Studies in Avian Biology No. 27:61–77, 2004.

PATTERNS OF SHOREBIRD USE OF THE SALTON SEA AND ADJACENT IMPERIAL VALLEY, CALIFORNIA

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Abstract. From 1989–1995 and in 1999, we recorded 34 species on shorebird surveys at the Salton Sea and adjacent Imperial Valley, California. Of 27 regularly occurring species, 4 were primarily year-round residents and breeders, 12 winter residents, and 11 migrants. Median shorebird totals were 78,835 in fall, 68,281 in spring, and 27,796 in winter; maximum counts on single surveys exceeded 100,000 in spring and fall. The only taxa exceeding 10,000 individuals in spring or fall were the Black-necked Stilt (*Himantopus mexicanus,* fall), American Avocet (*Recurvirostra americana,* fall), Western Sandpiper (*Calidris mauri,* spring and fall), and dowitchers (*Limnodromus* spp., spring). The American Avocet and Long-billed Dowitcher (*L. scolopaceus*) were the only species exceeding 5000 in winter. The Salton Sea remains an important breeding and wintering area for the Snowy Plover (*Charadrius alexandinus*). Increased coverage of agricultural fields in 1999 revealed 2486–3758 Mountain Plovers (*C. montanus*), representing 30% to 38% of the species' estimated world population. At all seasons, shorebirds concentrated primarily along the south and secondarily along the north and west shorelines. Still, distribution patterns around the Sea varied greatly among species, and several relied extensively on freshwater and brackish ponds. The Mountain Plover, Whimbrel (*Numenius phaeopus*), and Long-billed Curlew (*N. americanus*), primarily used agricultural fields of the Imperial Valley. The shorebird community at the Salton Sea shows affinities with coastal sites in California and west Mexico. Despite many similarities, the Salton Sea contrasts with other intermountain sites by serving as a stopover for several primarily coastal species, hosting large numbers of Whimbrels (spring) and Mountain Plovers (winter), and, for many species, acting mainly as a wintering area rather than a breeding area or migratory stopover. Shorebirds at the Salton Sea face potential threats from high salinity, disease outbreaks, contaminants, and eutrophication. Large restoration projects proposed to reduce salinity may have negative impacts if placed in shallow water or alkali flat habitats where large numbers of shorebirds or sensitive species concentrate.

Key Words: distribution patterns; habitat use; migratory stopover; Mountain Plover; Pacific Flyway; Colorado River Delta; wintering area.

PATRONES DE USO DEL MAR SALTON Y EL ADYACENTE VALLE IMPERIAL, CALIFORNIA POR AVES PLAYERAS

Resumen. De 1989–1995 y en 1999, documentamos 34 especies en censos de aves playeras en el Mar Salton y el adyacente Valle Imperial, California. De 27 especies que ocurren regularmente, 4 fueron primariamente residentes anuales de reproducción en la zona, 12 fueron residentes de invierno, y 11 migratorias. La mediana total de aves playeras fue 78,835 en otoño, 68,281 en primavera, y 27,796 en invierno; en primavera y otoño los conteos máximos de censos simples excedieron 100,000 individuos. Los únicos taxones que excedieron los 10,000 individuos en primavera u otoño fueron el Candelero Americano (*Himantopus mexicanus,* otoño), la Avoceta Americana (*Recurvirostra americana,* otoño), el Playero Occidental (*Calidris mauri,* primavera y otoño), y los Costureros (*Limnodromus* spp., primavera). La Avoceta Americana y el Costurero Pico Largo (*Limnodromus scolopaceus*) fueron las únicas especies que superaron los 5000 individuos en invierno. El Mar Salton sigue siendo un área importante de reproducción e invernada para el Chorlo Nevado (*Charadrius alexandrinus*). El aumento en cobertura de campos agrícolas en 1999 reveló 2486–3758 Chorlos Llaneros (*C. montanus*), representando entre 30% y 38% de la población mundial estimada para la especie. Durante todas las estaciones, las aves playeras se concentraron principalmente a lo largo de la costa sur y secundariamente a lo largo de las costas norte y oeste. Aún así, los patrones de distribución alrededor del Mar Salton variaron grandemente entre las especies, y varias dependieron extensamente de charcas de agua dulce y salobre. El Chorlo Llanero, el Zarapito Trinador (*Numenius phaeopus*), y el Zarapito Pico Largo (*Numenius americanus*) usaron principalmente campos agrícolas del Valle Imperial. La comunidad de aves playeras en el Mar Salton muestra afinidades con sitios costeros de California y el oeste de México. A pesar de muchas similitudes, el Mar Salton contrasta con otros sitios ubicados entre montañas sirviendo como un sitio de parada temporal para varias especies de aves principalmente playeras, albergando un gran número de Zarapitos Trinadores (primavera) y Chorlos Llaneros (invierno), y, para muchas especies, actuando básicamente como área de invernada en vez de área de reproducción o parada durante la migración. Las aves playeras en el Mar Salton enfrentan potenciales amenazas por la alta salinidad, brote de enfermedades, contaminantes, y eutrofización. Grandes proyectos de restauración propuestos para reducir la salinidad pueden tener impactos negativos si son llevados a cabo en aguas de poca profundidad o hábitats llanos alcalinos, donde se concentran grandes números de especies de aves playeras o de aves sensibles.

Palabras claves: área de invernada; Chorlo Llanero; Delta del Río Colorado; patrones de distribución; ruta de vuelo del Pacífico; sitios de parada durante la migración; uso de hábitat.

Shorebirds increasingly are a focus of conservation concern because of population declines and habitat loss (Page and Gill 1994, Brown et al. 2001). Although recent papers provide broad overviews of shorebird use of wetlands and agricultural habitats in western North America (Shuford et al. 1998, 2002a; Page et al. 1999), few data have been published on the patterns of shorebird use at individual sites (e.g., Stenzel et al. 2002), where most conservation and management efforts will be implemented. The Salton Sea recently has been given long overdue recognition for its great importance to populations of Pacific Flyway waterbirds (Shuford et al. 2002b, chapters in *this volume*). Shorebirds are among the most numerous groups of waterbirds at the Salton Sea during migration and winter, yet, other than for the Snowy Plover (Page et al. 1991, Shuford et al. 1995), few quantitative data have been published on their patterns of use of this site. Such data are needed to address concerns for the health of the Salton Sea ecosystem (USFWS 1997, Tetra Tech, Inc. 2000, Shuford et al. 2002b).

PRBO Conservation Science (PRBO) conducted surveys of shorebird use at the Salton Sea via the Pacific Flyway Project from 1989 to 1995 and the Salton Sea Reconnaissance Survey in 1999 (Shuford et al. 2000). Here we report the abundance and distribution patterns of shorebirds at the Salton Sea and adjacent Imperial Valley, highlight threats to these populations, suggest conservation measures for shorebirds, and identify future research needs.

STUDY AREA AND METHODS

The study area included the Salton Sea, Riverside and Imperial counties, California, and the adjacent Imperial Valley, Imperial County. We used several methods to characterize shorebird use in this area. From 1989 to 1995 and in 1999, we conducted comprehensive surveys of most shorebird habitat at the Salton Sea over short periods up to four times a year. We conducted a total of eight comprehensive surveys in fall (mid-August to mid-September), eight in spring (mid-April), five in early winter (mid-November to early December), and four in mid-winter (late January to early February). On each census, a team of professional biologists and skilled volunteers attempted to survey the entire Salton Sea shoreline, adjacent marshes and impoundments (Fig. 1, Areas 1–21) and various sites in the Imperial Valley, including the Finney-Ramer Unit of Imperial Wildlife Area (WA) south of Calipatria (Areas 22a–b) and private duck clubs near Brawley (Areas 22c–g). Except on winter surveys of Mountain Plovers (scientific names of all species are listed in Table 1) described below, we covered agricultural habitat of the Imperial Valley only on a limited and opportunistic basis. To obtain data on their patterns of distribution and habitat use around the Sea, observers kept separate tallies of shorebirds within 19 shoreline segments and three complexes of freshwater marshes and impoundments (Fig. 1). Observers generally conducted surveys with the aid of binoculars and spotting scopes and traveled by vehicle or on foot. During summer 1999, observers used an airboat to survey the shoreline from Iberia Wash at Salton City (boundary of Areas 5 and 6) south to, and including, the New River (Area 11b) to reduce the risk of heat exhaustion while covering this long, isolated stretch. Observations from aerial surveys conducted for other species of waterbirds found very few shorebirds away from the immediate shoreline where they were readily counted by ground based observers.

We instructed observers, when possible, to identify all shorebirds to species. Groups of unidentified shorebirds fell mostly into four categories: yellowlegs, either Greater or Lesser (*Tringa melanoleuca* or *T. flavipes*); small sandpipers of the genus *Calidris,* primarily Western and Least sandpipers (*C. mauri* and *C. minutilla*), and Dunlin (*C. alpina*); dowitchers, either Short-billed or Long-billed (*Limnodromus griseus* or *L. scolopaceus*); and phalaropes, either Wilson's or Red-necked (*Phalaropus tricolor* or *P. lobatus*). For analyses, we grouped identified and unidentified dowitchers as dowitcher spp. owing to the difficulty of identifying most individuals to species on surveys. Observations indicate that all wintering dowitchers are long-billeds, as no short-billeds have been recorded at the Sea from 29 November to 3 March (Patten et al. 2003). Although the Long-billed Dowitcher is the most numerous of the two species during migration, the Short-billed also occurs in substantial numbers seasonally (M. Patten, pers. comm.). We assigned unidentified shorebirds to species using methods described in Page et al. (1999).

We used the median numbers of shorebirds on comprehensive surveys to estimate the seasonal abundance of various taxa. Because of limited coverage on some surveys, we used only five fall, three early winter, one late winter, and five spring surveys to characterize shorebird abundance, and only four surveys in 1999 to analyze patterns of distribution around the Salton Sea and nearby wetlands. We excluded the November 1999 survey when calculating medians for winter, as comparisons with other winter counts suggested that shorebirds were still migrating in November. For graphing the distribution patterns of shorebird within study area wetlands in 1999, we grouped data for six subareas: west shore (Areas 3–10), north shore (Areas 1–2 and 19), east shore (Areas 13–18), south shore (Areas 11 and 12), nearshore ponds (Areas 20 and 21), and Imperial Valley ponds (Area 22; Fig. 1).

To document seasonal occurrence patterns of shorebirds, in 1999 we surveyed a subset of shoreline segments (1A–B, 8, 11A–D, 12A, 20A–D, and 21B; Fig. 1) once a month during winter and mid-summer and twice a month during spring and fall. We did not cover Area 8 on the 4–7 October survey because of adverse winds, but we estimated data for this segment by taking the mean of the two counts on either side of this survey. Finally, we combined data from the same subset of areas surveyed on the four comprehensive surveys in 1999 with the 14 partial surveys for a total of 18 surveys used to describe annual phenology. We characterized the seasonal occurrence patterns of 27

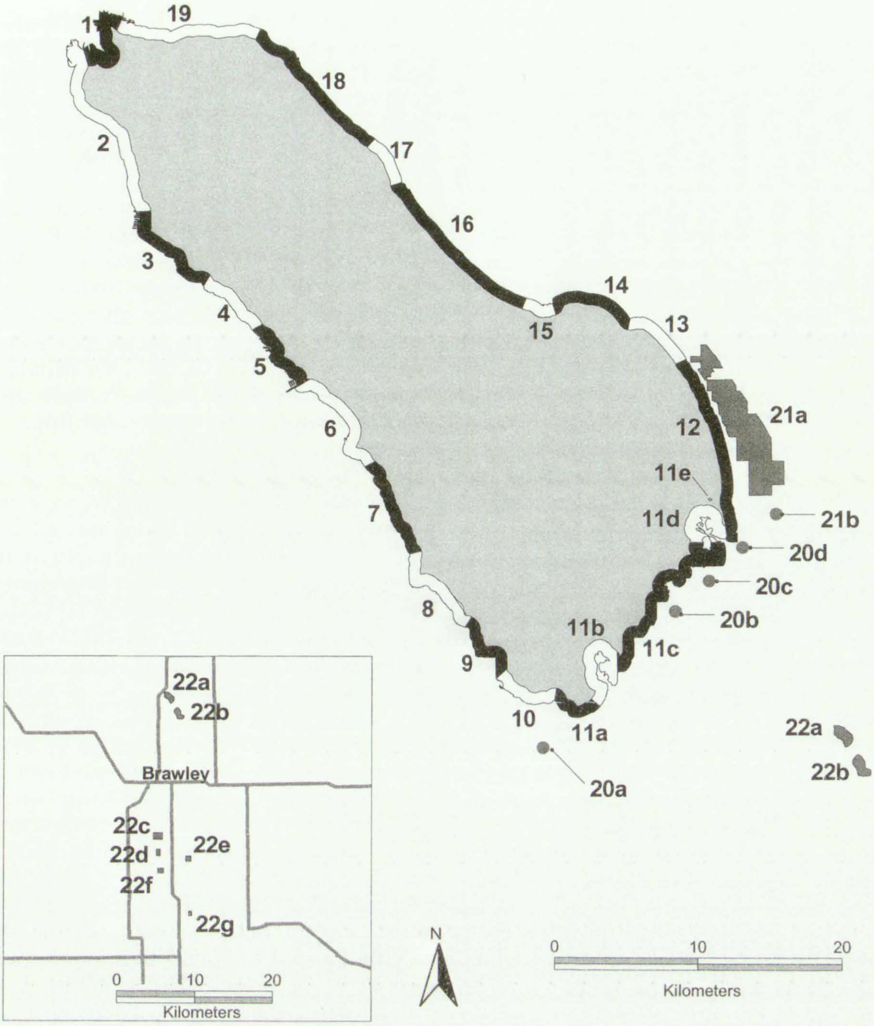

FIGURE 1. Numbered areas of the shoreline and inshore zone (within 1 km of shore) of the Salton Sea, California, and adjacent freshwater impoundments. Inset shows locations of duck clubs near Brawley in the Imperial Valley.

regularly occurring species, i.e., those recorded on at least three comprehensive surveys in any season. Although not meeting this latter criterion, we included the Mountain Plover in this characterization as it would have occurred on all comprehensive winter surveys if they had included most agricultural habitat in the Imperial Valley.

In 1999, we conducted three comprehensive surveys of Snowy Plovers at the Salton Sea to compare to prior data on this species (Shuford et al. 1995). We conducted the 22–30 January and 11–14 November surveys, when plovers are flocking and easiest to detect, as part of the comprehensive surveys described above and the 21–31 May survey as a separate census focusing entirely on Snowy Plovers. At that season, surveying is made more difficult by adults sitting cryptically on nests and by adults with chicks sometimes moving long distances to mob observers. To minimize these problems, we instructed observers to use both binoculars and spotting scopes to repeatedly scan long distances up and down beaches and alkali flats to try to detect incubating adults before the plovers sneaked off nests and scattered. We also asked observers to zigzag back and forth across beaches and alkali flats to try to detect roosting or incubating plovers or those foraging behind shoreline berms where they otherwise might be invisible from the upper beach. On very wide beaches and alkali flats, two observers worked in tandem, one covering the upper beach or alkali flats, the other the immediate shoreline, zigzagging as needed.

In 1999, we estimated the winter population size of the Mountain Plover via comprehensive surveys of 80% to 90% of the agricultural lands in the Imperial Valley on 14–15 February, 13–14 November, and 11–

12 December. Adjusting for individuals participating on both days of two-day survey periods, the number of observers ranged from 11 observers in eight parties on the 14–15 February survey to 26 observers in 15 parties on the 11–12 December survey. Observers drove all accessible roads and used binoculars and spotting scopes to carefully scan fields with appropriate plover habitat of barren ground or sparse low growth. On all surveys, observers recorded and mapped the location of all flocks and described the types of fields on which plovers occurred. In November and December, observers gathered additional data on the behavior (foraging, roosting, or flying) of plovers and on characteristics of fields where plovers were observed (% cover of vegetation vs. bare ground, dominant plant species, average plant height, burned or grazed vs. unburned or ungrazed, etc.). We also collected limited data on the Long-billed Curlew, particularly in November and December.

RESULTS

Species Richness and Overall Abundance

We detected 34 species of shorebirds on comprehensive surveys of the Salton Sea area (Tables 1, 2). Median shorebird totals were 78,835 (N = 5 surveys, min–max = 59,512–105,570) in fall, 68,281 (N = 5 surveys, min–max = 36,675–129,538) in spring, and 27,796 (N = 4 surveys, min–max = 19,724–70,059) in winter. The relatively low numbers in April 1999 compared with other springs may represent a lack of coincidence of the 1999 survey dates with the peak passage of Western Sandpipers, which can move through rapidly in large numbers. The high shorebird numbers in November 1999 likely reflects protracted migration through that period, as other winter counts were taken later in the season. In 1999, we counted 275 Snowy Plovers at the Salton Sea in January, 221 in May, and 170 in November, and 2486 Mountain Plovers in agricultural fields of the Imperial Valley in February, 2790 in November, and 3758 in December. The increase in Mountain Plover numbers across surveys may reflect a parallel increase in observer coverage.

Median counts of shorebirds at the Salton Sea were >1000 and <10,000 for six and four taxa and >10,000 for three and two taxa in fall and spring, respectively (Table 1). Median counts in winter were >1000 and <5000 for five taxa and >5000 for two taxa. The only taxa exceeding 10,000 individuals in spring or fall were the Black-necked Stilt (fall), American Avocet (fall), Western Sandpiper (spring and fall), and dowitcher spp. (spring). The only species exceeding 5000 in winter were the American Avocet and Long-billed Dowitcher.

Seasonal Occurrence Patterns

Seasonal occurrence patterns varied greatly among species of regularly occurring shorebirds (Figs. 2–5; Tables 1, 2). Of 27 such species, four were primarily year-round residents and breeders, 12 primarily winter residents, and 11 primarily migrants. Of year-round residents, the Black-necked Stilt and American Avocet also showed large peaks, representing fall migrants, in July and August and August to early November, respectively. Of species occurring primarily as migrants, the Semipalmated Plover, Ruddy Turnstone, Red Knot, Sanderling, and, particularly, the Whimbrel were more numerous in spring than fall, whereas this pattern was reversed for the Baird's Sandpiper and Wilson's and Red-necked phalaropes. Of primarily winter residents, dowitcher numbers were swelled the most by migrants in spring and fall.

Patterns of Distribution

At all seasons, shorebirds concentrated primarily along the south shoreline and secondarily along the north and west shorelines (Fig. 5 in Warnock et al. *this volume*). Shorebird densities were particularly impressive at all seasons along the shoreline (Area 12) of the Wister Unit of Imperial WA (Fig. 6). Still, many numerous species varied in their patterns of distribution (Fig. 7). The Marbled Godwit and Western Sandpiper concentrated heavily on the south shore of the Salton Sea; the Semipalmated Plover also concentrated there, except in April when it was widespread. The Black-necked Stilt and American Avocet were generally widespread but tended to concentrate more on the west and south shores and the south shore, respectively. By contrast, though fairly widespread, the Willet and Dunlin tended to concentrate on the west shore. The two yellowlegs species and the Least Sandpiper were widespread but tended to rely more on ponds than other species. Dowitchers were most numerous on the south shore and in adjacent nearshore ponds. The distribution patterns of the Black-bellied Plover and Long-billed Curlew in wetlands were influenced by their use of agricultural fields. Plovers foraged extensively along the Salton Sea shoreline, but their seasonal concentrations in Imperial Valley ponds reflected birds using these sites for roosting after foraging in nearby fields. The curlew was found primarily along the south shore and in Imperial Valley ponds; the curlews appeared to be primarily roosting rather than foraging in these habitats.

Several less numerous species also showed differential distribution patterns along the Salton Sea shoreline. In 1999, the Snowy Plover concentrated in areas similar to those used in prior years (see Shuford et al. 1995). At all seasons, plovers concentrated primarily on sandy beaches and sand or alkali flats along the western and southeastern shorelines of the Sea (Table 3; Figs. 1, 7). Areas of particular importance included the shoreline and expansive alkali flats of the western shoreline from Iberia Wash south through the northern portion of the Salton Sea Test Base and San Felipe Creek Delta (Area 6, northern part of 7, and 8) and the southeastern shoreline, breached impoundments, and sand spit paralleling Davis Road and the Wister Unit of Imperial WA (Area 12). In 1999, these areas, respectively, held about 44% and 33% of all plovers in January and 55% and 18% in May. Other species particularly concentrated on the west shoreline in spring were the Ruddy Turnstone (84% in Area 6), Red Knot (87% in Areas 5 and 6), and Sanderling (81% in Area 6). The Stilt Sandpiper concentrated primarily along the Wister shoreline (Area 12) and in brackish or freshwater ponds of or adjacent to the Salton Sea National Wildlife Refuge (Area 20). In 1999, 73% and 18% of Stilt Sandpipers in January and 43% and 52% in November were in Areas 12 and 20, respectively. Away from the Sea, small numbers also occurred in freshwater ponds of duck clubs near Brawley in the Imperial Valley.

Opportunistic coverage of agricultural fields of the Imperial Valley showed that several species were much more numerous there than in shoreline or other wetland habitats at or near the Salton Sea. The high count of 9837 Whimbrels at the Salton Sea in April 1989 was almost exclusively from agricultural fields in the Imperial Valley, which received only limited coverage. The magnitude of Long-billed Curlew abundance in the Imperial Valley is indicated by counts of about 2655 individuals in a single flock near Calipatria on 13 November 1999, a total of 5593 from coverage of about 60% of the Imperial Valley by six observers involved in a Mountain Plover survey on 11–12 December 1999, and 7476 on a multi-observer survey of the Salton Sea and portions of the Imperial Valley in August 1995. A mixed flock of shorebirds in a single flooded field in the Imperial Valley on 11 Dec 1999 held 153 Greater and 20 Lesser yellowlegs, which, respectively, represent 188% and 69% of the median number of these species found on three winter counts of the entire Salton Sea (Table 2). Similarly, G. McCaskie (pers. comm.) recorded about 150 Greater and 100 Lesser yellowlegs in one flooded field near Calipatria on 2 December 2000. The Black-bellied Plover also is fairly numerous in agricultural fields, and a roosting flock of 758 individuals at the New River Delta on 2 February 1999 likely moved there after foraging in nearby fields.

Overall, wintering Mountain Plovers were distributed widely over the Imperial Valley with no consistent areas of concentration (Fig. 8), presumably reflecting the shifting availability of suitable fields with the temporal and spatial variation in cultivation practices. The concentration of plovers in a relatively few sites in February appeared to reflect a preference by plovers for burned fields at that season as described below.

The types of fields used by Mountain Plovers varied by season. In February, 81% of all plovers were in stubble hayfields burned after harvest; the remainder, except for three individuals in an asparagus stubble field, were in short-stature, stubble hayfields yet to be burned. Most of the burned fields had some sparse new green growth. In three complexes of burned stubble hayfields holding about 1184 plovers, residual stubble about 3–5 cm tall covered about 50% of the ground with the remainder bare of vegetation. In November, 35% of the plovers were in bare tilled fields and 65% in fields of various crop types with new growth averaging <3 cm in height and ranging up to 95% vegetative cover. In December, 47% were in bare tilled fields and 53% in fields of various crop types, primarily in new stages of growth, ranging from <5% to 100% vegetative cover. Of plovers in fields with new crops, 69% were in fields in which plant height averaged <5 cm, 10% in which it averaged 5–10 cm, and 21% in which it averaged >10–20 cm. Additional practices that produced the low stature and sparse cover of vegetation attractive to plovers included grazing and mowing or harvesting of hay crops. Plovers using bare fields appeared to prefer actively or recently tilled fields. This appeared particularly to be the case in December when at least 649 (37%) of 1777 plovers in bare fields were in ones in which tractors were actively working; an additional but unknown percent were in fields that had recently been tilled. Tilled fields used by plovers tended to be relatively flat and smooth rather than extensively furrowed, undulating, or with large dirt clods. Although many fields with growing crops used by plovers were relatively flat throughout, many others had raised beds with flat tops and narrow intervening furrows in which plovers often stood or crouched.

DISCUSSION

SPECIES RICHNESS

In addition to the 34 shorebird species found on our surveys, an additional 11 rare to extremely rare species have been recorded in the Salton Sea area (Patten et al. 2003). Although it is difficult to compare species richness across wetlands with unequal observer coverage, by any measure the Salton Sea has a rich shorebird fauna that rivals or exceeds that of most sites in

TABLE 1. NUMBERS OF SHOREBIRDS ON SURVEYS OF THE SALTON SEA, CALIFORNIA, IN FALL AND SPRING, 1989–1995 AND 1999

	19 Aug 1989	14 Sep 1990	23 Aug 1991	21 Aug 1992	13 Aug 1999	23 Apr 1989	21 Apr 1990	27 Apr 1991	25 Apr 1992	17 Apr 1999
Black-bellied Plover *Pluvialis squatarola*	98	138	267	462	253	579	297	456	256	575
Pacific Golden-Plover *Pluvialis fulva*	0	0	0	0	0	1	0	0	0	1
Snowy Plover *Charadrius alexandrinus*	84	102	389	125	351	113	261	179	312	285
Semipalmated Plover *Charadrius semipalmatus*	131	38	89	67	139	811	483	607	232	131
Killdeer *Charadrius vociferous*	132	263	579	777	259	130	182	144	408	215
Mountain Plover *Charadrius montanus*	0	0	5	0	0	0	0	0	0	0
Black-necked Stilt *Himantopus mexicanus*	10,167	3,825	7,555	19,255	15,857	1,171	3,114	3,184	10,467	3,465
American Avocet *Recurvirostra americana*	19,382	16,545	14,121	12,717	10,037	5,926	3,111	7,052	14,356	7,001
Greater Yellowlegs *Tringa melanoleuca*	41	56	65	39	113	14	40	9	61	14
Lesser Yellowlegs *Tringa flavipes*	0	174	14	36	28	28	3	2	7	12
Solitary Sandpiper *Tringa solitaria*	0	0	0	0	1	0	0	0	0	0
Willet *Catoptrophorus semipalmatus*	781	1,147	1,093	566	582	208	337	197	104	682
Wandering Tattler *Heteroscelus incanus*	1	1	0	0	0	0	0	0	0	0
Spotted Sandpiper *Actitis macularia*	7	10	41	82	19	6	17	8	4	7
Whimbrel *Numenius phaeopus*	0	2	116	0	31	9,837	3,243	7,860	0	43
Long-billed Curlew *Numenius americanus*	3,761	1,374	670	2,425	394	102	31	48	34	33
Marbled Godwit *Limosa fedoa*	724	3,190	2,413	371	1,036	73	630	877	3,170	928
Ruddy Turnstone *Arenaria interpres*	2	3	5	29	10	11	26	37	46	44
Black Turnstone *Arenaria melanocephala*	0	0	0	0	0	4	0	0	0	0
Surfbird *Aphriza virgata*	0	0	0	0	0	5	0	0	0	0

TABLE 1. CONTINUED

	19 Aug 1989	14 Sep 1990	23 Aug 1991	21 Aug 1992	13 Aug 1999	23 Apr 1989	21 Apr 1990	27 Apr 1991	25 Apr 1992	17 Apr 1999
Red Knot *Calidris canutus*	22	0	0	0	1	502	366	365	126	371
Sanderling *Calidris alba*	0	70	0	0	39	135	265	132	0	249
Western Sandpiper *Calidris mauri*	9,336	54,374	34,961	35,653	34,394	36,053	38,225	58,444	67,343	14,700
Least Sandpiper *Calidris minutilla*	1,154	422	3,556	4,149	942	197	793	2,574	3,476	1,226
Baird's Sandpiper *Calidris bairdii*	23	0	6	6	1	0	0	0	0	0
Dunlin *Calidris alpina*	0	1	0	14	1	53	212	48	2,258	141
Stilt Sandpiper *Calidris himantopus*	0	48	85	40	15	0	10	35	0	1
Ruff *Philomachus pugnax*	0	0	0	0	3	0	0	0	0	0
Dowitcher spp. *Limnodromus griseus* or *L. scolopaceus*	5,939	10,704	9,320	15,533	7,153	12,109	10,126	14,624	26,443	6,492
Wilson's Snipe *Gallinago delicata*	0	0	0	0	2	3	7	3	0	1
Wilson's Phalarope *Phalaropus tricolor*	7,577	818	2,346	1,003	3,065	133	416	83	334	23
Red-necked Phalarope *Phalaropus lobatus*	150	12,265	1,139	4,350	32	77	754	1,816	101	32
Red Phalarope *Phalaropus fulicarius*	0	0	0	0	0	0	0	0	0	3
Totals	59,512	105,570	78,835	97,699	74,758	68,281	62,949	98,784	129,538	36,675

TABLE 2. NUMBERS OF SHOREBIRDS ON SURVEYS OF THE SALTON SEA, CALIFORNIA, IN WINTER, 1993, 1994, AND 1999

	6 Dec 1993	5 Dec 1994	11 Nov 1999	22 Jan 1999
Black-bellied Plover	982	430	1,381	1,310
Snowy Plover	285	214	170	275
Semipalmated Plover	29	31	122	73
Killdeer	451	175	228	277
Mountain Plover	169	52	0	0
Black-necked Stilt	4,012	2,159	5,938	3,941
American Avocet	5,836	3,363	18,800	7,318
Greater Yellowlegs	103	27	82	81
Lesser Yellowlegs	29	3	69	62
Yellowlegs spp.	0	30	0	0
Willet	1,834	1,540	1,531	1,162
Spotted Sandpiper	5	8	11	7
Long-billed Curlew	402	108	1,380	373
Marbled Godwit	1,381	1,283	1,205	1,297
Ruddy Turnstone	5	6	0	17
Red Knot	0	0	20	0
Sanderling	102	106	37	52
Western Sandpiper	3,273	4,714	22,526	1,573
Least Sandpiper	3,225	1,464	3,773	2,006
Dunlin	609	454	964	799
Stilt Sandpiper	12	134	206	164
Ruff	1	0	0	1
Dowitcher spp.[a]	5,671	3,419	11,589	6,356
Wilson's Snipe	6	4	5	24
Wilson's Phalarope	0	0	2	1
Red-necked Phalarope	0	0	20	0
Totals	28,422	19,724	70,059	27,169

[a] These are almost exclusively Long-billed Dowitchers. Only a few Short-billed Dowitchers were recorded on the November survey, and no short-billeds have been recorded at the Sea from 29 November to 3 March (Patten et al. 2003).

western North America. This richness appears to reflect the large size of the Sea, its varied saline and freshwater habitats (in proximity to extensive irrigated fields), its mild winter climate, and its location along a pathway to and from the Gulf of California. For comparison, species richness, for migration and winter, was 43 species for 56 wetlands of the Pacific Coast of the contiguous United States (Page et al. 1999), 38 species in the San Francisco Bay estuary (Stenzel et al. 2002), 35 species at Great Salt Lake (Paton et al. 1992), 33 species in the Central Valley (Shuford et al. 1998), and 29 and 27 species, in winter, at two and five large estuaries on the west coasts of Mexico (Engilis et al. 1998) and Baja California (Page et al. 1997), respectively. Hence, generally large wetlands with diverse habitats will have the highest species richness; all else being equal, coastal sites will hold more species than interior sites.

SEASONAL OCCURRENCE PATTERNS

Although it would have been ideal to have based our characterization of seasonal occurrence patterns solely on comprehensive surveys, on more frequent partial surveys, or on more years of data, we think our methods provide reasonable approximations of these patterns for most species. Still, our lack of surveys in early to mid-May appeared to truncate the depiction of the period of declining numbers of many wintering and migrant shorebirds in spring, when passage typically is more rapid than in fall. Generally this did not greatly distort the occurrence patterns of species reaching peak numbers in mid- to late April. The pattern was distorted, though, for the Red-necked Phalarope, which reaches peak numbers in early to mid-May (e.g., 3000+ on 11 May 2000, 5000+ on 9 May 2001; G. McCaskie, pers. comm.); the period of peak numbers appears to be slightly later at Great Salt Lake, where up to 20,000 were recorded on 19 May 1991 (Paton et al. 1992).

Because of its very mild winter climate and close proximity to the ocean, the Salton Sea's shorebirds have seasonal occurrence patterns with a greater affinity to those on the Pacific Coast than the interior of the West. Of 12 species that are primarily winter residents at the Salton Sea, nine are primarily winter residents and three are rare to uncommon migrants on the California coast (Shuford et al. 1989). By con-

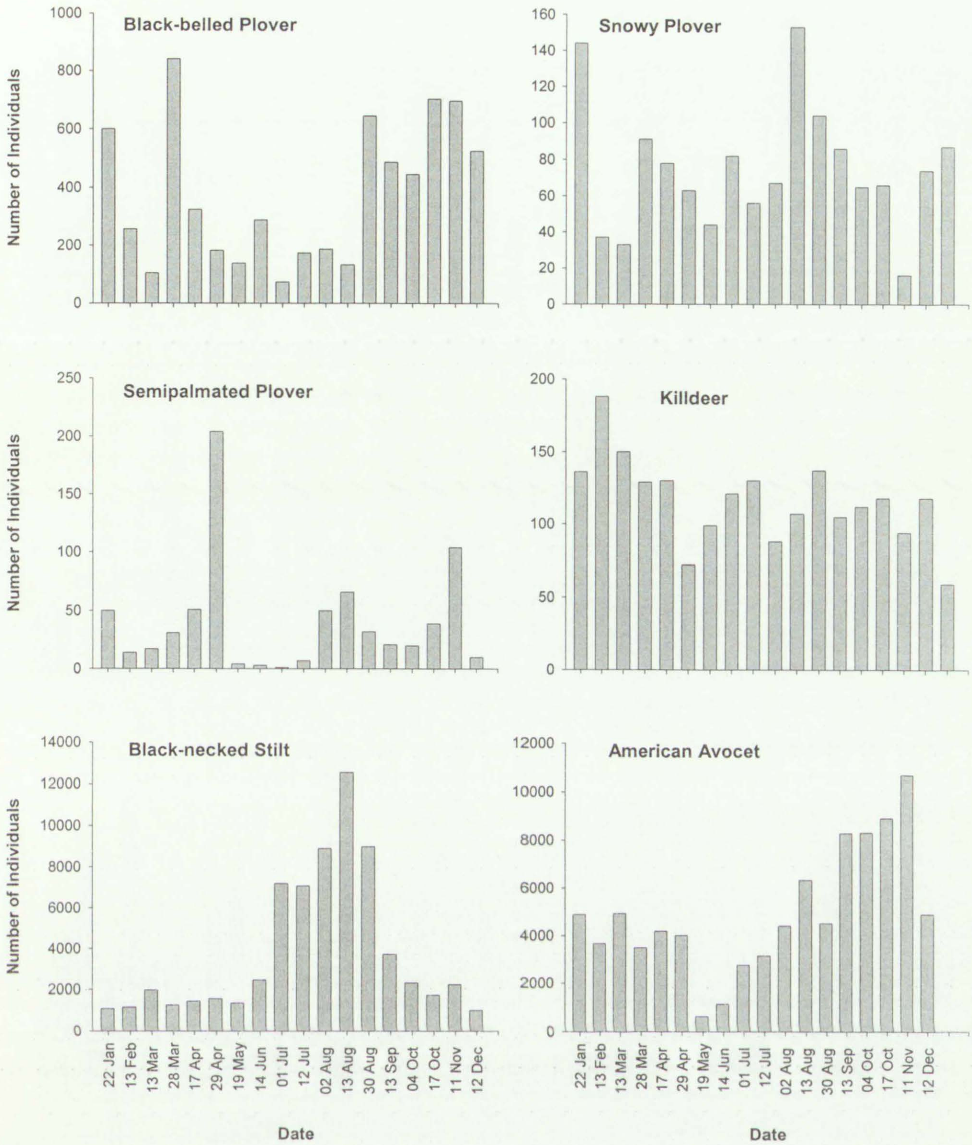

FIGURE 2. Seasonal occurrence patterns of the Black-bellied Plover, Snowy Plover, Semipalmated Plover, Killdeer, Black-necked Stilt, and American Avocet at the Salton Sea, California, in 1999. Data from 18 surveys of five areas of shoreline and freshwater ponds (see METHODS).

trast, none of the species wintering at the Salton Sea do so in even moderate numbers in the Intermountain West (Paton et al. 1992, Taylor et al. 1992). Many species of passage migrants at the Salton Sea, however, had patterns of occurrence similar to those both at sites in the Intermountain West (Paton et al. 1992, Taylor et al. 1992) and on the California coast (Shuford et al. 1989). Because of the Salton Sea's southerly location, migrants there generally appear to arrive earlier and depart sooner in spring and vice versa in fall compared with the central California coast and the northern Intermountain West, though more work is needed to document these patterns.

Importance of the Salton Sea

Regional comparisons indicate the Salton Sea ranks second, after Great Salt Lake, of the ten sites in the Intermountain West of western North

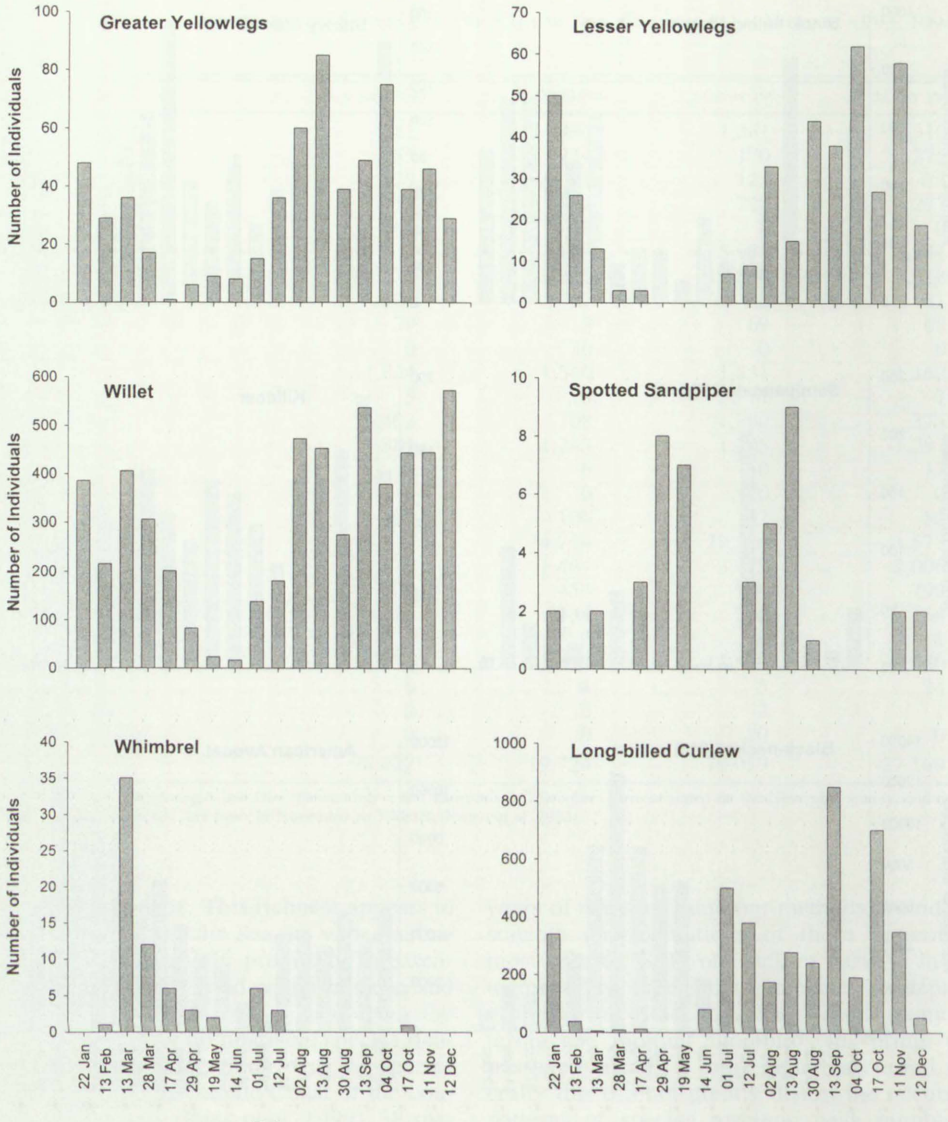

FIGURE 3. Seasonal occurrence patterns of the Greater Yellowlegs, Lesser Yellowlegs, Willet, Spotted Sandpiper, Whimbrel, and Long-billed Curlew at the Salton Sea, California, in 1999. Data from 18 surveys of five areas of shoreline and freshwater ponds (see METHODS).

America that hold >10,000 shorebirds (based on medians) in fall, first of three such sites in spring, and is the only one in winter (Shuford et al. 2002a; PRBO, unpubl. data). Unlike many interior sites that hold their largest numbers of shorebirds in fall—particularly saline lakes where large numbers of American Avocets and Wilson's Phalaropes stage—the Salton Sea holds comparable numbers in both spring and fall. Because annual and seasonal fluctuations in water levels are small at the Salton Sea, annual variation in shorebird numbers appears to be dampened there compared with other sites in the Intermountain West, such as the Lahontan Valley, Nevada (Neel and Henry 1997), that show great variation in the extent of shallow water habitat. Although its shorebird numbers in winter are much smaller than in migration, the Salton Sea is one of only three sites in the interior of the West, along with California's Central Valley and

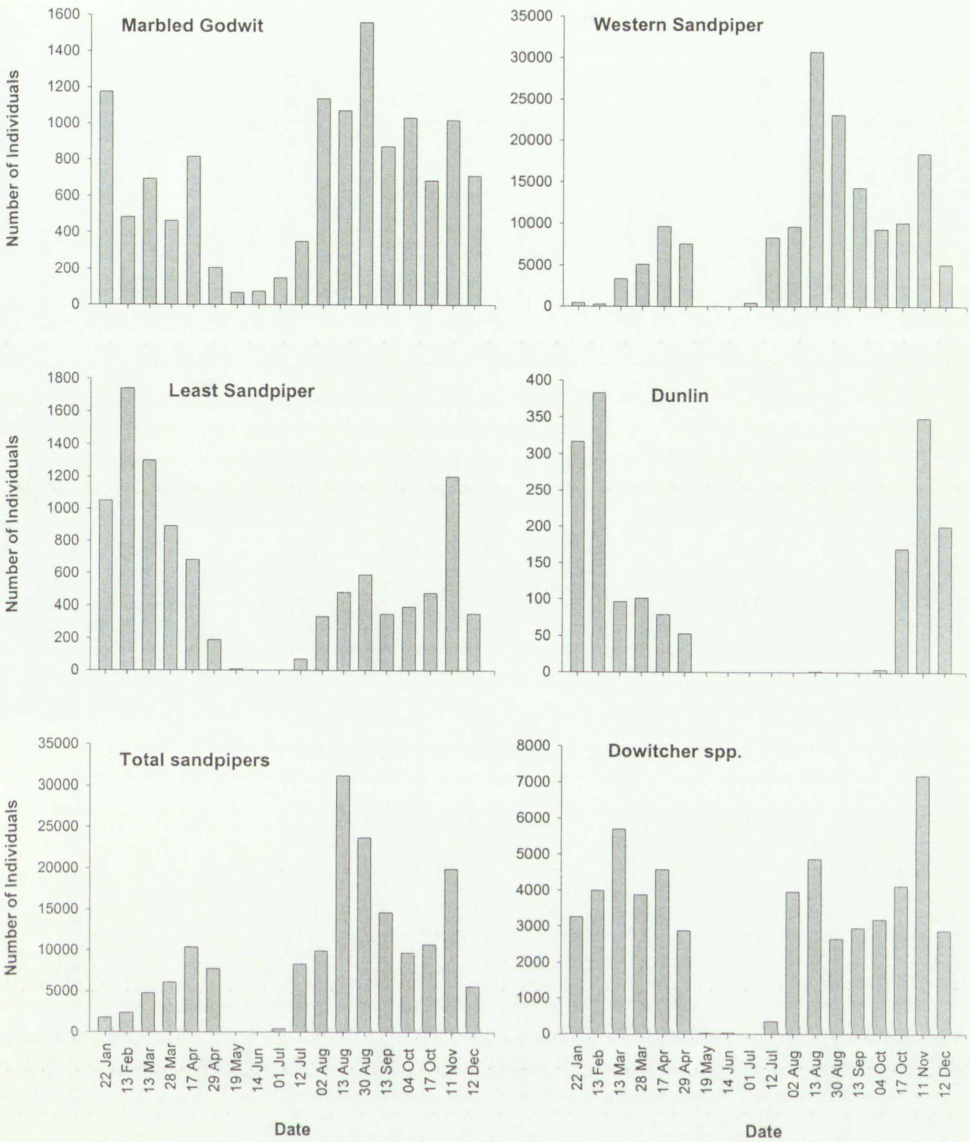

FIGURE 4. Seasonal occurrence patterns of the Marbled Godwit, Western Sandpiper, Least Sandpiper, Dunlin, total sandpipers, and dowitcher spp. at the Salton Sea, California, in 1999. Data from 18 surveys of five areas of shoreline and freshwater ponds (see METHODS).

Oregon's Willamette Valley, that hold tens of thousands of shorebirds in winter (Shuford et al. 1998; PRBO, unpubl. data).

Of common to abundant intermountain shorebirds, the Salton Sea held particularly high proportions of the estimated regional populations of the Black-necked Stilt (31%), Whimbrel (88%), small sandpipers (33%), and dowitchers (33%) in spring, and of the Willet (77%) and Long-billed Curlew (87%) in fall (Shuford et al. 2002a). Of uncommon to rare intermountain shorebirds, the Salton Sea held over 90% of the estimated populations of the Ruddy Turnstone, Red Knot, and Stilt Sandpiper in spring. Although not numerically dominant, the population of the Stilt Sandpiper wintering at the Salton Sea is one of few substantial ones of that species in the United States; the nearest known wintering site to the Sea is on the Sinaloa coast of west Mexico (Klima and Jehl 1998).

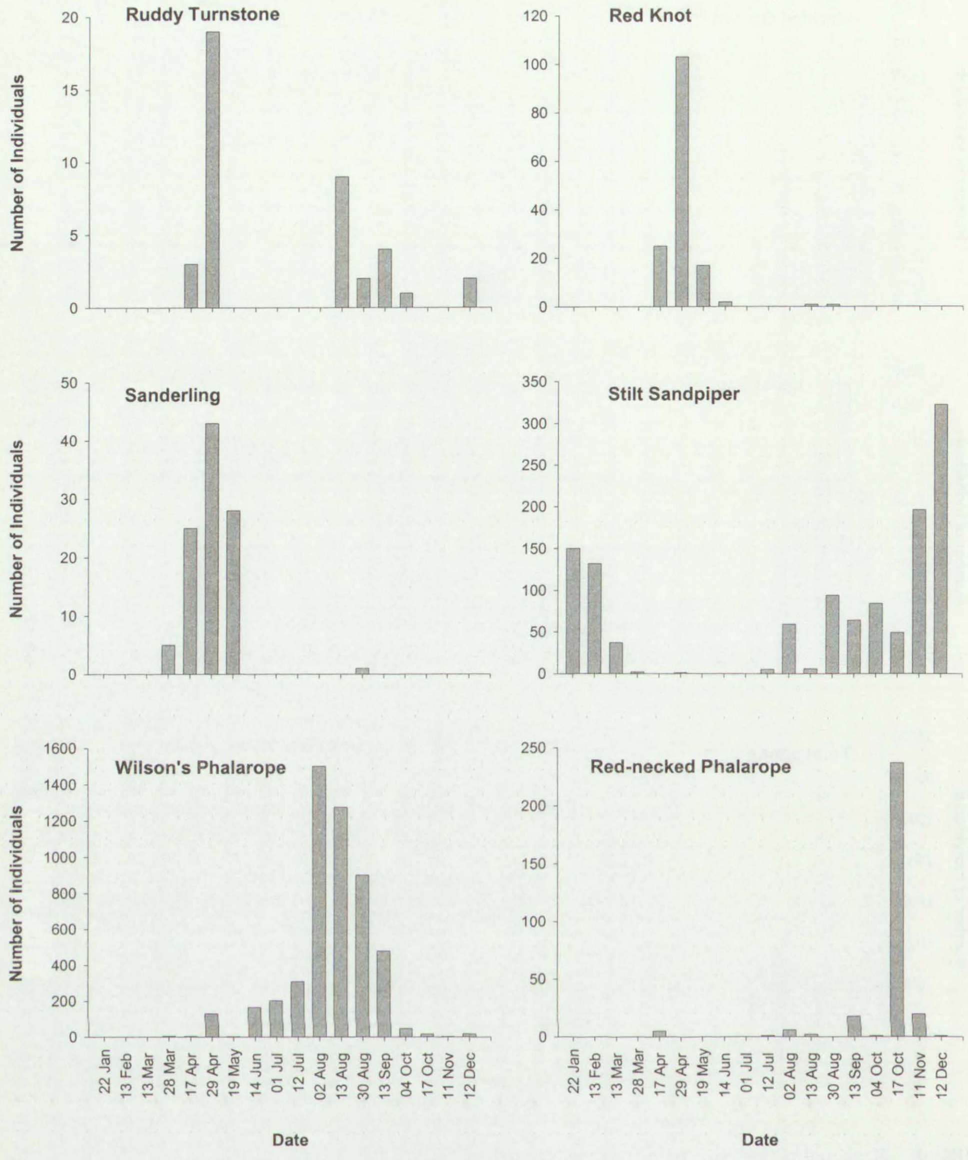

FIGURE 5. Seasonal occurrence patterns of the Ruddy Turnstone, Red Knot, Sanderling, Stilt Sandpiper, Wilson's Phalarope, and Red-necked Phalarope at the Salton Sea, California, in 1999. Data from 18 surveys of five areas of shoreline and freshwater ponds (see METHODS).

The Salton Sea also holds important populations of the Snowy and Mountain plovers. Surveys in 1999 reconfirmed that the Salton Sea supports the largest population of wintering Snowy Plovers in the interior of western North America (Shuford et al. 1995) and is one of a handful of key breeding areas in the interior of California (Page et al. 1991). Although California's Central and Imperial valleys are widely considered the primary wintering areas for the Mountain Plover (Knopf and Rupert 1995), our surveys suggest the latter area may be of much more crucial importance than previously thought. Regardless, the mean number for these three surveys represents about 30% to 38% of the species' estimated population of 8000 to 10,000 individuals (Anonymous 1999). On prior surveys across the California wintering range, the 2072 and 755 Mountain Plovers recorded in the Imperial Valley in 1994 and 1998, respectively, represented 61% and 35% of the totals of 3390 and 2179 individuals found statewide (B.

FIGURE 6. The juxtaposition of shallow waters along the Salton Sea shoreline, backwater embayments, and freshwater impoundments of the Wister Unit of Imperial Wildlife Area attract large numbers of migrant and wintering shorebirds (Photo by W. D. Shuford, 12 February 1999).

Barnes, pers. comm.; California Department of Fish and Game, unpubl. data; K. Hunting, pers. comm.). The higher totals in the Imperial Valley in 1999 almost surely reflect an increase in observer coverage there over prior years rather than a population increase. Counts of Mountain Plovers on the Salton Sea (south) Christmas Bird Count, covering only part of the northern Imperial Valley, have ranged from 0–1003 birds (median = 197 birds; N = 35) from 1965 to 2001 (http://www.audubon.org/bird/cbc/hr/index.html).

Affinities and Connectivity

. Comparisons of winter shorebird populations at the Salton Sea with those of California's Central Valley and Mexico's Río Colorado Delta, the closest marine shorebird habitat, indicates the Salton Sea has a closer affinity with the latter area (Table 4). The Salton Sea and the Río Colorado Delta both hold relatively high numbers of wintering American Avocets, Willets, and Marbled Godwits, relatively low numbers of Dunlin, and small numbers of wintering Sanderling. Unlike the Río Colorado Delta, and more like the Central Valley, the Salton Sea hosts relatively large numbers of wintering Black-necked Stilts and Long-billed Dowitchers, presumably because the Sea has a substantial amount of freshwater habitat and the Delta does not.

On a broader scale, the winter shorebird community at the Salton Sea also has a close affinity to that of the coasts of California (Page et al. 1999), western Baja California (Page et al. 1997), and the west coast of Mexico (Engilis et al. 1998). This affinity is shown by the occurrence at all sites of many species found wintering in both coastal (references above) and interior habitats (e.g., Shuford et al. 1998) and the substantial wintering populations at the Sea of the Semipalmated Plover, Willet, and Marbled Godwit, and small numbers of the Sanderling and Ruddy Turnstone, all of which are typical of coastal areas but rare or absent in winter in the interior. Conversely, several species found on the coasts of California, Baja California, and west Mexico in winter are lacking (Short-billed Dowitcher) or very rare (Whimbrel, Red Knot) at the Salton Sea then, though not in migration (Patten et al. 2003). Also, some strictly marine species found on the California coast are lacking (Black Oystercatcher, *Haematopus bachmani*; Wandering Tattler) or extremely rare (Black Turnstone) at the Sea in winter; small numbers

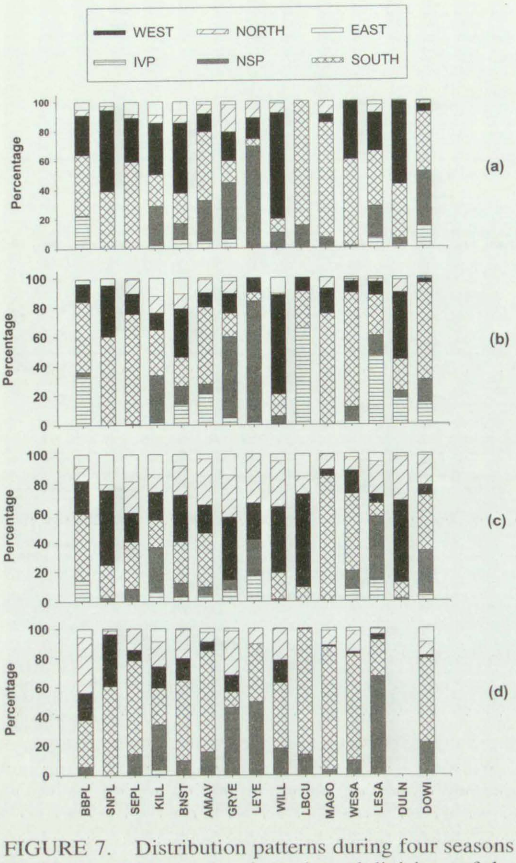

FIGURE 7. Distribution patterns during four seasons for 15 shorebird taxa by six major subdivisions of the Salton Sea study area. (a) = January, (b) = November, (c) = April, and (d) = August; East = east shore, IVP = Imperial Valley ponds, North = north shore, NSP = nearshore ponds, South = south shore, and West = west shore (see METHODS; Fig. 1); AMAV = American Avocet, BBPL = Black-bellied Plover, BNST = Black-necked Stilt, DOWI = dowitcher spp., DUNL = Dunlin, GRYE = Greater Yellowlegs, KILL = Killdeer, LBCU = Long-billed Curlew, LESA = Least Sandpiper, LEYE = Lesser Yellowlegs, MAGO = Marbled Godwit, SEPL = Semipalmated Plover, SNPL = Snowy Plover, WESA = Western Sandpiper, WILL = Willet.

of the latter two species also occur on the western Baja coast. Likewise, though found in western Baja California and west Mexico, the Wilson's Plover (*Charadrius wilsonia*) and American Oystercatcher (*Haematopus palliatus*) do not winter at the Sea. Finally, the Stilt Sandpiper winters at both the Salton Sea and the west coast of Mexico but not on the coasts of California or western Baja California.

Based on their known ranges, species that winter at, or migrate through, the Salton Sea come from diverse breeding areas ranging from the western North American arctic (e.g., Western Sandpiper) to the high plains of the United States (e.g., Mountain Plover). Yet, anecdotal evidence suggests a strong migrant connection between the Salton Sea and the west coast of Mexico, the Gulf of California, and the Pacific Coast of the United States, particularly in spring. Butler et al. (1996) reported a Western Sandpiper banded in Panama was found at the Salton Sea in spring. The large numbers of Whimbrels in the Imperial Valley in spring appear to represent a movement of birds from coastal Mexico (Howell and Webb 1995) that continues north to the west of the Sierra Nevada and through California's Central Valley (Shuford et al. 1998); very few move east of that range through the Great Basin (Shuford et al. 2002a). An even tighter coastal passage, linked by the Salton Sea, is suggested by moderate numbers of migrant Ruddy Turnstones, Red Knots, Sanderlings, and Short-billed Dowitchers found at the Sea (Table 1; Patten et al. 2003). These species move along the Pacific Coast of Mexico (Howell and Webb 1995) and the United States (Page et al. 1999), but away from the Salton Sea are rare elsewhere in the interior of California and much of the West (Shuford et al. 1998, 2002a).

Although the shorebird faunas of the Salton Sea and sites in the Intermountain West also have affinities, only the Sea serves as a stopover site for several primarily coastal species and hosts large numbers of migrant Whimbrels in spring and wintering Mountain Plovers. Also many species that occur primarily at other sites in the Intermountain West as breeders or migrants occur at the Sea primarily or extensively as winter residents (e.g., Willet, Long-billed Curlew, Marbled Godwit).

Threats and Conservation

Great concern has recently been expressed about the health of the Salton Sea ecosystem because of increasing salinity, large bird die-offs from diseases and unknown causes, potential harm from contaminants, and hyper-eutrophication (USFWS 1997, Setmire 2001, Shuford et al. 2002b, Meteyer et al. *this volume,* Rocke et al. *this volume*). Although the greatest threat to shorebird habitat in the Intermountain West is the scarcity of high quality fresh water (Engilis and Reid 1997, Oring et al. 2000), this threat is manifest in various ways. Many intermountain wetlands suffer from water diversions that reduce inflows and hence wetland acreage (e.g., Owens Lake, California). By contrast, the Salton Sea is the largest intermountain wetland threatened by an inflow of water of relatively high salinity, greatly increased at the Sea by high evaporation rates, and from contaminants from agricultural and urban sources. The salinity of

TABLE 3. NUMBERS OF SNOWY PLOVERS COUNTED IN VARIOUS AREAS AT THE SALTON SEA, CALIFORNIA (FIG. 1), IN 1999, WITH COMPARISONS TO PRIOR YEARS (DATA FROM SHUFORD ET AL. 1995)

	Breeding season			Winter			
Area	4–12 May 1978	4–14 May 1988	21–31 May 1999	3–8 Dec 1993	1–9 Dec 1994	22–27 Jan 1999	4–15 Nov 1999
1	2	4	4	14	3	7	0
2	0	0	5	10	0	1	0
3	12	8	4	0	1	0	0
4	7	14	2	46	16	17	4
5	32	18	7	21	9	0	0
6	38	14	71	102	31	84	37
7	0	24	16	17	16	6	6
8	29	38	35	26	18	30	13
9	3	3	5	0	7	2	0
10	0	0	4	15	3	14	0
11[a]	2	7	3	3	0	18	0
12	16	17	39	10	89	90	102
13	33	11	24	0	0	3	8
14	29	26	0	13	7	2	0
15	4	1	2	0	1	1	0
16	6	0	0	0	0	0	0
17	6	0	0	0	0	0	0
18	2	0	0	5	4	0	0
21B	5	13	0	3	9	0	0
Totals	226	198	221	285	214	275	170

[a] Also includes impoundments of Salton Sea National Wildlife Refuge (Area 20A–D) not tallied separately prior to 1999.

inflowing water may further increase, and water levels decrease, if water conservation measures allow transfers to urban southern California of water now reaching the Sea (CH2M HILL 2002). Within one to two decades, increasing salinity could cause a major shift at the Salton Sea to a brine shrimp (*Artemia* spp.)–brine fly (*Ephydra* spp.) dominated system (Tetra Tech, Inc. 2000). Such a change likely would favor species, such as phalaropes and avocets, that are especially adapted to exploit such food resources. It is unclear, though, if this might impact species at the Sea that favor freshwater habitats or shorebirds as a whole. Also, if water conservation measures alter current irrigation practices or lead to fallowing of substantial acreage of agricultural fields in the Imperial Valley, this may reduce shorebird use of these fields.

. Setmire et al. (1990, 1993) and the Imperial Irrigation District (1994) reviewed the results of bird contaminant studies at the Salton Sea. Most studies of the effects of contaminants on shorebirds at the Sea have focused on the Black-necked Stilt. Setmire et al. (1993) reported that 5% of the Black-necked Stilt eggs collected at the Salton Sea had at least a 10% probability of embryotoxicity, versus 60% at Kesterson NWR, an area of high selenium contamination. Stilt eggs also had boron concentrations as much as double the threshold levels associated with reduced gain in mass in ducklings, and stilt growth rates at the Sea were lower than those of stilts on the coast in an area not affected by agricultural wastewater. Also, high DDE concentrations in stilt eggs were thought to cause significant eggshell thinning. Although contaminants have not been shown to cause large-scale die-offs or reproductive problems, there is still ongoing concern for their potential impacts on waterbirds at the Salton Sea (C. Roberts, pers. comm.).

Substantial numbers of shorebirds have died at the Salton Sea from botulism and avian cholera (Shuford et al. 1999, Friend 2002). It is unclear, though, whether mortality rates of shorebirds from these diseases at the Sea are high compared with other sites in western North America or if factors contributing to the overall concern for the ecosystem's health are enhancing disease outbreaks at the Sea.

Proposals to restore the health of the Salton Sea ecosystem focus disproportionately on reducing salinity (Tetra Tech, Inc. 2000), as knowledge so far is inadequate for implementing effective disease reduction measures. One proposed method for reducing salinity involves construction of large within-sea evaporation ponds, which, if implemented, likely would displace substantial amounts of current shorebird habitat. Our results showing the highly concentrated distribution patterns of shorebirds as a whole and of some sensitive species, such as the Snowy Plover, indicate that large-scale evaporation

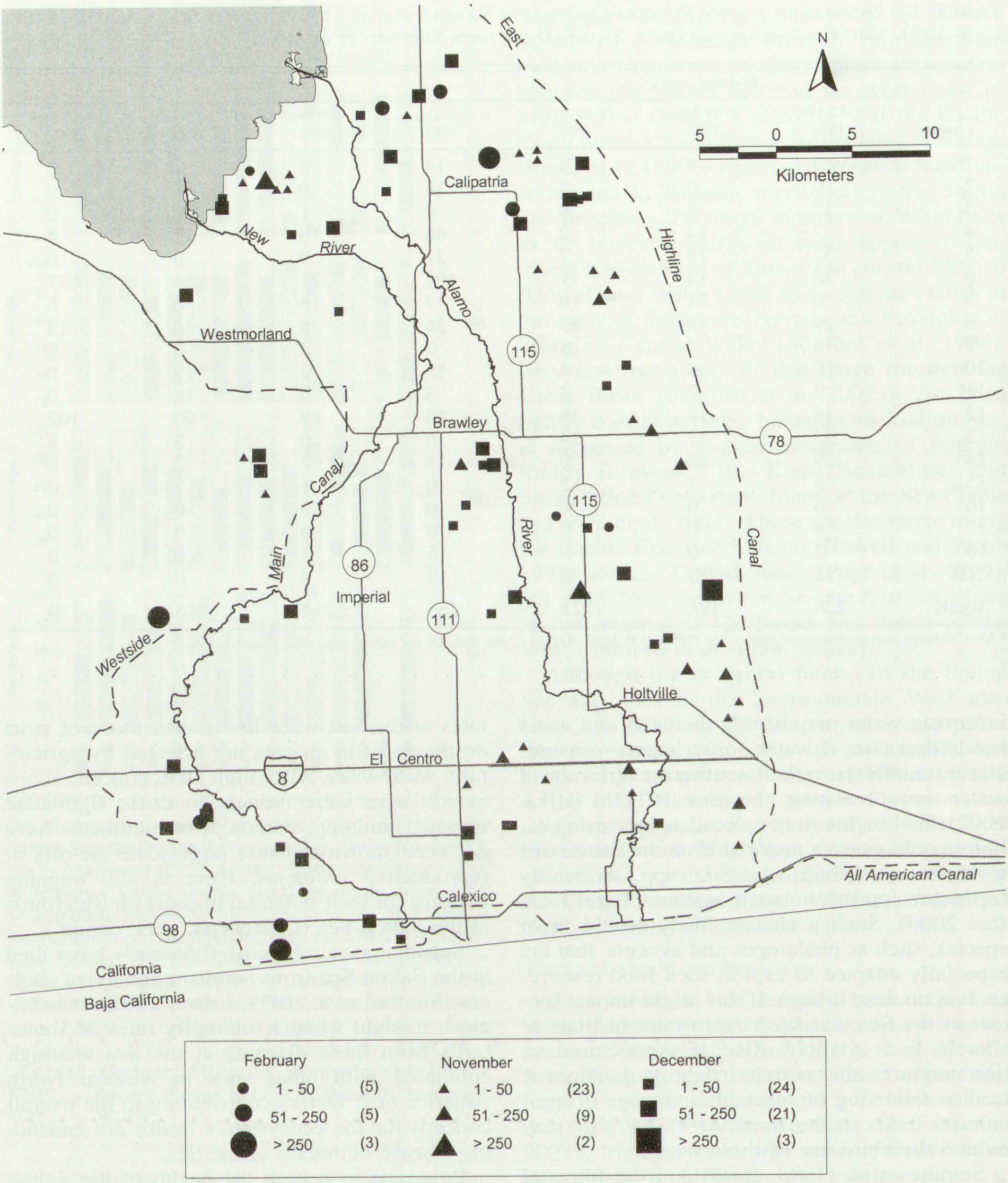

FIGURE 8. Distribution and relative size of Mountain Plover flocks on three surveys of the Imperial Valley, California, in 1999.

ponds or other similar projects should not be constructed along the southeastern, southern, western, or northern shorelines unless measures can be taken to maintain current shorebird habitats or adequately mitigate for their loss. It is unclear if large-scale evaporation ponds at the Sea might concentrate selenium at levels that have caused reproductive harm to shorebirds nesting at such ponds in the Central Valley (Skorupa and Ohlendorf 1991, Ohlendorf et al. 1993).

Although the U.S. Shorebird Conservation Plan shows great promise for conserving North American shorebirds (Brown et al. 2001), efforts

TABLE 4. COMPARISON OF PEAK WINTER SHOREBIRD POPULATIONS AT THE SALTON SEA (TABLE 2), RÍO COLORADO DELTA (MORRISON ET AL. 1992, MELLINK ET AL. 1997), AND CENTRAL VALLEY (SHUFORD ET AL. 1998)

Species	Salton Sea	Río Colorado Delta	Central Valley
Black-bellied Plover	1,300	4,600	10,200
Black-necked Stilt	4,000	380	13,400
American Avocet	7,300	9,400	4,000
Willet	1,800	8,000	110
Marbled Godwit	1,400	9,100	140
Western Sandpiper	4,700	75,000	8,400
Dunlin	800	100	176,000
Dowitcher spp.	6,400	2,900	118,000
Total shorebirds	28,000	164,000	374,000

to protect shorebirds and other waterbirds at the Salton Sea will be very expensive, lengthy, and difficult. Given the high demand for water in this arid region with a large and rapidly expanding human population, long-term success ultimately may hinge on our ability to stabilize or reduce the human population, conserve water resources, and elevate the priority of wildlife when allocating limited water supplies.

RESEARCH NEEDS

Much remains to be learned about the ecology of shorebirds at the Salton Sea. Studies lacking at the Salton Sea include ones on shorebird diets, the possible effect of selenium and other contaminants on shorebird reproductive success, and population sizes and habitat use patterns of shorebirds in agricultural fields. Long-term research is needed to compare the potential effects of salt and metals on immune function and survivorship of shorebirds at the Sea with populations at sites lacking these stresses. Banding and radio-telemetry studies also are needed to establish patterns of connectivity of the Salton Sea with other wetlands to focus conservation efforts at the appropriate scale. Finally, long-term monitoring is needed, particularly to document the effect of proposed restoration projects.

ACKNOWLEDGMENTS

The Pacific Flyway Project was funded by the Bay Foundation of Morro Bay, the Bradford Foundation, the Bureau of Reclamation, the Central Valley Habitat Joint Venture, Chevron USA Inc., the Dakin Foundation, Ducks Unlimited, the Katherine W. Dumke and Ezekiel R. Dumke, Jr., Foundation, Genentech, the Walter and Elise Haas Fund, the J. M. Long Foundation, the Marin, Morro Coast, and Stockton chapters of National Audubon Society, National Fish and Wildlife Foundation, the David and Lucille Packard Foundation, the San Francisco Foundation, the Strong Foundation, the True North Foundation, the Dean Witter Foundation, anonymous donors, and members of PRBO. Financial support for Salton Sea Reconnaissance Survey was provided by the Salton Sea Authority through U.S. Environmental Protection Agency grant # R826552-01-0.

We are grateful to all of the many volunteers who helped with surveys, but we would particularly like to thank K. Garrett, D. Julian, C. McGaugh, S. Meyers, B. Miller, M. Patten, and K. Sturm for their extensive support. G. Page provided leadership and inspiration for the Pacific Flyway Project. PRBO staff C. Hickey, K. Molina, and B. Mulrooney were extremely helpful in organizing and conducting surveys and database management. A. Black and D. Stralberg helped to prepare Figures 1 and 8. We are grateful to various state and federal agencies and private landowners who provided access to their lands for surveys. We thank M. Friend and the entire Salton Sea Science Subcommittee, B. Gump, T. Kirk, and D. Zembal for oversight and guidance of the Salton Sea Reconnaissance Survey. We are extremely, and particularly, grateful to K. Sturm, C. Bloom, S. Johnson, and other staff of the Sonny Bono Salton Sea National Wildlife Refuge for providing access to refuge lands for our research, supplying airboat support for shoreline surveys, and otherwise cooperating to ensure the success of our work. B. Barnes and K. Hunting kindly provided unpublished data on Mountain Plovers. An earlier draft of the manuscript benefited greatly from reviews by G. McCaskie, K. Molina, and L. Oring. This is Contribution 935 of PRBO.