

## Migratory waterbird use of the Great Salt Lake ecosystem

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### ABSTRACT

The Great Salt Lake (GSL) Waterbird Survey examined the relationship of migratory waterbirds with the GSL ecosystem through the spring, summer, and fall seasons, between years, and across a variety of habitats, between 1997 and 2001. An important part of the ecosystem is the dynamic lake elevation, which ranged from 1280.8 m (4199.3 ft) to 1282.4 m (4204.6 ft) above sea level (ASL) during the study. This shift in water level causes dramatic changes in the availability and quality of habitat used by more than 55 species of waterbirds. At the high lake elevation in 1999, many stands of emergent vegetation were inundated and salt burned. As the lake receded to its lowest point during the study period in 2001, extensive mud bars were left exposed and void of vegetation. Counts of waterbirds at GSL were completed every 10 days from April-September for five years and included the following families: *Gaviidae*, *Podicipedidae*, *Pelecanidae*, *Phalacrocoracidae*, *Ardeidae*, *Threskiornithidae*, *Anatidae*, *Rallidae*, *Gruidae*, *Charadriidae*, *Recurvirostridae*, *Scolopacidae*, *Laridae*. Avian use of the GSL ecosystem, as measured by bird use days (one bird use day equals one bird spending 24 hours within the study area during the study period), was the lowest during the high water year (1999) in the combined number of waterbirds present and number of days spent at GSL survey areas.

### INTRODUCTION

Studies investigating the importance of large terminal lakes in the Great Basin to waterbirds have focused on single species at the Great Salt Lake (GSL), and other large salt lakes, but no studies have provided extensive, comprehensive information on all waterbird species, particularly shorebirds. The Great Salt Lake Waterbird Survey (WBS) examined the temporal and spatial relationships of waterbirds in response to varying lake elevation of GSL during the spring, summer, and early fall months of 1997-2001. For this study, waterbirds were defined as species from the following families: *Gaviidae*, *Podicipedidae*, *Pelecanidae*, *Phalacrocoracidae*, *Ardeidae*, *Threskiornithidae*, *Anatidae*, *Rallidae*, *Gruidae*, *Charadriidae*, *Recurvirostridae*, *Scolopacidae*, *Laridae*. Water elevation at GSL can vary significantly, and for each year of the study the lake exhibited different habitat types available for bird use.

For many reasons, the GSL ecosystem is an important place for avian life. Large numbers of several species of migratory shorebirds stop at GSL on their way to and from their breeding grounds. Several species of colonial waterbirds

breed on the lake's islands and in the wetlands. Snowy Plovers are known to nest on the mudflats in greater numbers than anywhere else in the world. The world's largest staging concentration of Wilson's Phalaropes occurs here. In the fall, Brine Shrimp (*Artemia franciscana*) in GSL attract the second largest staging population of Eared Grebes in North America. The WBS monitored these populations as lake conditions varied and as the surrounding environment was modified.

This study also incorporated the participation of the community in the collection of waterbird data in the vast GSL ecosystem. Cooperators included State and Federal (BLM and USFWS) biologists, other professional State employees, and volunteers from several nonprofit organizations including national and local Audubon chapters, The Nature Conservancy, and Friends of Great Salt Lake. Other participants came from lake industries and various duck clubs, as well as the public at large. Volunteer participation was essential in order to cover a majority of waterbird habitat around GSL, and to survey throughout long field seasons over a period of five years.

## METHODS

**Study Area.** Because of the size of the GSL ecosystem, this study concentrated survey efforts on areas of known waterbird concentration within the GSL ecosystem. In general, this included the lake surface, shoreline, and associated wetlands, including the three major delta regions and nearby wetland complexes that drain into the GSL. Most of the survey areas occurred near the east side, as well as the north and south ends of the lake. There were a few survey areas on the west side and at the extreme north and south ends of the lake to investigate more xeric environments. An estimated 73 percent of important wetlands, largely within duck clubs, was not covered by this effort because of limited access and man power.

The selection of survey sites also considered land ownership, potential access, proximity to other survey areas, habitat type(s), the ability to recruit surveyors, specialized equipment needs, and other logistical factors. Routes and area sizes were largely predicated on the capacity to survey the site in a four-hour block of time or less. Survey areas were mapped and assigned a name and number. Over the five-year study period, five new survey areas were incorporated into the project.

**Survey Protocol.** Surveys were conducted every 10 days falling on or close to a designated target date. The first survey season in 1997 started in late June and continued until mid-September with a total of nine survey periods. Seasons in 1998-2001 had 17 survey periods from April through September. Four survey techniques were used based upon the area type: total count, shoreline transect with point sample, area count, and aerial survey.

Total Count: In total count areas, all waterbirds seen and heard in the accessible areas of the site were recorded. The number of observers varied based on the survey area demands (e.g., numbers of birds, size of site). Total count sites often were not completely covered because of inaccessibility or the presence of dense, emergent vegetation that obstructed viewing. Most often standardized travel routes were roadways on top of Wildlife Management Area (WMA) dikes, and in some areas transects were established. Many of these sites were located in state and federal WMAs or within the confines of private duck clubs or wildlife preserves.

Shoreline Transect with Point Sample: Surveys along the shoreline of the lake were comprised of a walking transect with at least one point sample. Several shoreline areas were surveyed using all-terrain vehicles (ATV) due to their length. Survey routes began at a designated starting point and followed the contours of the shore 100 yards from the waterline (distance estimated by sight). All waterbirds observed within 0.25 mile on either side of the transect line were recorded. Upon reaching a point sample location, the observer began a 10-minute count of all birds within a 0.25-mile radius circular plot. Habitat and behavioral observations were also collected at point sample locations. All birds recorded along the transect and within the point samples were treated as a total count and point counts were recorded separately.

Ninety percent of point sample locations were randomly selected along the shoreline route. Ten percent of point sample locations were selected from drainage points. Due to the dynamic nature of the GSL shoreline, the protocol required that a surveyor move at right angles from the permanently placed sample marker as necessitated by the fluctuating shoreline. At times under these conditions, the point sample marker was isolated some distance from the shoreline on land, or it was surrounded by water during high lake periods.

Area Count: One or more area counts were conducted at each of the large state WMAs and the federal wildlife habitat area (WHA). Area count sites were selected by the refuge managers based on their management needs. Counts were conducted along manmade impoundments or naturally occurring ponds with an identifiable boundary. Habitat and behavioral observations were also collected during area counts. In addition to the area counts, birds observed in all other accessible portions of the WMA were recorded, completing a total count of the entire WMA.

Aerial Survey: Surveys were conducted from the air to count birds occupying open water in the large bays, and in two areas with difficult access: Willard Spur and Stansbury Island, North. Each body of water (Farmington, Ogden, and Bear River bays and the Willard Spur) was broken into 0.25-mile wide transects spaced one mile apart. Transects were positioned 0.5 miles from the 1997 shoreline (GSL elevation approximately 1281.3 m (4201.1 ft) ASL) to avoid

overlap with shoreline surveys. In areas where shorelines were not surveyed (i.e. islands, remote areas, salt evaporation dikes), aerial surveys extended up to the shoreline. Geo-referenced transects established in 1997 were used throughout the remainder of the five-year survey period. Flights began around 7:30 am to ensure plenty of light. Speed of the plane varied according to the variety and abundance of waterbirds viewed below, but it was typically in the range of 80-100 mph. Elevation varied, but the pilot and observers worked at maintaining an elevation of approximately 80-200 feet above the water surface. Two observers identified and counted waterbirds out to 0.125 miles on each side of the plane while noting observations on audiocassette recorders.

**Data Analysis.** Waterbird counts were examined by species for each area, as lake totals for each year of the survey, and a combined five-year summary. Five-year species means were calculated by first averaging counts from all years for each survey period. Next, an overall mean for each species was computed by averaging the 17 survey period means. The same process was applied to specific survey periods of interest for each species to arrive at a more accurate estimate of population size during periods of peak occurrence. Means for suites of species were also calculated. Suites included unidentified groups that were not assigned to any species totals. For example, the Waterfowl suite includes all duck species and the "unidentified duck" category that cannot be assigned to any one species. Unidentified numbers are considerable in many cases and could not be overlooked. Peak numbers reported are the largest 5-year period mean for a particular species or suite.

To provide an assessment of the length of time individual bird populations occur within the ecosystem, bird use days were estimated from the data set. A bird use day is defined as one bird spending 24 hours within the study area during the study period. These figures were computed by multiplying the mean number of birds by the number of survey days. For 1998-2001 the study period each year was 170 days, April through September. The field season was considerably shorter in 1997, and so the mean bird numbers was potentially inflated by as much as 25 percent. For a more accurate comparison of bird use days between years, data from 1997 were omitted.

## RESULTS

The GSL mean elevation was 4201.9 ft ASL during the five-year study period. The range was 1.6 m (5.3 ft) with a low lake elevation of 1280.8 m (4199.3 ft) and peak of 1282.4 m (4204.6 ft) occurring on 15 June 1999 and 15 September 2001. The most notable rate of change was a decrease in elevation that occurred between 1999 and 2001 at 1.6 m (5.3 ft) and the greatest rate of change within one year was a 0.7 m (2.4 ft) decrease in 2000. Fluctuations in the lake elevation throughout seasons and between years correlated directly with changes in the surface area of the open water bays. As the lake level dropped in 2001, the area size of all bays also decreased. As a result, the

quantity and quality of available habitat for species that use open water spaces was highly variable through the duration of the study. Bear River Bay showed the greatest decrease in area size between the high and low lake years of 1999 and 2001. At the end of the survey season in 2001, the water surface area was approximately 207 km<sup>2</sup> (80 mi<sup>2</sup>) smaller than the same time during the high lake year of 1999.

The GSL elevation changes within survey seasons varied from 0.3 m (1 ft) in 1997 to 0.7 m (2.3 ft) in 2000. These conditions reflect the variation associated with the evaporation period of the annual lake cycle. The average seasonal change for the five-year study was 0.5 m (1.6 ft), which is inside the long term trend of annual elevation change.

The GSL Waterbird Survey covered approximately 21 percent of the total area, and approximately 28 percent of important waterbird habitat.

Data are missing at several levels of the Waterbird Survey, all of which have been accounted for in the data analyses. In 1997, the first seven survey periods were not surveyed because of unresolved logistical problems. The last survey period (17) was not part of the schedule in 1997, but it was added to the following four years to include arriving waterfowl. For some analyses, only four years (1998-2001) of data were used to maintain consistency in comparisons. Five years of data were used for individual species, suites and survey area comparisons.

Survey coverage varied between years, usually due to limited numbers of volunteers or restricted access at certain locations. Survey coverage within years also had some variation. Most areas were surveyed on a regular basis, and in cases where a survey period was missed, counts before and after a gap were averaged to fill in the missing point. Occasionally a survey area was not counted for multiple survey periods. These large gaps in coverage contribute to the conservative nature of these bird counts. For some analyses, incomplete data sets were not used.

The mean number of birds present during the five-year field season exceeded 1,051,609 (Table 1). The total reported is the sum of all waterbird species that were identified by observers. Counts of unidentified birds that were classified to a suite, such as "ducks" or "peeps" are not included in this summary. In some cases, these unidentified counts were significant, and therefore the total presented here is conservative. Peak numbers by species are also listed to indicate the magnitude of birds that pass through and use the GSL ecosystem during the migration period. Each survey period count was averaged over the five years, with the peak being the greatest of the 17 survey period means. Wilson's Phalaropes and Green-winged Teal comprise the most abundant species on average, their mean numbers reaching 126,629 and 121,804 respectively.

Bird counts recorded at the suite level were combined with species counts of the same suite, and five-year means were calculated (Table 2). Waterfowl and gulls contributed the largest numbers, and avocets, stilts, and phalaropes were also present in substantial numbers. Annual means were compared for all years

Table 1. Mean and peak numbers of waterbirds by species at Great Salt Lake during the months of April through September 1997-2001. Means are counts averaged over 17 survey periods during the season through five years, while peaks are the greatest of the 17 survey period means.

Species	Code	Mean	Peak
American Avocet	AMAV	94,006	122,083
Green-winged Teal	AGWT	121,804	159,829
American Coot	AMCO	35,464	60,481
American Wigeon	AMWI	11,055	21,493
American White Pelican	AWPE	25,480	41,318
Baird's Sandpiper	BASA	90	229
Black-bellied Plover	BBPL	1,086	1,948
Black-crowned Night-Heron	BCNH	206	342
Black Tern	BLTE	426	1,195
Black-necked Stilt	BNST	25,522	38,353
Bufflehead	BUFF	190	776
Blue-winged Teal	BWTE	211	901
Canada Goose	CAGO	10,201	15,477
California Gull	CAGU	80,193	142,240
Canvasback	CANV	645	2,040
Caspian Tern	CATE	95	253
Cinnamon Teal	CITE	16,795	26,586
Common Goldeneye	COGO	390	1,882
Double-crested Cormorant	DCCO	776	1,179
Eared Grebe	EAGR	93,221	156,036
Forster's Tern	FOTE	921	1,639
Franklin's Gull	FRGU	46,550	74,254
Gadwall	GADW	46,185	87,892
Greater Yellowlegs	GRYE	129	349
Great Blue Heron	GTBH	401	636
Killdeer	KILL	224	695
Long-billed Curlew	LBCU	125	194
Long-billed Dowitcher	LBDO	14,370	19,113
Least Sandpiper	LESA	569	1,826
Lesser Yellowlegs	LEYE	143	576
Marbled Godwit	MAGO	15,125	19,599
Mallard	MALL	45,352	69,066
Northern Pintail	NOPI	89,198	126,940
Northern Shoveler	NSHO	56,950	83,894
Pied-billed Grebe	PBGR	234	570
Ring-billed Gull	RBGU	9,048	10,504
Redhead	REDH	7,202	10,088
Red-necked Phalarope	RPHA	5,071	10,199
Ruddy Duck	RUDU	12,565	24,005
Sandhill Crane	SACR	92	187
Sanderling	SAND	878	2,491
Snowy Egret	SNEG	1,246	1,741
Snowy Plover	SNPL	363	621
Unidentified Scaup	UNSC	4,115	10,864
Western Grebe	WEGR	1,487	3,193
Western Sandpiper	WESA	21,938	82,254
White-faced Ibis	WFIB	25,576	37,568
Willet	WILL	1,067	1,466
Wilson's Phalarope	WIPH	126,629	171,876
<b>TOTAL</b>		<b>1,051,609</b>	

except 1997 because of the differences in number of survey periods and the number of survey areas (Figure 1). The annual mean in 1999 was noticeably smaller than in other years. Great Salt Lake elevation was higher in 1999 than the other four years of this study, and water covered many of the mudbars and salt burned emergent vegetation in associated wetlands.

On average, waterbirds spend 86,752,258 bird days at GSL between April and September (170 days). Bird use days are noticeably fewer in 1999. Bird use days by avocets and stilts were highest in 2000 and 2001, and for dowitchers and waterfowl in 1998. The years 2000 and 2001 showed higher bird use days for gulls. Herons and egrets seemed to be more uniform in their use of the lake through 1998-2000, but diminished in 2001. The highest year of small sandpiper presence was 2000, while for phalaropes the highest use year was 2001.

Count data were used to determine the time of peak presence by species and classified as to probable activity while at GSL (Table 3). These categories are departing and arriving winter residents (April and September), migrants to breeding grounds (April-May), local breeders (April-September), early migrants to wintering grounds (July-August), and later migrants to wintering grounds (August-September). Some species fit within more than one of the categories.

Species presence is shown by a weighted line through the appropriate time periods. Line designations are a subjective measurement of the portion of a species population known to be at Great Salt Lake at its peak time.

The five-year data set was used to describe GSL ecosystem use by individual species with local population sizes by survey period and their distribution around the lake (Figure 2). These data have been compared to global and North American population estimates where available. Each account reports the peak periods of species presence expressed by five-year means, the mean peak survey period, as well as the highest count recorded for one survey period during the five years. Mean occurrences by survey periods are charted and mapped by survey area. The account for American Avocets is the only species featured in this paper. For all other available species accounts for GSL please see Paul and Manning (2002).




## DISCUSSION
















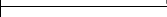




























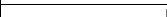








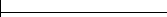

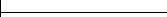

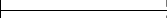







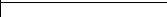







































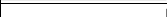


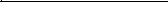








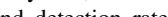




The magnitude of avian use of the GSL ecosystem is significant. This fact was recognized in 1992 with the designation of GSL as a site of hemispheric importance to shorebirds by the Western Hemispheric Shorebird Reserve Network. The Waterbird Survey serves to further describe the value of GSL habitats to all migratory waterbird species by quantifying population sizes, location, and makeup of preferred habitats under varying lake elevations, and identifying the time and duration of species presence at the lake whether for breeding or migratory stopovers. Many factors contribute to the numbers of

<u>Species Suite</u>	<u>Mean</u>
Avocets/Stilts	86,452
Dowitchers	667
Gulls	129,781
Heron/Egrets	1,546
Phalaropes	41,439
Small Sandpipers	11,945
Waterfowl	191,551

Table 2. Mean numbers of selected suites of species at Great Salt Lake during the months of April to September of the Waterbird Study years 1997-2001.

Table 3. Great Salt Lake waterbird phenology. See Table 1 for explanation of species abbreviations.

 The majority of the Great Salt Lake (GSL) population is present.  
 Approximately half or more of the peak GSL population is present.  
 Less than half of the peak GSL population is present.

Species	Departing Winter Resident (April)	Migrants to Breeding Grounds (April–May)	Local Breeders (April – September)	Early Migrants to Wintering Grounds (July – August)	Later Migrants to Wintering Grounds (August–Sept.)	Arriving Winter Resident (Sept.)
AGWT						
AMAV						
AMCO						
AMWI						
AWPE						
BASA						
BBPL						
BCNH						
BLTE						
BNST						
BUFF						
BWTE						
CAGO						
CAGU						
CANV						
CATE						
CITE						
COGO						
DCCO						
EAGR						
FOTE						
FRGU						
GADW						
GRYE						
GTBH						
KILL						
LBCU						
LBDO						
LESA						
LEYE						
MAGO						
MALL						
NOPI						
NSHO						
PBGR						
RBGU						
REDH						
RPHA						
RUDU						
SACR						
SAND						
SNEG						
SNPL						
WEGR						
UNSC						
WESA						
WFB						
WILL						
WIPH						

species observed in this vast ecosystem, including annual lake conditions and weather patterns, site access and detection rates, surveyor performance, and whether a species presence at the lake fits within the timing of the field season, as well as conditions at other locations within each species life history pattern.

It is important to consider the GSL elevation during the five-year study in context to historical lake elevation because of the known dramatic change in lake and shoreline habitats that occur due to the flat bottom nature of this playa lake. During the study period the lake ranged within 25 percent of the 6.3 m

(20.5 ft) range known to occur over the 154-year lake elevation record period. We consider the study period of 1997-2001 to be a reasonable representation of typical water level patterns. The average GSL elevation data and its deviation from the average reflect the long-term tendency of the lake to return to an equilibrium around 1281 m (4200 ft) ASL (Arnow 1980). At the same time, a few inches of gain or loss of lake elevation can have an exceptional effect on GSL shoreline habitats. When the lake was at 1282.4 m (4204.6 ft) ASL, it flooded emergent vegetation stands and reduced the shoreline playa reach between the water edge and uplands at other locations. Species that use flooded emergents for nesting colonized several locations around the lake. At this lake elevation, many mud bars were covered, including some that were previously used by colonial nesters. Land bridges between the mainland and small islands were covered by water, enhancing the attractiveness of the islands for colonial nesting species. Also, the distance between nearby uplands and water was shortened and water lapped at the feet of dikes and levies. In some cases, there were salt water intrusions into WMA ponds. Of note was the flooding of expansive bars that at lower lake elevations extend for miles into of the lake.

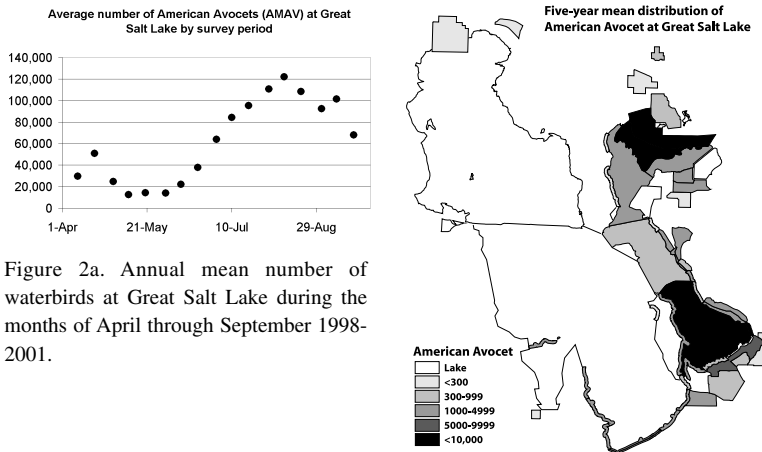


Figure 2a. Annual mean number of waterbirds at Great Salt Lake during the months of April through September 1998-2001.

Figure 2b. Species account for American Avocet, including data collected from this effort, and population estimates from outside sources (Morrison et al. 2001). Other species are in Paul and Manning (2002). The mean number reported in the table for GSL is an average of survey period means for selected months during which the species is present in abundance. The peak number reported is the largest of the survey period means. The high count is the largest count at GSL at any time throughout the five-year study. The abundance status is taken from Bromley and Webb (1995; e.g., C = common, seen frequently in habitat). The map for each species reflects the distribution of the mean number across waterbird survey areas as data were reported. Areas bordered in black but not shaded represent a count of zero.

Generally, 1999 was wetter and cooler than other years of the study. Ducks were more prevalent in the wetter, high lake year, and gulls, phalaropes, avocets and stilts favored the drier, low lake year with its abundant macro-invertebrate halophytes. On a smaller scale, dowitchers favored wetter years with good stands of emergent vegetation surrounding open water, and small sandpipers took advantage of dry-year invertebrates and abundant mudflat habitat.

The antithetical condition occurred in 2001 when the lake was at 1280.8 m (4199.3 ft), and also to some degree in 1997. The shorelines were dominated by extensive open mud bars, which in some cases isolated emergent wetlands from the salt water. The interphase between salt water and fresh water wetlands and uplands was widened in many places by hundreds of meters. Low relief mud bar islands were occupied by colonial nesting species, especially gulls, while nesters abandoned other islands when land bridges became exposed. Emergent wetlands were salt burned and set back to early growth stages as mosaic patterns of new emergents became established. Distance increased between shoreline foraging habitat and other lake habitats like fresh water inflows.

Changes in limnology are affected by volume, as an artifact of lake elevation. During low lake periods, the decreased volume increased brine concentration and subsequently influenced obligate salt tolerant plants and animals. In general, lower brine concentrations foster greater species diversity, but they may decrease productivity of individual species. High concentrations within a certain range (120-170 ppt) often generate lower species diversity, but large numbers of the species are present. These conditions occurred at GSL during the study period with excellent brine shrimp and brine fly populations during the years of 1997, 2000, and 2001 when the Gilbert Bay was below 1281.6 m (4202 ft) ASL during mid-summer and early fall.

Detection rates were variable across survey areas. Most often shoreline areas were classified as having 100 percent detection. In wetland complexes with tall, emergent vegetation, long viewing distances or access difficulties, detection rates were reduced. These situations were fairly consistent throughout the five years, and therefore the counts were consistent in the portions of an area that had clear viewing. These counts are still valuable and may be able to indicate changes within an area. For this reason and others, we believe that the numbers reported in this document are sound, but conservative.

Several survey areas were not covered for the entire five-year study period. Some areas were surveyed intermittently while others were covered for the first or last years of the study. Incomplete survey area data were rolled into an analysis of the years for which they were surveyed but excluded from any between year analyses.

Some survey sites are missing surveys from over the course of the five-year study. Most surveys missed were only intermittent with the surveys just before and after the missed survey period in place. In this circumstance, counts before and after the gap were averaged to estimate the missing data point.

From the five-year data set and other information and observations at the GSL, it is apparent that surveys missed peak occurrence periods for some

species of waterbirds. This is especially true for waterfowl and a few other species. Notably missing are: Bufflehead, Canvasback, Common Goldeneye, Northern Shoveler, Northern Pintail, Mallard, Redhead, and larger numbers of Eared Grebes. There are some waterbird species that are present in large numbers outside of this study period. Tundra Swan, Snow Goose, Greater and Lesser Scaup, Common Merganser, and Bonaparte's Gull are some of the birds missed by our surveys. There were other species that occurred in large numbers at the lake, but often not within the survey areas. These include Wilson's Phalaropes and Red-necked Phalaropes that occupy open regions of the GSL. Other species were secretive and often not detected, such as bitterns and rails. Species such as Long-billed Curlews and Willets use uplands for nesting, and part of their populations were not successfully surveyed.

The migration chronology data demonstrate the dynamics of migration as birds pulse through the ecosystem. This is especially true for long-range migrants. Western Sandpipers can occur in thousands at the lake in some survey sites, and dissipate before the next 10-day survey block. Red-necked and Wilson's Phalaropes are similar in this regard, as well as Eared Grebes as they pass through to breeding grounds. The GSL is an important migratory stopover for these species, though they do not stay for long periods of time in the spring, and their numbers may not appear significant in a seasonal mean calculation.

All sites surveyed contributed to the waterbird population and ecology of the GSL. Some sites were seasonally important, some were important to specific species or suites of species, some were more important in specific years, and some sites changed value depending on lake elevation or drainage flow patterns. There were many sites that had relatively consistent high value for a variety of species through the five-year study, such as the Bear River Migratory Bird Refuge. Other areas that consistently had high numbers of birds were Ogden Bay and Farmington Bay WMAs and the Layton Wetlands. Some survey areas with less-diverse habitats and species richness are important because of the connectivity they provide to other habitats in the ecosystem. As the lake elevation rises and falls, the state of emergent vegetation follows the type of available habitat changes. As a result, species diversity changes, and total abundance can differ depending on the natural history of the species. Therefore, total bird numbers are not the only way to judge the value of an area.

## CONCLUSIONS

The data presented here are a summary of highlights from a more extensive report that details species distribution, bird presence by site, and habitat descriptions (Paul and Manning 2002). It is a baseline inventory of migratory waterbird use of the GSL ecosystem, and is meant to be a resource for future studies and planning efforts. For example, further investigations that target breeding species are needed to refine the database. Breeding information for American Avocets, Black-necked Stilts, and Snowy Plovers which nest on mudflats may be more appropriately surveyed by an area search rather than a

shoreline transect. The Willard Spur is an area of high species diversity and abundance and would be more accurately counted from an airboat or several observation towers, rather than with an aerial survey. The results of this study are important in identifying what, when, and where should be the objectives of additional, focused studies.

This information is valuable to many entities around GSL and other organizations nationwide, and it was shared with such groups even while the study was ongoing. The National Audubon Society used the WBS database to nominate and designate several GSL sites as Important Bird Areas of global importance. It has also been used to support the protection of important shoreline on the south shore of GSL. Several planning efforts have applied WBS data in the development of conservation documents such as the GSL Comprehensive Management Plan, the Utah Division of Wildlife Resources Comprehensive Wildlife Plan, and the Intermountain West Regional Effort of the North American Waterbird Conservation Plan. The Utah Department of Transportation and others have utilized this database to make better decisions on critical issues involving highway development and growth along the Wasatch Front.

Because of the importance of this data set to so many, we recommend that it be updated on a regular basis. Population trends are most accurate when many years of data are available. Because the GSL is a dynamic system, long-term data collection is even more important, so that lake flooding and receding cycles will blend into larger scale population trends.

If it is desired to plan a similar inventory using volunteer help, we make the following recommendations. Provide ample training for volunteers to minimize the variation in skill levels between surveyors. This may be best achieved in small groups, ideally at the survey team level, and at the particular site where volunteers will be doing their surveys. Keep the protocol as simple as possible. The point sample section of the data form used in this study was too complicated, and data that were not recorded properly were not usable. Survey routes should be limited to that which can be covered in two hours. The Waterbird Survey had many dedicated volunteers who gave much of their time over five years to contribute to this effort. It is easier to have consistent volunteers when their travel and survey time is kept to a manageable amount. Develop a schedule for waterbird surveys through time. This process should consider the monitoring protocols set for the through the North American Waterfowl Management Plan, National Shorebird Plan, Continental Waterbird Plan, and consider any actions recommended by Partners In Flight.

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