Patterns of distribution, abundance, and habitat use of breeding Black-necked Stilts and American Avocets in California's Central Valley in 2003

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Cover photo: American Avocet (*Recurvirostra americana*) nest located in the dry bed of a vernal pool (right foreground) at Sacramento National Wildlife Refuge, 13 May 2003 (courtesy of Joe Silveira/Sacramento NWR).

ABSTRACT

From mid-May to mid-June 2003, we surveyed shallow-water habitats throughout California's Central Valley for breeding shorebirds, mainly Black-necked Stilts *(Himantopus mexicanus)* and American Avocets *(Recurvirostra americana).* Surveys consisted of ground counts at specific sites supplemented by aerial surveys and sampling of shorebird densities in Sacramento Valley rice fields. We estimated a total of about 29,602 Black-necked Stilts and 10,546 American Avocets in the entire Central Valley, exclusive of Suisun Marsh. The proportion of the total Central Valley population of stilts and avocets, respectively, found within four major geographic regions were: Sacramento Valley (74%, 36%), Delta (1%, 1%), San Joaquin Basin (2%, 7%), and Tulare Basin (23%, 57%). The ratio of stilts to avocets was 5.8:1 in the Sacramento Valley versus 1.1:1 in the San Joaquin Valley. The Sacramento Valley held 64% of the valleywide total of stilts and avocets combined, the Tulare Basin 32%, the San Joaquin Basin 4%, and the Delta 1%.

The most important habitats to stilts and avocets varied both between the species and among regions of the Central Valley. Of those accounting for >5% of the totals, rice (73%), managed wetlands (10%), and sewage ponds (6%) were the key habitats used by Black-necked Stilts, whereas rice (33%), managed wetlands (32%), agricultural evaporation ponds (15%), and sewage ponds (9%), and agricultural canals (7%) were important to American Avocets. Rice fields accounted for 98% of all stilts and 93% of all avocets in the Sacramento Valley. 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. The Tulare Basin was also the only region where agricultural evaporation ponds, agricultural canals and ditches, and water storage facilities

(water recharge ponds, storm water storage ponds, and reservoirs) supported large numbers of stilts and avocets. The proportion of shorebirds in managed wetlands in the Tulare Basin, and to a lesser degree in the Central Valley as a whole, was weighted heavily by the 831 stilts and 2054 avocets counted in a single compensation wetland in the Tulare Basin supplied by saline water from an adjacent agricultural evaporation basin.

Overall, shorebirds in the Central Valley currently are very reliant on various habitats that serve the production, water conveyance, storage, treatment, or disposal needs of agriculture, municipalities, or industry. Use of some of these habitats may expose shorebirds to toxic substances, and, regardless, reliance on these artificial environments is generally risky, as future changes in management practices may serve human efficiencies and economies but reduce benefits to wildlife. Our study highlights the need to restore and enhance large amounts of high quality wetland habitat in the Central Valley in the summer to counter historic wetland loss and potential future loss of other shallow-water habitats that may be of uncertain reliability and quality. Infrastructure improvements are needed to take advantage of surplus water in very wet years to opportunistically boost reproductive output of shorebirds and other waterbirds. It also would be valuable to work with agricultural interests to enhance the suitability of agricultural fields to nesting and foraging shorebirds while at the same time maintaining high crop yields. Additional research is needed to determine reproductive rates of stilts and avocets in various Central Valley habitats, identify factors limiting reproduction and actions necessary to increase nesting success, and document the local and landscape features of wetlands that support high densities of breeding shorebirds and high fledging rates of young.

INTRODUCTION

Although massive habitat alteration in this century has undoubtedly reduced many shorebird populations, information showing population declines in western North America is largely anecdotal (Page and Gill 1994). Concern over the effects of continued habitat loss on migrating and wintering shorebirds (Myers 1983, Senner and Howe 1984) led to the creation of a system of voluntary reserves in North and South America (Myers et al. 1987, Harrington and Perry 1995) and to the preparation of the U.S. Shorebird Conservation Plan (Brown et al. 2001). Shorebird conservation in the United States is currently being implemented on the ground mainly through regional shorebird conservation plans typically in partnership with joint ventures of the North American Waterfowl Management Plan.

The Central Valley 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) while the valley concurrently was converted to one of the most productive agricultural areas in the world. 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 in the Central Valley was recently greatly expanded by broadscale surveys that provide an overview of the abundance, geographic distribution, and habitat use of migrating and wintering shorebirds and that document the continent-wide importance of this region to shorebirds at these seasons (Shuford et al. 1998).

The Southern Pacific Shorebird Conservation Plan (Hickey et al. 2003) encompasses the Central Valley and coastal California. Within the former region, the Central Valley Shorebird Working Group functions as a technical subcommittee of the Central Valley Habitat Joint Venture. The regional 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 identified by the working group was the need to conduct surveys of breeding shorebirds in the Central Valley. Not only is very little known about their status in the region at this season but wetland habitat reaches its nadir then. The breeding season takes on additional importance because the proportion of current to historic wetland acreage appears to be much lower in summer than at any other season.

To fill this important data gap regarding breeding shorebirds, we coordinated counts 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 broadscale habitat use of Black-necked Stilts *(Himantopus mexicanus)* and American Avocets *(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

The study area included the vast majority of California's Central Valley. The Central Valley is surrounded by mountains, except for its western drainage into San Francisco Bay, and averages about 644 km (400 mi) long and 64 km (40 mi) wide. It is divided into the Sacramento Valley, draining southward, the San Joaquin Valley, draining northward, 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 it is not discussed further. The Sacramento Valley is further divided into the Colusa, Butte, Sutter, American, and Yolo drainage basins, and the San Joaquin Valley into the San Joaquin Basin and, the usually closed, Tulare Basin. We generally report data for four major subregions of the Central Valley – Sacramento Valley, Delta, San Joaquin Basin, and Tulare Basin.

Total precipitation in the Central Valley was close to normal in the winter prior to our surveys but was well above average in the spring of 2003. Precipitation for the climate year (1 July-30 June) 2002-2003 was 100.3 and 46.2 cm (39.5 and 18.2 in) in the Sacramento and San Joaquin drainage divisions, respectively. These figures represent 105% and 90%, respectively, of the long-term averages (n = 108 yrs) for these areas (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 (8.6 and 5.1 in), respectively, which represents 195% and 193% of the long-term averages at that season. The extent of 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 shorebirds at all shallow-water habitats throughout the Central Valley from mid-May to mid-June 2003. The types of habitats surveyed included agricultural canals and ditches, agricultural evaporation ponds, dairy lagoons and other farm ponds, fish farm ponds, irrigated fields and pastures, managed wetlands (in state and federal wildlife areas, 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 reconnaissance while in the field.

To minimize over- or undercounting of shorebirds arising from their movement both locally or regionally, we surveyed breeding shorebirds 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. Survey periods were: Tulare Basin (15-29 May), San Joaquin Basin and Delta (22 May-5 June), and Sacramento Valley (1-15 June). 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 populations of Black-necked Stilts and American Avocets, characteristic breeding shorebirds in Central Valley wetlands. We recognized that some birds counted would likely be nonbreeders given not all individuals of both species breed in their first year and some nonbreeding avocets summer in nesting areas (Robinson et al. 1997, 1999).

Although we instructed observers to count all breeding shorebirds present at each site, it was not possible to obtain valleywide population estimates for other species because specialized surveys would have been needed for all of them. Although the Killdeer *(Charadrius vociferous)* is perhaps the most numerous breeding shorebird in the Central Valley, it nests at such a wide variety of wetland, agricultural, and other upland sites that is was not possible to cover many of them. Within the Central Valley, most Snowy Plovers *(Charadrius alexandrinus)* now nest very locally at saline agricultural evaporation ponds in the Tulare Basin and a few on the salt-encrusted margins of managed wetlands in the Tulare and San Joaquin basins (Henderson and Page 1981, Page et al. 1991, L. Ruport pers. comm.); although most of their nesting sites are known, they are so cryptic they require special survey methods. Spotted Sandpipers *(Actitis macularia)* breed in the Central Valley mainly on the edges of rivers and streams in the Sacramento Valley (Gaines 1974), habitats not targeted by this survey. Wilson's Snipe *(Gallinago delicata)* breed very locally in low marsh or wet meadow habitat on the extreme eastern edge of the Sacramento Valley in central Yuba County and northwestern Placer County (McKibben and Hofmann 1985). Obtaining population estimates for snipe in these areas would have required surveys to detect them when performing aerial displays, mainly during crepuscular hours, as otherwise they are easily overlooked. Wilson's Phalaropes *(Phalaropus tricolor)* breed very locally in rice fields and other wetlands in the Sacramento and San Joaquin valleys (Grinnell and Miller 1944, Lee 1984) but they migrate so late in spring that it was not possible to distinguish migrant from breeding phalaropes during most of the period selected to survey other species.

Because of the huge expanse of the study area and varying logistical constraints among habitats and subregions, we used a combination of survey methods, including ground counts, aerial surveys, and sampling of rice fields in the Sacramento Valley, as described below. PRBO staff coordinated the overall survey effort and delegated coordination of censuses at some large wetland complexes, at scattered wetlands within certain easement programs, or throughout major subregions to collaborating regional experts.

Ground Counts

PRBO staff and numerous professional and amateur field ornithologists conducted ground counts at the vast majority of sites surveyed. We provided all observers with a protocol for counting breeding shorebirds, nests, and broods, for estimating the size of the survey site, and for gathering habitat data. Ground counts generally were conducted at those discrete sites to which we had obtained access. Observers covered such sites 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. Evidence of confirmed nesting was obtained by observing nests with eggs and/or recently hatched chicks, adults sitting in incubation posture on apparent nests, or broods of mobile young smaller in size than adults.

Aerial Surveys

To complement other survey methods, we flew portions of the Central Valley by fixed-winged (Cessna 185 Skywagon) aircraft on four dates from 21 May to 12 June to survey areas it was not feasible to cover on the ground. We flew at altitudes averaging 1000 ft (300 m) to look for potential habitat, and when it was located we descended to about 150 ft (45 m) above the ground and reduced air speed to about 90 knots while counting shorebirds. Two observers counted shorebirds, each looking out opposite sides of the plane. J. Humphrey and D. Shuford conducted the counts on the first three dates, J. Humphrey and Sanja Hinic on the last. Within all areas surveyed we did not cover some specific sites that we knew would be surveyed by other observers on the ground on other dates.

The areas covered by air and the dates of these surveys are:

(1) Delta (part) on 21 May (5 hrs): we surveyed the area bounded by the city of Sacramento on the north, the lower edge of the Sierra Nevada foothills on the east, Hwy 4 on the south, and I-5 on the west and the area bounded by Sacramento on the north, the Sacramento River Deep Water Ship Channel (and to the south the area extending west across Liberty Is. and Hastings Tract to Hwy 13) on the west, Hwy 12 on the south, and I-5 on the east.

(2) Delta (part) and San Joaquin Basin (part) on 22 May (6 hrs): we surveyed the area bounded by I-5 on the east, Hwy 12 on the north, a line following the Bird Landing and Collinsville roads then down to Antioch on the west, and Hwy 4 on the south. At the southwest corner of this area we also dipped south to survey Clifton Court Forebay and Coney Island, and from the length of Hwy 4 we looked south but did not see any potential habitat to survey. We also surveyed the area southeast of Stockton bounded by Hwy 4 on the north, the edge of the Sierra foothills on the east, Berenda Slough/Reservoir (just south of the Merced-Madera Co. line) on the south, and

Hwy 99 on the west. Within the latter region, we did not survey areas of cultivated rice in eastern San Joaquin and Stanislaus counties, which were covered independently by other observers on the ground on other dates.

(3) Sacramento Valley (part) on 6 June (4 hrs): we covered the Butte Sink; the Sutter Bypass; the portion of the Sutter Basin from the Sutter Bypass at the south edge of the Sutter Buttes east to Yuba City and between the Sutter Buttes and Feather River north to East Gridley; north to Thermalito Afterbay and adjacent farm ponds; the area bounded by Hwy 70 on the west, the town of Palmero on the north, the Sierra foothills on the east, and the Yuba River on the south; the Olivehurst area west and southwest of Beale AFB and south to the Yuba-Sutter county border at Bear Creek; and the Cache Creek Settling Basin and adjacent Yolo Bypass north of I-5.

(4) Yolo Basin (part), San Joaquin Basin (part), and Tulare Basin (part) on 12 June (6 hrs): we covered the area of the southern Yolo Basin bounded by Hwy 13 on the east, Hwy 12 on the south, Travis AFB on the west, and Hwy 80 and the town of Dixon on the north and the portions of the northern Tulare and southern San Joaquin basins bounded by I-5 on the west, Hwy 41 on the south, a line roughly from the west side of Lemoore NAS north to Fresno Slough, the James Bypass, and the San Joaquin River then up to Firebaugh on the east, and Nees Ave. on the north. We covered additional smaller portions of the San Joaquin Basin including a triangular area in Fresno County bounded by Hwy 33, Nees Ave., and Fairfax Rd. and an oblong area in Madera County bounded by the San Joaquin River on the west and south, the Chowchilla Canal/ Bypass on the east, and an arbitrary east-west line just north of Ash Slough on the north.

We suspect the aerial surveys provided minimum counts of breeding shorebirds, as individuals at that season are often widely scattered and some birds, particularly those sitting on nests, may not flush and, if not, are hard to pick out against the background. A much higher proportion of the shorebirds present are likely seen on aerial surveys in winter and during spring and fall migration, when most shorebirds occur in conspicuous flocks, often numbering in the thousands. Fortunately, because of the limited amounts of shallow-water habitat available in late spring and summer we relied on aerial surveys to a much lesser degree than have prior valleywide surveys of migrant and wintering shorebirds (see Shuford et al. 1998). Despite their limitations, aerial surveys of breeding shorebirds do provide valuable information on the distribution and relative proportions of stilts and avocets.

Sampling of Rice Fields

We collected data on shorebird densities in a random sample of individual rice fields in the Sacramento Valley to allow estimation of overall shorebird numbers in the extensive area of rice cultivation in that region. By contrast, in the limited areas of rice in the Delta and San Joaquin Basin we tried to count all shorebirds directly.

Typically about 97% of all California rice is grown in the Sacramento Valley, where the total amount averaged 197,689 ha (488,500 acres) from 1995 to 2002 (Calif. Agric. Statistics Service: http://www.nass.usda.gov/ca/coest/indexce.htm). In 2003, an estimated 201,534 ha (498,000 acres) was planted statewide (CASS 2003a) but acreage breakdowns by county or region were unavailable at the time of writing this report (Jack Rutz in litt.). The combined (much smaller) acreage total for wild rice and sweet rice, not included in the statewide total above, also was unavailable at the time of report writing.

In 2003, planting of rice was delayed by heavy showers in April and early-May and some intended acreage was not planted (NASS 2003). Planting on average was delayed roughly three weeks (5-6 weeks in some areas) in the Sacramento Valley compared to 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.).

Sampling of rice fields in the Sacramento Valley was conducted by C. Hickey, J. Humphrey, and D. Shuford with extensive help from Andy Engilis, Anne Engilis, Myrnie Mayville, Fritz Reid, and Irene Torres. From 5-19 June, we collectively sampled a total of 497 rice fields in Butte (52), Glenn (76), Colusa (76), Sutter (86), Yuba (38), Placer (38), Sacramento (52), and Yolo (79) counties. 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. That sets of fields typically take 2-3 days to flood before they are planted, indicates that planting dates are a conservative gauge of the fields' suitability for shorebirds, which may use them as soon as water is available

We randomly selected the individual fields to sample, while also attempting to distribute samples broadly across each county, and used binoculars or spotting scopes to carefully scan each field for foraging adults, incubating adults, and broods. To enable us to estimate densities of shorebirds in each sampled field, we obtained data on the size of the field using one of several methods: (1) collecting three or more GPS (Global Positioning System) points at the corners of fields, which allowed plotting a polygon and calculating its size on GIS (Geographic Information System) software, (2) estimating the length and width of individual 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, calculating the length and width of a field using a car odometer.

Rice Data Analysis

We estimated the mean stilt and avocet density in rice in each of eight Sacramento Valley counties on the basis of our survey of a simple random sample of rice fields as described above. Although the acreages of rice planted in 2003 are not yet available, we estimated the county acreages as an average of the 2001 and 2002 totals. When the actual 2003 acreages become available later in 2004, they can be substituted for these estimated values. We estimated the total number of stilts and avocets using rice fields in each county as the estimated density of each species per hectare from our sample multiplied by the estimated hectares of rice planted. Because both the hectares and the densities are estimated, we used the variance formula for the product of random variables with no covariance (Mood et al. 1974) as follows:

$var[S] = s^2 * var[W] + W^2 * var[s] + var[s] * var[W]$, for stilts, and

$var[A] = a^2 * var[W] + W^2 * var[a] + var[a] * var[W]$ for avocets, where

S = the total number of stilts estimated for the county,

s = the sample density of stilts for the county,

A = the total number of avocets estimated for the county,

a = the sample density of avocets for the county, and

W = the estimated number of hectares of rice for the county.

We found no significant covariance between the density of either stilts or avocets and the size of rice fields in any of the eight counties. We assumed no covariance between the sampled density of stilts and avocets and the countywide estimated rice area totals.

RESULTS

Abundance and Distribution

We estimated about 29,602 Black-necked Stilts and 10,546 American Avocets were in the Central Valley, exclusive of Suisun Marsh, during the 2003 breeding season (Tables 1-3). Of these species, respectively, 21,827 (74%) and 3744 (36%) were in the Sacramento Valley, 160 (1%) and 87 (1%) in the Delta, 695 (2%) and 732 (7%) in the San Joaquin Basin, and 6920 (23%) and 5983 (57%) in the Tulare Basin. The ratio of stilts to avocets was 5.8:1 in the Sacramento Valley versus 1.1:1 in the San Joaquin Valley. The Sacramento Valley held 64% of the valleywide total of stilts and avocets combined, the Tulare Basin 32%, the San Joaquin Basin 4%, and the Delta 1%.

Habitat Use

The most important habitats to stilts and avocets varied both between the species and among regions of the Central Valley. In respective order of use, rice, managed wetlands, and sewage ponds combined held about 89% of all Black-necked Stilts, whereas rice, managed wetlands, agricultural evaporation ponds, and sewage ponds held about 90% of all American Avocets (Tables 1-3). As discussed further for the Tulare Basin, the percentage of these shorebirds in managed wetland habitat is weighted heavily by the 831 stilts and 2054 avocets counted in a single compensation wetland supplied by saline water from an adjacent agricultural evaporation basin.

In the Sacramento Valley, we estimated the number of Black-necked Stilts and American Avocets breeding in rice fields to be 21,412 (SE = 1408, 95% CI = [18,652, 24,172]) and 3469 (SE = 437, 95% CI = [2613, 4326]) adults, respectively (Table 1). 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 (Table 2 and 3). The most important habitats to the few stilts and avocets breeding in the Delta were rice fields, miscellaneous (mostly agricultural) habitats, and sewage ponds. Key habitats for stilts and avocets in the San Joaquin Basin were managed wetlands, sewage ponds, and miscellaneous (mostly agricultural) habitats.

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, storm water 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 somewhat misleading, though, as a very high proportion of these were recorded 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 21% and 12% of the Tulare Basin totals for stilts and avocets, respectively.

DISCUSSION

Coverage

Although we did not survey every potential site for breeding shorebirds in the Central Valley, our efforts were comprehensive in nature, and we judge that shorebirds numbers in areas not covered were relatively small. We surveyed almost all managed wetland habitat that had water in early summer either from the ground or by aerial surveys. Coverage was not as complete in some other habitats. In the Tulare Basin we did not survey all agricultural canals and ditches, particularly on the west side of the basin. Likewise, we did not survey many dairy wastewater lagoons in that region. 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, but we probably underestimated numbers in the much smaller areas of rice in the Delta and San Joaquin Basin, where counts were done mainly from perimeter roads. Our coverage of vernal pools, particularly on the east side of the Delta and San Joaquin Valley, was from aerial surveys, which likely underestimate shorebird numbers for reasons stated in the Methods. Also, we might have found more breeding shorebirds in vernal pools if we had surveyed this habitat earlier in the season; vernal pools at Sacramento NWR 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.). Despite these limitations, our data appear to adequately describe the current overall patterns of abundance, distribution, and broadscale habitat use of stilts and avocets in the Central Valley.

Historical versus Current Conditions

Before European settlement, California's Central Valley contained extensive shallow-water wetland habitat, which varied dramatically both seasonally and annually depending on the amount of flooding from winter rains or high spring runoff from snowmelt. These ephemeral shallow-water 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 Black Terns, *Chlidonias niger*). By the middle of the 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 breeding habitat for stilts and avocets in the Central Valley appears to have been offset to some degree by the creation of salt ponds in the San Francisco Bay estuary, where nesting populations of both species increased earlier in this century (Gill 1977).

Today almost all of the streams flowing into the Central Valley are dammed and, hence, flooding of the valley floor occurs in extremely wet years only, and usually water does not persist for long before it is drained off, except sometimes in the closed Tulare Basin. Even today large numbers of shorebirds can respond rapidly to such conditions when they occur: on 23 June 1998, following an El Niño winter, a single set of flooded fields (1 mi x 0.5 mi in size) south of Alpaugh, Tulare County, held about 1010 Black-necked Stilts (D. Shuford pers. obs.). If water were available such habitat could be created fairly easily.

Today a very high proportion of the habitat in the Central Valley available for breeding shorebirds occurs in areas 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 available to determine whether these birds are producing numbers of young adequate to maintain a stable population size or whether they are exposed to harmful substances that might reduce their breeding success. Regardless, reliance on these environments is generally risky, as future changes in management practices may serve human efficiencies and economies but reduce benefits to wildlife.

Evaluation of habitat changes in the Central Valley should be placed in a broader context. Counts in May 2001 found 1184 stilts and 2765 avocets on the coast in South San Francisco Bay, but proposed restoration plans to convert salt ponds to tidal marshes there is likely to have negative effects, particularly on avocets (Rintoul et al. 2003). Because these bay habitats have served as *de facto* mitigation for historic habitat loss in the Central Valley, it would be valuable to counter any future losses of coastal salt ponds by enhancing Central Valley breeding habitats.

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 agricultural, municipal, or industrial practices, and wetland designs that may lead to very high levels of predation. Breeding shorebirds should benefit, though, 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. Still, securing a dependable, high quality water supply for wetlands will be an ongoing challenge in light of California's expanding human population, arid climate, and a water delivery system already stretched to its limits. Competition with other interests for increasingly expensive 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) potentially could be reversed in the future.

In the 1980s, high levels of salts and trace elements in agricultural drain water 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 et al. 1987, 1993; Skorupa and Ohlendorf 1991). Exposure to selenium has been reduced in wetlands by closing those with extreme concentrations or by providing uncontaminated water, but, despite steady declines in selenium levels, concentrations in some species still exceed those known to impair reproduction (Paveglio et al. 1992, 1997; Hothem and Welsh 1994a, 1994b). 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 contamination risk to wildlife by closing some ponds, hazing birds at remaining ponds or physically altering ponds to make them less attractive, and creating nearby uncontaminated wetlands as alternative habitat (Moore et al. 1990, Steele and Bradford 1991, Bradford 1992). Although long-term monitoring of shorebirds and other waterbirds is being conducted at the remaining evaporation ponds and the alternative wetlands, no analyses have been done to determine whether populations of breeding shorebirds have increased or decreased in response to these changes (R. Hansen unpubl. data). Because we found large numbers of stilts and avocets breeding along agricultural canals, some of which carry subsurface salty drain water with high selenium concentrations, it would be valuable to know if the levels of selenium in such canal waters are high enough to cause reproductive harm.

Use of pesticides in rice fields has caused periodic mortality in waterfowl, raptors, and, rarely, shorebirds, but no chronic problem has been documented (Littrell 1988). It is unclear, though, what effect these pesticides may have on the invertebrate resources in rice fields upon which breeding stilts and avocets depend. Loss of invertebrate diversity or biomass potentially could lead to chick starvation. Agricultural practices that rapidly draw down water levels in rice fields have exposed Black Tern nests to rat predation only to later destroy renesting attempts when fields were reflooded above original levels (Lee 1984). Such drawdowns in rice fields are less likely to increase predation rates on nests of stilts and avocets, which typically are placed on the sloping edges of ponds or narrow levees between rice fields. Drawdowns are more likely to enhance foraging opportunities for breeding shorebirds by exposing invertebrates that otherwise would be unavailable.

Secure nesting sites appear to be more limited in agricultural settings than in managed wetlands. At agricultural evaporation ponds where stilts and avocets nest mainly on easily searched, linear levees because of a lack of islands, predation (primarily by coyotes, *Canis latrans*) leads to average losses of about 90-95% of all nests initiated (R. Hansen and J. Seay/H.T. Harvey unpubl. data). Observations in the Tulare Basin during our study 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 (R. Hansen pers. obs.).

Urban encroachment also 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 the effect on shorebirds is unknown. A $17 billion agriculture industry (CASS 2003b) dominates land use in the Central Valley, and its future could tremendously influence shorebird habitat either positively or negatively via shifting cropping patterns and farming practices in response to national or global economic forces and technological advances.

Management and Research Recommendations

Managers and researchers should work collaboratively to study the ecological requirements of breeding shorebirds in the Central Valley and to implement management practices that suit shorebird needs while maintaining high overall species diversity. We make the following preliminary recommendations for management and research priorities:

Management

- Increase the acreage of summer wetland habitat to augment breeding shorebird populations to counter historic wetland loss and potential future loss of other shallow-water habitats (agricultural, municipal, industrial) that may be of uncertain reliability because of shifting human needs or may be exposing shorebirds to potential harm from contaminants. The Central Valley Shorebird Working Group has set goals of increasing summer wetland habitat by two times the current amount in both the Sacramento Valley and in the Delta, by three times in the San Joaquin Basin, and by ten times in the Tulare Basin; these goals should be revised as new information becomes available.

- Enhance the suitability of established wetlands to breeding shorebirds by providing more barren or sparsely vegetated nesting islands and increasing foraging opportunities by maintaining shallow water and making gradual slopes on pond and island edges.
- When restoring wetlands, do so with hydrologic or ecologic equivalents based on a landscape, rather than an individual project, scale (Bedford 1996; see Shuford et al. 1998). Where feasible, provide additional saline playa lake habitat 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.
- Invest in 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, this might involve the purchase of retired agricultural lands and readying them with impoundments, with islands, which could be flooded when surplus water becomes available. In the San Joaquin and Yolo basins, this might involve installation of water diversion structures along bypasses next to established wetlands. Water could then be circulated into ponds and back into bypasses downstream to provide shorebird habitat while avoiding the creation of stagnant water areas that might promote botulism outbreaks or excessive mosquito breeding.
- Work with agricultural interests to enhance the suitability of agricultural fields to nesting and foraging shorebirds while at the same time maintaining high crop yields. Even if densities of breeding shorebirds remain low in agricultural fields relative to managed wetlands the former are highly preferable to alternatives such as urban and suburban

development. When possible, provide landowners with incentives to keep producing crops that benefit shorebirds and other waterbirds.

Research

- Initiate studies to determine reproductive rates of stilts and avocets in various habitat types in the Central Valley. Where rates are low, do further research to identify factors limiting reproduction (e.g., non-native predators, contaminants, lack of secure nesting islands) and actions that can be taken to increase nesting success.
- Conduct research to identify the features of wetlands that support high densities of breeding shorebirds and high fledging rates of young. Important local factors to consider would be the number, type, and location of nesting islands, extent and height of wetland vegetation, ideal water depths, and diversity of relief in pond bottoms. Also, investigate landscape features that may influence the size and success of nesting shorebird populations, including the importance of the size of individual wetlands and their proximity to other wetlands, other habitats, or human activities.
- Conduct surveys of breeding shorebirds to determine population size and habitat use in Suisun Marsh, an area transitional between that of this study and a similar one in the San Francisco Bay estuary (Rintoul et al. 2003).
- Analyze long-term data on shorebird numbers in agricultural evaporation ponds and associated compensation wetlands to determine whether shorebird numbers have increased or decreased in response to structural changes in the former habitat and creation of the latter habitat.

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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		American Avocet	
			No. per 100 ha (±SE)[c]	Estimated Numbers (±SE)[c]	No. per 100 ha (±SE)[c]	Estimated Numbers (±SE)[c]
Butte	37,798	52	10.9±4.2	4120±1609	0.0±0.0	0.0±0.0
Colusa	53,580	76	7.1±2.2	3825±1172	1.5±0.7	809±384
Glenn	33,548	76	5.3±2.3	1786±767	0.3±0.3	91±94
Placer	4290	38	13.0±5.7	557±249	0.6±0.4	25±19
Sacramento	3238	52	55.2±27.1	1787±876	0.8±3.4	267±111
Sutter	38,324	86	15.5±6.9	5936±2671	2.7±2.3	1050±900
Yolo	11,635	79	28.1±6.5	3268±760	10.1±3.4	1174±399
Yuba	14,791	38	0.9±0.5	133±72	0.4±0.4	53±54
TOTALS	197,203	497	–	21,412±1408	–	3469±437

[a] Estimates based on a simple random sampling of individual rice fields (see Methods).

[b] Hectares of planted rice by county are the means for 2001 and 2002 because figures for 2003 were not yet available (see Methods). Means for Tehama and Solano counties, which we did not sample for stilts and avocets, were 344 and 142 hectares, respectively. County totals do not include the number of hectares of wild rice and sweet rice, which are much fewer than those for traditional rice.

[c] See Methods for details of calculations.

Table 2 NUMBERS (PERCENTAGE) OF BREEDING BLACK-NECKED STILTS IN VARIOUS HABITAT TYPES BY REGIONS 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 (10.0)
Sewage ponds	133 (0.6)	33 (20.6)	274 (39.4)	1329 (19.2)	1769 (6.0)
Rice fields	21,412 (98.1)	72 (45.0)	26 (3.7)	0 (0.0)	21,510 (72.7)
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 (4.0)
Agricultural canals	0 (0.0)	0 (0.0)	0 (0.0)	958 (13.8)	958 (3.2)
Totals all habitats	21,827	160	695	6920	29,602

Table 3 NUMBERS (PERCENTAGE) OF BREEDING AMERICAN AVOCETS IN VARIOUS HABITAT TYPES BY REGIONS OF THE CENTRAL VALLEY IN 2003

	Sacramento Valley	Delta	San Joaquin Basin	Tulare Basin	Central Valley Total
Managed wetlands	137 (3.7)	3 (3.4)	395 (54.0)	2890 (48.3)	3425 (32.5)
Sewage ponds	121 (3.2)	12 (13.8)	217 (29.6)	614 (10.3)	964 (9.1)
Rice fields	3469 (92.6)	27 (31.0)	15 (2.0)	0 (0.0)	3511 (33.3)
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 (14.6)
Agricultural canals	0 (0.0)	0 (0.0)	0 (0.0)	694 (11.6)	694 (6.6)
Totals all habitats	3744	87	732	5983	10,546