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BREEDING STATUS AND HABITAT USE OF BLACK-NECKED STILTS AND AMERICAN AVOCETS IN SOUTH SAN FRANCISCO BAY

CHRIS RINTOUL, NILS WARNOCK, and GARY W. PAGE, PRBO Conservation Science, 4990 Shoreline Highway, Stinson Beach, California 94970

JANET T. HANSON, San Francisco Bay Bird Observatory, P.O. Box 247, Alviso, California 95002

ABSTRACT: In light of recent and proposed restoration projects that will affect bird numbers in San Francisco Bay, California, we assessed the status of breeding populations of the Black-necked Stilt (*Himantopus mexicanus*) and American Avocet (*Recurvirostra americana*) in South San Francisco Bay in May 2001. We counted 1184 stilts and 2765 avocets. Considering only birds observed exhibiting breeding behaviors, our low estimates of breeding birds in the south bay were 270 stilts and 880 avocets, but the true numbers are probably closer to the number of stilts and avocets we actually counted. Our estimates of the breeding population fall within the range of similar estimates from the south bay 20–30 years ago. We know of no other sites on the Pacific coast of the United States with breeding populations of stilts and avocets whose sizes approach those of the South San Francisco Bay. The greatest numbers of stilts and avocets bred on salt ponds in the south bay; lesser numbers bred in a combination of fresh and salt marshes. The observed use by stilts and avocets of available habitat differed significantly from expected use. Stilts used tidal marshes and salt ponds approximately in order of availability, whereas avocets made greater use of salt ponds. Within marshes, stilts most often used vegetated areas followed by mudflat/open water habitat, whereas for avocets the pattern was reversed. Within salt ponds, both species were most often observed on islands, but their order of use of other microhabitats in salt ponds differed. We observed little use of tidal flats by breeding stilts and avocets.

The San Francisco Bay estuary (hereafter, the bay) is recognized as a site of hemispheric importance to shorebirds (Harrington and Perry 1995) because it holds over 500,000 shorebirds (Page et al. 1999). Over 90% of the bay's wetlands, especially tidal marsh, have been filled or diked over the past 150 years to create agricultural lands and salt-evaporation ponds (Harvey et al. 1988, Goals Project 1999). Salt ponds now cover over 12,000 ha around San Francisco and San Pablo bays (Goals Project 1999), the majority being in South San Francisco Bay (hereafter, the south bay).

The presence of American Avocet bones in native American middens suggests that this species was in the bay prior to the first published report in 1884 (Grinnell et al. 1918, Howard 1929). The first breeding record was an observation of downy young in 1926 (Gill 1977), a year prior to Grinnell and Wythe's (1927) listing the bird as an irregularly common visitor to the bay. No additional documentation of breeding by avocets exists prior to Martin's (1939) discovery of young in Santa Clara County in 1937. By 1952, Sibley (1952) considered the species to be a common resident but listed only scattered breeding records for 1941 and 1950. In 1972, Gill (1972) estimated 1800 breeding pairs in the south bay. Subsequent studies by Moss (1980) and Rigney and Rigney (1981) estimated 800 and 650 breeding pairs, respectively.

Grinnell et al. (1918) noted that Black-necked Stilts appeared sparingly in the bay, and Grinnell and Wythe (1927) reported the first nesting there by this species. The Black-necked Stilt remained an uncommon summer resident and rare winter visitant in the south bay through the early 1950s (Sibley 1952). Numbers of nesting stilts increased over the next two decades with breeding populations in the south bay estimated at 400–500 pairs in 1971 (Gill 1972) and 600–650 pairs in 1981 (Rigney and Rigney 1981). The creation of salt ponds has been credited with increasing breeding and nonbreeding populations of Black-necked Stilts and American Avocets in the bay (Gill 1977, Harvey et al. 1988), providing roosting, foraging, and nesting habitat for both species.

Here, we report on a spring survey in 2001 that examined the abundance, distribution, behavior, and habitat use of stilts and avocets in the south bay. We compare our results to those from prior surveys in the early 1970s and 1980s and discuss our findings with respect to various active or proposed restoration projects that may affect future breeding populations of these birds.

STUDY AREA AND METHODS

We surveyed stilts and avocets in San Francisco Bay south of the San Mateo Bridge (Figures 1 and 2) where other studies have focused and where the majority of the estuary's stilts and avocets breed (Gill 1977, Harvey et al. 1992). Two survey teams started on opposite sides of the bay and, in general, moved south to complete coverage of the study area. We searched salt ponds and other wetlands in their entirety for adult stilts and avocets. We also surveyed tidal flats adjacent to salt ponds and marshes that border the bay as far out as we could see. Although we tried to cover all wetlands, some private salt-crystallization ponds were not accessible (see Figure 1 or 2). In addition, outer Bair Island and its immediate vicinity, including adjacent tidal flats, were not surveyed because of difficulties in access. We surveyed 9613 ha of salt ponds, 4068 ha of tidal or diked marshes, 575 ha of other diked wetlands, and approximately 4039 ha of tidal flats.

Study Period and Survey Technique

We surveyed for 120 hours from 15 to 25 May 2001, during the peak breeding period for stilt and avocets in the south bay (PRBO unpubl. data; see also Robinson et al. 1997, Robinson et al. 1999). Two teams of two or

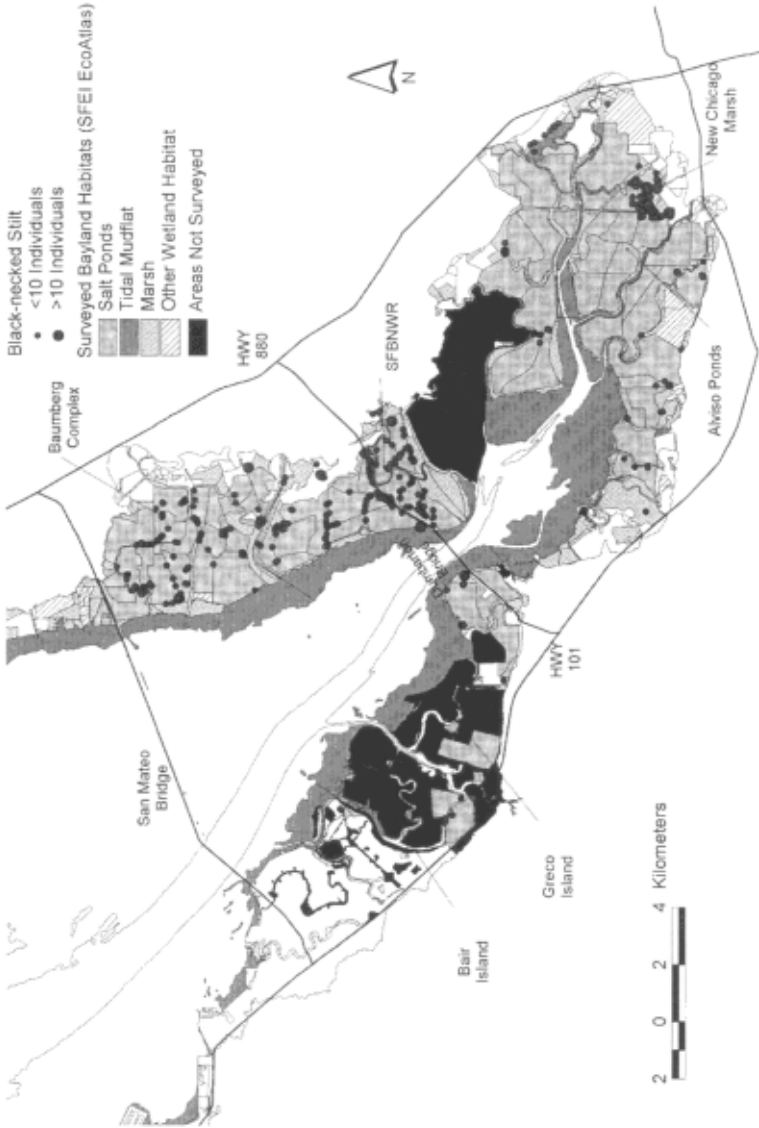

Figure 1. Locations of Black-necked Stilts during a breeding survey of South San Francisco Bay, May 2001. SFBNWR, Don Edwards San Francisco Bay National Wildlife Refuge.

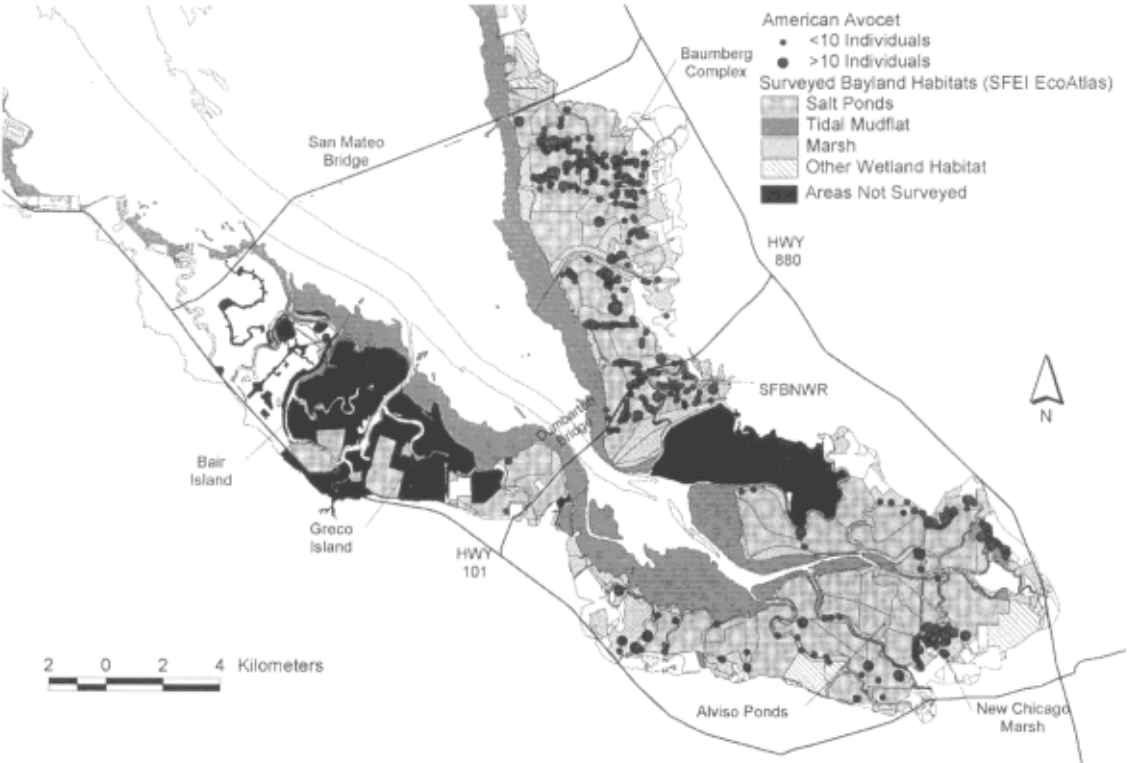

Figure 2. Locations of American Avocets during a breeding survey of South San Francisco Bay, May 2001. SFBNWR, Don Edwards San Francisco Bay National Wildlife Refuge.

three observers drove or walked all levees and roads, counting from vehicles or exiting the vehicle to count areas requiring a greater field of view, using spotting scopes and binoculars. Although locating nests was not the goal of the survey, we recorded all nests that we found. We tried to avoid disturbing nesting birds, but in a few areas of high nesting activity, observers walked levees and counted nests and eggs.

Data collected for adult birds included number of individuals, behavior, habitat, microhabitat, and observed breeding status. Adults' behavior was recorded as (1) alarm (alarm calling though not actively engaged in a distraction display), (2) brooding (adults attending young), (3) breeding display (copulation or postcopulatory display), (4) distraction display (mobbing behavior or broken-wing display), (5) feeding (eating or searching for food), (6) incubating (sitting on or standing at a nest), (7) roosting (sitting, standing, or preening), (8) alert (standing in an alert posture and not alarm calling), or (9) other. We did not use incomplete and/or questionable behavior observations for analysis (<2% of total observations). For most analyses, we grouped behaviors as potential breeding, feeding, or other behaviors. Breeding activities included brooding, breeding display, distraction display, and incubation behaviors. Feeding and swim-feeding behaviors made up the feeding category, while alarm, alert, roosting, and other behaviors constituted the other category.

For analysis, we categorized habitats as: marsh, salt pond, tidal flat, or other wetland. Marshes included all tidal, freshwater, diked, and vegetated marshes. Other wetland habitat included other diked wetlands, sewage ponds, and miscellaneous habitats. Salt ponds and tidal mudflats were their own categories.

We categorized microhabitats as (1) channel (channel or slough within a habitat), (2) dike (on side or top of dike or levee bordering a habitat), (3) island (of dry substrate that could not be covered by water in a strong wind), (4) mud (dry or wet, including shallow water <10 cm deep), (5) shore (wet or dry substrate within 1 m of shoreline), (6) vegetated marsh, or (7) water (>10 cm deep). We chose 10 cm as an approximate cut-off depth because water depths of > 10 cm preclude use by most shorebirds except those that swim (Safran et al. 1997, Isola et al. 2000).

We plotted locations of observations on maps visually, then transferred them to a geographic-information system by means of ArcView 3.2a (ESRI, Redlands, CA).

Statistics

We tested for differences between species in frequencies of behavior, habitat, and microhabitat use with Pearson's χ^2 test (Snedecor and Cochran 1967), using Stata (version 6.0; Stata Corp., College Station, TX). For our analysis comparing observed versus expected habitat use of stilts and avocets, we calculated the expected frequency of habitat use based on the area of each habitat we surveyed (see Methods above). For instance, marshes constituted 22.2 % of the habitat we compared (Table 1); therefore, the expected frequency of the 401 observations of Black-necked Stilts for that habitat was 89 observations. For all analysis, we recorded groups of

Table 1 Habitat Use of Black-necked Stilts and American Avocets During Surveys of South San Francisco Bay, California, May 2001

	Black-necked Stilt Observed	American Avocet Observed	Expected[a]
Marsh[b]	29.2%	13.5%	22.2%
Salt pond	55.4%	75.6%	52.6%
Tidal mudflat	1.2%	1.3%	22.2%
Other wetland[c]	14.2%	9.6%	3.2%
Total observations[d]	401	757	

[a]Expected use based on available habitat (see Methods).

[b]Marsh habitat includes both fresh and salt marshes.

[c]Other wetlands include diked wetlands, sewage ponds, and other habitats.

[d]In all habitats combined.

individuals engaged in the same behavior at the same time and place as one observation to avoid violating assumptions of independence of observations (Martin and Bateson 1986). Statistical tests were two-tailed, and differences were considered significant at $P = 0.05$.

RESULTS

We recorded 1184 adults and 71 chicks of the Black-necked Stilt, 2765 adults and 189 chicks of the American Avocet. Of 397 behavior observations of stilts, 30.5% were breeding, 42.3% were feeding, and 27.2% as other behaviors. Of 753 observations of avocets, 35.5% were breeding, 32.7% were feeding, and 31.9% were recorded as other behaviors.

Salt ponds, the most extensive habitat we surveyed, contained the greatest numbers of stilts and avocets (Table 1). Marshes held the next largest numbers, followed by other wetlands and tidal mudflat. Both species' observed habitat use differed significantly from that expected if use was random use (Black-necked Stilt, $\chi^2_3 = 106.8$, $P = 0.000$, if tidal flats are excluded, $\chi^2_2 = 22.6$, $P = 0.000$; American Avocet, $\chi^2_3 = 211.4$, $P = 0.000$, if tidal flats are excluded, $\chi^2_2 = 54.1$, $P = 0.000$; Table 1). If analyses are restricted to nesting birds, both species' habitat use also differed significantly ($\chi^2_2 = 53.5$, $P = 0.000$). Of the 137 Black-necked Stilt nests described, 21% were in marshes, 69% were around salt ponds, and 9% were in other habitats, whereas of the 409 American Avocet nests described, 3% were in marshes, 93% were around salt ponds, and 4% were in other habitats. There was no significant difference in habitat use of stilts and avocets with broods ($\chi^2_2 = 2.21$, $P = 0.33$). Of the 15 Black-necked Stilt broods described, 20% were in marshes, 53% were around salt ponds, and 27% were in other habitats, whereas of the 63 American Avocet broods described, 11% were in marshes, 73% were around salt ponds, and 16% were in other habitats. We observed five groups of stilts and ten of avocets using tidal flats (Table 1).

Table 2 Comparison of Observed Microhabitat Use by Black-necked Stilts and American Avocets within Marshes and Salt Ponds of South San Francisco Bay, California, May 2001

	Marshes		Salt Ponds	
Microhabitat	Stilt	Avocet	Stilt	Avocet
Channel	2.6%	10.8%	—[a]	—
Levee	—	—	13.1%	18.7%
Island	1.7%	2.9%	31.1%	39.5%
Mudflat/open water	42.7%	51.0%	26.1%	24.7%
Shoreline	—	—	29.7%	16.4%
Vegetated marsh	47.9%	34.3%	—	—
Other	5.1%	1.0%	0%	0.7%
Total groups[b]	117	102	222	572

[a]—, microhabitat not present in broader habitat category.

[b]All microhabitats combined (see Methods).

Stilts and avocets differed in microhabitat use in both marshes ($\chi^2_4 = 12.3$, $P = 0.016$) and salt ponds ($\chi^2_4 = 21.8$, $P = 0.000$). In marshes, stilts were most often observed in vegetated areas, followed by mudflat/open water habitat, whereas for avocets, the pattern was reversed (Table 2). In salt ponds, both species were most often observed on islands, but their order of use of other microhabitats in salt ponds differed (Table 2).

DISCUSSION

Only individuals exhibiting breeding behaviors considered, the minimum number of breeding Black-necked Stilts and American Avocets in the south bay was 270 and 879 birds, respectively. Undoubtedly these are underestimates, given that in the breeding season birds frequently engage in other behaviors or are between nesting attempts (Gibson 1978). If all stilts and avocets we counted were breeding and the sex ratio is 1:1 (Robinson et al. 1997, Robinson et al. 1999), there were approximately 590 pairs of stilts and 1380 pairs of avocets in the south bay. An unknown proportion of our estimated breeding birds were likely nonbreeders because not all individuals of both species breed in their first year and some nonbreeding avocets summer in nesting areas (Robinson et al. 1997, Robinson et al. 1999). Our estimate of 590 pairs of the Black-necked Stilt in the south bay is within the range of previous estimates of 400–650 pairs (Gill 1972, Rigney and Rigney 1981). Our estimate for breeding avocets also falls within the broader range of 650–1800 pairs from prior studies in the south bay (Gill 1972, Rigney and Rigney 1981).

Different counting techniques and coverage areas may account for many of the differences in estimates of stilt and avocet breeding populations in San

Francisco Bay. These differences are difficult to evaluate since exact areas that were covered on previous surveys are unknown. Gill (1972) did not survey all available south bay habitat. He relied on extrapolations to estimate 1800 pairs of breeding avocets, using the product of average nearest-neighbor nesting distances multiplied by miles of insular and noninsular levees. His estimate of 400–500 breeding stilt pairs was based on "impressions of adults observed throughout certain sections of the South Bay" (Gill 1972). Rigney and Rigney (1981) also did not survey all available habitat in the south bay, but they employed a calculation that combined amount of the study area covered, percent of nesting missed because of survey timing, and number of birds observed.

We too were unable to survey parts of the south bay, and this may affect our estimates of breeding stilts and avocets. However, much of our unsurveyed area consisted of salt-crystallizing ponds and developed bay fill. Waterbirds' use of ponds whose salinity is over 250 parts per thousand is consistently low (Takekawa et al. 2000, Warnock et al. 2002), in part undoubtedly because of the lack of invertebrate prey at these high salinities (Goals Project 2000). Potentially good habitat exists on outer Bair and Greco islands, which we did not cover. Gill (1971), however, found only two avocet scrapes on outer Bair Island, and our recent visits to the island revealed no colonies of breeding stilts or avocets (San Francisco Bay Bird Observatory unpubl. data).

In parts of the West, breeding and wintering avocet populations have increased (Colwell et al. 2001), but that does not appear to be the case in San Francisco Bay. We know of no other sites on the Pacific coast of the United States that have breeding-season numbers of stilts and avocets approaching those in the south bay (see also Small 1994). Some regions in the California interior, including the Klamath Basin (D. Shuford pers. comm., Small 1994), Central Valley (Small 1994), and Salton Sea (Shuford et al. 2000), may hold higher breeding numbers than the south bay in some years.

Since the 1980s, core breeding sites for stilts and avocets in the south bay have changed somewhat. Gill (1972) and Rigney and Rigney (1981) reported concentrations of breeding stilts and avocets in the Alviso salt ponds at the southern tip of the bay. We also found concentrations in the Alviso region, especially around New Chicago Marsh. Highest numbers, however, were on the east side of the south bay, between the San Mateo and Dumbarton bridges and just south of the Dumbarton Bridge (Figures 1 and 2). We located 77 avocet and 9 stilt nests in the Baumberg region, whereas Rigney and Rigney (1981) found 2 avocet and 5 stilt nests there. Presumably, long-term habitat change during the past 20 years has altered distributions of nesting stilts and avocets in the south bay. Short-term alterations can affect the breeding populations as well. Active management of salt ponds can change the ponds' depth and other features (Ver Planck 1958) rapidly enough to make foraging or breeding habitat for stilts and avocets suitable or unsuitable in a matter of days.

Our study points out differences in the use of south bay habitats by stilts and avocets during the breeding season. Salt ponds contained more than

half of all stilt and three-quarters of all avocet observations, surpassing expected use as a function of habitat availability. As well as being important breeding habitat for both species, salt ponds also serve as important foraging and roosting areas in winter (Swarth et al. 1982, Takekawa et al. 2001, Warnock et al. 2002).

The high use of marshes by stilts in the south bay mirrors the pattern found in other areas (Hamilton 1975, Robinson et al. 1999). American Avocets (adults and nests) were found less frequently in marshes than were stilts, and within this habitat most avocets were observed in open areas of shallow water. The New Chicago Marsh, a managed tidal marsh in the Alviso region, was an exception, as it held high numbers of breeding avocets and stilts (Figures 1 and 2). The uneven topography of this historical tidal marsh provides a variety of microhabitats including shallow ponded water, vegetation, and mudflats (S. Macias pers. comm.). The marsh is protected from tidal influence by a group of salt ponds bordering its northern edge. This closeness of the pickleweed- (*Salicornia* spp.) dominated marsh to salt ponds and the marsh's relatively stable water levels appeared to create a suitable rearing area for young stilts and avocets. The pickleweed was tall enough to provide the young cover from predators, and the nearby salt ponds provided an abundant supply of insects such as brine flies (*Ephydra* spp., W. A. Maffei in Goals Project 2000, pp. 179–182) for foraging broods of stilts and avocets moving between these habitats.

Tidal flats were little used by stilts and avocets during the breeding season. Similar observations of low use of tidal flats by avocets were reported by Boettcher et al. (1995), who found 3% and 6% of all observed nonbreeding avocets using tidal flats in coastal South Carolina in 1991 and 1992, respectively. Swarth et al. (1982) and Harvey (1988) also rarely observed stilts using tidal mudflats in San Francisco Bay.

Other studies have shown levees to be important nesting sites for stilts and avocets (Gill 1973, Hamilton 1975, Rigney and Rigney 1981, Robinson et al. 1997, Robinson et al. 1999). We found fewer than 20% of the stilts and avocets on levees during our breeding survey and greatest use on islands. In the south bay, it is likely levees are used for breeding less often than are islands because of their accessibility to human disturbance (C. Rintoul pers. obs.) and to mammalian predators, such as the introduced Red Fox (*Vulpes vulpes*) (E. K. Harding in Goals Project 2000, pp. 252–252). Gill (pers. comm.) suggests that his 1971 study may have found more use of levees by stilts and avocets because it predated the arrival of the Red Fox in the south bay. We found islands, including old fragmented levees separated from the surrounding network, heavily used by stilts and avocets, as noted in other studies (Gill 1973, Rigney and Rigney 1981, Swarth et al. 1982, Robinson et al. 1997, Robinson et al. 1999).

Our results reconfirm the importance of South San Francisco Bay as a breeding area for stilts and avocets on the Pacific coast of the United States. Annual fluctuations of nesting stilts and avocets probably exist, and monitoring is needed to understand this variability better. Current conservation proposals for San Francisco Bay (i.e., Goals Project 1999) include the conversion of existing habitats, especially salt ponds, into tidal marsh. The

effects of the conversion of part of 6475–8500 ha of salt ponds to tidal marshes will likely be negative on breeding avocets, whereas the effects on the stilt are more difficult to predict. For both species, modification of tidal marshes to include features of salt ponds like open bodies of shallow water for foraging and islands for breeding may be beneficial. Additional research is necessary to investigate these species' differences in diet in the south bay marshes and salt ponds.

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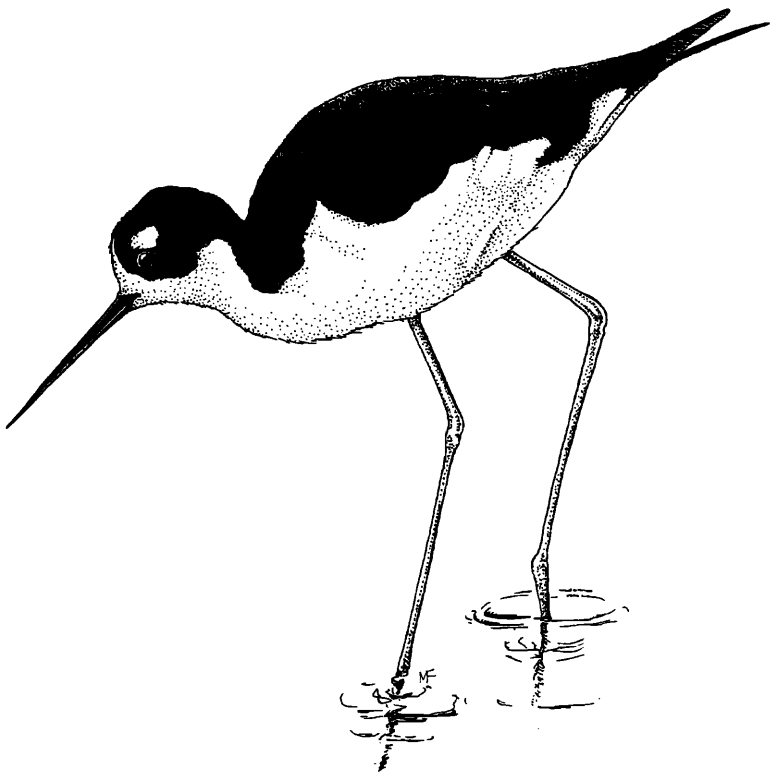

Black-necked Stilt

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