1			1

Trading Bay				Redoubt Bay				Tuxedni Bay		
1-5	6-10	11-15	Total	1-6	7-14	15-21	Total	1-9	10-18	Total
				1	16	4	21			
									3	3
13	33	23	69	7	100	11	118			
17	8		25							
					5		5			
	11		11							
									15	15
18	18	37	73						1	1
1	11		12		12	400	412			
	20	205	225	17	250	7,455	7,722	8,000	55	8,055
2	2		4		2		2			
10		22	32			5	5			
87	39		126							
	47		47		35		35			
5	10		15							
270			270							
58	50	52	160		45		45			
	400		400	650	575		1,225		35	35
						1	1			
1			1							
					12	2	14			
32	66	2	100		5		5			
15	2		17							
						2	2			
2			2			200	200			
13			13							
15	2		17							
2			2							
6			6			20	20			
	2		2							
1			1			170	170			
	5		5							
	6		6		25		25			

Appendix D. Continued.

		Susitna Flats				
Survey/taxa	All bays	1-8	9-16	17-26	27-34	Total
11-Jul-97						
Black-bellied Plover	103		70	33		103
Yellowlegs spp.	2			2		2
Whimbrel	20				20	20
Hudsonian Godwit	35				11	11
Dowitcher spp.	58				8	8
Unid. med. shorebird	5		5			5
Unid. small shorebird	47		40			40
19-Jul-97						
Yellowlegs spp.	1					
Whimbrel	1					
Hudsonian Godwit	106			84	3	87
Dowitcher spp.	21			21		21
Unid. small shorebird	8				6	6
26-Jul-97						
Black-bellied Plover	254	14	135			149
Yellowlegs spp.	16		16			16
Whimbrel	38		18	9		27
Hudsonian Godwit	38			26	12	38
Dowitcher spp.	121			121		121
Unid. med. shorebird	15		15			15
Unid. small shorebird	86	34	12	40		86
6-Aug-97						
Black-bellied Plover	23			6		6
Yellowlegs spp.	21		21			21
Whimbrel	4					
Dowitcher spp.	25					
Red-necked Phalarope	8					
Unid. small shorebird	95					
18-Aug-97						
Whimbrel	40					
Unid. small shorebird	105					
29-Aug-97						
Yellowlegs spp.	37					
Whimbrel	4					
Dunlin	80					
12-Sep-97						
Unid. small shorebird	1			1		1
30-Sep-97						
Dowitcher spp.	29					
10-Oct-97						
Yellowlegs spp.	2	2				2
Rock Sandpiper	90	15	44	31		90

Trading Bay				Redoubt Bay				Tuxedni Bay		
1-5	6-10	11-15	Total	1-6	7-14	15-21	Total	1-9	10-18	Total
12		1	13	11			11			
				50			50			
		7	7							
					1		1			
				1			1			
2	15		17	2			2			
				2			2			
105			105							
11			11							
17			17							
				4			4			
						25	25			
8			8							
20	75		95							
						40	40			
45			45			60	60			
					37		37			
	2		2			2	2			
					80		80			
				29			29			

Appendix D. Continued.

Survey/taxa	All bays	Susitna Flats 1-8	9-16	17-26	27-34	Total
17-Oct-97						
Rock Sandpiper	167			3		3
8-Nov-97						
Rock Sandpiper	21,640	3,500	17,500			21,000
5-Dec-97						
Rock Sandpiper	21,290		850	9,340	1,100	11,290
4-Jan-98						
Rock Sandpiper	16,930	9		878	740	1,627
4-Feb-98						
Rock Sandpiper	20,166			20,000		20,000
4-Mar-98						
Rock Sandpiper	19,707	207			4,500	4,707
3-Apr-98						
Rock Sandpiper	9,800		8,500	1,300		9,800
26-Apr-98						
Black-bellied Plover	140					
1-May-98						
Yellowlegs spp.	1					
Hudsonian Godwit	472					
Dowitcher spp.	50					
3-May-98						
Black-bellied Plover	1,492					
Yellowlegs spp.	2				2	2
Whimbrel	34					
Hudsonian Godwit	575			4	10	14
Black Turnstone	1					
Dowitcher spp.	1,406			70	5	75
Unid. large shorebird	19					
Unid. med. shorebird	104			4		4
Unid. small shorebird	121,727		7	1,300	900	2,207
5-May-98						
Black-bellied Plover	972					
Whimbrel	8					
Hudsonian Godwit	215			12		12
Red Knot	3					
Dowitcher spp.	876			35	23	58
Unid. large shorebird	48					
Unid. med. shorebird	80					
Unid. small shorebird	138,056			12	3	15

Trading Bay				Redoubt Bay				Tuxedni Bay		
1-5	6-10	11-15	Total	1-6	7-14	15-21	Total	1-9	10-18	Total
16			16	148			148			
640			640							
5,500	4,500		10,000							
	3,800	11,500	15,300			3	3			
166			166							
15,000			15,000							
				60	80		140			
									1	1
40			40			152	152		280	280
						50	50			
		127	127	154	1,018	193	1,365			
									34	34
56	10	70	136	11	43	320	374		51	51
						1	1			
4	11	613	628		275	388	663	40		40
4		15	19							
				100			100			
800	35,400	37,770	73,970	3,100	16,300	12,550	31,950	5,600	8,000	13,600
				165	449	263	877		95	95
				8			8			
11	15	3	29	39	135		174			
						3	3			
1	65	89	155	54	250	289	593		70	70
				48			48			
						80	80			
1,455	2,800	2,000	6,255	8,676	27,490	66,200	102,366	19,000	10,420	29,420

Appendix D. Continued.

Survey/taxa	All bays	Susitna Flats 1-8	9-16	17-26	27-34	Total
9-May-98						
Yellowlegs spp.	2			2		2
Hudsonian Godwit	768	2		17	706	725
Surfbird	315			4		4
Dowitcher spp.	866			325	540	865
Unid. large shorebird	1,080		1			1
Unid. med. shorebird	5,282					
Unid. small shorebird	123,065			100	200	300
11-May-98						
Black-bellied Plover	100			10		10
Whimbrel	17					
Hudsonian Godwit	59					
Surfbird	412					
Dowitcher spp.	1,248			84	145	229
Unid. large shorebird	2					
Unid. med. shorebird	259					
Unid. small shorebird	140,549			600		600
13-May-98						
Black-bellied Plover	144	1	1		12	14
Whimbrel	15			1		1
Hudsonian Godwit	108			38		38
Surfbird	5					
Dowitcher spp.	4,883			1579	470	2049
Unid. small shorebird	161,344	1,985	639	671	1,290	4,585
16-May-98						
Black-bellied Plover	11	2	4			6
Whimbrel	46		2	5	1	8
Hudsonian Godwit	72		9	11	7	27
Bar-tailed Godwit	2					
Marbled Godwit	1					
Surfbird	38			25		25
Dowitcher spp.	454		58	142	25	225
Unid. large shorebird	38					
Unid. med. shorebird	166		15	52	54	121
Unid. small shorebird	20,100		171	237	70	478

Trading Bay				Redoubt Bay				Tuxedni Bay		
1-5	6-10	11-15	Total	1-6	7-14	15-21	Total	1-9	10-18	Total
43			43							
						271	271	40		40
1			1							
	40	92	132	60	53	834	947			
95	145	382	622		70	1,590	1,660		3,000	3,000
590	70	1,570	2,230	980	2,155	52,610	55,745	27,070	37,720	64,790
						10	10	80		80
1		16	17							
51	6	2	59							
		9	9			3	3	400		400
129	38	259	426	400	94	99	593			
1			1			1	1			
	20	11	31	208			208	20		20
6,619	4,672	3,837	15,128	8,891	17,484	35,516	61,891	46,725	16,205	62,930
	10		10	120			120			
3		3	6			4	4		4	4
67			67		3		3			
						5	5			
	409	766	1,175	505	904	250	1,659			
8,484	15,291	20,572	44,347	9,733	11,591	68,288	89,612	21,100	1,700	22,800
5			5							
2	5		7			21	21		10	10
30	10	5	45							
									2	2
						1	1			
									13	13
54	67	38	159			30	30	40		40
16	5	10	31		7		7			
		18	18		18	9	27			
100	100	242	442	270	2,557	7,778	10,605	6,885	1,690	8,575

Appendix D. Continued.

		Susitna Flats				
Survey/taxa	All bays	1-8	9-16	17-26	27-34	Total
19-May-98						
Black-bellied Plover	5				2	2
Golden-Plover spp.	6					
Whimbrel	95					
Hudsonian Godwit	32			7	5	12
Bar-tailed Godwit	18					
Marbled Godwit	1					
Red Knot	60					
Rock Sandpiper	2			2		2
Dowitcher spp.	331			137	21	158
Unid. large shorebird	17					
Unid. med. shorebird	48				7	7
Unid. small shorebird	2,676			28	134	162
5-Jun-98						
Whimbrel	26				16	16
Hudsonian Godwit	159			48	41	89
Dowitcher spp.	55			20	14	34
Unid. large shorebird	7					
24-Jun-98						
Whimbrel	21					
Hudsonian Godwit	143			130	5	135
Dowitcher spp.	76			45	30	75
Unid. med. shorebird	51					
Unid. small shorebird	18	10	6			16
9-Jul-98						
Hudsonian Godwit	13			13		13
Dowitcher spp.	4			4		4
Unid. small shorebird	1					
6-Aug-98						
Black-bellied Plover	108	14				14
Yellowlegs spp.	51	12	33			45
Hudsonian Godwit	13					
Dowitcher spp.	37		2			2
Unid. small shorebird	803	115		45	40	200
28-Aug-98						
Rock Sandpiper	8	8				8
Unid. small shorebird	65		65			65
21-Sep-98						
Yellowlegs spp.	1	1				
14-Oct-98						
Rock Sandpiper	1,126	1	1,125			1,126

Trading Bay				Redoubt Bay				Tuxedni Bay		
1-5	6-10	11-15	Total	1-6	7-14	15-21	Total	1-9	10-18	Total
	1	2	3							
	6		6							
2		18	20			71	71		4	4
15	3	1	19	1			1			
		3	3			11	11		4	4
						1	1			
					60		60			
	15	11	26	5	42	95	142		5	5
	5	5	10		7		7			
				4	30	7	41			
62	25	53	140	20	912	792	1,724	610	40	650
					1	9	10			
70			70							
20			20			1	1			
7			7							
13	8		21							
4			4	4			4			
1			1							
						51	51			
					2		2			
						1	1			
94			94							
6			6							
4			4	9			9			
	35		35							
30	46	87	163	320	120		440			

Appendix D. Continued.

		Susitna Flats				
Survey/taxa	All bays	1-8	9-16	17-26	27-34	Total
30-Oct-98						
Yellowlegs spp.	1					
Rock Sandpiper	18,000	400	600	8,500		9,500
Dunlin	2					
20-Nov-98						
Rock Sandpiper	17,849	4	11,825	6,000		17,829
21-Dec-98						
Rock Sandpiper	17,523			17,520		17,520
22-Jan-99						
Rock Sandpiper	8,600			3,759		3,759
2-Feb-99						
Rock Sandpiper	3,182			150	919	1,069

Trading Bay				Redoubt Bay				Tuxedni Bay		
1-5	6-10	11-15	Total	1-6	7-14	15-21	Total	1-9	10-18	Total
						1	1			
	8,500		8,500							
					2		2			
	20		20							
3			3							
2,215	2,291	335	4,841							
917		210	1,127	30	6	950	986			

U.S. Department of the Interior
U.S. Geological Survey
Biological Resources Division

As the Nation's principal conservation agency, the Department of the Interior has responsibility for most of our nationally owned public lands and natural resources. This responsibility includes fostering the sound use of our lands and water resources; protecting our fish, wildlife, and biological diversity; preserving the environment and cultural values of our natural parks and historical places; and providing for enjoyment of life through outdoor recreation. The Department assesses our energy and mineral resources and works to ensure that their development is in the best interests of all our people by encouraging stewardship and citizen participation in their care. The Department also has a major responsibility for American Indian reservation communities.