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ESTIMATES OF COASTAL SHOREBIRD ABUNDANCE: THE IMPORTANCE OF MULTIPLE COUNTS

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Abstract.—Variability in estimates of shorebird abundance derived from four sequential 30-min counts conducted at Humboldt Bay, California during November 1990 and February 1991 was estimated. The November survey was scheduled so that the first of four consecutive 30-min counts occurred when the tide had just inundated intertidal habitats, whereas inundation occurred during or just after the last of four February counts. Percent bias was normally high (15–78%) in both counts when compared with the maximum count of selected shorebird species or groups. Compared with November counts, those in February varied less and peaked during the penultimate and last count. These findings suggest that multiple counts are more useful than single surveys, especially to identify optimal observation times relative to inundation of intertidal flats. Data from multiple surveys offer at least two potential ways of estimating shorebird abundance: average (or median) estimates and single, maximum estimates.

ESTIMADOS DE LA ABUNDANCIA DE PLAYEROS: LA IMPORTANCIA DE CONTEOS MÚLTIPLES

Sinopsis.—Se determinó la variabilidad de estimados de abundancia de playeros utilizando cuatro conteos secuenciales (de 30 min). El estudio se llevó a cabo en la Bahía de Humboldt en California durante noviembre de 1990 y febrero de 1991. La encuesta de noviembre fue planeada de tal manera que el primero de los cuatro conteos ocurriera cuando le marea hubiera inundado los habitats intermareales. El censo de febrero se programó de forma tal que la inundación se llevara a cabo durante o justo después del último conteo. El porcentaje de sesgo resultó alto (15–78%) en ambos tipos de conteos cuando estos fueron comparados con el conteo máximo de grupos o especies de playeros seleccionados. Los conteos de febrero, en comparación con los de noviembre, variaron menos y mostraron picos durante el penúltimo y último conteo. Los resultados sugieren que los conteos múltiples son más útiles que los censos individuales, particularmente para identificar los periodos óptimos de observación en planicies intermareales o inundables. Los datos de conteos múltiples ofrecen al menos dos formas potenciales de estimar la abundancia de playeros: estimados promedio (o de la media), o un solo estimado del número máximo de individuos.

In North America, two monitoring projects, the International Shorebird Survey (ISS) and Pacific Flyway Project (PFP), have been developed to assess trends (ISS) in shorebird populations (Howe et al. 1989) and gauge the relative importance of wetland complexes (PFP) to nonbreeding shorebirds (Myers et al. 1987, Senner and Howe 1984). Briefly, the protocol for these projects directs volunteer observers to assess wader abundance at sites (every 10 d for ISS and once for PFP) during peak migration periods, taking into account the timing of surveys relative to the position of the sun and direction of observation, and tidal factors if the site is coastal. These methods suggest that observers either make note of the tide height or try to bracket surveys around the high tide period (Howe and Collazo 1989).

We became interested in ways to improve survey methods after conducting preliminary counts of shorebirds at Humboldt Bay on the Northern California coast. Early in our efforts, it became apparent that the timing of a survey relative to tidal amplitude and peak could dramatically influence estimates of wader abundance and that the effect of tidal amplitude on numbers may vary widely among species. In this paper, we present data on wader abundance derived from two winter surveys that differed in the occurrence of high tide. Specifically, we analyze abundances for a selected group of species at Humboldt Bay and compare numbers derived from a single count with abundance estimates obtained from the maximum number observed during four consecutive counts. Finally, we make suggestions for improving survey methodology for intertidal areas similar to Humboldt Bay, prompted by pleas from several sources (Howe and Collazo 1989, Howe et al. 1989).

METHODS

Humboldt Bay is an important site for nonbreeding shorebirds. Historically, the bay has supported up to 100,000 nonbreeding shorebirds at any one time; and over 35 species have been recorded (Gerstenberg 1979, Senner and Howe 1984; Colwell, unpubl. data). Undoubtedly, the total number of shorebirds using Humboldt Bay is much greater than 100,000 considering that little is known of migratory shorebird turnover rates (Howe et al. 1989).

We began working on shorebirds at Humboldt Bay in the fall of 1989. Humboldt Bay consists of North and South bay sections, connected by a narrow channel; bay habitats are largely mudflats and sandflats surrounded by salt marsh and agricultural lands. The western edge of the bay fronts extensive (approx. 25 km) sandy beach habitat. For complete description of the bay see Gerstenberg (1979).

Our survey methods deviate slightly from those suggested by others (e.g., Howe and Collazo 1989) owing to the large number of volunteers (faculty, students and local birders) that participated in our surveys. Instead of having observers survey large sections of habitat, which usually requires that they be mobile, we coordinate more than 50 observers who censused from fixed locations around the bay. Moreover, rather than asking for a single count coinciding with high tide, we asked observers to census shorebirds four times during a 2-h period preceding high tide. In other words, survey periods consisted of four consecutive 30-min count intervals; adjacent observers coordinated their counts so as to minimize counting the same birds. All surveys continued until all shorebirds were counted.

We examined temporal variability in counts of selected shorebird species by summing observations from all Humboldt Bay locations surveyed on 18 Nov. 1990 and 17 Feb. 1991. We chose these dates because they exemplify the type of temporal variability coordinators of survey efforts wish to control; we feel they are representative of our count data as a whole. The timing of surveys relative to the tide varied considerably between these two count periods. The November survey started at 0800 hours after a −0.5 m low tide at 0645 hours and the last count at 0930 hours preceded a high tide of 2.7 m, which occurred at 1300 hours. The February survey started at 0930 hours after a 0730 hour low tide of 0.4 m and the last count occurred at 1100 hours, nearly 3 h (1345 hours) in advance of a high tide of 1.5 m.

For both November and February surveys we established survey times in an attempt to maximize the probability that birds would be confined to a small area near shore, which would make them easier to count. Thus, we did not census precisely at high tide, but generally 2–3 h prior to high tide. Appropriate times were approximations but we validated times by investigating survey areas prior to the actual count dates on days of similar tidal conditions.

We did not assume that we ever obtained a complete enumeration of individuals of any species in Humboldt Bay. To evaluate the influence of frequency and timing of counts on maximum estimates of shorebird abundance, we assumed that the maximum count obtained from the four counts was the closest to the true number present. We then compared each of the summed counts with the maximum number. We present data for four species (American Avocet, *Recurvirostra americana*; Black-bellied Plover, *Pluvialis squatarola*; Marbled Godwit, *Limosa fedoa*; and Willet, *Catoptrophorus semipalmatus*), which are easily identified and visible across a wide range of observation conditions owing to their large size and distinctive morphology. We also present data for combined counts of three species of *Calidris* sandpipers (Dunlin, *C. alpina*; Western Sandpiper, *C. mauri*; and Least Sandpiper, *C. minutilla*) and all shorebirds combined.

RESULTS

The timing of the November 1990 survey occurred such that the initial (0800 hours) count produced the maximum of the four counts for all species or groups except the American Avocet (Fig. 1). This period was also the one in which tidal flats became inundated. November counts varied greatly, with coefficients of variation (CV) ranging from 24 to 94% and mean percent bias exceeding 40% for all species or groups except Marbled Godwit (Table 1). Six of 18 counts (depicted in Fig. 1 as those that were not maximum) fell below 50% of the highest count for that taxon.

By comparison, the timing of the February survey occurred such that later (after 0930 hours) counts produced the maximum of the four counts

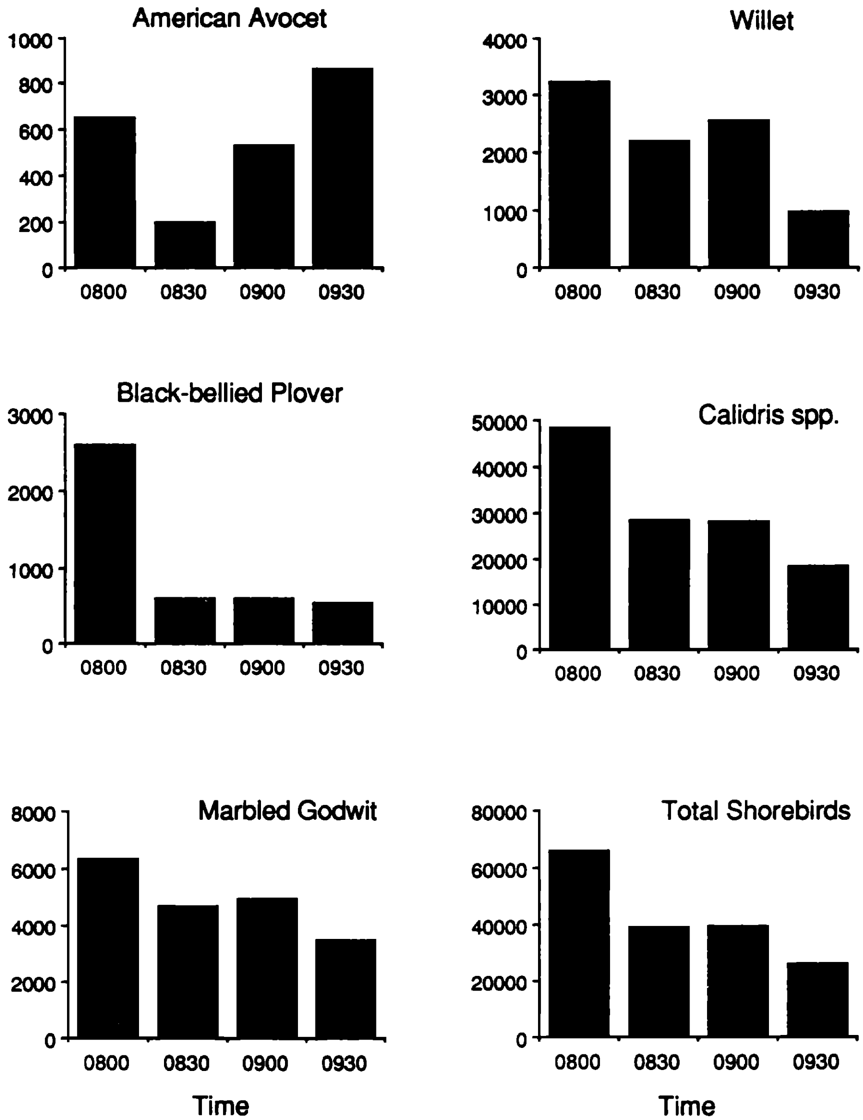

FIGURE 1. Estimates of shorebird abundance from four survey periods of the 18 Nov. 1990 survey of Humboldt Bay, California. *Calidris* spp. is the combined total of *C. alpina*, *C. mauri* and *C. minutilla*.

for all taxa, although the timing of the maximum count differed among groups (Fig. 2). Inundation of intertidal habitats occurred between 1030 and 1100 hours. In general, February counts did not vary as much as November counts (Table 1); only the CV for Black-bellied Plover ex-

TABLE 1. Shorebird abundance during November 1990 and February 1991 surveys of Humboldt Bay, California, expressed as the maximum number of birds observed, with coefficient of variation (CV) and mean percent bias of each count relative to the maximum count.

	November			February		
Species	Maximum	CV	Mean % bias[a]	Maximum	CV	Mean % bias[a]
American Avocet	860	49	46	1000	20	25
Black-bellied Plover	2611	93	78	1475	53	59
Marbled Godwit	6327	24	31	7780	17	15
Willet	3217	42	41	2244	37	30
Calidris spp.	48,577	41	49	31,050	21	28
Total shorebirds	66,008	40	47	43,896	17	18

[a] % bias = ([estimate − maximum value])/maximum value) × 100.

ceeded 50%. Percent bias ranged from 15 to 59% and, unlike the November survey, most (14 of 18) counts exceeded 50% of the maximum count (Fig. 2).

DISCUSSION

Programs such as the ISS and PFP are valuable sources of data for conservation of migratory birds, especially when surveys are conducted in a standardized manner. Howe et al. (1989) used ISS data to evaluate population trends for a variety of North American shorebirds. Additionally, survey data have been used to evaluate the distribution and abundance of shorebirds on wetlands throughout North America with the objective of identifying critical shorebird habitats. In fact, recognition of wetlands as areas of critical importance by the Western Hemisphere Shorebird Reserve Network (Myers et al. 1987, Senner and Howe 1984) makes use of counts conducted by volunteer observers.

Despite their value to conservation, data from shorebird surveys exhibit appreciable variation that makes meaningful analysis difficult. Variation may arise from a variety of factors, some of which are real and attributable to population changes, differences in timing of counts relative to yearly variation in seasonal migration, weather-influenced observation conditions and inter-habitat movements of birds. Considerable variation, however, may result from measurement error owing to a number of sources, and survey methods should attempt to control that error (Howe and Collazo 1989), or at least to minimize it in relation to real or sampling variation.

Our comparison of two winter surveys from Humboldt Bay suggests two means by which improved survey precision could be affected. These improvements are to conduct multiple surveys as opposed to single counts, and to synchronize coastal shorebird counts to periods of optimum observation conditions based on tides. We briefly summarize why we have made these suggestions.

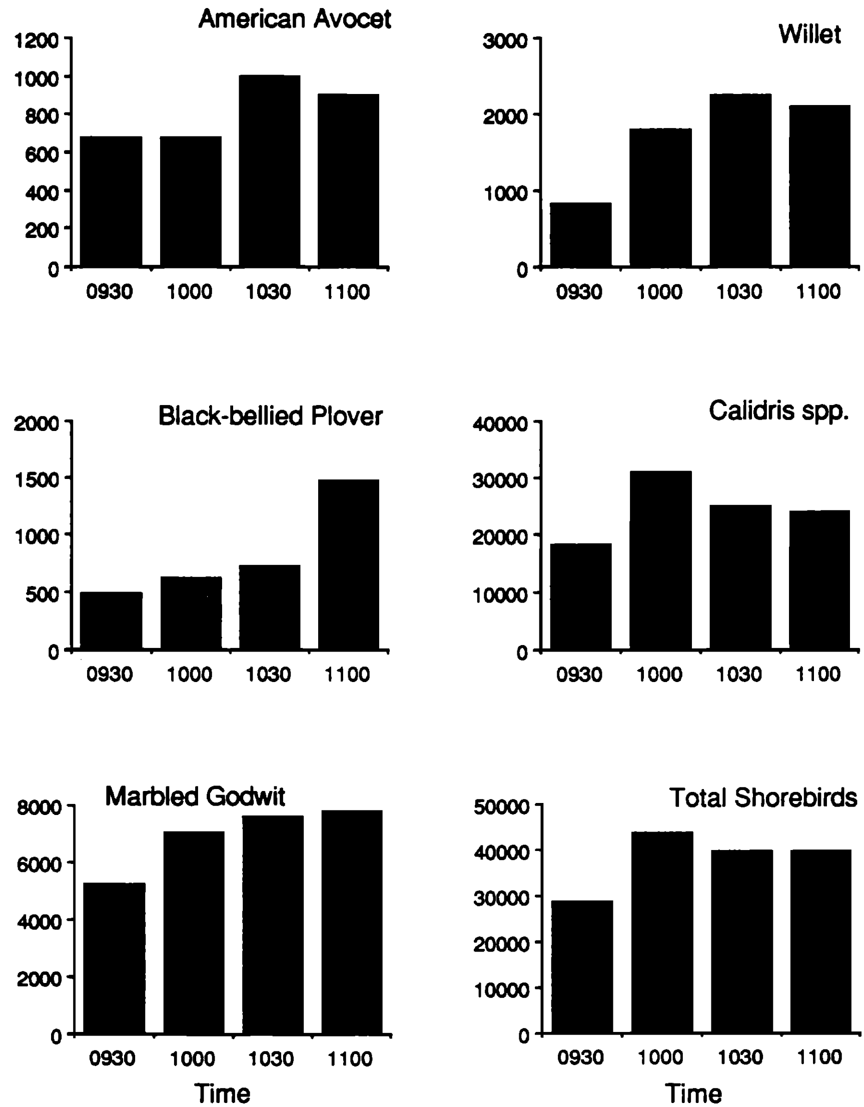

FIGURE. 2. Estimates of shorebird abundance from four survey periods of the 17 Feb. 1991 survey of Humboldt Bay, California (see caption of Figure 1 and text for details).

First, multiple counts are desirable over single counts because of the high variability of single counts relative to maximum estimates of abundance. Considering any one count within the sequence of four, our estimate of abundance could have been biased by 15 to 78% for any taxa and 18 to 47% for all shorebirds (Table 1). This range of variation was comparable to that obtained from similar analyses of subunits of the bay (e.g., North Bay variation: 16 to 78% for taxa; and 35 to 58% for all shorebirds). At estuaries such as Humboldt Bay, where large numbers of birds winter and migrate (Gerstenberg 1979; Senner and Howe 1984; Colwell, unpubl. data), a single count may fail to account for a large number of birds, especially if it is poorly timed relative to optimal observation conditions. Therefore, appreciable variability in surveys may be minimized by conducting multiple counts.

Second, the effects of tides on wader abundance have been known for decades (see Burger 1984). Two possible solutions to survey problems associated with tides are to count birds at high tide roosts or to survey when birds are confined to intertidal flats. At Humboldt Bay, we chose the latter approach for two reasons. First, although some "traditional" roosts are known, data from other surveys (Colwell, unpubl. data) suggest that roosts form unpredictably (e.g., on open beaches or in pastures). Second, during the rainy season (October–March) many birds forage in agricultural fields and pastures when tidal flats are inundated. These terrestrial habitats are considerably more difficult to survey.

In comparing our two survey dates, we showed February counts to be less variable than November counts (Table 1). Moreover, February numbers generally increased during later counts, which coincided with tidal inundation of mudflats (but not high tide). By contrast, the first November count usually yielded maximum numbers and subsequent counts often represented only a small fraction of the total birds present in the bay (Table 1). We suggest that the November count suffered because observations occurred mostly after tidal inundation of habitats, whereas the February survey represents nearly ideal counting conditions relative to tide. Not only do these data indicate the value of multiple counts over single counts, they emphasize that timing of counts is crucial. At Humboldt Bay, where observers count birds from locations surrounding large intertidal flats, the best time to count shorebirds occurs when tidal flats at upper reaches of the bay are just being inundated, which forces foraging birds into habitats close to observers. Despite detailed knowledge of local tidal regimes, it is often difficult to accurately predict when these conditions will occur. Thus, scheduling one count to coincide with optimum observation conditions may be difficult. Therefore, we argue that multiple counts, from which estimates of abundance can be gleaned, are better than a single survey.

Our data suggest that with regard to tidal inundation optimal observation times may vary among species. For example, compared with most species, Marbled Godwit counts exhibited less variation (CV of 24 and 17 for November and February, respectively) in abundance. By contrast, other groups, especially Black-bellied Plover (CV of 93 and 53, respectively), and calidridine sandpipers (CV of 41 and 21, respectively) exhibited more variation. The causes of such variation may include (but are not limited to) differences in observer ability and interspecific variation in patterns or habitat use.

Large-scale survey efforts already have been valuable in conservation and management of migratory shorebird species and their habitats (Howe et al. 1989, Myers et al. 1987). To a certain extent, our suggestions for improving survey methods may be limited to circumstances similar to Humboldt Bay, where a large group of observers is available to conduct counts, and they may not be applicable to sites where few observers survey large areas. Nevertheless, we believe that coordinators of surveys should continually attempt to improve their methods and this may be one way in which they may do so.

For coordinators of shorebird surveys, we offer the following suggestions with regard to using multiple, sequential counts. Multiple surveys may be valuable as a preliminary means of identifying the best observation times relative to the interaction of local tidal regimes with habitat configurations. To achieve best results, observers should note tidal conditions in association with ease of identifying and counting birds. Additionally, we suggest two options with regard to estimating local shorebird abundance based on data derived from multiple surveys. One possibility involves using average (or median) abundances derived from surveys. This option would be especially appropriate when variation in abundance is low among consecutive counts, and error may be largely attributable to observers. When counts vary appreciably among survey intervals, however, use of the maximum count from multiple surveys may be appropriate. This may be especially true when low counts coincide with poor conditions for counting birds (e.g., extensive tidal flats with birds at great distance from observers). Regardless of how data are summarized, however, we emphasize that optimal observation times may vary among species, which may require that coordinators derive estimates from maximum counts that occur during different survey intervals. Finally, in addition to our recommendations, we urge groups to coordinate survey protocols to yield more meaningful data for conservation decisions, and we suggest that survey methods continually be improved.

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LITERATURE CITED

BURGER, J. 1984. Abiotic factors affecting migrant shorebirds. Pp. 1–72, *in* J. Burger, and B. L. Olla, eds. Shorebirds: migration and foraging behavior. Plenum Press, New York, New York.

GERSTENBERG, R. H. 1979. Habitat utilization by wintering and migrating shorebirds on Humboldt Bay, California. Studies Avian Biol. 2:33–40.

HOWE, M. A., P. H. GEISSLER, AND B. A. HARRINGTON. 1989. Population trends of North American shorebirds based on the International Shorebird Survey. Biol. Cons. 49:185–199.

HOWE, M. A., AND J. A. COLLAZO. 1989. Census and survey techniques for shorebirds.

U.S. Fish and Wildlife Service Southeastern Region Nongame Bird Management Workshop. Atlanta, Georgia.

MYERS, J. P., R. I. G. MORRISON, P. Z. ANTAS, B. A. HARRINGTON, T. E. LOVEJOY, M. SALLABERRY, S. E. SENNER, AND A. TARAK. 1987. Conservation strategy for migratory species. Amer. Sci. 75:19–26.

SENNER, S. E., AND M. A. HOWE. 1984. Conservation of nearctic shorebirds. Pp. 379–421, *in* J. Burger, and B. L. Olla, eds. Shorebirds: breeding behavior and populations. Plenum Press, New York, New York.

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REQUEST FOR INFORMATION: BIRDS OF THE SERENGETI

The birds of the Serengeti National Park Tanzania, B.O.U. Checklist No. 5 by Dieter Schmidl will soon be out of print and the author will therefore revise the data for a new printing.

Please send *Serengeti records* to Dieter Schmidl, Max-Planck-Institut, D-82319 Seewiesen, Post Starnberg, FRG. Any records would be gratefully received and acknowledged.