RESULTS OF THE FIRST COMPREHENSIVE SHOREBIRD CENSUS OF SAN FRANCISCO AND SAN PABLO BAYS

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INTRODUCTION

In the western North American flyway, two sites have been recognized for the large number of shorebirds they support in spring migration: the Copper River delta system and Greys Harbor (Isleib 1979, Senner 1979, Herman and Bulger 1981, Figure 1). For many years, the San Francisco Bay-San Pablo Bay-Suisun Bay system (hereafter called the Bay System) in central California has been suspected to be one of the most important spring migration stopover points for shorebirds on the western North American flyway. However, its size (over 1500 km², of which about 200 km² are salt evaporators and about 170 km² are tidal flat), the widths of some of its tidal flats and the inaccessibility of much of its shore and adjacent wetlands have discouraged attempts to document the total numbers of shorebirds it supports.

One previous project has aimed at documenting the number of birds across many sites on San Pablo and San Francisco Bays. From February 1964 to January 1966, approximately 60 observers participated in twice-monthly counts of all wetland birds (including loons, grebes, pelicans, cormorants, herons, geese, ducks, coots, shorebirds, gulls and terns) from 139 shorebird observation points around the Bays (Bollman *et al.* 1970). The study reports seasonal patterns of bird use for several habitat types in the Bays and documents high numbers of shorebirds relative to other wetland birds visible from shore. However, the scarcity of observers relative to the task of counting all wetland birds, the lack of coverage of all sites during each census period and the problem of determining what proportion of the bays' shorebirds could be seen from the 139 sites, prevented an estimate of the total number of shorebirds using San Pablo and San Francisco bays. Other studies of the numbers of shorebirds on San Pablo and San Francisco Bays have focused on isolated sites or non-shoreline habitat (*eg.* Storer 1951, Jurek 1974, Roemer and Feeney unpubl. data, Pratt unpubl. data).

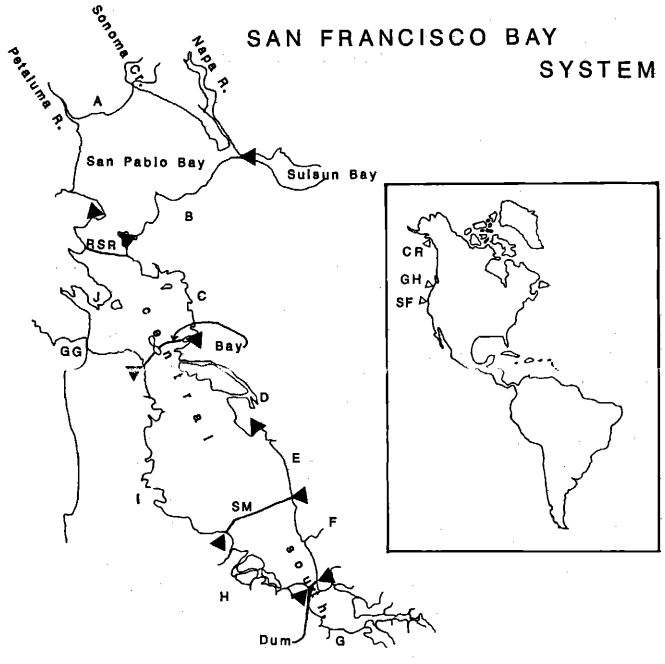

Figure 1. The San Francisco Bay System compreising San Francisco Bay (central and south), San Pablo Bay and Suisun Bay regions. Boundaries among 10 areas (A-J) within San Pablo and San Francisco Bays are indicated by solid triangles. Bridges indicated are Golden Gate (GG), Richmon-San Rafael (RSR), Bay, San Mateo (SM) and Dumbarton (Dum). The inset map shows the locations of the San Francisco Bay System (SF), Grays Harbour (GH) and Copper River System (CR).

On 16 and 17 April, 1988, 183 observers conducted the first coordinated census of all shorebirds on San Francisco and San Pablo Bays. Most of the tidal flat habitat in the Bay System is located in these two bays. The census was the first of its kind and had two major objectives: to make as accurate as possible an estimate of the number of shorebirds using San Pablo and San Francisco Bays on a single day during spring migration and to work out the logistic and technical problems of conducting a simultaneous census of the Bay System. Here, we report the results of this census.

METHODS

The shoreline of San Francisco and San Pablo Bays together was divided into ten areas, shown in Figure 1. In each area, the shoreline was further divided into census segments, each with several observation points from which birds could be counted. The size of each segment was determined by the length of shoreline that we thought a census team could cover in about two hours and by natural features such as deep channels or points of land. The shoreline of Area A comprised 20 segments, but the other nine areas only between 6 and 15 segments. We visited almost all shoreline segments between 1 February and 20 March to set segment boundaries and to obtain information on the shoreline type, barrier channels, points of access, required access permission and area hazards.

Our census also included 71 non-shoreline sites, of which 65 were in areas A, F and G. These included many of the diked or seasonal wetland sites in the U.S. Fish and Wildlife Service's (USFWS) Diked Baylands Wildlife Study, salt evaporation ponds in the north and south bays, sewage treatment plants and other areas of which observers were already aware. Except for south Bay salt evaporators, we did not visit most of the non-shoreline sites before the count, instead relying on the participants' knowledge of these areas to ensure proper coverage.

For two months prior to the counts, we solicited volunteer counters by placing notices in local Audubon Society newsletters and by personally contacting over 125 experienced observers. After assessing the experience that volunteers had in identifying and counting shorebirds, we organized teams of one or more people to cover each census segment, including

at least one experienced censuser in teams that were to cover areas likely to have the highest shorebird numbers. Observers were provided with decriptions of their areas, forms for recording census results, a description of census design and protocol and a starting time for counts. Starting times for adjacent segments were the same. In most cases, each team began at the same time as the team in one of the adjacent shoreline segments and worked toward the other neighboring team at the other boundary.

The ground census was held on the weekend of 16-17 April 1988; an aerial census of San Pablo Bay was conducted the following day, on 18 April. On 16 April areas A, B, C, D, J and the northern part of I were covered; on 17 April areas E, F, G, H and the southern part of I were covered (Figure 1). We covered 97 of the 105 shoreline segments identified in the ten areas; segments not covered were in areas A, C, G and J. Four sites with substantial tidal flat in area B were not covered on 16 April due to access problems. Estimates of the number of birds in those sites were obtained during aerial flight on 18 April. Among the shoreline segments not covered, the ones in areas A, C and J were mostly rocky or urban sites. All of these areas had very little tidal flat and undoubtedly held very few shorebirds. In area G, three shoreline segments were missed because the census team did not get to the shoreline before the tide had covered all flats; a team in one of the adjacent segments realized that the team covering one of the missed segments was late and made a partial count of the birds there.

The count was conducted mid-morning, on a moderatly high, rising tide. We hoped to count the shorebirds while they were still on the tidal flats to obtain estimates of shorebird use for different parts of the Bays. Counters were asked to cover non-shoreline sites, such as salt evaporators, included with their shoreline segments before they counted shoreline tidal flats. Since shorebirds on tidal flats at low tide move to non-shoreline sites as the tide rises, only low-tide counts of birds at non-shoreline sites were added to the total Bay count. We asked that counters also count the high-tide roosts after the shoreline counts, if possible. High-tide counts, which would have included birds already counted on the shoreline, were considered separately and were not included in the total count.

Censusers were asked to count all shorebirds in their areas. We suggested that they combine counts for Long-billed Dowitcher *Limnodromus scolopaceus* and Short-billed Dowitcher *L. griseus* since their specific identifications are difficult and sometimes impossible to make under census conditions. We asked that all rare species be described.

In some cases, it was not possible for counters to determine the proportions of each species in mixed-species flocks of sandpipers. In such cases we asked the censusers to note the species they identified within these flocks of unallocated shorebird speceis. Usually, unallocated sandpipers were either Least Sandpipers *Calidris minutilla* and Western Sandpipers *C. mauri*, or Least and Western Sandpipers and Dunlins *C. alpina*. For each census site we incorporated the number of unallocated birds in mixed species flocks into the identified species if the proportion and number of identified individuals were sufficiently high (as described below), assuming that the composition of unallocated birds in the mixed-species flocks was similar to that of the identified species. If there were only two species in the unallocated group, they were apportioned into the identified species when the number of identified individuals was greater than 50 and exceeded the number of unallocated individuals. If there were three unallocated species in the group, they were apportioned when the total number of identified individuals was greater than 100 and the proportion of identified individuals was at least two-thirds of the total in the group. Unallocated individuals that did not meet these criteria were left as combined species groups (e.g., Least/Western sandpiper) in the final presentation of the data (Table 1).

There is an inherent error in a census of this kind, due to movement of birds between areas, that cannot be estimated during a single census. To address this, we used census site totals for counts only during a given period and did not count any flocks that possibly could have been counted previously by another team, based on the very valuable notes on flock movement provided by most teams after the census.

In order to obtain some final, though tentative, totals for each species, we calculated grossly-adjusted species totals. These calculations were made using the (somewhat tenuous) assumption that, for each for the ten areas, the species composition of the unallocated, combined species groups was similar to the species composition of the groups of identified individuals. Although this assumption is likely to be incorrect in some cases, the number of unallocated individuals was not high enough overall (or in many areas, except B and E, Table 1) to cause substantial differences between the species' relative proportions of identified totals and those of grossly-adjusted totals.

RESULTS AND DISCUSSION

Shorebird Numbers

Twenty-eight species of shorebirds, totalling 838 470 individuals, were found on the census. The grossly-adjusted totals were 555 967 Western Sandpipers (66% of the total), 139 713 Dunlin (16%), 62 458 Dowitchers (mostly Short-billed Dowitchers; 7%), 32 353 Marbled Godwits (*Limosa fedoa*; 4%) and 16 775 Least Sandpipers (2%). Each of the other 22 species made up 1% or less of the total counted.

The largest numbers of shorebirds occurred in the south Bay and on San Pablo Bay. Seventy percent of the shorebirds were found south of the San Mateo Bridge (areas F, G and H), with the largest number between the San Mateo and Dumbarton Bridges on the east side of the south Bay (area F). The tidal flats in these areas are relatively wide at low tide and the shoreline is backed by salt evaporators.

The evaporators contribute to the value of south Bay and San Pablo Bay areas by providing undisturbed high-tide habitat areas for shorebirds using the tidal flats. Although few shorebirds other than Snowy Plovers *Charadrius alexandrinus*, Black-necked Stilts *Himantopus mexicanus*, American Avocets *Recurvirostra americana*, Greater Yellowlegs *Tringa melanoleuca*, Lesser Yellowlegs *T. flavipes*, Wilson's Phalaropes *Phalaropus tricolor* and Red-necked Phalaropes *P. lobatus* were found in the evaporators before the tidal flat counts, many if not most of the shorebirds sought

Table 1. Results of the San Francisco Bay System shorebird census, 16-18 April 1988. See Figure 1 for area locations.

Species	A	B	C	D	E	F	G	H	I	J	TOTAL
Black-bellied Plover	2 977	244	168	216	225	873	5 214	662	237	130	10 946
Lesser Golden Plover					1						1
Snowy Plover					51	32	17	3			103
Semipalmated Plover	193	94	35	54	63	8	106	87	30	25	695
Killdeer	104	7	17	18	31	3	47	15	16	23	281
Black-necked Stilt	34		2	27	32	814	1 532	58	5	37	2 541
American Avocet	755		30	99	103	695	4 347	178	2	38	6 247
Greater Yellowlegs	50		9	3	8	404	82	2	2	11	571
Lesser Yellowlegs	1					95	3				99
Yellowlegs	2			6		29					37
Willet	755	162	135	144	323	1 777	249	1 412	73	93	5 123
Wandering Tattler				2							2
Spotted Sandpiper	1	2	3	8	1		1			10	26
Whimbrel	52	1	11	11	2	8	7	14	20	9	135
Long-billed Curlew	129	3		6	8	57	40	42	3	5	293
Marbled Godwit	11 206	446	145	2 438	1 279	7 669	5 895	2 742	192	11	32 023
Marbled Godwit/Willet				350							350
Ruddy Turnstone	3	1	12		21	76	2	5	9		129
Black Turnstone	1	156	11	3	5			15	19	2	212
Red Knot	28	1 371		8	4	160	1	6	1		1 639
Sanderling	5	95	599	115	21	4		1	27	7	874
Western Sandpiper	56 691	4 936	6 966	816	5 954	209 331	133 644	50 452	3 944	1 229	473 963
Least Sandpiper	3 882	452	359	156	1 078	2 374	2 723	280	721	398	12 423
Least/Western Sandpiper	15 238		565	200	191	12	46 569	430	2 450	90	65 745
Baird's Sandpiper	1					1					2
Dunlin	48 294	5 123	1 667	2 417	757	51 501	13 709	64	1 937	208	125 677
Dunlin/West./Least sndp.	6 774	21 742	60		5 130	20	2	280		116	34 124
Dunlin/Western sndp.							200				200
Sander./West./Least sndp.										48	48
Dunlin/Bl.-bellied Plover				300							300
Short-billed Dowitcher	98	24	393	8	6	620	13	481	250	277	2 170
Long-billed Dowitcher	10	5	8		12	2	1	37		1	76
dowitcher spp.	9 351	1 932	1 305	3 204	1 004	27 874	8 813	4 451	1 371	907	60 212
Common Snipe	3						1			1	5
Wilson's Phalarope						132	81				213
Red-necked Phalarope	1					61	721	135			918
phalarope spp.								67			67
TOTALS	156 639	36 796	12 500	10 609	16 310	304 632	224 020	61 979	11 309	3 676	838 470

Table 2. High tide roost counts of selected salt evaporators of south San Francisco Bay.

	Area F	G
Black-bellied Plover	798	54
Semipalmated Plover	0	24
Greater Yellowlegs	51	21
Lesser Yellowlegs	1	4
Willet	1 410	62
Marbled Godwit	8 360	44
Ruddy Turnstone	12	0
Red Knot	1	2
Sanderling	8	0
Western Sandpiper	86 615	12 792
Least Sandpiper	1 088	5 073
Least/Western Sandpipers	200	1 605
Dunlin	13 898	2 773
Western Sandpiper/Dunlin	7 000	274 310
dowitchers	5 461	8 509

refuge in the evaporators as the rising tide covered the flats. High-tide counts in evaporators south of the Dumbarton Bridge (area G) totalled over 296 000 small sandpipers (Least Sandpipers, Western Sandpipers and Dunlins), and one team counted over 240 000 small sandpipers at one evaporator. We did not cover high-tide habitat sites in area H evaporators but know from aerial censuses that there are important roost sites there.

Using high-tide evaporator counts for areas F and G, we were not able to account for all shorebirds seen on the tidal flats of these areas. This, in part, is due to birds using high-tide roosts in areas different from their tidal flat feeding areas. For example, we observed birds from area H tidal flat, just north of the Dumbarton Bridge, fly south into area G as the tide rose. High-tide counts in area F accounted for 91% of the Black-bellied Plovers *Pluvialis squatarola*, 79% of the Willets *Catoptrophorus semipalmatus* and all of the Marbled Godwits counted on the tidal flats in that area at lower tides. In contrast, high-tide counts of dowitchers at the same evaporators accounted for only 19% of the area F tidal flat counts Tables 1 and 2. High-tide counts at evaporators in area G yielded only 10% of the Black-bellied Plovers, 25% of the Willets, 1% of the Marbled Godwits but 96% of the dowitchers counted on the tidal flats of that area Tables 1 and 2. Combined high-tide evaporator counts of areas F and G yielded 88% of the 460 000 small sandpipers (defined above) counted on the tidal flats of those areas. Since some shorebirds roosted at the base of the outer bay levees and possibly in other nearby wetlands of which we had no knowledge and because we did not cover evaporator roost sites in area H, we did not identify all of the important high-tide refuges used by birds on the census days.

We found 23% of the total number of shorebirds on San Pablo Bay (areas A and B), mostly along the west and north shores (area A) where tidal flats are continuous and relatively wide at low tide. Broad salt marsh areas to the south, west and north and salt evaporators to the north provided high-tide habitat for birds using San Pablo Bay flats. Although we were not able to cover all of the non-shoreline wetland habitat in San Pablo Bay, we could identify some high-tide sites used after the tidal flats census. Most were wetlands associated with the Napa River and salt evaporators north of San Pablo Bay, which provided habitat at high tide for birds that feed along the north San Pablo Bay shoreline. At high tide, we found that large shorebird flocks from the west and north shore tidal flats of San Pablo Bay converged at the mouth of the Petaluma River and flocks from the north shore flats converged at Sonoma Creek mouth but we were unable to determine if those birds remained at these area throughout the high-tide cycle.

Central San Francisco Bay (areas C, D, E, I and J) supported fewer shorebirds than either south San Francisco Bay or San Pablo Bay. Numbers of shorebirds at some sites in the central Bay may have been underestimated, because scheduled census start times were about 30 minutes too late to take advantage of the best tide conditions for counting. In many areas of the central Bay, however, the tidal flat habitat is limited and fragmented by both naturally steep shoreline and human-deposited bay fill. Urban development has eliminated much of the non-shoreline wetland habitat in this area. Nonetheless, the central Bay areas may be relatively important for particular species at various times of the year and may hold relatively large numbers of shorebirds when amount of habitat is taken into account.

Species Distributions within the Bay System on the Census

Seven of the eight most numerous species tended to be widespread over the ten areas of San Pablo and San Francisco Bays, although three of these were noticeably scarce in the central Bay areas. Western Sandpipers, Dunlins, dowitchers, Marbled Godwits, Least Sandpipers, Black-bellied Plovers and Willets occurred in all ten areas, with at least 90 individuals of each species counted in nine of the ten areas (Table 1). Less than 10% of the toal number of Black-bellied Plovers, Western Sandpipers and Dunlin, however, seen were in the central Bay (Table 3). American Avocets were much more localized: 70% of the Bay System total were south of the Dumbarton Bridge and they were absent or scarce in two areas (Table 1).

Common but not abundant species (those whose grossly-adjusted totals for the entire census were between 100 and 5 000) varied from being relatively widespread over the ten areas to being highly localized in a couple of areas. Semipalmated Plovers *Charadrius semipalmatus*, Killdeers *C. vociferus* and Whimbrels *Numenius phaeopus* occurred in all areas and no area held more than 40% of the species' totals. Although Black-necked Stilts, Red Knots *Calidris canutus*, Sanderlings *C. alba*, Greater Yellowlegs, Ruddy Turnstones *Arenaria interpres* and Black Turnstones *A. melanocephala* each occurred in eight or nine bay areas, 59% to 84% of the individuals of these species were found in just one of the ten areas (Table 1). Less common species were more localized. Snowy Plovers, Lesser Yellowlegs, Wilson's Phalaropes and Red-necked Phalaropes only occurred in two to four bay areas; all were on salt evaporators. In fact, over 80% of the stilts, the avocets, both yellowlegs and both phalaropes were seen in the south Bay, where salt evaporators are the dominant feature of the upper shoreline (Table 3).

Five species occurred in very small numbers on the count (Table 1). One Lesser Golden Plover *Pluvialis dominica* was seen in area E. The two Baird's Sandpipers *Calidris bairdii* were seen at a sewage pond in area A and on a salt evaporator in area F. These species are rare on the West Coast in spring. Two Wandering Tattlers *Heteroscelus incanus* were found on rip-rapped shoreline in area D; this outer

Table 3. The percent distribution of shorebirds among three regions of the San Francisco Bay System. An asterisk indicates < 0.5%.

	San Pablo Bay	Central San Francisco Bay	South San Francisco Bay	
Areas Included	AB	CDEIJ	FGH	Grossly Adjusted Total
Black-bellied Plover	29	9	62	10 971
Snowy Plover	0	50	50	103
Semipalmated Plover	41	30	29	695
Killdeer	40	37	23	281
Black-necked Stilt	1	4	95	2 541
American Avocet	12	4	84	6 247
Greater Yellowlegs	9	6	85	602
Lesser Yellowlegs	1	0	99	105
Willet	18	15	67	5 143
Whimbrel	39	39	21	135
Long-billed Curlew	45	8	47	293
Marbled Godwit	36	14	50	32 353
Ruddy Turnstone	3	33	64	129
Black Turnstone	74	19	7	212
Red Knot	85	1	14	1 639
Sanderling	11	88	1	874
Western Sandpiper	16	5	79	555 967
Least Sandpiper	39	24	38	16 775
Dunlin	48	6	47	139 713
dowitchers	18	14	68	62 458
Wilson's Phalarope	0	0	100	213
Red-necked Phalarope	*	0	100	985
Total shorebirds	23	7	70	838 470

coast species tends to be uncommon in the Bay. Twenty-two of the 26 Spotted Sandpipers *Actitis macularia* were in the central Bay. This species is often found along bluff-backed bay shoreline, most of which is in the central Bay. Common Snipe *Gallinago gallinago* occurred mostly in marshy pastures and other areas of low vegetation, where our coverage was sparse; only five were seen.

Evaluating the Census

Overall, 95% of the census sites were covered between 16 and 18 April. Due to habitat characteristics described in the Methods, shoreline segments not covered in areas A, C and J undoubtedly held very few shorebirds. In contrast, sites not covered in area G undoubtedly would have contributed several thousand shorebirds to the total, given the high densities found in all other shoreline areas of the south Bay. Therefore, the lack of counts for the shoreline segments in area G could have created a substantial downward bias in the estimated species totals.

We suspect that the 16-18 April census did not cover the peak of shorebird abundance in the San Francisco Bay region, based on information from nearby Bolinas Lagoon, Greys Harbor in Washington and the Copper River Delta area in Alaska. Western Sandpiper peak numbers occur between 20 and 23 April (possibly even a bit later in some years) in Bolinas Lagoon (Page *et al.* 1979), between 23 and 25 April in Washington (Herman and Bulger 1981) and in early May in south-central Alaska (Isleib 1979). Peak number for Western Sandpipers in Bolinas Lagoon this year occurred on 23 April (N. Warnock, unpubl. data). We suspect that peak numbers of Western Sandpipers in the San Francisco Bay System probably occur at or slightly before the peak at Bolinas Lagoon and that we may have missed the peak number of Western Sandpipers staging in San Francisco Bay by as much as a week. Dowitcher numbers are at spring peaks in Bolinas Lagoon between mid- and late April, so the census may have encompassed the San Francisco Bay spring peak for dowitchers. No spring peaks have been demonstrated for Marbled Godwits, Least Sandpipers and Dunlins in Bolinas Lagoon (Page *et al.* 1979) or San Francisco Bay (Storer 1951, Jurek 1974) and the numbers we counted of these species are probably of the magnitude of their late winter population sizes on San Pablo and San Francisco Bays. Species such as American Avocet, Willet and Long-billed Curlew *Numenius americanus* have already begun to migrate from the coast by mid-April, so the census totals should be well below winter numbers on the Bays. Numbers of later migrants such as Semipalmated Plover and Whimbrel have only begun to build to spring peaks by mid-April. Detailed information from regular and frequent spring censuses over several years at several sites on the Bay would be valuable for establishing the patterns of movement during this dynamic period of the shorebird year in the Bay System.

One additional point worth mentioning is that any single census of an area during migration does not measure the total number of individuals that stop at that area. In fact, peak numbers only represent the minimum number of individuals that use an area during a migratory period. Given the paucity of information on turnover of individuals, however, we defer any attempt to estimate the total number of shorebirds that passed through the Bay System in April and May 1988.

CONCLUSIONS

The 16-18 April census firmly established the San Pablo-San Francisco Bay estuary as a major spring staging area for shorebirds on the Pacific Flyway. Given our conservative decisions on counting flocks that moved between areas and our lack of coverage of three promising areas, we believe that our final estimate is biased downward. There is also an

unmeasured error due to observer ability and bird movement (which was considerable in the south Bay) that probably produces overestimates in some sites and underestimates in others). We have no measure of this source of error. Subjectively assessing our final estimate of 838 000 shorebirds, we suspect that there were between 600 000 and 1 200 000 shorebirds on San Pablo and San Francisco Bays during the census weekend and that the number then may have not reached the spring maximum. To round out the perspective on the role of the Bay System in supporting shorebirds, its importance as a breeding area, fall migratory area and wintering area must also be recognized. In the coming years, we hope to supply information on the year round habitat values of the Bay to shorebirds.

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