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

W. David Shuford and Nils Warnock
Point Reyes Bird Observatory, 4990 Shoreline Highway, Stinson Beach, CA 94970,
email: dshuford@prbo.org

Robert L. McKernan
San Bernardino County Museum, 2024 Orange Tree Lane, Redlands, CA 92374

Corresponding author: W. David Shuford, Point Reyes Bird Observatory, 4990 Shoreline Highway, Stinson Beach, CA 94970; ph: 415-868-1221, ext. 14; fax: 415-868-1946; email: dshuford@prbo.org

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Abstract. From 1989 to 1999, we surveyed shorebirds at the Salton Sea and in the adjacent Imperial Valley, California. Of 27 regularly occurring species (of 34 recorded), 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 (fall), American Avocet (fall), Western Sandpiper (spring and fall), and dowitcher spp. (spring). The American Avocet and Long-billed Dowitcher were the only species exceeding 5,000 in winter. The Salton Sea remains an important breeding and wintering area for the Snowy Plover, but more extensive coverage of agricultural fields in 1999 revealed 2,486-3,758 Mountain Plovers, 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, and Long-billed Curlew primarily used agricultural fields of the Imperial Valley. Wintering and migrant shorebirds at the Salton Sea, respectively, show an affinity with those at the Río Colorado Delta and with the Pacific Coast of Mexico and the United States. Shorebirds at the Salton Sea face threats from increasing salinity, disease outbreaks, and, potentially, from contaminants from agricultural and urban sources. Large restoration projects proposed to reduce salinity may have negative impacts if placed where large numbers of shorebirds or sensitive species concentrate.

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

Shorebirds increasingly are the focus of conservation concern because of population declines and habitat loss (Page and Gill 1994, Brown et al. 2000). Although recent papers provide broad overviews of shorebird use of wetlands and agricultural habitats in western North America (Shuford et al. 1998, Page et al. 1999), few data have been published on the patterns of shorebird use at individual sites, 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. 2000, papers 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, Shuford et al. 1999, Tetra Tech, Inc. 2000).

Point Reyes Bird Observatory 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-Aug to mid-Sep), eight in spring (mid-Apr), five in early winter (mid-Nov to early Dec), and four in mid-winter (late Jan to early Feb). On each census, a team of professional biologists and skilled volunteers attempted to survey the entire Salton Sea shoreline, adjacent marshes and impoundments, and various sites in the Imperial Valley, including the Finney-Ramer Unit of Imperial Wildlife Area (WA) south of Calipatria and private duck clubs near Brawley. Except on winter surveys of Mountain Plovers, 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 south to, and including, the New River to reduce the risk of heat exhaustion while covering this long, isolated stretch.

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; small sandpipers of the genus *Calidris*, primarily Western and Least Sandpipers, and Dunlin; dowitchers, either Short-billed or Long-billed; and phalaropes, either Wilson's or Red-necked. For analyses, we grouped both identified and unidentified dowitchers as dowitcher spp. owing to the difficulty of identifying most individuals to species on surveys. Incidental observations indicate that all wintering dowitchers are Long-billeds. 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 in litt.). We assigned unidentified shorebirds to species using methods described in Page et al. (1999), leaving some (dowitchers) in unidentified categories when the ratio of unidentified to identified was high. Scientific names for all species are listed in Table 1.

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 three winter surveys to analyze patterns of distribution around the Salton Sea shoreline. 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) (Figure 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 4 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 regularly occurring species, i.e. those recorded on at least three comprehensive surveys in any season. Although it did not meet 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 snuck off nests and scattered. We also asked observers to zig-zag 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, zig-zagging 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 8 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 (percent 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 and 2). Median shorebird totals were 78,835 (N = 5, min.-max. = 59,512-105,570) in fall, 68,281 (N = 5, min-max. = 36,675-129,538) in spring, and 27,796 (N = 4, min-max. = 19,724-70,059) in winter. The relatively low numbers in April 1999 compared with others springs may represent a lack of coincidence of the 1999 survey dates with the peak passage of Western Sandpipers, which can move through very 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 2,486 Mountain Plovers in agricultural fields of the Imperial Valley in February, 2,790 in November, and 3,758 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 >1,000 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 >1,000 and <5,000 for five taxa and >5,000 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 5,000 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 and 2). Of 27 such species, 4 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. XXX 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. Still many numerous species varied in their patterns of distribution (Figure 6). 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 to roost 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 in these habitats and foraging in agricultural fields.

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 and 6). 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 9,837 Whimbrels at the Salton Sea in April 1989 was almost exclusively from of agricultural fields in the Imperial Valley, which received only limited coverage. The order of magnitude of Long-billed Curlew abundance in the Imperial Valley is indicated by counts of about 2,655 individuals in a single flock near Calipatria on 13 November 1999, a total of 5,593 from coverage of about 60% of the Imperial Valley by six observers involved in a Mountain Plover survey on 11-12 December 1999, and 7,476 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). 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. 7), 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 3 individuals in a 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 1,184 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 1,777 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 undulating and with large dirt clods. Although many fields with growing crops used by plovers were relatively flat throughout, many others had raised beds with flats tops and narrow intervening furrows in which plovers often stood or crouched.

DISCUSSION

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 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 (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. 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 Oregon's Willamette Valley, that hold tens of thousands of shorebirds in winter (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. 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 still the only substantial one of that species in North America (G. McCaskie pers. comm.).

The Salton Sea also holds very 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 8,000 to 10,000 individuals (Anonymous 1999). On prior surveys across the California wintering range, the 2,072 and 755 Mountain Plovers recorded in the Imperial Valley in 1994 and 1998, respectively, represented 61% and 35% of the totals of 3,390 and 2,179 individuals found statewide (B. Barnes in litt., CDFG unpubl. data, K. Hunting in litt.). 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 0-1,025 birds (median = 180 birds; N = 33) from 1965 to 1999.

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.

Although little solid information exists on the origin of migrant shorebirds at the Salton Sea, anecdotal evidence suggests there is a strong migrant connection with 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 very large numbers of Whimbrels in the Imperial Valley in spring appear to be come from coastal Mexico (Howell and Webb 1995) then move north to the west of the Sierra Nevada, as large numbers also pass through California's Central Valley (Shuford et al. 1998) but very few move east of that range through the Great Basin (PRBO unpubl. data). An even tighter coastal passage, linked by the Salton Sea, is suggested by the use of the Sea by moderate numbers of migrant Ruddy Turnstones, Red Knots, and Sanderlings (Table 1). 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 (PRBO unpubl. data). Based on their know ranges, species that winter at the Salton Sea come from diverse breeding areas ranging from the western North American arctic (e.g., Western Sandpiper) to the Central Plains of the United States (e.g., Mountain Plover).

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, and potential harm from contaminants (USFWS 1997, Shuford et al. 1999). Although the greatest threat to shorebird habitat in the Intermountain West is the scarcity of high quality fresh water (Engilis and Reed 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 imported water of high salinity and from contaminants from agricultural and urban sources. 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 at hypersaline lakes in the

Intermountain West. It is unclear, though, if this might impact species at the Sea that favor freshwater habitats or shorebirds as a whole.

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 weight gain 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 (see Roberts this volume).

Substantial numbers of shorebirds have died at the Salton Sea from botulism and avian cholera (Shuford et al. 1999). 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 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.

Although the U.S. Shorebird Conservation Plan shows great promise for conserving North American shorebirds (Brown et al. 2000), efforts 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. 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.

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

	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 *Pluvialia 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 alexandinus*	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
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.	5,939	10,704	9,320	15,533	7,153	12,109	10,126	14,624	26,443	6,492

Limnodromus griseus or L. scolopaceus										
Common Snipe	0	0	0	0	2	3	7	3	0	1
Gallinago gallinago										
Wilson's Phalarope	7,577	818	2,346	1,003	3,065	133	416	83	334	23
Phalaropus tricolor										
Red-necked Phalarope	150	12,265	1,139	4,350	32	77	754	1,816	101	32
Phalaropus lobatus										
Red Phalarope	0	0	0	0	0	0	0	0	0	3
Phalaropus fulicarius										
Totals	59,512	105,570	78,835	97,699	74,758	68,281	62,949	98,784	29,538	36,675

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

	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.	5,671	3,419	11,589	6,356
Common 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

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 SSNWR (Area 20A-D) not tallied separately prior to 1999.

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

Figure Legends

FIGURE 1 (Figure 4-3). Numbered areas of the shoreline and inshore zone (within 0.5 km of shore) of the Salton Sea, California, and adjacent freshwater impoundments. Inset shows locations of duck clubs near Brawley in the Imperial Valley.

FIGURE 2 (Figure 5-6f). 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).

FIGURE 3 (Figure 6-g). 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).

FIGURE 4 (Figure 6-h). 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).

FIGURE 5 (Figure 5-6i). 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).

FIGURE 6. Distribution patterns during four seasons for 15 shorebird taxa by six major subdivisions of the Salton Sea study area: West = west shore, North = north shore, East = east shore, South = south shore, NSP = nearshore ponds, and IVP = Imperial Valley ponds (see Methods; Fig. 1). BBPL = Black-bellied Plover, SNPL = Snowy Plover, SEPL = Semipalmated Plover, KILL = Killdeer, BNST = Black-necked Stilt, AMAV = American Avocet, GRYE = Greater Yellowlegs, LEYE = Lesser Yellowlegs, WILL = Willet, LBCU = Long-billed Curlew, MAGO = Marbled Godwit, WESA = Western Sandpiper, LESA = Least Sandpiper, DUNL = Dunlin, DOWI = dowitcher spp.

FIGURE 7 (Figure 5-9). Distribution and relative size of Mountain Plover flocks on three surveys of the Imperial Valley, California, in 1999.

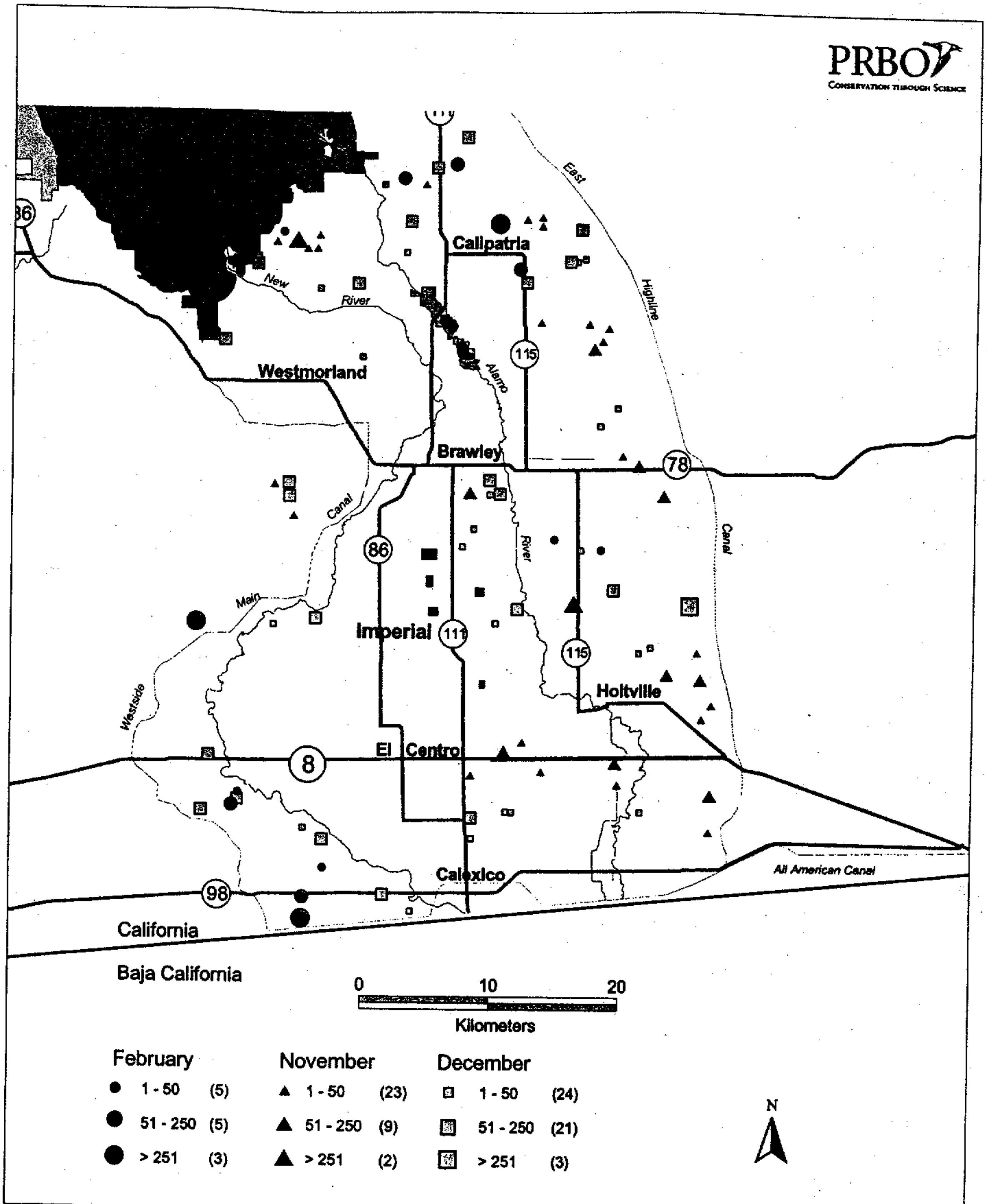

Figure 5 - 9. Distribution and relative size of Mountain Plover flocks on three surveys of the Imperial Valley, California, in 1999.

Figure 7

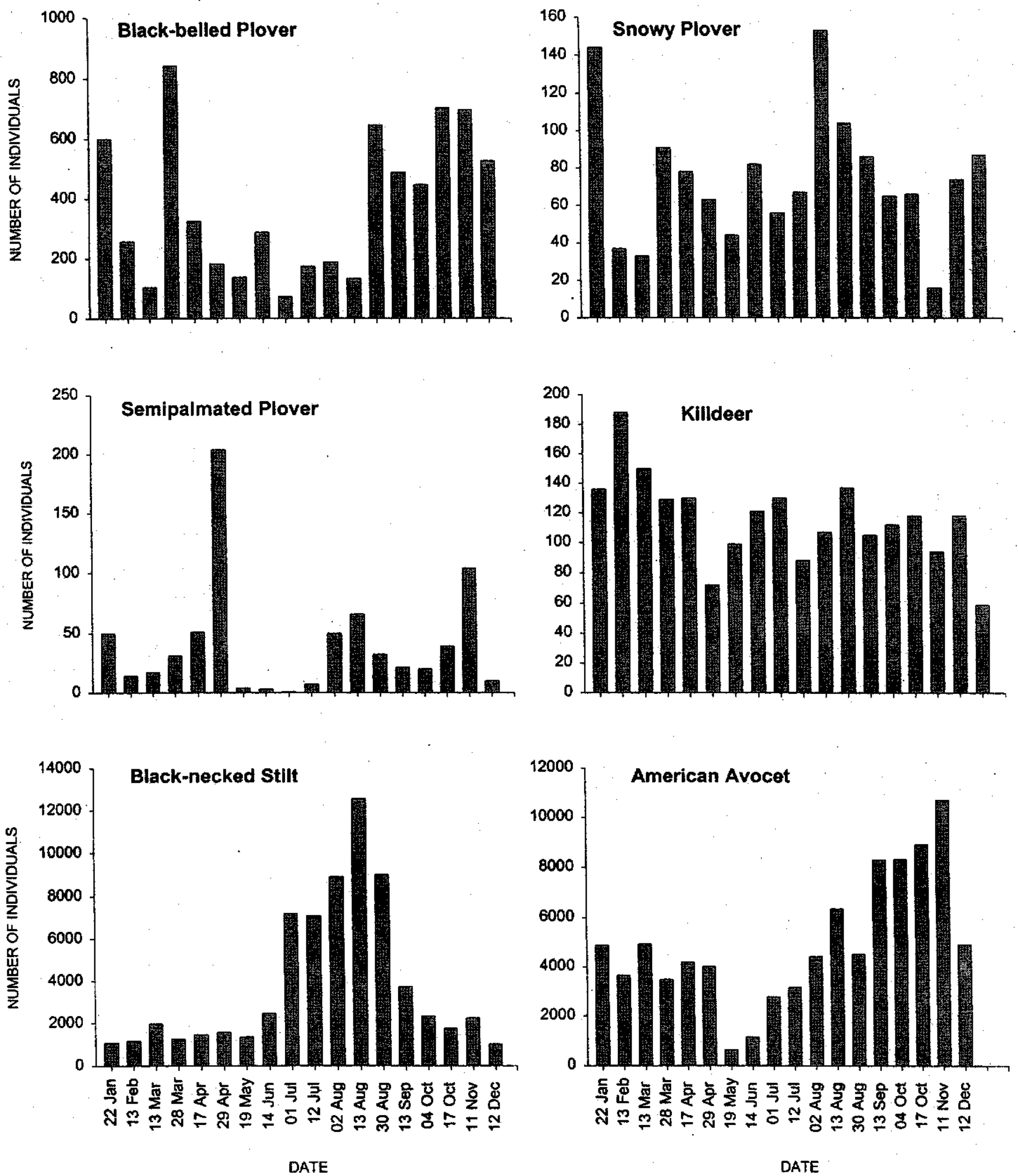
Black-belled Plover
Snowy Plover
Semipalmated Plover
Killdeer
Black-necked Stilt
American Avocet
NUMBER OF INDIVIDUALS
DATE
22 Jan
13 Feb
13 Mar
28 Mar
17 Apr
29 Apr
19 May
14 Jun
01 Jul
12 Jul
02 Aug
13 Aug
30 Aug
13 Sep
04 Oct
17 Oct
11 Nov
12 Dec

Figure 2

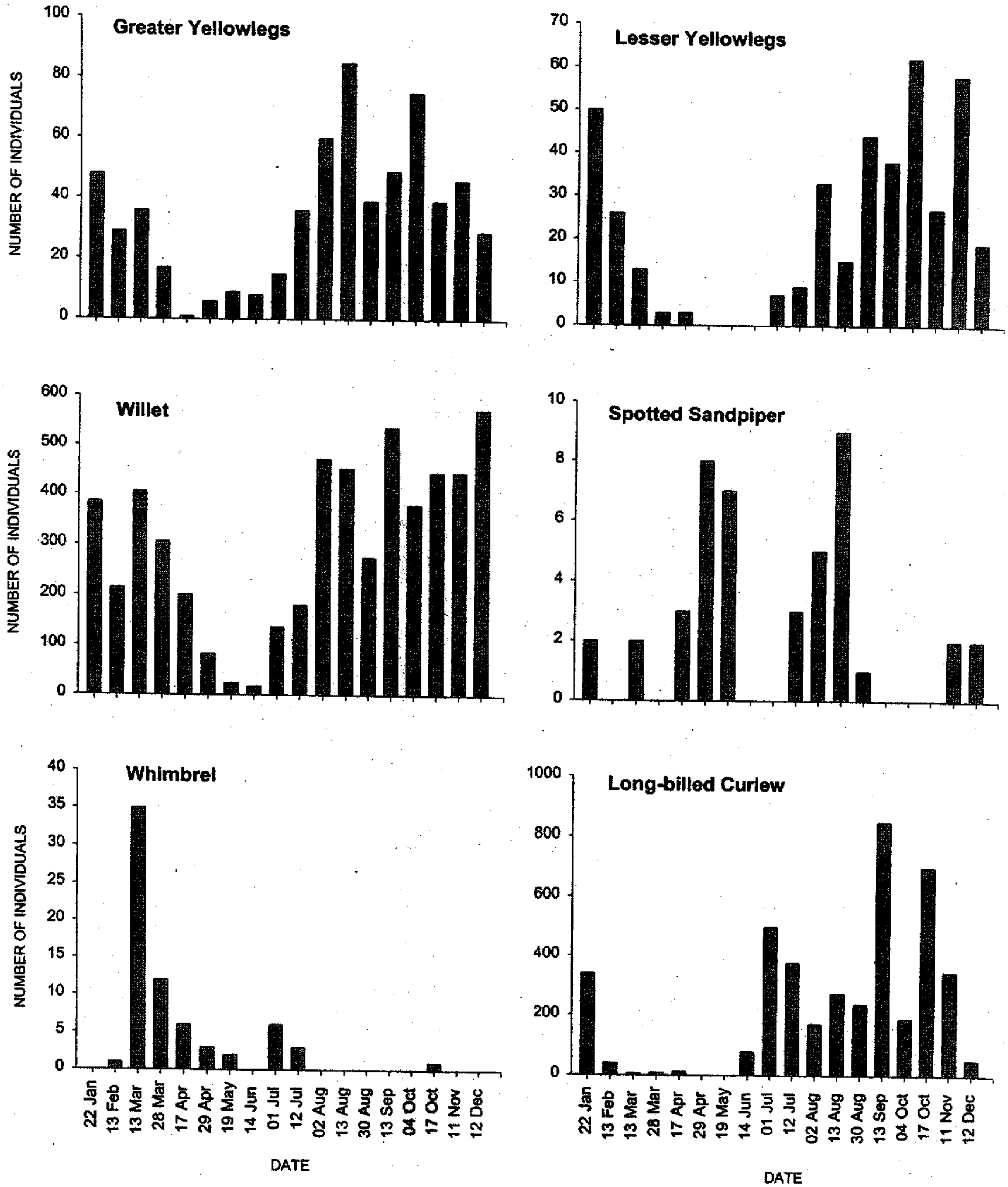
Greater Yellowlegs
Lesser Yellowlegs
Willet
Spotted Sandpiper
Whimbrel
Long-billed Curlew
NUMBER OF INDIVIDUALS
DATE
22 Jan
13 Feb
13 Mar
28 Mar
17 Apr
29 Apr
19 May
14 Jun
01 Jul
12 Jul
02 Aug
13 Aug
30 Aug
13 Sep
04 Oct
17 Oct
11 Nov
12 Dec

Figure 3

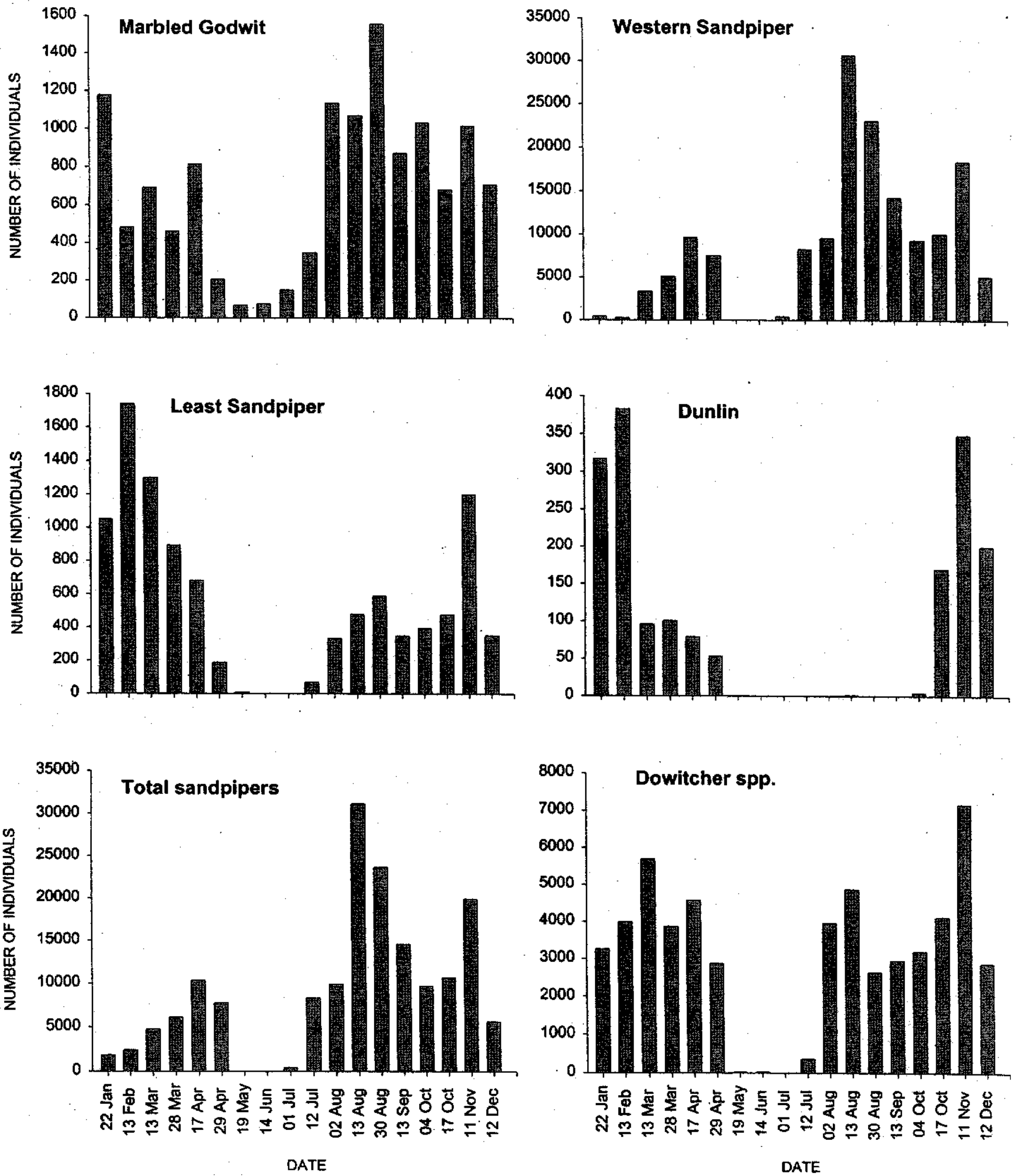
Marbled Godwit
Western Sandpiper
Least Sandpiper
Dunlin
Total sandpipers
Dowitcher spp.
NUMBER OF INDIVIDUALS
DATE
22 Jan
13 Feb
13 Mar
28 Mar
17 Apr
29 Apr
19 May
14 Jun
01 Jul
12 Jul
02 Aug
13 Aug
30 Aug
13 Sep
04 Oct
17 Oct
11 Nov
12 Dec

Figure 4

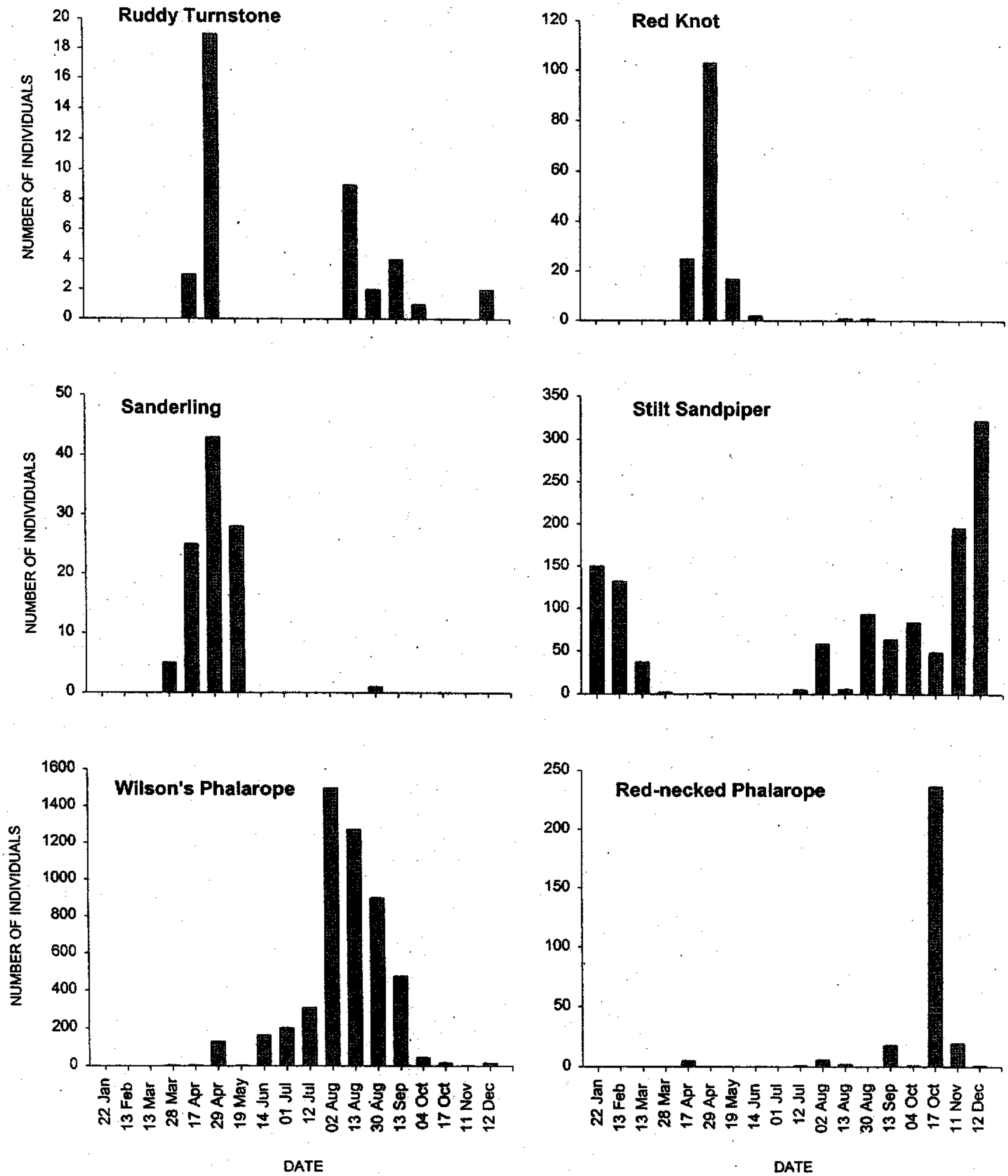
Ruddy Turnstone
Red Knot
Sanderling
Stilt Sandpiper
Wilson's Phalarope
Red-necked Phalarope
NUMBER OF INDIVIDUALS
DATE
22 Jan
13 Feb
13 Mar
28 Mar
17 Apr
29 Apr
19 May
14 Jun
01 Jul
12 Jul
02 Aug
13 Aug
30 Aug
13 Sep
04 Oct
17 Oct
11 Nov
12 Dec

Figure 5

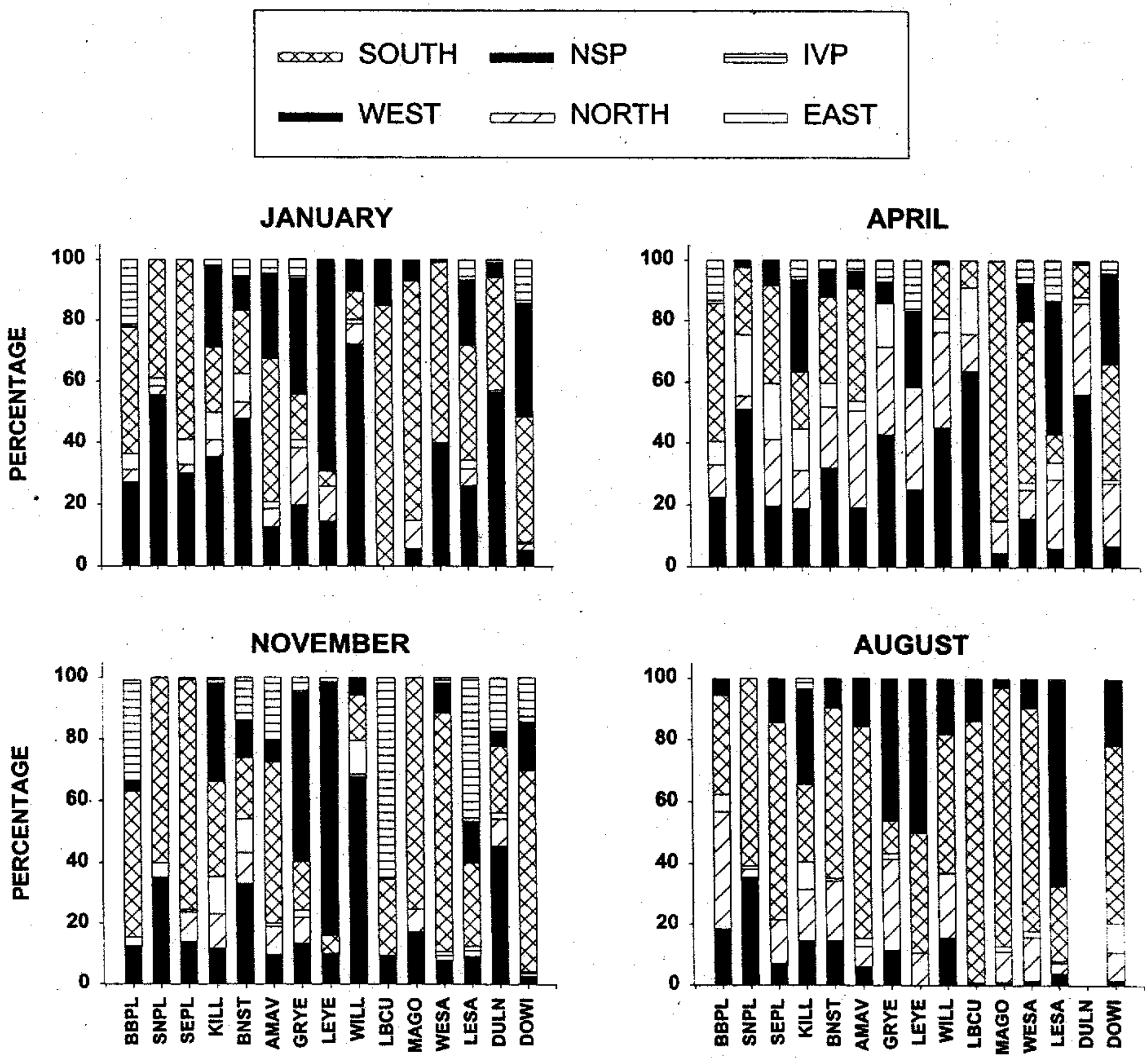
SOUTH
NSP
IVP
WEST
NORTH
EAST
JANUARY
APRIL
NOVEMBER
AUGUST
PERCENTAGE
PERCENTAGE
0
20
40
60
80
100
BBPL
SNPL
SEPL
KILL
BNST
AMAV
GRYE
LEYE
WILL
LBCU
MAGO
WESA
LESA
DULN
DOWI

Figure 6

1) NSP
2) South
3) west
4) North
5) East
6) IVP

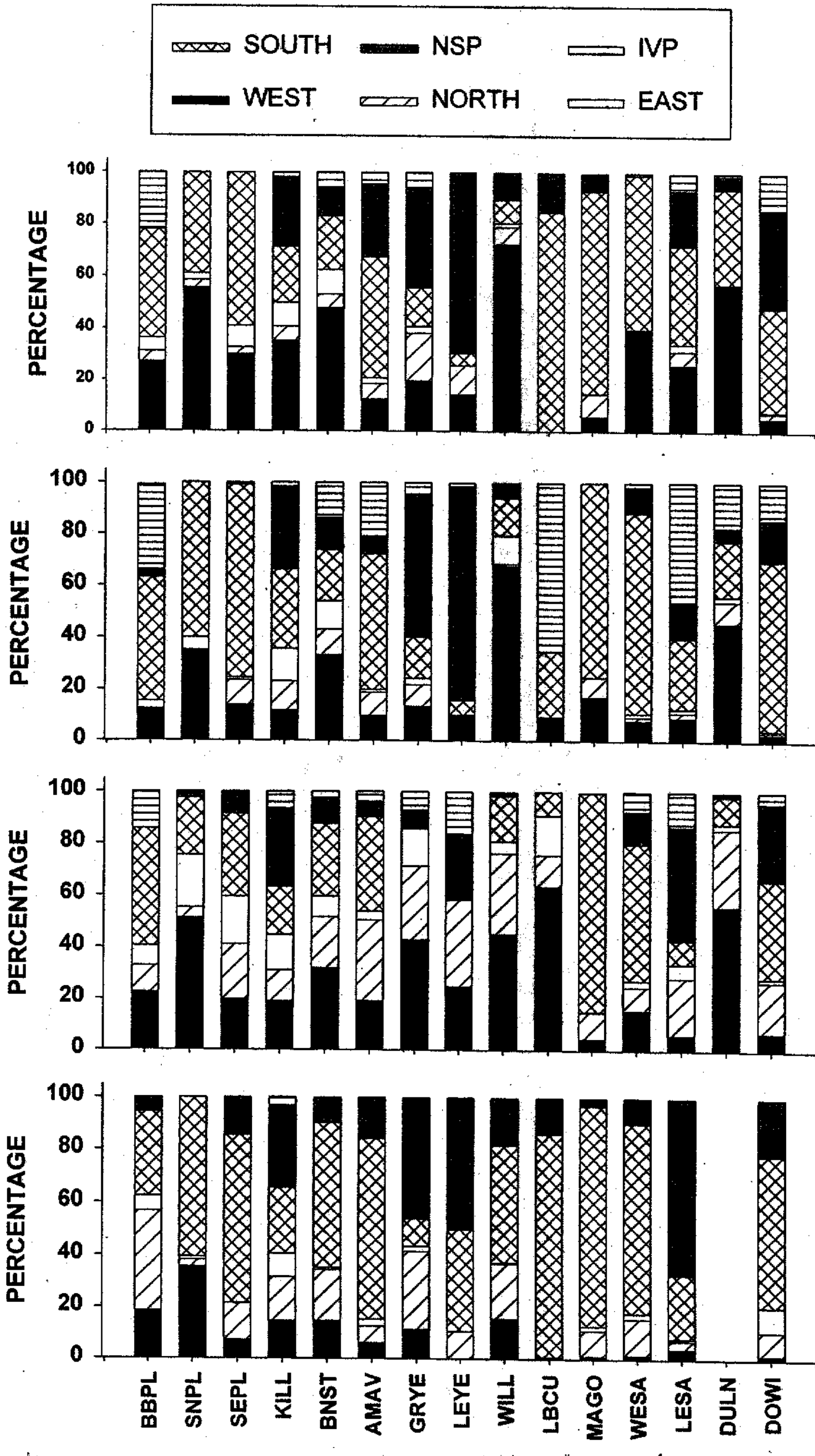

Fig. 6 (revised)

Nils, Tried this version after [1st] put me in box and like it better than 1st version