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MONITORING SPECIES RICHNESS AND ABUNDANCE OF SHOREBIRDS IN THE WESTERN GREAT BASIN[1]

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Abstract. Broad-scale avian surveys have been attempted within North America with mixed results. Arid regions, such as the Great Basin, are often poorly sampled because of the vastness of the region, inaccessibility of sites, and few ornithologists. In addition, extreme variability in wetland habitat conditions present special problems for conducting censuses of species inhabiting these areas. We examined these issues in assessing multi-scale shorebird (order: Charadriiformes) censuses conducted in the western Great Basin from 1992–1997. On ground surveys, we recorded 31 species of shorebirds, but were unable to accurately estimate population size. Conversely, on aerial surveys we were able to estimate regional abundance of some shorebirds, but were unable to determine species diversity. Aerial surveys of three large alkali lakes in Oregon (Goose, Summer, and Abert Lakes) revealed > 300,000 shorebirds in one year of this study, of which 67% were American Avocets (*Recurvirostra americana*) and 30% phalaropes (*Phalaropus* spp.). These lakes clearly meet Western Hemisphere Shorebird Reserve Network guidelines for designation as important shorebird sites. Based upon simulations of our monitoring effort and the magnitude and variation of numbers of American Avocets, detection of 5–10% negative declines in populations of these birds would take a minimum of 7–23 years of comparable effort. We conclude that a combination of ground and aerial surveys must be conducted at multiple sites and years and over a large region to obtain an accurate picture of the diversity, abundance, and trends of shorebirds in the western Great Basin.

Key words: censusing, conservation, Great Basin, monitoring, shorebirds, wetlands, WHSRN site.

INTRODUCTION

A dominant emphasis in avian ecology has been to determine and explain patterns of distribution and abundance of bird species (Wiens and Rotenberry 1981, Wiens 1989). However, in North America and elsewhere, we still lack basic ecological information such as population sizes for many species of birds, including most shorebirds (Order: Charadriiformes, Page and Gill 1994, Rose and Scott 1994). Numerous methods have been developed to obtain accurate measures of bird distribution, diversity, and abundance. Constant-effort mist netting, point counts, strip transects, and other methods have been used to monitor avian populations (Bibby et al. 1992, Ralph et al. 1993). These efforts at local sites have been combined to promote an understanding of bird distribution and abundance indices at regional and global scales. Tremendous effort has gone into developing landscape-level, volunteer-based survey methods, including the North

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American Breeding Bird Survey (BBS, Droege 1990) and the Audubon Christmas Bird Counts (CBC, Butcher 1990).

Habitats used by birds increasingly are affected as human populations expand (Terborgh 1989). This has resulted in ever greater demands for data on the status of avian populations in order to prioritize efforts for species and habitat protection, and to make informed management decisions (Howe et al. 1989, Reed et al. 1997). This is particularly true for shorebirds, because the wetland habitats used by most species are some of the most threatened in the United States (Dahl 1990). Existing counts, however, inadequately cover habitats used by many species of shorebirds (Harrington 1995), particularly at interior wetlands of the United States such as those in the Great Basin (Warnock 1997).

Much of what we know about the abundance and distribution of shorebirds is based upon sites of large concentrations of migrating shorebirds, resulting in a biased model of distribution variously called the "coastal" (Skagen 1997) or "staging" paradigm (Robinson and Warnock 1997). In recent years, more attention has been paid to the fact that many species of shorebirds spend the majority of their life-cycle away from coastal areas in more dispersed habitat (Skagen and Knopf 1993, Farmer and Parent 1997, Robinson and Warnock 1997). Thirty-seven species of shorebirds commonly migrate through the midcontinent of North America, often in high numbers (Skagen and Knopf 1993, Skagen 1997). Large sections of the world's populations of American Avocets (*Recurvirostra americana,* Page and Gill 1994), Long-billed Dowitchers (*Limnodromus scolopaceus,* Neel and Henry 1997), Wilson's Phalaropes (*Phalaropus tricolor,* Jehl 1988), and North America's population of Snowy Plovers (*Charadrius alexandrinus,* Page et al. 1995) are found in the Great Basin during parts of the year.

There is, therefore, a need to develop methods for monitoring shorebird use in the interior regions of North America (Reed et al. 1997). The longest running, most widely-used survey method for shorebirds in North America, the International Shorebird Survey (ISS), has been in existence since 1972 (Howe et al. 1989, Howe 1990). This volunteer-based survey effort asks observers to monitor sites with significant and consistent use by shorebirds every 10 days through peak migration periods (Howe 1990); most effort has been east of the Rocky Mountains (Harrington 1995). Another large-scale survey of migratory shorebirds, the Pacific Flyway Project, was based upon "snapshots" of numbers of shorebirds at almost all significant wetlands within the entire Pacific Flyway during one peak period in spring and in fall (Shuford et al. 1998). Although these surveys have provided valuable data on shorebird populations in many regions, coverage of vast interior regions such as the western Great Basin has not been complete, especially at smaller sites (Fig. 1).

The importance of wetlands in the western Great Basin to some shorebird populations has been well documented (Jehl 1994, Oring and Reed 1997); but only half of the 9 species of shorebirds that breed within the western Great Basin and few of the 11 most common species of migrant shorebirds have been studied in any detail within this region (Warnock 1997). At the same time, fueled by some of the fastest developing urban areas in the United States, a burgeoning human demand for already scarce water resources has exacerbated detrimental effects on waterbird populations within the Great Basin (Kadlec and Smith 1989, Neel and Henry 1997, Rubega and Robinson 1997). For researchers, managers, and policy makers attempting to mitigate human effects on waterbirds in this region and others like it, developing biologically meaningful and fiscally feasible census methods is essential to making informed management and conservation decisions.

Due to the critical need for census data and the lack of established protocols, we compared ground and aerial survey methods at different wetlands and wetland types within a large area of the western Great Basin to help explain the timing and abundance of shorebird use of wetlands within this region. We also address potential problems in estimating trends of shorebird populations in the Basin, using American Avocets as an example.

METHODS

STUDY AREAS

Our study sites included four major lake systems within an area of the western Great Basin between 40°09′N, 120°15′W (Honey Lake, California) and 42°50′N, 120°45′W (Summer Lake, Oregon) (Fig. 1). This region is characterized by arid Great Basin high desert (Engilis and Reed

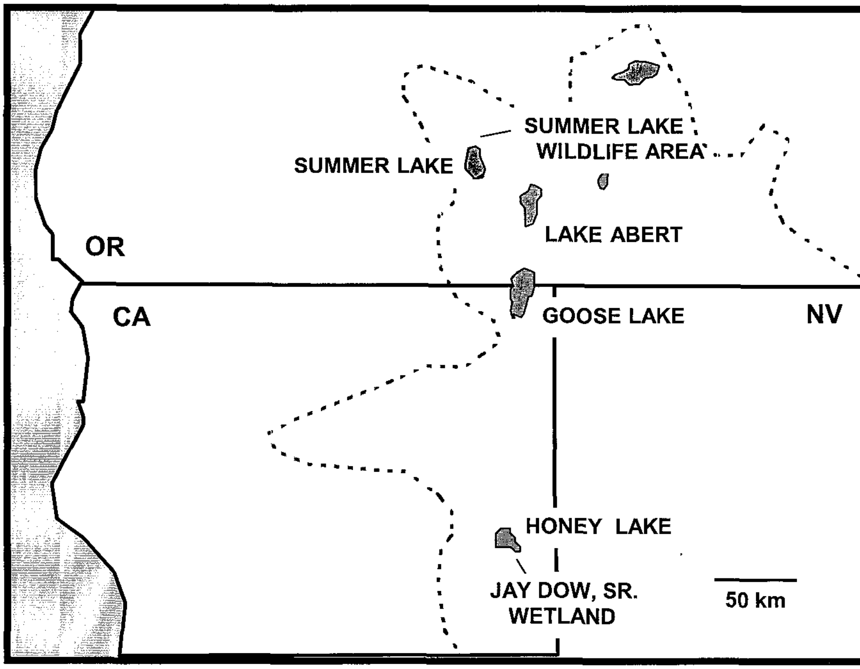

FIGURE 1. Map of study areas within the western Great Basin. Dashed line indicates border of Great Basin region.

1997). Wetlands within the basin are terminal, drained only by evapotranspiration, and tend to contain highly saline, alkaline waters whose levels change significantly within and between years (Johnson et al. 1985). At Doyle, California just south of Honey Lake, annual precipitation levels between 1992–1997 ranged from 21.8–68.3 cm (measured by National Oceanic and Atmospheric Administration, National Climate Data Center, Asheville, North Carolina), with 1995 and 1996 being particularly wet years. During this same period, a similar pattern in precipitation was observed at Summer Lake, Oregon (range 18.8–47.3 cm, measured by M. St. Louis, Oregon Department Fish and Wildlife).

GROUND COUNTS

We established two focal study sites at managed wetlands maintained with fresh water: Jay Dow, Sr. Wetlands (JDOW) at the south end of Honey Lake, California, and Summer Lake Wildlife Area (SLWA) at the northwest side of Summer Lake, Oregon. We conducted ground surveys at the 540-ha JDOW at 14 water units over a 6-year period (1992–1997). Mean number of days between counts ranged from 7.1 to 14.7 days (Table 1). At the 46,153-ha SLWA, we conducted ground counts approximately every 7 days during the spring, summer, and fall, over three years (1995–1997, Table 1) at 19 water units covering about 4,400 ha. During these ground counts, teams of experienced biologists equipped with spotting scopes counted individuals of all shorebirds. Generally, all birds were identified to species, although Long-billed and Short-billed Dowitchers (*Limnodromus griseus*), Greater and Lesser Yellowlegs (*Tringa melanoleuca, T. flavipes*), Wilson's and Red-necked phalaropes (*Phalaropus lobatus*), and Least and Western Sandpipers (*Calidris minutilla, C. mauri*) were sometimes grouped. Because each site was relatively small and contained extensive road systems, we were able to completely count each wetland area during every survey.

AERIAL COUNTS

We conducted weekly aerial censuses (1996, 10 April to 27 September, n = 20 flights; 1997, 11 April to 24 September, n = 19 flights) of Summer (not including SLWA), Abert, and Goose Lakes (Fig. 1, all lakes were flown on the same day) from a Piper Super Cub flying at an ap-

TABLE 1. Ground survey effort at Jay Dow, Sr. Wetlands, California (JDOW) and Summer Lake Wildlife Area, Oregon (SLWA).

Location	Year	Surveys	First survey	Last survey	Mean (± SD) days between surveys	Additional surveys
SLWA	1995	15	4 May	28 Aug	8.3 ± 5.7	
	1996	23	9 May	26 Sep	7.7 ± 1.5	
	1997	21	6 May	24 Sep	7.1 ± 0.8	
JDOW	1992	21	22 Apr	10 Sep	7.1 ± 0.6	8 Oct, 5 Nov, 2 Dec, 4 Dec
	1993	19	16 Mar	31 Aug	9.3 ± 4.6	
	1994	16	24 Apr	30 Sep	10.6 ± 4.3	15 Oct, 17 Nov
	1995	14	4 Mar	12 Sep	14.7 ± 9.6	22 Feb, 15 Oct, 25 Nov
	1996	17	8 Mar	31 Jul	7.1 ± 0.6	31 Jan, 6 Feb, 16 Feb, 1 Mar, 7 Mar
	1997	20	6 Mar	10 Aug	8.3 ± 2.7	31 Jan, 6 Feb, 19 Feb, 26 Feb

proximate altitude of 25 m at 160 km hr^{-1}. Aerial counts were conducted by one individual in 1996 and a different individual in 1997 (with the exception of two flights). Although some species such as American Avocets and Black-necked Stilts (*Himantopus himantopus*) were easy to identify from the air, other species were difficult to separate so we grouped similar species (listed above, Dunlin *C. alpina* grouped with Least and Western Sandpipers).

STATISTICAL ANALYSES

Tests were two-tailed, significance was set at $P \leq 0.05$, and statistical analyses were performed using STATA (Release 5.0, Stata Press, College Station, TX), unless otherwise indicated. Data were examined for departures from normality and homogeneity by preliminary graphing and testing of data. We tested for differences in the number of breeding and migrating species detected per census between years with the Kruskal-Wallis test (KW test). We used the Pearson Chi Square test to determine if there were significant differences between SLWA and JDOW in the frequency of species occurrence.

We also conducted analyses to estimate how many years it would take to confidently detect negative declines in American Avocet populations in the western Great Basin, using the program MONITOR (Gibbs 1995). This program combines linear regression analysis with Monte Carlo simulations to estimate the statistical power of detecting a trend of a population over a given period of time for a user-defined monitoring program (Gibbs and Melvin 1997). Each model was simulated 500 times. For postbreeding models, our survey route consisted of Goose, Summer, and Abert Lakes (where significant numbers of postbreeding avocets concentrate) censused from the air. The three lakes were treated as one plot. In 1996 and 1997, we recorded maximum numbers of avocets in August, so we estimated yearly abundance and variation of avocet numbers at these lakes by using abundance data only from August. Model sensitivity to yearly variation in postbreeding avocet numbers was analyzed varying the standard deviation of our mean August numbers ± 0.25. For our breeding models, we ran them using the mean and standard deviation of numbers of American Avocets counted during ground surveys at the SLWA in May (when all birds should be breeders) from 1995 to 1997.

RESULTS

SPECIES RICHNESS, PHENOLOGY, AND ABUNDANCE AT MANAGED WETLANDS

During ground surveys, we recorded 31 species of shorebirds of which 9 breed and 22 are nonbreeding migrants in the western Great Basin (Appendix). All breeding species were sighted at both sites in all years of the study. The number of migrant species detected per census also did not differ among years (KW test, JDOW, $\chi^2_2 = 3.6$, $P = 0.16$; SLWA, $\chi^2_2 = 1.0$, $P = 0.59$). The most commonly sighted migrant species were Western and Least Sandpipers, Red-necked Phalaropes, Long-billed Dowitchers, Semipalmated Plovers (*Charadrius semipalmatus*), Dunlin, and Greater Yellowlegs (unpubl. data, Fig. 2). Using birds identified to species at JDOW and SLWA, ratios of grouped species were as follows: 6.9 Greater Yellowlegs to 1 Lesser Yellowleg (n = 1,183 yellowlegs), 1.8 Wilson's Phalaropes to 1 Red-necked Phalarope (n = 13,872 phalaropes), and 1.4 Western Sandpipers

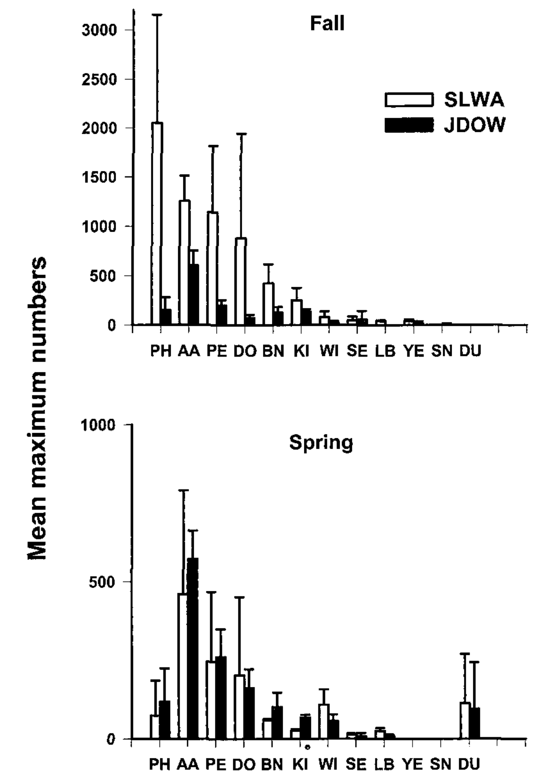

FIGURE 2. Mean maximum number (+ SD) of shorebirds present at Jay Dow, Sr. Wetlands (JDOW), California and the Summer Lake Wildlife Area (SLWA), Oregon. Mean maximum counts represent the mean of the highest counts recorded for each species in each season (spring, 6 February to 17 June; fall, 18 June to 2 December) for 1995, 1996, and 1997. Species codes: PH = phalarope spp., AA = American Avocet, PE = peeps, DO = dowitcher spp., BN = Black-necked Stilt, KI = Killdeer, WI = Willet, SE = Semipalmated Plover, LB = Long-billed Curlew, YE = yellowlegs spp., SN = Snowy Plover, DU = Dunlin.

to 1 Least Sandpiper (n = 11,708 sandpipers). No Short-billed Dowitchers were identified by observers at JDOW or at SLWA, although flocks are occasionally seen in the Great Basin (Hainline 1974; D. Shuford, pers. comm.).

Taxa with the highest maximum counts in both spring and fall were generally American Avocets, phalaropes, peeps, dowitchers, and Black-necked Stilts, although highest numbers of species and their order of abundance varied by season and site (Fig. 2). At SLWA, the most numerous shorebirds were phalaropes in fall, and American Avocets in spring. Avocets were most numerous in both seasons at JDOW (Fig. 2). We never counted more than 1,000 individuals of any species at JDOW or SLWA in spring. In fall, we recorded single day high counts of 2,840 phalaropes, 1,912 peeps, and 1,522 American Avocets at SLWA, however, maximum numbers varied greatly among years (Fig. 2).

Of the breeding species, Long-billed Curlews (*Numenius americanus*, χ^2_1 = 7.2, P = 0.007), and Willets (*Catoptrophorus semipalmatus*, χ^2_1 = 4.4, P = 0.04) were more likely to be observed at SLWA, and Wilson's Phalaropes (χ^2_1 = 11.0, P = 0.001) at JDOW. We found no differences in the detection of migrant species between the two sites.

Small numbers of Greater Yellowlegs were present at our managed wetlands as early as mid-February, but most migrant shorebirds did not begin arriving until mid-April (Fig. 3). Peak spring migration of migrant shorebirds occurred during late April and early May. During the spring, JDOW had more than three migrant species present only for an average of 3 weeks (23 April–13 May). Following this peak, migrant shorebirds were largely absent from the western Great Basin for a brief period roughly from the last week of May through the first 10 days of June (Fig. 3). During the fall, more than 3 migrant species were present at JDOW for 15 weeks (2 July–14 October). We observed a similar discrepancy between the length of spring and fall migration periods for migrant species at SLWA. After mid-October, shorebirds sighted at JDOW were almost always one of five species: Dunlin, Least Sandpiper, Long-billed Dowitcher, Greater Yellowlegs, or Killdeer (*Charadrius vociferus*, the only breeding species to stay late in the fall, and the first breeding species to return, around mid-February).

PHENOLOGY AND ABUNDANCE ON LARGE LAKES

Total numbers of shorebirds using Goose, Summer, and Abert Lakes remained at or slightly below 2,000 individuals from mid-April when aerial surveys began until early June, climbed steadily into August, and then dropped to the end of September when surveys ceased (Fig. 4). During censuses of the three lakes in 1996, we counted a total of 166,035 shorebirds including 63% American Avocets, 30% phalaropes, 4% peeps, 1% Willets, and 2% other species. From censuses in 1997, we counted a total of 329,957 shorebirds consisting of 67% American Avocets, 30% phalaropes, 2% peeps, and < 1% other spe-

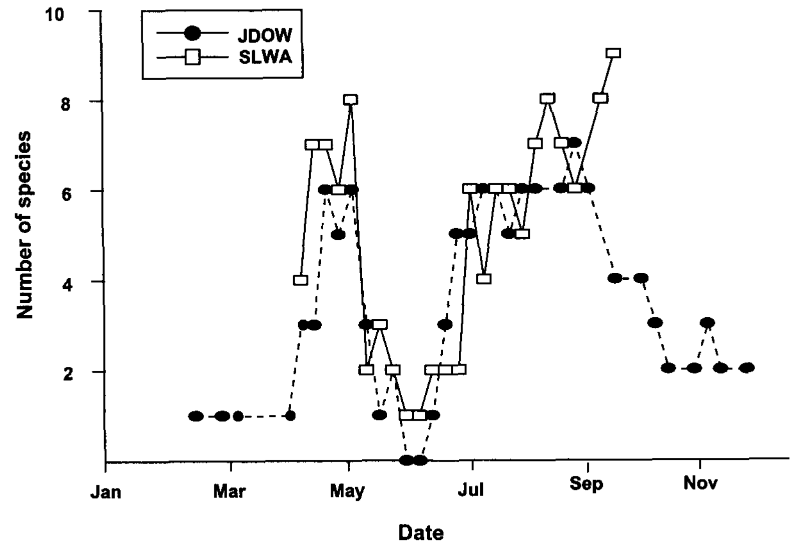

FIGURE 3. Phenology (by week) of migrant shorebird species seen at Jay Dow, Sr. Wetlands (JDOW), California and the Summer Lake Wildlife Area (SLWA), Oregon. Species known to breed in the Great Basin (see Appendix) not included.

cies. Peak single day counts of shorebirds from aerial surveys at Goose, Summer, and Abert Lakes combined were 20,541 individuals in 1996 (2 August) and 44,523 individuals (13 August) in 1997 (Fig. 4). Of those in 1996, 62% were American Avocets, 34% phalaropes, and 4% other species, whereas in 1997, 68% were American Avocets, 29% phalaropes, and 3% other species. In 1995, we flew a single aerial survey of the three lakes on 2 August, where we counted 75,325 individuals, of which 34% were American Avocets and the rest small shorebirds (mostly phalaropes).

Peak numbers of American Avocets and phal-

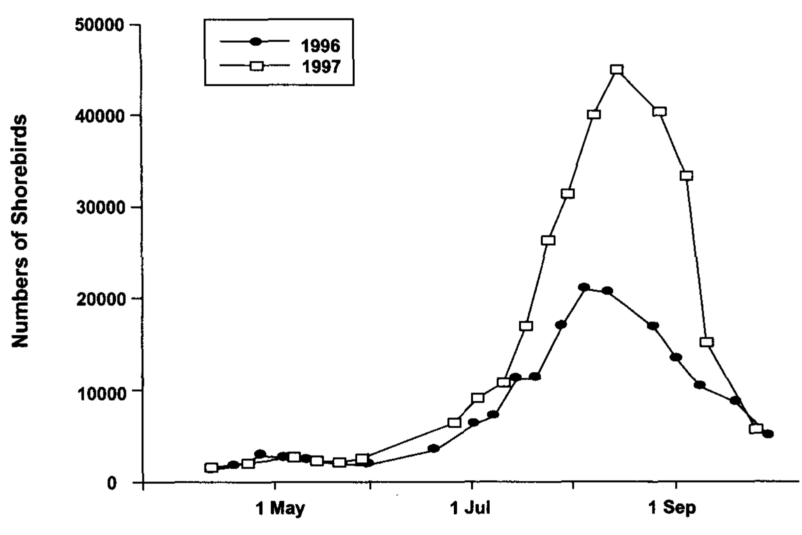

FIGURE 4. Total numbers of shorebirds seen during aerial surveys of Abert, Goose, and Summer Lakes, Oregon, 1996 and 1997.

TABLE 2. Maximum single day numbers of most abundant shorebirds counted during aerial flights at Abert, Goose, and Summer lakes, Oregon (1996–1997).

	Lake	1996 number	1996 date	1997 number	1997 date
American Avocet	Goose	2,658	23 Aug	1,861	9 Sep
	Summer	10,494	2 Aug	15,460	26 Aug
	Abert	3,452	6 Sep	15,345	13 Aug
Black-necked Stilt	Goose	216	23 Aug	139	20 Aug
	Summer	—	—	107	9 Sep
	Abert	55	23 Aug	75	11 Apr
Dowitcher spp.	Goose	310	6 Sep	27	13 May
	Summer	—	—	—	—
	Abert	112	21 Apr	—	—
Peeps	Goose	226	12 Jul	580	22 Apr
	Summer	525	18 Jul	1,100	13 Aug
	Abert	1,130	2 May	617	6 May
Phalarope spp.	Goose	315	2 Aug	575	16 Jul
	Summer	250	23 Aug	500	3 Sep
	Abert	8,467	9 Aug	15,450	20 Aug
Willet	Goose	261	17 Jun	466	1 Jul
	Summer	58	17 Jun	52	22 Apr
	Abert	95	29 Jun	73	9 Jul
All shorebirds	Goose	3,480	23 Aug	1,891	9 Sep
	Summer	10,611	2 Aug	15,660	26 Aug
	Abert	9,696	9 Aug	27,389	13 Aug

aropes were higher in 1997 than in 1996 at Summer and Abert Lakes but not Goose Lake (Table 2). Lake Abert had highest numbers of phalaropes in both years, whereas we counted less than 600 phalaropes at either Goose or Summer Lakes (Table 2). Small numbers of Black-bellied Plovers (*Pluvialis squatarola*) and dowitchers were recorded at Goose Lake. Lake Abert also had small numbers of dowitchers. Willets and Long-billed Curlews were most abundant at Goose Lake during both years. Of the three lakes, Summer Lake had the highest counts of American Avocets. Lake Abert and Summer Lake had about 15,000 American Avocets in 1997, but in 1996 these lakes had fewer than 3,500 and > 10,000 birds, respectively. Goose Lake never held more than 2,700 avocets during any census in 1996 and 1997, but on 2 August 1995, it held 10,100 American Avocets. Maximum counts of peeps were > 1,000 at Summer Lake in 1997 and at Lake Abert in 1996 (Table 2).

POWER TO DETECT TRENDS

Mean (± SD) number of postbreeding American Avocets for Goose, Summer, and Abert Lakes combined was 18,776 ± 9,890 birds (n = 7 counts) in August for 1996 and 1997. The breeding season total of American Avocets at the SLWA from 1995–1997 was 173 ± 42 birds (n = 8 counts).

Assuming that a power estimate > 0.80 will allow detection of a trend with statistical confidence (Cohen 1988), 19 years of survey data with the same scale and effort of this study would be needed to detect a 5% decline in August avocet numbers, and 13 years to detect a 10% decline (Fig. 5). If the variation in observed avocet numbers is decreased by 25%, detection of a 5% decrease would take 15 years and detection of a 10% decline 10 years. If variation in our counts is increased by 25%, detection of a 5% decrease in avocet numbers would take 23 years and detection of a 10% decrease 17 years. For SLWA, approximately 10 years of comparable census effort would be needed to detect a 5% decline in breeding avocet numbers, and 7 years to detect a 10% decline (Fig. 5).

DISCUSSION

IMPORTANCE OF REGION TO SHOREBIRDS

The western Great Basin is of critical importance to many shorebirds from March through October (Oring and Reed 1997). The Western Hemisphere Shorebird Network (WHSRN) guidelines for identifying important shorebird sites uses three designations based upon total

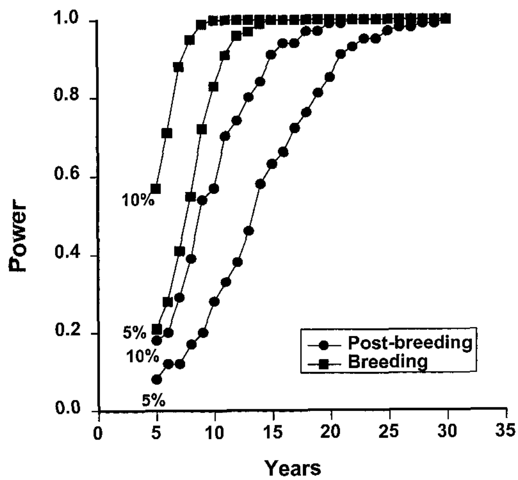

FIGURE 5. Power to detect 5% and 10% negative declines in American Avocet populations in parts of the western Great Basin as a function of years of census effort. Postbreeding model is one in which the magnitude and variation of avocet numbers used in our simulation were calculated from combined single-day surveys (n = 7) of staging avocets in August at Abert, Goose, and Summer Lakes counted during aerial surveys in 1996 and 1997. Breeding model is one in which the magnitude and variation of avocet numbers used in our simulation were calculated from numbers of avocets at Summer Lake Wildlife Area counted in May (n = 8 surveys) during ground surveys from 1995–1997.

shorebird numbers and flyway population size: Hemispheric site, 500,000 shorebirds annually and/or 30% of a species' flyway population; International site, 100,000 shorebirds annually and/or 15% of a species' flyway population; and Regional site, 20,000 shorebirds annually and/or 5% of a species' flyway population (Harrington and Perry 1995). Looking at total shorebird numbers, Lake Abert has had single day counts of > 100,000 birds (Jehl 1988; L. Oring, unpubl. data), qualifying it as a site of International importance. We counted > 18,000 shorebirds in 1995 on a single day at Summer Lake (unpubl. data) and more than 15,000 shorebirds on a single day in 1997 (Table 2). The lake easily supports > 20,000 shorebirds in a given year meeting the criteria for being designated a Regional site. Depending on turnover of species and the year, it may occasionally support > 100,000 shorebirds in a year, given that > 50,000 shorebirds have been seen at the site on a single day in the past (see below).

Looking at the importance of these lakes to the Pacific Flyway population of particular species, Abert and Summer Lakes are key sites for American Avocet (this study) and Wilson's Phalarope (Jehl 1988). Page and Gill (1994) estimated the Pacific Flyway population of American Avocets to be around 100,000 individuals. A subsequent single-day count of avocets in fall at Great Salt Lake exceeded 250,000 birds (Shuford et al. 1994), but it is unlikely that all of these birds originate from the Pacific Flyway. At Summer Lake and Lake Abert our maximum single day counts of avocets were > 15,000. However, on 24 July 1981, an estimated 50,000 avocets were counted at Summer Lake, while Lake Abert has held an estimated 30,000 avocets (Nehls 1994). These numbers probably qualify Summer Lake and Lake Abert for designation as sites of International importance for Pacific Flyway American Avocets if we assume there is some turnover of individuals and the Pacific Flyway population is less than what is seen at the Great Salt Lake. Using the same assumptions, based on our single day count in 1995 at Goose Lake of > 10,000 avocets, Goose Lake likely is a site of Regional importance for avocets. In past years, > 20,000 Least Sandpipers (on 1 May 1987) have been recorded at Summer Lake (Paulson 1993), qualifying it at least as a site of Regional importance for that species (Harrington and Perry 1995). Based on the numbers of birds that stop there, Lake Abert is a site of International importance to Wilson's Phalaropes, although single-day estimates of birds have fluctuated greatly among years from less than 5,000 to more than 100,000 birds (Boula 1987, Jehl 1988, this study).

Regardless of how the different lakes are classified under WHSRN criteria, an exercise often made difficult by unknown population estimates of particular species and poorly defined flyways, in most years Lake Abert is probably second only to the Great Salt Lake in importance to migrant Great Basin shorebirds. The three lakes, Goose, Summer, and Abert, are within a 90 km radius, and there is frequent exchange of some shorebirds between these sites (Plissner et al., unpubl. data). If we consider these lakes as a single functioning unit (Haig et al. 1998), then their importance to global populations of shorebirds is even greater.

EXISTING SHOREBIRD MONITORING PROGRAMS

Other established monitoring programs could have been implemented at the sites we surveyed, but with shortcomings. ISS methodology would have worked at JDOW and SLWA. These sites are accessible by car or foot and have consistent water available (hence consistent shorebird habitat), but the magnitude of most postbreeding shorebird populations at these sites is much lower than at the large, alkali lakes. On the larger lakes, however, logistic constraints generally preclude ISS methodology. Most sites lack comprehensive road access. Even at lakes with some road access, decreasing water levels later in the summer (or early in the spring in dry years) create vast expanses of mudflats. Most birds concentrate at the water's edge or in shallow water that may stretch for kilometers, so counting them from the shore is often impossible (Reed et al. 1997). Distribution of birds, depending on the species, can be highly clumped (S. Haig and L. Oring, unpubl. data), and counting one visible part of the lake does not necessarily reflect what is on the lake as a whole. Therefore, consistent counting of these sites requires comprehensive aerial or airboat censuses (D. Shuford, pers. comm.) with accompanying costs and expertise beyond the level of most volunteers.

The Pacific Flyway Project used aerial and airboat surveys combined with ground work to achieve their goal of identifying important shorebird sites within the Pacific Flyway (D. Shuford, pers. comm.). Their methodology, if it were to be modified to monitor shorebirds for trends, has one potential problem in that the two brief count periods, one in spring and one in fall, are not sufficient to monitor shorebirds throughout the entire region due to differing phenology and speed of migration among species. Most of the subarctic and Arctic migrants pass through the area in a 3–5 week period. Length of stay of migrating shorebirds at Great Basin sites is largely unknown. In spring, migrating Western Sandpipers remain at Honey Lake only about 2 days (Warnock and Bishop 1998), a length of stay probably similar to many other spring shorebird migrants. Even our 7-day interval or the 10-day interval recommended by ISS between censuses may be inadequate to document use of the Great Basin in the spring for species where a large percentage of the flyway population can stop and pass through a single site in a few days and then not be seen again in the Basin, as seems to happen with Least Sandpipers and Long-billed Dowitchers. Thus, in spring, censuses probably should be 2–4 days apart to avoid missing these single, large concentrations of shorebirds that are passing through quickly. Fall passage of migrants is 15–20 weeks long with peaks varying by species, age, and sex (typically females followed by males and then juveniles; Boula 1987, Paulson 1993). Wilson's Phalaropes may spend 5–6 weeks at some of the saline lakes within the western Great Basin (Jehl 1997). The ISS-recommended 10-day interval between censuses may be adequate to document use of sites during fall migration in the western Great Basin for at least some species.

Critical to this effort is knowing turnover rates of birds passing through this region (Reed et al. 1997, Warnock and Bishop 1998). Not knowing turnover rates of shorebirds hinders our ability to design efficient monitoring programs, greatly weakens the interpretive power of count data, and precludes accurate estimation of maximum population sizes using the region.

MONITORING ISSUES

Censusing and monitoring migrant shorebirds using wetlands in vast, arid regions such as the Great Basin can be difficult and expensive. As a consequence, it is important to clearly identify goals of any monitoring work (Taylor 1991, Reed et al. 1997). Most large-scale waterbird monitoring projects are defined by two goals: (1) the relatively short-term goal of identifying the importance of particular areas to waterbirds with preliminary estimates of sizes of waterbird populations using the identified areas (Howe et al. 1989), and (2) the long-term goal of estimating the variation in magnitude and trends of populations of waterbirds using those sites (Pienkowski 1991, Moser et al. 1993, Watkins 1993).

In this study, we have achieved the first goal, that is, to identify the importance of particular sites to migrating shorebirds within a large area of the western Great Basin. Censusing only from the ground or the air and censusing only at one type of wetland would not have achieved this goal as revealed by our combination of ground and aerial censuses at a variety of sites. Phenology and abundance of birds in managed wetlands (the sites most easily surveyed with volunteers and just ground effort) can be quite different from those on the large alkali lakes. For instance, avocet numbers within SLWA through August were somewhat cyclical, probably as a result of the cycle of the local breeding birds (Gibson 1971). On the main lake, however, there

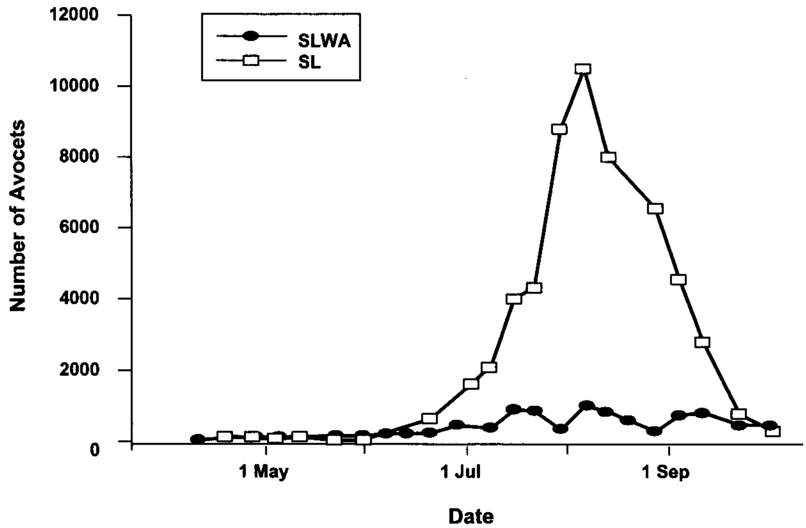

FIGURE 6. Comparison of numbers of American Avocets seen in Oregon during weekly ground surveys at Summer Lake Wildlife Area (SLWA), and during aerial surveys of Summer Lake (SL).

was a steady increase of mainly postbreeding birds beginning in June that resulted in a curve with a single peak in August (Fig. 6, although it should be noted that in some years this peak can be later; W. Devaurs, pers. comm.). Numbers of avocets at SLWA never exceeded 1,600 birds, whereas Summer Lake had almost ten times that amount. Timing of maximum numbers of avocets at Summer Lake coincided with maximum numbers at SLWA in 1996, but in 1997 maximum numbers of avocets at Summer Lake occurred a month later than at SLWA. Extrapolating census results from either the managed wetlands or the large lakes to the whole region would lead to potentially misleading conclusions regarding the use of habitat, abundance, and trends of shorebirds in the Basin. Therefore, we recommend a combination of ground counts and aerial surveys over large enough spatial and temporal scales to evaluate the importance of the western Great Basin to shorebirds.

Our study demonstrates potential problems with respect to the goal of estimating population sizes and trends in the western Great Basin. The most formidable problem lies with the extreme variability in environmental conditions within the Basin that may result in great fluctuations in shorebird numbers (Neel and Henry 1997). In particular, shorebirds must cope with fluctuating water levels of wetlands within and among years (Robinson and Warnock 1997), making it difficult to predict shorebird use within and among sites in any given year or across years. Drought periods can result in some lakes and most smaller wetlands drying up completely, leaving no habitat for shorebirds (Alberico 1993). Even at the larger lakes where it is rare for water to totally disappear, numbers can differ greatly among years. At Lake Abert, avocet numbers quadrupled from 1996 to 1997, while phalarope numbers almost doubled. During our aerial surveys, we never counted over 1,150 peeps at one time on any of the three large alkali lakes, but in other years tens of thousands of Least and Western Sandpipers have been seen at these lakes: 23,150 Least Sandpipers on 1 May 1987 at Summer Lake (Paulson 1993), and 15,000 Least/Western Sandpipers on 4 May 1989 at Lake Abert (Kristensen et al. 1991).

Results above suggest that it is possible to estimate trends of shorebird populations within regions like the Great Basin through a combination of ground and aerial surveys, timed differently for spring and fall migration. Because of the high variation in numbers of birds among years, lakes, and species, such a program requires a long-term effort over a large spatial scale (Barter 1993, Reed et al. 1997). Our simulated results modeling the power needed to detect negative declines in American Avocet numbers using the western Great Basin support this contention. Numbers of years needed to detect trends of shorebirds with some degree of power will vary. Measuring trends of local breeding populations generally will require less effort than measuring trends of large concentrations of postbreeding birds. However, monitoring large concentrations probably will have more interpretive power with regards to the flyway population because the birds originate from a much larger geographic scale.

It is important to realize that due to the variation in how species of shorebirds use different wetlands within the Great Basin, methods and sites that are successful for estimating trends of one species will likely not be appropriate for another. For instance, methods used and areas surveyed for postbreeding American Avocets would result in an inaccurate account of population trends for species such as Killdeer and Long-billed Curlews that do not have clumped postbreeding distributions. To get an accurate picture of Common Snipe (*Gallinago gallinago*) numbers and distribution would entail an entirely different survey methodology than used for species listed above (Reed et al. 1997). Whether one is interested in monitoring shorebirds in a local area of wetlands or throughout the Great Basin, identifying target species, and standardizing areas surveyed, methods, and effort are critical components of a successful, cost effective program (Reed et al. 1997).

Our study points to inadequacies of current large-scale shorebird monitoring programs. Our suggested solutions to some of the problems of censusing and monitoring shorebirds will require additional time and expenses not usually covered by traditional bird census methods. Therefore, conservationists and managers will be faced with a compromising situation. In the Great Basin, additional information on basic issues such as definition of important shorebird areas in the region is still needed. Such data will enhance our ability to focus monitoring efforts on appropriate areas and define appropriate protocols for species of interest.

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APPENDIX

List of species of shorebirds seen during course of study in the western Great Basin.

Known breeders: American Avocet, Black-necked Stilt, Common Snipe, Killdeer, Long-billed Curlew, Snowy Plover, Spotted Sandpiper *Actitis macularia*, Willet, Wilson's Phalarope

Migrants: American Golden-Plover *Pluvialis dominica*, Black-bellied Plover, Semipalmated Plover, Baird's Sandpiper, Dunlin, Greater Yellowlegs, Least Sandpiper, Lesser Yellowlegs, Long-billed Dowitcher, Marbled Godwit *Limosa fedoa*, Pectoral Sandpiper *Calidris melanotos*, Red Knot *C. canutus*, Red Phalarope *Phalaropus fulicaria*, Red-necked Phalarope, Ruddy Turnstone *Arenaria interpres*, Sanderling *Calidris alba*, Semipalmated Sandpiper *C. pusilla*, Short-billed Dowitcher, Solitary Sandpiper *Tringa solitaria*, Stilt Sandpiper *Calidris himantopus*, Western Sandpiper, Whimbrel *Numenius phaeopus*.