SHOREBIRDS OF HUMBOLDT BAY, CALIFORNIA: ABUNDANCE ESTIMATES AND CONSERVATION IMPLICATIONS

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Long stretches of the Pacific coast of North America are rocky or sandy, punctuated by only a few large bays and river estuaries. During migration and winter most shorebirds (suborder Charadrii) use these bays and estuaries (Senner and Howe 1984, Page et al. 1992), which also are the center of human activities that place shorebird populations at risk (Myers et al. 1987). Senner and Howe (1984) identified Humboldt Bay, California, as one of 58 important North American sites for shorebirds, estimating largely from the work of Gerstenberg (1972) that over 100,000 shorebirds of approximately 30 species use Humboldt Bay as a wintering area or migration stopover site. Additionally, Page et al. (1991) emphasized the area's importance to the coastal population of the Snowy Plover (see Table 1 for scientific names), recently listed as threatened under the Federal Endangered Species Act (Miller 1993).

As a foundation for future conservation efforts directed at shorebirds of Humboldt Bay and the Pacific flyway, this paper reports results of the first three years of continuing shorebird surveys beginning in fall 1990. Here, I examine seasonal variation in shorebird abundance, comparing recent results with other studies (Gerstenberg 1972, Page et al. 1992) in an attempt to understand the current and historical importance of Humboldt Bay to shorebirds of the Pacific flyway. Finally, I discuss these findings relative to potential threats facing shorebird populations.

STUDY AREA

Humboldt Bay, the largest bay between San Francisco Bay, California (420 km south), and Coos Bay, Oregon (350 km north), covers 90 km^2 at high tide, divided into three sections (Costa and Stork 1984). A large northern portion, Arcata Bay, is separated from a smaller southern embayment, South Bay, by a narrow channel and bay known as Entrance Bay, which opens to the ocean. At low water, approximately 70% of Humboldt Bay consists of mud and sand flats, dissected by a complex system of channels. Only Entrance Bay remains approximately constant in surface area over a tidal cycle (Costa and Stork 1984).

Nearly a century ago, humans diked the bay and converted salt marsh and tidal flats to agricultural lands, principally pastures (Hoff 1979). Most of this pastureland is situated north and east of Arcata Bay, but some lies adjacent to South Bay. To the west and separated from the bay by two large spits is approximately 25 km of sandy ocean beach, extending north to the mouth of Little River and south beyond the mouth of the Eel River to Centerville Beach. Estuaries at the mouths of these rivers also provide habitat for shorebirds. Rocky intertidal habitat occurs sparingly at the jetties at Humboldt Bay's entrance and in greater amounts north in the vicinity of

Trinidad. See Gerstenberg (1972), Hoff (1979), and Nelson (1989) for a complete description of Humboldt Bay habitats.

METHODS

Beginning in fall 1989, in collaboration with E. T. Nelson and R. J. Cooper, I began coordinating shorebird surveys at Humboldt Bay as part of the Pacific Flyway Project initiated by Point Reyes Bird Observatory (see Page et al. 1992). Surveying shorebirds at Humboldt Bay is easier than at many places because many enthusiastic and experienced birders are easily organized to survey shorebirds at sites readily accessible by road, the configuration of the bay allows observers to get close to birds just prior to inundation of tidal flats by rising tides, and the timing of tidal inundation varies little over the bay, the difference between the extremes of Arcata Bay and South Bay being approximately 45 minutes, enabling synchronous counting of birds under similar conditions.

Data reported here are from surveys at sites within and adjacent to the bay, established in an attempt to balance the objectives of maximizing coverage of habitats while minimizing possibilities of observers counting the same birds. Four surveys were done each of the three years, once in fall (25 August–8 September), once in early winter (10–18 November), once in late winter (17–23 February), and once in spring (25–28 April). I chose these survey dates to coincide with fall and spring migration and to bracket the winter period in which movements of birds declined.

For each survey, I coordinated multiple observers who counted birds from 22 to 37 fixed locations (Table 1) using binoculars and spotting scopes. At each location observers conducted four synchronized counts of shorebirds at half-hour intervals. At fewer sites (n = 8), participants surveyed shorebirds either by walking beaches for one hour and then reversing direction and conducting a second count or by driving through agricultural lands along predetermined routes (n = 3). These sites were not surveyed when participants were few. Surveys of shorebirds using beaches and agricultural land coincided with surveys at locations around the bay, but I collated the data with the first and third counts at fixed sites. All surveys were scheduled during rising tides so that the advancing water pushed birds toward observers. See Colwell and Cooper (1993) for details and discussion of survey methods.

I collated observations from each survey site using the following variables: date, start time of survey (half-hour interval), survey site, species of shorebird, and number of individuals observed. Sometimes the distance at which observers viewed birds or observer inexperience made identification of species difficult. In these cases, observers classified birds into one of three broader categories: *large shorebirds* (i.e., Whimbrel, Marbled Godwit, Long-billed Curlew, and Willet), *small calidridine sandpipers* (i.e., Dunlin, Western Sandpiper, and Least Sandpiper), and *yellowlegs*. Additionally, owing to difficulty in identifying species of dowitchers, I combined all information for this genus.

For each survey date, I estimated the abundance of each species and all shorebirds in the following manner. First, I tallied each species' abundance during each half-hour survey period by summing counts across survey sites. Next, I estimated each species' abundance using the highest count from the four survey periods. Finally, I estimated the total number of shorebirds as the sum of species' maximum counts regardless of survey period.

RESULTS

Observers recorded 32 shorebird species during the 12 surveys and 19–24 species during any single survey (Table 1). Although average species richness varied little from season to season (mean = 22 for each season), species composition changed slightly owing to the presence or absence of uncommon species (e.g., Black-necked Stilt, Buff-breasted Sandpiper) or arrival and departure of migratory species (e.g., Dunlin).

Estimates of total shorebird abundance varied widely from survey to survey (Table 1). Maximum (83,647) and minimum (17,751) counts occurred in April 1991 and in February 1993, respectively. The abundance of individual species varied across five orders of magnitude (Table 1). Three sandpipers (*Calidris* spp.) accounted for 53–87% of all shorebirds. Thus changes in total shorebird abundance arose largely from changes in sandpiper abundance. Each year, shorebird abundance increased from summer to early winter, declined during the winter, and either increased or decreased during spring.

DISCUSSION

Importance of Humboldt Bay

Estimates of shorebird abundance (Table 1) suggest that the Humboldt Bay area supports 19–24 species and 10^4–10^5 shorebirds at any one time during migration and winter. Comparisons with earlier shorebird studies at Humboldt Bay and elsewhere along the Pacific coast (Page et al. 1992) are difficult owing to differences in area surveyed and variation in survey methods. Despite these differences, however, some comparisons are warranted.

Pacific Coast Comparisons

Compared with other Pacific coast sites (see Boland 1988, Page et al. 1992), Humboldt Bay supports a rich shorebird community. Forty-six species have been recorded, including approximately 30 that may be encountered regularly (Gerstenberg 1972, Harris 1991). Analyses of Christmas Bird Count (CBC; excluding Humboldt Bay) data indicate that winter shorebird diversity along the Pacific coast is inversely correlated with latitude, a pattern more closely associated with declining (northward) diversity and availability of prey than habitat diversity (Boland 1988). Data reported here suggest that winter shorebird diversity at Humboldt Bay surpasses that reported for other sites within approximately 5° latitude north and south on the Pacific coast. This observation is supported by eight years (1984–91) of CBC data (not analyzed by Boland 1988) from the two counts conducted within the Humboldt Bay area: species richness for

Table 1 Maximum Counts of Shorebirds at Humboldt Bay, September 1990–April 1993

	Season												
	Fall			Early Winter			Late Winter			Spring			
Species	8 Sep 1990	25 Aug 1991	29 Aug 1992	18 Nov 1990	10 Nov 1991	15 Nov 1992	17 Feb 1991	23 Feb 1992	21 Feb 1993	28 Apr 1991	25 Apr 1992	25 Apr 1993	Order-of-Magnitude Estimate[a]
Black-bellied Plover *Pluvialis squatarola*	667	972	807	2612	499	762	1475	766	1499	174	118	293	10^3-10^4
Pacific Golden Plover *Pluvialis fulva*	2	—	—	—	2	—	—	—	—	—	—	—	<10^1
Snowy Plover *Charadrius alexandrinus*	—	19	23	10	24	32	15	—	11	1	—	19	10^1-10^2
Semipalmated Plover *Charadrius semipalmatus*	32	411	215	469	548	85	1495	151	42	255	73	500	10^2-10^3
Killdeer *Charadrius vociferus*	20	1	27	315	24	10	478	100	126	3	3	9	10^2-10^3
Black Oystercatcher *Haematopus bachmani*	—	—	3	1	6	18	1	—	22	5	—	19	10^1-10^2
Black-necked Stilt *Himantopus mexicanus*	—	—	—	—	—	—	1	—	—	—	—	—	<10^1
American Avocet *Recurvirostra americana*	474	94	128	860	1023	885	1000	802	847	73	74	50	10^2-10^3
Greater Yellowlegs *Tringa melanoleuca*	71	42	16	12	17	16	33	7	10	40	7	31	10^1-10^2
Lesser Yellowlegs *Tringa flavipes*	14	2	3	—	3	1	2	—	—	1	—	4	<10^1
Yellowlegs spp. *Tringa* spp.	68	4	9	—	17	6	25	29	74	9	1	11	—
Willet *Catoptrophorus semipalmatus*	1648	801	750	3217	2715	972	2249	1155	352	348	69	64	10^3-10^4
Wandering Tattler *Heteroscelus incanus*	1	—	1	—	1	—	1	1	1	15	9	5	<10^1
Spotted Sandpiper *Actitis macularia*	2	1	9	2	2	2	—	—	1	4	1	1	<10^1
Whimbrel *Numenius phaeopus*	26	61	53	4	3	4	3	9	3	223	146	146	10^2-10^3
Long-billed Curlew *Numenius americanus*	173	85	137	286	133	66	94	90	352	33	399	14	10^2-10^3
Marbled Godwit *Limosa fedoa*	6955	2176	3524	6331	6840	3982	7865	5129	2332	6900	1113	350	10^3-10^4

Large sandpipers[b]	1631	1877	819	2000	—	1352	—	292	650	2590	17	2375	—
Ruddy Turnstone													
Arenaria interpres	—	8	1	2	75	1	—	—	9	2	2	9	10^{1}-10^{2}
Black Turnstone													
Arenaria melanocephala	3	—	32	33	57	35	93	146	35	75	15	42	10^{1}-10^{2}
Surfbird													
Aphriza virgata	—	—	30	—	—	25	22	58	39	17	—	23	10^{1}-10^{2}
Buff-breasted Sandpiper													
Tryngites subruficollis	1	1	—	—	—	—	—	—	—	—	—	—	$<10^{1}$
Red Knot													
Calidris canutus	8	7	5	38	10	5	1	30	2	7	55	4	10^{1}-10^{2}
Sanderling													
Calidris alba	176	167	670	1120	632	693	351	726	133	598	9	725	10^{2}-10^{3}
Baird's Sandpiper													
Calidris bairdii	2	2	—	—	—	—	—	—	—	—	—	—	$<10^{1}$
Western Sandpiper													
Calidris mauri	6295	2382	7774	7420	6537	3500	6100	913	697	7380	9732	2422	10^{3}-10^{4}
Least Sandpiper													
Calidris minutilla	142	540	783	3058	3772	228	2390	796	140	1047	273	169	10^{3}-10^{4}
Rock Sandpiper													
Calidris ptilocnemis	—	—	—	—	—	—	—	2	—	—	—	—	$<10^{1}$
Dunlin													
Calidris alpina	25	—	—	22960	12338	4146	23246	5393	3122	23303	4309	3629	10^{4}-10^{5}
Small sandpipers													
Calidris spp.	7873	8724	20105	15214	21233	20149	6070	8020	6745	37565	3652	9269	—
Dowitchers													
Limnodromus spp.	736	656	451	471	1307	278	1766	375	495	2979	930	128	10^{2}-10^{3}
Common Snipe													
Gallinago gallinago	—	—	—	19	—	9	1	1	12	—	—	2	$<10^{1}$
Red-necked Phalarope													
Phalaropus lobatus	5	—	3	—	—	—	—	—	—	—	—	—	$<10^{1}$
Red Phalarope													
Phalaropus fulicaria	—	—	—	—	1	—	—	—	—	—	—	—	$<10^{1}$
Species richness[c]	23	20	23	21	24	23	23	21	23	23	19	24	
Total shorebirds	27050	19033	36377	66454	57802	37261	54772	24981	17751	83647	20634	20299	10^{4}-10^{5}
Number of observers	50	24	44	57	50	39	62	47	46	47	35	41	
Number of sites surveyed	32	22	29	33	31	27	37	32	30	30	26	27	

[a]Spans a species' single maximum count based on all seasons.
[b]Includes Marbled Godwit, Long-billed Curlew, Willet, and Whimbrel.
[c]Total includes only one dowitcher.

Arcata and Centerville CBCs averages 23 and 24, respectively (S. W. Harris pers. comm.). Therefore, inclusion of data from Humboldt Bay in Boland's (1988) comparison likely would have yielded an even more precipitous decline in species richness just north of Humboldt Bay. Data provided here, as well as elsewhere (Boland 1988, Page et al. 1992), indicate that this latitudinal pattern arises because Humboldt Bay lies at the northern limit of the wintering range of several species (e.g., American Avocet, Marbled Godwit, and perhaps Red Knot, Long-billed Curlew, and Short-billed Dowitcher).

Results of Pacific Flyway Project surveys at other Pacific coast sites (Page et al. 1992) suggest that Humboldt Bay's importance (based on order-of-magnitude estimates of abundance) to shorebirds varies seasonally. During winter, Humboldt Bay ranks second to San Francisco Bay ($>10^5$ birds) in shorebird abundance. During fall, Humboldt Bay is also among the most important sites, whereas during spring, it does not appear to be as heavily used as other estuaries and bays (e.g., Columbia River estuary, Grays Harbor, Fraser River delta).

Humboldt Bay Comparisons

During the three years of this study, the largest number of shorebirds (83,647) occurred during spring migration (April 1991) when birds move through the area rapidly. This is less than Gerstenberg's (in Senner and Howe 1984) migration-period estimate of more than 100,000 birds. The latter estimate was based on an extrapolation of bird abundance in study plots to the entire area of the bay and supplemented by aerial surveys (R. Gerstenberg pers. comm.). Winter estimates of shorebird abundance probably are influenced less by bird movements than those during migration. However, declines in shorebird abundance between November and February suggest that local movements take place even at this time of year. Gerstenberg (1972) estimated a maximum of 50,000 birds in single winter (November 1969) roosts, exceeding most bay-wide estimates from this study (Table 1). This comparison is especially interesting because Gerstenberg's largest roosts were at sites where the maximum count during this study approximated 10,000 birds. Even if Gerstenberg's estimates of flock size erred by 50%, his *single-site* total falls within this study's range of winter estimates for the *entire bay* (Table 1). Thus numbers of shorebirds using the Humboldt Bay area apparently have declined in the last 25 years. The most noteworthy exception to this pattern is the American Avocet, which has experienced a population increase during the past 25 years (Harris 1991).

Shorebird Conservation at Humboldt Bay

Shorebird conservationists have emphasized estimating numbers of birds using regional flyways or individual sites, with the aim of understanding population trends (e.g., Howe et al. 1989) or designating critical habitats (e.g., Page et al. 1992). Shorebirds concentrate in large numbers during the nonbreeding season at a limited number of wetlands. It is at these locations that shorebird populations are most vulnerable to a variety of anthropogenic factors, and these wetland habitats remain the weakest links in conservation efforts directed at migratory species (Myers et al. 1987). Therefore, conservation of shorebirds may necessitate a broader perspective than for other birds. Nevertheless, an understanding of local conservation issues is important to global efforts.

Shorebird distribution and abundance in the Humboldt Bay area presumably has been influenced by habitat alteration and degradation, as well as human disturbance. Humboldt Bay has changed dramatically over the past century by diking, filling, dredging, and aquaculture, which have altered natural ecosystems. By 1980, the original wetlands of Humboldt Bay had been reduced 30% (Shapiro and Associates 1980). Alarmingly, however, less than 3% of approximately 6300 ha of tidelands and channels in Humboldt Bay are currently protected by state and federal agencies (K. Foerster pers. comm.). Conversion of intertidal habitat to agricultural lands probably influenced local shorebird distribution. Currently, however, pasturelands are used regularly by shorebirds, especially during winter when rains and short vegetation enhance foraging opportunities (Hoff 1979).

In Arcata Bay, oyster (*Crassostrea virginica*) culture (oysters grown on intertidal substrates) is an important local industry that alters a large proportion of intertidal habitat. Some potential effects of oyster harvest include alteration of intertidal flats, destruction of eelgrass (*Zostera marina*) beds, and changes in invertebrate populations owing to harvest techniques (Waddell 1964). Furthermore, indiscriminate dumping of shells and human disturbance during harvest may affect birds. These impacts are probably greatest for waterfowl, especially the Brant (*Branta bernicla*), which forages on eelgrass (Waddell 1964), but impacts on invertebrates probably influence shorebirds by altering the quality of foraging areas.

Elsewhere around Humboldt Bay, human disturbance is probably greatest along the 25 km of beaches where recreation is concentrated and Snowy Plovers breed (Page et al. 1991). Nelson (1989) suggested that disturbance along the south spit of Humboldt Bay had displaced plovers that had nested there in the past, and M. Fisher (pers. comm.) observed a nest there destroyed by vehicles in 1993.

Nonbreeding shorebirds also may be influenced by human activities on beaches. Large numbers roost on beaches at high tides, when they may be particularly susceptible to human disturbance. Nelson (1989) reported that people disturbed roosting shorebirds during 20% of his surveys. Although human activity on the beaches adjacent to Humboldt Bay is high (over 34,000 recreational users estimated between 1 January and 31 August 1988 for Samoa Peninsula; Gearheart 1988), its effects are unknown and warrant study. So far, however, recreational use of Humboldt Bay beaches does not approach the high levels associated with the changes in shorebird distribution observed along the Atlantic coast of North America (Pfister et al. 1992).

SUMMARY

I examined seasonal variation in shorebird abundance at Humboldt Bay, California, on the basis of 12 surveys conducted over 3 years by multiple

observers. Relative to other Pacific coast sites (see Boland 1988, Page et al. 1992), the Humboldt Bay shorebird community is diverse (approximately 45 species overall and 19–24 species during any one season) and abundant (10^4–10^5 shorebirds, but numbers vary widely from season to season and year to year). Comparison with earlier studies of shorebirds at Humboldt Bay suggests that overall shorebird abundance has declined. During winter, this area hosts the following proportions of Pacific flyway populations (see Page and Gill 1994): Marbled Godwit, 5–8%; Dunlin, 4–5%; Willet, 3–4%; American Avocet, 1%. Conservatively, these numbers suggest that Humboldt Bay qualifies as a "regional site" (>20,000 shorebirds or at least 5% of a flyway population) under the Western Hemisphere Shorebird Reserve Network (Hunter et al. 1991). Estimates during migration periods, however, suggest this area may merit classification as an "international site" (100,000 shorebirds or at least 15% of a flyway population). Further understanding of the importance of Humboldt Bay to shorebirds requires more precise estimates of shorebird abundance based on improved survey techniques and greater knowledge of species-specific turnover rates.

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