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SEASONAL ABUNDANCE AND HABITAT USE OF SHOREBIRDS ON AN OSO BAY MUDFLAT, CORPUS CHRISTI, TEXAS

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Abstract.—Shorebirds (Charadrii) were censused for a year at weekly to biweekly intervals along an approximately 1-km transect on an Oso Bay tidal mudflat surrounding Ward Island, Corpus Christi, Nueces County, Texas. A total of 34,822 shorebirds of 26 species were observed and categorized by their use of three microhabitats. The greatest shorebird use of the area occurred during the winter and early spring (January-March) in south Texas, but the highest species diversity was recorded during the peak of fall migration (September-October). Low shorebird abundance and diversity were observed during the summer. Of the four most common species in the study area, Dunlins (*Calidris alpina*) and dowitchers (*Limnodromus* spp.) exhibited the greatest similarity in their habitat preferences. Shorebirds were less restricted to microhabitats during the winter when food resources were likely highest. It is suggested that the abundance of food and feeding habitat along the Texas coast during the winter and early spring may have been a factor in the evolution of circular migratory patterns in many shorebird species.

ABUNDANCIA ESTACIONAL Y UTILIZACIÓN DE HABITAT POR PARTE DE PLAYEROS EN UN LODAZAL DE OSO BAY, CORPUS CHRISTI, TEXAS

Sinopsis.—Durante un año, se llevaron a cabo censos de playeros (Charadrii) con una frecuencia semanal o bisemanal a lo largo de un transecto de aproximadamente un kilómetro de largo en un lodazal de Oso Bay, Corpus Christi, Texas. Un total de 34,822 playeros pertenecientes a 26 especies, fueron observados y clasificados por el uso de tres microhabitats. El uso mayor de todo el área ocurrió durante el invierno y el comienzo de la primavera (enero-marzo), pero hubo mayor diversidad de especies durante el pico de la migración en el otoño (septiembre-octubre). Durante el verano se notó baja diversidad y abundancia de playeros. De las cuatro especies más comunes en el área de estudio, *Calidris alpina* y los chorlos (*Limnodromus* spp.) exhibieron la mayor similaridad en preferencia de habitat. Los playeros estuvieron menos restringidos a microhabitats durante el invierno, cuando la comida parece estar en mayor abundancia. Se sugiere que la abundancia de alimentos durante el invierno y el comienzo de la primavera y la presencia de habitats para alimentarse a lo largo de la costa de Texas podría ser un factor importante en la evolución de patrones migratorios circulares de muchas especies de playeros.

Most shorebirds are highly migratory and their presence along the Gulf of Mexico coast, a major wintering and migratory staging area, is largely seasonal. In Texas, the marine-influenced communities, including the shores of the open coast, lagoons, bays, estuaries and marshes, provide the most extensive habitats used by resident and migratory shorebirds. Although many features of these environments have been thoroughly studied, relatively little attention has been paid to the avian components

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of these marine systems. Furthermore, most of the shorebird research on the Texas coast has emphasized the sandy beaches bordering the Gulf of Mexico (Chapman 1981, 1984) despite the fact that this region provides a smaller proportion of suitable habitat for shorebirds in Texas than other marine environments (Diener 1975).

Like many other coastal areas, the Texas coastline is under constant threat of more extensive development. The rapid destruction of wetlands in wintering and migratory staging areas makes shorebirds prime candidates for population declines (Howe et al. 1989). Conservation and management of the remaining coastal wetlands in Texas will require an understanding of the variation in the numbers and kinds of organisms supported by each habitat type. Such understanding must develop from descriptive studies of the relative abundance of each species throughout the year and the way in which each species uses the wetlands that are available. This is particularly important because many shorebird species or populations follow a circular migratory route, taking a more central route northwards than southwards (Harrington and Morrison 1979). Numerous authors (e.g., Myers 1983, Myers et al. 1987, Senner and Howe 1984, Wunderle et al. 1989) have emphasized the importance of having accurate baseline information on shorebird distribution and abundance along all portions of the migratory routes including the breeding and wintering grounds. The purpose of this study was to quantify the seasonal abundance and habitat utilization of shorebirds on an intertidal mudflat of a bay system in southern Texas.

STUDY AREA AND METHODS

The study site was located on an extensive wind-tidal mudflat surrounding Ward Island (Fig. 1), currently the location of the Corpus Christi State University campus in Corpus Christi, Nueces County, Texas. Ward Island originated as a small island formed by spit accretion in the mouth of the Cayo del Oso (Oso Bay), a small secondary embayment, at its juncture with Corpus Christi Bay (Morton and Paine 1984). Ward Island was enlarged in the early 1940s by the deposition of fill material. Oso Bay is the receiving basin for Oso Creek, which is an intermittent stream draining the coastal uplands (mostly farmlands) west of Corpus Christi.

The periphery of Ward Island consists largely of clay wind-tidal flats subject to inundation primarily in response to wind-driven tides (Smith 1974). There are two extremes in tidal coverage. From May to November, the prevailing winds are southerly or southeasterly and water often covers much of the mudflat. Southeasterly winds have a moderate fetch across Oso Bay and cause erosion along the southeastern shoreline of Ward Island while flooding the tidal flats on the northeastern side. During December, January and February, 15–20 "northers" (rapidly moving cold fronts) pass through coastal Texas bringing rain and winds up to 80 km/h. During these sudden 24–36-h storms, North winds generate intense wave activity in the larger bays but push water away from the

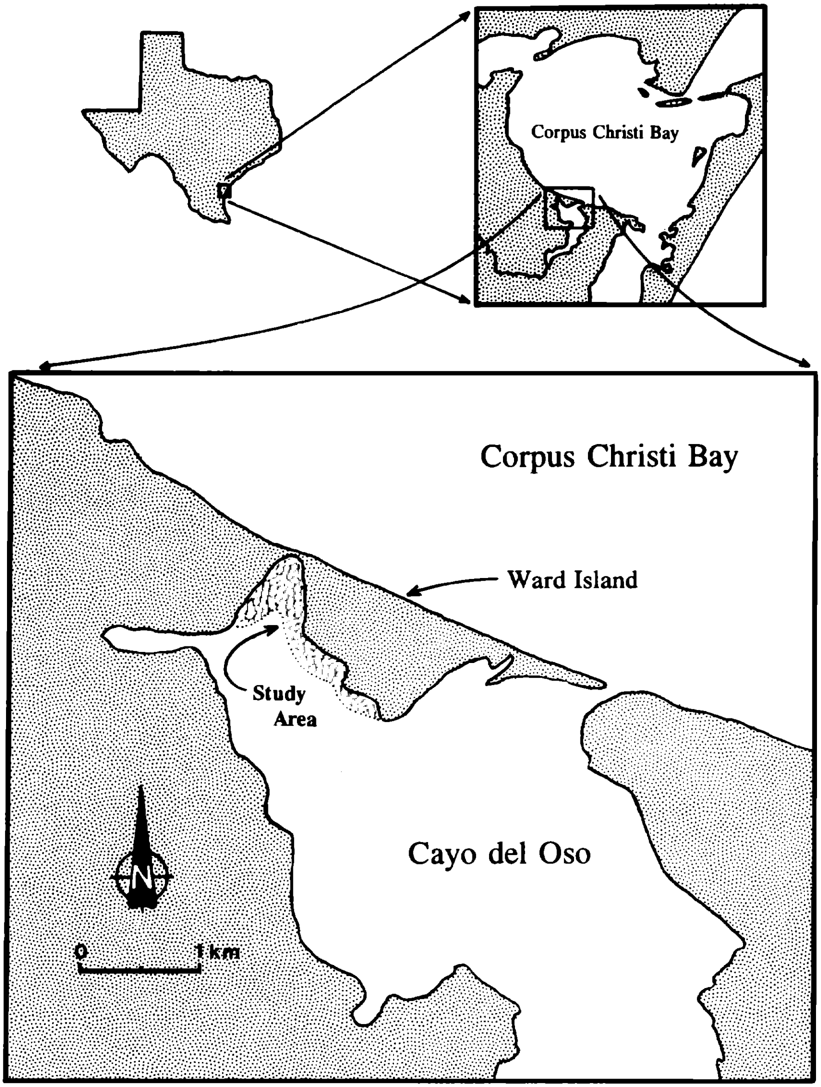

FIGURE 1. Location of study area relative to Ward Island and the juncture between Corpus Christi Bay and the Cayo del Oso on the Texas coast.

tidal-flats around Ward Island. Consequently, a large mudflat is exposed. Diurnal and semi-diurnal astronomical tides are generally small in amplitude in this region (Diener 1975) and have little influence on the extent of the mudflat. Superimposed on the tidal fluctuations caused by the wind, however, is a long-period or semiannual rise and fall of the water level in the bay system (Smith 1974). High water occurs in late May and late

October, whereas the periods of extreme low water are in late February and late July.

Shorebird censuses on the Ward Island mudflat were conducted at weekly or biweekly intervals along an approximately 1-km transect. The area was surveyed on foot from a fixed path that paralleled the shoreline. Shorebirds were counted up to three times during each census and were categorized by species and microhabitat use. Four species common on the southern Texas coast proved difficult to identify. Consequently, the Long- and Short-Billed Dowitchers (*Limnodromus scolopaceus* and *L. griseus*) were regarded as a single category, "dowitchers." Likewise, the Western and Semipalmated Sandpipers (*Calidris mauri* and *C. pusilla*), which are difficult to distinguish in the field (Harrington and Morrison 1979), were lumped as "peeps."

The study area contained three microhabitats: 1) an area of dry and slightly damp clay-sand substrate, which supported sparse stands of glasswort (*Salicornia* sp.), shoregrass (*Monanthochloe littoralis*) and saltgrass (*Distichilis spicata*), and was flooded only during periods of excessive southeasterly winds; 2) an area ranging from the moist substrate at the shoreline to water deep enough to reach the joint between the tibio-tarsus and tarso-metatarsus (or "ankle") of a shorebird; and 3) a flooded area with depths exceeding the ankle joint of a bird. We subsequently referred to the three areas as 1) "flat," 2) "shoreface" and 3) "submerged." Although the division of inundated areas into microhabitats based on the leg length of a species may involve some inaccuracy, it seemed appropriate to judge water depth relative to the ability of a species to function at that depth (Baker and Baker 1973). This criterion was important for categorizing short-legged species of birds at temporary features such as tidal pools.

Abundances and microhabitat preferences (i.e., frequencies) were determined using SPSS^x (SPSS Inc. 1983). Shannon-Weiner diversity indices were calculated each month. Habitat breadths, a mathematical index based upon microhabitat-use frequencies, was calculated for each species using a formula based on the Shannon-Weiner diversity index (Smith 1980). Calculated indices of habitat breadth could potentially range from 0, indicating the maximum degree of habitat specialization, to 1.0, indicating habitat generalization. Habitat overlap was determined using the method of Horn (1966).

RESULTS

Twenty-six shorebird species were observed during the study period, but five species were documented fewer than five times. Shorebird abundances fluctuated widely throughout most of the year. Shorebirds used the mudflat all year long, but numbers were low during the summer months (Table 1). The most frequently observed species were Willets (*Cataptrophorus semipalmatus*) and Black-Bellied Plovers (*Pluvialis squatarola*), which were present throughout the year in small numbers. The most common species were Dunlins (*Calidris alpina*), dowitchers, Amer-

Table 1. Abundances of all species of shorebirds observed on the Oso Bay mudflat during 33 censuses in the fall (1 Aug.–31 Oct.), 30 censuses during the winter (1 Nov.–31 Jan.), 36 censuses during the spring (1 Feb.–30 Apr.) and 30 censuses during the summer (1 May–31 Jul.). Numbers in parentheses represent the percent relative abundance during each season and were calculated only for species with sample sizes >300.

Species	Fall	Winter	Spring	Summer	Total
Peeps	3160 (66.5)	4623 (39.8)	4980 (29.7)	86 (5.1)	12,849
Dowitchers	323 (6.8)	1196 (10.3)	4038 (24.1)	367 (21.9)	5924
Calidris alpina	88 (1.9)	2064 (17.8)	2017 (12.0)	327 (19.5)	4496
Recurvirostra americana	154 (3.2)	1967 (16.9)	2239 (13.4)	0 (0.0)	4360
Pluvialis squatorola	159 (3.3)	737 (6.3)	632 (3.8)	212 (12.6)	1740
Limosa fedoa	155 (3.3)	138 (1.2)	919 (5.6)	38 (2.2)	1250
Cataptrophorus semipalmatus	192 (4.0)	159 (1.4)	521 (3.1)	217 (12.9)	1089
Himantopus mexicanus	142 (3.0)	279 (2.4)	445 (2.7)	39 (2.3)	905
Calidris alba	110 (2.3)	130 (1.1)	296 (1.8)	26 (1.6)	562
Charadrius wilsonia	113 (2.4)	3 (0.0)	160 (0.9)	184 (11.0)	460
Charadrius semipalmatus	21 (0.4)	106 (0.9)	212 (1.3)	1 (0.0)	340
Numenius americanus	75	7	1	43	206
Calidris himantopus	2	0	104	95	201
Tringa flavipes	2	4	91	0	97
Charadrius alexandrinus	8	57	21	0	86
Charadrius vociferus	23	59	1	0	83
Arenaria interpres	14	36	14	5	69
Phalaropus tricolor	0	0	13	21	34
Tringa melanoleuca	3	8	13	0	24
Numenius phaeopus	0	0	9	12	21
Charadrius melodus	11	0	8	1	20
Calidris bairdii	0	0	2	1	3
Actitis macularia	0	0	1	1	2
Calidris melanotus	0	0	0	1	1
Total	4755	11,623	16,768	1677	34,822

TABLE 2. Mean monthly densities (number/km) and Shannon-Weiner diversity indices.

Month	Density	Diversity
January 1985	736	2.44
February	485	2.58
March	613	2.63
April	338	3.08
May	74	2.90
June	29	2.26
July	70	2.36
August	424	1.14
September	43	3.22
October	63	3.22
November	202	2.38
December	406	2.34
January 1986	364	2.35

ican Avocets (*Recurvirostra americana*), and peeps. Together, these species comprised greater than 80% of the total shorebird population from November to March, 73% in April and 55% in May and October. Dowitchers comprised 51% of the shorebird population during July, but were displaced as the most abundant shorebirds by peeps (83% of the total population) in August. During June and September, no species or group of species dominated in numbers.

Diversity indices reflect both species richness and abundance (Table 2). Although the greatest shorebird use of the area occurred during January–March, the coldest months of the year in southern Texas, the greatest species diversity in the area occurred during September and October, the peak of fall migration. Low species diversity occurred throughout the summer months. Most of the shorebirds that frequented Oso Bay mudflats during the summer were species that breed in the area.

All but two species observed five or more times used all of the available microhabitats to some extent (Table 3). Monthly habitat breadth indices of the four most common species show much fluctuation (Table 4), which may be related not only to changes in shorebird abundance but also to possible changes in resource abundance. Dunlins and peeps were the most generalized species in their habitat-use patterns whereas dowitchers and American Avocets were more specialized.

When the habitat-use patterns for the four most common species were compared on a monthly basis to determine the extent of microhabitat overlap between species, much overlap was found (Table 5). Dunlins and dowitchers were the most similar in their overall habitat preferences. Throughout the year, both preferred to feed in the submerged zone. Avocets and peeps exhibited the least microhabitat overlap.

DISCUSSION

Shorebirds were most abundant on the tidal flats of Oso Bay during spring migration (February–April) and the winter months (November–

TABLE 3. Overall microhabitat preferences (%) for all species (in descending order by relative abundance).

Species	Submerged	Shoreface	Flat
Pluvialis squatorola	25	48	27
Cataptrophorus semipalmatus	44	22	34
Peeps	29	54	17
Dowitchers	60	37	4
Calidris alpina	51	37	12
Calidris alba	28	57	18
Charadrius wilsonia	10	34	56
Numenius americanus	25	20	55
Recurvirostra americana	74	20	6
Limosa fedoa	69	22	9
Himantopus mexicanus	75	19	3
Charadrius semipalmatus	13	63	25
Charadrius vociferus	5	29	66
Calidris himantopus	71	29	0
Tringa flavipes	76	18	6
Charadrius alexandrinus	4	50	46
Numenius phaeopus	6	31	63
Tringa melanoleuca	53	34	13
Arenaria interpres	25	42	33
Charadrius melodus	0	64	36
Phalaropus tricolor	25	75	0
Calidris bairdii	50	50	0
Actitis macularia	0	50	50
Calidris melanotus	0	100	0

January). The area did not seem to be important as a stopover for large numbers of birds during the fall, however. High diversity indices for September and October indicated that the area was used by many species in relatively low numbers. A large flock of migrating peeps stopped over briefly in August 1985, resulting in an artifically low diversity index for that month.

During the periods when the Oso Bay area is most heavily used by shorebirds, the food resources are abundant. Normally cyclic populations of phytoplankton (Henley and Rauschuber 1978), benthic organisms (Flint and Kalke 1985), and intertidal marcoinvertebrates (Vega 1988) are at their peak abundance during the winter and early spring. Even though food supply may be adequate during the winter and spring months on Oso Bay mudflats, Goss-Custard (1970, 1980) demonstrated that adequate foraging space on the entire area is also necessary for individuals to meet their energetic requirements.

Duffy et al. (1981) suggested that competition in shorebird populations can be assessed by examining their use of the habitat. If interspecific competion for space or food was important in limiting shorebird populations during the winter and early spring on Oso Bay, then small habitat breadth values and reduced habitat overlap would be expected. Throughout the months when overall shorebird abundance was the greatest, how-

TABLE 4. Monthly habitat overlap values for each species pair when habitat breadth values for dowitchers (Do), Dunlins (Dn), American Avocets (Av), and peeps (Pe) are compared.

Month	Do–Dn	Do–Av	Do–Pe	Dn–Av	Dn–Pe	Av–Pe
January 1985	0.870	0.965	0.685	0.808	0.948	0.596
February	0.961	0.947	0.843	0.835	0.956	0.651
March	0.997	0.937	0.950	0.974	0.842	0.833
April	0.967	0.957	0.902	0.999	0.936	0.936
May	0.964	—	0.837	—	0.891	—
June	—	—	—	—	—	—
July	—	—	—	—	—	—
August	—	—	0.925	—	—	—
September	0.811	—	0.971	—	0.933	—
October	0.893	0.980	0.917	0.864	0.863	0.819
November	0.986	0.981	0.884	0.992	0.891	0.828
December	0.978	0.998	0.855	0.963	0.927	0.824
January 1986	0.952	0.994	0.880	0.945	0.941	0.844
Overall	0.982	0.977	0.916	0.961	0.962	0.854

ever, the opposite was true; the four most abundant shorebird species, Dunlins, American Avocets, dowitchers and peeps, all exhibited a high degree of habitat overlap. The avocets often fed in deeper water than the other species and obtained food by sweeping their bills from side to side at the sediment surface (Hamilton 1975). As a result, the habitat breadths calculated for avocets were generally smaller than those for Dunlins, peeps, and dowitchers because the avocets were not bound to organisms living in the substrate. Dunlins, peeps and dowitchers fed in shallow water by probing in the sediment. Although these species occupy the same feeding habitat, they might exploit different resources by probing to different depths (Quammen 1984) or feeding in areas differing slightly in

TABLE 5. Monthly habitat breadth values for each species.

Month	Dunlins	Dowitchers	Avocets	Peeps
January 1985	0.966	0.624	0.492	0.914
February	0.909	0.769	0.497	0.834
March	0.746	0.797	0.646	0.906
April	0.935	0.791	0.942	0.927
May	0.808	0.613	—	0.892
June	—	—	—	—
July	—	0.853	—	—
August	—	0.556	—	0.894
September	0.512	0.512	—	0.625
October	0.921	0.631	0.579	0.432
November	0.819	0.737	0.691	0.869
December	0.606	0.482	0.432	0.797
January 1986	0.750	0.473	0.373	0.791
Average	0.876	0.728	0.650	0.901

sediment granulometry (Quammen 1982). A similar correlation between resource abundance and relaxation of competition was found by Wilson (1990) in Nova Scotia during August, the peak period of migration through the area by Semipalmated Sandpipers.

Shorebird habitat breadths in the summer and fall months are generally smaller than those in the winter. This may indicate that resources are less abundant or that habitats are less available during the summer and fall. The mudflat area is reduced during this part of the year due to the influence of the prevailing southeasterly wind on tidal movements. Phytoplankton and benthic infaunal populations decline dramatically during the summer as water temperatures and salinities increase in the shallow bays (Flint and Kalke 1985, Henley and Rauschuber 1978). The influence of interspecific competition among shorebirds can be demonstrated during the summer and fall, however. Dowitcher habitat breadths were wide in July when these birds had the mudflat nearly to themselves. Following an influx of peeps in August, dowitcher habitat breadths contracted substantially. Habitat overlap remained high during that period because the area available for foraging was still reduced.

Peak resource abundance in the Oso Bay area appears to occur in the winter and early spring, the period when resource abundances on the eastern and western coasts of North America are at their lowest. Competition for space and, by extension, food resources, is minimal in the Oso Bay area during the winter and early spring when shorebird abundances are at the maximum. If resources are the most abundant on the Texas coast during the winter and northward migration, then this availability may help explain the evolution of the circular migration patterns seen in many species of shorebirds.

Circular migratory routes were hypothesized by Cooke (1910) who suggested that, after breeding in arctic and subarctic habitats, many North American shorebirds migrate during the late summer and early fall to coastal staging areas in southeastern Canada and northeastern United States. There the shorebirds feed on abundant food resources and store fat in preparation for a nonstop flight over the Atlantic Ocean to wintering areas in Central and South America (Hicklin 1987, McNeil and Burton 1977, Morrison 1984, Myers et al. 1987, Williams et al. 1977). Many species accumulate insufficient energy reserves on the wintering grounds to complete a trans-oceanic flight northward and, therefore, return to the breeding grounds by crossing the Caribbean Sea and migrating northward along the Atlantic coast or up the Mississippi Flyway (McNeil and Burton 1977). By comparing the morphology of Semipalmated Sandpiper specimens from migration areas with reference samples from different parts of the breeding range, Harrington and Morrison (1979) were able to trace the southward and northward migratory patterns of different breeding populations. They found that some Semipalmated Sandpipers exhibited a somewhat elliptical migratory pattern with passage southward along the Atlantic coast during the fall and spring movements northward through the central states. Myers et al. (1990) suggest that such circuitous pathways may be followed by a variety of species including Lesser Golden-Plovers (*Pluvialis dominica*), White-rumped Sandpipers (*Calidris fusicollis*), and Sanderlings (*Calidris alba*).

If the Texas coast is logistically important to the migratory patterns of several shorebird species, the protection of mudflats and other shoreline habitats is essential. Such habitats are often viewed as barren and unproductive when, in fact, they provide resources that are crucial to the survival of many species.

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