SUMMER DISTRIBUTION, ABUNDANCE, AND HABITAT USE OF BLACK-NECKED STILTS AND AMERICAN AVOCETS IN CALIFORNIA'S CENTRAL VALLEY

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ABSTRACT: Little is known about breeding shorebirds in California's Central Valley on which conservation actions could be based. In summer 2003, we surveyed shallow-water habitats throughout that region for Black-necked Stilts (*Himantopus mexicanus*) and American Avocets (*Recurvirostra americana*). Survey methods included ground counts, aerial surveys, and sampling of Sacramento Valley rice fields. We estimated about 30,000 Black-necked Stilts and 10,700 American Avocets in the Central Valley, exclusive of Suisun Marsh. The proportion of stilts and avocets, respectively, within four subregions were Sacramento Valley 74% and 37%, delta 1% and 1%, San Joaquin basin 2% and 7%, and Tulare basin 23% and 56%. The ratio of stilts to avocets was 5.6:1 in the Sacramento Valley, 1.1:1 in the San Joaquin Valley. The Sacramento Valley held 64% of all stilts and avocets, the Tulare basin 32%, the San Joaquin basin 3%, and the delta 1%. Key habitats were rice fields (73%), managed wetlands (10%), and sewage ponds (6%) for stilts, and rice (35%), managed wetlands (32%), agricultural evaporation ponds (14%), sewage ponds (9%), and agricultural canals (6%) for avocets. Rice held 98% of all stilts and 93% of all avocets in the Sacramento Valley. The Tulare basin had five habitats that held >10% of its total for at least one of the species and was the only region where agricultural evaporation ponds, agricultural canals and ditches, and water-storage facilities supported large numbers of shorebirds. Overall, >80% of all stilts and avocets in the Central Valley were found in environments created for agriculture, water management, or industry, where they may be exposed to toxins. Their reliance on these artificial environments is risky, as future changes to serve human economies may reduce the value of such habitats to wildlife. Thus there is a need to restore and enhance high-quality wetlands in the Central Valley to counter historic losses and potential future loss of other shallow-water habitats of uncertain reliability and quality.

California's Central Valley, one of the most productive agricultural areas in the world, has been a particular focus of wetland conservation because over 90% of its historic wetlands have been lost during the past 150 years (Frayer et al. 1989, Kempka et al. 1991). Current efforts to increase wetland habitat in the Central Valley in response to continent-wide declines of waterfowl also aim to benefit other wetland-dependent birds, including shorebirds (USFWS 1990, Streeter et al. 1993), but are hampered by a paucity of biological data on most species. Prior information on shorebird occurrence in the Central Valley consists mainly of surveys of small isolated sites (Jurek 1973, 1974), coarse descriptions of seasonal abundance patterns and habitat selection in the Sacramento Valley (Manolis and Tangren 1975), and studies of single species (e.g., Pitelka 1950). Knowledge of shorebird use of the Central Valley was greatly expanded by broad-scale surveys in the early 1990s that provided an overview of the abundance, geographic distribution, habitat use, and continent-wide importance of migrating and wintering shorebirds of this region (Shuford et al. 1998).

Concern over continued loss of shorebird habitat (Myers 1983, Senner and Howe 1984) led to the preparation of the U.S. Shorebird Conservation Plan (Brown et al. 2001), which is currently being implemented mainly through regional shorebird conservation plans in partnership with joint ventures of the North American Waterfowl Management Plan (NAWMP Plan Committee 2004). The Southern Pacific Shorebird Conservation Plan (Hickey et al. 2003) encompasses the Central Valley and coastal California. Within this area, the Central Valley Shorebird Working Group strives to set population and habitat objectives, implement conservation recommendations, and define research and monitoring priorities for shorebirds. Among the highest research priorities the group identified was the need for surveys of breeding shorebirds in the Central Valley. Little is known about their status in the region in summer, a period when wetland habitat reaches its annual nadir and for which wetland loss has been even greater than at other seasons.

To fill this important data gap, we coordinated counts of potentially breeding shorebirds at wetlands and other shallow-water habitats throughout the Central Valley from mid-May to mid-June 2003. Here we report the patterns of geographic distribution, abundance, and broad-scale habitat use of the Black-necked Stilt (*Himantopus mexicanus*) and American Avocet (*Recurvirostra americana*), the shorebird species most representative of these habitats in the Central Valley. We also identify threats to nesting shorebirds and make recommendations for management and research needed to ensure the effective conservation of their populations and habitat in this region.

Study Area

California's Central Valley, averaging about 644 km long and 64 km wide, runs north to south through the heart of the state, where it is surrounded by mountains except at its western drainage into the San Francisco Bay estuary. It is divided into the Sacramento Valley, draining south, the San Joaquin Valley, draining north, the Sacramento–San Joaquin River delta (hereafter delta), where these rivers converge, and Suisun Marsh, where land-locked wetlands merge with tidal habitats of the San Francisco Bay estuary. We did not survey shorebirds in Suisun Marsh hence do not discuss it further. We report data for four major subregions of the Central Valley: Sacramento Valley, delta, and the San Joaquin and Tulare basins of the San Joaquin Valley (see map in Shuford et al. 1998).

Precipitation in the Central Valley was close to normal in the winter prior to our surveys but well above average in the spring of 2003. Precipitation for the climate year (1 July–30 June) 2002–2003, averaged over many stations, was 100.3 and 46.2 cm in the Sacramento and San Joaquin drainages, respectively, representing 105% and 90% of their long-term averages (n = 108 yrs) (Western Regional Climate Center; http://www.wrcc.dri.edu/divisional.html). Precipitation for late spring (1 April–31 May) 2003 for these regions was 21.8 and 12.9 cm, respectively, representing 195% and 193% of the long-term averages. The atypical rainfall in the spring delayed planting of rice in the Sacramento Valley, as described below, but otherwise appeared to have limited effects on shorebirds and their habitats. Spring rains may have slightly delayed the drying out of some shallow-water habitats, but the normal winter precipitation overall did not create extensive ephemeral breeding habitat, as occurs in years of exceptional rainfall (e.g., 1997–98; Shuford et al. 2001).

METHODS

Survey Design

We attempted to count breeding and potentially breeding shorebirds at all shallow-water habitats throughout the Central Valley from mid-May to mid-June 2003. Habitats surveyed included agricultural canals and ditches, agricultural evaporation ponds, dairy lagoons and other farm ponds, fish ponds, irrigated fields and pastures, managed wetlands (in state wildlife areas, federal refuges, duck clubs, or other reserves), oxbow lakes, park or other urban ponds, ponds at food-processing plants, rice fields, reservoirs, sewage ponds, slough channels, storm-water retention ponds, water-recharge ponds, vernal pools and other ephemeral wetlands, and miscellaneous water bodies. We identified potential sites to survey for breeding shorebirds on the basis of extensive prior experience counting migratory and wintering shorebirds in the Central Valley (see Shuford et al. 1998), from discussions with knowledgeable local experts, and from additional field reconnaissance.

To minimize over- or undercounts of shorebirds arising from their local or regional movements, we surveyed them in a short period near the beginning of the breeding season but after the end of spring migration. Because of the study area's great size and the limited number of available observers, we staggered the timing of surveys from south to north. Our primary survey periods were 15–29 May for the Tulare basin, 22 May–5 June for the San Joaquin basin and delta, and 1–15 June for the Sacramento Valley. Although the vast majority of sites were surveyed within these periods, when this was not feasible observers censused some sites slightly later in the season.

Our primary focus was to estimate the size of the breeding populations of Black-necked Stilts and American Avocets in Central Valley wetlands. We recognized that some birds counted and included in our valleywide totals were likely nonbreeders, given not all individuals of both species breed in their first year, and some nonbreeding avocets summer in known nesting areas (Robinson et al. 1997, 1999). Although we instructed observers to count all potentially breeding shorebirds present at each site, it was not possible to obtain valleywide population estimates for other species. Surveying the Killdeer (*Charadrius vociferus*) was beyond our capabilities because it uses such a wide variety of wetland, agricultural, and upland sites, and other species—the Snowy Plover (*Charadrius alexandrinus*), Spotted Sandpiper (*Actitis macularia*), and Wilson's Snipe (*Gallinago delicata*)—either breed so locally in the Central Valley, use mainly habitats other than wetlands, or are so cryptic that they require specialized surveys (see discussion in Shuford et al. 2004a).

Because of the huge size of the study area and logistical constraints varying by habitat and subregion, we used a combination of survey methods, as described below.

Ground Counts

PRBO staff and numerous professional and amateur field ornithologists conducted ground counts at the vast majority of sites surveyed. Because of the difficulty of defining what constitutes an individual "site" within complexes of shallow-water habitats, we did not tally the total number of sites surveyed. Still, they numbered in the hundreds, and a complete list of them is available by request from the authors. We provided all observers with a protocol for counting breeding shorebirds, nests, and broods, for estimating the size of the survey site, and for describing habitat. Although we requested that observers record all nests or broods seen, we did not ask them to determine whether or not all adult shorebirds present were breeding or not, as this generally is not possible during a brief one-time survey. Observers conducted ground counts at those discrete sites to which we had obtained access, either by walking or by driving levees or roads and by scanning all suitable foraging and nesting habitat for shorebirds using binoculars and spotting scopes. They confirmed nesting by observing nests with eggs or recently hatched chicks, adults sitting in incubation posture on apparent nests, or broods of mobile young smaller in size than adults.

Aerial Surveys

PRBO staff flew portions of the Central Valley by fixed-winged aircraft (Cessna 185 Skywagon) to survey areas not feasibly covered from the ground: five hours for part of the delta on 21 May, six hours for other portions of the delta and part of the San Joaquin basin on 22 May, four hours for part of the Sacramento Valley on 6 June, and six hours for part of the Yolo, San Joaquin, and Tulare basins on 12 June. Details of the areas covered are described in Shuford et al. (2004a). We flew at altitudes averaging 300 m to look for potential habitat, and when it was located we descended to about 45 m and reduced air speed to about 90 knots to count shorebirds. Two observers counted shorebirds, each looking out opposite sides of the plane. Within all areas surveyed, we did not cover sites that we knew would be surveyed by other observers on the ground on other dates.

Sampling of Rice Fields

We counted shorebirds from the ground in a random sample of rice fields broadly distributed across the Sacramento Valley to allow estimation of overall shorebird numbers in the extensive area of rice cultivation in that region. As with ground counts in other habitats, we used binoculars or spotting scopes to scan each field carefully for foraging adults, incubating adults, and broods. To enable us to estimate densities of shorebirds in each sampled field, we obtained data on their size either by (1) collecting Global Positioning System (GPS) points at the corners of fields, defining a polygon, and calculating its size with geographic-information system (GIS) software, (2) estimating the length and width of fields using a laser GPS unit, which allowed easy calculation of the field's area, (3) obtaining acreages directly from ranchers' maps, or (4), in a small number of cases, driving perimeter roads to calculate the length and width of a field using a car odometer. By contrast, in the limited areas of rice in the delta and San Joaquin basin we tried to count all shorebirds directly.

In 2003, farmers planted an estimated 208,205 ha of various types of rice in the Central Valley. Of the 200,921 ha planted in the Sacramento Valley, 198,705 ha were the commonly grown rice *Oryza sativa* (USDA, National Agricultural Statistics Service, Calif. Statistical Office, Sacramento; http://www.nass.usda.gov/ca/coest/indexce.htm) and 2216 ha were wild rice (*Zizania palustris* var. *interior*; Calif. Wild Rice Advisory Board, Sacramento). For analyses, we used the total amount of all types of rice because we were not able to distinguish between them in the field early in the rice-growing season.

In 2003, heavy showers in April and early May delayed the planting of rice, and some intended acreage was not planted (NASS 2003). In the Sacramento Valley, on average, planting was delayed roughly three weeks (5–6 weeks in some areas) later than in a normal year (peak planting usually 1–10 May); planting on the west side of the valley was advanced about two weeks over that on the east side (P. Buttner pers. comm.). Overall an estimated 80% of all rice in California had been planted by 1 June, 90% by 8 June, and 100% by 15 June (USDC and USDA 2003, P. Buttner pers. comm.). Reflecting the earlier initiation there, it appears that 100% of the rice on the west side of the valley had been planted by 8 June (P. Buttner pers. comm.). Fields are typically planted at most two or three days after they are flooded, so planting dates are a conservative gauge of the fields' suitability for shorebirds, which may use them as soon as water is available.

We estimated the total number of stilts and avocets in rice fields of the Sacramento Valley by county by multiplying the number of hectares planted in all types of rice times the mean density estimate for that county (birds/ha). We estimated densities for a sample of 497 rice fields, spread among eight counties, by using the bird counts and measurements of field size for each field sampled. Despite the late start to the rice season and the west-to-east differences in planting, we apparently sampled most fields at or close to the time when all rice had been planted; sampling began on the west side on 5 June, on the east side on 10 June, and was completed by 19 June.

RESULTS

Abundance and Distribution

We estimated that 30,006 adult Black-necked Stilts and 10,748 adult American Avocets were in the Central Valley, exclusive of Suisun Marsh, at the time of our survey (Tables 1–3). Of these species, respectively, 22,231 (74%) and 3946 (37%) were in the Sacramento Valley, 160 (1%) and 87 (1%) were in the delta, 695 (2%) and 732 (7%) were in the San Joaquin basin, and 6920 (23%) and 5983 (56%) were in the Tulare basin. The ratio of stilts to avocets was 5.6:1 in the Sacramento Valley, 1.1:1 in the San Joaquin Valley. The Sacramento Valley held 64% of the valleywide total of

Table 1 Estimated Numbers of Black-necked Stilts and American Avocets Breeding in Sacramento Valley Rice Fields, 5–19 June 2003[a]

County	Hectares planted rice[b]	Fields sampled (*n*)	Black-necked Stilt: No. per 100 ha (±SE[c])	Black-necked Stilt: Estimated numbers (±SE)	American Avocet: No. per 100 ha (±SE)	American Avocet: Estimated numbers (±SE)
Butte	35,532	52	10.9 ± 4.2	3873 ± 1508	0.0 ± 0.0	0.0 ± 0.0
Colusa	55,848	76	7.1 ± 2.2	3987 ± 1165	1.5 ± 0.7	843 ± 400
Glenn	33,387	76	5.3 ± 2.3	1776 ± 767	0.3 ± 0.3	90 ± 94
Placer	3804	38	13.0 ± 5.7	494 ± 252	0.6 ± 0.4	22 ± 16
Sacramento	3278	52	55.2 ± 27.1	1809 ± 875	8.3 ± 3.4	271 ± 112
Sutter	39,215	86	15.5 ± 6.9	6074 ± 2668	2.7 ± 2.3	1075 ± 919
Yolo	13,072	79	28.1 ± 6.5	3672 ± 736	10.1 ± 3.4	1319 ± 446
Yuba	14,326	38	0.9 ± 0.5	129 ± 72	0.4 ± 0.4	52 ± 52
Totals	198,462	497	—	21,816 ± 1392	—	3671 ± 453

[a]Estimates based on a simple random sampling of individual rice fields (see Methods); sampled fields collectively held a total of 439 stilts and 59 avocets.

[b]Hectares of planted rice by county encompasses all types of rice, including sweet and wild rice. The value for Tehama County, which we did not sample for stilts and avocets, was 243 hectares.

[c]SE, standard error.

stilts and avocets combined, the Tulare basin 32%, the San Joaquin basin 3%, and the delta 1%.

Overall, we tallied 937 and 1071 nests and 499 and 700 broods of stilts and avocets, respectively. Of the totals, 85% and 87% of the combined nests and broods of the respective species were recorded in the Tulare basin.

Habitat Use

The habitats with the most stilts and avocets varied by species and region of the Central Valley. In decreasing order of use, rice, managed wetlands,

Table 2 Numbers (Percentage) of Breeding Black-necked Stilts by Habitat Type and Region of the Central Valley in 2003

	Sacramento Valley	Delta	San Joaquin basin	Tulare basin	Central Valley total
Managed wetlands	219 (1.0)	4 (2.5)	307 (44.2)	2441 (35.3)	2971 (9.9)
Sewage ponds	133 (0.6)	33 (20.6)	274 (39.4)	1329 (19.2)	1769 (5.9)
Rice fields	21,816 (98.1)	72 (45.0)	26 (3.7)	0 (0.0)	21,914 (73.0)
Water-storage facilities	42 (0.2)	0 (0.0)	2 (0.3)	820 (11.8)	864 (2.9)
Miscellaneous	21 (0.1)	51 (31.9)	86 (12.4)	202 (2.9)	360 (1.2)
Evaporation ponds	0 (0.0)	0 (0.0)	0 (0.0)	1170 (16.9)	1170 (3.9)
Agricultural canals	0 (0.0)	0 (0.0)	0 (0.0)	958 (13.8)	958 (3.2)
Totals all habitats	22,231	160	695	6920	30,006

Table 3 Numbers (Percentage) of Breeding American Avocets by Habitat Type and Region of the Central Valley in 2003

	Sacramento Valley	Delta	San Joaquin basin	Tulare basin	Central Valley total
Managed wetlands	137 (3.5)	3 (3.4)	395 (54.0)	2890 (48.3)	3425 (31.9)
Sewage ponds	121 (3.1)	12 (13.8)	217 (29.6)	614 (10.3)	964 (9.0)
Rice fields	3671 (93.0)	27 (31.0)	15 (2.0)	0 (0.0)	3713 (34.5)
Water-storage facilities	11 (0.3)	0 (0.0)	1 (0.1)	192 (3.2)	204 (1.9)
Miscellaneous	6 (0.2)	45 (51.7)	104 (14.2)	55 (0.9)	210 (2.0)
Evaporation ponds	0 (0.0)	0 (0.0)	0 (0.0)	1538 (25.7)	1538 (14.3)
Agricultural canals	0 (0.0)	0 (0.0)	0 (0.0)	694 (11.6)	694 (6.5)
Totals all habitats	3946	87	732	5983	10,748

and sewage ponds combined held 89% of all Black-necked Stilts, whereas rice, managed wetlands, agricultural evaporation ponds, and sewage ponds held 90% of all American Avocets (Tables 1–3). As discussed further below, the percentage of these shorebirds in managed wetlands is weighted heavily by the numbers, particularly of avocets, at a single atypical site in the Tulare basin.

In the Sacramento Valley, we estimated 21,816 (standard error 1392, 95% confidence interval 19,087–24,545) adult stilts and 3671 (standard error 453, 95% confidence interval 2784–4559) adult avocets in rice fields (Table 1). Densities of stilts and avocets in rice fields in the Sacramento Valley varied considerably from county to county. Rice fields accounted for 98% of all stilts and 93% of all avocets in this region. The only other habitats that held ≥3% of either species' regional total were managed wetlands and sewage ponds for avocets (Tables 2 and 3). The habitats most frequently used by the few stilts and avocets in the delta were rice fields, miscellaneous (mostly agricultural) habitats, and sewage ponds. Key habitats for both species in the San Joaquin basin were managed wetlands, sewage ponds, and miscellaneous (mostly agricultural) habitats. In the Central Valley overall, we found >89% of all stilts, >66% of all avocets, and >83% of both species combined in habitats created for agricultural, municipal, or industrial needs.

Stilts and avocets were more evenly distributed among a greater number of habitats in the Tulare basin than in other regions of the Central Valley. Five habitats in the Tulare basin held >10% of the basinwide total for at least one of the two species (Tables 2 and 3). The Tulare basin was also the only region where agricultural evaporation ponds, agricultural canals and ditches, and water-storage facilities (water-recharge ponds, stormwater-storage ponds, and reservoirs) supported large numbers of stilts and avocets. The percent of stilts (35%) and avocets (48%) in managed wetlands in the Tulare basin is heavily weighted by the very high proportion of these found in wetland mitigation or compensation habitats created to offset the potential harm to shorebirds and other wildlife from selenium concentrated in agricultural evaporation ponds. One of these compensation wetlands, supplied by saline water from an adjacent evaporation basin, alone held 831 stilts and 2054 avocets, representing 22% of all recurvirostrids in the Tulare basin and 7% of those in the entire Central Valley. Exclusive of these mitigation or compensation wetlands, other managed wetlands accounted for 23% and 14% of the Tulare basin totals for stilts and avocets, respectively.

DISCUSSION

Coverage

We did not survey every potential site for breeding shorebirds in the Central Valley but judge that we did not miss substantial numbers of stilts and avocets. We surveyed almost all managed wetlands that had water in early summer, either from the ground or by aerial surveys. In the Tulare basin, we did not survey every agricultural canal and ditch, particularly on the west side of the basin, or many dairy wastewater lagoons throughout. Although we surveyed the vast majority of the large sets of sewage ponds throughout the Central Valley, we did not survey some small sets, the ones, though, least likely to hold many shorebirds. Our sampling of rice fields throughout the Sacramento Valley was sufficient to estimate shorebird numbers there. However, we probably undercounted numbers in the much smaller areas of rice in the delta and San Joaquin basin, where, rather than sampling, we tried to make comprehensive counts from perimeter, and some internal, roads. Our coverage of vernal pools, particularly on the east side of the delta and San Joaquin Valley, was from aerial surveys, which likely underestimated the birds' numbers. Aerial surveys provided minimum counts, as at that season breeding shorebirds can be widely scattered, and some, particularly those sitting on nests, may not flush, making them hard to pick out against the background. Fortunately, because of the limited extent of shallow water remaining in late spring and summer we relied on aerial surveys to a degree much less than have prior valleywide surveys of migrant and wintering shorebirds (see Shuford et al. 1998). Despite their limitations, aerial surveys of breeding shorebirds did provide valuable information on the distribution and relative proportions of stilts and avocets.

Irrespective of limitations that may have reduced overall counts of stilts and avocets, the timing of counts may have under- or overestimated the value of certain habitats to breeding shorebirds. We might have found more breeding shorebirds in vernal pools before they dried out or in managed wetlands being drawn down if we had surveyed these habitats earlier in the season. For example, vernal pools at Sacramento National Wildlife Refuge where shorebirds were breeding in mid-May had dried out by the time of our surveys of the Sacramento Valley in early June (M. Wolder, J. Silveira pers. comm.). Conversely, we may have somewhat overestimated the value of artificial habitats created for agricultural, municipal, or industrial needs. Most of these habitats typically are supplied with water throughout the summer and hence may absorb some birds moving from habitats that dry out earlier in the season.

Despite these limitations, we judge our data adequately described the general patterns of abundance, distribution, and habitat use of stilts and avocets in the Central Valley in 2003. These patterns are likely fairly typical of normal years but may differ markedly from those in years following very wet winters, when extensive flooded habitat can remain into the breeding season, particularly in the closed Tulare basin.

That we found 86% of total stilt and avocet nests and broods in the Tulare basin was largely an artifact of our contrasting survey methods in the two subregions of the Central Valley with large numbers of both species. Over 99% of shorebirds in the Tulare basin were counted by direct ground surveys of individual sites, whereas about 95% in the Sacramento Valley were estimated from samples of a relatively small proportion of the total extent of rice fields.

Comparative Abundance

Our estimates of about 30,000 Black-necked Stilts and 10,700 American Avocets in the Central Valley are far higher than the few breeding-season estimates of these species for other large sites or broad areas of California. Assuming that all the birds we counted were breeding and the sex ratio is 1:1 (Robinson et al. 1997, 1999), there were about 15,000 pairs of stilts and 5350 pairs of avocets in the Central Valley in 2003. Applying these same assumptions to count data, Rintoul et al. (2003) estimated 590 pairs of stilts and 1380 pairs of avocets in south San Francisco Bay in 2001. Prior estimates for south San Francisco Bay, differing in area coverage and employing extrapolations for unsurveyed areas, are 400–650 pairs of stilts and 650–1800 pairs of avocets (Gill 1972, Rigney and Rigney 1981). Rintoul et al. (2003) knew of no other sites on the U.S. Pacific coast with breeding numbers approaching those in south San Francisco Bay. The salt works at south San Diego Bay together with smaller sites on the coastal slope of San Diego County, however, may collectively hold numbers of stilts comparable to those in south San Francisco Bay, as Unitt (2004) reported about 1000 stilts winter in San Diego County and they are "about as abundant in summer as at other seasons."

Large numbers of stilts and avocets also breed at sites east of the Cascade–Sierra axis. Counts in June 2003 yielded about 1650 pairs of stilts and 1000 pairs of avocets in the Klamath basin on the Oregon–California border (Shuford et al. 2004b); respectively, about 86% and 90% were in California and 78% and 74% were at Lower Klamath National Wildlife Refuge (PRBO unpubl. data). There are few estimates for the Great Basin within California. Oring et al. (2000) reported that roughly 500 pairs of avocets nest at Honey Lake in Lassen County. Numbers of avocets at Owens Lake, Inyo County, have increased to 1763–2893 individuals (about 882–1446 pairs) in 2003–2005 since extensive areas of the lakebed were shallowly flooded to control dust (PRBO unpubl. data). Large numbers of stilts nest at the Salton Sea in the Colorado Desert, but breeding-season surveys of the entire sea are lacking. Periodic counts at reference sites at the Salton Sea throughout 1999 showed relatively stable numbers of stilts from March through May, with a steep increase from mid-June through mid-August (Shuford et al. 2000). These data suggest that numerous seawide shorebird counts made from mid- to late April, the peak of migration for many other species, may provide reasonable approximations of the breeding population of stilts at the sea. The median number of stilts on seven April counts at the Salton Sea from 1989 to 1995 was 3149 (range 1171–10,467; Shuford et al. 2002a), and 3465 were counted in April 1999 (Shuford et al. 2002b). Although these counts suggest that about 1500–1700 pairs of stilts nest at the Salton Sea in most years, it would be valuable to confirm with seawide counts in May whether the broad range in numbers in prior April counts reflects mostly year-to-year variability in breeding stilts or perhaps pulses of migrants not detected in the periodic counts at reference sites in 1999.

Historical versus Current Conditions

Before European settlement, California's Central Valley contained extensive shallow-water wetlands, which varied dramatically both seasonally and annually depending on the amount of flooding from winter rains or spring runoff from snowmelt. These ephemeral wetlands were highly productive, and when they persisted into spring and summer provided important habitat for many species of breeding waterbirds, including shorebirds (see Shuford et al. 2001 for the Black Tern, *Chlidonias niger*). By the mid 20th century, aggregate numbers of stilts and avocets in California had already been reduced commensurate with the reduction in the extent of interior marshlands (Grinnell and Miller 1944). Loss of natural breeding habitat in the Central Valley was offset to an unknown degree by the creation there of various artificial habitats to meet human needs and by the development of salt ponds in the San Francisco Bay estuary, where nesting populations of both species increased earlier in the 20th century (Gill 1977).

Today almost all streams flowing into the Central Valley are dammed and, hence, the valley floor is flooded in extremely wet years only. For example, floods in the Sacramento Valley that occurred historically about every 2 years now occur once every 7 to 13 years, and 10-year floods, by historic standards, now occur about once every 100 years (Bay Institute 1998). Also, now floodwater usually does not persist long before it is drained off, except sometimes in the closed Tulare basin. Large numbers of shorebirds still respond rapidly to flood conditions: on 23 June 1998, following an El Niño winter, a single set of flooded fields (size 1.6 × 0.8 km) south of Alpaugh, Tulare County, held about 1010 Black-necked Stilts (Shuford pers. obs.).

Today a high proportion of the habitat in the Central Valley available for breeding shorebirds occurs where water is used for agricultural, municipal, or industrial needs. Although such sites sometimes support high densities of breeding shorebirds, there is almost no information on whether these birds produce young sufficient to maintain stable populations or if their exposure to harmful substances might reduce breeding success. Regardless, reliance on these environments is generally risky, as future changes in management practices may reduce benefits to wildlife.

Breeding Habitat

The concentration of >80% of all stilts and avocets in the Central Valley in artificial environments appears to be atypical at this scale elsewhere in the range of these species. Robinson et al. (1997, 1999) described stilts and avocets as breeding in many human-altered habitats, such as salt, evaporation, and sewage ponds. Still, natural or managed wetlands seem to be the most important breeding habitats for these species over large portions of their ranges (e.g., Oring et al. 2000) with large concentrations at shallow-water environments created for commercial or municipal purposes being infrequent (e.g., Rintoul et al. 2003 for salt ponds).

Threats to Breeding Shorebirds

Known or potential threats to shorebirds in the Central Valley are poor or toxic water quality; habitat loss or degradation to urbanization; changing or detrimental agricultural, municipal, or industrial practices in artificial habitats; and increasing competition for water among municipal, agricultural, and wildlife interests.

In the late 1970s and early 1980s, high levels of salts and trace elements in agricultural drainwater in the San Joaquin Valley, sent to wetlands to provide wildlife habitat or to agricultural evaporation ponds for disposal, resulted in bioaccumulation of selenium sufficient to harm reproduction of shorebirds, including stilts and avocets (Ohlendorf 2002). Exposure to selenium has since been reduced by closing wetlands with extreme concentrations or by providing uncontaminated water. Despite steady declines in selenium levels, concentrations in some species still exceed those known to impair reproduction. It is unknown if there are sublethal effects of selenium on chicks at this, the most vulnerable, stage of the species' life cycle.

Evaporation-pond operators have been required to reduce the risk of wildlife contamination by closing some ponds, making remaining ponds less attractive to birds, and creating nearby uncontaminated wetlands as alternative habitat (Moore et al. 1990, Steele and Bradford 1991, Bradford 1992). Modifications to discourage bird use—removal of islands, increasing the steepness of levee slopes, maintenance of relatively high (0.6 m) water levels, and hazing—that greatly reduced the number of stilts and avocets nesting at large complexes of ponds in the Tulare basin have been offset by the creation of highly managed compensation wetlands (equipped, for example, with an electric predator-exclusion fence 1.3 m high) that support high numbers and densities of nesting avocets and stilts (Davis et al. 2005). Despite these improvements, some of the large numbers of stilts and avocets we found breeding along agricultural canals may remain at risk when foraging at canals carrying drainwater with high concentrations of selenium.

The effects of contaminants on shorebirds using sewage ponds and agricultural fields are poorly known. Use of pesticides in rice fields has caused occasional mortality in waterfowl, raptors, and, rarely, shorebirds, but no chronic problem has been documented (Littrell 1988). It is unclear, though, what effect pesticides may have on the invertebrates on which stilts and avocets feed in rice fields. Loss of invertebrate diversity or biomass could lead to chick starvation. However, studies showing that some female Mallards (*Anas platyrhynchos*) renest after losing first broods and that ducklings' survival rate is 60% suggest that the quantity of invertebrates in rice fields is adequate (G. Yarris pers. comm.).

Urban growth directly threatens wetlands, most notably at the Grasslands wetlands complex near Los Banos (T. Poole pers. comm.). Urbanization continues to reduce agricultural lands in the Central Valley at a rate among the highest in North America (American Farmland Trust 1995, Sorensen et al. 1997). Although rice acreage has been increasing in the Sacramento Valley overall in the last decade (http://www.nass.usda.gov/Statistics_by_State/California/index.asp), urban expansion is reducing the acreage of this crop between Sacramento and the Marysville–Yuba City area. This reduction could affect the stilt and avocet adversely, as their densities generally were highest in rice fields in the counties—Sacramento, Yolo, Sutter, and Placer—with or adjacent to rapid urban expansion. This pattern does not apply to all birds using rice fields, though; prior surveys of Black Terns in Sacramento Valley rice fields generally found the highest densities in the counties farthest from human population centers (Shuford et al. 2001). Elsewhere, restoration of habitat previously lost to urbanization or industrialization will benefit certain species but may reverse prior gains for breeding shorebirds. In south San Francisco Bay, which holds large numbers of breeding stilts and avocets, plans to convert salt ponds to tidal marshes are likely to have negative effects, particularly on avocets (Rintoul et al. 2003). Because salt ponds have inadvertently compensated for some historic habitat loss in the Central Valley, it would be valuable to counter any future losses of coastal salt ponds, if infeasible locally, by enhancing Central Valley breeding habitats.

A $19 billion agriculture industry (CASS 2004) dominates land use in the Central Valley, and its future could influence shorebird habitat tremendously, either positively or negatively, via shifting cropping patterns or farming practices in response to economic forces and technological advances. In the meantime, some current agricultural practices may pose challenges for shorebirds. Rapid short-term drawdowns of water in rice fields, practiced early in the season by some growers, may result in increased predation rates on shorebird nests, reduced foraging opportunities, or the destruction of nests when fields are reflooded (see Lee 1984 for effects on Black Terns).

Secure nesting sites generally appear to be more limited in agricultural settings than in managed wetlands with suitable islands. At agricultural evaporation ponds managed to eliminate vegetative cover and potential nesting islands, stilts and avocets nesting mainly on barren linear levees experience average losses of about 90–95% of all nests to predation (primarily by coyotes, *Canis latrans*) (Hansen and J. Seay/H. T. Harvey unpubl. data). Conversely, nest success at an alternative wetland with an electric predator-exclusion fence averaged 82% for avocets and 75% for stilts over 10 years (Davis et al. 2005). Also, islands or other secure nest sites generally are unavailable in the extensive rice fields of the Sacramento Valley. During our study, observations in the Tulare basin of large numbers of stilt and avocet nests placed in fallow fields near agricultural canals and ditches, and even some located between rows of growing crops such as cotton, also suggest a lack of high-quality nest sites. Although compensation habitat created to mitigate the impacts of evaporation ponds can support large numbers of nesting stilts and avocets, the design of some may lead to increased mortality from crowding. At one compensation habitat, long earthen lanes, alternating with parallel lanes of open water, expose mobile chicks to pecking by adults when chicks wander from their territories or move along the earthen lanes to reach suitable foraging areas (Hansen pers. obs.).

Securing a dependable, high-quality water supply for wetlands is a never-ending challenge in light of California's expanding human population, arid climate, and water-delivery system already stretched to its limits. Competition for increasingly valuable water is bound to intensify, and recent gains from legislation providing a reliable water supply for wetlands (e.g., Central Valley Project Improvement Act; Title 34 of Public Law 102-575) could be reversed in the future. Maintaining shallow water in wetlands in the breeding season is particularly costly because of high evaporation rates in the Central Valley at that time. Also, municipal water districts have begun to purchase water from water districts in the Sacramento Valley, which can affect the amount of rice available to shorebirds and the agricultural drainwater available for managed wetlands (C. Isola in litt.).

Management and Research Recommendations

Despite known and potential threats, breeding shorebirds should benefit from wetland restoration and enhancement for waterfowl and other wildlife (e.g., USFWS 1990) and, particularly, from heightened interest in increasing the amount of wetland habitat in summer. Hence we recommend that a high priority be placed on increasing the acreage of summer wetland habitat to augment breeding shorebird populations. This increase would counter historic wetland loss and potential future loss of various artificial environments used by shorebirds. Increasing shorebird breeding habitat could be accomplished by buying land with water rights, making structural improvements on land to accept surplus water in extremely wet years, or providing private landowners with economic incentives to flood wetlands in summer (e.g., Conservation Reserve Program, Landowner Incentive Program, California Waterfowl Habitat Program).

As needed, the suitability of established wetlands to breeding shorebirds should be enhanced by providing more barren or sparsely vegetated nesting islands and increasing foraging opportunities by maintaining shallow water and making gradual slopes on the shores of ponds and islands (e.g., Engilis and Reid 1997). Wetland restoration with hydrologic or ecologic equivalents based on the scale of a landscape would be more valuable than that on the scale of an individual project (Bedford 1996; see Shuford et al. 1998) so that in the long term restoration will provide a mix of habitats reflective of historic conditions. Where feasible, we recommend augmenting saline playas in the Tulare basin; providing saline water alone will not be enough to attract certain species, such as the Snowy Plover, that also need alkali flats for nesting and foraging (e.g., Paton and Bachman 1997).

Shorebirds would likely benefit substantially from land acquisition and infrastructure improvements that can be used to take advantage of surplus water in very wet winters to provide boom conditions for nesting. In the Tulare basin, an alternative is to purchase retired agricultural lands and ready them with impoundments (with islands) that could be flooded when surplus water becomes available. In the San Joaquin and Yolo basins, an option is to install water-diversion structures along bypasses next to established wetlands. Water could then be circulated into ponds, slowing it down and spreading it out, then back into bypasses downstream, thus providing shorebird habitat while avoiding the creation of stagnant water areas that might promote botulism outbreaks or excessive mosquito breeding. Because of the current extensive use of croplands, particularly rice, by shorebirds, it would be beneficial to work with agricultural interests to enhance the suitability of fields to nesting and foraging shorebirds, while maintaining high crop yields, or to provide economic incentives to maintain islands or open foraging areas on a small portion of fields. Even if densities of breeding shorebirds in agricultural fields remain low relative to those in managed wetlands, agriculture is much superior to urban and suburban development. When possible, landowners should be provided with incentives to keep producing crops like rice that benefit shorebirds and other waterbirds, particularly through key legislation such as the periodically renewed federal farm bill.

It would be valuable to assess the reproductive rates of stilts and avocets in various habitat types in the Central Valley to identify factors limiting reproduction, wetland features that support high densities of successfully breeding shorebirds, and actions that can be taken to increase nesting success. Important factors may be the number, type, and location of nesting islands, extent and height of wetland vegetation, water depth, and diversity of relief in pond bottoms. It also would be important to identify landscape features that influence the size and success of populations of nesting shorebirds, including the size of individual wetlands and their proximity to other wetlands, other habitats, or human activities. Because of the high use of rice fields by breeding shorebirds, a study of reproductive success in this habitat would be particularly relevant. A study of the effects of water management in wetlands, where rapid spring drawdowns can leave shorebird nests and broods high and dry (C. Isola in litt.), would also be valuable.

Censuses of breeding shorebirds are needed to determine population size and habitat use in important but poorly known areas of the state. These include Suisun Marsh (where the Central Valley transitions to the San Francisco Bay estuary), the southern California coast, and large sites east of the Cascade–Sierra axis.

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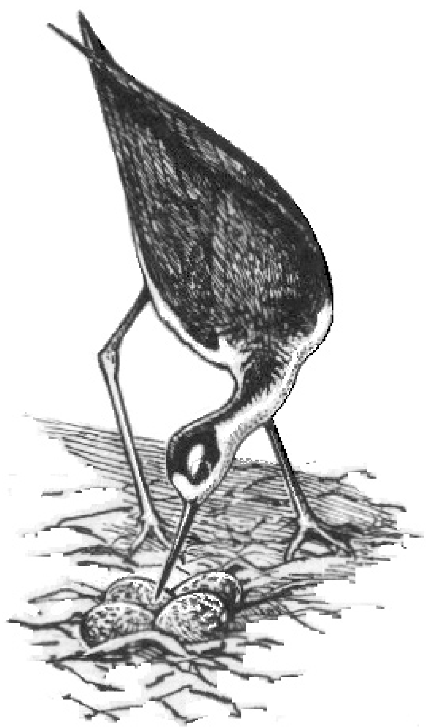

Black-necked Stilt

Sketch by Tim Manolis