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ABUNDANCE AND DISTRIBUTION OF SHOREBIRDS AT THE CABO ROJO SALT FLATS, PUERTO RICO

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Abstract.—Migratory and resident shorebirds were censused from a vehicle or on foot at the Cabo Rojo salt flats, Puerto Rico from 1985 to 1992. A total of 28 species was identified. Highest number of individuals was recorded between August and December, and again in March each year. Migrants made up about 87% of the counts annually except in June when counts were split evenly between resident and migrant species. The most abundant migrants were small calidrid sandpipers, Lesser Yellowlegs (*Tringa flavipes*) and Stilt Sandpipers (*Calidris himantopus*). Black-necked Stilts (*Himantopus mexicanus*) were the most abundant resident species. During fall, daily peak counts ranged from 3477 to 8059 individuals. August had the highest mean counts (3459 ± 896 SE). Shorebird numbers recorded in October, the midpoint of fall migration, remained stable over 8 yr. Within the salt flats, shorebird distribution varied by census unit, season and year. Factors influencing their distribution include food availability and hydrological conditions, which are largely the result of salt extraction operations. The salt flats are numerically the most important site for shorebirds in Puerto Rico. Regionally, the salt flats are an important stopover area when compared to 22 other sites in the Caribbean. Of the peak number of shorebirds reported for all sites, 29% were recorded at the salt flats. The salt flats are of regional importance to small calidrids, Stilt Sandpipers, and Snowy Plovers (*Charadrius alexandrinus*).

ABUNDANCIA Y DISTRIBUCIÓN DE PLAYEROS EN LAS SALINAS DE CABO ROJO, PUERTO RICO

Sinopsis.—Playeros residentes y migratorios fueron censados en las salinas de Cabo Rojo, Puerto Rico de 1985 a 1992. Un total de 28 especies fueron identificadas. Cada año, los contajes más altos se registraron entre agosto y diciembre, y nuevamente en marzo. El 87% de los individuos contados a través del año son migratorios excepto en junio cuando la proporción entre migratorios y residentes fue similar. Playeritos del género *Calidris,* Playero

Guineilla Pequeño (*Tringa flavipes*), Playero Patilargo (*Calidris himantopus*) y la Viuda (*Himantopus mexicanus*) fueron las especies más abundantes. Durante el otoño, los contajes diarios más altos fluctuaron entre 3477 y 8059 individuos. En agosto se registraron los contajes promedios más altos (3459 ± 896 SE). El número de playeros contados en octubre durante 8 años permaneció estable. La distribución de playeros varía por área, estación y año. La misma es afectada por la disponibilidad de alimentos y las condiciones hidrológicas de las salinas que en gran medida son el resultado de las operaciones de extracción de sal. Las salinas son numéricamente el área más importante para playeros en Puerto Rico. Regionalmente, emergen como un área de importancia cuando se compara con otras 22 áreas en el Caribe. Del total de los números máximos informados para todas las áreas, 29% son reportados para las salinas. Las salinas son de importancia regional para playeritos del género *Calidris*, Playero Patilargo, y el Playero Blanco (*Charadrius alexandrinus*).

Shorebird overwintering survival rates and subsequent reproductive output can be significantly affected by the quality and continued availability of migratory and wintering areas (Myers et al. 1987, Myers and Sallabery 1985, Senner and Howe 1984). The importance of identifying and protecting these sites has been recognized by conservation agencies and organizations throughout the Western Hemisphere, and represents an international conservation challenge (Myers et al. 1987). Most of this work has taken place in northern latitudes, however (Harrington and Morrison 1979). Senner and Howe (1984) listed stopover and wintering areas in North America and provided an idea of their importance based on survey information. Complementary information for the Caribbean, Central and South America, where most of the North American shorebirds migrate, is lacking or fragmentary at the best (see Morrison 1984, Morrison and Ross 1989).

Early attempts to identify valuable shorebird habitats in Puerto Rico were made by Raffaele and Duffield (1979). In their work, the Cabo Rojo salt flats were identified as one of the prime habitats for resident and migratory shorebirds in the island. The value of the salt flats to aquatic wildlife was subsequently stressed by Del Llano et al. (1986) and Ortiz-Rosas and Quevedo-Bonilla (1987). Progress towards recognizing the significance of the salt flats and formulating appropriate conservation strategies has been hampered by lack of baseline information, however. The need for these data is heightened by the ever increasing demands to develop wetlands and shoreline habitats on the island (Moreno and Pérez 1980, Raffaele and Duffield 1979). Unfortunately, shorebirds are some of the least studied birds in Puerto Rico. Available information consists of checklists, notes, and short-term surveys (e.g., Collazo et al. 1987; Danforth 1929; Leopold 1963; McCandless 1961, 1962; Moreno and Pérez 1980; Wetmore 1916). Work by Wunderle et al. (1989) at the Jobos Bay Estuary constitutes the only consistent, year-round effort to quantify shorebird abundance and species composition. Work by Lee (1989) on Snowy and Wilson's (*Charadrius wilsonia*) Plovers represents the only intensive research on the breeding ecology of resident species. In 1985, studies were initiated to augment our knowledge of shorebird migrational patterns in the eastern Caribbean and document the significance of the Cabo Rojo salt flats. Here we report on the species composition, abun-

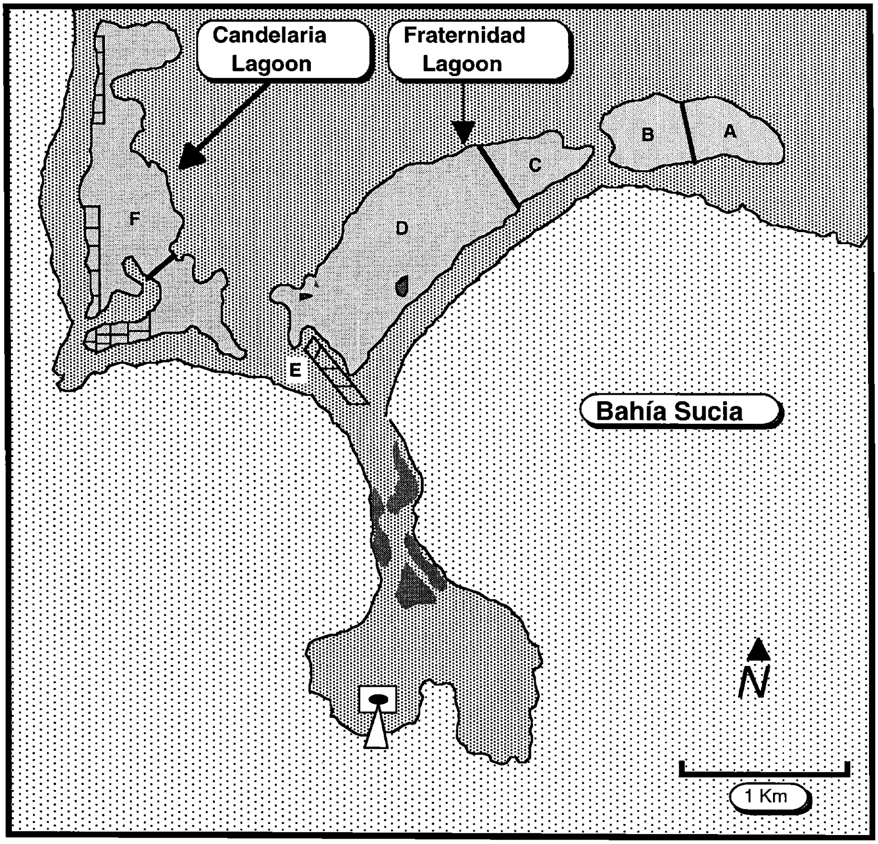

FIGURE 1. Map of the Cabo Rojo salt flats showing Fraternidad and Candelaria systems and census units (A–F).

dance and distribution of resident and migratory shorebirds at the Cabo Rojo salt flats based on data collected 1985–1992. We also assess the significance of the salt flats at a local and regional scale by comparing our findings to data obtained from 22 other sites in the Caribbean.

STUDY AREA

The Cabo Rojo salt flats are located in southwestern Puerto Rico (67°12′N, 18°57′W). Two large but shallow (maximum depth 46 cm) lagoons (Fraternidad and Candelaria), covering approximately 445 ha, are the most striking features of the area (Fig. 1). Both lagoons are used as holding or storage ponds prior to channeling water to evaporating basins built for salt extraction. Both Fraternidad and Candelaria have their own systems of evaporating basins.

To facilitate shorebird counts and elucidate distribution patterns, the salt flats were divided into six census units, arbitrarily defined by physical features (e.g., dikes, evaporating basins) and designated A–F. Units A–E occur within the Fraternidad system (Fig. 1). Units toward eastern Fraternidad (A, B) are flooded seasonally (fall), by both rainfall and tidal influence. Ocean water is pumped regularly into unit C, moved onto unit D, and ultimately, to evaporating basins (unit E). Unit F comprises all of the Candelaria system. This system has only one holding pond located southeast of the evaporating basins. The northern portion of the Candelaria lagoon has no connection to the ocean and is usually dry. Flooding occurs when enough water is pumped into the southern portions of Candelaria and overflows, or after heavy rains.

METHODS

Shorebirds were censused every year during July–December, the period of primary interest. Censuses were also conducted during the remainder of the year in 1986 and 1987. Censuses were conducted every 2 wk from October 1985 to December 1987, and in July, August and October–December 1988. Weekly counts were conducted each fall in 1989 (October–November), 1990 (August–November), 1991 (August–December) and 1992 (September–December). Counts were made with the aid of binoculars and spotting scopes from a vehicle or on foot along dirt roads, parallel to census units. Censuses were conducted from 0630 to 1000 hours. When possible, all individuals were identified to species. As a result of difficulties involved in separating Least (*Calidris minutilla*), Semipalmated (*Calidris pusilla*), Western (*Calidris mauri*) and White-rumped (*Calidris fuscicollis*) Sandpipers on the basis of their winter plumages and occurrence in large mixed-species flocks, we pooled these species under the category of small calidrid sandpipers.

On the basis of abundance patterns, we divided the year into two seasons, spring (January–June) and fall (July–December). Abundance was expressed as the mean number of shorebirds ($\pm$ SE) per month or season. Prior to calculating these means, counts within a given month and year were averaged to obtain a monthly estimate and minimize problems associated with repeated measures (Hurlbert 1984). Monthly means for fall were based on 3–8 yr, depending on the month, whereas those for spring were based on 2 yr. Seasonal means were obtained by averaging monthly estimates within a given year and season, and then averaging means across years, 8 yr for fall and 2 yr for spring. Population trends over the duration of the study (i.e., increasing, decreasing or stable) for the shorebird community and for selected species were examined using regression analysis. October counts were selected for this analysis because they were replicated every year. Also, October marks the mid-point of fall migration and the shorebird assemblage is well represented both in terms of species richness and numbers.

We examined patterns of shorebird distribution within the salt flats because salt extraction operations have created a mosaic of habitats, comprised mostly of an array of hydrological conditions. We then explained observed patterns on the basis of available information. In Fraternidad, for instance, the existing range of hydrological conditions has been shown to affect shorebird prey composition and availability (Grear 1992). We tested whether the mean number of birds/ha during fall from 1985 to 1992 were the same among census units using ANOVA. We used birds/ha to account for area differences in census units. Data met assumptions of normality. Month, a repeated measure, was nested within year (Hurlbert 1984). Orthogonal contrasts were used to determine if means from significant terms in the model were different from each other using JMP (SAS Institute, Inc. 1989). Contrasts were considered significant at $P <$ 0.05. Mean numbers per ha were also calculated for selected species for spring and fall, and depicted graphically. The approximate size of each census unit was obtained from surveying data (U.S. Fish and Wildlife Service Caribbean Field Office, Boquerón, Puerto Rico). The deepest portions (geometric core areas) of Fraternidad and Candelaria lagoons (areas D and F) were seldom used by shorebirds. Adjusted area estimates were obtained using a band of 150–200 m running inward from the sandy-vegetation edge around each system. This adjustment ensured comparisons among units with uniform water depth. Area estimates (ha) per census unit were 17.4 (A), 19.0 (B), 15.4 (C), 72.3 (D), 10 (E) and 104.6 (F). Area E was 10 ha.

The relative importance of the salt flats was assessed at the local and regional levels. At the local level, we compared the sum of total observations (year-round) recorded at the salt flats to those from Jobos Bay Estuary (Wunderle et al. 1989). At a regional level, census data were compared to those from 22 other coastal sites (including Jobos Bay) across the Caribbean. Census data were obtained from the International Shorebird Survey (Manomet Observatory), henceforth ISS, except for those obtained by Wunderle et al. (1989). Censuses at ISS localities were conducted since 1974 and generally made at 10-d intervals. To avoid problems associated with uneven sampling efforts and large variances, we used the maximum count of each species as the estimate for a given site (Colwell and Cooper 1993). Sites with at least 3 yr of data were selected to allow for interannual variability in peak numbers. Salt flats census data were compared to data from the Caribbean sites in two ways. Firstly, the relative abundance of each of 24 species and one species group (small calidrids or peeps) at the salt flats was expressed as a percentage of a grand total (peak counts) for each species from all sites. Secondly, salt flats numbers were expressed as a percentage of a multi-site grand total. The grand total was obtained by adding the single highest count of each species at each site and then summing site totals.

RESULTS

A total of 28 species was recorded from 1985 to 1992 (Table 1). Twenty four were North American migrants. Black-necked Stilts, Snowy Plovers, Wilson's Plovers and Killdeers (*Charadrius vociferus*) breed locally and thus are considered residents. On the basis of year-round (1986, 1987)

TABLE 1. Species composition, mean seasonal number (SE) and relative abundance of shorebirds observed at the Cabo Rojo salt flats, Puerto Rico from 1985 to 1992. Sample sizes (number of years) for fall and spring were eight and two, respectively. Lower sample sizes and resident status are indicated parenthetically. Relative abundance of each of 18 species and one species group (Calidrid Sandpipers) at the salt flats were expressed as a percentage of the grand total (peak fall counts) for each species obtained at 23 Caribbean sites (salt flats included). Data were collected through the International Shorebird Survey Program (Manomet Observatory for Conservation Sciences).

Species	Fall (Jul.–Dec.)	Spring (Jan.–Jun.)	% of grand total
Calidrid Sandpipers (Least, Western, Semipalmated and White-rumped)	1948 (264)	807 (296)	47
Stilt Sandpiper	406 (62.5)	22 (9.7)	43
Lesser Yellowlegs	384 (41.0)	173 (55.6)	21
Black-necked Stilt (resident)	287 (37.0)	59 (45.1)	65
Semipalmated Plover	31 (3.8)	15 (0.5)	13
Snowy Plover (resident)	27 (4.5)	21 (7.5)	68
Wilson's Plover (resident)	23 (3.2)	10 (2.8)	42
Greater Yellowlegs	23 (8.0)	14 (9.1)	40
Ruddy Turnstone	17 (2.6)	24 (5.0)	11
Black Bellied Plover	16 (2.7)	11 (2.2)	8
Short-billed Dowitcher	14 (5.3)	18 (—)[a]	19
Red-necked Phalarope (n = 4)	8 (2.2)	—[a]	
Pectoral Sandpiper	5 (1.4)	—[a]	8
Killdeer (resident)	5 (1.6)	4 (2.7)	
Red Knot	4 (0.4)	—[a]	20
Sanderling	4 (1.1)	10 (—)[a]	12
Spotted Sandpiper	4 (0.8)	4 (0.2)	13
Willet	4 (0.4)	1 (—)[a]	3
Whimbrel	3 (0.3)	1 (—)[a]	9
Piping Plover (n = 4)	2 (0.5)	2 (0.2)	79
Hudsonian Godwit (n = 3)	1 (0.3)	—[a]	
Buff-breasted Sandpiper	1 (—)[a]	—[a]	
Wilson's Phalarope (n = 2)	1 (0)	—[a]	
Lesser Golden Plover	2 (—)[a]	—[a]	4

[a] Species not observed or observed only on one occasion.

data, species richness per month was highest in August (23 species) and lowest in June (10 species). Small calidrids, Lesser Yellowlegs and Stilt Sandpipers were the most abundant migrants. Collectively these species comprised 85% and 83% of the mean number of shorebirds recorded during fall and spring, respectively. Black-necked Stilts were the most abundant resident followed by the Snowy Plover. According to Raffaele's (1989) abundance rating, over half of the species were common (5–20 observed in a single day) to very common (≥20 observed in a single day) in either season. Of the resident community, only the Killdeer was uncommon (observed at least twice a year). Migrants recorded once were the Buff-breasted Sandpiper (*Tryngites subruficullis*) and Lesser Golden Plover (*Pluvialis dominica*). Migrants present during fall but not in spring were the Pectoral Sandpiper (*Calidris melanotos*), Red Knot (*Calidris can-*

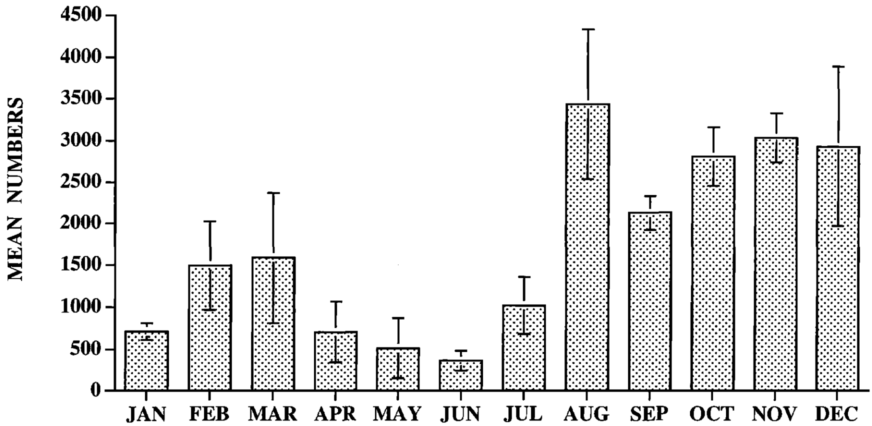

FIGURE 2. Seasonal number of shorebirds (mean ± SE) recorded at the Cabo Rojo salt flats, Puerto Rico. Means for July–December were based on 3–8 yr, depending on the month. Means for January to June were based on 1986 and 1987.

utus), Hudsonian Godwit (*Limosa haemastica*) and Red-necked Phalarope (*Phalaropus lobatus*) (Table 1).

The fall migratory season extends from July–August to December (Fig. 2). Monthly averages were highest in August (3459 ± 896) and variability was greatest in August and December. Shorebird numbers dropped markedly in January, increased during February and March, and decreased and remained at their lowest levels through spring and early summer (Fig. 2). Peak monthly averages varied by species. Small calidrids (2638 ± 1047) and Black-necked Stilts (328 ± 99) peaked in December. Lesser Yellowlegs (639 ± 277) and Stilt Sandpipers (797 ± 191) peaked in August whereas Snowy Plovers peaked in July (49 ± 20). Daily peak counts during fall for the entire shorebird community ranged from 3477 (11 Dec. 1992) to 8058 (10 Oct. 1989) individuals. Highest daily counts for the most common migrant and resident species were: 6190 for small Calidrids (6 Dec. 1985); 1421 for Lesser Yellowlegs (8 Aug. 1986); 1674 for Stilt Sandpipers (1 Oct. 1989); 930 for Black-necked Stilts (6 Oct. 1989); and 89 for Snowy Plovers (30 Jul. 1986). On the basis of year-round data, migrants made up the majority of the counts (~87%) except in June when counts were split evenly between residents and migrants.

As a community, shorebird numbers recorded in October over 8 yr remained stable ($\bar{x}$ = 3023 ± 1145; F = 0.20; df = 1, 6; P = 0.77). Population trends also remained stable for small calidrids ($\bar{x}$ = 1927 ± 682; F = 0.40; df = 1, 6; P = 0.84); Stilt Sandpipers ($\bar{x}$ = 443 ± 252; F = 0.24; df = 1, 6; P = 0.63); and Lesser Yellowlegs ($\bar{x}$ = 415 ± 244; F = 2.03; df = 1, 6; P = 0.20). October numbers were also stable for the resident Black-necked Stilt ($\bar{x}$ = 294 ± 198; F = 0.16; df = 1,6; P = 0.69) and Snowy Plover ($\bar{x}$ = 32 ± 29; F = 0.02; df = 1, 6; P = 0.89).

During fall, the shorebird community distribution varied significantly by census unit and year (F = 1.89; df = 34, 109; P = 0.007). Yearly densities were significantly greater in units A (1987, 1989, 1990) or B (1985, 1986, 1991) except in 1988 (higher in C) and 1992 (higher in E). At the species level, patterns varied by season (Fig. 3). Small calidrids concentrated on units C and D during spring, and on A and B during fall. Small calidrids were also the densest of all four species on unit F. Lesser Yellowlegs were more dense on units B and C in spring, and on A and B in fall. Black-necked Stilts were most numerous on units A and C both during spring and fall. Snowy Plovers concentrated mostly on units C, D and E in spring, whereas in fall, distribution was more even with highest densities in unit C.

During 1985–1986, Wunderle et al. (1989) recorded a total of 22,575 individuals in Jobos Bay Estuary. During the same period, we recorded a total of 41,418 or 83% more individuals. In 1986–1987, observations totaled 47,862 or 112% more than those recorded at Jobos Bay. Regionally, peak number of shorebirds recorded at the salt flats made up 29% of the total peak numbers recorded in 23 Caribbean sites (including the salt flats) (Table 2). The salt flats were only rivaled by Trinidad with 27% of the observations. A second site in Puerto Rico, Jobos Bay Estuary, accounted for 7% of the observations. In terms of relative abundance, ≥40% of the Greater Yellowlegs (*Tringa melanoleuca*), Stilt Sandpipers and small calidrid sandpipers were recorded at the salt flats (Table 1). Black-necked Stilts and Wilson's Plovers comprised 65% and 42% of the observations for the region, respectively. Numbers of Snowy and Piping Plovers (*Charadrius melodus*) at the salt flats constituted over 65% of the total regional observations.

DISCUSSION

The Cabo Rojo salt flats support at least 118 species of terrestrial and aquatic avian species (U.S. Fish Wildlife Service 1988, 1993). Shorebirds, however, constitute the largest avian component. Twenty-eight species were recorded during our study. Of these, 23 could be recorded in 1 mo (e.g., August) and daily community counts sometimes exceeded 8000 individuals. Migrants, primarily small calidrids, Stilt Sandpipers and Lesser Yellowlegs, dominated counts year-round except in June. As in the Jobos Bay Estuary (Wunderle et al. 1989), these species were the most abundant at the salt flats. Black-necked Stilts were the only resident species to achieve comparable abundance levels to migrants during either spring or fall periods. High standard errors during August and December punctuate the transition from low to high numbers (July–August) and vice versa (December–January), and define the fall migratory season at the flats. Preliminary data on seasonal changes in sex and age ratios, and mark-resight data (Harrington unpubl. data, U.S. Fish and Wildlife Service 1988) indicate that this is a period of high population turnover. Birds seen during fall probably stage at the salt flats for varying lengths of time (see Alerstam and Lindstrom 1990) before moving south to their migratory terminus. Population fluctuations, particularly late in the season,

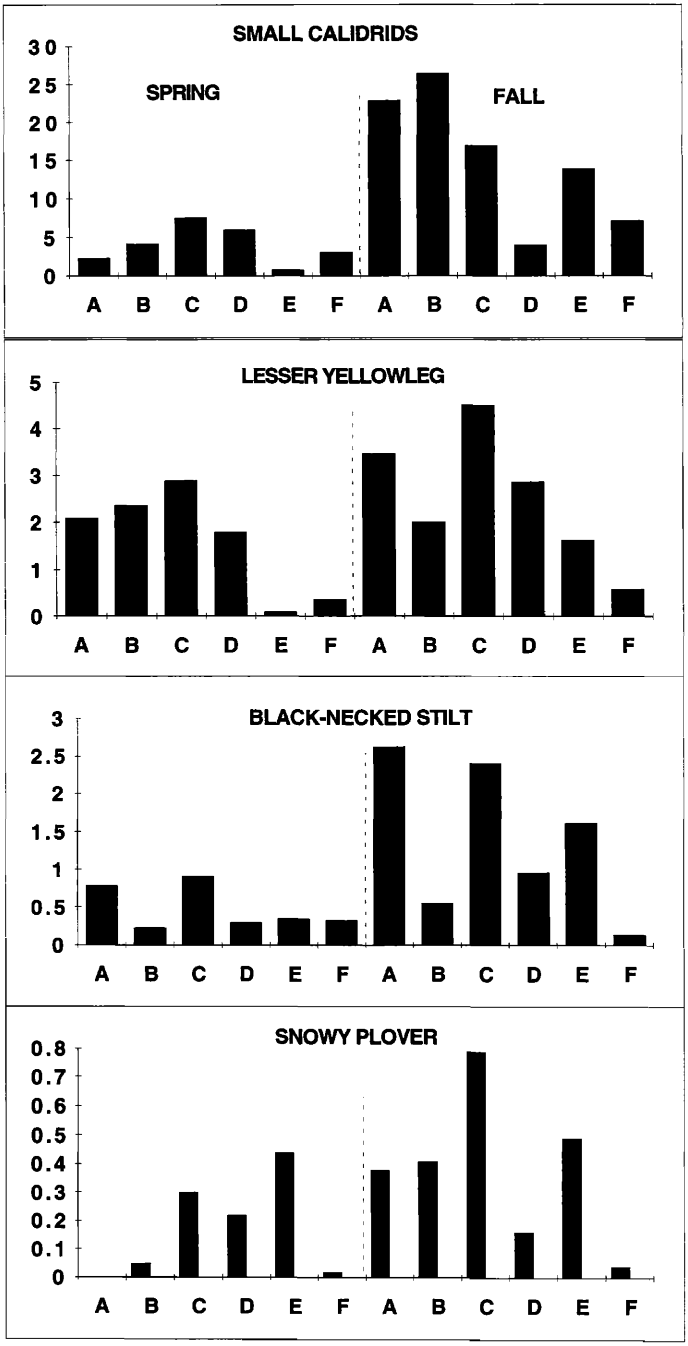
SMALL CALIDRIDS
SPRING
FALL
30
25
20
15
10
5
0
A B C D E F A B C D E F
LESSER YELLOWLEG
5
4
3
2
1
0
A B C D E F A B C D E F
BLACK-NECKED STILT
3
2.5
2
1.5
1
0.5
0
A B C D E F A B C D E F
SNOWY PLOVER
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
A B C D E F A B C D E F

TABLE 2. Percent of peak shorebird numbers recorded at 23 locations in the Caribbean participating in the International Shorebird Survey Program Manomet Observatory for Conservation Sciences). Locations with at least 3 yr of data were included.

ISS location	Peak #	% of total
Aruba, Sewage Treatment Plant	501	1.2
Anegada Island	3190	7.8
Antigua, West Indies	2051	5.0
Antigua, Buccaneer Cove	432	1.1
Antigua, Fitches Creek	173	0.4
Antigua, Salt Flats	827	2.0
Antigua, Beach Hotel	91	0.2
Bahamas, Nassau	1	0.002
Bahamas, Staniard Creek	91	0.2
Bahamas, Fofar Field Station	10	0.02
Bahamas, Somerset Beach	63	0.2
Bahamas, San Andros	2	0.005
Grenada, Pt. Saline	524	1.3
Jamaica, Yallah's Pond	948	2.3
Puerto Rico, Constitution Bridge	1977	4.8
Puerto Rico, Culebra Ponds	36	0.1
Puerto Rico, Cabo Rojo Salt Flats	12,039	29.4
Puerto Rico, Jobos Bay Estuary	2812	6.8
Trinidad, Pointe-a-Pierre	10,870	26.6
St. Thomas, USVI, Red Bay	52	0.1
St. Thomas, USVI, Lagoons	243	0.6
St. Croix, U.S. Virgin Islands	3730	9.1
St. John, U.S. Virgin Islands	239	0.6
Grand Total	40,902	100.0

probably include birds converging at the salt flats from adjacent islands or sites elsewhere in Puerto Rico before departing from the flats in December–January.

Seasonal patterns of shorebird numbers between the salt flats and Jobos Bay Estuary (Wunderle et al. 1989) were similar. Differences between sites exist in terms of species richness and abundance. Not much importance is placed on the former because differences could be accounted for by varying lengths of sampling (1 vs. 8 yr). Differences in numbers are probably indicative of the significance of each site on a local scale, however. Between-site comparisons indicated that we recorded 83–112% more birds than Wunderle et al. (1989) at Jobos Bay. Sharp differences in abundance also emerge when daily peak counts are considered (peak count at Jobos Bay was 2812). These findings and those reported by Moreno

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FIGURE 3. Mean number of shorebirds per ha recorded in six census units during spring (January–June) and fall (July–December) at the Cabo Rojo salt flats, Puerto Rico. Means for July–December are based on 1985–1992. Means for January to June are based on 1986 and 1987. Letters refer to census units shown in Figure 1.

and Pérez (1980) suggest that the salt flats are numerically the most important area for shorebirds in the island.

Numbers of shorebirds recorded in October remained relatively stable. This was the case for the entire community as well as for small calidrids, Stilt Sandpipers, Lesser Yellowlegs, Black-necked Stilts and Snowy Plovers. A stable trend suggests that suitable habitat conditions existed during our monitoring efforts and that, for migrant shorebirds, the salt flats are a traditional staging area. Local trends are of limited value in assessing population status of a species. Changes in numbers can be caused by changes in size and composition of the migratory population or by conditions permitting arrival (e.g., weather) (Clark et al. 1993, Colwell 1993, Morrison 1984). Analyses at a larger scale are more appropriate (i.e., Howe et al. 1989), and these indicate that Sanderlings (*Calidris alba*), Short-billed Dowitchers (*Limnodromus griseus*) and Whimbrels (*Numenius paeopus*) have undergone significant population declines. None of these species rely on the salt flats as a primary staging area. As these species winter primarily in Central and South America (Morrison 1984, Myers et al. 1985), continued efforts to identify staging and wintering areas elsewhere in the Neotropics are necessary.

Shorebirds distributed themselves primarily in census units A, B and C (Fraternidad) during fall, and in units D and portions of F (Candelaria) during spring. Water level fluctuations, presence of avian predators, availability of alternate habitat, and prey availability are important determinants of shorebird spatial arrangements (see Burger 1984, Clark et al. 1993, Colwell and Landrum 1993). In Fraternidad, the availability of *Dasyhelea* (Diptera), *Trichocorixa* (Hemiptera), and *Artemia* (Anostraca) influence small calidrid distribution (Grear 1992). These prey species are found along a gradient of salinity that runs from units A and B (lower salinity) to unit C, and ultimately, D near the evaporating basins (highest salinity). Small calidrids exhibited preferences for *Dasyhelea* and *Trichocorixa,* species that thrive in lower salinities (e.g., near ocean levels) (Grear 1992). Highest densities of these prey and calidrid sandpipers occurred primarily in units A, B and C. Areas of high salinity (i.e., D), where *Artemia* was densest, was primarily used when units with preferred prey were inaccessible (e.g., deep water). The preponderance of other species (e.g., Lesser Yellowlegs, Black-necked Stilts, Stilt Sandpipers) in units A, B and C possibly also responded to patterns of *Dasyhelea* and *Trichocorixa* availability. Calidrid sandpipers used Candelaria primarily for roosting in 1990 and 1991 (Grear 1992). Although water depth is thought be an important factor, we cannot fully account for the lower incidence of foraging activities recorded for calidrid sandpipers and other shorebirds in Candelaria (Grear 1992). At present, we lack complementary data on prey availability for the Candelaria system. Abundance fluctuations in unit E were due primarily to roosting populations. The evaporating basins of both systems also serve as nesting habitat for Snowy Plovers (Lee 1989). These observations highlight the different but essential functions provided by various habitats at the salt flats.

The period between August and December encompasses Puerto Rico's rainy season. Tidal amplitude increases through fall reaching maximum levels during early winter. These factors affect prey availability (e.g., water depth, salinity) and shorebird distribution as suggested above. During spring, however, Puerto Rico goes through its dry season and the amplitude of tides decrease. At this time, portions of the salt flats dry up partially or completely, most notably eastern Fraternidad (units A and B) and northern portions of Candelaria (unit F). Water is present in units C and D (Fraternidad), and the southern portions of unit F (Candelaria), mostly due to salt extraction activities (e.g., water pumping). Whether this pattern reflects historical conditions is unknown since salt extraction operations have been in existence for at least 150 yr (U.S. Fish and Wildlife Service 1988, 1993).

Existing hydrological conditions are believed to influence seasonal patterns of shorebird distribution and use. Locally and in contrast to Jobos Bay (Wunderle et al. 1989), Snowy and Wilson's Plovers remain and breed at the salt flats during the dry season (Collazo et al. 1987, Lee 1989). A contributing factor may be the presence of water in portions of the salt flats year round. Units C, D and F gain numerical importance during spring as indicated by census data. They also provide important foraging areas in late-summer and early-fall to migrant shorebirds until rainfall and tidal flows make other areas (e.g., eastern Fraternidad) available. Regionally, habitat reduction during the dry season might explain the weak influx, presumably northbound migrants, recorded during February and March. Wunderle et al. (1989) hypothesized that alternating habitat conditions between the wet and dry seasons in the Caribbean influence patterns of high and low numbers of migrating shorebirds during fall and spring, respectively. Unfortunately, this alternating-conditions hypothesis cannot be examined critically because patterns of habitat availability and shorebird use west of Puerto Rico (e.g, Hispaniola, Jamaica, Cuba) are not known. Alternative hypotheses advanced to explain the numerically weak spring migration through the eastern Caribbean include changes in trade wind patterns and age composition of the migratory population (Morrison 1984).

We used ISS data to place our fall season findings within a geographical context. Interpretive problems with ISS data were discussed by Howe et al. (1989), and stem from inconsistent sampling, turnover rates and timing of sampling. Inferences herein are cautious and are intented to assess the importance of the salt flats rather than to rank sites (e.g., ordinal scale). Under these criteria, the Cabo Rojo salt flats emerged as an important stopover area among 23 Caribbean sites (salt flats included), accounting for 29% of the peak numbers recorded. These numbers compare favorably with those of a site in Trinidad, an island close to major wintering grounds of many species recorded at the salt flats (Morrison 1984, Morrison and Ross 1989). The salt flats serve as an important staging area for small Calidrids, Stilt Sandpipers and Greater Yellowlegs. About 65% of the Snowy Plover peak numbers were recorded at the salt flats. Snowy Plovers are locally endangered (Departmento Recursos Naturales 1985) and a candidate species for listing under the Endangered Species Act (as amended). The salt flats support the only known breeding population in the eastern Caribbean (Lee 1989), and may constitute a stronghold for the species in the wider Caribbean. The salt flats also emerged as an important wintering site for Piping Plovers. This species was recorded in 4 of 8 yr, averaging two individuals (peak = 4) during either fall or spring. The numerical significance of the salt flats is diminished when other sites not included in the ISS database are considered, however. Sites in Cuba and Bahamas reported peak counts of 11 and 29 individuals, respectively (Haig and Plissner 1993).

The conservation value of the salt flats depends not only on their continued availability but also on their quality (Myers et al. 1987). We recommend that a habitat management plan be formulated taking into account functions provided by different habitat units within the salt flats, factors influencing habitat quality (e.g., prey base) and the effects of the salt extraction operations. The latter is important because they effectively dominate the hydrology of the Fraternidad and Candelaria systems, hence, much of the salt flats' carrying capacity.

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