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COASTAL ZONE USE BY POSTBREEDING SHOREBIRDS IN NORTHERN ALASKA

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Abstract: Knowledge of shorebird habitat requirements along the Arctic coast of Alaska is crucial to assess potential impacts of oil development. Therefore, I studied abundance and use of habitat by postbreeding shorebirds migrating through the coastal zone of the Colville River delta. Unvegetated silt barrens and vegetated and partially vegetated saltmarshes were surveyed for shorebirds during 1987 and 1988. I recorded 18 species of which 5 species constituted 90% of 32,639 individuals observed. Dunlins (*Calidris alpina*) dominated observations (59% of all individuals). Across years and habitats, 150 birds/km^2 were present in the delta coastal zone. Density of dunlins and sanderlings (*C. alba*) were higher ($P \leq 0.025$) on shoreline silt barrens whereas densities of all other species were equitably distributed among silt barrens and saltmarshes ($P > 0.05$). Shorebirds, other than dunlins and sanderlings, were positively associated ($P \leq 0.01$) with wet, sparsely vegetated saltmarshes. No other site surveyed in northern Alaska hosted as many dunlins as the Colville River delta. Migrating shorebirds using coastal habitats, dunlins in particular, could be adversely affected by coastal oil development.

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Key words: Alaska, Arctic, *Calidris* spp., Colville River delta, density, habitat, migration, oil development, shorebirds.

Although studies have identified Arctic sites where migrant shorebirds concentrate (Myers et al. 1988), little is known about shorebirds' habitat use. Connors et al. (1979) found that shorebirds in the Arctic changed habitat use, from upland tundra breeding sites to coastal migration sites, as summer progressed. The Colville River delta has the most extensive saltmarsh and coastal silt barren habitats along the central Beaufort Sea coast and was suspected of supporting large numbers of migrating shorebirds (Connors et al. 1981). Although avian studies have been conducted on the Colville River delta (Rothe et al. 1982), no information has been gathered on coastal zone habitat use by postbreeding shorebirds. As pressure from oil development increases on the North Slope of Alaska, an understanding of the habitat requirements of species that would be affected by such alterations is imperative. Thus, I measured the abundance, density, and habitat use by postbreeding shorebirds migrating through the coastal zone of the Colville River delta.

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STUDY AREA

The Colville River delta lies 75 km west of Prudhoe Bay, Alaska. The Colville River, draining 29% of the North Slope, forms a 600-km^2 delta where it empties into Harrison Bay (Walker 1983). Coastal habitats occupied a 6-km band at the delta's northern edge (Fig. 1). The area was composed of well-vegetated and partially vegetated saltmarshes, brackish ponds, and barren silt flats (Walker 1983). Although permafrost was the underlying force shaping the delta surface, the character of the coastal zone was influenced by spring flooding of the river and inundation of the ocean during fall storms (Walker 1983). The coastal zone was defined as the region from the interface of land and bay to the inland extent of terrestrial saltwater intrusion (Connors et al. 1979). Areas inundated by saltwater were readily identifiable by plant species composition.

I used vegetational studies by Rothe et al. (1982) and Walker (1985) to distinguish 5 coastal habitats in 1987: terminal shoreline silt barrens, subterminal shoreline silt barrens, interior silt barrens, sparse forb-graminoid tundra, and

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saline, wet sedge/grass-sedge tundra. In 1988, I defined 12 habitats to include components of surface pattern (polygonization) and moisture. Silt barrens included unvegetated silt deposits adjacent to river channels (subterminal [1]) or the bay (terminal). Terminal shoreline silt barrens were either straight and steep (regular [2]) or meandering and gradual (irregular [3]). Interior silt barrens (4) were inundated only during spring breakup or fall storms and dried out during summer. Sparse forb-graminoid tundra included sparsely vegetated (15–60% cover) areas underlain with clumps of plants killed by saltwater intrusion. Sparse-forb tundra (5) was dominated by scurvy grass (*Cochlearia officinalis*) and bryophytes with minor amounts of chickweed (*Stellaria humifusa*), alkali grass (*Puccinellia* spp.), and sedges (*Carex* spp.). Sparse forb-graminoid tundra (moist [6], wet [7], or polygonal [8]) was dominated by chickweed, sedges, tundra grass (*Dupontia fischeri*), and alkali grass. Moisture level divisions in sparsely vegetated and well-vegetated (>60% cover) habitats included moist soil (moist), saturated soils or standing water (wet), and low-centered, polygonal ponds with vegetated rims (polygonal). Well-vegetated saltmarshes consisted of saline sedge tundra (wet [9] or polygonal [10]), dominated by sedges, tundra grass, and alkali grass, and saline grass-sedge tundra (moist [11] or polygonal [12]), dominated by cotton grass (*Eriophorum* spp.), tundra grass, and sedges. The latter habitat was drier and contained foxtail (*Alopecurus alpinus*), dock (*Rumex arcticus*), and saxifrages (*Saxifraga* spp.). Complete descriptions are provided in Andres (1989). Nomenclature of habitats complements and augments Walker's (1985) system, and saltmarsh types were defined as coastal wetlands (VIII) by Bergman et al. (1977).

METHODS

I used Rothe et al.'s (1982) LANDSAT-derived vegetational map to divide the study area into habitat strata. Each stratum consisted of only 1 habitat and its composition was verified during the first 2 weeks of surveys. In 1987, 65 strata of 5 habitats were delineated; in 1988 the number of habitat designations increased to 12 and the number of strata to 79. Stratum size was constrained by topographic features, access, and time costs of sampling. Size reflected only the terrestrial portion of the habitat and excluded water bodies evident at a 1:30,000 scale. Widths of shoreline silt barren strata were delimited from the mean distance inland from the water's edge at which birds occurred in the stratum (determined from study in 1986) and varied from 5 to 30 m. Consequently, silt barrens were divided into interior and perimeter portions.

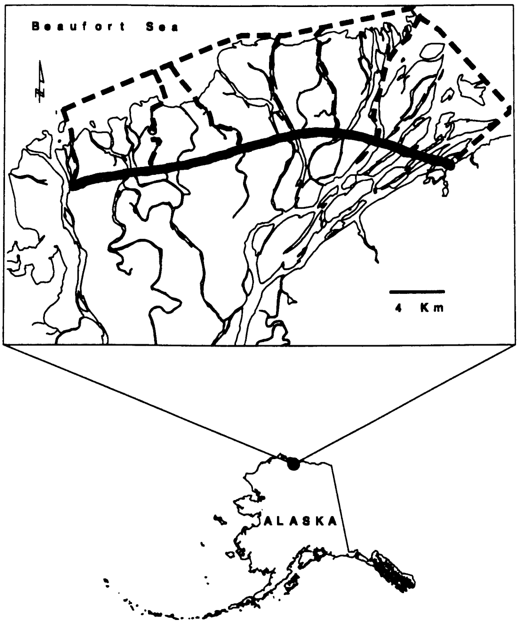

Fig. 1. Location of the coastal zone of the Colville River delta, Alaska. The study area, delineated by the solid line, encompassed 97% of the coastal zone and was divided into 6 subdivisions (dashed lines), one of which was surveyed each day.

The temporal frame for sampling strata included all possible days between 2 July and 2 September. The sampling unit was a km^2-day and the response variable was the number of shorebirds (of a given species or species group). To reduce travel costs, daily stratified samples were restricted to 1 of 6 subdivisions (Fig. 1). All shoreline silt barren strata and half of the saltmarsh strata within a subdivision were surveyed by a 2-person crew. Sampling within habitat strata was systematic; each shoreline silt barren stratum was surveyed, at a minimum, every 8 days and each saltmarsh stratum every 16 days. Because variability in shorebird use was higher in shoreline silt barren strata (Andres, unpubl. data), greater effort was allocated in these strata. I departed from stratified sampling procedures by restricting the habitats that were sampled in the same day to a single subdivision. Because strata were not independently chosen, estimates of covariance among strata sampled

Table 1. Mean estimated abundance and density of shorebirds found in the coastal habitats of the Colville River delta, Alaska (1987–88).

	$\bar{x}$ no. present					
Species	Shoreline (/km)	CV[a]	Delta (/km^2)	Total no.	CV[a]	Proportion of total
All species	16.8	0.22	149.9	4,586	0.18	1.00
Dunlin	13.9	0.33	71.9	2,202	0.31	0.48
Semipalmated sandpiper (*Calidris pusilla*)	2.0	0.65	33.9	1,040	0.32	0.22
Red-necked phalarope (*Phalaropus lobatus*)	0.1	0.43	15.7	481	0.23	0.10
Western sandpiper (*C. mauri*)	0.4	0.38	8.5	262	0.40	0.06
Pectoral sandpiper (*C. melanotos*)	<0.1		6.1	186	0.28	0.04
Stilt sandpiper (*C. himantopus*)	<0.1		3.7	112	0.36	0.03
Red phalarope (*Phalaropus fulcaria*)	0.1	0.45	2.1	63	0.38	0.01
Black-bellied plover (*Pluvialis squatarola*)	0.1	0.31	1.9	59	0.25	0.01
Lesser golden plover (*P. dominica*)	<0.1		1.6	48	0.37	0.01
Ruddy turnstone (*Arenaria interpres*)	0.1	0.32	1.7	51	0.23	0.01
Long-billed dowitcher (*Limnodromus scolopaceus*)	<0.1		1.1	33	0.66	<0.01
Sanderling	0.1	0.35	0.5	15	0.32	<0.01
Baird's sandpiper (*C. bairdii*)	<0.1		0.5	13	0.39	<0.01
Buff-breasted sandpiper (*Tryngites subruficollis*)			0.2	5	0.78	<0.01
Bar-tailed godwit (*Limosa lapponica*)	<0.1		<0.1	1		<0.01
White-rumped sandpiper (*C. fuscicollis*)	<0.1		<0.1	1		<0.01
Whimbrel (*Numenius phaeopus*)	<0.1		<0.1	1		<0.01
Rock sandpiper (*C. ptilocnemis*)			<0.1	<1		<0.01

[a] Coefficient of variation (SE/$\bar{x}$). CVs are not presented for low values.

on the same day were included in variance estimates.

I calculated estimates of mean density, total number, and proportion of the total and their associated variances and covariances, using formulas for stratified random sampling (Cochran 1977). I performed analyses on species that constituted $\geq$1% of all observations. Point estimates should be interpreted as either a density or abundance (total number) of shorebirds present in the delta at an instant in time. Unequal sample sizes, unequal variances, and covariances between estimates violated assumptions of multiple comparisons procedures (Day and Quinn 1989). I examined comparisons between broad habitat types (and among years), using *t*-tests with adjusted Bonferroni probabilities. Degrees of freedom were calculated using Satterthwaite's approximation for stratified samples (Snedecor and Cochran 1980).

I integrated density and abundance considerations of shorebird habitat use by examining the proportion of the total number of birds occurring in a habitat in relation to the proportion of that habitat occurring in the coastal zone. Because the number of habitats included in an analysis influences results (Johnson 1980), I followed the recommendation of Porter and Church (1987) and included only habitats where birds were found. Because interior silt barrens were not used by postbreeding shorebirds, I eliminated them from analytical considerations; 4 habitats were considered in 1987 and 11 in 1988. For habitats defined in 1987, I averaged estimates across years. I tested proportional use by shorebirds in relation to proportional area with Z-tests (along with Bonferroni probabilities). Species differences in habitat use were qualitatively assessed by examining the density patterns among habitats. I combined species that showed similar habitat use patterns into one group.

RESULTS

I recorded 18 shorebird species during coastal zone surveys; 5 species constituted 90% of the sightings (Table 1). Covariances between strata contributed an additional 33% to the delta-wide variance estimate for 1987 and 50% to the variance estimate in 1988. Abundance and density of all species combined did not differ between years (*t*-test, $P > 0.05$) and no single species differed ($P > 0.05$) in abundance between years.

Examination of individual species' use of habitat classes defined in 1987 revealed 2 groups. Dunlins and sanderlings occurred at a higher abundance and density on shoreline silt barrens than in saltmarshes (Table 2; $P \leq 0.025$). The remaining species occurred at higher abundances in saltmarshes ($P \leq 0.001$) but did not differ ($P > 0.05$) in density between silt barrens and saltmarshes (Table 2). Compared with other species, dunlins and sanderlings occurred at higher densities ($P \leq 0.025$) on shoreline silt barrens and at lower densities ($P \leq 0.001$) in saltmarshes. The only difference between abundance on terminal and subterminal shoreline silt barrens ($P \leq 0.025$) was found when all species were considered. However, a higher number of dunlins and sanderlings ($P \leq 0.025$) occurred on terminal shoreline silt barrens than on subterminal silt barrens in 1987. There were no differences ($P > 0.05$) between the mean density or abundance of shorebirds using saline sedge/grass-sedge or sparse forb-graminoid habitats for any species group (Table 2). Shorebirds were consistent in their relative habitat use between years (Table 3; $P > 0.05$).

Of the saltmarsh habitats defined in 1988, shorebird densities in wet, sparse forb-graminoid tundra were higher than in other saltmarsh habitats (all 7 comparisons at $P \leq 0.05$; Table 4). Conversely, moist, saline grass-sedge tundra tended to have lower densities of shorebirds than did most other habitats (5 of 7 comparisons at $P \leq 0.05$; Table 4). The greatest abundances of shorebirds using saltmarshes occurred in moist and wet, sparse forb-graminoid and wet, saline sedge habitats. In general, wetter, less vegetated saltmarsh habitats tended to have higher densities of shorebirds. Although density (birds/km^2) or abundance did not differ among shoreline silt barren habitats, linear density (birds/km) of all shorebird species differed ($P \leq 0.05$) between irregular shoreline silt barrens (36.9 ± 10.6) and subterminal silt barrens (7.5 ± 1.9) in 1988. High variances associated with counts on irregular terminal shoreline silt barrens might have resulted from high water levels on silt barrens in mid-August.

Of coastal habitats used by shorebirds, shoreline silt barrens made up only 8% of the delta yet received 47% of all shorebird use. Dunlins and sanderlings, but not other species, were concentrated on shoreline silt barrens (Table 5). Although irregular terminal shoreline silt barrens (6% of the coastal area) received 55% of dunlin and sanderling use in 1988, a high variance estimate, largely influenced by a sudden pulse of birds moving onto the silt barrens after high water receded in mid-August, precluded detection of use versus availability differences. Only subterminal shoreline silt barrens were used disproportionately by dunlins and sanderlings

Table 2. Density (birds/km^2) and total number of postbreeding shorebirds occurring on shoreline silt barrens and saltmarshes of the Colville River delta, Alaska, 1987–88.

Habitat	Area (km^2)	All species				Dunlin and sanderling				Other species			
		Total	SE	Density	SE	Total	SE	Density	SE	Total	SE	Density	SE
Shoreline silt barren	2.42	2,135	547	882	226	1,776	549	733	227	360	168	149	69
Terminal	1.92	1,665	429	867	223	1,386	440	722	229	279	136	145	70
Subterminal	0.49	469	123	954	251	390	124	793	252	80	33	163	67
Saltmarshes	28.16	2,453	397	87	14	443	88	16	3	2,011	342	72	12
Sparse forb-graminoid	11.23	1,309	258	117	23	218	56	19	5	1,091	244	97	22
Saline sedge/grass-sedge	16.84	1,144	164	68	10	225	54	13	3	919	151	55	9

Table 3. Estimated proportion of the total number of shorebirds occurring on shoreline silt barrens and in saltmarshes of the Colville River delta, Alaska, during 1987–88.

	Shoreline silt barrens				Saltmarshes				
	Terminal		Subterminal		Sparse forb-graminoid		Saline sedge/grass-sedge		
	Proportion	SE	Proportion	SE	Proportion	SE	Proportion	SE	Total no.
All species									
1987	0.41	0.10	0.09	0.02	0.27	0.04	0.24	0.03	4,140
1988	0.33	0.09	0.12	0.03	0.30	0.07	0.26	0.04	5,031
Dunlin and sanderling									
1987	0.67	0.20	0.13	0.04	0.08	0.02	0.12	0.03	2,172
1988	0.58	0.21	0.22	0.07	0.12	0.03	0.09	0.02	2,262
Other species									
1987	0.11	0.02	0.03	0.01	0.49	0.07	0.37	0.05	1,968
1988	0.12	0.07	0.03	0.01	0.44	0.11	0.40	0.07	2,769

in 1988. Saline sedge/grass-sedge habitats contributed 55% of coastal area coverage but was little used by all species. Sparse forb/forb-graminoid habitats (37% of the delta) were not used by dunlins and sanderlings but were proportionately used by other species. In 1988, only wet, sparse forb-graminoid tundra received higher use than expected by its proportional coverage by species other than dunlin and sanderling. All remaining saltmarsh types were either little used or used proportionately by all species.

DISCUSSION

In addition to the 18 species recorded during my surveys, 12 other species have been recorded in the coastal areas of the Colville River delta (Andres 1989). The number of species recorded in the delta represents 71% of all shorebird species recorded on the North Slope of Alaska (Troy 1985).

Use of the coastal zone by shorebirds in arctic Alaska has been documented for the Chukchi Beaufort seacoasts in a series of surveys (1975–81) sponsored by the Outer Continental Shelf Environmental Assessment Program (summarized in Connors et al. 1984, Connors and Connors 1985). Additional coastal shorebird surveys have been made in the Prudhoe Bay area (LGL Res. Assoc., Inc. 1982) and were incorporated in the baseline study of the Arctic National Wildlife Refuge (Moitoret 1983, Garner and Reynolds 1986). Average shorebird abundance along the delta's shoreline silt barrens ranks it as one of the most heavily used sites on the North Slope.

The dunlin is more abundant on the Colville River delta than at any other site previously surveyed on the North Slope. The abundance of dunlins on the Colville River delta can be attributed to the presence of terminal shoreline silt barrens. Eighty percent of all dunlins used the edges of silt barrens. Contrary to the saltmarsh-silt barren mosaic of the Colville River delta, barrier island sites surveyed at Point Barrow were composed of gravel bars and were dominated by phalaropes (*Phalaropus* spp., 88%; Connors et al. 1979). The migratory shorebird assemblage using coastal marshes of the Arctic National Wildlife Refuge in northeastern Alaska was dominated by the semipalmated sandpiper (Moitoret 1983).

Wet, sparse forb-graminoid saltmarshes and irregular, terminal silt barrens are important habitats for migratory shorebirds. High use in these areas is, most likely, related to prey availability; most birds were observed foraging (89%, $n = 30{,}754$). The density of postbreeding shorebirds was positively correlated with chironomid and oligochaete density on shoreline silt barrens and in sparse forb-graminoid saltmarshes (Andres 1989). Within saltmarshes, variation in prey density, in turn, was correlated with moisture level (Andres 1989). Variation in invertebrate prey and shorebird populations on terminal shoreline silt barrens was related to differences in shoreline slope and substrate composition (Andres 1989). Because stopover habitats are used as refueling stops by migratory birds, shorebirds should select habitats where fat accumulation is maximized.

Covering >60% of the coastal area of the delta, the interiors of terminal silt barrens were not used by postbreeding shorebirds. The lack of substrate moisture, and depressed prey populations, likely deterred foraging shorebirds. Inclusion of this habitat in use-availability considerations would cause all other habitats to display positive habitat use. Thus, little would be gained from the analysis because it is already known that all other habitats receive more use than do interior silt barrens.

MANAGEMENT IMPLICATIONS

The dual approach of examining density and abundance merits attention in the decision-making process. If a management decision is directed toward alteration of a particular habitat, the estimate of the total number (and hence the proportion of the total number) of shorebirds present in that habitat would be a valid measure of the importance of this habitat to a species or group of species. Alternatively, if a decision would affect only small patches of a given habitat, an area-sensitive measure (density) would be helpful in determining the habitat value. Use-availability indices integrate these 2 approaches and provide a single measure of the value of a habitat. However, high, positive use of a habitat probably indicates a preference for the habitat, but neutral or negative results should not be viewed as habitat avoidance. Avoided habitats are those in which no birds occurred (e.g., interior silt barrens, open bay). Thus, use-availability analyses should be compared hierarchically.

If complete turnover of the migratory shorebird population is possible every 7 days, approximately 41,000 shorebirds might use the delta during their fall migration (Andres 1989). Shoreline silt barrens alone could provide stopover habitat for 18,000 dunlins. The dependence of dunlins and sanderlings on terminal shoreline silt barrens of the Colville River delta makes them highly susceptible to coastal oil development. Shoreline oiling from offshore spills could directly affect migrating shorebirds by oiling their plumages and indirectly affect them by killing benthic prey populations. Low wave energy, fine-grained beaches, characteristic of the Colville's silt barrens, are known to retain oil (Natl. Res. Counc. 1985). Although species using saltmarsh habitats might be less susceptible to direct effects of environmental oil contamination, disturbances associated with construction and maintenance activities of oil development could adversely affect the migrant shorebird population passing through the delta.

Table 4. Density (birds/km²) and total number of postbreeding shorebirds occurring on shorelines and in saltmarshes of the Colville River delta, Alaska, 1988.

Habitat	Area km²	All species				Dunlin and sanderling				Other species			
		Total	SE	Density	SE	Total	SE	Density	SE	Total	SE	Density	SE
Shorelines													
Irregular terminal	1.87	1,585	456	849	244	1,252	450	671	240	333	186	178	100
Regular terminal	0.06	70	34	1,111	539	61	34	963	537	9	7	148	105
Subterminal	0.49	584	152	1,188	309	489	150	994	304	95	43	194	87
Saltmarshes													
Sparse forb	1.86	52	41	28	22	2	1	1	0	50	41	27	22
Moist, sparse forb-graminoid	6.62	497	175	75	26	52	25	8	4	455	133	67	20
Wet, sparse forb-graminoid	1.75	788	191	451	109	203	51	116	29	585	156	335	89
Polygonal sparse forb-graminoid	1.10	147	32	133	29	10	4	9	4	137	30	124	27
Wet saline sedge	9.12	820	180	90	20	156	47	17	5	663	150	72	16
Polygonal saline sedge	1.86	227	42	122	23	7	3	4	2	220	40	118	22
Moist saline grass-sedge	3.77	92	23	25	6	10	4	3	1	82	21	22	6
Polygonal saline grass-sedge	2.09	170	29	81	14	20	7	9	3	150	29	72	14

Table 5. Mean proportional shorebird use [P(T)] and proportional area [P(A)] of coastal habitats on the Colville River delta, Alaska, 1987–88.

		Dunlin and sanderling			Other species		
Habitat	P(A)	P(T)	P(T) − P(A)	P^a	P(T)	P(T) − P(A)	P^a
1987 defined habitats							
Terminal shoreline silt barren	0.063	0.626	0.563	0.009	0.115	0.052	0.204
Subterminal shoreline silt barren	0.016	0.175	0.159	0.009	0.033	0.017	0.126
Sparse forb/forb-graminoid	0.370	0.098	−0.272	≤0.001	0.465	0.095	0.227
Saline sedge/grass-sedge	0.551	0.102	−0.449	≤0.001	0.385	−0.166	0.009
1988 defined habitats							
Irregular terminal shoreline	0.061	0.554	0.493	0.019	0.120	0.059	0.271
Regular terminal shoreline	0.002	0.027	0.025	0.099	0.003	0.001	0.352
Subterminal shoreline	0.016	0.217	0.201	0.004	0.034	0.018	0.194
Sparse forb	0.061	0.001	−0.060	≤0.001	0.018	−0.043	0.007
Moist sparse forb-graminoid	0.216	0.023	−0.193	≤0.001	0.160	−0.056	0.201
Wet sparse forb-graminoid	0.057	0.090	0.033	0.144	0.211	0.154	0.010
Polygonal sparse forb-graminoid	0.036	0.005	−0.031	≤0.001	0.049	0.013	0.199
Wet saline sedge	0.298	0.069	−0.229	≤0.001	0.240	−0.058	0.225
Polygonal saline sedge	0.061	0.003	−0.058	≤0.001	0.079	0.018	0.174
Moist saline sedge	0.123	0.005	−0.118	≤0.001	0.030	−0.093	≤0.001
Polygonal saline grass-sedge	0.068	0.009	−0.059	≤0.001	0.054	−0.014	0.178

[a] Z-values computed by large sample approximation of the binomial test (Hollander and Wolfe 1973). Differences for 1987 were significant if $P \leq 0.025$ and differences for 1988 were significant if $P \leq 0.01$.

Of all waterbird species using Jamaica Bay National Wildlife Refuge in New York, shorebirds were the most susceptible to human-induced disturbances (Burger 1981). Little is known about the effects of disturbance on coastal migrating shorebirds in the Arctic.

Conclusions on the importance of delta silt barrens to migrating shorebirds differ from conclusions reached by Meehan and Jennings (1988) on the value of these habitats to waterfowl. Coastal silt barrens ranked last in use by waterfowl. Although silt barren and saltmarsh habitats are most extensive in the Colville River delta, these habitats are dispersed throughout coastal areas of northern Alaska. Consideration of coastal habitat use by migratory shorebirds, particularly land-water interfaces of silt barrens and wet, sparse forb-graminoid saltmarshes, should be included in development decisions regarding Alaska's North Slope. Monitoring development-induced changes in the behavior and habitat use of postbreeding shorebirds is critical to assess the impacts of oil development activities.

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ANTICHOLINESTERASE EXPOSURE OF WHITE-WINGED DOVES BREEDING IN LOWER RIO GRANDE VALLEY, TEXAS

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Abstract: We studied exposure of breeding white-winged doves (*Zenaida asiatica*) to anticholinesterase compounds (organophosphorus and carbamate pesticides) in the Lower Rio Grande Valley (LRGV), Texas. Widespread use of organophosphorus pesticides and dove population declines prompted the study. We collected breeding adult doves in May and July 1991 ($n = 28$) and July 1992 ($n = 33$) at 6 locations. We used depression of whole-brain cholinesterase (ChE) activity (2 SD below control mean) to detect exposure; values from 4 hand-reared doves fed commercial pigeon chow served as the control. Mean brain ChE activity was lower ($P < 0.027$) than the control sample at all 6 locations in 1991; 79% of the birds were diagnostic of exposure (>16.1% ChE depression). Pooled 1992 field samples also were lower ($P < 0.036$) than were control samples; doves from 4 of the 6 locations had brain ChE activity below ($P < 0.088$) controls. Overall, 39% of 1992 doves were diagnostic of exposure to anticholinesterase compounds. Higher exposure rates in 1991 were probably due to increased use of organophosphorus pesticides. Research is needed documenting effects of sublethal exposure on white-winged dove productivity.

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Organophosphorus and carbamate pesticides are anticholinesterase substances responsible for mortality of large numbers of birds of various species (Grue et al. 1983, Smith 1987). A threshold of about 50% depression in whole-brain ChE activity can be diagnostic of death from anticholinesterase poisoning (Ludke et al. 1975), and brain ChE activity is widely used to diagnose